GrafNav / GrafNet, GrafNav Lite, GrafMov, Inertial Explorer

for Windows 95^{TM} ,98^{TM} ,2000^{TM} , XP^{TM} & NT^{TM}

Operating Manual

Version 7.50

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Chapter 1   Introduction

Section 1   Overview

This manual is a reference for GrafNav/GrafNet, GrafNav Lite, Inertial Explorer, and GrafNav/GrafNet with the moving baseline upgrade. Contained in this manual are step-by-step tutorials and in-depth information on each available option. Logging software, utilities and GPS raw data converters are described here in addition to the processing software.

The following components may be included with this package:
GrafNav is a full-featured kinematic and static Windows 95, 98, 2000, XP and NT GPS post-processing package. Using Waypoint's proprietary GPS processing engine, GrafNav will support most single and dual frequency commercial and OEM receivers. GrafNav also processes GPS/GLONASS combined data. When combined with a very easy to use Windows graphical interface, users can get centimetre accuracies almost instantaneously. Now GrafNav will support multi-base (MB) processing.

GrafNav will switch transparently from STATIC to KINEMATIC processing, as long as the static/kinematic flag is set properly in the GPB raw GPS data file. A fixed static solution is available for static initialization on short or medium length baselines (30 - 50 km). A float static solution is available for long and/or noisy baselines. Kinematic Ambiguity Resolution (KAR) allows the user to start in kinematic mode and/or fix otherwise unrecoverable cycle slips. For dual frequency users, ionospheric processing can improve accuracies as well. All of these features are contained in the same program, and can all be used during the same project. Chapter 2 is devoted to GrafNav.

GrafNet is a multi-baseline static network-processing package. It allows the user to combine days or weeks worth of static GPS baselines into a single network tying all points together. The entire project can be processed in a single operation meaning the user can work on other tasks, but with Waypoint's fast processor, processing can take minutes rather than hours. When complete, GrafNet colour-codes the baselines depending on whether they passed internal tests. Therefore, the user can concentrate his processing efforts on a few troublesome baselines rather than on the entire project. GrafNet allows four types of static baseline processing including the fixed static solution, the float solution and an ionospheric free solution. See Chapter 3 Using GrafNet for more information.

GrafNav Lite is a simplified version of GrafNav. It contains all of the conversion and logging utilities, but will only process at 1 Hz or lower rates. Only the float static initialization is included, and KAR is not supported. Despite this, accuracies of 5-20 cm can be achieved with GrafNav Lite. Use the GrafNav description given in Chapter 2 as a reference.

GrafNav Batch/GrafNav Lite Batch – This program module that comes with GrafNav/GrafNet, GrafNav Lite, and GrafNav/GrafNet with Moving Baseline upgrade, facilitates batch processing of static and kinematic baselines. For GrafNav/GrafNet users, GrafNet is a more effective batch processing tool for static baselines. For GrafNav Lite users, GrafNet is not available and this tool must be used. The two main uses of GrafNav Batch are:

a) One base station and many remote occupations. The remote occupation can be observed by one or more GPS units. Up to 128 baselines can be processed in this manner.

b) One kinematic remote processed with respect to two or more bases. The batch processor can be used to automatically process forward/reverse and combine these solutions into one optimal solution. A new feature in version 7.50 will allow the user to process multi-baselines in GrafNav Batch with two or more base stations. See Chapter 2 for more details.

GrafNav can also be executed on individual bases, which may make working with an individual baseline easier. Otherwise, GrafNav Batch has many of the features of GrafNav, including data plotting utilities.

A **GPS Data Logger** is included to facilitate GPS data logging directly from a variety of GPS receivers under a Windows 95, 98, 2000 and NT environment. Supported receivers include Thales (Ashtech), NovAtel, Canadian Marconi, Rockwell Jupiter, Trimble, Parthus, and Javad. Features like tagging stations and satellite lock plots are included as well. Logging is performed directly into Waypoint's custom format. Under Windows 95 and 98, Waypoint's own device drivers are used (i.e. WPCOMM.VXD), while the driver supplied by Microsoft's is used for Windows 2000 and NT. This program is described in Chapter 8.

Also included is a Windows CE version of the data logger. It has many of the same capabilities as the Windows version, and it is described in detail in Chapter 8 Section 2.

Conversion utilities are included to convert the manufacturer specific raw GPS data files to Waypoint's own format. Supported formats are:

- Allen Osborne Associates (AOA version only)
- Conexant Jupiter/NAVCOR
- CSI SLX/DGPS-MAX
- Javad/Topcon
- Leica SR/MX/System 500/System 1200
- Magellan
- Motorola Oncore
- NavCom
- NovAtel CMC All Star/Super Star
- NovAtel OEM2/3/4/SoftSurv

- RINEX (v.2.0 and 2.1)
- Rockwell PLGR/MPE12 (Rockwell version only)
- Septentrio SBF
- Sirf Binary
- Thales Download (Ashtech) B-File Format/Real Time/DSNP
- Trimble DAT/Real Time/TSIP/TIPY
- U-Blox

These decoders can be accessed external to GrafNav/GrafNet/GrafNav Lite/Inertial Explorer or from within the interface.   They are further described in Chapter 7.

GPS raw data utilities are included that resample, splice and reduce the size of raw data files. A raw GPS data viewer is also included. This will allow you to view the data collected by the GPS receiver in order to detect any problems. These utilities are described in Chapter 6.

The following modes of processing are supported:
Static processing involves the determination of a three dimensional baseline between two stations. There are two types of static solutions supported by GrafNav: a float solution and a fixed solution. These two solutions are explained in more detail later in this section. GrafNav Lite only supports the float solution.

Kinematic processing is initialized either with a static survey, from a known point or using Kinematic Ambiguity Resolution (KAR). Following initialization, the antenna mounted vehicle moves from station to station. In some cases, it may be possible to remove the antenna and place it over the desired point. However, in other cases such as an aircraft, positions can be interpolated.

A **fixed static solution** is available when sufficient cycle slip-free data is available. This algorithm starts with the float solution, and using this as a seed, it searches for the nearby integer combinations. Then, it will calculate RMS fits for these integer intersections. The intersection list will be sorted about this value. In single frequency, fixed static solution requires at least 10-15 minutes of continuous static data, and more on longer baselines. Dual frequency receivers require about 1/2 - 2/3 of the time. Fixed solutions are not reliable on baselines longer than 15 km for single frequency and 30 km for dual frequency. For version 7.50, fixed solution is now solved for all static periods.

The **float solution** does not solve for integer ambiguities, and can take much longer to converge to centimetre accuracies. Since integers are not forced, the float solution tends to be less accurate than the fixed or KAR solutions. For longer baselines (>10 km in single frequency and >30-40 km in dual frequency), integers are often not solvable. In such cases, the float solution is often the best alternative. For dual frequency, be sure to enable the ionospheric free correction mode from the Dual Frequency Options. Solution plots can also be viewed from within the GrafNav environment using the plot functions under the Output Menu.
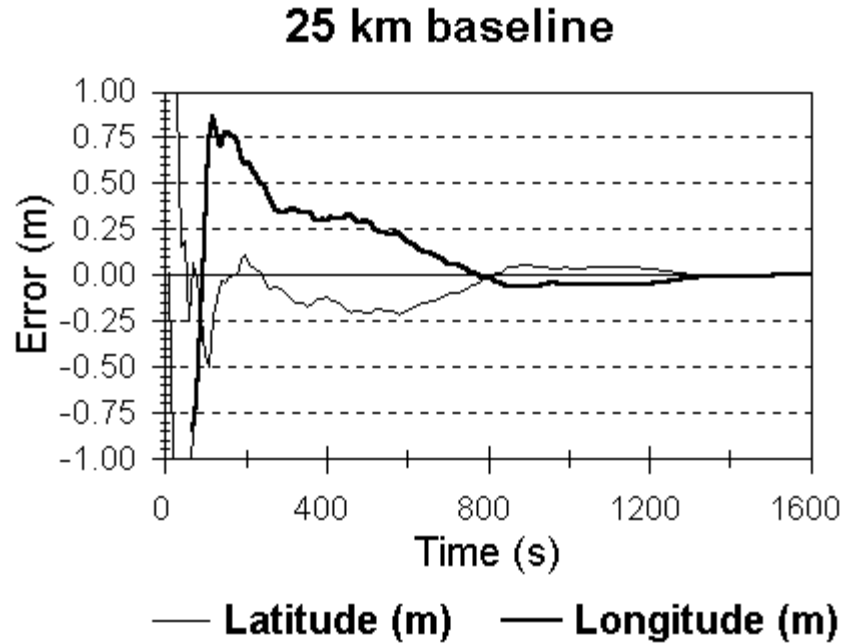
Figure 1.1 Example of GPS Processing Static Convergence (float solution)

Kinematic Ambiguity Resolution (KAR) searches the ambiguities after a serious loss of lock and is useful for precise kinematic processing as it achieves centimetre accuracies. This is the so-called on-the-fly (OTF) algorithm. This technique requires 5 or more satellites in view, and it is helped considerably by L2 (dual frequency) phase measurements. KAR can be useful for single frequency receivers if open conditions are present. KAR is generally engaged at the start or after periods of extremely poor geometry or loss of lock. For dual frequency, it can be used for reliable initialization if baseline lengths are less than 30 km. Single frequency can also be initialized in this manner, but static methods are more reliable.

Table 1.1 Product Comparison Chart

Capabilities	GrafNav/ GrafNet	GrafNav Static	GrafNav Lite	GrafMov	Utilities Only	Inertial Explorer
Float Static	✓	✓	✓	✓		✓
Float Kinematic	✓		✓	✓		✓
Fixed Integer Static (Fixed Solution)	✓	✓		✓		✓
Fixed Integer Kinematic (KAR)	✓			✓		✓
Dual Frequency	✓	✓		✓		✓
Single Point	✓	✓	✓	✓		✓
Moving Baseline				✓		
GPS Azimuth Determination				✓		
IMU Processing						✓
Kinematic < 1sec Data Rates	✓			✓		✓
Mission Planner	✓	✓	✓	✓	✓	✓
GPS Data Conversion	✓	✓	✓	✓	✓	✓
Coordinate/Datum Conversion	✓	✓	✓	✓	✓	✓
GPS Data Logger	✓	✓	✓	✓	✓	✓
Download Service Data (FTP)	✓	✓	✓	✓	✓	✓

Section 2   For People Who Do Not Read Manuals

For users who generally do not read manuals, these are the sections that should still be considered for reading, in order of importance:

1) Chapter 10 Section 1, Chapter 10 Section 2 and Chapter 10 Section 3 contains tips on improving accuracies and additional information on multi-base processing.
2) Chapter 2 Section 3 is a reference section describing the processing settings.
3) Chapter 7 contains some tips on converting data from each type of GPS receiver. Conversion settings are also described here.
4) Chapter 10 Section 5 is a useful Q & A style description of Datums, Geoids and Grids for users who are not well versed in these areas.

Section 3   Installing GrafNav/GrafNet or GrafNav Lite

1.3.1   What You Need To Start

The minimum software and hardware your computer system needs to run GrafNav for Windows are:

- GrafNav/GrafNet for Windows is distributed on a compact disc.
- A Waypoint Protection Key burned for the correct product and has a version number of at least 7.50. The key can be read via *Start | Programs | Software Package | Utilities | Hardware Upgrade Utility*.
- A computer running Windows 95, 98, 2000, XP or NT (Version 3.51 or 4.0).
- At least 64 MB of RAM and 20 MB of space on your hard disk.
- A 486 CPU is sufficient, but a Pentium is suggested. Furthermore, Pentium II or higher CPUs will run significantly faster.

1.3.2   Installation CD - GrafNav/GrafNet

1.3.2.1   Common Problems with Upgrading GrafNav/GrafNet

GrafNav/GrafNet is distributed with a Sentinel hardware lock. Upgrading to a new version will require a new key code for the hardware lock, and expired demo codes will also need new codes for the software package to continue working. Waypoint Consulting Inc. should be contacted for obtaining new key codes. For contact information, see Section 5 of this chapter.

Once the GrafNav/GrafNet software is installed, press the Start Menu button and click on *Programs | Waypoint GPS | Utilities | Hardlock Upgrade Utility* to start updating your hardware lock. Click on the Read Key button and copy down the existing key code and save the code. This will help prevent the loss of a full working GrafNav/GrafNet key code when the user is testing out a newer demo or beta version of the software. To upgrade the key, enter the given key code in the following format ####-####-####-#### and press Upgrade.

Note: Versions 7.50 and greater of KeyUtil.exe are not compatible with previous versions. The software will only function if they key has been upgraded with a newer version of KeyUtil (ie. 7.50 and greater). The version number appears the title bar.

1.3.2.2   Installing the Software

GrafNav/GrafNet is distributed on CD media. To install the software, insert the CD into the CDROM drive. From the Windows Start button, select Run. Type D:\Setup (where D: would be your CDROM drive), or navigate to the CD by selecting Browse. Follow the instructions during installation.

Your software should now be installed. Sample GPS data is provided under the \Data directory of the CD. Copy some data on to your hard disk and try processing it. There is a Getting Started Section at the start of the GrafNav and GrafNet Chapters.

1.3.2.3   Hardware Lock Problems

The hardlock is needed when GrafNav, GrafNav Lite and GrafNet process. For almost all users, the software will work without problems. However, every now and then, some users have difficulties with the hardlock supplied with the software.

Currently, this product only works with one type of hardware key, which are manufactured by Sentinel. The Sentinel locks are beige colored and have memory. Encoded in the memory is the user's serial number, version number, software type (i.e. GrafNav/GrafNet, GrafMov, POSGPS, etc.). The memory may also contain the demonstration status if applicable. The information on the Sentinel lock's memory can be read using the Hardlock Upgrade Utility, which can be accessed from the software's program group in the Start Menu.

1.3.2.4   Sentinel Hardlock Problems

Currently, there are no known compatibility issues with this hardlock. In Windows 95/98, it will work without the drivers even being installed. However, for Windows 2000 and NT, it is important that the drivers are installed and the system is restarted.

The most often cause of problems is due to drivers not being installed, especially by preliminary versions of version 6.00 and prior versions of GrafNav/GrafNet. Such versions will also not work with the Sentinel key. The error message for such an error is 'FATAL ERR – Hardlock error! Unable to open Sentinel hardware lock driver – Install driver (error code 12)'.

Another common cause of problems is an incompatible version number for the software type between the processor and key. In this case, you will need to contact your dealer. This returns one of two error messages 'FATAL ERR – Hardlock error! Hardware key is intended for a software version older than what is being used – reinstall older version or upgrade key'. Demo keys burned after the week roll-over (i.e. August 22, 1999) will only work with version 6.01 or greater. If an error occurs, this message will be returned, 'FATAL ERR – Hardlock error! Demo software is being used outside of demo usage period – Upgrade to working version or call to extend demo period'.

In a few cases, failed or intermittent locks have been encountered. These usually return an error labeled 'FATAL ERR – Hardlock error! Waypoint hardware key not found – Check printer port (error code 3)'. Test procedures have improved, but if the problem occurs, the lock will need to be replaced. Note that an RMA number is required before a shipment will be accepted. Please contact you dealer for instructions.

Otherwise, the error code number that is shown in the error message corresponds to the following:

 0 - SUCCESS

 1 - INVALID FUNCTION CODE was specified - See your language's include
       file for valid API function codes. Generally, this error should not

occur if you are using a Rainbow-provided interface to communicate with the driver.

2 - INVALID PACKET - A checksum error was detected in the command packet, indicating an internal inconsistency. The packet record structure may have been tampered with. Generally, this error should not occur if you are using a Rainbow-provided interface to communicate with the driver.

3 - UNIT NOT FOUND - The specific unit could not be found. Make sure you are sending the correct information to find the unit. This error is returned by other functions if the unit has disappeared (that is, unplugged).

4 - ACCESS DENIED - You attempted to perform an illegal action on a word. For example, you may have tried to read an algorithm/hidden word, write to a locked word, or decrement a word that is not a data nor counter word.

5 - INVALID MEMORY ADDRESS - You specified an invalid SentinelSuperPro memory address. Valid addresses are 0-63 decimal (0-3F hex). Cells 0-7 are invalid for many operations. Algorithm descriptors must be referenced by the first (even) address.

6 - INVALID ACCESS CODE - You specified an invalid access code. The access code must be 0 (read/write date), 1 (read only data), 2 (counter), or 3 (algorithm/hidden).

7 - PORT IS BUSY - The requested operation could not be completed because the port is busy. This can happen if there is considerable printer activity, or if a unit on the port is performing a write operation and is blocking the port. Try the function again.

8 - WRITE NOT READY - The write or decrement could not be performed due to a momentary lack of sufficient power. Try the operation again.

9 - NO PORT FOUND - No parallel ports could be found on the workstation.

10 - ALREADY ZERO - You tried to decrement a counter or data word that already contains the value 0. If you are using the counter to control demo program executions, this condition may occur after the corresponding algorithm descriptor has been reactivated with its activation password.

12 - DRIVER NOT INSTALLED - The system device driver was not installed or detected. Communication with the unit was not possible. Please verify that the device driver is properly loaded.

13 - COMMUNICATIONS ERROR - The system device driver is having problems
  communicating with the unit. Please verify that the device driver
  is properly installed.

18 - VERSION NOT SUPPORTED - The current system device driver is outdated.
  Please update the system device driver.

19 - OS ENVIRONMENT NOT SUPPORTED - The Operating System or
  Environment is currently not supported by the client library. Please
  contact Tech Support.

20 - QUERY TOO LONG - The maximum query string supported is 56 characters.
  Send a shorter string.

30 - DRIVER IS BUSY - The system device driver is busy. Try the operation
  again.

31 - PORT ALLOCATION FAILURE - Failed to allocate a parallel port through
  the Operating System's parallel port contention handler.

32 - PORT RELEASE FAILURE - Failed to release a previously allocated
  parallel port through the Operating System's parallel port
  contention handler.

39 - ACQUIRE PORT TIMEOUT - Failed to acquire access to a parallel port
  within the defined time-out.

42 - SIGNAL NOT SUPPORTED - The particular machine does not support a signal
  line. For example, an attempt was made to use the ACK line on a
  NEC 9800 computer. The NEC 9800 does not have an ACK line.
  Therefore, this error is reported.

57 - INITIALIZE NOT CALLED - Failed to call the client library's initialize
  API. This API must be called prior to the API that generated this
  error.

58 - DRIVER TYPE NOT SUPPORTED - The type of driver access, either direct
  I/O or system driver, is not supported for the defined Operating
  System and client library.

59 - FAILURE ON DRIVER COMMUNICATION - The client library failed on
  communicating with a Rainbow system driver.

60 - SERVER PROBABLY NOT UP – The server is not responding; the client has
  timed out.

61 - UNKNOWN HOST – The server host is unknown. The server is not on the
network, or an invalid host name was specified.

62 - SEND TO FAILED – The client was unable to send a message to the server.

63 - SOCKET CREATION FAILED – The client was unable to open a network
socket. Make sure the TCP/IP or IPX protocol is properly installed on the system.

64 - NO RESOURCES – Could not locate enough licensing requirements.
Insufficient resources (such as memory) are available to complete the
request, or an error occurred in attempting to allocate the needed memory.

65 – BROADCAST NOT SUPPORTED – The broadcast is not supported by the
network interface on the system.

66 – BAD SERVER MESSAGE – Could not understand a message received from
the server. An error occurred in decrypting (or decoding) a server message at
the client end.

67 – NO SERVER RUNNING – Cannot communicate to the server. Verify that
the server is running. The server on the specified host may not be available
for processing the request.

68 – NO NETWORK – Unable to communicate with the specified host. Network
communication problems encountered.

69 – NO SERVER RESPONSE – No server responded to the client broadcast.
There is no server running in the subnet, or no server in the subnet has the
desired key connected.

70 – NO LICENSE AVAILABLE – All licenses are currently in use. Server
has no more licenses available for this request.

71 – INVALID LICENSE – The license is no longer valid. License expired due
to time-out.

72 – INVALID OPERATION – The specified operation cannot be performed.
Tried to set the contact server after obtaining a license, or tried to call
FindFirstUnit function on a packet that already has a license.

73 – BUFFER TOO SMALL – The size of the buffer is not sufficient to hold
the expected data.

74 - INTERNAL ERROR – An internal error, such as failure to encrypt or decrypt
a message being sent or received, has occurred.

75 – PACKET ALREADY INITIALIZED – The packet being initialized was
   already initialized.

255 – INVALID STATUS – An invalid status code was returned.

The Alladin (black) hardlock is no longer supported by GrafNav/GrafNet. Therefore, if
you have such a key, then it must be exchanged for one of the Sentinel keys to run
version 6.02 and later. There may be an upgrade charge for this operation.

1.3.2.5   What else is on the CD?

There are a number of directories on the CD containing additional programs and data.
These include the following:

\Data
This directory contains sample GPS data for GrafNav and GrafNet for various types of
GPS receivers. Browse through the subdirectories of \Data to see what data is available.
To process, it is easiest to copy the contents of a directory (or all directories) to your hard
disk since the CD will not allow file creation.

\Hardlock
This directory contains the drivers necessary for Windows 2000 and NT installation. The
Windows 95 VXD is also there. All hardlock drivers should be installed automatically
during installation.

\Geoid
This directory contains geoid files for U.S. (Geoid96, Alaska96, Geoid99, Geoid03),
Mexico97, Australia (AusGeoid93 and AusGeoid98) and the World (EGM96). These
files allow mean-sea-level (orthometric) heights to be computed using GrafNav and
GrafNet. Files are in the .WPG (Waypoint Geoid) format. For Canada, files must be
downloaded from the Geodetic Survey Division of Geomatics Canada. This directory
also contains Geoid99 for the continental US and Alaska. Other regions of the world are
also available. Check the CD or Waypoint's FTP site (call for information).

\DosUtils
This directory contains various DOS and Win32 console utilities that are not installed
with the software. Generally, these utilities are replaced by capabilities within the
windows product.

\Ctl3D
This directory contains versions of CTL3D32.DLL for both Windows 95 and Windows
NT. See the readme.txt file. Newer versions of the software may not need this DLL.

\Devkit
This directory contains a command-line program that can execute the Dynamic Link
Library (DLL) that GrafNav, GrafNet and GrafNav Batch use for processing, which is
useful for off-line batch processing. This directory also contains sample 'C' source code

for linking to this DLL. See the Application Note.doc file for further explanations. This is the so-called 'Developers Kit'.

\ManualPdf
Contains this manual in Adobe Acrobat format.

Section 4   New Features in GrafNav

Existing GrafNav/GrafNet, GrafMov and GrafNav Lite customers can obtain the latest version if they have purchased or upgraded within the last year. Users whose year will run out before the release date will not be able to receive the release copy of the software. In such a case, an upgrade should be ordered.

1.4.1   What is new with version 7.50?

Processing Engine:
- True multi-base (MB) processing capabilities. Users can now utilize all (or some) of the base stations simultaneously in the Kalman filter. Accuracies are generally improved over older methodology (which is still supported).
- KAR can attempt to fix from all base stations, but generally will use the closest base.
- KAR can automatically engage when approaching a new base station (optional).
- The fixed static solution can attempt to fix to all base stations (within distance and time tolerances). It will pick the best passed solution for each static session.
- Much improved satellite weighting. Users can select from elevation based or C/N0 based schemes. Carrier standard deviation is automatically adjusted for distance and other effects.
- Bad data rejections/corrections are much simpler to control. Parameters are more dynamic, and users need only select a "level" of rejection. Software handles bad carrier data better than before.
- User can control how easily filter reset will happen.
- Much better control over omitting satellites and baselines. For instance, baseline and/or satellite can be omitted just from KAR or from overall solution.
- Better handling of satellite serial drop-outs.
- For P-Y code data, users can process single frequency L2/P2 or utilize P1 instead of C/A for processing (new GPB format only).

GrafNav Interface:
- GrafNav performs full MB processing. GrafNav Batch only needs to be used if user wishes to perform *older* sequential style MB processing.
- For MB processing, a number of new plots have been added that show individual graphs for each base station. Plots include code/carrier/doppler RMS, code/carrier position separation, effective baseline weighting, distance to base, DOPs, number of satellites and number of baselines used.
- GrafNav now tracks user name and process ID string for each "run".

- GrafNav saves history of processing settings and coarse statistical data (e.g. forward/reverse separation), which can also be plotted. This allows users to not only restore previous settings, but compare results from various "runs" as well.
- Data gaps in master files can be automatically filled when master is added to project. GrafNav can also show analysis of time gaps and other timing errors.
- User can resample to higher data interval right within GrafNav. Concatenate, slice and resample no longer need to be used.
- Plot selection is now much easier. Most commonly used plots are available for quick selection.
- Users can copy a plot to clipboard for pasting into other applications.
- Selection of x-axis and y-axis plot ranges is now much faster.
- More compact storage of individual satellite and baseline residuals in "Binary Value" files.
- Improved processing screen.
- Menus are now reorganized to make them more intuitive.
- Processing settings are reorganized and are more intuitive.
- Combined solution automatically loaded on start-up. A number of other user preferences can also be set (e.g. CMB file can be automatically created on fwd/rev combination).
- Improved ability to remove processing files.
- Base station map projection coordinates can now be entered in Metres, Feet or US Survey Feet.
- .EPP and .STA files can be quickly viewed for each observation file.
- Better remote antenna height handling with respect to static sessions.

GrafNav Batch:
- Both sequential (old-style) multi-base and new MB processing *baselines* can be loaded simultaneously making comparisons easy.
- "Combined" baselines can now be combined, which helps in comparing trajectories.
- GrafNav Batch can now import GrafNav .CFG files, meaning projects can be started in GrafNav and moved to GrafNav Batch.
- All new GrafNav features implemented in GrafNav Batch.

Utilities/Converters:
- Addition of U-Blox converter
- Addition of Thales DSNP decoder
- Addition of Leica System 1200 decoder
- Better reporting of version numbers
- Improved NovAtel OEM-4 ephemeris decoding
- GpbView can compute clock offset from C/A, P1 or P2 code. Previously only C/A was possible.
- Added stations in Download and Coordinate Favorites
- Many of the built-in favorite coordinates account for continental drift
- Better TCP support in WLOG

Bug fixes:
- Static/Kinematic coverage plot now supports week rollover
- Better time display in Object Viewer/Menu
- Better Javad event mark handling
- Projects no longer "auto-saved" on exit. User prompted first
- Fixed a number of issues with static sessions

1.4.2   What was new with version 7.01?

Late Version 7.00 bug fixes (included with Version 7.01)
- Reversed fixed solution did not work with new format
- Fixed Glonass+KAR processing bug
- Trimble real-time converter fixed cycle slip and outputs new format
- Concatenate, Slice and Resample has better directory handling
- Trimble Decoder now supports data rates higher than 1 Hz

Version 7.01 bug fixes
- Plotting bug fixed where KAR always being selected
- Time problem in batch processor fixed
- Concatenate, Slice and Resample fixed bug with adding file names
- Bug fixed in Ashtech B-File (HOSE) decoder where channel 12 was being rejected
- Lambert conformal scale factor now properly being computed
- Better support for UTM map display
- Locktime base satellite slip now more properly being detected
- Cycle slip on base satellite was sometimes not being properly handled (fixed in build 1/26/04 and later)
- Javad/Topcon decoder now better handles data from newer Javad firmware versions. Problem fixed where some epochs were being missed during decoding.
- NovAtel OEM3 decoder now reads CLKB record.
- GPB->RINEX now outputs a continuous week number for receivers that output the 10 bit value.
- RINEX->GPB prompts for .NAV file if missing. In addition, a .NAV file can be decoded on its own.
- Trimble DAT decoder now properly decodes static/kinematic flags.
- Antenna height could be mixed up in GrafNav during static mode. Generally, it happens when the antenna height in the station file is different than that selected for processing and happens most easily from GrafNet->GrafNav. In GrafNav, it is important to change the antenna height for the static session as opposed to the global value, and there is now a message to this regard. The transition between GrafNet->GrafNav has been improved.

Version 7.01 new features
- New about box that includes key control and better version/date reporting
- All manufact files can now be downloaded from Waypoint's FTP site

- DEMs can be loaded, displayed and used for more accurate vertical scale factor computation
- Allow more than one combined baseline to be added in GrafNav Batch
- GpbView allows user to enter site specific meteorological parameters
- GpbView displays processing messages and single point processor better compensates for extremely bad data.
- Additional modes added for GrafMov azimuth determination. Azimuth computation possible for a variable baseline length
- Septentrio GPS data decoder now included
- Addition of Ashtech DG-16 real-time CT message
- Trimble real-time decoder now support 40h message and better high data rate support
- RINEX ephemeris files can be decoded separately
- Four new networks and a number of stations were added to the Download program
- Download can also download IONEX and precise clock files
- IONEX model can be used for single frequency single point and differential processing
- Solutions and settings can be imported from one project (and Batch baseline) to another

Inertial Explorer bug fixes
- Export wizard now better handles high data rates
- Bug were events were lost during interpolation has been corrected.
- Bug fixed where users can now better create their own IMU error models. Previously values would get lost

Inertial Explorer new features
- Users can plot IMU coverage in addition to Master and Remote GPS coverage. This plot will also show IMU data time gaps.
- Error models have been added for DMARS-I and HG-1700 IMUs
- User can now flexibly import IMU data into Inertial Explorer using the new 'Convert IMU' utility. It allows users to convert their own IMU data to Waypoint's common format. Users can set axes, scale factors, time systems and directions to handle most formats available
- Inertial Explorer now supports a generic .IMR IMU raw data file that is common for all formats. Existing formats are still currently supported, but future versions may only support IMR. Users can either create this file themselves or use the flexible 'Convert IMU' utility
- Users can now process data from IMUs that are not parallel to the body frame. That is, the IMU need not be level when the vehicle is level. The user must know the angles of orientation
- The IMU processing window now better integrated into GrafNav windows
- IMU software now outputs a meaningful quality number
- IMU processor now transfers GPS statistics after IMU processing

- Export wizard can now export ω, φ, κ angles oriented to map system.
- Users can now select start/end IMU processing time from plots

1.4.3   What was new with version 7.00?

Processing Engine:
- Totally re-designed processing engine employing a more robust Kalman filter
- More realistic error modeling in float solution
- Updated KAR algorithm which is more robust
- New precise code-only single point processor
- Improved antenna modeling (more antennas included and there is now more control over them). Elevation based corrections also now applied.
- New GPB data format implemented with more data variables (e.g. C/No and L2 Locktimes are now present in the format).
- Ability to solve for fixed static solution midstream in data (e.g. for every static session). There is no limit to number of static fixes for stop and go data.
- Totally new message log output with more meaningful warnings and errors. Cycle slip messages can now be disabled.
- Totally new .fss/rss file output that also reflects input settings.
- Better handling of individual satellite data gaps.
- Improved static initialization accuracy from fixed solution and from known points.

User Interface:
- New Options profiles now available. Users can save combinations of processing settings that work well. The software will also come with pre-loaded profiles.
- Auto-start allows selection of an Options Profile *or Factory Defaults*
- Improved viewing capabilities for static sessions and KAR, while fixes and status are now displayed in the plots and on map window.
- Users can now edit names and antenna height for static sessions.
- Updated satellite lock plot display that also shows data gaps
- Improved ability to interpolate for both distance and time in export wizard
- New individual satellite plot that shows: carrier and C/A residuals, elevation values and C/N0 values.
- Satellite residuals can now be plotted for forward and reverse direction.
- Users can now reject user-selected periods in forward and reverse combination.
- Better tracking and selection of previous projects
- Improved orthometric height input
- Batch processor now handles static sessions and features better

Utilities and Converters:
- Implementation of new GPB format in the most popular data converters and all utilities.
- New utility added to more easily switch between static and kinematic

- New RINEX export and import converters developed. Also now supports RINEX station markers.
- Addition of CSI SLX GPS data converter
- Support for NovAtel/Waypoint OEM4 ultra-compressed record. Much improved handling of erroneous week numbers originating from OEM-4 ephemeris files
- New raw data viewer that allows bi-directional movement.
- Two new networks added to the download utility (networks in France and Japan). There are now over 2400 stations available to the user.
- Download program will now download SP3 files as well. In addition, RINEX files are now optionally left in processing directory.
- Improved point searching in the Favorites
- Improvements to 'Concatenate, slice and resample' utility and new interpolator has been added. Ability to interpolate one GPB file onto the times of another.
- WLOG now supports NAVCOM and CSI-SLX receivers
- WLOG supports high speed serial connections (230400 baud) for supported receivers (e.g. NovAtel OEM4)
- WLOG better support for TCP connections
- Added support of latest processor to WinCE Logger.
- WinCE Logger can now time tag external line terminated data (e.g. magnetometer, sonar etc…) and store them as an event.

1.4.4 What was new with version 6.03?

- Our OTF algorithms have undergone a number of improvements to better handle long baselines. This included distance dependent weighting and better controls to reject bad solutions. Additional options have been added to facilitate faster resolution on short baselines (i.e. a few epochs).
- The datum handling has been totally redeveloped. We now support a 7 parameter transformation, a 10 parameter transformation (7-param + rotational velocity), and the NGS's NADCON grid transformation format. In addition, the software is not pre-loaded with most of the world's datums, while adding your own transformations is simple. It is also now possible to compute 3 or 7 parameter datum transformations from two coordinate files.
- We have added a download utility that allows users to download the nearest CORS, IGS and AUSLIG GPS service data. Users need only specify their location and the nearest stations will be located automatically. This utility will download the data, convert to our format from RINEX and resample to the desired interval.
- Our handling of master (and other station) coordinate favorites has been much improved. Users can now group their favorites and load a list of coordinates from a file. Ellipsoidal/orthometric height flags and datums are also retained for each favorite point. The CORS and IGS station coordinates are also preloaded.
- We have a newly developed WinCE data logger available. We have added support for more GPS receivers and the functionality of the data logger is being much increased. We are supporting as many screen sizes as possible, and the display is user configurable.

- The Windows Data logger now supports additional receivers such as Trimble 4XXX, NovAtel OEM4 and Ashtech DBEN format.
- An additional post-processing decoder has been added for Trimble Real-time while a numerous improvements have been made to existing decoders.
- Feature handling has been much improved. Users can now re-number features/camera marks. Moreover, editing is much easier, and any changes are automatically saved. Users can also apply time shifts.
- For photogrammetry users, we have much improved the ability to import and export camera event marks. New import formats are supported (e.g. RC-30/ASCOT), while users can apply a 3-D offset to the aerial camera principal point.
- Users can enter the master station coordinates in Grid in addition to geographic. We are also now keeping track of what height is entered (i.e. ellipsoidal or orthometric) which aids coordinate exporting.
- The Export Wizard has a number of additions including the ability to transformation into another datum,
- DXF output is also now available directly from GrafNav and GrafNet.
- Data plotting has been improved considerably. Loaded stations/camera marks are plotted on the graphs to show users if problem areas are significant. Users can also locate times on the map or in the message log file by clicking on the graph. These new features make it much easier to analyze data.
- We have also added two additional plots such as static/kinematic coverage + a bar graph for the number of satellites.
- Users can search for epochs on the map. The map can also now display grid coordinates.
- Users can apply any combination of datum, coordinates and geoid height conversions to a coordinate file to create a new converted file.
- GrafNet is seeing a number of improvements including better display of sessions and their quality statistics. Now the session menu shows RMS, reliability, standard deviation, etc.. for each baseline.
- In GrafNet, control points can now be horizontal, vertical or 3-D. This is a great convenience from before, where users had to go through a number of steps to handle such points.
- GrafNet now has built-in support for grid coordinates and control points with orthometric heights can be entered.
- GrafNet has a few more processing controls
- GrafNav Batch encompasses all the improvements of GrafNav. In addition, it can now print, display the map window and import stations and camera event marks. Users can also now add user defined options within GrafNav Batch.

1.4.5 What was new with version 6.02?

Version 6.02 saw the following improvements:

- Ionospheric L2 Noise Modeling was added to KAR. This facilitates much farther KAR fix distances and has much improved reliabilities. Even for shorter

distances, Waypoint's KAR algorithm has been much improved for dual frequencies.

- In static, the fixed solution now has ionospheric modeling, which has vastly improved accuracies on baselines between 15 and 75 km.
- GrafNav and GrafNet bad data handling capabilities received a complete overhaul for Version 6.02, which now handles more combinations of data errors.
- GPS antenna modeling for GrafNav and GrafNet. A number of manufacturer models are included, while users can add their own antennas as well. This antenna modeling takes into account L1 and L2 phase centre offsets from the measuring mark and slant measurement corrections.
- GrafNav now has the ability to fix the position at any number of points or stations visited in a kinematic survey. This includes the ability to snap to the nearest integer ambiguity.
- Mission Planning has been added to GrafNav. This includes differential capabilities, useful on longer baselines.
- Multi-base station batch processor. GrafNav Batch now has the ability to optimally combine data from up to 100 base stations (up to 8 can be plotted) making multi-base processing a much simpler task.
- GrafNav and GrafNet can now process dual frequency GPS + GLONASS data (note: only GPS data is used for fixed integer determination). Former versions could only process single frequency GPS+GLONASS data.
- Better velocity accuracies are now available under extremely high dynamics.
- GrafNav now has much improved plotting capabilities. This includes additional graphs such as the fixed/float ambiguity status, while plots are now dynamically configurable.
- KAR now processes approximately 50% faster.
- Improved decoding for the Javad, NovAtel Glonass and Ashtech receivers. Better detection of unhealthy satellites was added to most decoders.
- Command line baseline processing interface is now available. Users can add processing capabilities to their own software or batch files.
- Data logging software has a much improved startup interface. In addition, the ability to output RTCM corrections to an additional serial port has been added.
- A beta version of the Windows CE data logger is now included. Currently, Ashtech, CMC, NovAtel are supported, while support for more receivers are planned for the future. A number of CE platforms have been tested.

1.4.6 What was new with version 6.01?

Version 6.01 saw the following improvements:

- Printing capabilities
- Export Wizard that allows the user to customize ASCII output using over 100 data variables from GrafNav and GrafNet
- Data conversion utility that auto-detects the GPS receiver data type
- Kinematic batch processing. Static batch processing can be performed by GrafNet

- Processing Summary which shows overall statistics of a kinematic mission
- Distance and Azimuth Tool that computes the true azimuth and distance between two selected points
- Updated Graphical interface including a new toolbar and tabbed options dialogue boxes
- Added KAR options such as the ability to engage KAR at the user's request
- Improvements to windows data logger
- Improved KAR message output to summary files
- Better Fixed/Float ambiguity reporting
- Extended DOP computations
- Support for additional GPS receivers such as Garmin 25/35 and Leica System 500
- Improved bad data handling such as in forest canopies

Section 5   Customer Support

If you purchased GrafNav/GrafNet, GrafNav Lite or GrafMov through a vendor, please contact them for support. Otherwise, Waypoint can be contacted as follows:

Waypoint Consulting Inc.
Suite 210, Riverbend Atrium One
200 Rivercrest Drive S.E
Calgary, Alberta
T2C 2X5 Canada

Phone: (403) 720-3800
Fax: (403) 720-3868
Email: support@waypnt.com
Web: www.waypnt.com

Please indicate:
- Key number
- Program Name and Version (see Help/About)
- Nature of problem
- Type of GPS receivers used
- Nature of the application

Chapter 2 GrafNav

Section 1 Getting Started with GrafNav

GrafNav is a full-featured kinematic and static GPS post-processing package using Waypoint's proprietary GPS processing engine. It supports both single and multi-baseline (MB) processing. GrafNav will support most single and dual frequency commercial and OEM receivers (see Chapter 7 Convert for further information). This section goes through the basics of GrafNav including how to process in a step-by-step tutorial for first time users. This chapter also describes the features contained within GrafNav Lite. When GrafNav is referred to, it can be assumed that GrafNav Lite is also implied. Please refer to Table 1.1 Product Comparison Chart on page 5 for a list of differences between GrafNav lite and GrafNav.

2.1.1 How to Start Processing Baseline(s)

The following is a 10-step tutorial to help you start processing one or more baselines at once. Each menu is defined in detail in the following chapters. For first time users we suggest that you run the software and follow the steps below.

Note: This manual assumes that you are familiar with your Windows operating system and are familiar with using a mouse. If not, please refer to Windows Help for assistance. It also assumes that you have master and remote GPS data files collected in a directory that you have created.

Step 1:   **Start GrafNav**
Assuming that you have followed the installation instructions properly, you will have a program group called Waypoint GPS 7.50. In this program group, there will be a program called GrafNav. Highlight GrafNav to start the program.

Step 2:   **Convert GPS Data**
If your data was collected using something other than one of the data logging programs supplied by Waypoint, then you must convert your files. If the data was logged raw (i.e. as it comes from the GPS receiver), then you will have to convert it first.

Use *File | Convert | Raw GPS to GPB* to access the converter. Browse to the directory that contains the data. Select 'Auto Add All' to auto-detect GPS formats. You may wish to investigate the conversion options (select Options or Global Options) to convert your rover to kinematic. The GPBView utility can also be used to switch between static and kinematic (see Chapter 6 Section 3 for more information on the GPB Viewer). Chapter 7 contains a complete description of the Convert utility.

Step 3:   Download Service Data (optional)

If no master stations were used, master GPS data can also be downloaded from the Internet. In such a case, select Download Service Data from the Tools Menu. A CORS or IGS station can be added directly from a list, or you can add the closest one to your project area. The simplest is usually to use the Add Closest tab. Type your approximate position in. If it is not known, then the average position can be computed from the remote GPB file. Select 'Position from GPB' and choose your converted GPB file. On the main page, be sure to enter the proper time and date of your survey and the directory where the files are to be saved. See Chapter 6 Section 9 Download Service Data for a more complete description of this utility.

Step 4:   Create New Project

Select File from the Main Menu bar and choose New Project and File Name. You can also use the Auto Start feature, which will automatically bring up all the necessary dialogue boxes. For our purposes in this tutorial we will go through all the steps manually. Note that if you have already processed a baseline, a .CFG file will be present. You can select Open Project and skip to Step 7.

A dialogue box will appear asking you to enter the name of your new project. The default directory may be where GrafNav was installed. You should switch to the directory that contains your raw GPS data. Entering the name of a project that already exists will overwrite the file contents. Type in the name of your new project and press enter or click OK using the left mouse button.

Step 5:   Load Master File(s)

At this point, the screen will appear empty. From the File Menu choose Add Master GPB File(s). This adds the GPS data from each of the base stations. Note that you need a minimum of 1 base station that overlaps the remote file in terms of data and time. From the list of .GPB files, select the file(s) collected at the base station and select OK. The program will load the .GPB file and then a dialogue box will appear prompting you to enter the appropriate master station coordinates. The program will use the average coordinates by default. It is important that you enter the proper coordinates if they known. For multi-baselines this is especially important. If your elevation value is orthometric then select the 'Enter MSL Height' button. This will cause the mean-sea-level (MSL) height to be converted to ellipsoidal. Note that the difference between ellipsoidal and orthometric heights can be as large as 100 m.

This is also a good time to select the processing datum. Click the 'Datum Options' button. Select the Datum from the list in the Processing Datum box. In addition, be sure that the radio button labeled 'Use processing datum by setting processing datum to local datum' is selected. See Chapter 10.5.2 for more information on Datums. If the datum has changed, GrafNav will warn the user.

Step 6:   Load Remote File

Once again, the screen will appear blank. From the File menu choose Add Remote GPS File. From the list of .GPB files, choose the file collected at the remote station and press

enter or click OK. The program will then prompt you to enter the remote station antenna height. Enter the height of the antenna or range pole (height of phase centre above ground!) and press enter. **NOTE: This antenna height applies primarily to kinematic trajectories. It will be overridden by features (stations/events) and static sessions. For changing the antenna height on static sessions, select *Output | View Objects | Static/Kar*, then select 'Edit' for each static session, see Section 2.6.7**   If the antenna height is changing, then features must be used to define the antenna height at various points (see Section 2.6.6 View/Edit Features (Feature Editor)).

Step 7:   Select Processing Settings (Type of Data)

From *Options | Load Settings | <profile name>*, select a profile that represents your data type, or select Factory Defaults. <program defaults> is a default profile that can be created by the user.

Step 8:   Process

From the Process Menu choose Process Differential. A dialogue box will appear prompting you for more information. For this tutorial, we will accept the defaults that are automatic. For the static initialization mode select Float for kinematic initialization or Fixed Static if you have a sufficiently long static period at the start. Refer to Chapter 2 Section 3 Processing Options for more information. For long baseline processing (i.e. airborne) and dual frequency data, select 'Use L2 for ionospheric processing' from the Dual Frequency Options.

Upon selecting Process, the program will begin post-processing your GPS data. Note that it is a good idea to become familiar with the different modes of GPS processing, as you may have to use them for problem data sets.

While the program is processing, "keep an eye" on the quality bar. It should ideally settle down to a level of 1 or 2 and stay there if the GPS data is reasonably good. The meaning of the quality number is given in Section 2.9.3 Processing Window. If this bar spikes, it will probably coincide with a loss of lock or large phase and pseudorange RMS values, and possibly unstable ambiguity numbers and corresponding solutions. For slower computers it may be possible to view the values during processing. However, for newer faster units, epochs fly by at such a high speed that visual inspection is impossible. This should not cause concern since all statistics are available from the Plot GPS Data function under the Output Menu.

Step 9:   Plotting and Quality Control

Under the Output Menu, choose Plot GPS Data. From the list of options you can show the following plots:

Combined Separation	If both forward and reverse processing was enabled, then this plot will show the difference. Ideally, they should agree very well.
RMS-C/A Code	This shows how well the pseudorange measurements fit in the Kalman Filter. Larger values (i.e. >5 m) are an indication of poor signal quality or multipath.

RMS-L1 Phase	This shows the fit of the carrier phase. If ionospheric processing was enabled, then this value includes L2. Values larger than 2 cm indicate noisy data. On longer baselines, RMS values of 1-4 cm are typical.
Float/Fixed Amb. Status	Shows if the ambiguities are 'floating' or 'fixed'. Fixed indicates that the integer solution is solved for and a higher accuracy has been attained. Single frequency and GrafNav Lite users will normally not see a fixed integer solution for kinematic data if the default settings are used.
DOP-PDOP...	This shows an indicator of satellite geometry. Smaller numbers indicate a better geometry. Values over 3.5 are generally considered "poor".
Number of Satellites	This shows a bar graph of the number of satellites used in the solution. 4 are always necessary, while 6 or more are considered "good".
Quality Number	This is the same value displayed during processing. Lower is better. See Section 2.9.3 for a description of the meaning of this indicator.

Section 2.6.1 further describes the plotting feature.

Step 10:   Export Final Coordinates

From the Output Menu, select Export Wizard. Select the source for the solution. Epochs will output the trajectory, while features will export any loaded features. For photogrammetry users wishing to export interpolated camera positions, event marks must first be loaded (see Section 2.2.10 Loading Camera Event Marks). After selecting the source, a profile must be selected. Users can choose from a number of default profiles. Select Next. For the Datum screen, just use the processing datum. Users may also be prompted for the geoid undulation file. The distribution CD contains a number of Geoids in the Geoids directory.

See Section 7 for more information.

This was a brief overview on how to load a file and process the data. The following sections deal with each menu and the options that are offered in detail.

Section 2   File Menu Options

2.2.1   Starting a New Project

File | New Project | File Name/Auto Start
To process a baseline for the first time, you must start a New Project. Choosing New Project from the File Menu prompts you to choose between "File Name" and "Auto Start".

The "File Name" option allows you to choose a new name for your project. Once a new name has been chosen, you must then go through all of the necessary steps manually. Auto Start automatically prompts you for all the information required to process a data set. The following steps will guide you through the auto-start process.

Create a new GrafNav project

1. Enter the new name of your project.
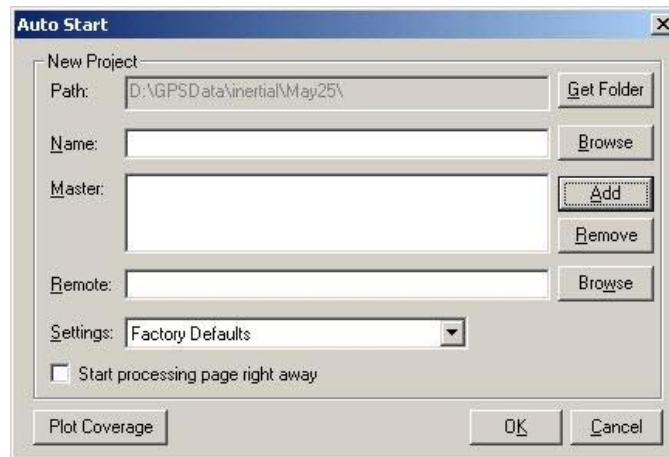
Figure 2.1 Auto Start

If you choose a name of an existing project, the project information will be overwritten. Auto Start works best, if the desired path is entered in this step.

2. Choose the master station file(s) (.GPB).

This is the file collected at the base station. Raw GPS data files must first be converted to Waypoint's common format (i.e. .GPB). See Chapter 7 for more information on converting data. Waypoint's data logging software can create .GPB files directly, which saves you from having to perform this step.

3. Choose the remote file (.GPB).

Note: the base and remote station files MUST be collected at the same time. For users that are not sure, click the 'Plot coverage' button to display the static/kinematic coverage plot.

4. Choose a setting and press OK.

There are five preset settings, Factory Defaults, GrafNav Defaults, Airborne, Ground Vehicle, and Tree Cover. Choose the settings those best fits, when in doubt just choose either the Factory Defaults or GrafNav Defaults.

5. Enter the exact master station coordinates for each base station loaded.

Entering the proper base station coordinates is essential for obtaining high accuracies. The values that appear are averaged from the GPB file, and may have errors of 10 or more meters. For IGS and CORS stations, ARP (antenna reference point) coordinates are pre-loaded in the Favorites Manager (see Section 8 Favourites Manager for more information). As always, datums are very important, and it should be noted that CORS sites are stored in NAD83 and IGS sites in WGS84. WGS84 coordinates are different from NAD83 coordinates by ~2 m, so care should be taken when using these coordinates. Be sure to set the ellipsoidal/orthometric height flag correctly. See Section 2.2.4 for more information.

6. Enter the remote station antenna height.

You should enter the remote station antenna height at this point. If you do not enter the antenna height, the ending height coordinates will include the antenna height, which will cause a vertical shift. If you are only interested in the height of the antenna (above ellipsoid or sea level), then enter zero. **NOTE: This antenna height applies primarily to kinematic trajectories. It will be overridden by features (stations/events) and static sessions. For changing the antenna height on static sessions, select Output | View Objects | Static/Kar, then select 'Edit' for each static session, see Section 2.6.7**

7. Processing your GPS Data

See Chapter 2 Section 3 Processing Options for more information on processing.

2.2.2   Opening an Existing Project

File | Open Project
To open an existing project:

1. Choose Open Project from the File Menu.
2. A dialogue box will appear asking you to select the name of an existing project (.CFG file). Choose the name of the project and press enter or click OK.

The Auto Start feature can also be used to open an existing project. The auto start option is under *File Menu | New Project* or under the *Process Menu | Auto Start*.

2.2.3   Saving your Project File

File | Save Project
The program will automatically save your project file prior to processing. Any changes made to features (i.e. name, time, antenna height, etc.) are also saved.

Use the Save As command under the file menu to create a new project that has identical processing options as the current project. This will allow you to change the options in the new project and process the data without losing the solution computed by the original

configuration. This can also be done by viewing the processing history, see Section 2.4.11 for details.

2.2.4   Add Master File(s)

File | Add Master File(s)

When starting a new project, the program needs the master station information. Binary measurement data is stored in our custom .GPB format. This format is receiver independent and only stores necessary information to minimize disk space requirements. This format contains a position record, and the number of measurement records for each epoch. GPBVIEW is a useful utility to inspect and modify this file (see Chapter 6 Section 3).

1. Choose Master GPS File(s) from the file menu after you have given your new project a name.
2. From the list of available .GPB files select the files which contain the data collected at the base station(s).
3. The program will then prompt you to enter the master station coordinates.
4. Enter the coordinates of the base station in latitude, longitude and height. Make sure the datum matches the one selected in the general options. Selecting the elevation type (e.g. orthometric or ellipsoidal) will tell the Export Wizard whether nor not to apply a relative correction for orthometric height computations. Note that this is the height used for computation. Thus, if baselines are long (i.e. 300+km), users will get better results if they enter an ellipsoidal height directly here.
5. Select either the simple or advanced antenna height model to use for your master station and press OK (see below).
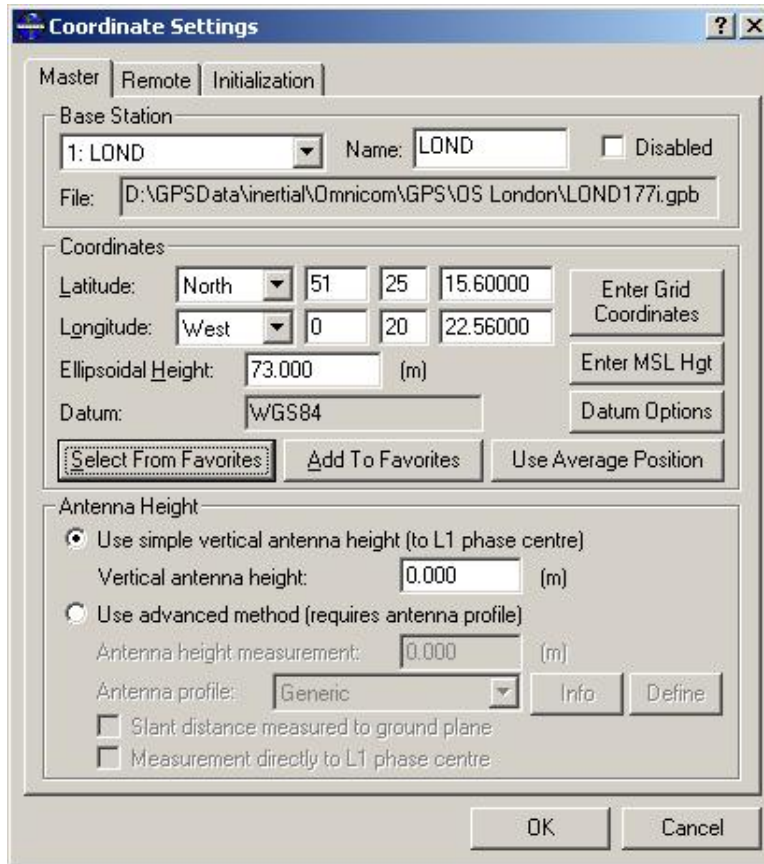
Figure 2.2 Coordinate Options

Coordinates

Note: The program calculates the average coordinates, but you should use the exact base station coordinates to improve accuracy. This is especially important for multi-base projects, see Section 10.2.2 for an explanation why. Version 7.50 has coordinates for CORS, IGS, AUSLIG, IGN, ASI, BKGI, CDDIS, OLG and GSI stations pre-loaded in the Station Favorites (see Section 8 of this chapter for more information on the favourites manager). Watch out for the datum that the coordinates are expressed in, as mismatching datums can add many meters of error (e.g. NAD83 and WGS84 are different by ~2 m).

Users can also now enter the horizontal coordinates in Grid (e.g. UTM). This is performed by pressing the 'Enter Grid Coordinates' button. Setting the grid type and zone beforehand (Options->Grid) will make the initial values much closer to the real values.

Datums

If the coordinates are in a datum other than WGS84, make sure to select the proper datum in the general options. For instance, NAD83 is different from WGS84 by approximately two meters. ITRF94+ is co-located with WGS84. Users can still process in WGS84 but enter the base coordinates in similar datums such as NAD83. The final result will be the

same. However, selecting the proper datum is always suggested. There are two reasons for doing this:

- Output files will contain the proper datum name, which avoid later confusion.
- If favorites are selected from datums other than the processing datum, a warning will appear. This is important since the IGS coordinates are in ITRF and not NAD83!
- Accuracies on very long static baselines will be improved.

See Section 2.3.11 for more information on datum options or Section 10.5.2 for a discussion on datums.

Antenna Models

The simple model and Generic profile for the advanced model are identical and assume that there are no horizontal, L1 phase, or L2 phase offsets from the antenna height measurement. For each antenna height profile, the information can be obtained, added, edited, and removed. Information from the dialogue box includes the antenna manufacturer, the name of the antenna, the horizontal distance from the phase centre to the edge of the ground plane, the L1 phase offset from the origin, the L2 phase offset from the origin, and the location of the origin on the antenna. See Section 3.3.3 for a diagram. The origin is set to one of five following settings and antenna heights are measured from unknown, the antenna base, the top of the ground plane, the bottom of the ground plane, or the measuring mark. Users can also use a slant distance from the measuring mark/origin to measure to the ground plane instead of an antenna height. GrafNav uses Pythagorean Theorem to find the antenna height using the user defined slant distance and the horizontal distance in the antenna profile.

Note: The antenna models are from the NGS. They may not be using the measuring mark on the antenna as the origin. This can add an error of several centimeters to the antenna height. Users should check each antenna model before using them. Users should always ensure that the final overall vertical antenna height is from the monument to the L1 phase centre. The greyed vertical antenna height box will show this value.

2.2.5 Loading the Remote .GPB File

File | Add Remote GPB File
When starting a new project, the program needs the remote station information. Binary measurement data is stored in our custom .GPB format. This format is receiver independent and only stores necessary information to minimize disk space requirements. This format contains a position record and the number of measurement records for each epoch. GPBVIEW is a useful utility to inspect and modify this file.

1. Choose the Remote GPS File option from the file menu after you have given your new project a name and you have chosen the appropriate master .GPB file.
2. From the list of available .GPB files choose the file collected at the Remote Station.
3. The program will then prompt you to enter the remote station antenna height.
4. Enter the antenna height and press enter. For more details on antenna height models, please refer to Section 2.2.4. **NOTE: This antenna height applies primarily to kinematic trajectories. It will be overriden by features (stations/events) and static**

sessions. For changing the antenna height on static sessions, select *Output | View Objects | Static/Kar*, then select 'Edit' for each static session, see Section 2.6.7.

Note: If you do not enter the appropriate antenna height, the program will assume that the height was zero and calculate the Height based on this information. If a .STA file exists and a station mark is present in that file, the last antenna height will show up by default.

2.2.6 Choosing an Alternate Ephemeris or Adding IONEX and Satellite Clock Files

File | Alternate Ephemeris Files

Broadcast Ephemeris
The ephemeris file contains trajectory information used to reconstruct the orbit of each satellite. This data is necessary for any kind of GPS positioning. Generally, the GPS receiver includes ephemeris data with its raw data files. Either the decoder or the logging software will take care of converting these files to the .EPP format. However, the user should still sometimes monitor data logging and ensure that enough ephemerides are being saved. Generally, new ephemerides are produced every 1-2 hours. Receivers will also output ephemerides at startup or when satellites rise.

Under normal circumstances, the combined base and remote ephemeris files contain enough ephemerides. However, in some cases, one or both of these files have been corrupted, missed or does not contain all of the ephemerides needed. In this case, another file such as that from the remote can be loaded. This is done as follows:

1. From the File Menu, choose 'Alternate Ephemeris Files'.
2. The program will display a list of ephemeris files (.epp), precise ephemeris files (.sp3), IONEX files (.yyI), or clock files (.clk). Click Add to add .epp files to the project.
3. Click OK.

Ephemerides from different stations or precise ephemerides that span over a day can all be added to the list to be included with the processing. Ephemeris files can be obtained by using the Download Service Data utility (Tools Menu). Download the IGS file for the nearest station. For precise ephemeris, select the options tab and enable precise ephemeris download.

Precise Ephemeris
The precise ephemerides are post-mission computed trajectories, which are more accurate than the broadcast ephemerides. Since S/A is disabled, the differences between broadcast and precise ephemeris are minimal and the broadcast ephemeris should suffice for most applications. Differences in final coordinates will only be observed on extremely long static baselines. **The use of precise ephemeris is highly suggested for single point positioning.** Geodetic services such as the NGS in the United States, the Geodetic Survey of Canada and some European agencies compute these orbits on a continual basis using a global network of tracking stations. In most cases, this data is available a few

days after the actual mission took place. The easiest way to download .SP3 (and other precise files) files is via Waypoint's download program (see Section 6.9.2).

GrafNav only supports precise orbits stored in the .SP3 format, which was originally created by the NGS. Luckily, most agencies use this format. Orbits, which have been optimized for the USA, are available free of charge from the NGS at the following Internet location: http://www.ngs.noaa.gov.

To load a precise ephemeris file in the .SP3 format, follow these steps:

1. From the File Menu, choose 'Alternate Ephemeris Files'
2. The program will display a list of ephemeris files (.epp), precise ephemeris files (.sp3), IONEX files (.yyI), or clock files (.clk). Click Add to add .sp3 files to the project.
3. Click OK.

It should be noted that GrafNav's precise orbit implementation requires that a broadcast orbit also be available. This file can be selected using the steps described in the broadcast ephemeris section. Therefore, the precise ephemeris feature cannot be used to circumvent missed broadcast orbit information.

IONEX and Satellite Clock Files
IONEX (IONosphere Map EXchange) files contain information of the Total Electron Count (TEC) in a two dimensional grid. For single frequency long range differential or single point processing, the information in an IONEX file can add corrections (helpful to the L1 frequency). These are available for download using the download utility; see Section 6.9.2 for a list of producers available.

Satellite clock files contain a list of biases that can be used to assist single point positioning, as the clock bias is differenced out in differential positioning. The clock files can also be downloaded using the download utility, see Section 6.9.2 .

To load IONEX files in the .yyI (yy being the year) format, or Satellite clock files (.clk), follow these steps:

1. From the File Menu, choose 'Alternate Ephemeris Files'
2. The program will display a list of ephemeris files (.epp), precise ephemeris files (.sp3), IONEX files (.yyI), or clock files (.clk). Click Add to add .yyI or .clk files to the project.
3. Click OK.

2.2.7   Showing Master File(s) Information

File | Show Master Files
This command brings up the Object Menu for the base stations only.

The following features (buttons) are available:
View   This will bring up the Object Info message box for the selected object.
View/Edit GPS   This will display a list of actions that the user can view or change to the master file(s). The user can do the following:
- ***Show Station Info****:* Displays information about the station (name, coords, antenna height etc.)
- ***Show GPB Info****:* Displays information about the GPB file (length, start/end times, interval etc.)
- ***Show Time Gaps****:* Displays information about any time gaps in the data.
- ***View Raw GPS Data****:* Opens the master file in GPB Viewer, see Chapter 6 Section 3 for more information on GPB Viewer.
- ***View Ephemeris File****:* Opens the .EPP file in the internal viewer.
- ***View Station File****:* Opens the .STA file in the internal viewer. The station file contains the following:
    a) Copy of RINEX header, which contains antenna type/name, data interval, marker information etc. See Figure 2.3 as an example of a RINEX header.
    b) Fixed Station name, antenna height, and position.
    c) Station Features
    d) Event Markers
- ***Insert Static/Kinematic Markers****:* Opens up the menu to insert static/kinematic markers in the file. See Chapter 6 Section 6 for more details on this feature.
- ***Edit****:* This will allow you to edit the name, coordinates and antenna height for the selected base station.
- ***Resample Fill Gaps****:* Users have the following resampling options:
        i) Resample to master interval – this will fill any data gaps.
        ii) Resample to processing interval – this will fill gaps and allow the user to either lower or increase the data rate. To alter this rate, change the data interval from the General Options (see Section 2.3.2).
        iii) Resample to Remote epochs – this will prodice a .GPB file with matching epoch times to the remote GPB file. A data gap present in the remote will also be present in the master (after resampling, that is) as well. This method serves two purposes: A) Removes unneeded data present before and after remote observation time period. B) Allows resampling to remote GPB files that do not sample on a constant rate. (e.g. SIRF, GSU I/II etc.)
        NOTE: Resampling can cause additional error. For original data intervals of 5.0 seconds or less, the error is negligible for kinematic processing. However, for 30 second data, this error is 1-2 cm, and can hamper integer ambiguity resolution. The original interval for RINEX files can be determined by viewing the corresponding .STA file. Look for the 'Interval' header, see Figure 2.3. Under

no circumstances should resampling be performed for static processing.

Figure 2.3 RINEX .sta file header

- *Disable*: This will disable the selected master station from processing and can be enabled later on.
- *Remove*: Remove the master file completely from the project.
- *Plot L1 Locktime*: Plots the L1 locktime plot. See Section 2.6.1 for details
- *Plot L2 Locktime*: Plots the L2 locktime plot. See Section 2.6.1 for details

Edit This will allow editing of the the name, coordinates and antenna height for the selected base station.

Add to Favorites This will add the object with solution to the list of Favorites (see Section 8 of this chapter for more details).

2.2.8 Loading a Station File (.STA)

File | Load | Station File

The program automatically loads the ASCII station file with the same name as your remote .GPB file. If your station file has a different name than the .GPB file, then you will have to load the file separately. Our data logging software and most of the decoders produce station files. GrafNav now supports a new station format as well. After loading a station file, they are saved to the *project* .NST file.

1. Under the File Menu, select 'Load' then 'Station File'.
2. A dialogue box will ask you to choose a .STA file from the list.
3. Choose the alternate station file and press enter.

2.2.9   Loading an Existing Solution

File | Load | Existing Solution

Opening an existing project that you have already processed does not automatically load the processed solution. The .FWD, .REV or .CMB files contain all the information computed for each GPS epoch by GrafNav. This feature allows you to load the solution from another project. For instance, a .CMB file produced by the multi-base station combining process can be loaded this way.

1. Under the File Menu, select 'Load' then 'Station File'.
2. Select a .FWD, .REV or a .CMB file. The program will then read in the processed results.

2.2.10   Loading Camera Event Marks

File | Load | Camera Event Marks

This feature can be used to load external time tagged events from an ASCII file. The events must be referenced to GPS time (not UTC). The source of the events may come from an aerial camera, sounding equipment or other real-time device, and the GPS receiver must support a mark or pulse input for this feature to work. See photogrammetry options (Section 2.5.4 Photogrammetry Options) for a discussion on how GrafNav interpolates event positions.

2.2.10.1   Where can I find Camera Event Marks?

1. LOGGPS logging NovAtel data. These are stored in the .STA file and should get automatically loaded with the remote file. If they do not exist, then there may be a problem with the marks or they are located in another file. Use the File-Load-Station File menu option to load them. Numbering is performed by LOGGPS.
2. Many new converters save the camera event marks directly to the station file. In this case, there is no need to go through the process of this chapter. To load events in this format, use the *File | Load | Station File* feature.
3. *NovAtel raw binary data in the form of the MKPB or MKTB record. The NovAtel Converter (NOV2GPB) writes these marks to an external .MRK file. Load using the NovAtel option. Numbering is performed by NOV2GPB.
4. Ashtech receiver with internal memory. The HOSE or corresponding utility that downloads the receiver data should create a file called PHOTO.DAT. Newer variants start with an M????.###. This file contains the event marks and can be loaded by GrafNav using the Ashtech option. The GMT date of the first event mark must be entered. Numbering is performed automatically starting at 1.
5. *Trimble 4000 series receiver. The camera marks are located in the .DAT file and are automatically extracted by the Trimble Converter (TRIM2GPB) to the .STA file. This file has the same prefix as the remote .DAT and .GPB files. The Trimble receiver performs numbering. Older versions of GrafNav extract the events to a .SUM file.
6. Leica .EV0 and .TDU files. These are the event marks produced by the Leica software. This can be imported using the Leica option. This file may contain time in the local time zone. If not, enter the time zone offset as zero. The time zone

correction as well as the GMT date of the first mark must be entered. Numbering is performed automatically starting at 1.

7. LH Systems ASCOT (RC-30) has a format very similar to .EV0, except that it also has the relative angles of the camera mount. This can later be used to apply a 3-D offset for the antenna/camera difference.

8. *Leica SR series receivers store camera marks in a .EVT file. During decoding, this file is converted to a .MRK file, which contains the event number and GPS time (seconds of the week). This file can be loaded by selecting the .MRK.

9. A number of User formats are also provided. These allow users to import the time and name of each event mark. Optional variables include line number, which comes across as the description. In addition, attitude information can also be loaded (see below). The time format may be seconds of the GPS week, GMT HH:MM:SS.SSS and local HH:MM:SS.SSS.

* Pre-Version 7.00 files only

2.2.10.2 How Do I Load Camera Event Marks?

From the File Menu, select Load, then Camera Event Marks. The following screen will appear.
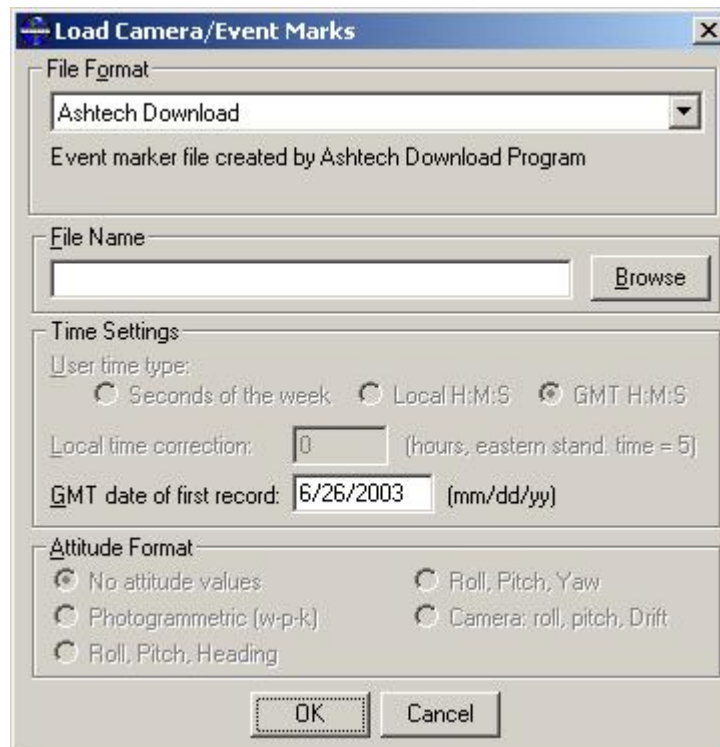
Figure 2.4 Load Camera/Event Marks screen

1. **File format** - Described above.
2. **Pulse file name** - Use the browse button to select the file of interest. The file name depends on the receiver format and is explained above. Normally, Ashtech is PHOTO.DAT, NovAtel is .MRK, Trimble is .SUM, and Leica is .EVO, etc…

3.   **User time** format - This selects time format of the User1 to User5 formats. They may either be GPS seconds of the week (0-604800), GMT hours (referenced to GPS time), minutes and seconds (HH:MM:SS.SSSS) or Local hours, minutes and seconds (HH:MM:SS.SSSS). UTC time cannot be loaded and the correction must be applied externally.

4.   **Local time correction** - This is necessary for both Leica and user defined formats using local hours minutes seconds. This is the number of hours offset from GMT. For the Eastern Standard Time Zone, this number is 5. For the Pacific Standard Time Zone, this number is 8. During daylight savings time, these numbers are reduced by one. An incorrect entry will cause the camera marks to not be displayed or to be displayed in the wrong place.

5.   **GMT date of first record** - This is necessary for Leica, Ashtech and user defined formats implementing hours minutes seconds. It is the date (month/day/year) of the first exposure record. It is <u>not</u> the date in local time, which may differ towards the end of the day. An invalid date will cause the marks to not be displayed at all.

6.   **Attitude Information** – For user formats that include attitude information, a definition of attitude is required (how are the angles defined). Currently, the following attitude formats are supported:

      i)   Photogrammetric (w-p-k) – These angles are defined as omega primary, phi secondary and kappa tertiary (ground-to-air)

      ii)   Camera (roll, pitch, drift) – These angles are the relative angles between the camera and aircraft's frame

      iii)   There are other formats listed, but their exact definition has not been defined yet.

2.2.10.3   How do I know my marks have been loaded?

Generally, if your raw GPS receiver data has positions, you should see the event marks as small cyan (bright blue) circles. This is also the case if the data has been successfully processed. In such a case, if no dots are present, then the times are usually wrong or no event marks have been loaded. The Feature Editor is a very useful way of determining what has been loaded (select View/Edit Features from the Output Menu).

2.2.10.4   How do I extract the coordinates?

In order to obtain the coordinates from the camera marks, you must use the Write Coordinates option or the Export Wizard. The Export Wizard is preferable because it has more datum options and it can apply a 3-D offset. You must process before any coordinates can be exported.

2.2.11   Importing TTP Names From Leica SR Into GrafNav

Time tagged points (TTP) created with Leica 5 data collector are named stations with position, time and antenna height information also available. However, firmware versions 3.0 and greater do not store the station names within the .TTP file. Rather, these names are stored within the database structure (control.db). Unfortunately, Waypoint cannot access this file directly, and the point information contained within the database must be converted to ASCII, which is the IDEX file. **This feature can be ignored for Leica System 500 files.**

The IDEX file can be created by Leica's Ski software. Versions 2.2 and later allow the user to access this feature without a Ski hardware key, and Leica customers can obtain this software from their local dealer. There should be no charge without the key.

An IDEX file can be created, after downloading from the data collector. Use the following steps:

- Unplug your Waypoint hardware lock. However, Ski lock is not required.
- Run Ski 2.2 or higher. This may take a while as it searches for a hardware lock.
- Select Project
- Select Manager, New
- Select a path that is empty or open an existing project via Manager Open
- Close the window by clicking on the "close file" icon
- Select Import
- Select measurement, back up/PCMCIA
- Move to the Rover directory containing DS and .db files
- Select jobs that you wish to include in IDEX file
- Press the "Insert" button. (This may take some time)
- Press the "OK" button
- Close the "Import" window by pressing the "close" icon
- Select View/Edit
- Select utilities, export to IDEX
- Type in a meaningful name
- Deselect variance/covariance information (optional)
- Select "Measured"
- Press the "Save" button. (This may take some time)
- Close the window by pressing the "close" icon

Once an IDEX file has been created, it can be loaded into GrafNav. This is done as follows:

- Create or open a GrafNav project containing the correct Leica data
- After processing, at least one direction, the TTP points should be visible and numbered 1,2,3… These would have been loaded from the .STA file
- From the file menu, select Load, and Leica IDEX file
- Move to the directory containing the IDEX file created via Ski
- You should see a message showing how many IDEX points were matched to TTP points. Points are matched via their times. Often there will be fewer matched points than the original number of TTP points due to several reasons such as: points deleted in the field, and/or static session marks being added

2.2.12   Loading Stations with Known Coordinates

File | Load | Stations with Known Lat/Long

This option allows users to load and display a file that contains the known station coordinates. The known coordinates are displayed with pink triangles and pink lines, while the stations computed by the program have yellow triangles. **To join the stations and generate a pink line, include a + sign before each station ID in your file**.

File Name:

Choose the file that contains your station information. The default file extension is *.lat. If your file has an alternate extension, choose ALL FILES from Files of Type. Any file can be chosen here as long as the coordinates are in one of the formats described below.

Lat/Long Format:

Your coordinates must be in one of the following formats:

Degrees Minutes Seconds   i.e. 51 03 28.3214
Degrees Decimal Minutes   i.e. 51 03.4720
Decimal Degrees   i.e. 51.0579

ID String Handling:

This tells the program how to handle the file. The first column is usually the station ID's. The following will tell the program how to separate the ID from the Coordinates.

Use First Continuous Word (no spaces: Use this if spaces separate your ID and Coordinates.

Comma Separation: Use this if commas separate your ID and Coordinates.

Use First 'n' columns: If you know where your coordinates start, you can enter the number for the program to begin at. Each character is a column.

2.2.13   Digital Elevation Models

File | Load | Digital Elevation Model

Please see Chapter 10 Section 4 for more information on DEMs.

2.2.14   Viewing an ASCII File

View | ASCII File(s)

The View ASCII file command allows you to view any of the files generated by the program in ASCII format. The ASCII files include Epochs Solution (.FWD or .REV), Message Logs (.FML or .RML), Static Summary (.FSS or .RSS), Station Files (.STA), Ephemeris File (.EPP), Output Files (.LAT, .UTM, .ST, .XYZ, .LAM, .LOC), and Configuration Files (.CFG).

1. From the View Menu, choose ASCII file(s)

2. Change the list of file types option to show the extension of the file type that you would like to see or choose *.* to see all files in the current directory.

3. Highlight the file that you would like to view and press enter.

Right-click with the mouse to view additional features. Such features include the ability to change the font. Selected regions can also be copied for pasting in other applications.

2.2.15 Viewing Raw Binary GPS Data

File | GPB Utilities |View Raw GPS Data
This option is also available under the process menu, under the View Master and View Remote options, or as a separate utility called GPB VIEWER. This option allows the user to view and edit the binary GPS data in the .GPB format.

Please refer to Chapter 6 Section 3 for information.

2.2.16 Viewing Current CFG File

View | Current CFG File
This option allows the user to view the Configuration Files (.CFG) of the current project. The CFG file is just an ASCII file. Also known as the project file, it contains all of the settings and options.

2.2.17 Viewing Features

View | Features
Please refer to Section 2.6.6 View/Edit Features (Feature Editor)

2.2.18 Viewing Objects

View | Objects
Please refer to Section 2.6.7 View Objects

2.2.19 Removing Processing Files

File | Removing Processing Files
This option removes all the files associated to the current project or any projects in the directory. These files include fml, fwd, fss, rml, rev, and rss files. If the All Files is chosen, then all files with the above extension will be deleted. If Current Project is chosen, only the files with the project name and the above extension with will be deleted.

2.2.20 GPB Utilities

File | GPB Utilities
Concatenate, Slice and Resample – Please refer to Chapter 6 Section 4 for information.
View Raw GPS Data – Please refer to Chapter 6 Section 3 for information.
Convert GPB to RINEX – Please refer to Chapter 6 Section 5 for information.
Insert Static/Kinematic Markers – Please refer to Chapter 6 Section 6.

2.2.21 Converting GPS Data

File | Convert

If you collected data using a program other than our logging software, then you must convert your files in order to use the GrafNav software. Waypoint supplies several conversion utilities, which can be invoked from within GrafNav.

Refer to Chapter 7 for more information on the Conversion Utility.

Convert GPB to RINEX – Please refer to Chapter 6 Section 5 for information.

Section 3   Processing Options

Process Direction

Forward   Process your data set forward (i.e. same time direction as it was collected).

Reverse   Process your data set reverse. This will start at the end *in time* and stop at the beginning.

Both   Process both forward and reverse. After completion, the two solutions are combined, if the preference option is turned on, (see Section 2.5.2). This method is most effective for kinematic processing. For static processing, use either forward or reverse. GrafNav has the ability to better combine static forward and reverse solution.

Process Data Type

Automatic: Tries to detect a dual frequency, single frequency or code only receiver data. **This is the preferred process data type**. If two types of data are detected, the lesser of the two will be used. For instance, if one dual frequency is combined with a single frequency, only single frequency processing will be utilized. If L2 tracking is very poor (i.e. very few satellites are tracking L2), then a dual frequency GPS receiver may be detected as single frequency.

Single Frequency: Process with C/A code, L1 carrier phase and L1 Doppler data in a combined Kalman filter. Each of these data variables must be available. Integer ambiguities can also be fixed using KAR or the fixed static solution (see below). Single frequency is usually less reliable than dual frequency and has the disadvantage of not being able to correct for the ionosphere. Single frequency is normally always more accurate than C/A code only.

Dual Frequency: For GPS receivers that track L2 carrier phase, processing dual frequency has two benefits. Integer ambiguity resolution (e.g. KAR and fixed solution) are much more reliable. Resolution is much faster as well. For instance, KAR can resolve in a few minutes what could take 10-20 minutes in single frequency. Secondly, ionospheric correction can be enabled (see Dual Frequency Options). This greatly

improves accuracies on baselines longer than 10 km. Please note that processing dual frequency on single frequency data has no benefit, and may have adverse effects.

C/A Code only: This will process in an advanced differential correction mode. In kinematic mode, the accuracy will be the same as real-time differential (i.e. RTCM corrections). In static mode, the accuracy will be higher due to the averaging effect. Normally, C/A only processing is only performed for data with no (or incomplete) carrier phase information.

Occupation mode: This is a special mode of operation designed for use in high tree cover areas. In this mode, the user should stay stationary over each point for 2-5 minutes. Carrier phase lock need not be maintained during travel between points. Since the carrier phase is used in static mode (not kinematic) sub-metre accuracies can be achievable in such terrain. GLONASS processing is also suggested to add additional satellites.

Static Initialization

Float Solution: The float solution does not solve for integer ambiguities. This setting is also necessary for kinematic initialization**.** Since integers are not solved for, the float solution tends to be less accurate than the Fixed Static solution. For longer baselines (>10 km in single frequency and >30-40 km in dual frequency) integers are often not solvable. In such cases, the float solution is the best alternative. For dual frequency, be sure to enable the ionospheric free correction mode from the Dual Frequency Options.

Fixed Solution: This setting processes the carrier phase in order to obtain a static fixed integer solution. If the integers are correctly determined, this mode is the most accurate. For longer static baselines, an ionospheric correction is applied to the fixed solution. See Fixed Static Options in Section 2.3.7. For single frequency, a minimum of 10 minutes is required and 15 minutes is suggested. For dual frequency, only a few minutes will work, but users often choose to stay longer to lessen the likelihood that a point be re-observed. Note that time should be increased with baseline lengths for both single and dual frequencies.

Kinematic Ambiguity Resolution

Kinematic Ambiguity Resolution (KAR) is the process of solving for fixed integers on a moving antenna. KAR will also engage in static mode if the 'Engage KAR in STATIC mode' setting is enabled in the KAR Options. KAR is very useful to regain integer (high accuracy) positions at onset or after a loss of lock.

Automatic	KAR is enabled for dual frequency and disabled for single. KAR is not applicable for C/A only processing.
On	Forces KAR to be enabled for single and dual frequencies. Single frequency KAR can take 8-25 minutes to resolve. In such a case, it should only be used with high quality receivers and open conditions.
Off	Forces KAR to never be engaged.

Manual Only   KAR is only engaged at user selected times. These times can be
defined from the Advanced KAR Options.

2.3.1   Processing Settings

Process | Process Differential
For differential processing, normally the Process button (or menu option) is selected. See
also Chapter 10 Section 1 Tips on Maximizing Accuracies for modifying these settings
to optimize your solution.

Main Processing Settings
GrafNav provides several processing features allowing you to choose the options best
suited to your application.
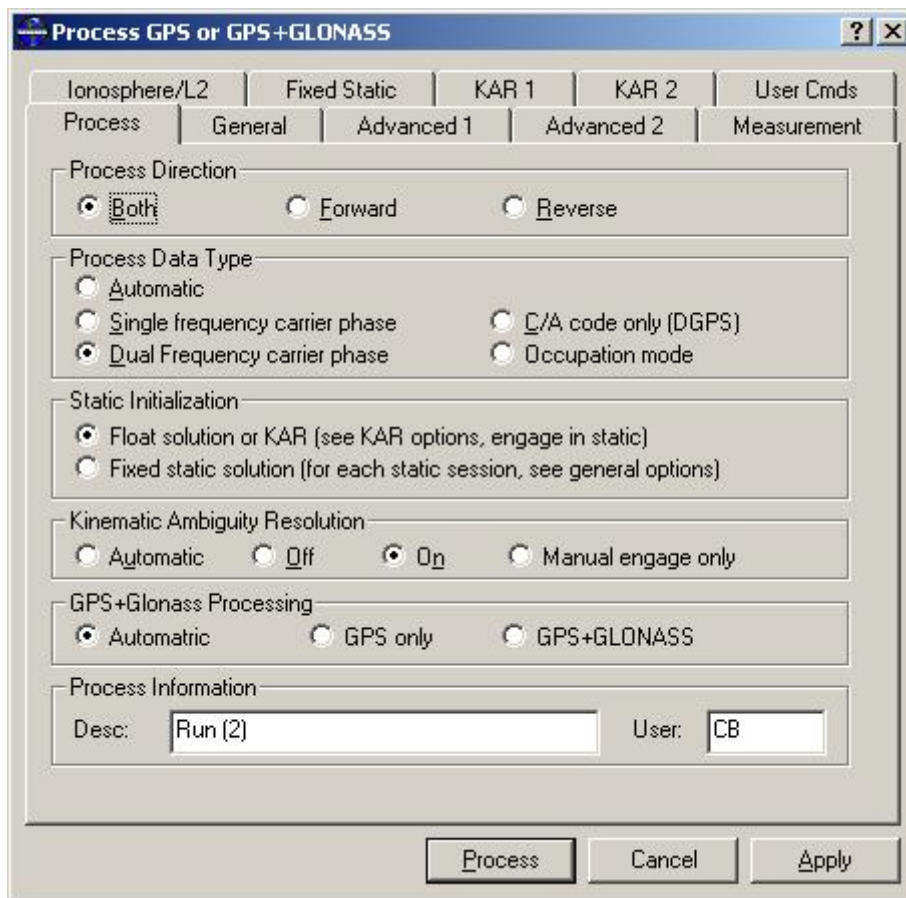
Figure 2.5 Processing Options

Process Direction
Forward
Process your data set forward (i.e. same time direction as it was collected).
Reverse
Process your data set reverse. This will start at the end *in time* and stop at the beginning.

Both
Process both forward and reverse. After completion, the two solutions are combined.
This method is most effective for kinematic processing. For static processing, use either
forward or reverse. GrafNav has the ability to better combine static forward and reverse
solution.

Process Data Type
Automatic
The feature automatically searches the data for dual frequency, single frequency or C/A
code only. If the master and remote files are of a different type, then the less of the two
will be used. The order is C/A only, single frequency then dual frequency.

Single Frequency
This will process with C/A code, L1 carrier phase and L1 Doppler data in a combined
Kalman filter. Each of these data variables must be available. Integer ambiguities can
also be fixed using KAR or the fixed static solution (see below). Single frequency is
usually less reliable than dual frequency and has the disadvantage of not being able to
correct for the ionosphere. Single frequency is normally always more accurate than C/A
code only.

Dual Frequency
For GPS receivers that track L2 carrier phase, processing dual frequency has two
benefits. Integer ambiguity resolution (e.g. KAR and fixed solution) is much more
reliable, and the resolution time is much faster. For instance, KAR using dual frequency
data can resolve in a few minutes what could take 10-20 minutes in single frequency.
Secondly, ionospheric correction can be enabled with dual frequency data. This greatly
improves accuracies on baselines longer than 10 km. Please note that processing dual
frequency on single frequency data will have no benefit, and may have adverse effects.

C/A Code only
This will process in an advanced differential correction mode. In kinematic mode, the
accuracy will be the same as real-time differential (i.e. RTCM corrections). In static
mode, the accuracy will be higher due to averaging effect. Normally, C/A only
processing is only performed for data with no (or incomplete) carrier phase information.

Occupation mode
This is a special mode of operation designed for use in high tree cover areas. In this
mode, the user should stay stationary over each point for 2-5 minutes. Carrier phase lock
need not be maintained during travel between points. Since the carrier phase is used in
static mode (not kinematic) sub-metre accuracies can be achievable in such terrain.
GLONASS processing is also suggested to add additional satellites.

Static Initialization
Float Solution
The float solution does not solve for integer ambiguities. **This setting is also necessary
for kinematic initialization.** Since integers are not solved for, the float solution tends to

be less accurate than the fixed static solutions. For longer baselines (>10 km in single frequency and >30-40 km in dual frequency) integers are often not solvable. In such cases, the float solution is often the best alternative. For dual frequency, be sure to enable the ionospheric free correction mode from the Dual Frequency Options.

Fixed Solution
Process carrier phase in order to obtain a static fixed integer solution. If the integers are correctly determined, this mode is the most accurate. For longer baselines, an ionospheric correction is applied to the fixed solution. For single frequency, a minimum of 10 minutes is required and 15 minutes is suggested. For dual frequency, only a few minutes will work. However, users often choose to stay longer to lessen the likelihood that a point be re-observed. Note that time should be increased with baseline lengths for both single and dual frequencies. Enabling this will solve fixed integers on all static sessions (see Section 2.3.7 Fixed Static Options). Note that short time or long distance baselines may be disabled during processing. See Section 2.3.3 Advanced Options 1.

Kinematic Ambiguity Resolution
Kinematic Ambiguity Resolution (KAR) is the process of solving fixed integers on a moving antenna. KAR will also engage in static mode if the 'Engage KAR in STATIC mode' setting is enabled in the KAR Options. KAR is very useful to regain integer (high accuracy) positions at onset or after a loss of lock. KAR requires 5 or more satellites and 6 satellites are suggested.

Automatic	KAR is enabled for dual frequency and disabled for single. KAR is not applicable for C/A only processing.
On	Forces KAR to be enabled for single and dual frequencies. Single frequency KAR can take 8-25 minutes to resolve, and it should only be used with high quality receivers and open conditions.
Off	Forces KAR to never be engaged.
Manual Only	Only engage KAR at times specified in the Advanced KAR options. KAR will not be engaged if there is a loss of lock

GPS+GLONASS Processing
Normally, GrafNav will automatically detect if there is GLONASS data. However, if this detection fails or if the GLONASS data is causing problems, then satellite system type may need to be selected (i.e. GPS Only or GPS+GLONASS).

Process Information
The description information can be entered by the user of the processing run. By default the program will use Run (1) and increment after each processing run. The initials can be entered by the user to indicate who processed the data. This information is stored in the processing history, see Section 2.4.11 for details.

2.3.2 General Options

Settings | Individual | General
Most commonly used settings:

- Elevation Mask
- Data Interval
- Time Range
- Datum
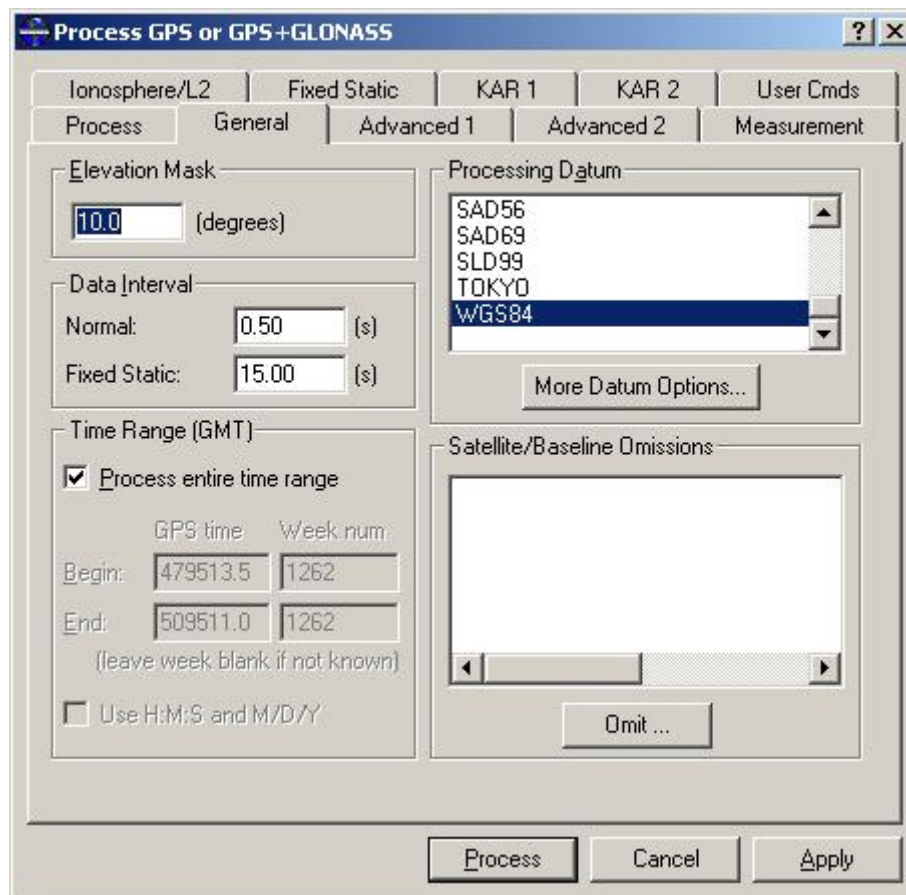
Figure 2.6 General Processing Options

Elevation Mask
The default elevation cut-off for satellite processing is 10 degrees. You may wish to raise this to 15 degrees, but we do not suggest that you lower it. If the default is set too high, you may miss satellites that are important to the geometry of the position. Lowering the number can cause noisy satellites to degrade the solution, 13 degrees works well for many airborne data sets.

Data Interval
The program automatically lines up both the master and remote data sets at the data collection rate. If this is not desired, you may specify the interval at which you wish to process the data. For the fixed solution, the Fixed Static interval will be use rather than

the Normal interval. Processing with data in static mode with intervals shorter than 15 s is not beneficial. In fact, it can result in overly optimistic accuracy estimates. This is due to the high time correlation of carrier phase data over periods less than 15 seconds. A smaller value (i.e. more data usage) will not improve accuracies. If zero is entered for the interval, all epoch will be processed.

Time Range
Normally, GrafNav will process the entire data set. This means starting at the first epoch the master and remote has in common and ending at the last. Users may, however, wish to limit the scope of processing to avoid problematic time periods. Such time periods are usually isolated from the data plots. The beginning and end times are entered here. These times are for forward processing (i.e. begin time is before end time). For reverse processing, GrafNav starts at the end time and stops at the begin time. The default time system is GPS seconds of the week (0-604800), but times can also be entered in hours, minutes and seconds. These are in the GMT time zone (i.e. GPS time).

Processing Datum
Normally, the processing datum is the same as that where your base station coordinates are referenced to. In this case, select the processing datum from the list. Alternately, processing can be in a global datum such as WGS84, and coordinates can be entered in the local datum. The second approach is more complex and should only be used by users who thoroughly understand datums. Select 'More Datum Options…' to enable/disable datums and to enable coordinate input in a different datum than the processing datum. See 10.5.2 Datums for more information on datums.

Omit Satellites
This can be used to reject the following:
- a) One, or all satellites;
- b) For one or all baselines;
- c) On a specified time range or for all epochs
- d) From processing totally or just from integer processing (i.e. KAR and Fixed Static).

An omission record consists of the preceeding information and numerous omissions can be added.

2.3.3 Advanced Options 1

Settings | Individual | Advanced
Most commonly used settings:
- Carrier Locktime Cut-off
- Write epochs containing bad data
- Write cycle slips to message log
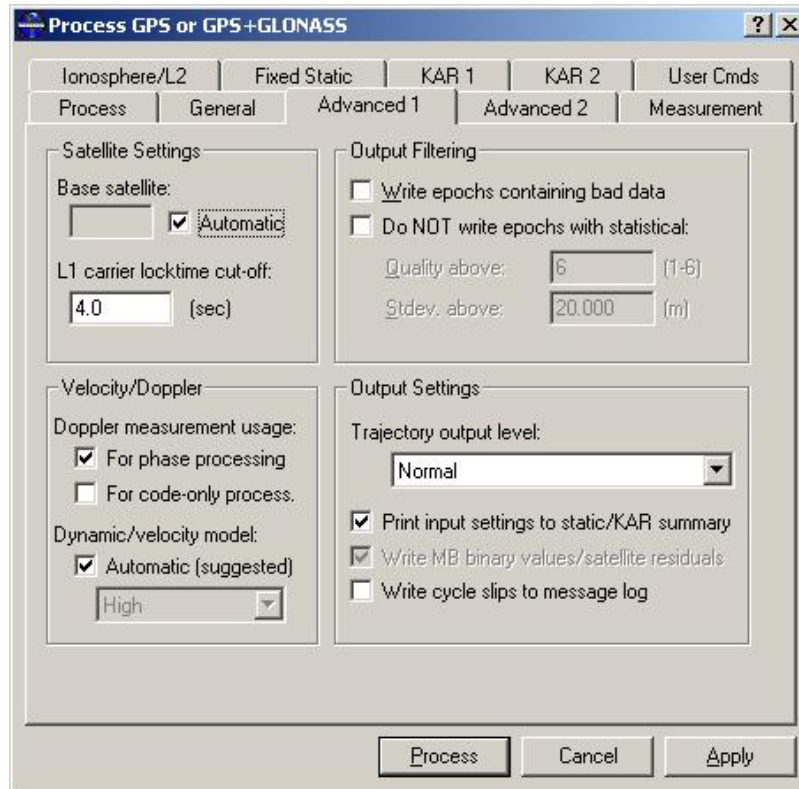
Figure 2.7 Advanced 1 Processing Options

Satellite Settings
Base Satellite
This is the satellite initially used as the base for the differenced observations. For most cases, automatic selection is much preferred.

L1 Carrier Locktime Cut-off
The number of seconds of carrier phase lock before data for that channel is deemed usable. This allows users to reject data for the first 'n' seconds since loss of lock. The default value is 4, but higher numbers (8-12 s) can be very beneficial to some GPS receivers—especially low-cost ones.

Velocity/Doppler
Use Doppler Measurement
Option to use Doppler measurement for Phase processing or Code-only processing. *For Phase processing* is the default setting. The Doppler is mainly used for velocity

determination. One may wish to disable it if numerous Doppler error warnings are present in the message log.

Dynamic Model
This setting controls whether the constant velocity vehicle dynamic constraint is to be utilized. The main purpose of this setting is to much improve velocity determination if the Doppler measurement usage is disabled (e.g. code-only processing).

Generally this setting is best left at automatic, which is as follows:
- Dynamic constrain Off if Doppler usage enabled
- Dynamic constrain High if Doppler usage disabled

Otherwise the user may select one of the following:
       High – Vehicle dynamics (100 m position error due to velocity change)
       Med – Vehicle dynamics (10 m position error due to velocity change)
       Low – Vehicle dynamics (1 m position error due to velocity change)
       Off – No constraint

Output Filtering
This group box has two options that allow you to customize the way GrafNav deals with bad data.

Write epochs containing bad data
This command forces GrafNav to print out all positions that it computes, regardless of whether it has deemed the data to be good or bad. By default, GrafNav will not print positions for epochs for which the Kalman filter has detect large measurement errors. This option should only be used if you need a position for as many epochs as possible, and if you are not concerned about some low quality positions.

Do not write epochs with poor statistics
This option allows you to remove epochs from a solution that have quality numbers, or standard deviations greater than some threshold. This option can be used to attempt to filter out bad positions from the output.

Output Settings
Trajectory output level
This option allows you to select the format of the epoch output files. The Normal format is the format that GrafNav uses by default. The 'Extended' format is identical to the 'Normal' format, except it has additional fields for the relative vector information, position and velocity covariances and the ambiguity values. You should use this format if you require the additional information. The GrafNet format is suited specifically for GrafNet in order to minimize disk file usage.

Print input settings to static/KAR summary
With this checkbox enabled, the processing settings will be printed at the start of the FSS/RSS file. This can be useful for tracking which options were used for a same solution file.

Write MB Binary values/satellite residuals
When enabled, carrier code and residuals will be written to .fbv and .rbv files. For MB processing, this setting will always be enabled. See Section 9.1.4 on details of .fbv and .rbv files.

Write cycle slips to message log
With this checkbox enabled, satellite cycle slips and rising/falling messages will be printed to the FML/RML file. This messages, although numerous, can be helpful in locating a problem satellite. Disabling will create a much more concise message log.

2.3.4   Advanced Options 2

Settings | Individual | Advanced
Most commonly used settings:
- Fixed static tolerances
- Save ambiguities on satellite drop-outs
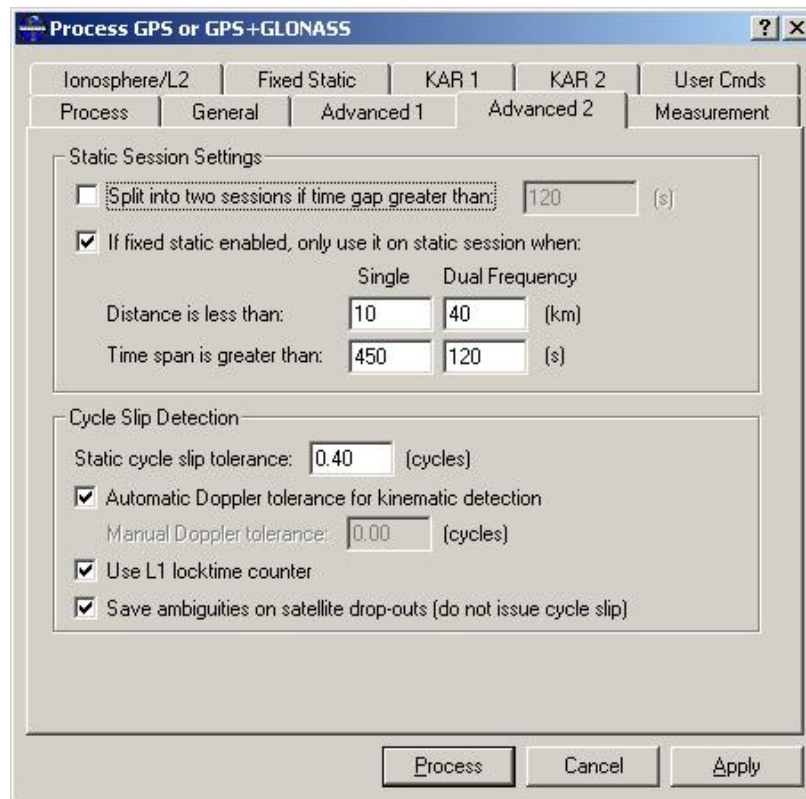
Figure 2.8 Advanced 2 Processing Options

Static Session Settings
These parameters govern how GrafNav processes static baseline.

Split if time gap greater than
With this enabled, the processing software will treat time gaps greater than the tolerance as an indication of a new station occupation. Enabling this setting is useful for two reasons:
  i.   Raw GPS data has no kinematic epochs between static sessions.
  ii. Blockages are so severe that the receiver outputs no records between static sessions.

Fixed solution usage
GrafNav can compute a fixed static solution for any number of static sessions. To prevent unreliable static fixes on very long baselines or short time periods, this page allows the user to specify maximum distance and minimum time tolerances. There are separate controls for single frequency and dual frequency, as dual frequency can span a longer distance and requires less data. In addition, the fixed static solution on individual static sessions can be enabled or disabled by right-clicking on a particular static session (select Edit). Note that for these to take effect, Fixed Static must be enabled on the main processing screen.

Cycle Slip Detection
These parameters govern how GrafNav detects L1 phase cycle slips. In general, GrafNav relies on a procedure of using the locktime read or computed in the decoders combined with a Doppler check.

Static cycle slip tolerance
This is the tolerance used to detect cycle slips in static mode. Generally, there is no need to change this unless the user is processing extremely noisy carrier data, where this value may need to be raised. In static mode, the fine static check is turned on. This allows GrafNav to detect very small cycle slips and is now by default ON. For the fixed solution, this is automatically used and cycle slips are also corrected. To disable the cycle slip correction for the fixed solution add the user command (FIX_CORRECT_SLIP = OFF).

Locktime counter
In kinematic mode, the locktime cycle slip check uses flags generated by the GPS receiver. This should normally always be enabled.

Save ambiguities on satellite drop-outs
Some receivers can be susceptible to periodically dropping satellites (with no loss of lock). These are due mostly to serial data errors. Without this setting enabled, these dropouts will be treated as a cycle slip. Enabling this setting is especially beneficial for Ashtech receivers. In some cases, it is better to interpret this loss of lock as a cycle slip. A good indicator that this checkbox should be disabled is if a filter reset message ($$$) follows the message 'Prn # dropped out for #.#s on b/l ??? -- will try to save ambiguity'.

2.3.5 Measurement Options

Settings | Individual | Measurements
Most commonly used settings:

- Measurement standard deviation (code and carrier)
- Outlier detection/rejection level
- Distance effects
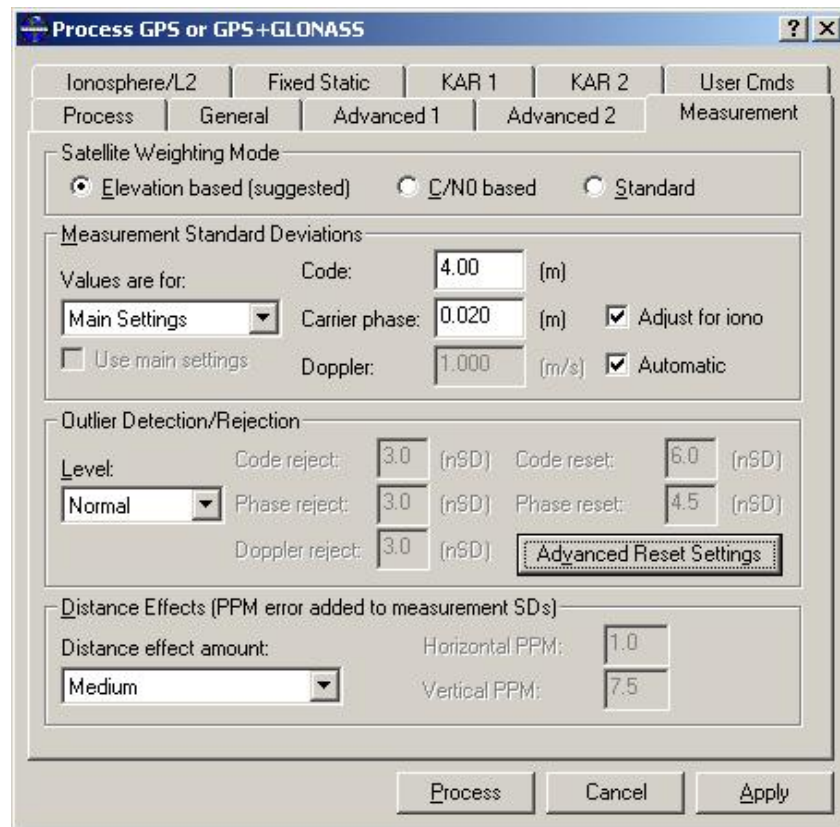
Figure 2.9 Processing Options

Satellite Weighting Mode

Elevation Based   Satellites are weighted inversely according to the elevation
                         angle ($w_f = 1 / \sin\varepsilon$). Using this mode is suggested.

C/N0 Based   L1 C/N0 can be used for weighting as well
                         ($f = V + 10^{CN0/10}$). L2 C/N0 will be used for ionospheric
                         processing (if available). If L1 C/N0 is not available on all
                         master/remote raw data files, weighting will revert to
                         elevation based. Before using this weighting mode, plot
                         the C/N0 values for all files to verify:
                             a) That the data is available.
                             b) Values are in proper 30-50 dB range.

Some receivers output SNR or "signal counts" instead of C/N0. Such recever data should not be used.

Standard

Uses a constant weight value for all satellites. Using this mode is not suggested as baseline distance effects are disabled.

Note that GrafNav's weighting is relative rather than absolute. The magnitude of the nominal elevation (45 deg) or nominal C/N0 (50 dB) is controlled via the measurement standard deviation values. Scientific and advanced users can use the user command STD_REF for more controls (see Appendix A). Also note that using the C/N0 base weighting should theoretically produce "best" weight. However, scientific testing has not shown this to be the case. In addition, C/N0 values vary from receiver to receiver and may have a time lag associated with them. Many do not output C/N0 at all. Therefore, using C/N0 based weighting can actually be hazardous.

Measurement Standard Deviations

Code SD

Controls the standard deviation at reference elevation or C/N0 for C/A, P1, and P2 codes.

Carrier SD

Controls the standard deviation at reference elevation or C/N0 for L1 carrier. Adjust for iono will adjust the carrier standard deviation for additional error resulting in L1/L2 combination. This should be on.

Doppler SD

Controls the standard deviation at reference elevation or C/N0 for the Doppler. Automatic causes 0.25 or 1.0 m/s to be used depending if the receiver type measures Doppler.

These values are normally set for all baselines. However, individual baseline settings can be altered. In such a case, the baseline name will have a '*' appear next to it.

Outlier Detection/Rejection

These settings control how the processing engine rejects bad satellite measurements using the residuals. Basically, it rejects based on "sigma tolerances", which are the number of standard deviations needed to flag an outlier. There are two levels of outliers:

a) Rejection – An attempt is made to reject satellites, measurements or baselines. If too many continuous rejections are encountered, a reset is issued.

b) Reset – For very large errors, cycle slips are issued to all satellites (which is called a reset).

The easiest way to control the "amount of rejection" is to select one of the levels. Possible levels include: Normal, strict phase, strict code, strict both (code+phase) loose phase, loose code, loose both (code+phase) or manual. In the manual mode, users can

enter the exact rejection and reset values for each measurement. In general, users may wish to use a stricter phase tolerance in reduce the number of visible spikes in the carrier RMS plot—especially for the carrier phase.

Advanced Reset Settings
None of these values would be commonly changed by the user. However, power users do have access to them (see Figure 2.10).

Figure 2.10 Advanced Reset Settings

Maximum continuous rejections before reset is engages – This is the number of seconds of continuous rejections before a reset is engaged. Some high data rate kinematic applications may find it appropriate to lower this value.

Epochs to skip before reset induced on code error – On occurrence of a code error, the processing engine can attempt to reject an epoch's data. This may prevent a reset, but at the expense of a position drop-out. Users may wish to lower this value to permit fewer missed epochs.

Epochs to skip before reset induced on phase error – This is similar to that above, except for the carrier phase. In general, one or two epochs distinguish between a one epoch carrier spike (which disappears) and a missed cycle slip (which acts as a step function on the carrier residuals). Only the former can be handled by skipping an epoch.

Reliability tolerance for rejecting satellites or baselines – This is the ratio between the second best residual and the best residual necessary to detect an successful satellite or baseline removal. Generally, this value is left at 4.0, but it can be lowered (if a correction is missed) or increased (if incorrect corrections are occurring).

Distance Effects (PPM Error)
To properly account for distance dependent error sources, a parts-per-million (PPM) value is added to code and carrier phase measurement standard deviations. A PPM is added for the horizontal (spatial) distance and the vertical (height) distance between each master and the remote. The easiest way is to select the "error amount" which can be: Small, Medium or Large. Large would be used during a heavy ionospheric disturbance.

In addition, Large would cause a stronger weighting on the nearest base station. The actual PPM values used for each of these levels is determined by the processing engine and is dependent on the type of processing. To view the PPM values used, bring up the Static/KAR Summary file after processing. For example:

> ; Measurement Weighting Options:
> ;   Weighting Mode : Elevation Based
> ;   Main SD Values :
> ;   Code SD   : 4.00 m
> ;   Phase SD   : 0.0200 m, (adjusting for iono. correction)
> ;   Doppler SD   : 0.250 m/s
> ;   Baseline Values:
> ;   2530   : Using Main SD Values
> ;   cosa   : Using Main SD Values
> ;   Reject. Level : NORMAL
> ;   Max Rej Sec   : 15.0 (s)
> ;   Skip Code Rej : 5 nEpochs
> ;   Skip Phase Rej : 1 nEpochs
> ;   Reliability Tol: 4.00 , (for rejecting bad satellites)
> ;   Dist. Effects : **Medium, (HzPPM: 0.6, VertPPM: 5.5)**

Manual distance effects can be entered as well. In this case, the user would enter the horizontal and vertical values directly. Finally, this effect can be disabled, but this is NOT suggested—especially for multi-base processing.

2.3.6   L2/Ionosphere Options

Settings | Individual | L2/Ionosphere
GrafNav supports full dual frequency processing. For this feature to work, both the master and remote receiver must be dual frequency GPS receivers.

Most commonly used settings:
- Use L2 for dual frequency ionospheric processing
- Correct C/A for ionospheric using dual frequency data (500+ km only)

Advantages
By making measurements on both L1 and L2, the ionosphere error can be resolved. The effect of the ionosphere under normal conditions and in the absence of ionospheric storms is a small effect at 0.5 - 2 PPM (5-20 cm per 100 km). Because L1 and L2 carrier phase need to be combined to remove the ionosphere, the measurement noise will increase from sub 1 cm to 1-3 cm. A further problem occurs because L2 is more prone to cycle slips. For the ionospheric-free model, a cycle slip on L2 will induce a total cycle slip for that satellite. For the relative ionospheric model, this is not the case making it less sensitive to L2 slips. However, this adds additional noise to the solution, which can sometimes cause the relative model to be less accurate. Generally, ionospheric correction becomes beneficial on baselines greater than 10 km.

Another good reason for employing dual frequency is to improve the reliability of integer ambiguity search techniques. By combining the L1 and L2 carrier phase the so-called widelane is formed. These techniques are employed for Fixed Static and Kinematic Ambiguity Resolution (KAR). The result is that these techniques will work much more reliably, solve on longer distances and require less observation time.
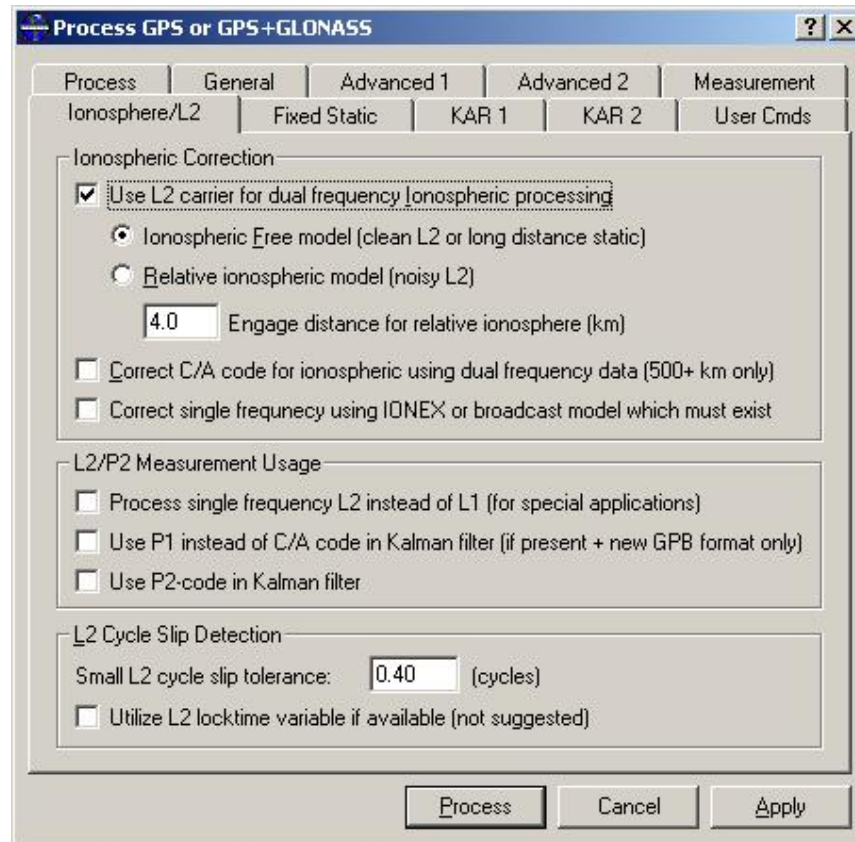
Figure 2.11 Dual Frequency (L2/Ionosphere) Processing Options

Ionospheric Correction
Use L2 carrier for dual frequency Ionospheric Processing
Once selecting this option, either the relative ionospheric or the ionospheric free type must be selected.

Ionospheric Free Model
This can be used for static or kinematic. The Iono-free solution will do a better job of resolving the ionospheric error at the expense of being more susceptible to cycle slips. Static baseline should only use this method.

For choosing between Iono-Free and Relative Iono Models there are several rules of thumb:
- If the L2 data is very clean with minimal losses of lock, then the iono-free model often works better.
- If the L2 data is continually losing lock, then the Relative model can be better.

- The relative likes to start close, but it is not necessary. In many cases both models will give similar results.
- It is also often a good idea to try both models. Sometimes one will work quite a bit better than the other.
- Iono-free should be used in static. It will aid the fixed static solution if the iono noise model is used.

Generally, for most GPS receivers, iono-free is superior to the relative model.

Relative Ionospheric Model
This is normally used when static initialization occurs when the base and remote are close and the ionospheric error at that base-remote separation can be assumed to be zero. Using the relative transfer algorithm, the ionospheric error is accumulated as the base and remote get farther apart. The distance from the base station when the relative transfer starts can be set using the Engage Distance. If loss of lock occurs, then this ionospheric transfer cannot continue. After this point, this solution becomes very similar to the ionospheric free model. Because of this last feature, the relative model can be used even if the starting point is far from the base. Since the relative model is less sensitive to L2 cycle slips, choosing this model might work better on data with frequent L2 cycle slips.

Engage Distance for Relative Ionosphere
This parameter is combined with relative ionospheric processing and it sets the radius from the base station before the relative ionospheric correction starts. This is an advanced parameter and changing it will cause little difference in the final solution. Users may wish to lower this value during periods of high ionosphere activity. The default value is 4.0 km.

Correct C/A code for Ionosphere
By combining the C/A code and the P2-code, the ionospheric effect can be removed from the pseudorange measurement. However, this adds additional noise on the order of a few meters. Thus, baselines need to be very long before the effect of the ionospheric is larger than the additional noise induced. Generally, baselines need to be 500 km or more in length.

Correct Single Frequency using IONEX or broadcast model which must exist
IONEX files contain information relating to the ionosphere on a given day. It can be used with single frequency processing to assist in the ionospheric modeling process. They can be downloaded using the download utility, see section 6.9.2 for more information on IONEX files and downloading them. To add them to the project, see Section 2.2.6 in adding precise ephemeris, satellite clock, and IONEX files.

L2/P2 Measurement Usage
Process Single Frequency L2 instead of L1 (Special Applications)
This mode utilizes L2 for carrier and P2 for code, and is most appropriate for special applications, such as:

a) GPS simulator testing
b) P-Y code receiver testing

c)   Operation during Jamming using a P-Y code receiver
For civilian receivers, there is no benefit to using this mode of processing.

Use P1 instead of C/A Code in the Kalman Filter
By default, the processing engine uses C/A for processing in the Kalman filter. Some
receivers can deliver better performance if the P1 code is used instead. Note that this
requires the NEW GPB format. In addition, P1 code data must be present (see *View |
GPS Observations | Station | View Raw GPS Data*).

Use P2-Code in Kalman Filter
Under normal circumstances P2-code measurements are not employed. This is because
most dual frequency receivers use narrow correlators (or similar technology) for their
C/A code measurements and these tend to be more robust and reliable than the P2-code.
Enabling this feature will add this measurement to the Kalman Filter thereby possibly
improving convergence.

L2 Cycle Slip Detection
L2 Small Cycle Slip Tolerance
Both KAR and relative ionospheric processing check for small cycle slips on L2 by
comparing it against the L1 phase. Raising this value too high will increase the chance of
a half cycle slip being detected. Lowering this value may cause false cycle slips to be
induced by noise. Changing this value requires analysis of the results and should only be
done by advanced users.

Utilize L2 Locktime Variable if available
In general, the default method of L2 cycle slip detection which compares L2 against L1 is
superior and generally results in less false detection. However, the user has the option of
using the L2 locktime variable which utilizes the cycle slip detection of the GPS receiver.
Watch out if too many cycle slips are being detected. If this is the case, you will see
many more warning in the message log if Static Slip warnings are enabled from the
Advanced 1 Settings. In addition, the forward or reverse position estimated accuracy
may be higher (if ionospheric processing is used).

2.3.7 Fixed Static Options

Settings | Individual | Fixed Solution
The search region size can be controlled along with the L2 noise model (see Advanced
KAR).

Most commonly used settings:
- Refine L1/L2 integer solutions
- Stricter RMS tolerance
- Stricter reliability tolerance
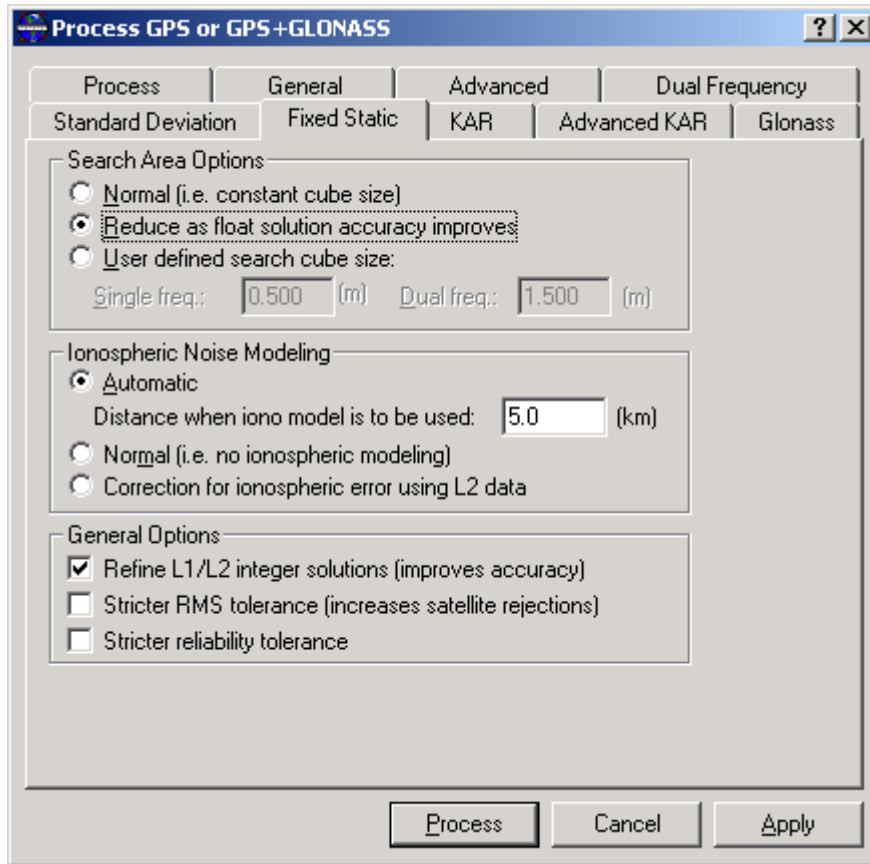
Figure 2.12 Fixed Static Processing Options

Search Area Options

Normal	This is the default search area, which is a constant search region size.
Auto-reduce	An auto-reducing search area is helpful for situations where the fixed solution is failing the reliability tests. Normally, this would be the case on short baselines, possibly with single frequency measurements.
User	A user defined search area is not often used. However, if the float solution is known to converge very close to the correction solution, then enter zero here.

Ionospheric Noise Modeling

The Ionospheric noise model controls how the L2 measurements are treated in the fixed solution. Due to anti-spoofing, L2 can be noisier than L1. Therefore, on shorter baselines, a noise model placing more weight on L1 (i.e. Normal L2 Noise) can deliver better results.

Normal	This is similar to the High noise model for KAR.

Iono   This noise model corrects for the ionosphere in its computation. This can improve accuracies, but noise might be higher on short baselines.

Automatic   This noise model chooses between Normal and Iono based upon the distance tolerance given.

General Options

For more detail about the following options, please refer to Section 2.3.8.

Refine L1/L2 integer solutions   This setting can be helpful in obtaining more accurate integer fixes. However, it can also result in poorer results. Generally, it helps more than it hurts.

Stricter RMS tolerance   This option applies lower tolerance to the RMS value of the best intersection.

Stricter reliability tolerance   The reliability is the ratio of the carrier RMS values between the second best and best intersections. Enabling this checkbox will apply a more stringent tolerance.

2.3.8   KAR 1 Options

Settings | Individual | KAR

Kinematic Ambiguity Resolution (KAR) is a technique that allows the user to compute an integer fixed solution (i.e. 2 cm) while the remote antenna is in motion. Typical applications would be kinematic initialization and initialization after loss of lock.

A KAR solution that uses dual frequency data is considerably more reliable than if only single frequency data is available. This is due to the additional measurements present with the L2 phase. However, KAR can deliver accurate results with single frequency, it just takes longer. Secondly, both single and dual frequency KAR requires at least 5 satellites. If KAR fails after a given length of time, then it starts searching over again.

KAR may skip some data after loss of lock, but it will try to go backwards as far as possible. The .FSS or .RSS file (Static/KAR summary) will show when KAR was engaged and when it was restored. Additional KAR statistics will also be shown here.
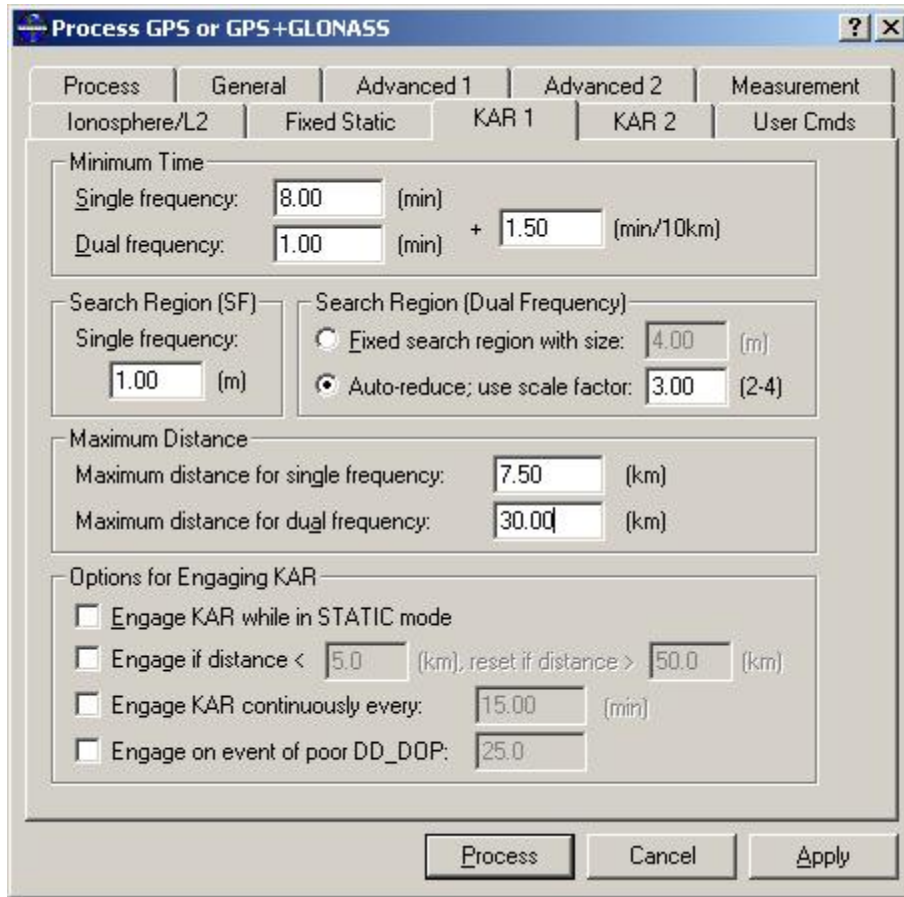
Figure 2.13 KAR 1 Processing Options

Minimum Time

Single Frequency
This is the minimum amount of time before KAR is invoked for single frequency. The default value is 8 minutes. This value should not be set to lower than 5 minutes unless azimuth determination is enabled in GrafMov.

Dual Frequency
This is the minimum amount of time before KAR is invoked in dual frequency mode. The default value is 1.0 minute. Users may wish to lower this value for urban data sets where fast ambiguity determination is very helpful. Longer baseline airborne users may wish to increase this number to minimize the effect of the ionosphere.

The value to the right is added to the time for every 10 km that the remote is from the base. For instance, if a dual frequency receiver is used, and the base-remote separation is 20 km, then the overall minimum time will be 1.0 min + 1.5 min*20/10 = 4 minutes.

Search Region Size
Single Frequency
This is the size of the search area for single frequency KAR. Because the single frequency KAR is invoked after 8 minutes or so, this value can be quite small. The default value is 1.0 m. Valid values range from 80 cm to 1.2 m.

Dual Frequency
For dual frequency KAR, there are two ways to determine the search area:
a)   Use a fixed search range (e.g. 4.0 m by default). This value is often lowered to 2-3 m to speed up KAR resolution time (used by fast KAR).
b)   Auto-reduce, which means that the covariance information is used for search area estimation. To ensure that the entire search area is encompassed, the ambiguity standard deviation is multiplied by a factor (e.g. 3). If a user feels that the standard deviations are overly optimistic, then raising this factor can be helpful. This mode is suggested.

Maximum Distance
Maximum distance for single/dual frequency
KAR will not engage if the remote is too far from the base. This improves reliabilities. The distance tolerance for engaging KAR in both single and dual frequency is defined here. Normally, the maximum allowable distance for single frequency is 7.5 km, while for dual frequency it is 30 km. These values are designed for a period where the ionospheric activity is high (i.e. year 2000). In subsequent years, these tolerances can be lengthened. This option (i.e. 'Maximum engage distance') only controls when KAR is started.

Options for Engaging KAR
Engage KAR while in STATIC mode
Normally, KAR will not engage in static mode. This is to allow static processing methods to take precedence. However, for users that wish to engage KAR in static, the option 'Engage KAR while in STATIC mode' should be enabled. Be cautious when combining this with the fixed static solution, as KAR's solution may supersede that of the fixed solution in certain circumstances.

Engage if distance < (tol1), reset if > (tol2)
This method of engaging can be very useful for airborne multi-base processing applications where the aircraft flies over various base stations. It will engage the first time that the distance is closer than *tol1*. If the distance becomes greater than *tol2*, then a flag is reset and *tol1* will be tested again. Note that all distances are in kilometres.

Engage KAR Continuously
This will engage KAR at a specified interval, and is most often used in monitoring applications. This value is usually set around 5-20 minutes. As this mode makes no attempt to check either baseline distance or data quality, it should be the least desirable mode for engaging KAR in airborne data. Consider using 'Engage on distance', engage on DOP or or Manual engage instead.

Engage on Poor DOP
The number of cycle slip free satellites to maintain lock is four. In some cases this minimum is maintained, but the geometry of these satellites is very poor. This can be seen as a spike in the DD_DOP plot. If the DD_DOP is extremely poor, the plot will not show the large DD_DOP as GrafNav skips past these epochs as their accuracy can be suspect. This will cause a gap in the data. The default DD_DOP tolerance is 100, but this can be changed using the DOP_TOL command.

Setting this checkbox will engage KAR after the DOP recovers from being very poor. The default tolerance is 25, but users may wish to increase or decrease this to control how KAR reacts at a poor DD_DOP. Note that KAR automatically engages if the DD_DOP is greater than DOP_TOL (i.e. 100) regardless of this setting. For DOPs above the DOP_TOL (i.e. 100), the solution is not available so users will need to view the .FML and .RML files for occurrences.

2.3.9   KAR 2 Options
Settings | Individual | KAR
Most commonly used settings:
- Stricter reliability tolerance
- Stricter RMS tolerance
- Use fast KAR
- Refine L1/L2 KAR search
- L2 Noise Model
- Manual KAR Engage
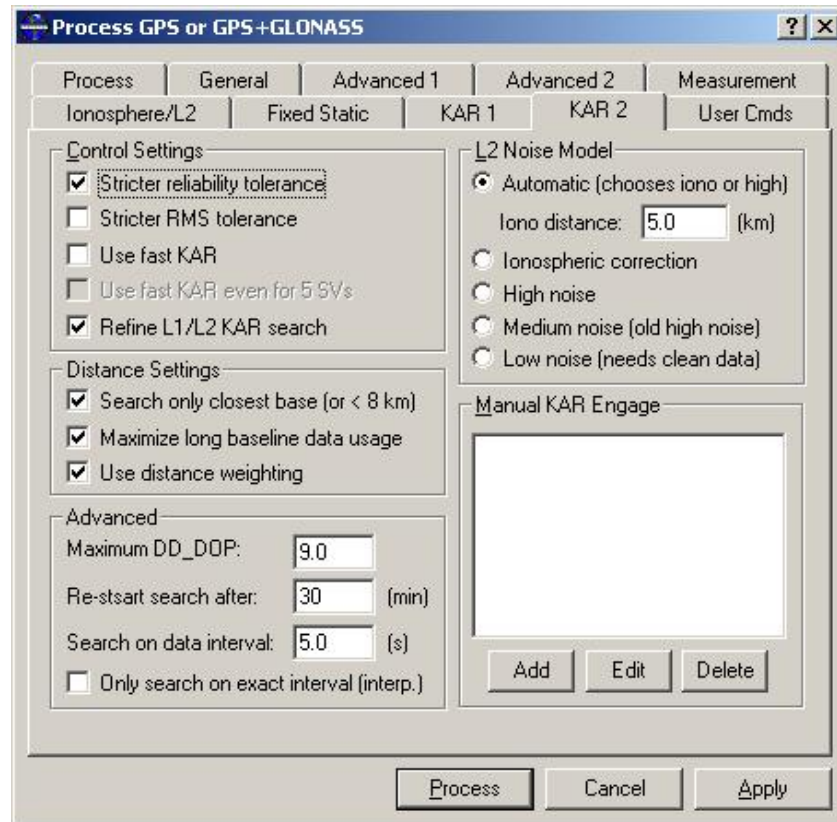
Figure 2.14 KAR 2 Processing Options

Control Settings

Stricter Reliability Tolerance
The reliability is the ratio of the carrier RMS values between the second best and best intersections. Larger values indicate increased reliability. The tolerance for accepting a reliability number is dynamic within GrafNav. Enabling this checkbox will apply a more stringent tolerance. Basically, a bias is added to the existing *dynamic* tolerance to make the tolerance stricter. This setting would be used to reduce the occurrence of incorrect KAR intersections. The reason that users may not wish to use this all the time is that it can cause to KAR to take longer to resolve or sometimes not resolve at all.

Stricter RMS Tolerance
This option is similar to the above except that it applies a lower tolerance to the RMS value of the best intersection. The tolerance, normally 0.065 cycles, is lowered to 0.05 cycles. The tolerance can also be altered using the KAR_RMS_TOL command. If this command is used, then this option will further lower the tolerance by 0.015 cycles. Like before, setting this will reduce incorrect KAR intersections. In fact, of the two, this feature is usually more effective. Some users may wish also to use both.

Use Fast KAR
Check this box to enable fast kinematic ambiguity resolution. Upon its selection, the user has the option of further specifying if they wish to also engage fast KAR even if only five

satellites (the minimum required for KAR computations) are present. Note that solutions computed using five satellites tend to be less reliable.

Fast Kinematic ambiguity determination, while not necessary in most GPS work done today, can be of large benefit to certain applications. Some examples of these applications include race car or rocket trajectory determination, some types of road surveys, and other surveys under generally open conditions with scattered obstructions of the sky. It can also be used to independently verify a KAR solution if different KAR fixes are obtained in forward and reverse processing.

By default, GrafNav will compute a float solution for 1 minute + 1.50 minutes/km (dual frequency) or 8 minutes + 1.50 minutes/km (single frequency) upon a kinematic initialization or following a simultaneous loss of lock on a sufficient number of satellites. This typically provides enough data to reliably resolve satellite ambiguities under reasonable GPS conditions.

As long as KAR successfully resolves, GrafNav will restore the ambiguities in the data from the moment it engaged so that centimetre accuracies are only unavailable for the actual period of signal obstruction. Hence, as long as no additional complete signal obstructions are encountered following the initial loss of lock, KAR will generally successfully resolve given good quality phase measurements and low multipath.

There is a problem with this methodology if your GPS survey is performed in an environment littered with signal obstructions. In this case, KAR may not resolve as it could have less data between successive losses of lock than the minimum time specified in the KAR options. Therefore engaging the fast KAR option will make several internal changes to the processing options. These changes include:

- Reducing the minimum KAR time to 0 minutes + 0 minutes/km
- Reducing the maximum time before KAR is started over to 8 minutes
- Increasing the amount of data KAR uses in its computations

The first change has the effect of telling GrafNav to resolve the ambiguities as quickly as possible. The second change forces KAR to be recomputed more often, and the third change helps reduce the amount of time KAR requires to resolve by increasing the amount of data it uses.

The following options are recommended only for dual frequency GPS users, as fast single frequency ambiguity determination is inherently unreliable. As well, before users should consider using fast kinematic ambiguity resolution, they should be aware of its limitations. Fast KAR is generally only reliable under the following conditions:

- Relatively close master-remote separations (< 7 km)
- Many (7 or more) satellites in view above a 10-degree elevation mask
- Dual frequency measurements are available
- Low multipath environment

- Clean carrier phase measurements

Even so, we recommend using Fast KAR only if needed.

Use Fast KAR even for 5 SV's
Five satellites is the minimum required for KAR computations. It is therefore risky to use fast kinematic ambiguity resolution in this situation. However, given otherwise favourable conditions (low multipath, clean phase measurements and a close master remote separation), it can be used successfully.

For more information regarding fast kinematic ambiguity determination, it's applications, limitations and accuracy, we refer you to the report titled "Fast Kinematic Ambiguity Determination in GrafNav v.6.03" located in the technical report section of our website (www.waypnt.com).

Refine L1/L2 KAR Search
When this option is checked a more intelligent methodology is used to correctly compute intersections. Sometimes ionospheric noise or carrier multipath can make it difficult to determine the carrier L1/L2 ambiguities. With this setting on, an additional search is performed. This can lead to faster and more correct ambiguity resolution. This setting also works well in combination with the stricter reliability / RMS tolerance setting – especially when accuracy improvement is the goal.

Distance Settings
Search only for closest base (or < 8 km)
This checkbox only applies for multi-base processing, and it causes KAR to utilize the closest base station (or those which are closer than 8 km). Disabling causes all base stations to be used and is normally not desirable. If a certain base station causes suspect fixes due to poor quality data, then consider disabling it (*View | GPS Observation | Master ___ | Disable*) or omitting it from KAR usage (see General Option, omit settings).

Maximize Long Baseline Data Useage
With this setting disabled, KAR stops using data as soon as the remote is significantly longer than the maximum distance. This can result in minimal data being used; thereby causing lower reliability. Will this setting enabled, all usable data less than maximum distance is utilized by KAR.

Use Distance Weighting
KAR has the ability to weight by the inverse of the base-remote distance (baselines shorther than 6 km will not be affected). This is helpful for airborne data as the effect of the ionosphere is distance dependent.

Advanced
Maximum Allowed DOP
KAR will not search if the DD_DOP is greater than this tolerance. This is to preserve the reliability of the solution. KAR solutions with high DOPs can be unreliable. However,

raising this value allows KAR to search where otherwise the software would skip past this data. The default value is 9.0.

Restart Search After
This is the time length before KAR will start searching over again. Lowering this value can cause fixed integer gaps to be lower. However, KAR will be prevented from using more data than indicated. This is more practical for dual than single frequency because single frequency KAR often needs 15 or more minutes to resolve. The default value is 30 minutes and this value is normally left 'as is'.

Search on data interval
This defines how many seconds between epochs that KAR will use for processing. Generally, if carrier phase errors are random (i.e. white noise), then using a lower interval will improve results at the expense of memory usage and computational time. If errors are systematic (i.e. colored/ionospheric noise), lowering this value will help little.

Exact interval (for interpolating data)
GPS data can be interpolated with the 'Concatenate, Slice and Resample' utility or using the 'Download Service Data' feature. In either case, additional errors of 1-2 cm can be added to measurements, which is sufficient to cause KAR not to work. However, if the 'Exact Interval' check box is enabled and the data interval 'Use on interval' has been set to the original source data interval (e.g. 30 s), then KAR will not be affected. Users may also wish to lengthen the minimum KAR time (KAR Options) to use more data, as one point every 30 seconds is quite sparse.

L2 Noise Model for KAR
KAR supports a number of L2 noise models, which model how GrafNav handles L2 data in dual frequency KAR. Due to anti-spoofing, L2 can be significantly noisier than L1 and this difference must be taken into account. The following noise models are available for L2:

High	This is different than the Version 6.01 (and previous) high noise model. It is more robust and is less susceptible to ionospheric noise.
Iono	This noise model corrects for the ionosphere, and seeds the ionospheric correction algorithms forming a more accurate KAR fix.
Medium	This is the old high noise model. There should be few cases where it performs better than the new high noise model.
Low	The low noise model places more weight on L2. It normally does not perform as well as the previous noise models, but for short baselines it may be helpful.
Automatic	The automatic noise model is the default, and it chooses between the High and the Iono noise model depending on the current distance. The distance tolerance is specified in the dialogue box.

Manual KAR Engage
Users can manually engage KAR at times that they feel it is necessary. For instance, there may be a perfect time when an airborne platform is very close to the base. In such a case, also consider lowering the minimum KAR time. The user must specify the time of engagement as well as the process direction. This feature works well combined with the process KAR (Manual Only) setting in the Process Settings. This will allow KAR to only be engaged when selected by the user.

2.3.10 GLONASS Options

Settings | Individual | Glonass
The GLONASS options govern the way GrafNav will use GLONASS measurements when computing a solution.

Solve for GPS-GLONASS Time Difference as Kalman Filter State
This option forces the time difference between the GPS and GLONASS time systems to be computed in the Kalman Filter. The difference between the two time systems is never more than a few meters (3-5m). Corrections to the GLONASS pseudo-ranges will be made using this time difference, but the phase measurements will not be corrected since they vary only by the change in this difference over time, which is extremely small. Computed ambiguities will account for the remaining error.

The initial value for the time difference filter state can be set if you know what it is. The initial standard deviation describes the confidence that you have in the initial value that you have set. The standard deviation should be between a few centimeters to a few meters. If you do not know what the initial value is, and you still want to compute it, enter zero and set the standard deviation of the state to about 2m or more.

The spectral density is noise that you purposefully add to the computation of the time difference state. Since both the GPS and GLONASS time systems are very stable, this number is always small, from about $0.001mm^2/s$ to $0.01mm^2/s$. If the spectral density is set too high, then the time difference computed will fluctuate erratically and never stabilize.

2.3.11 Datum Options

Settings | Datum
This screen is invoked by selecting Datum from the Options Menu. Users selecting 'More Datum Options…" from the General Processing Options will also see this screen. Figure 2.15 shows the property sheet that is displayed. Subsequent pages are the same as those for the Datum Manager, which can be accessed from the Tools Menu. The Datum Manager has one additional feature. It can convert geographic coordinates from one datum to another. See Section 10.5.2 Datums for more information.
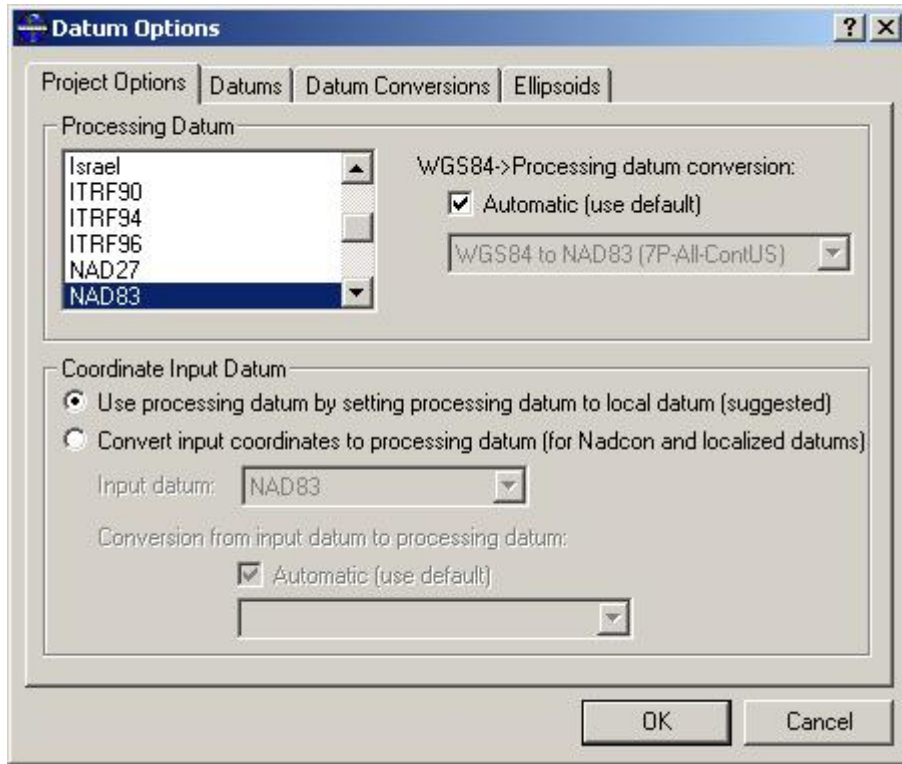
Figure 2.15 Datum Options

Project Options
Processing Datum
This is the datum in which the data is processed. The way GrafNav/GrafNet works is that it will convert the satellite coordinates into this datum. **By far the easiest procedure is to select the local datum from the list of datums**. If it does not exist, then select the Datum tab and enable the datum. If the desired datum does not exist, then a datum and conversion will need to be added. See Section 10.5.2 Datums for more information.

The 'WGS84->Processing datum conversion' is the set of transformation parameters used to convert between datums. Selecting the 'Automatic' checkbox will choose the default datum conversion. Another datum conversion can be made default by selecting the 'Datum Conversions' tab. Otherwise, deselecting the 'Automatic' checkbox will allow users to select a datum conversion more appropriate for a given area. The accuracy of the datum conversion becomes more important with increasing baseline length.

Coordinate Input Datum
In some cases, users will want to process in a more global datum such as WGS84, but enter the base coordinates in the local datum (e.g. NAD27). There are two reasons a user would do this:
- A grid style (e.g. NADCON) conversion is used to transform between datums. Such transformation will not convert satellites as they are often outside of the boundaries (see Section 10.5.2 Datums).

- The datum conversion is heavily localized. This means that it may have very large rotation values and its transformation is only valid over a small area (e.g. a city or state). Similar to NADCON, a user would not want to convert satellite coordinates using this transformation.

To enter coordinates in a different datum than the processing datum, ensure that the radio button labeled 'Convert input coordinates to processing datum' is selected. In such a case, the datum conversion becomes very important. Even more important is that the same conversion be used to later transform the output back to that datum. Otherwise, a datum error of several meters may be induced on the final coordinates. Currently, only the Export Wizard supports datum transformations. Thus, if this feature is used, do not use 'write coordinates'!!! See Section 10.5.2 Datums for more information. In any event, be cautious with datum conversions, as their accuracy can always be suspect.

Datums
This page allows you to enable/disable datums. For instance, there are 110+ datums in the list. Only a few of these are shown in many of the datum selection lists. This is to make it easier to find a datum. Users will want to disable unnecessary datums and enables the ones that are required. New datums can also be added here. If a new datum is added, be sure to add a conversion as well (see Section 10.5.2 Datums).

Datum Conversions
This page allows users to inspect, edit and add new conversions between datums. Normally, conversions are from/toWGS84. However, conversions between any two datums can be added. This page can also be used to make a particular conversion the default conversion for a given datum pair. See Section 10.5.2 Datums for more information.

Ellipsoids
This page allows users to inspect the A and B or A and 1/F values for a particular ellipsoid. Users can also add new ellipsoids. Most of the world's ellipsoids should already be added.

2.3.12 Process Single Point Options
Process | Process Single Point
This dialogue box appears when the user selects code-only single point processing from the process menu. This feature allows users to process the raw measurements within a GPB file without using the base station. Generally, accuracies are poorer than differential (even on longer baselines), but this feature can be useful if the nearest base is very distant. Quality control and clock issues can also be addressed with this feature. The top of the dialogue box shows the GPB file name, ephemeris file (precise or broadcast) and the method of ionospheric correction that will be applied.

Accuracies can be improved via the usage of the precise ephemeris, IONEX files, and satellite clock files (which can be defined via *File | Alternate Ephemeris Files*). Downloading these files is very easy with the new Download Service Data program (see

Tools | Download Service Data followed by selecting the *Options* tab). With the 'Download SP3 files' checkbox enabled, the most accurate precise ephemeris file will be downloaded from the IGS FTP site. IONEX and satellite clock files can also be obtained using the download program, see Section 6.9.2 for more details. Click 'Change Precise Files' to add them to the project.
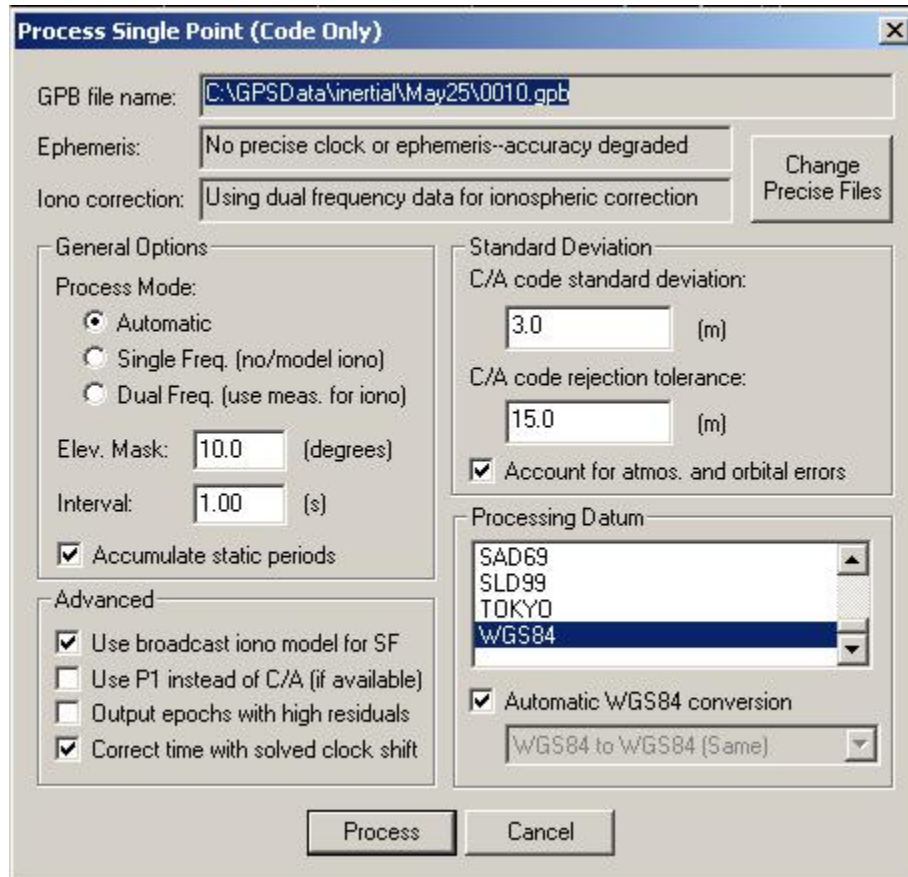
Figure 2.16 Process Single Point

General Options
Process Mode:

Automatic	Chooses between single or dual frequency depending on whether the GPB file has L1 only or L1/L2 measurements.
Single Freq.	Forces C/A only processing. Currently, the only means of removing ionospheric errors in single frequency is to utilize the broadcast (ICD-200) ionospheric model (Alpha and Beta values in GpsIon {} record within .EPP file).
Dual Freq.	Enables dual frequency ionospheric correction, which is computed from both the C/A *or P1* and P2 signals. If L1 and L2 carrier are available, this correction is further refined.
Elev. Mask	Satellites below this elevation value will be rejected.

Interval   Only process epochs that fall on this data interval (which is specified in seconds). Use a value of 0.0 to process all epochs.

Accumulate static periods   Enable this checkbox to compute a weighted average for static periods thus improving accuracies.

Advanced
Use broadcast iono model for SF   Enable this to use the ICD-200 broadcast or IONEX ionospheric mode for single frequency correction (if it is available in the .EPP file).
Use P1 instead of C/A   For some receivers, interchannel biases between C/A and P2 result in a less accurate ionospheric correction being computed. If these receivers also have a P1 signal (see GPB Viewer to find out if they do), then P1 can be used to compute a more accurate correction. P1 will also be used in the single point least-squares computation.
Output epochs with high residuals   The single point processor normally rejects epochs with high residuals that cannot be fixed. Enable this checkbox to always output solution data regardless of quality.
Correct time with solved clock shift   Normally, the single point process uses the raw receiver measurement time stored in the GPB format. However, if the corrected time in the GPB file is deemed more accurate, then enabling this setting will not use the computed clock correction to compute a new corrected time. This can be helpful for processing some data sets with times problems--especially in the OLD GPB format.

Standard Deviation
C/A code standard deviation   This is the estimated accuracy of the C/A code measurement. An accurate number here will result in better accuracy estimates, but will not affect the trajectory.
C/A code rejection tolerance   This setting is useful for defining the tolerance above which measurements will be detected an erroneous. First the software will attempt to fix such errors (by removing the satellite), or it will reject the entire epoch is a bad satellite cannot be located.

Account for atmos. and orbital errors   Adjust final accuracy estimate using nominal orbit, tropospheric, ionospheric and receiver clock errors. Like the C/A code standard deviation, this will not affect the actual trajectory.

Processing Datum
See 10.5.2 Datums for more information on datums.

Section 4   Additional Features (Before and After Processing)

2.4.1   Master Station Coordinates

Settings | Coordinate | Master Tab
This option allows you to change the master station coordinates. When starting a new project, the program prompts the user for the master station coordinates. If you did not enter the exact coordinates at that time, you can go to this option to enter them after the project has already started. **See Section 2.2.4 for more information**.

Note: If the coordinates are in a datum other than WGS84, make sure to select the proper datum from the Datum Options button.

2.4.2   Remote Initialization

Settings |Coordinate | Initialization Tab
With this feature, users can "fix" the remote position at any number of times or locations within the survey. This feature works best with shorter baseline lengths, and it is intended primarily for surveyors. However, on long baselines combined with dual frequency receivers, baselines can also be fixed to some degree.

The procedure is normally as follows:
- Determine when (or where) the antenna was over the known point. This is a point of known latitude, longitude and height. It could be a station name (as it appears on the GrafNav screen), or it could be a specific time.
- Define if a fix is to take place in the forward, reverse, or both processing.
- 'Snap to integer' works well on shorter baselines and can result in improved accuracies. It moves the point to the closest carrier phase integer ambiguity intersection. It can be spotty on noisier data as only one epoch is used.
- Make sure to enter the proper antenna height.
- The time window defines how close a time can be and still perform a fix.
- Finally, enter the position of the fix coordinates. This is the monument position.
- The Ambiguity fix works best on longer baselines such as airborne data.
- Automatic selects a method best suited.
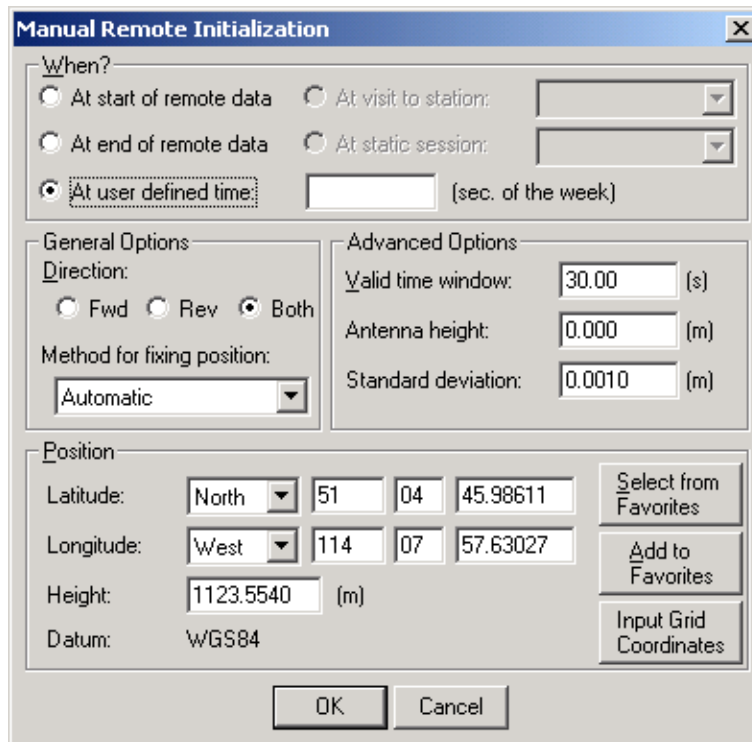
Figure 2.17 Remote Initialization

When?
Here is where the user selects or enters the times where the initialization took place. For kinematic trajectories, selection of a time is preferable to the start/end method because the software may not start processing on the very first epoch. Be sure to set a sufficiently small time window below. For stations or static sessions, be sure that the antenna height is correct.

General Options
Direction
Fwd	Forward direction.
Rev	Reverse direction.
Both	Both forward and reverse direction.

Method for fixing position
Automatic	The selects one of the modes below based upon baseline length, base/remote height difference and estimated accuracy of the current epoch.
Ambiguity Fix	This tends be the most robust method overal and does the best job of keeping the position selected (which includes any errors that may be present). Airborne applications should only use this method.

Snap to Integer	Practical for short baseline applications (such as surveying). It selects the nearest integer position, which means that input position must be accurate to at least 1/2 cycle (10 cm for L1 and 40 cm for L1L2).
Position Fix	This works when the position's accuracy is suspect. In general, the user can try to speed up convergence but this does not always show that much of an improvement over not using a seed at all.

Advanced Options

Valid time window	In the When? section, user has selected at which point the fix should be applied. This setting defines how close the an epoch should be before it should be used. For kinematic trajectories, this value should be 1/2 the processing data rate.
Antenna height	Height of the antenna position above the marker position supplied below.
Standard deviation	Estimated accuracy of the position supplied below. This will be most important for the position fix mode or in the automatic setting (which uses it to decide which method of fix to use).

Position
This is the marker position to be utilized for all of the above modes of position fix. This height *plus* the antenna height is the location to be used for the antenna position. See Section 2.2.4 for more details.

2.4.3 Combining Forward and Reverse Solutions

Process | Combine Solutions | Forward and Reverse
This is the process of taking GrafNav solution files processed both in forward and reverse mode to form an optimal solution. Newer versions of GrafNav no longer allow users to select the mode for combining, as variance weighting will always be used.

What are the benefits?
The overall accuracy is improved because in many cases the forward solution is more accurate than the reverse *or vice versa* for a given epoch. This accuracy difference may change during the mission. In turn, the weighting function (see Section 2.6.1 Plot GPS Data) should reflect these accuracy differences.

By combining the two solutions a difference can be computed and plotted (2.6.1 Plot GPS Data). This difference graph gives an indication of solution accuracy and problem areas. However, it should be noted that the actual accuracy would often be better as the combining process places more weight on the solution with greater estimated accuracy.

Before this process can be invoked, there must be a forward (*project*.FWD) and reverse (*project*.REV) solution file present.

How does the process work?
A weight between 0 and 100 is assigned to both the forward and reverse solution. The sum of both will equal 100. All three axes (latitude, longitude and height) are assigned the same weighting value. The weight is computed by 1 / variance. Fixed integer positions will be weighted much stronger than float solutions.

The combined solution is intended for kinematic processing. The combined solution will average static epochs, but it will not average static sessions.

Where do I find the coordinates from the combined solution?
The combined solution does not create a separate output file. To view the coordinates, you must write the coordinates or use the Export Wizard (the Export Wizard is suggested). This can be done by writing epochs or features (i.e. stations). To create a "combined" file with the same format as the forward or reverse solutions, use Export .CMB File from the Output Menu. There is also a command line utility available to do this combination.

2.4.4 Combine Any Two Solutions

Process | Combine Solutions | Any two solutions
This feature is similar to the Combine Forward and Reverse option, but any two solutions can be combined. Either forward, reverse or combined solutions can be combined. Users may wish to combine files from different processing settings of the same master and remote. It can be very helpful for examining the effect of making changes to the options, or users can compare a fixed to a float solution to try and detect a bad ambiguity resolution.

Combining combined solutions is also possible. Using GrafNav Batch is preferable, however, users may also wish to use this feature. In order to make this possible, the combined solutions must first be exported. From the Output Menu, select 'Write Combined (.CMB) File' from each GrafNav project. Then in the current GrafNav project (which may be one of the two), use the 'Combine Any Two Solutions' feature.

IMPORTANT: These solutions must be collected at the same time using the same antenna and the same receiver.

2.4.5 Combine Settings

Process | Combine Solutions | Combine Settings
This feature is similar to the Combine Forward and Reverse option. It allows the user to reject certain time intervals of the Forward or Reverse solution. This way, areas where there are bad results will not be included into the combined solution.
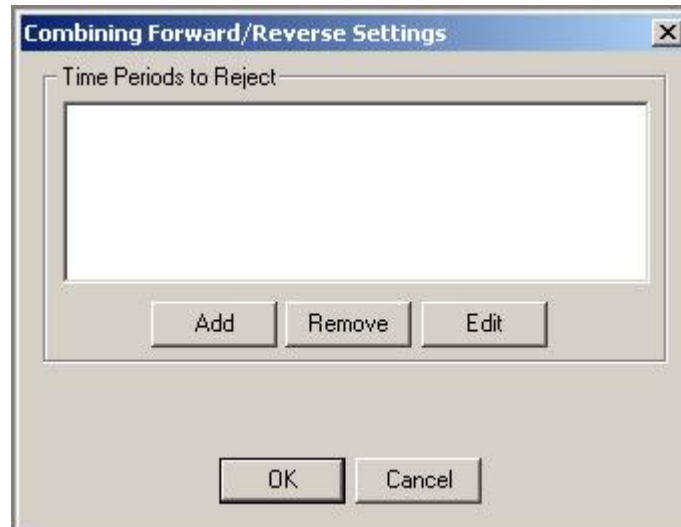
Figure 2.18 Combine Settings

Click on the Add button to enter the times where the forward or reverse solution is to be excluded from the combined solution.

2.4.6 GPS Observations

View | GPS Observations
Here the user can check on information relating to the master(s) and remote files. These include viewing station data, raw GPS data, resampling options, editing, plotting locktime plots etc. See Section 2.2.7 for more details on these options.

2.4.7 Epoch Output

View | Forward/Reverse Solution | Trajectory
This file provides a detailed record of the output at each epoch. It is principally useful for keeping a record of the data computed for kinematic processing. Refer to Section 9.1.3 .FWD or .REV for a description of both the old and new output formats. By enlarge, the plotting feature will plot most of the statistical information contained in these files. However, some users may wish to look at the actual raw numbers.

Users would view this file for the following reasons:
  - Compare the exact numerical values between epochs or solutions.
  - View the statistical and epoch information for an exact point in time. Press F3 to search for a time.
  - View specific satellites or what the base satellite is. The plotting functions on indicate how many satellites are used.
  - If the command VERBOSE=ON is used, then additional KAR information is printed to this file.

2.4.8 Message Log

View | Forward/Reversed Solution | Message Log
This file simply echoes all warning messages sent to the message window during processing. See Section 9.1.1 for more details.

Some of the messages sent are as follows:
- Status messages on the progress of KAR and fixed solution.
- When KAR is engaged and why (i.e. due to loss of lock, poor geometry, etc…) (***).
- Ephemeris messages such as satellites whose ephemeris is missing.
- Epochs of less than 4 satellites.
- Notifications of extremely poor DOP (i.e. DD_DOP>100). These epochs are skipped, the DOP at these epochs will not be plotted from the Plot GPS Data option. This is the only way to see these locations.
- Cycle slip warnings -- These are very important as they give you a time and record of the occurrence of these slips. In some cases, cycle slips or many slips will indicate problems (especially in kinematic mode). Only shown if 'Write cycle slip warnings to message log' is enabled through Advance 1 options.
- Warnings of data errors such as filter resets, rejected satellites and invalid measurements ($$$).
- When entering static and kinematic modes.
- Changes in the satellite constellation. These include changes in the base satellite, satellites rising or below elevation mask, etc.
- Notification of position fixes (###).
- Notification of data omission.

2.4.9 Static Session/KAR Summary

View | Forward/Reverse Solutions | Static/KAR Summary
This file shows initial processing settings, final static solution, KAR fixes, and program completion status. See Chapter 9 File Formats for a complete description of the format.

Some reasons for looking at this file are:
- View the final solution for a static period.
- Locate when KAR engaged and what the statistics were. This can be useful for evaluating if, when and where KAR engaged incorrectly.
- Check the master station coordinates, datum or other start-up settings.
- View the periods when and how long satellites are tracked for the static fixed solution.
- See which satellites were rejected during the static fixed solution.
- See the solution type used for a static solution (e.g. L1-Float, L1L2-NewFixed, …).
- See the slope distance, horizontal distance and ellipsoidal (corrected) distance for a static period.
- Program completion information.

2.4.10   View the Reverse Solution Output Files

Same as Forward.

2.4.11   View Processing History

View | Processing History
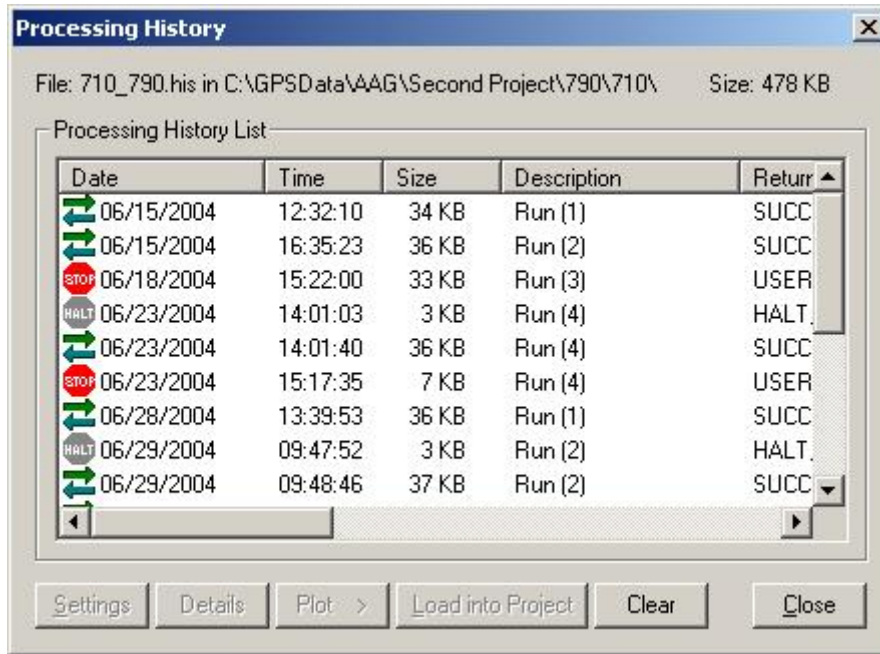
Figure 2.19 Processing History

This displays the processing history in a time ordered list. It contains the date, time, size of the history, the description of the run, processing directions, the user's initials and the return status. Clicking on 'Settings' will bring up the processing settings used for that run. Clicking on 'Details' will bring up a window that dispays more information about the processing run, including the configuration file. See Figure 2.20.
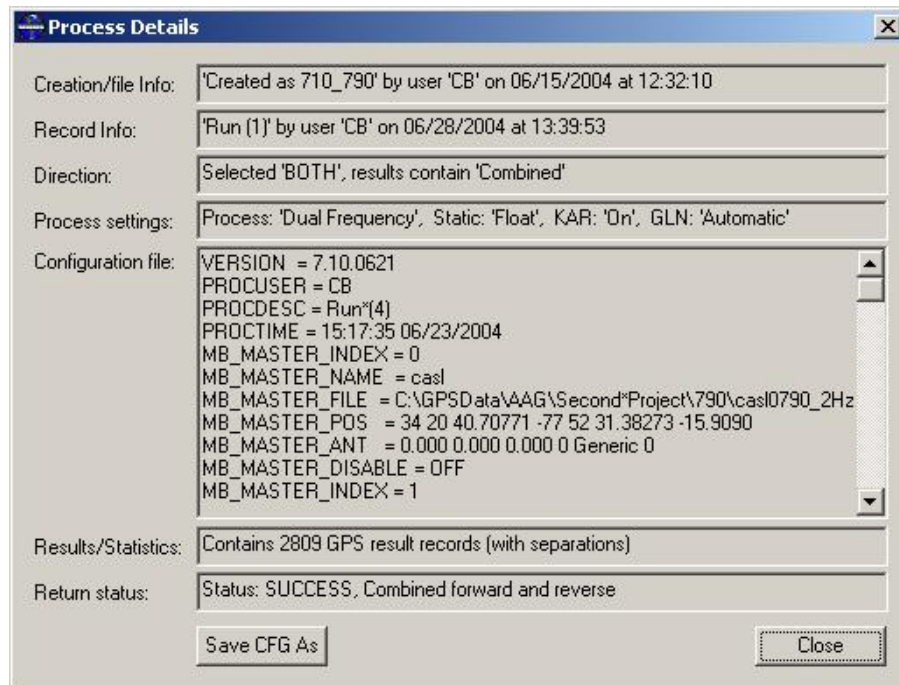
Figure 2.20 Processing Details

If the user wishes to save these processing settings into a new configuration file, click 'Save CFG As' and a new dialogue box will prompt the user for a new name. This is an effective way to start a new project using a previous configuration.

The Process History saves certain statistics every 10 seconds. This is useful for comparing processes. The user can plot these values by clicking 'Plot'. The user can plot the forward/reverse separation, estimated position accuracy, float/fixed ambiguity status, and the quality factor. Note that not all plots may be available if both directions were not processed or if processing was interrupted (e.g. user stopped processing).

Clicking 'Load into project' will load the settings from a particular run into the current settings. The user will be prompted if they wish to make a backup of the current project settings. Selecting 'Yes' will save the current configuration into a .bak file before overwriting with the previous configuration.

By pressing 'Clear' the processing history will be entirely deleted. Select 'Yes' to confirm.

If two process history selections are made, the 'compare' button can be pressed to compare CFG files. This can be helpful in determining what settings are different. See Appendix A Summary of Commandsfor the meaning of these commands.

2.4.12   View Processing Summary

View | Processing Summary

This summary screen provides statistics about the current forward, reverse, or combined solution that is loaded in GrafNav. It is mainly intended for kinematic processing, however it can be used for static despite being less meaningful. The Processing Summary includes details such as solution type, baseline distances, total number of epochs (i.e. in the remote .GPB file), epochs not processed, and epochs with bad C/A code and L1 phase measurements. Bad C/A code and L1 phase measurements are deemed as unacceptable based on the standard deviation rejection tolerances + Distance PPM error specified in the Standard Deviation processing options.

Statistics such as RMS values of the C/A code, L1 phase, L1 Doppler measurements, quality number percentages, estimated position standard deviations calculated from the Kalman filtering, and percentages of epochs having double difference DOPs over 10, provide a quick, convenient method of assessing processed solutions. The forward/reverse separation RMS values for E,N, and H are listed, and a new addition is the forward/reverse separation RMS values of E,N, and H for 25%-75% weighting.

The latter RMS values take into account the weighting of the forward/reverse combined solution only in the region of 25%-75% where the float solution has had time to converge to a lower value of error since the larger error values occur at the beginning of the processing direction. The same can be said for a KAR fixed solution as well. The RMS values for the 25%-75% weighting of the combined solution are generally lower than the RMS values from the forward/reverse separation because if one solution has high error values, most of the weighting will go to the other processing direction.

Note that this screen can be added to the end of the output text file created with the Export Wizard (see Header/Footer settings).

2.4.13   View Return Status

View | Return Status

This option will display the last processing status. This feature allows you to see whether the processing was successful or, if not, why. It shows the contents of the finish{} record in the fss/rss file.

2.4.14   View the GPS Raw Binary Data

View | Raw GPS Data

Binary measurement data is stored in our custom .GPB format. This format is receiver independent and only stores necessary information to minimize disk space requirements. This format contains a position record and the number of measurement records for each epoch. See Chapter 6 Section 3 for more information on this feature.

2.4.15 View the Current .CFG file

View | Current CFG file

This will open the configuration file with the internal viewer. Processing options and user comannds are stored in this file so that the project can be opened at a different time with the same configurations. The definitions of the commands are located in Appendix A of this manual.

Section 5   Settings Menu

2.5.1 Grid Options

Settings | Grid

GrafNav projects now store grid information. Users may wish to setup a grid for the following reasons:

- Master coordinates can also be entered in grid directly. This can be very convenient if source sheets do not have geographic coordinates
- The map screen can plot in grid coordinates
- DXF output will use these Grid Settings.
- Export Wizard can use a defined grid using the Selectable Grid field.

New grid definitions can be added by clicking 'Define Grid' in the Grid Options or via *Tools Menu | Grid/Map Projections | Define*. Such grid definitions can be used here and the Export Wizard (use Selectable Grid variable). Note that the write coordinates feature cannot use selectable Grids.

2.5.2 Preferences

Settings | Preferences…

Display Preferences

This option allows you to edit the main screen display and other preferences. The default for the zoom increment is 3. The user can change this to any integer number greater than zero.

'Use H:M:S m/d/y for default time system' encourages GrafNav to display this time format instead of seconds of the GPS week.

'Show direction arrows' shows arrows in the direction of travel on the map screen.

Coordinates for Display

'Geographic' displays the latitude and longitude on the screen. The orientation is such that the positive y-axis is true-north.

'Local level' shows the vector difference between the master and remote. It is most useful for GrafMov where users can see the relative separation rather than the absolute position, which is less meaningful.

'Grid' coordinates can also now be displayed. To set the Grid system, choose Grid from the Options Menu. Note that the UTM zone has not been set. In such a case, the display may be severely rotated. Use the Grid Options to set the zone correctly. See Section 2.5.1 for Grid Options.

Zoom Level Specific
The next set of options is based on each zoom level. Level 0 is the main screen without being zoomed. Each level has its own set of default display options that can be changed to meet with individual preferences. The zoom level options include Font Size and Symbol Size. The Show Text option allows the text to be seen on the screen such as the word MASTER at the base station.

Multibase Static Session Plotting Options
The user can choose whether to plot the static session lines to all base stations, to the nearest base station, or not to draw any lines at all.

Solution Preferences
Under the 'Solution' tab, the user can set their preferences in GrafNav. Enabling 'Load solution on project start' will load the .fwd and .rev files into the project once a .cfg file is opened, if they exist. Enabling 'Combine forward/reverse after successful processing' will automatically load the combined solution into the project after processing forward or reverse direction. A combined solution is always loaded after processing both directions. Enabling 'Automatically write .CMB file after processing' will write a .cmb file after processing. Note that this will slow down the CPU response after processing if a large project has been processed.   If the option 'Prompt user when finished processing' is turned on it will display a message at the center of the screen once processing is complete. If it is turned off the user should hear a beep after processing (unless an error occurs).

2.5.3   DEM Plotting Options
Settings | DEM Plotting

Using the DEM display plotting Options can help speed issues with using large DEMs in GrafNav, see Figure 2.21 below.
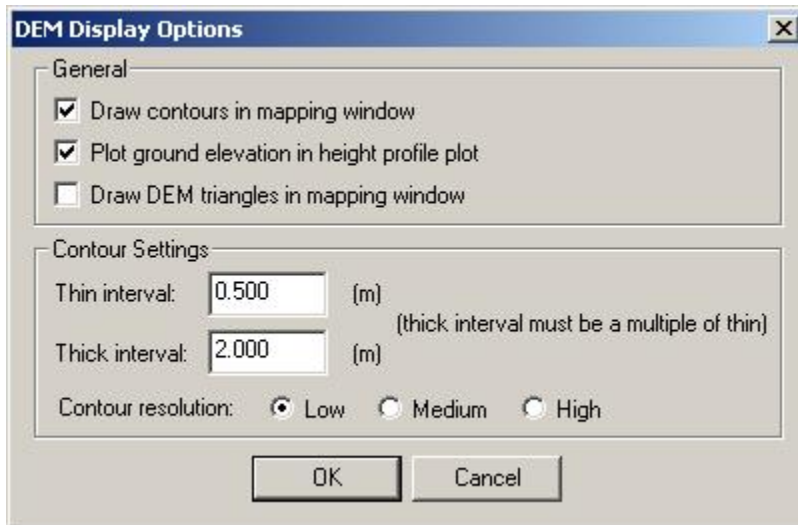
Figure 2.21 DEM Display Options

Drawing contours in mapping window will show up along with the trajectory to show a topographic representation of the GPS survey. Zooming in may be required to view the elevation of each contour. Drawing the DEM triangles will display the TIN model of the network formed. Turning these options off can reduce any sluggish response from the program when viewing the map window.

Plotting the ground elevation in the height profile plot allows the user to check the ground height compared to the height of their trajectory. Sometimes the ground height can slow down the plotting of the height profile. Turing this off allows the user to only view the height of their trajectory.

The user can also control the interval of the contour elevations by entering the thick and thin line intervals. Note that the thick interval must be a multiple of the thin. The contour resolution can also be controlled. Selecting a higher resolution will show more smoothness in the contour lines, although this gives more details and may slow down CPU response and use more RAM. Having a lower contour resolution can speed up the response from GrafNav.

2.5.4 Photogrammetry Options

Settings | Photogrammetry
The options described here are useful for using GrafNav for the purposes of GPS assisted aerotriangulation. This includes a control over how interpolation is implemented, and it includes a special processing mode useful in conjunction with Bundle adjustment drift parameters.

Figure 2.22 Photogrammetry Options

Camera Pulse Interpolation
These options determine how the camera marks are interpolated. More information on loading camera marks can be found in Section 2.2.10. Since each photograph is seldom taken on the even epoch, it must be interpolated to compute a proper position. There are two methods of interpolation supported by GrafNav: Linear interpolation and a 2nd order polynomial. The polynomial interpolation will give the best accuracies, but it can sometimes induce larger errors if epochs are missed or dynamics are very high. This can be detected by viewing the RMS value computed for each camera pulse, which can be viewed by clicking on the station or writing the coordinates, selecting features and doing <u>no</u> geoid correction. In such cases, the linear interpolation model will deliver better results. The size of the window for which the polynomial is fitted can also be controlled. Ideally, this number should be kept at 4, but it can be increased for more averaging. This can sometimes be dangerous unless very high data rates are available. The linear interpolation model is much simpler and gives no RMS statistics. It merely fits a line between the two nearest epochs and places the camera mark on it. It is simple but effective.

2.5.5 User Defined Options

Settings| Individual | User Defined
The User Defined Options dialogue box can be used to change any command that is passed to GrafNav (Refer to Appendix A for a list of commands). It can be used to modify commands that are set by the other dialogue boxes, or set commands that are not normally used (those commands not handled by the other dialogue boxes).

When a configuration file is loaded, all commands that are not handled by the other options dialogue boxes will appear in the User Defined Options dialogue box. This

includes commands that do not exist in the version of GrafNav that you are using. Commands that do not exist can easily be deleted here.

2.5.6 Load Settings From

Settings | Load Settings From

This feature permits users to load configuration settings from one of the following:

- Factory Defaults – Built-in default settings (cannot be altered by user).
- <Program> Defaults – Startup settings that can alter by user. Otherwise, same as Factory Defaults.
- Pre-loaded Profiles (e.g. Airborne, Low Cost, Tree Cover, etc.) – These are settings that come preloaded with the software.
- User created profiles – These are profiles that can be created by the user.

2.5.7 Manage Settings

Settings| Manage Profiles

Figure 2.23 Manage Settings

Create from Project	Create new CFG profile uses the current project's settings.
Load into Project	Same as 'Load Settings From' menu selection. Basically this loads the options from this profile into the current project.
Update from Profile	Updates the CFG profile with the current project settings.
Rename	Allows profile to be renamed.
Edit	Brings up processing setting dialogue, which allows the selected CFG profile to be modified. Note: Modifications to pre-loaded settings will be lost if software is reinstalled.

Delete   Deletes the selected profile.
Copy From   Creates a copy of the currently selected profile.

Section 6   Output Menu

2.6.1   Plot GPS Data

Output | Plot GPS Data

This feature is very useful for analyzing GPS data and processed results. The plots are divided into eight groups: Most common, Accuracy, Measurement, Separation, Quality Control, Coordinate Values, Miscellaneous, and All plots. The 'Build Custom List' button allows users to form their own list of plots that will show up under the 'custom group'. See Figure 2.24.
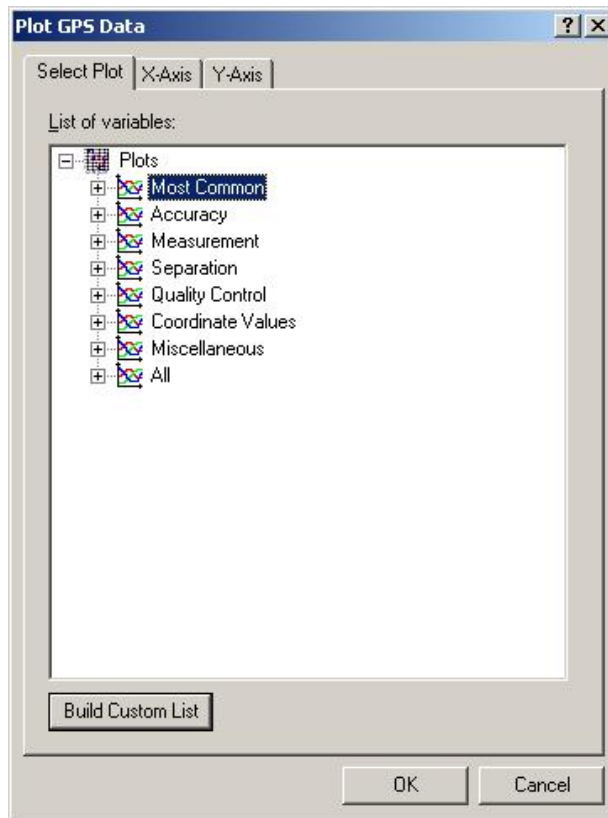
Figure 2.24 List of plotting categories

Along with selecting the plot type, users can define X-Axis and Y-Axis information. Changes made to these pages will be retained for future plots. For instance, if a time range is entered in the X-Axis, this same time range will be used for future plots in this project. This can be very useful to inspect a narrow time slice. Users can still make changes to axes information after the plot has been displayed by right-clicking on the plot.

If features are loaded (e.g. stations or camera marks), then plots will show these as vertical red bars at the top of the plot. For most *but not all* of the graphs, clicking on the feature will show solution status information.

Plot features available via the mouse right-click are:

- Edit Axes – Users can change the ranges on the x and y axes. In addition, users can switch between seconds of the week and hours minutes seconds time display.
- Edit Titles – Users can modify the plot, x-axis and y-axes titles.
- Set Y-Axis Range – Previous settings of the time range are stored here
- Set X-Axis Range – Previous settings of the Y-Axis are stored here
- Auto-scale (X-Axis) – This feature will show the entire time range of the data.
- Auto-scale (Y-Axis) – This feature will show the entire value range of the data.
- Set Start Plot Time – This will make the current time the x-axis minimum.
- Set End Plot Time – This will make the current time the x-axis maximum.
- Set Maximum Plot Value – This will make the current value the y-axis maximum.
- Set Minimum Plot Value – This will make the current value the y-axis minimum.
- Copy – This will copy the plot onto the clipboard as a bitmap (.bmp file) and users can paste the image in another application such as MS Word or Paint.
- Copy (without title) – This will copy the plot onto the clipboard as a bitmap (.bmp file) without the title of the plot.
- Go to Time in Forward Message Log – This will search the forward message log for a time closest to the time clicked on. Note that KAR may rewind the file to some degree. Users may need to search below the found location to find the rewound epoch.
- Go to Time in Reverse Message Log – Same as above but for the reverse message log.
- Go to Time on Map – This will show the epoch on the map pertaining to the time clicked on. This is a handy feature to geographically locate problem areas.
- Set Start Processing Time (GPS/IMU) – This will make the current selected time the begin time in the General Options for GPS processing or IMU processing. Note that not all plots have this feature enabled.
- Set End Processing Time – Same as above, but it sets the end processing time.
- Engage KAR at Time – This will engage KAR the current selected time.

List of Available Plots

Acceleration Profile   **Advanced**
This plot shows the approximate acceleration computed by the baseline processor. To permit this plot to be shown, users must also enable Extended output from the Advanced options (see 'Epoch Output' in the bottom right corner).

Ambiguity Drift   **Advanced**
This value indicates solution stability—especially for a float solution. Under ideal
conditions, the ambiguities should be driftless, thereby having a drift of 0 cycles / sec.
Normally this number will be 0-0.03 cycles for very stable solutions, and 0.03-0.05 for
quality 2 stability, and otherwise Q3 and up. Most users rely on the quality number
instead of the Ambiguity Drift. The quality number is partially derived from this
parameter.

Combined Separation   **Novice**
Requires forward and reverse solutions to be combined. Basically, this is the difference
between the two combined solutions. For multi-baseline combination in GrafNav Batch,
this is the *maximum minus minimum* difference between baselines for each epoch, and the
number will always be positive.

Combined RMS   **Intermediate**
This plot is only applicable for multi-base processing. Instead of showing *maximum
minus minimum* like the Combined Separation plot does, it shows the weighted RMS of
the baseline. Thus, if one baseline does not fit well, but it is given a very low weighting,
it will not affect this plot as much. It is a good idea to view both just to be sure, as this
plot can be optimistic.

Combined Weighting   **Intermediate**
This requires that two solutions be combined. It is the weighting factor (0-100) given to
both the forward and reverse solution. Note that this is not the weighting of different
baselines in a multi-baseline project. See the 'Effective Baseline Weighting Plot' in
Multi-base plotting (see Section 2.6.2).

Combined Number of Solutions   **Intermediate**
This plot shows the number of baselines that are used to form a combined baseline. This
can be useful for multi-base processing.

Distance Separation   **Novice**
This plot shows the difference between the 1st master and remote in kilometers. It can be
useful to identify where the master and remote are either far apart or close in kinematic
data. Under the advanced plotting, it can be shown in meters. For multi-base distance
separation, see 'Distance to base stations plot' (see Section 2.6.2).

DOP – DD_DOP   **Intermediate**
Indicates satellite geometry relating to position. Small values indicate better geometry.
This value is the double difference DOP and is approximately PDOP^2. Although, it can
be somewhat lowered due to the differential modeling. The DD_DOP is used for all
internal checks and DOP related options in the software. Epochs with extremely poor
DD_DOP (>100) are skipped and will not be plotted. Use the DOP_TOL command to
change the default DD_DOP tolerance of 100.

DOP –PDOP, HDOP, VDOP   **Novice**
Indicates satellite geometry relating to position. Small values indicate better geometry.
Lines are displayed for position DOP (PDOP), horizontal position DOP (HDOP) and
vertical position DOP (VDOP). These values should be similar to other PDOP
computations, but differences can be visible due to the double differencing (i.e. different
base satellite selection).

Estimated Clock Accuracy   **Advanced**
This plot shows the estimated standard deviation computed by the least-squares single
point processor. In general, it will match position accuracies.

Estimated Position Accuracy   **Novice**
This option plots the standard deviations of the east, north and up directions versus time
for your solution. A fourth channel, the total standard deviation with a distance
dependent component is also plotted. Viewing this plot for individual forward or reverse
solutions will show losses of lock very nicely.

Estimated Velocity Accuracy   **Intermediate**
Velocity is the local level component (easting, northing, up) computed by the Kalman
filter. These are mostly derived from the Doppler measurements. Plotting the Doppler
RMS is a good means to check the actual accuracy base on real data. Plotting the
estimated standard deviation shows the theoretical accuracy base on the Kalman filter
error estimates.

Float/Fixed Ambiguity Status   **Novice**
This plot shows whether an epoch has a fixed or float ambiguity status. Fixed integer
ambiguities generally have better accuracies, and they are preferable for obtaining <20
cm accuracies. This plot will also show if there are zero, one or more fixed ambiguities
used to determine a combined solution.

GPS/GLONASS Time Offset   **Advanced**
The time offset shown here is the computed difference between the GPS system time and
the GLONASS system time. Also, part of the time-offset value is due to small inter-
channel biases between the GLONASS channels with respect to one another and with
respect to the GPS channels.

Height Profile   **Novice**
Height over the processing time period. This can be a very good quality control measure
in areas where the height is very stable.

Individual Satellite Statistics   **Intermediate**
Shows satellite code residuals, phase residuals, elevation angles and C/NO values for
individual PRNs.

Local Level Vector   Advanced
This is the vector between base and remote centered about the main base station. It is useful for moving baseline processing. For absolute positioning applications, the distance separation combined with the height profile is usually a better diagnostic tool.

Number of Satellites (BAR)   Novice
Number of satellites for epochs with at least 4. Note that epochs with less than 4 satellites will not be displayed as these epochs are skipped. This plot gives a nice overview of how many satellites there are. Data sets with large numbers of epochs may wish to use the line graph, as this plot better shows every time the number of satellites drops to a minimum.

Number of Satellites (LINE)   Advanced
This plot shows the number of GPS, GLONASS and total satellites. Note that epochs with less than 4 satellites will not be displayed as these epochs are skipped. The plot is not as nice to look at as the bar graph, but it actually contains more information.

Quality Factor   Novice
Increasing quality factors indicate a worse solution. Quality 1 and 2 are the best, and indicate a converged static solution or continuous in kinematic mode. For precise kinematic processing, a quality number of 1 should be maintained since it indicates a fixed integer carrier phase solution. A quality factor of 2, normally indicates a converged float solution or a nosier fixed integer. Quality 3 and 4 indicate converging float or very noisy fixed integer. Quality 5 to 6 usually are epochs with DGPS accuracies. For code-only processing, quality factors of 3 or higher are to be expected.

Receiver Clock Offset   Advanced
The single point processor computes a clock correction on an epoch-by-epoch basis. This value is the difference between the receiver's clock and the GPS time system. For some applications, users may wish to plot and moniter this value.

RMS – C/A Code   Novice
This is a good indicator of receiver code measurement accuracy. It is also a good indicator of multi-path for carrier phase processing. Large jumps <u>can</u> be induced by missed carrier phase cycle slips.

RMS – Carrier Phase   Novice
This is a good indicator of carrier phase measurement accuracy. If the signal is affected by the ionosphere and other error sources, the RMS will be greater than the few centimetre range and can be as large as 10 cm or more for single frequency. Because the code and carrier phase are combined, some noise from the C/A code can seep into the carrier phase.

RMS – L1 Doppler   Advanced
The Doppler is predominantly used for velocity determination. User's using GrafNav in conjunction with inertial (INS) integration should pay close attention to this plot. It will

give a good indication of what standard deviation to give velocity data in the inertial Kalman filter.

Non-inertial users can view this plot to get a good indication of velocity accuracies. However, pay close attention to the Doppler weighting in GrafNav's Kalman Filter *(see Section 2.3.5 for more information)*. Large Doppler errors can also sometimes result in the L1 carrier phase RMS to rise. In this case, the L1 Doppler standard deviation should be raised or Doppler usage should be disabled (see Section 2.3.3 Advanced Options).

RMS – P Code   **Advanced**
If the option 'Use P-Code in Kalman Filter' is turned on in the Dual Frequency options, then this feature can be used to plot the P-Code RMS.

Satellite Lock – Cycle Slips   **Intermediate**
This plot is used to view the general quality of the data contained in a .GPB file. The plot shows four data characteristics. The first is the cycle slips in the data for each satellite. This information can be very useful because it is possible to detect poor tracking. Cycle slips are shown as vertical lines in the bars. The second data characteristic is the times that data is available for each satellite contained in the .GPB file. Data availability is shown by any colour of bar. To compare coverage of multiple .GPB files, use the Static/Kinematic Coverage plot. The third characteristic that is shown is the elevation angle for each of the satellites. The different bar colours represent different elevation ranges. The last data characteristic shown is data that cannot be used in the processing as the options stand. This data is shown in red. There are two reasons for data to be flagged as red:

- If the C/A range, or the phase data (L1 or L2) are invalid.
- If the locktime of the satellite is less than the locktime cutoff.
- Black indicates that there is an ephemeris missing. GLONASS satellites will also be plotted in black.

Static Session Convergence   **Intermediate**
This plot assumes that the last epoch in the static session is exact. A float solution convergence plot is then formed. This gives an indicator of how well a static solution is stabilizing.

Static/Kinematic + Coverage   **Novice**
This plot is new for Version 6.03. It has three purposes. Firstly, it shows if and when GPB files are static and kinematic. Secondly, it can be used to overlay multiple GPB files to see when they overlap in time. Finally, it tries to indicate weak periods of the data that may result in a loss of lock. Since it does not examine processed data, it is not as reliable as other indicators (e.g. Position Standard Deviation). Inertial Explorer users can also plot IMU coverage in addition to Master and Remote GPS coverage. This plot will also show IMU data time gaps.

User Selected File – Plot data from   **Advanced**
This feature can be used to plot data from a comma or space separated file. This spares
the user from having to use a program such as Microsoft Excel or MatLab to plot the
data. It can also be used to plot the results of the Compare utility (see Chapter 6 Section
1).

Velocity Profile   **Intermediate**
Plot shows north, east and up velocities over the processing time period. This can be
used to determine when the antenna is moving.

Azimuth/Heading data (GrafMov Only)   **Intermediate**
Shows the azimuth in heading determination mode.

Azimuth/Heading standard deviation (GrafMov Only)   **Intermediate**
Shows the standard deviation of the azimuth computation for heading determination
mode. Users should also examine the fixed/float ambiguity status flag.

Antenna Distance Error (GrafMov Only)   **Advanced**
Shows the difference between the computed antenna distance and that given by the user.
This is a good quality control check.

Attitude (Roll and Pitch) (Inertial Explorer Only)   **Novice**
Plots the Roll and Pitch values from GPS/INS processing.

Attitude (Azimuth/Heading) (Inertial Explorer Only)   **Novice**
Plots the heading and GPS COG (Course-over-Ground) that was computed from the
GPS/INS processing.

Attitude Separation (Inertial Explorer Only)   **Novice**
This plot requires forward and reverse IMU solutions to be combined. To combine
forward and reverse IMU solutions, select the *Process Menu | Combine Solutions | IMU
Forward and Reverse*. Basically, this plot shows the difference between the combined
solutions in terms of Roll, Pitch, and Heading.

Estimated Attitude Accuracy (Inertial Explorer Only)   **Novice**
This plot shows the estimated accuracy (standard deviation) computed in the GPS/INS
Kalman filter in terms of Roll, Pitch, and Heading.

Estimated Gyro Drift Accuracy (Inertial Explorer Only)   **Intermediate**
This plot shows the estimated standard deviation of the gyro drift rate. This plot
generally decreases with time. It is plotted in terms of the X (right direction), Y (forward
direction), and Z (up direction) of the INS body.

Estimated Accelerometer Bias Accuracy (Inertial Explorer Only)   Intermediate
This shows the estimated standard deviation of the accelerometer bias. It is plotted in
terms of the X (right direction), Y (forward direction), and Z (up direction) of the INS
body.

IMU Accelerometer Bias (Inertial Explorer Only)   Intermediate
This is the apparent output in acceleration when there is no input acceleration present. It
is computed by the GPS/INS Kalman filter and the effects may be sinusoidal or random.
It is plotted in terms of the X (right direction), Y (forward direction), and Z (up direction)
of the INS body.

IMU Angular Rates (Inertial Explorer Only)   Advanced
This plot shows the gyroscope rate of change of attitude in the X, Y, and Z axes of the
IMU body with the drift removed. This plot is used to check the gyros.

IMU GPS Position Misclosure (Inertial Explorer Only)   Intermediate
This plot shows the difference between the GPS solution and the mechanized INS
positions obtained from the GPS/INS processing. This is a good analysis tool used to
check the GPS/INS solution as well as checking INS stability. Large jumps or spikes
may indicate a bad INS solution.

IMU GPS Velocity Misclosure (Inertial Explorer Only)   Intermediate
This plot shows the difference between the GPS calculated velocity and the mechanized
INS velocity obtained from the GPS/INS processing. Another good analysis tool used to
check INS stability.

IMU Gyro Drift Rate (Inertial Explorer Only)   Intermediate
This is the apparent change in angular rate over a period of time. It is computed by the
GPS/INS Kalman filter and the effects are usually random. It is plotted in terms of the X
(right direction), Y (forward direction), and Z (up direction) of the INS body.

IMU Heading COG difference (Inertial Explorer Only)   Advanced
This plot is the difference between the IMU heading and the GPS Course-over-Ground
values. The absolute IMU heading/GPS COG can be seen in the Attitude
(Azimuth/Heading) Plot.

2.6.2 Multi-Baseline Plotting

Output | Plot Multi-Base
If a user processes more than one baseline, there are additional plotting tools available to
display measurements and separations of multi-baselines. This tool plots values present
in the .fbv and .rbv files (see Section 9.1.4). Figure 2.25 displays the multi-base plotting
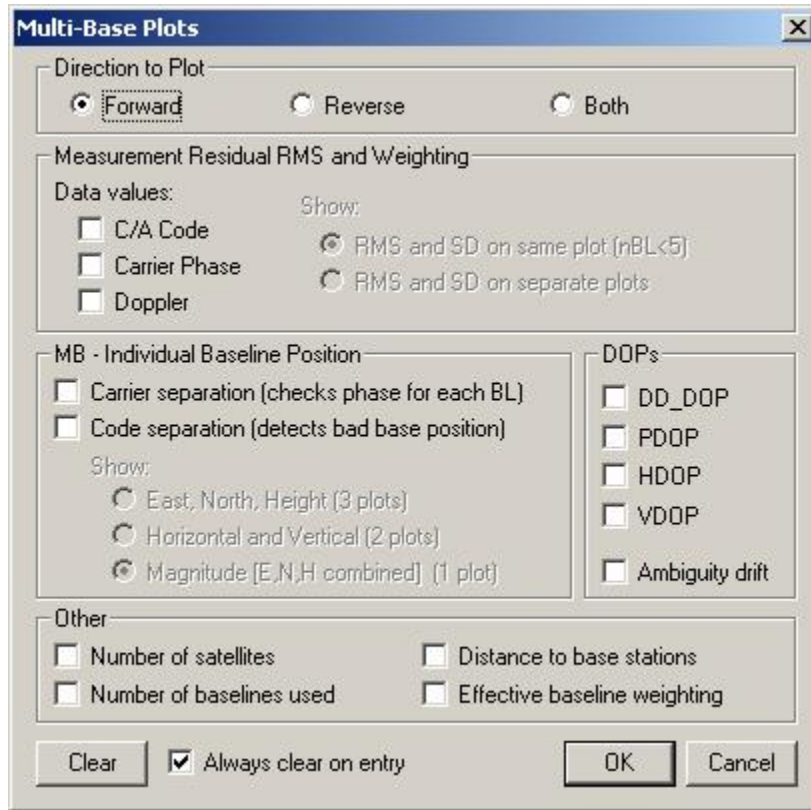window.

Figure 2.25 Multi-Base Plotting

The user can select from the measurement, individual carrier and code separations (baseline check), DOPs, or other miscellaneous plots. The user can also specify the direction of plotting as forward, reverse, or both directions.

C/A Code (MB Only)   **Measurement Residual RMS and Weighting**
This plot shows root mean square (RMS) of C/A code residuals for each baseline. In addition, the measurement standard deviations are plotted on the same (or separate plot). This plot can be useful for identifying a one base station has better or worse code residuals than another.

Carrier Phase (MB Only)   **Measurement Residual RMS and Weighting**
Similar to that of the code, this shows the carrier RMS for each baseline. Viewing this separated value is preferable to the combine value shown from 'Plot GPS Data'. This plot most effectively shows if a base station's coordinates are incorrect (see Section 10.2.2 for an example).

Doppler (MB Only)   **Measurement Residual RMS and Weighting**
Use this plot to identify problematic Doppler data originating from one of the base stations. This only needs to be of concern for users requiring accurate velocity.

Carrier Separation (MB Only)   **Individual Baseline Position**
This shows the difference between the Kalman filter (KF) position (using all base stations) and a least-squares based solution using the code and carrier (using carrier

ambiguities solved in the KF). It can be useful for determining which base's data is causing larger errors. It is not a good accuracy assessment tool.

Code Separation (MB Only)   **Individual Baseline Position**
This is a less helpful plot because any differences between the bases are normally shrouded in the code noise. However, large base station position errors can be observed here. In addition, this is an effective way of spotting poor quality code measurements stemming from one of the bases. In such a case, consider using larger standard deviations for this problematic base.

DD_DOP (MB Only)   **DOPs**
Indicates satellite geometry relating to position for each baseline. Small values indicate better geometry. This value is the double difference DOP and is approximately PDOP^2. Although, it can be somewhat lowered due to the differential modeling. The DD_DOP is used for all internal checks and DOP related options in the software. Epochs with extremely poor DD_DOP (>100) are skipped and will not be plotted. Use the DOP_TOL command to change the default DD_DOP tolerance of 100.

PDOP, HDOP, VDOP (MB Only)   **DOPs**
Indicates satellite geometry relating to position for each baseline. Small values indicate better geometry. Lines are displayed for position DOP (PDOP), horizontal position DOP (HDOP) and vertical position DOP (VDOP). These values should be similar to other PDOP computations, but differences can be visible due to the double differencing (i.e. different base satellite selection).

Number of Satellites (MB Only)   **Other**
This displays a line graph of the number of satellites for each baseline. Note that epochs with less than 4 satellites will not be displayed as these epochs are skipped. This plot gives a nice overview of how many satellites there are visibile from each baseline.

Effective Baseline Weighting (MB Only)   **Other**
This indicates the approximate percentage weighting that could be assigned to each baseline if a linear combination were used. Although this value is not used for processing, it can be a helpful indicator to the user.

Distance to Base Stations (MB Only)   **Other**
This plot shows the difference between the masters and remote in kilometers. It can be useful to identify where the master and remote are far apart or close in kinematic data.

Number of Baselines   **Other**
This shows the number of base stations uses for processing each epoch. It is an important means of assessing if certain bases are rejecting (or not lined up during processing).

Ambiguity Drift (MB Only)   **Other**
This would be the individual ambiguity drift for each baseline. See 'Ambiguity Drift' under Plot GPS Data for more information.

2.6.3   Write Coordinates

Output | Write Coordinates
This allows you to write coordinates in various coordinate frames. Select this item in order to transform computed latitudes and longitudes to Transverse Mercator or Lambert Projections. The main reason for using Write Coordinates is to export specialized formats such as Waypoint .CMB, azimuth output, etc…

Note: Write Coordinates is the old way GrafNav used to export coordinates, it is retained for backward compatibility. Users are urged to use the Export Wizard since it has more Grid, Datum and transformation options.

What follows are the options available when using the Write Coordinates feature.

File Name
Type in a filename in which to store your coordinates and station names. This file will contain much of the output significant to your survey. The output format will be approximately):

Station X Y Z   Quality StdDev

Information:
The output file given by the filename above will contain all or only part of the information processed by the processing component and saved in the .FWD & .REV in GrafNav or .OUT file in GrafNet.

Time Format
The Time Format button brings up the Epoch Output Time Format dialogue box, which allows you to change the time format in the coordinate file. The dialogue box allows three major operations: setting the time format, correcting the time, and interpolation of missing data.
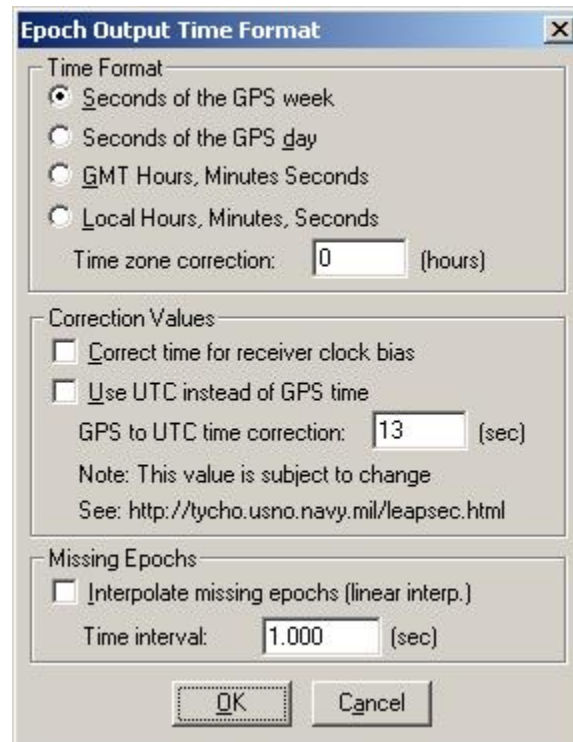
Figure 2.26 Write Coordinates Time Format

1.   **Time Format**
This section allows you to change the format that the time will take. Four time formats are available: GPS seconds of the week, GPS seconds of the day, GMT (UTC) HMS, or local HMS. The last format requires that a time zone correction. The best output format to use depends what you intend to do with the coordinates.

2.   **Correction Values**
There are two time corrections that you can apply. The first correction is to apply the receiver clock bias to the GPS time. This corrects the time to the actual time that the receiver made the measurement. This correction can be as high as 1 millisecond. This can be very significant in applications that require time synchronization between various instruments and devices. For example in many inertial applications, attitude is very important. Depending on the dynamics of the application, attitude can change very quickly, and small-timing errors can become significant.

The second correction that can be done must be made when GPS times are converted to UTC times. GPS time is a linear time scale. This means that there is never a second that is missed, or counted twice. UTC time, on the other hand is not linear. UTC time is held fixed with relationship to the stars. There are many global effects that change this relationship very slightly, so corrections to the UTC time are made in the form of leap-seconds. These corrections can be made as often as every six months, but usually only happen every twelve or eighteen months. To determine what the UTC correction is for

the time your data was collected, please consult the web site
http://tycho.usno.navy.mil/leapsec.html

3.   **Missing Epochs**
The last section of the Epoch Output Time Format dialogue box allows you to interpolate
position for missing epochs based on existing epochs. The option uses a simple linear
interpolator. Simply check the check box, and set the interval that you would like the
interpolation to occur at. This option is very useful for application like GIS where
accuracy may not be as important as simply having a continuous trajectory of positions.

Source
1. *Epochs*: The output file will contain X,Y,Z from every epoch gathered by the GPS
   receiver.

2. *Features*: The output file will only contain information at STATIONS marked by the
   data logging program LOGGPS.EXE.

3. *Static Sessions*: The final solution of each individual static occupation separated by
   kinematic occupation.

4. *Single Point Solution*: Solutions computed by the GPS receiver in real-time. For a
   single receiver (i.e. no radio link), accuracies will be 5-10 m. For a real-time DGPS
   configuration, accuracies will be 1-5 m.

5. *Station File RTK Results*:

Coordinate Type:
1.   **Geographic** (Lat/Long/Ht) & UTM:
Follow the current dialogue box using Degrees/Minutes/Seconds as the horizontal
coordinate units and meters or feet for the elevation coordinate unit.

The program will calculate the UTM zone for you unless you have chosen User Entered
under Information.

2.   **3TM** or Transverse Mercator **map projections**
Follow the current dialogue box using meters or feet for both horizontal and elevation
coordinate units.

A new dialogue box will appear prompting the user to enter the Central Meridian and the
scale factor for that meridian.

        i.e. 114 00 00
             .9999

False easting on the central meridian and false northing, for example 10,000,000 from the
equator if you are in the southern hemisphere. See State Plane if in U.S.

3.   **Lambert Conformal - Map Projections**

Follow current dialogue box using meters and feet for both coordinate units. At this point, a new dialogue box will appear prompting you for more information such as the Origin Parallel and the lower standard parallel. See State Plane if in U.S.

4.   **XYZ-ECEF - Earth Centered Coordinate Frame (x, y, z)**

Follow the dialogue box using meters or feet as the coordinate units for both horizontal and elevation.

5.   **State Plane**

To convert coordinates for specific state planes, follow the dialogue box using meters or feet for both the horizontal coordinate unit and the elevation coordinate unit.
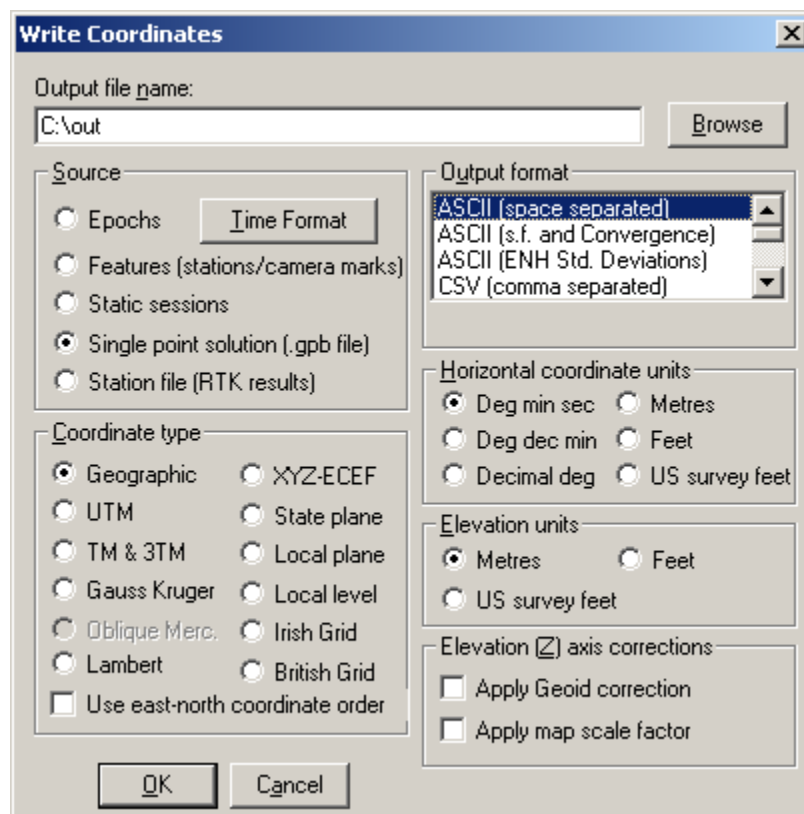

Figure 2.27 Write Coordinates Dialogue Box

The next dialogue box will ask you for the state plane that you would like the coordinates converted in. Once you have selected the state plane the program will ask you for the coordinates. When changing the datum, be careful to re-process before writing coordinates. To view the result, select Output from the Main Menu and then View Coordinates.

6.   **Local Level**

Local level coordinates have horizontal and vertical coordinates in units of meters or feet. Coordinates have three components: north, east and height. The origin of the coordinate

system is at the base station. The north and east axis form a plane. The height axis is always perpendicular to the ellipsoid, or in other words follows the curve of the ellipsoid. This means that this coordinate system is not Cartesian.

7.   **Gauss – Kruger**
This is a TM coordinate system used primarily in Europe. The zones are the same as the UTM zones. The difference between this projection and the UTM projects is that the scale factor is 1.0 for Gauss – Kruger.

8.   **Local XY Plane**
See 2.7.3 Wizard Option Screens under Local Plane Options.

Output Format:
The data will be written in one of the formats given here.

ASCII
Data simply delimited by spaces.

ASCII (s.f. and convergence)
As above with additional columns for the scale factor and meridian convergence of the projection.

ASCII (ENH Std. Deviations)
An ASCII format with additional columns reserved for east, north, and height standard deviations in the position. The complete standard deviation for the position with the distance dependant component is also given.

CSV (for EXCEL)
Data delimited by commas.

Waypoint OutRec (.CMB)
Prints a standard forward solution file. This is good for storing the forward reverse combination results. This can be exported directly from the Output Menu.

INS/GPS Integrator
This output format produces a file with all data that would be useful in the integration of GPS with INS.

Also available are: Itres Research data format

Epoch Statistics (.dat file)
The epoch statistics generates a comma separated .dat file, which contains the following information:
Time, Quality Factor, L1 Phase RMS (m), CA Code RMS (m), Ambiguity Drift (cycles/sec), Covariance/Standard Deviation (m), Number of Satellites.

Combination Information
This data is separated by commas and includes the following information:
Time is the time in GPS seconds of the week.

DNorth (m) is the difference in northing between the forward and reverse solution.

DEast (m) is the difference in easting between the forward and reverse solution.

DHeight (m) is the difference in Height between the forward and reverse solution.

Fwd Weight (%) is the percentage of the forward solution used in the combination.

Rev Weight (%) is the percentage of the reverse solution used in the combination.

Local Level Vector
This coordinate system has the origin at the master station. The positive y-axis is pointing true north at the master station, and the positive x-axis is point true east. The z-axis is defined vertically and is the difference between the ellipsoidal heights of the remote and master stations. These axes may not be aligned to true north at the remote station. This effect is known as *convergence of the meridians*, and the difference between coordinate y-axis and true north is expressed as follows:

$$d\alpha = (\lambda remote - \lambda master) * \sin(\varphi remote) \tag{1}$$

Where, $d\alpha$ is the azimuth difference (radians), λ is longitude (radians) and φ is latitude (radians). The local level vector can be written directly from the Write Coordinates item from the Output menu. Select Local Level Vector under Output Format.

Horizontal Coordinate Unit
Horizontal coordinate data will be written in degrees, minutes, and seconds for lat/long/ht, meters or feet for UTM. Refer to the Coordinate Type for a description on which unit to use for each coordinate.

Elevation Coordinate Units
Elevations may be written in meters or feet.

Apply Geoid height correction
See 2.7.3 Wizard Option Screens under Geoid Correction Options.

Apply map scale factor
See 2.7.3 Wizard Option Screens under Vertical Scale Factor Options.

2.6.4 View Coordinates

Output | View Coordinates
This allows you to view the coordinate files created by the Write Coordinates or Export Wizard Features. Users can print files using this methodology (from the File Menu, select Print).

2.6.5 Export to DXF

Output | Export to DXF
DXF is a file format that can be read by various CAD packages. The 'Export to DXF' utility lets you output your GrafNav/GrafNet project into DXF format.
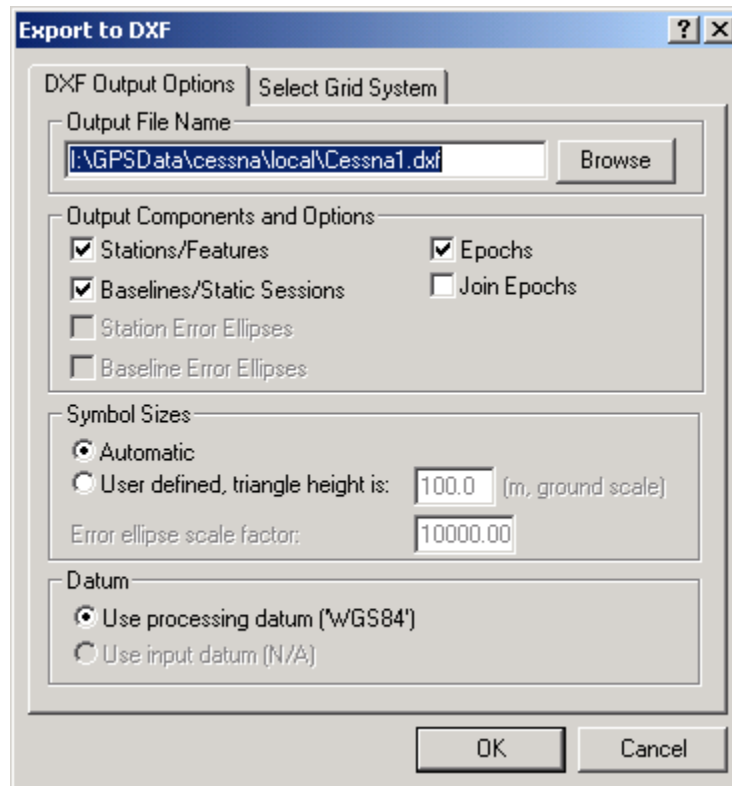

Figure 2.28 Export DXF Options

The above figure shows the 'Export to DXF' dialogue box, which is the same for GrafNav and GrafNet. However, certain options are disabled if you are using GrafNav/GrafNet. For example, Error Ellipse output is only available in GrafNet. The options relevant to GrafNav are explained here. Refer to Section 3.6.1 Export to DXF for information on the GrafNet specific options.
The output file name is the name and path of the DXF file that is to be created. The **Station/Features** output component will output all the stations and features to the DXF file. The size of the stations and features is governed by the symbol size.
Baselines/Static Sessions output component will output baselines between all the static sessions. The colour of the baseline will be the same as it was in GrafNav. That is, quality 1 is green and quality 6 is red. The colour for **Epoch** and **Join Epoch** output is

also dependent on the quality number. The Epoch **control** outputs each epoch, which is only useful for kinematic surveys. The size is again dependent on the symbol size option. **Join Epochs** simply joins a line between epochs, which is also only useful for kinematic data. **Symbol size** defines the size of the symbols in the DXF file. It is recommended that you use **'Automatic'** on your first run. If the symbol size turns out too small or large you can try the user defined size. This may take a couple tries to get the correct size. The **Datum options** let you choose if you want to use the processing datum or input datum. To change any of the grid options select the **'Select Grid System'** tab. If you are using UTM, State Plane or any other zone dependent grid check that zone entered is correct. Do not assume the default is correct.

2.6.6 View/Edit Features (Feature Editor)
View | Features

Users will want to use the Feature Editor for the following reasons:
- Examine which features are loaded.
- Examine the quality/accuracy of features after processing.
- Examine the time difference, azimuth and distance between successive marks to identify timing and numbering errors.
- Edit feature names, description and remarks. For camera marks, the line number can be inserted into Desc/Info field.
- Re-number stations and camera event marks.
- Features can be disabled so that they will be neither displayed nor exported.
- Edit the crab/drift angle for applying 3-D offsets to camera event marks.

Note that changes made to stations are now saved automatically to a *project*.nst file. To revert back to the original station information, use *File | Load | Station File* or *File | Load | Camera Event Marks*.
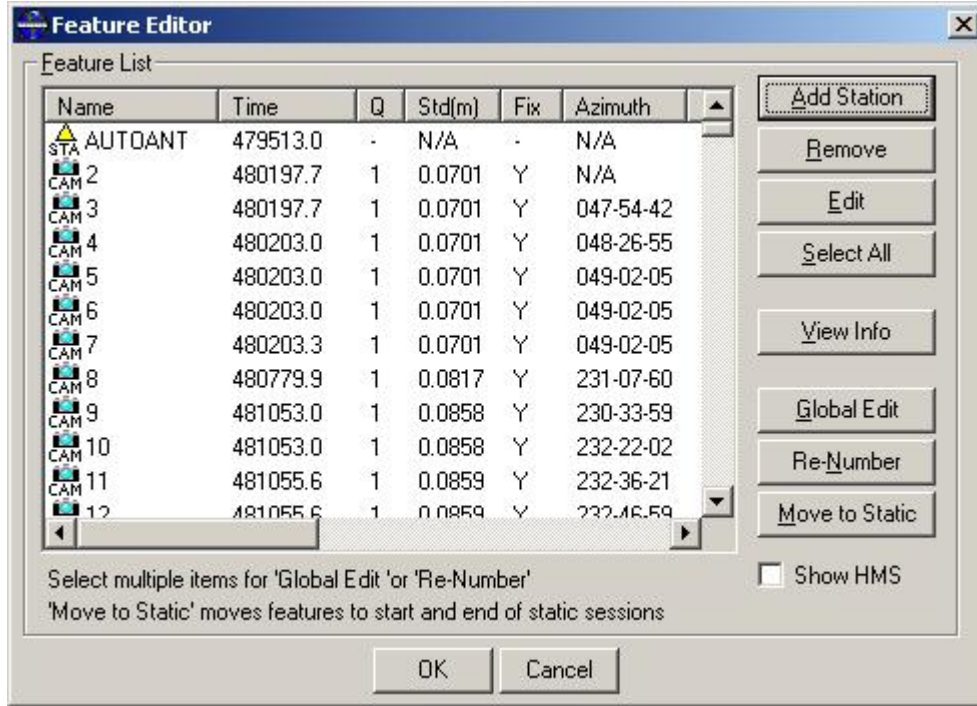
Figure 2.29 Feature Editor

The following columns are displayed:

Name   This is the name of the feature. The symbol next to the name indicates the type of point (e.g. Station, Camera Mark or GIS Mark). The symbol will be grayed if the feature is disabled.

Time   This is the time that the feature was captured. This is GPS time and not UTC. To show the time in HH:MM:SS, select the 'Show HMS' checkbox.

Q   Quality Number. 1=best, 6=worst. 1=fixed integer, 2=stable float, 3+4=converging float, 5+6=DGPS

Std(m)   Combined north, east + height standard deviation which includes additive PPM based error.

Fix   Y=Fixed ineger, N=float solution

Azimuth   Azimuth in degrees-minutes-seconds from previous point to current point

Dist(m)   Distance from previous point to current point in meters

Dt(s)   Time difference between current and previous point (seconds)

Height   Height of feature in meters. Normally, this would be an ellipsoidal height. However, if the master station height was entered as orthometric, than this height will be closer to orthometric. Use Export Wizard to get the exact orthometric height. For stations with antenna heights (e.g. STA and GIS marks) then this height will be of the monument and not of the antenna.

Name   Repeat of the point name

AntHgt   Height of the antenna above the monument. Note that the camera marks do not have an antenna height and N/A is displayed. If a remote antenna

height is used in addition ot this value, the remote antenna height is added before this value is subtracted.

Desc/Info Description of the point or line info for camera mark

Remarks Remarks field

The following features (buttons) are available:

Add Station This allows the user to manually add a station. Stations can also be added by right-clicking on epochs in the map window. Users may wish to add stations to static sessions that have none. This serves two purposes: 1) static sessions cannot handle a varying antenna height 2) The move-to-static feature only works on static sessions with features (see below).

Remove Removes the selected stations. Multiple stations can be selected. Users may wish to consider disabling a feature as opposed to deleting it permanently.

Edit Edits the station name, description and remarks for the current selection. Only the first selection in the list will be edited. For editing multiple feature selections, use the Global Edit button.

View Info Shows processing information about the current selected feature. If a station has just been added, then information cannot be displayed.

Global Edit If multiple features have been selected, then this button can be used to make changes to the entire selection. Modifications can be made to the antenna height, description, camera line information, remarks, enable/disable flag and drift/crab angle. See the Loading Camera Event Marks section for a definition of the sign of the angle.

Re-Number This button allows users to re-number a selection of stations. Numbering can start at the bottom or the top. In addition, users can specify the starting number and the increment value. To decrement numbering use a negative number.

Move-to-Static This feature is useful for seismic and other surveys where users are over a point for a very short amount of time. This process will move stations within static sessions to the end-points. Basically, each static session that has a station will see the station replaced with one at the start and one at the end. The remarks field is modified to be BEGIN_STATIC or END_STATIC, which notifies the Export Wizard to combine the two solutions upon output. Upon combination, features where the begin solution and end solution do not match will be flagged to aid quality control.

Note: Global Edit, Re-Number and Move-to-Static work with multiple feature selections. To select a continuous block, hold down the shift key while clicking on features. To select individual features, use the ctrl key instead of the shift key.

2.6.7 View Objects

View | Objects | All
The command brings up the Object Menu for all of the epochs, Static/KAR, features/stations, and RTK Data in the project. The Object Menu can also be brought up by right-clicking on an epoch of interest of the Map window. In that case, only the features and epochs in the neighborhood of the click will be displayed.
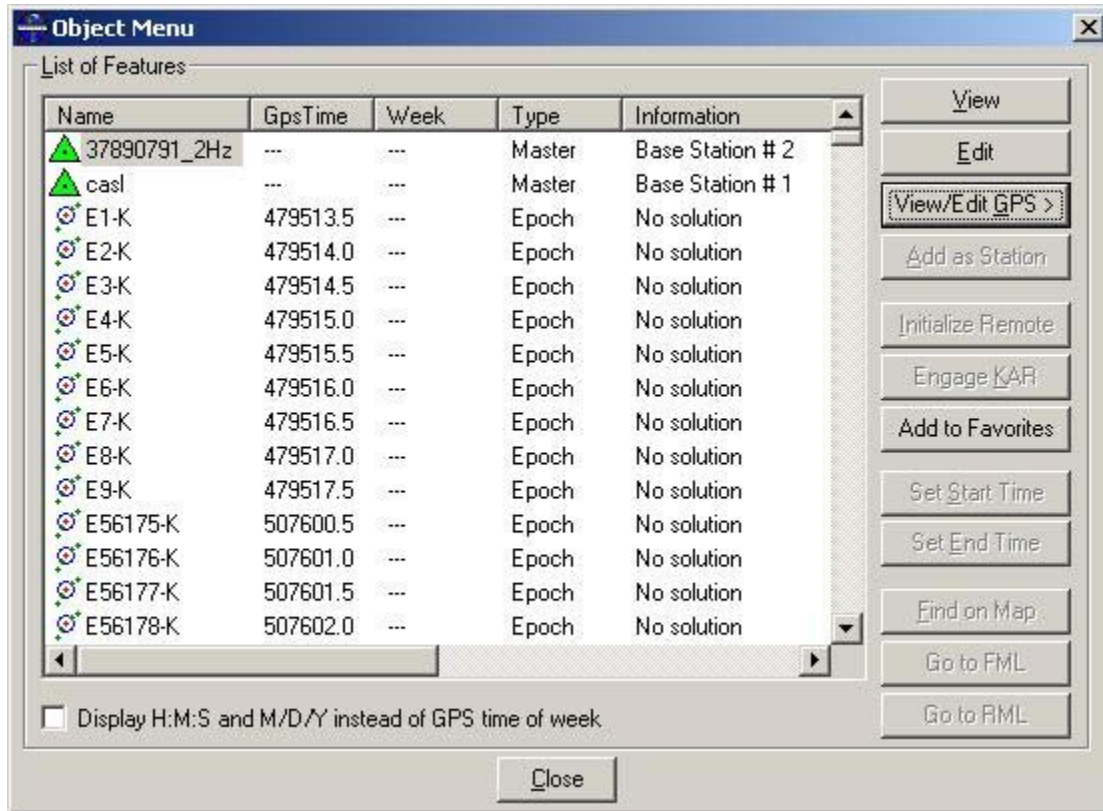

Figure 2.30 Object Menu

The following features (buttons) are available:

View	This will bring up the Object Info message box for the selected object.
Edit	Edits the station name, description and remarks for the current selection. If a master station is selected, this will allow you to edit the coordinate and antenna height.
View/Edit GPS	Various functions available. See Section 2.2.7 for a description of these functions.
Add as Station	This allows the user to manually add a station. The time will be automatically set as the selected object.
Initialize Remote	This allows the user to "fix" the remote position at time of the selected object. This will only work on objects with valid solutions.
Engage KAR	KAR will be engage at the selected object's time.

Add to Favorites	This will add the object with solution to the list of Favorites (see Section 8 of this chapter for more details).
Find on Map	This will show the epoch on the map of the selected object.
Go to FML	This will search the forward message log for a time closest to the time of the selected object.
Go to RML	Same as above but for the reverse message log.

The Set Start Time and Set End Time buttons will use the select object as the start or end time for the processing (see Section 2.3.2).

For static baseline, the 'Edit' button will display the following Static Session dialogue box. It allows users to change station naming, antenna height and fixed static options (if desired).
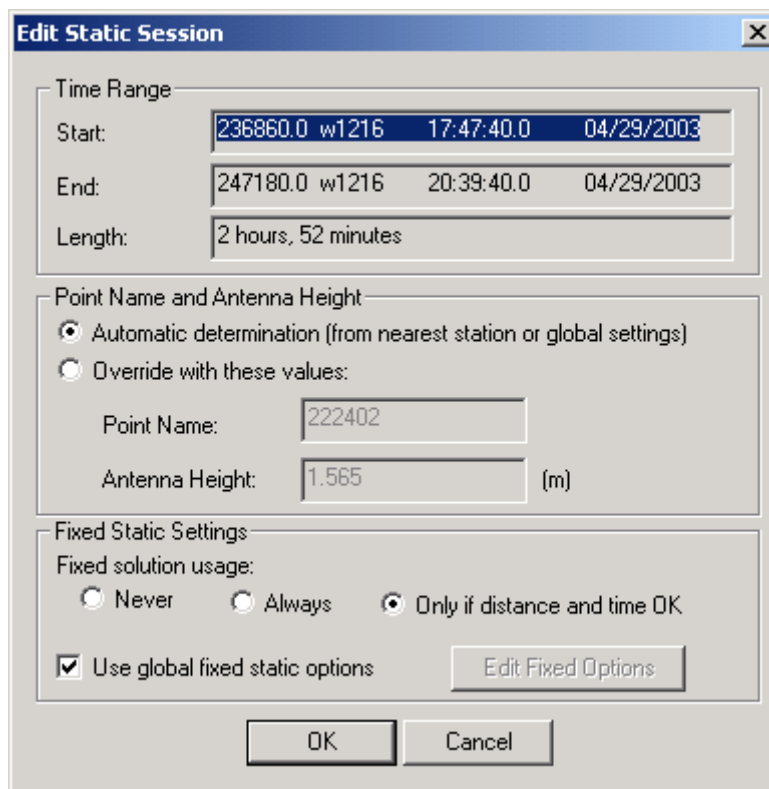

Figure 2.31 Static Session

Time Range

Start	This displays start time and date of the data set. It displays the GPS second, week number, GMT time zone, and date (mm/dd/yyyy) respectively.
End	This is the same as 'Start' but for the end time.
Length	This is the duration of the data set. This is simply just the end time subtract the start time.

Point Name and Antenna Height

Automatic Determination   The will extract the antenna height and point names from the nearest station. If no station exists that is close enough, then it will use the global remote antenna height and a station name of STATIC_???.

Override with these values
> *Point Name*   This is the name of the station. User may change the name if they wish.
> *Antenna Height*   This is the antenna height of the station. **User should enter the antenna height if this value is known, espeicailly if a static session is being processed from GrafNav.**

Fixed Static Settings

Fixed solution usage
> *Never*   Always use the float solution for each static session
> *Always*   Utilize the fixed integer solution for each session
> *Only if distance and time OK*   Check the distance and time to ensure that:
> a) The distance is not too long
> b) The time span is long enough
> The tolerances are set under the General Processing Options (see Static Session Settings)

Use global fixed static options
> *Edit Fixed Options*   See Section 2.3.7.

In some cases, the user may know a position of an epoch or point from some other means. This could be via a previous survey, or from another base station. It can be very helpful to seed *or even fix* the current trajectory using this other position. There are several means to to this which are explained below. Fixing a position can also be easily performed by "right-clicking" on an object (e.g. epoch, feature or static session) containing a processed position.

Section 7   Export Coordinates Wizard

The Export Wizard allows the user to customize the output text format to suit their needs. In addition, it has more features for controlling offsets, datums and corrections than the Write Coordinates method for exporting coordinates. Users can select from some 150+ data variables to either try to re-produce an existing format or create their own with exactly the information that they need. Please contact customer support if you need help with this capability.

2.7.1   Creating Files and Profiles with Export Wizard

Output | Export Wizard
The new export wizard integrates the features of write coordinates with the flexibility of a user friendly graphical user interface that allows the user to create different output format

profiles. Export profiles can be moved from one machine to another by copying the .PRF files to the directory containing the GrafNav/GrafNet software. This means that profiles need only be created once.
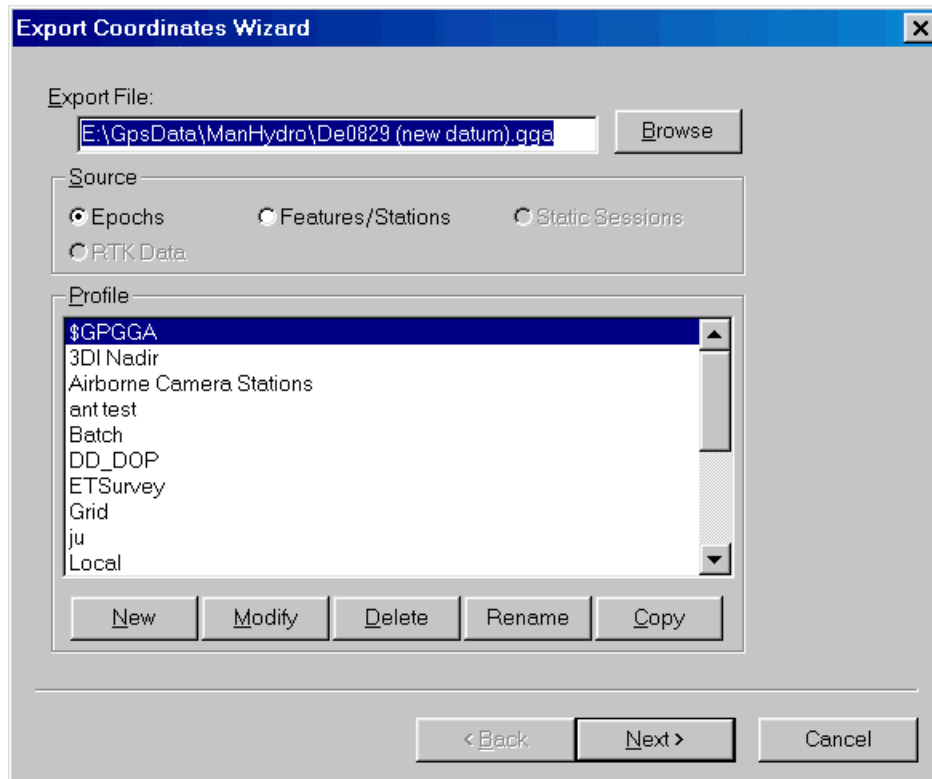

Figure 2.32 Export Wizard

Creating a Profile
1. To define a profile, click the New button and type in a unique name for your profile.
2. From the Define Profile window, start creating your profile by adding variables you need into the export variables list by highlighting the chosen variable and either click Add (will add to bottom of list), Insert (will add variable above highlighted variable in list), or double-click the variable. Listed below are options that can be changed to personalize each profile and also a variable reference list.
3. Once the user is finished adding all the necessary components of the profile, click OK to save the profile. The process of creating profiles is discussed further on in this chapter.

Creating an Output File
1. Type in a file name for your output file in the dialogue bar in the Export Coordinates Wizard window or accept the default name for the file (based on <project name>.txt)
2. After a profile has been defined, click Next in the above window to start creating your output file.

3. Fill in the Export Wizard Option Dialogue Boxes in accordance with the settings needed (descriptions of the wizard dialogue boxes and their options are listed below in an individual section).
4. Click Preview to view your file before saving it to the file path name specified.
5. Click Finish to save your output file.

Tips
1. If the user wants to create a profile that does not have spaces between variable entries since the record is based on column width, the user can change this option by going to the define profile <name> window. Click the Field Separator button and select the 'none' option for separation character to remove any field separators in the entire file. The same procedure can be used to change the file to be space or comma delimited as well.

2. When the user wants to change the file by adding a header/footer of a specific format, the Header/Footer option in the Define Profile Window allows the user to add headers/footers from a predefined text file. If specific characters are needed to designate the start and end of a text file, strings of characters can also be added to the beginning and end of the file.

3. For formats that require no decimal points to be shown in the file (ie.SEGP1, Blue Book), the decimal points can be removed by going into the chosen variable and under the Format option (or double click on the variable in the Export Variables List) in the Define Profile window, and selecting the 'Do not print decimal point' box.

4. For profiles that require some delimiting with characters at places and no spaces between some values follow these steps. If you want to create a format that is like this:

    StationName   hhmmssss ddmmsssssssN

    with a fixed width of 15 for the station name, fixed width 2 for hours, fixed width 2 for minutes, fixed width 4 for seconds with 2 decimal places and no decimal point, space delimiter, 2 fixed places for degrees, fixed width of 2 for arc minutes, and a fixed width of 7 for arc seconds with 5 decimal places, an alphanumerical character representing north or south for latitude.

    - From the Station Names/Info menu in the define profile window, add the Station Name variable and choose a fixed width of 15, and left-justify for format.
    - From the Time/Date menu, select the GPS time variable and change the format to Hours with fixed width 2 and pad field with zeros. Repeat this step for GPS Time (Minutes). For GPS Time (Seconds), select a fixed width of 4, 2 decimal places, pad field with zeros, and Do not print decimal place.
    - Under the Miscellaneous menu, select the Field Separator variable and choose space as the separator character

- In the Geographic Coordinates menu, choose Latitude and change the format to Degrees (unsigned) with a fixed width of 2 and pad the variable field with zeros. Repeat this process for Latitude (Minutes). For Latitude (Decimal Seconds), change the fixed width to 7, the number of decimal places to 5, pad field with zeros, and select Do not print decimal places.
- Select the Latitude variable again and change the format to N, S, E, W character with a fixed width of 1.

If the user needs a text string label to designate the type of record being printed/read (i.e. $--GLL, *81*), open up the Miscellaneous menu and add the User Text String variable. Change the format of the string by entering the text needed for the label and select the fixed width option if the format is dependent on column width.

5. Check out the Header/Footer button. Users can put in their own header file, they can show datum/projections information, column descriptions and titles. A special character can also be inserted at the start of each header line. This makes it easier for other software to skip past the header. At the bottom of the file users can add errors/warnings of any problems that were encountered. In addition, processing summary information can also be added.
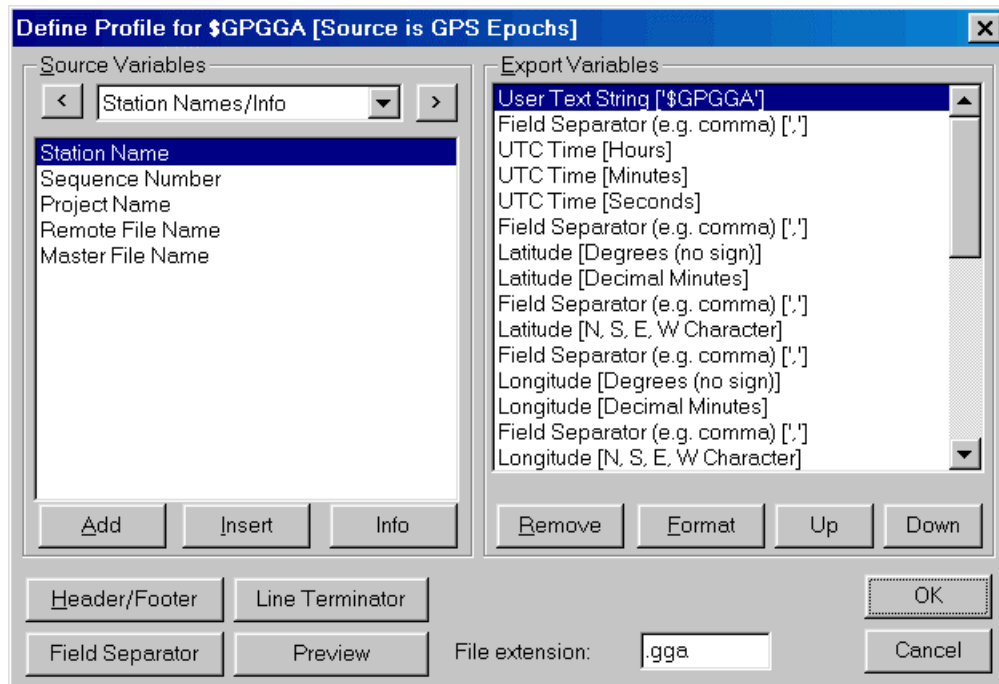

Figure 2.33 Creating a Profile

Options

Source Variables	This pull down menu and backwards and forwards buttons lets the user toggle between variable categories for choosing variables

Export Variables	A list of variables in a scroll down menu that will appear in the output file in the path name set in Export File
Add	Adds a new variable to the end of the Export Variables list
Insert	Inserts a new variable above the highlighted variable in the Export Variables list
Info	Gives a brief description of the variable and provides information from which source the variable can be used
Remove	Removes the highlighted variable from the scroll down list
Format	Allows the user to change options such as fixed width, number of decimal places, padding values with zeroes, left-justify, exponential output, and string text content; also changes format the variable is displayed in (i.e. GPS Time: seconds of the week, HH:MM:SS.SS
Up/Down	Moves the highlighted variable up/down the list of variables

Figure 2.34 Line Termination

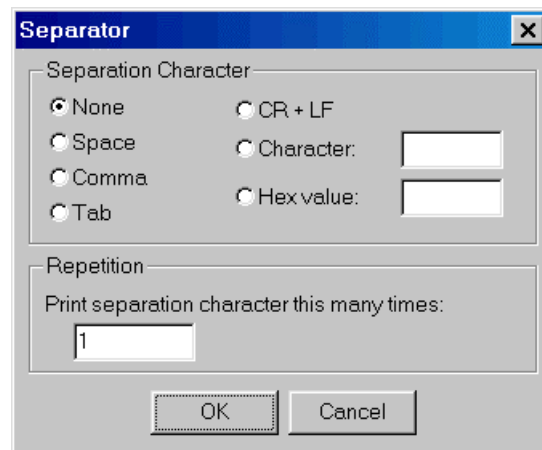| *Line Termination*	Allows the user to choose how to modify the line termination of each record written to the file

Figure 2.35 Field Separation Character

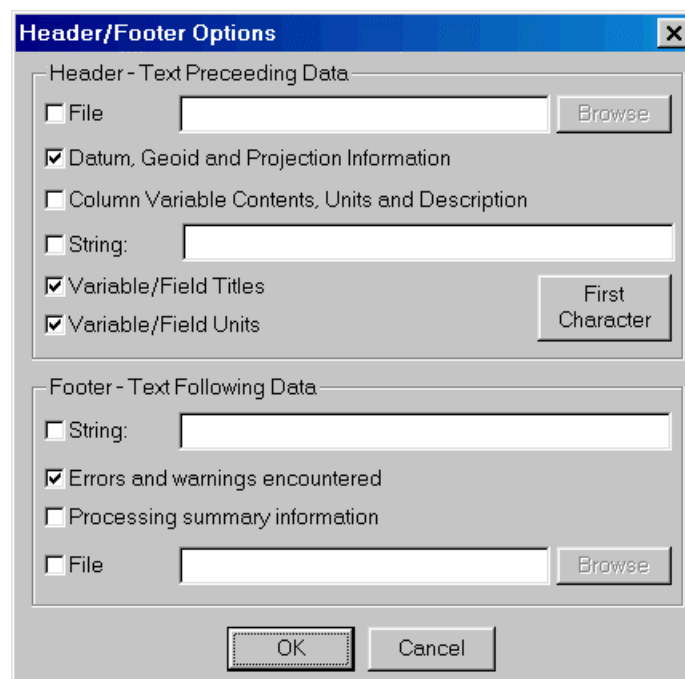| Field Separator	Lets the user choose the character used to separate each variable in a record in the output file

Figure 2.36 Header Footer Options

Header

File	Allows the user to select a file by path name or browse button that will be inserted at the top of the output file as a header

Datum, Geoid, and Projection Information	Inserts details about the datums, geoid, and projections used on the variables printed out (i.e. if UTM eastings and northings were selected, the UTM zone would be included in this portion of text); also lists the coordinates of the master station
Column Variable Contents and Description	This will insert an information record for each variable selected. It will show the column header (i.e. variable name, units and a description).
String	Adds a string of user defined text underneath Datum, Geoid, and Projection Information
Variable/Field Titles & Variable/Field Units	Allows the export wizard to adjust the titles and units in field width and the ability to add special characters to the titles

Footer

|	
String	Inserts a user defined string immediately after the data output
Errors and warnings encountered	Adds error and warning messages to the end of the data output to alert the user of any problems
Processing Summary Information	Shows the same summary screen as the View Processing Summary from the Process Options
File	Lets the user choose a file (by path name or browse button) for the footer that will be added to the very end of the output file
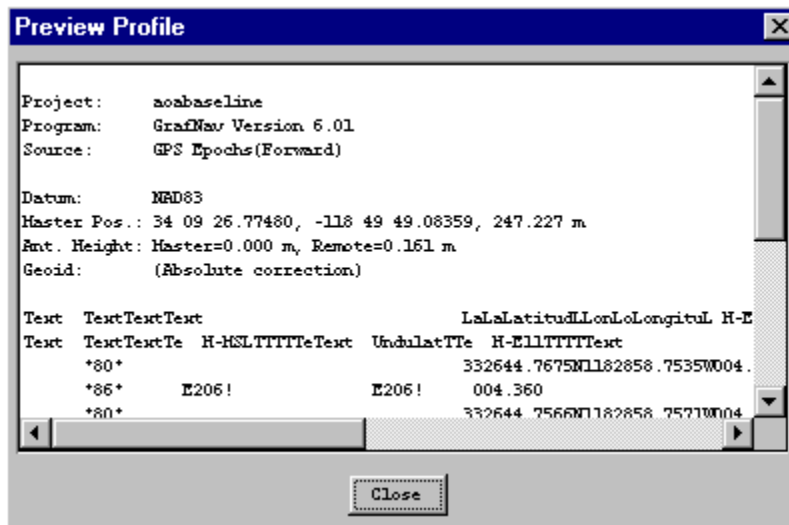
Figure 2.37 Export Wizard Preview

Preview	Displays what the output data will look like once it is written to a file

2.7.2 Variable Reference

The following list briefly describes the numerous variables that users can define in their profiles for output format. Note that not all variables are available for use with each source.

Variable	Description
Absolute ECEF-XYZ	XYZ coordinates in the Earth Centred Earth Fixed Frame which is a Cartesian frame centred at the ellipsoid origin
Ambiguity Drift	Drift on ambiguities over time; low ambiguities indicate stable solution
Antenna Height	Height of the pole or tripod above the station marker
Azimuth (1->2)	Angle between true north and the baseline made from between FROM and TO stations
Azimuth (2->1)	Angle between true north and the baseline made from between TO and FROM stations
British-East, North	East and North coordinates in the British State Plane projection
C/A RMS	Root mean square of C/A code signal
Checksum (8-bit)	The absolute value calculated by using XOR, ADD, or NMEA methodology on the 8 data bits of each character in the sentence; decimal and hexadecimal formats may be selected (user will be prompted for these options after the profile is created)
Combined Scale Factor	Scale factor used by surveyors. It applies the map scale factor combined with the ellipsoidal height correction, which can be used to scale distances on the ellipsoid to the earth's surface.
Combined Standard Deviation	Combines east, north, up position standard deviations into one value. Same value is written by Write Coordinates.

Convergence	Meridian convergence for the current location in the current map projection
Corrected GPS Time	GPS time corrected for receiver clock bias
Course Over Ground	Direction of travel indicated by velocity vector.
Date	Date of the epoch or feature
Description	Description of the station or feature from the .STA file
Double Difference DOP	Double Difference DOP which is approximately equivalent to PDOP2
East, North, Height Fwd/Rev Separations	Separations between the forward and reverse solution in the east, north, and height axes
East, North, Height Fwd/Rev RMS	Root mean square of the separations between the forward and reverse solution in the east, north, and height axes
East, North, Up Standard Deviations	Estimated east, north up position standard deviations in the local level frame
East, North, Up Velocities	East, North, Up velocity components in the local level frame
East, North, Up Velocity Standard Deviations	Estimated east, north up velocity standard deviations in the local level frame
East, North, Up Offset Applied	When a 3-D offset is applied to camera event marks, this field can be used to verify that the proper offset is applied. This offset is oriented to local level (i.e. true-north).
ECEF Covariance Matrix	Estimated ECEF position covariance matrix; needs extended output in GrafNav
ECEF Vector XYZ	XYZ components of the vector between base and remote in the ECEF frame
ECEF Velocity Covariance Matrix	Estimated ECEF velocity covariance matrix; needs extended output in GrafNav

ECEF XYZ Standard Deviations	Estimated ECEF position standard deviations in the XYZ axes; needs extended output in GrafNav
ECEF XYZ velocities	XYZ velocity components in the ECEF frame
ECEF XYZ Velocity Standard Deviations	Estimated ECEF velocity standard deviations in the XYZ axes; needs extended output in GrafNav
Ellipsoidal Height	Height above current ellipsoid; based on datum selected during processing
Ellipsoidal Height Scale Factor	Used to scale distances on the ellipsoid to the earth's surface.
End Time	End time of the static session
Error Ellipse Orientation	Orientation of the error ellipse (theta)
Error Ellipse Semi-Major	Estimated error along the semi-major axis of the error ellipse (a)
Error Ellipse Semi-Minor	Estimated error along the semi-minor axis of the error ellipse (b)
Extended Ambiguity Status	Indicates if KAR fixed the ambiguities.
Field Separator	User can select what character separates each variable in a record
Fixed Reliability	Reliability number for fixed static solutions
Float/Fixed Ambiguity Status	Indicates if KAR fixed the ambiguities. Also available in GrafNet.
Gauss Kruger-East, North	East and North coordinates in the Gauss Kruger projection
Geoidal Undulation	Height of the ellipsoid above or below the geoid (user will be prompted with options after profile creation)
GLONASS/GPS Time Offset	Time difference between GPS and GLONASS expressed in meters
GLONASS/GPS Time Offset Stdev.	Standard deviation of the time difference between GPS and GLONASS expressed in meters

GPS Corrected Time	Exact time of measurement in the GPS time frame.
GPS Course-over-ground(track)	Direction of travel computed from trajectory (velocity)
GPS Time/Date	Time of the epoch or feature; time format may be changed to user's preference
GPS Week Number	Week number for GPS data starting from January 4, 1980; Depending in the format, this week number may or may not reset after 1023
Heading Angle	Negative yaw (see IMU angle definition).
Height Difference	Vertical height difference between stations
Height Error Estimate	Estimated error along the vertical axis (dh)
Horizontal Distance	Horizontal distance on the ellipsoid between stations (geodesic)
Horizontal Standard Deviation	Estimated position standard deviation in the east and north axes of a local level frame
Irish-East, North	East and North coordinates in the Irish State Plane projection
L1 Doppler RMS	Root mean square of L1 Doppler signal; useful for INS integration
L1 RMS	L1, or Iono-free root mean square
Lambert-East, North	East and North coordinates in the Lambert Conformal projection
Latitude	North/South geographic coordinate
Local Level Covariance Matrix	Estimated local level position covariance matrix; needs extended output in GrafNav
Local Level Velocity Covariance Matrix	Estimated local level velocity covariance matrix; needs extended output in GrafNav

Local Level XYZ	Local level left hand side frame where the x axis is pointing east, the y axis is pointing north and the z axis is pointing up; the frame is centred at the master station
Local plane XYZ	XYZ axes of a coordinate frame defined by two or more points (see local plane options)
Local Time/Date	GPS time and date with time-zone offset applied
Longitude	East/West geographic coordinate
Map Scale Factor	Map projection scale computed for a location
Master File Name	Name of Master GPB file
Num Fwd+Rev or Comb Baselines	Number of baselines used in the combine the solution.
Num GLONASS satellites	Number of GLONASS satellites
Num GPS satellites	Number of GPS satellites
Number of Satellites	Total number of GPS and GLONASS satellites
Orthometric Height	Height above the geoid (mean sea level height)(user will be prompted with options after profile creation)
PDOP, HDOP, VDOP	Position dilution of precision, horizontal position dilution of precision and vertical DOP. May be slightly different than values from other sources due to the differential computation
Pitch Angle	IMU pitch angle (see IMU angle definition)
Project Name	Name of current project. Useful to separate multiple baselines in GrafNav Batch.
P2 RMS	Root mean square of P2 code signal
Quality Number	Quality factor from GrafNav; 1 (best) to 6 (worst)
Relative Azimuth	Azimuth between current and previous feature or epoch.

Relative Height Difference	Relative height difference between current and previous epochs or features
Relative Horizontal Distance	Uncorrected horizontal distance on the ellipsoid between the current and previous epochs. Multiply by Combined Scale Factor to bring to mapping plane and surface
Relative Slope Distance	Free-air distance between neighboring epochs or features. Distance between current and previous.
Remarks	Remarks of the station or feature from the .STA file
Remote File Name	Name of Remote GPB file
Roll Angle	IMU roll angle (see IMU angle definition).
Roll, Pitch, Heading Separation	The difference between the combined solutions in terms of Roll, Pitch, and Heading.
Roll, Pitch, Heading StdDev	Estimated attitude accuracy.
Scale Factor	Horizontal distance ratio between the globe and the map distance for the current point in the current map projection
Selectable Grid	Allows user to enter a north and east value for a user defined grid. Grids can be modified and added using the Grid Manager (see Tools Menu).
Sequence Number	Allows the user to number epochs in the data with a user defined start and end sequence number, as well as, an incremental value
Slope Distance	Free air distance between stations
Solution Type	Type of solution used. In GrafNav, possible solution types include SF-Carrier, DF-Carrier, IonoFree, RelIono, CaOnly, SingPoint. In GrafNet, FixedSoln, FloatSoln.
Standard Dev. (NO PPM)	Trace of the covariance matrix expressed as a standard deviation; no distance dependent errors included
Start Time	Start time of the static session

State Plane-East, North	East and North coordinates in the US State Plane projection
Static/Kinematic Status	Indicates if an epoch is static or kinematic
Station Name	Name describing the station, feature or camera mark
Surface Distance	Horizontal distance between the two stations on the surface (corrected geodesic)
Time Length	Time length of the static session
Time Transfer …	Time transfer variables computed if the COMPUTE_CLOCK command is used
TM-East, North	East and North coordinates in the Transverse Mercator projection
Total Slope Distance	Spatial distance between two points
Total Horizontal Distance	The shortest path between two points on the surface of a sphere (e.g. Great circle)
User Text String	String of text defined by user
UTC Corrected Time	Same as UTC Time, but a correction for the receiver clock bias is applied. This is the most precise time. Only applicable for epochs.
UTC Date	Date in UTC time.
UTC Time	Time which is available in various format. This is the epochs or feature time offset from GPS seconds by the GPS-UTC time offset (see http://maia.usno.navy.mil/). This time is uncorrected for the receiver clock bias
UTM-East, North	East and North coordinates in the Universal Transverse Mercator projection
VSF. Ellipsoidal Height	Ellipsoidal height corrected by the map scale factor (see VSF options below)
VSF. Orthometric Height	Orthometric height corrected by the map scale factor (see VSF options). Used in photogrammetry applications to create an elevation that is more compatible with measured ground coordinates

XYZ Accelerometer Bias	This is the apparent output in acceleration when there is no input acceleration present. It is computed by the GPS/INS Kalman filter and the effects may be sinusoidal or random.
XYZ Gyro Drift	This is the apparent change in angular rate over a period of time. It is computed by the GPS/INS Kalman filter and the effects are usually random.

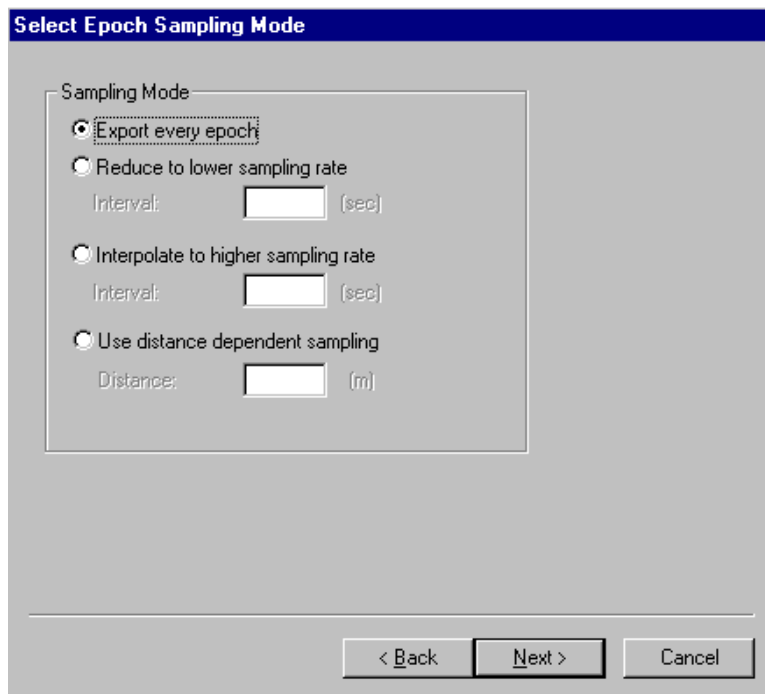## 2.7.3 Wizard Option Screens

Epoch Sampling Options

Figure 2.38 Export Wizard Sampling Options

Export every epoch	Prints out the variables for every epoch in the .fwd/.rev file
Reduce to lower sampling rate	Prints out the variables for every x number of seconds at a lower sampling rate(i.e. every 10th epoch)
Interpolate to higher sampling rate	Prints out the variables for every x number of seconds at a higher sampling rate(i.e. every ½ epoch); this option can also be used to fill in missing epochs where a linear interpolation is used

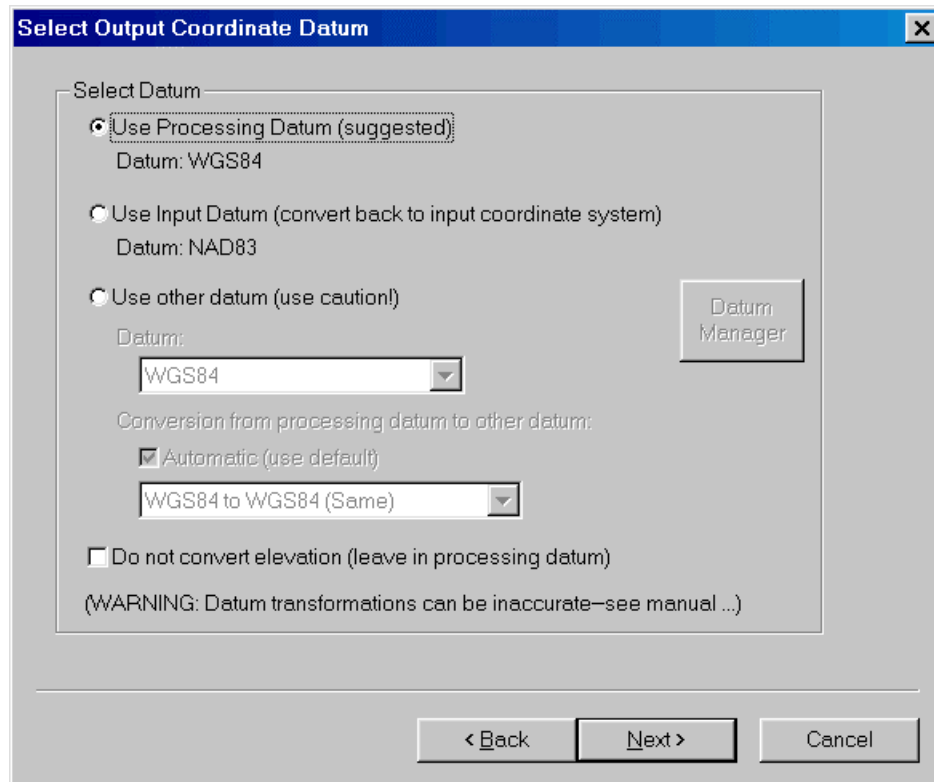| *Use distance dependent sampling*	Only exports an epoch every 'n' meters

Datum Options

Figure 2.39 Output Datum Options

This page allows users to select the datum final coordinates will be output in. Caution should be taken when any datum other than the processing datum is used (see Chapter 10 Section 3). The Input Datum allows users to convert back into the datum that coordinates were entered in. This is only applicable if this datum is different from the processing datum.

Finally, 'Use Other Datum' allows users to convert to a datum separate. **Again, extreme caution should be taken. Many meters of additional error can be added this way**. Be sure to select the closest appropriate conversion. The conversion selected by 'Automatic' may not be best.

'Do not convert elevation values' is applicable if the Geoid model is meant for the processing datum (e.g. NAD83), but final horizontal coordinate output is in another datum (e.g. NAD27).

UTC/Local Time Options
This correction for UTC time must be used when GPS times are converted to UTC times. GPS uses a linear time scale and never misses or counts a second twice, however, UTC time is not linear. UTC time holds a fixed relationship to the stars and there are many global effects that can change this relationship slightly. These corrections can be made as often as every six months but are usually only necessary every twelve or eighteen months. To determine what the UTC correction should be at the time the data was collected, please consult the following website: http://tycho.usno.navy.mil/leapsec.html

This page also allows users to set the time zone offset for local time output. This is the number of hours offset from GMT.

Apply 3-D Offset

Figure 2.40 Apply 3-D Offset Page

This page will appear if camera event marks are being exported. It allows users to apply a 3-dimensional offset from the antenna to the measurement device (e.g. entry nodal point on aerial camera). The offset is defined in the local body system of the aircraft, and not the camera. The right handed coordinate system is defined as follows:
   x-axis positive axis through the front nose of the aircraft
   y-axis positive axis through the left wing
   z-axis positive axis through the roof
Note that this vector is from camera to antenna (i.e. z-axis value is normally positive).

In order to transform this body frame vector to local level, aircraft attitude is required. This can be supplied when the camera event marks are imported. If no attitude is present, then the heading is assumed to be the course-over-ground (direction of travel). This can have errors of many degrees due to the aircraft's crab angle. User's can also supply a crab/drift angle (if known) in the Feature Editor (see Section 2.6.6 View/Edit Features (Feature Editor)) using the Global Edit button. Note that the export wizard has variables for the offsets after they have been rotated to local level. It is suggested that these be exported to check offset vector.
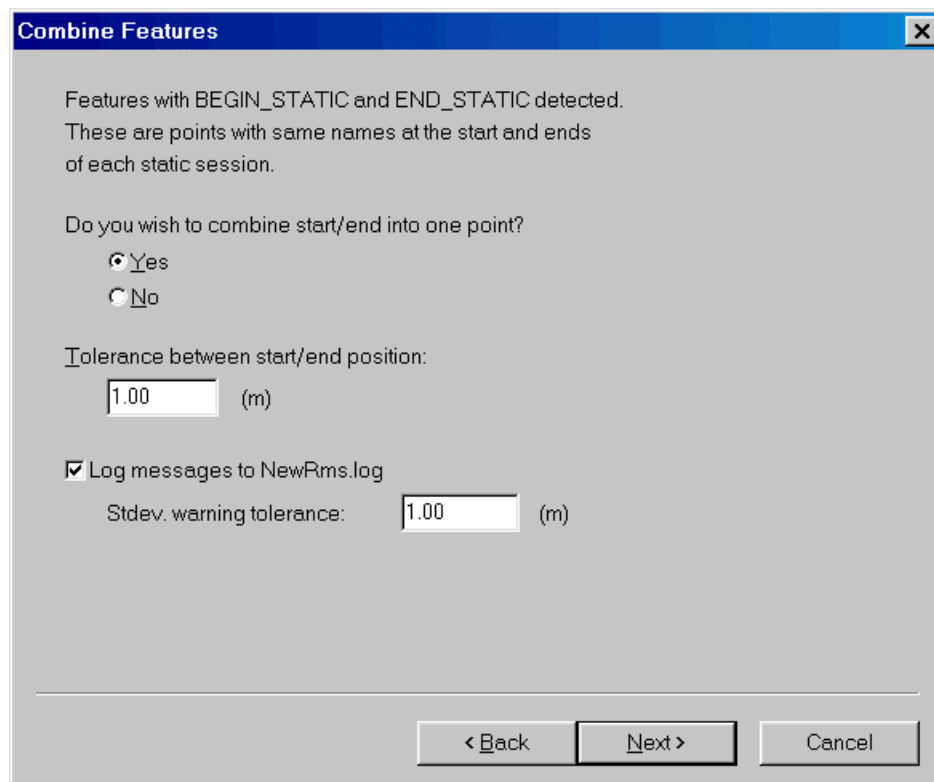
Combine Features

Figure 2.41 Combine Features

For data sets with numerous static sessions separated by kinematic, coordinates can be produced in a more optimum fashion. This is done by forming a combined solution using the solutions from the start and end of each static period. It is also important to process both forward and reverse, and a combined solution should be loaded. This methodology works well because in applications such as high tree cover, the first and last epochs of a given static session can be significantly different. This feature flags such points and puts more weight on the solution with the best estimated standard deviation.

In order for features to be combined, features/stations must be selected as the Source from the main Export Wizard screen. In addition, each static session must have a station at the start and end. The remarks field for such stations should be "BEGIN_STATIC" at

the start and "END_STATIC" at the end. The Ashtech Download decoder will automatically insert these fields if the 'Extract station information from Ashtech D-File' setting is used along with the Seismark data collector software. The new WinCE data logger will also create such files if the appropriate station selection is used. Otherwise, features can be moved to static session start and end using the Feature Editor (i.e. Move to Static button).

When 'Combine Features' is used, a .log file can be created that shows statistics about each combination. In addition, the remarks field will be replaced with a status message. The KinSurveyStations export profile is well suited for use with this methodology.

Tolerance between start/end position:
This is the minimum difference between start/end values necessary to generate an error message. For the above Figure 2.41, if the horizontal or vertical difference is less than 1 m, then the combination is deemed to be OK.

Log messages to File.log
This checkbox allows messages to be logged to a separate file. This is a good quality control feature. The 'Stdev. warning tolerance' is used to flag points with very poor estimated standard deviations.

Select Grid System and Settings
If the selectable grid north and/or east variable is used, then this page is displayed. It is the same page if the Grid Options are selected from the Options Menu. Basically, users will select the Grid model to use. For some grids such as UTM, the zone number must also be entered. For State Plane, the state plane zone (STATE + REGION) must be selected.

UTM Options

Zone Number	The UTM zone of the desired output; Note that UTM zones are separated by 6° and start numbering from west to east starting at 180° W with the central meridian at 177°W

Gauss-Kruger Options

Zone Number	Defines Gauss-Kruger zone, that output should be in (see UTM)

Transverse Mercator Options

Central Meridian	Defines the central meridian of the Transverse Mercator projection
Central Meridian Scale Factor	Specifies the scale factor along the central meridian

False Easting/Northing	If the coordinates in the TM projection are negative values, the false eastings and northings force the coordinates to all positive values

If a latitude origin is specified in your Transverse Mercator coordinate system, then use the Grid Manager along with the Selectable Grid export variables, as this supports this parameter.

State Plane Options

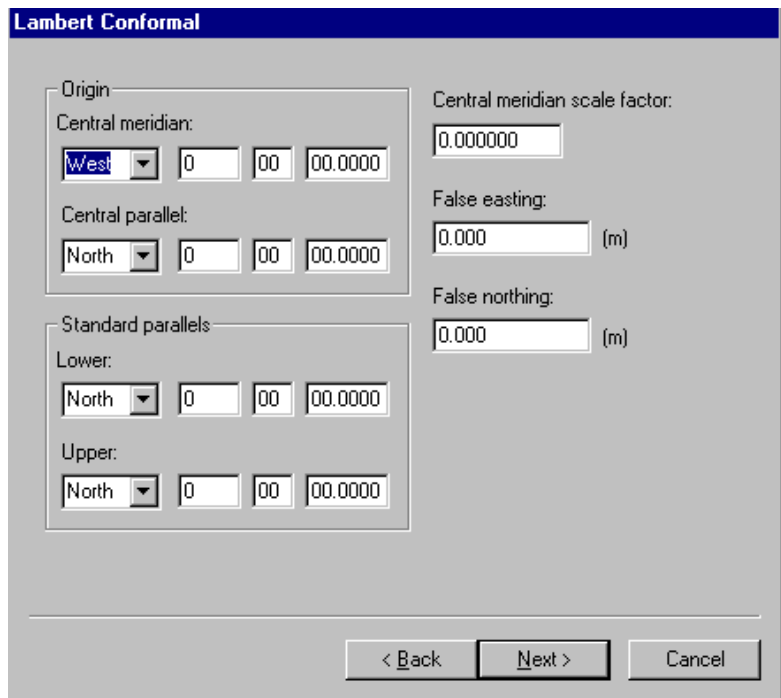| *Select region*	Allows the user to define which state plane region the points are in
Datum	The datum is set for NAD83 for all state plane coordinates; NAD27 will be selected if processing is in that datum. The user may not change the datum. This must be done through the datum or processing options.

Lambert Conformal Options

Figure 2.42 Lambert Conformal Options

Origin
Central Meridian and Central Parallel: Defines the central meridian and parallel for the Lambert Conformal projection (dms).

Standard Parallels
Lower and Upper Standard Parallels: Specifies which lower and upper parallels are standard (i.e. constant scale factor) (dms).

Central meridian scale factor
Initializes the scale factor along the central meridian (usually 1.0).

False Easting, False Northing
If the coordinates in the Lambert Conformal projection are negative values, the false easting and northing force the coordinates to all positive values.
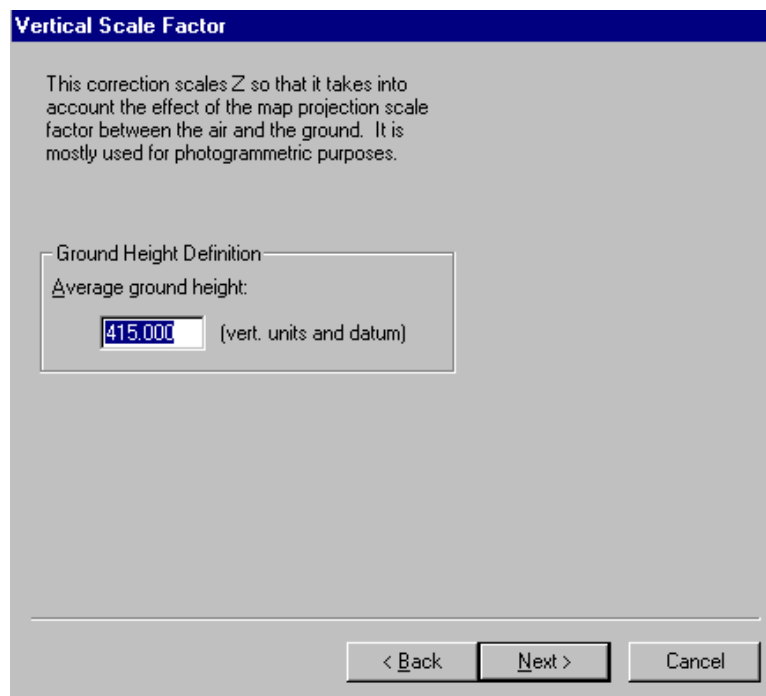
Vertical Scale Factor Options

Figure 2.43 Vertical Scale Factor

This correction is normally only used by photogrammetric users. When performing photogrammetric aerial triangulations, these algorithms known as block adjustments often assume the scale factor for the horizontal and vertical coordinates. The block adjustment can either be a bundle adjustment (e.g. GPSBund, PAT-B, ALBANY, etc…) or an independent model adjustment (e.g. SPACE-M, PAT-M). When map projection coordinates (e.g. UTM, Gauss-Kruger, State Plane, Lambert, etc…) are used in the adjustment, then the horizontal coordinates are scaled by the map projection scale factor, while vertical coordinates if uncorrected will have a scale factor of one. Adjustments like PC-GIANT that work in a geocentric frame are unaffected but such adjustments are not very compatible with soft-copy systems.

To counter-act this problem, GrafNav can apply a correction to the vertical component that corrects for much of the scale error. Currently, GrafNav assumes a constant terrain height, and this correction will be most accurate in flat areas. It will be less accurate in areas with high relief as the constant height model no longer holds true. Aircraft height variations are taken into account. GrafNav will prompt the user for the average height of the ground. If the user outputs height in feet, then this height should also be in feet.

Local Plane Options
This feature enables you to rotate and scale processed feature or epoch output coordinates into a local coordinate frame. Note that the Z coordinate will be a differential ellipsoidal height, and not a Cartesian coordinate. There are three types of local transformations supported in GrafNav and GrafNet: a 4-parameter 2D transformation, a 6-parameter 2D transformation, and a 7-parameter 3D transformation. The parameters that are solved by each transformation are shown in the table below:

Transformation:	Parameters:
4-parameter 2D	2 translations, 1 rotation, 1 scale
6-parameter 2D	2 translations, 1 rotation, 2 scales, 1 skew angle
7-parameter 3D	3 translations, 3 rotations, 1 scale

The local frame that you will transform the processed output coordinates into is defined by a number of previously surveyed points. The minimum number of such points needed for the transformation depends on the number of parameters that need to be solved for. In general, the minimum number of individual coordinates (i.e. X, Y, and Z) that need to be defined for any specific transformation is equal to the number of parameters being solved for. Each coordinate must be given in either meters or feet.

So, for the 4-parameter 2D transformation, the northings and eastings of at least two points will be required. Similarly, for the 6-parameter 2D transformation, the northings and eastings of three points will be required. Performing a 7-parameter 3D transformation requires seven known coordinates. Six of these coordinates must define two points completely (i.e. X, Y, and Z). Either a height for a third point must be entered, or another horizontal pair of coordinates must be entered to solve for the final parameter.

Using the 6-parameter 2D transformation or the 7-parameter 3D transformation can be very dangerous. The horizontal axes (i.e. X, and Y) will probably no longer be perpendicular to one another when using the 6-parameter 2D since the transformation allows for a skew between these axes. Coordinates transformed using the 7-parameter 3D transformation are not necessarily in a local-level frame any more, which can cause severe problems in many applications.

To indicate which type of transformation you would like to perform, and which points you would like to use as known points, GrafNav provides the *Local Coordinate Transformation* dialogue box shown on the following page.
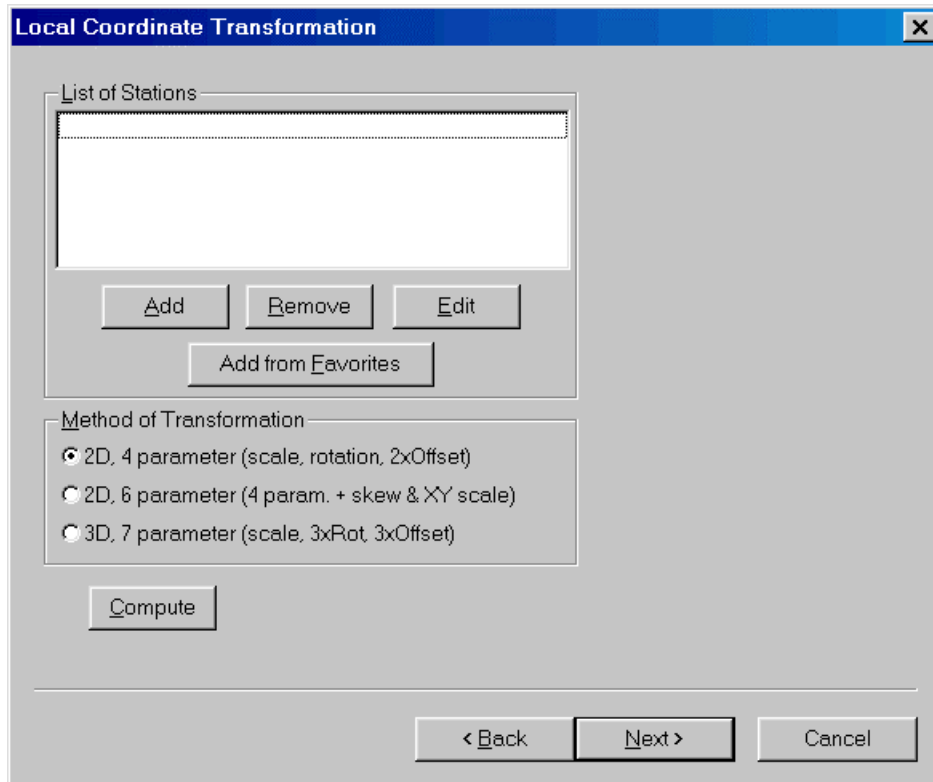
Figure 2.44 Local Coordinate Transformation Dialogue Box

Use the **Add**, **Remove**, and **Edit** buttons to define the reference points in the transformation. The *Local Station Information* dialogue box below is used to add and edit points. The name given to a known point must be the same as the name of the station it corresponds to. Pressing the search button will provide a list of the points that GrafNav or GrafNet has GPS coordinates or master coordinate for, and a list of the points with known coordinates that have previously loaded. These lists are displayed in the *Search for Station* dialogue box.
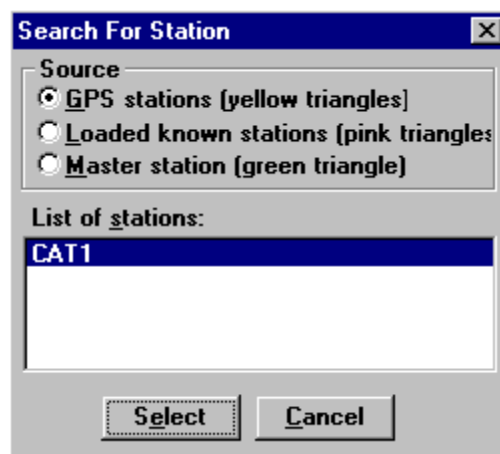

Figure 2.45 Adding a station

The Favorite Points that are referred to in the first two dialogue boxes are points that you may want to use as known points in many different projects. GrafNav saves the coordinates of these points to a file called 'local.fav' in the program files directory so that they can be used at any time without having to be re-entered. To use one of these points in the transformation, its name must be the same as its corresponding point in GrafNav.
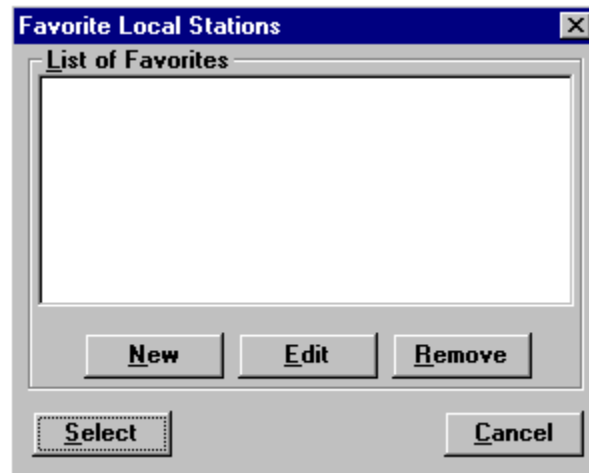

Figure 2.46 List of Favourites
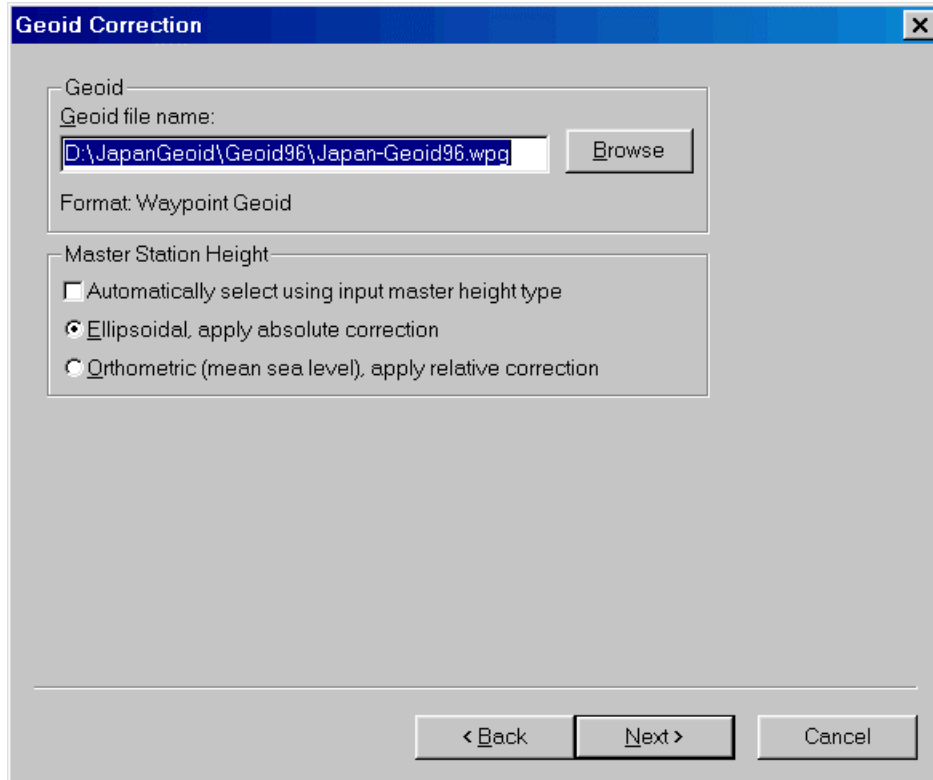
Geoid Correction Options

Figure 2.47 Geoid Correction Options

GPS works in the ellipsoidal height system. However, many maps and vertical datums are defined in the orthometric system (height above mean sea level). GrafNav can make use of the .BIN/.SLV and .GEO GEOID files produced by the Canadian and American governments. GrafNav also supports various geoids in the .WPG (Waypoint Geoid Format). This includes files for US Geoid99 and Geoid96, Australia AusGeoid93, and EGM96 for the World. These files are located on the distribution CD in the \Geoid directory. Using these files, GrafNav can produce orthometric heights as output.

The user will be asked where the GEOID files reside and whether the base station height is orthometric or ellipsoidal. Selecting "Orthometric" will apply a relative geoid correction, while using "Ellipsoidal" will apply an absolute correction. The automatic setting ('automatically select using input master height type') will use the ellipsoidal/orthometric flag selected in the master station input.

Note that the Geoid Correction option requires geoid95.bin and geoid95.slv or geoid91.bin and geoid91.slv from the Geodetic Survey of Canada, geoid##.geo from NGS in the United States or the appropriate .WPG file. For Canada, these files must be obtained from GSC since they are NOT PROVIDED.

Geoid		
	Geoid File Name	Allows the user to select the proper file containing information on the geoid and its format
Master Station Height		
	Automatically select using input master height type	Uses the ellipsoidal/orthometric height flag that can be selected when the master station coordinates are entered. When selected, the *grayed* radio button below will indicate which selection was made.
	Ellipsoidal	Height entered for the master station coordinates is an ellipsoidal height
	Orthometric (mean sea level)	Height entered for the master station is an orthometric (mean sea level) height

2.7.4 Export Wizard Tutorials - Creating Your Own Format

To familiarize the user with Export Wizard, several tutorials on how to use the wizard are included in the following section to give the user a background on the process of creating a custom output format. Several frequently data formats have been created as profiles to help the user.

$GPGGA – NMEA format Example
GGA – Global Positioning System Fix Data
Time, position and fix related data for a GPS receiver.

$GPGGA,hhmmss.ss,llll.ll,a,yyyyy.yy,a,x,xx,x.x,x.x,M,x.x,M,xxxx*hh<CR><LF>

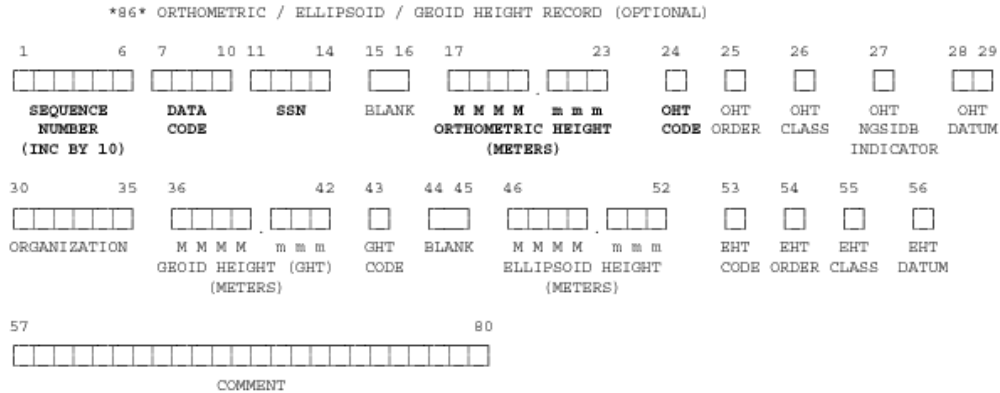| Description	Format	Comments
UTC of position	hhmmss.ss	hoursminutes.decimal, where there are 2 fixed digits for hours, 2 for minutes, and variable number of decimal places for decimal minutes fraction (however, user must specify this manually to the number of decimal places in the export wizard); leading zeros are needed for hhmmss.ss
Latitude	llll.ll	degreesminutes.decimal;2 fixed digits for degrees, 2 fixed digits for minutes, and a variable number of decimal places for decimal minutes fraction; pad with leading zeros
Latitude – N/S	A	Alphanumerical character for N or S
Longitude	yyyyy.yy	degreesminutes.decimal;2 fixed digits for degrees, 2 fixed digits for minutes, and a variable number of decimal places for decimal minutes fraction; pad with leading zeros

Longitude – E/W	A	Alphanumerical character for E or W
GPS Quality indicator	X	Numerical character; 0-8; refer to NMEA 0183: Standard For Interfacing Marine Electronic Devices Version 2.30 for GPS Quality indicator codes
Number of satellites in use	Xx	00-12; numerical field; pad with leading zeros
Horizontal Dilution of Precision	x.x	Variable field width
Altitude re: mean sea level (geoid), meters	x.x,M	Variable field width for altitude; alphanumerical character M for meters
Geoidal separation (undulation), meters	x.x,M	Variable field width for geoidal separation; alphanumerical character M for meters
Age of differential GPS data	x.x	Variable field width; time in seconds since last SC104 Type 1 or 9 update, null field (,,) when DGPS is not used
Differential reference station ID	Xxxx	0000-1023; numerical field; pad with leading zeros

To use the Export Wizard step by step to create a custom format, follow these instructions:

Steps:
1. Open a project in GrafNav and load a forward or reverse solution.
2. Open the export wizard by pressing the Export Wizard button on the tool bar or access it from the menu *Output | Export Wizard*.
3. Type in the file path name or press the Browse button if you want to select a file other than the default file name.
4. Press the New button to create a new profile and enter the profile name in the space.
5. A Define Profile window will appear after OK is pressed, variables can be added to the Export Variables list from the Source Variables window beside it.
6. Click on Header/Footer and remove all checked boxes in the options dialogue box

7. Press the Line Terminator button, and make sure the line terminator characters are CR+LF
8. For the field separator, press the Field Separator button and click the None option since not all variables need to be separated by commas. Field separators can be manually added into the Export Variables list if needed.
9. To begin the data format sentence with $GPGGA, select Miscellaneous from the scroll down menu of Source Variables and highlight User Text String. Double-click on User Text String and type in $GPGGA into the bar, click on the fixed width box and fill in a width of 6 in the box.
10. In the same 'Miscellaneous' menu, double click on the Field Separator variable and select the comma radio button.
11. Go to the Time/Date menu and select UTC Time and add it to the list. First change the UTC Time format to Hours under the Format/Units menu and next make sure the fixed width and the pad field with zeros options are selected. Repeat the same procedure for minutes and seconds.
12. Add another comma field separator from the 'Miscellaneous' menu.
13. Go to the Geographic Coordinates menu and add the Latitude variable. Change the format to Degrees (unsigned) and then add Latitude again under the format of Decimal Minutes. Enable the fixed width and pad field with zeros options.
14. Add a comma field separator.
15. From the Geographic Coordinates menu, add Latitude again using the format N, S, E, W Character option.
16. Add a comma field separator.
17. Repeat steps 12-15 under the Geographic Coordinates menu for Longitude.
18. For GPS Quality indicator, use the User Text String variable in the 'Miscellaneous' menu to add a string of 1 character long. Be sure to fix the width to 1.
19. Add a comma field separator.
20. From the Statistics menu, add the number of satellites variable and fix the field width to 2 and select the pad field with zeros option.
21. Add a comma field separator.
22. The HDOP is not a valid variable at this time (June 10, 1999), but the Double-Difference DOP is available. Add the DDOP from the Statistics menu.
23. Add a comma field separator.
24. Under the Height/Elevation menu, select and add Orthometric Height to the list and make sure the units are in meters.
25. Add a comma field separator.
26. From the 'Miscellaneous' menu, add a User Text String of one character (fixed width) of the letter M.
27. Add a comma field separator.
28. From the Height/Elevation menu, add Geoidal Undulation to the list and check to see if the units are in meters.
29. Add a comma field separator.
30. From the 'Miscellaneous' menu, add a User Text String of one character (fixed width) of the letter M.
31. Add a comma field separator.

32. If you are not using DGPS, the age of differential GPS data option can be ignored by adding a null character (i.e.''). Therefore, add a comma field separator.

33. Go to the Station Names/Info menu and add the Sequence Number variable to take the place of the Differential reference station ID (0000-1023). The user will be prompted later after profile creation for the range of the station ID numbers and the increment value.

34. Add the checksum delimiter by using Field Separator under Miscellaneous and select the Character radio button and type the * symbol in the box.

35. From the 'Miscellaneous' menu, choose the Checksum (8-bit) variable and change the format to NMEA-methodology enabled and hexadecimal format for $GPGGA.

36. Press OK and then Next to start choosing the final options before outputting your file.

37. Select the geoid file name by typing in the path name or use the Browse button. Select either ellipsoidal or orthometric height based on which one was used for the master station.

38. Under the Sampling Mode dialogue box, choose the sampling rate for the number of epochs to be printed out. Press Next.

39. Select the Output UTC time instead of GPS option and either keep the nominal UTC time offset or type in your own. Press Next.

40. For the Sequence Number options, start the count at 0 and restart counting sequence when the count exceeds 1023, increment the sequence value by 1 and check the option of continuing the count for epochs not written. Press Next.

41. Press Preview if you would like to take a look at your file before saving it. Press Finish to save the file.

NGS Blue Book *80* ,*86* Example

The following example goes through the procedure of making a basic *80*, and a *86* data code record for the NGS Blue Book format. Since the format requires that there are no decimal points in the data record, slight modifications to the units and field width will have to be made to accommodate for this profile.

```
                *86* ORTHOMETRIC / ELLIPSOID / GEOID HEIGHT RECORD (OPTIONAL)

    1        6  7    10 11     14  15 16  17              23  24   25    26     27      28 29
   [_____][____][____]  [__]  [_____.____]  [_]  [_]   [_]   [_]    [__]
   SEQUENCE       DATA      SSN   BLANK   M M M M    m m m  OHT  OHT   OHT    OHT     OHT
    NUMBER        CODE                 ORTHOMETRIC HEIGHT   CODE ORDER CLASS  NGSIDB  DATUM
   (INC BY 10)                           (METERS)                           INDICATOR

   30       35  36              42  43   44 45  46          52  53   54    55     56
   [_____][_____.____]  [_]  [_]   [_____.____]  [_]  [_]   [_]    [_]
   ORGANIZATION   M M M M    m m m  GHT  BLANK   M M M M    m m m  EHT  EHT   EHT    EHT
              GEOID HEIGHT (GHT)  CODE           ELLIPSOID HEIGHT   CODE ORDER CLASS  DATUM
                  (METERS)                         (METERS)

   57                                      80
   [_____]
               COMMENT
```

Steps:
1. Open a project in GrafNav and load a forward or reverse solution.
2. Open the export wizard by pressing the Export Wizard button on the tool bar or access it from the menu *Output | Export Wizard*.
3. Type in the file path name or press the Browse button if you want to select a file other than the default file name.
4. Press the New button to create a new profile and enter the profile name in the space.
5. A Define Profile window will appear after OK is pressed, and variables can be added to the Export Variables list from the Source Variables window beside it.
6. Click on Header/Footer and remove all checked boxes in the options dialogue box
7. Press the Line Terminator button, and make sure the line terminator characters are CR+LF
8. For the field separator, press the Field Separator button and click the None option since not all variables need to be separated by commas. Field separators can be manually added into the Export Variables list if needed.
9. Go into the Station Names/Info menu and add the Sequence Number variable of fixed width 6 and select the pad field with zeros option. After the profile is created, the options for start and end time, as well as, the incrementing value will be prompted from the user.
10. Using the User Text String, add a fixed width 4 for the string containing the data code *80*
11. Add a User Text String from the 'Miscellaneous' menu of fixed width 4 for SSN.
12. From the Station Names/Info menu, add the variable Station Name to the Export Variables list, and change the fixed width to 30 and unclick the Left-Justify box.
13. Go to the geographic Coordinates menu and add the Latitude variable. Change the format to Degrees (unsigned) with a fixed width of 2, padded with leading zeros, and then add Latitude again, but now change the format to Minutes with fixed width 2 and padded with leading zeros as well. Make sure that both degrees and minutes do not have decimal places. Add Latitude once again and change the format to Decimal Seconds with fixed width 7 and the padded with leading zeros option and do not display decimal point options selected.
14. From the Geographic Coordinates menu, add Latitude again using the format N, S, E, W Character option.
15. Repeat steps 12-13 for Longitude; however change the fixed width of Longitude (Degrees) to 3 instead of 2.

16. From the Height/Elevation menu, add Ellipsoidal Height, fix the width to 6 and change the units to meters and make sure the pad with leading zeros and do not show decimal point options are selected.

17. Using User Text String from the 'Miscellaneous' menu, create fixed width strings of 1, 2, 1, and 1 space width for each of the following: Elevation Code, State Code, Station Order, and Station Type.

18. From the 'Miscellaneous' menu, select the Field Separator and add CR+LF to the list.

19. Go into the Station Names/Info menu and add the Sequence Number variable of fixed width 6 and select the pad field with zeros option. After the profile is created, the options for start and end time, as well as, the incrementing value will be prompted from the user.

20. Using the User Text String, add a fixed width 4 for the string containing the data code *86*

21. Add a User Text String from the 'Miscellaneous' menu of fixed width 4 for SSN.

22. Add a fixed width 2 User Text String for a blank to the variables list from the 'Miscellaneous' menu.

23. From the Height/Elevation menu, add Orthometric Height, fix the width to 7 and change the units to meters and make sure the pad with leading zeros and do not show decimal point options are selected.

24. From User Text String in 'Miscellaneous', make strings of widths 1, 1, 1, 1, 2, and 6 for OHT code, OHT order, OHT class, OHT NGISDB indicator, OHT datum, and Organization.

25. From the Height/Elevation menu, add Geoidal Undulation, fix the width to 7 and change the units to meters and make sure the pad with leading zeros and do not show decimal point options are selected.

26. Add 2 User text Strings of fixed widths 1 and 2 for the variables GHT code and blank.

27. From the Height/Elevation menu, add Ellipsoidal Height, fix the width to 7 and change the units to meters and make sure the pad with leading zeros and do not show decimal point options are selected.

28. Create User Text Strings from the 'Miscellaneous' menu for EHT code, EHT order, EHT class, EHT Datum, and Comment for fixed widths of 1, 1, 1, 1, and 24 and click OK when finished.

29. Click Next, and now select the file path name or press the Browse button to select the geoid file from the directory tree structure. Select either ellipsoidal height or orthometric height based on the type of height that was measured at the master station. Press Next.

30. Depending on how many epochs the user wants printed to a text file, select one of the options: Export every epoch, Reduce to lower sampling rate, Interpolate sampling rate, Use distance dependent sampling. If there is a large amount of data or if there are missing epochs, the latter options are suggested. Press Next.

31. Select 0 for the start value of the Sequence Number, increment the sequence number by 10 for Blue Book records, and select a reset value after the Sequence Number exceeds 99999. Make sure the continue incrementing even when epochs/features are not written option is chosen. Press Next.

32. Press Preview to view the file being created. Press Finish to save the file.

Section 8   Favourites Manager

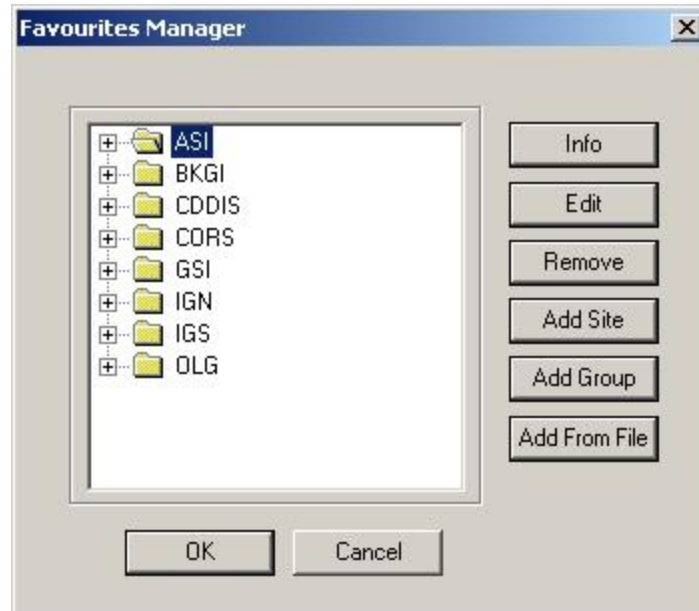## 2.8.1   Getting Started

Figure 2.48 Favourites Manager

Use this feature to avoid unnecessarily retyping coordinates that are used often. It is accessed from GrafNav, GrafNet, and GrafNav Batch from the Tools menu.

Upon loading the Favourites Manager, a list of favourite groups appears. If this feature has never been used before, eight or possibly nine groups should appear:

- ASI
- BKGI
- CDDIS
- CORS
- GSI
- IGN
- IGS
- OLG
- Previous_Fav (may not appear)

The groups ASI, BKGI, CDDIS, CORS, GSI, IGN, IGS and OLG contain a list of control points that continuously collect GPS data that can be downloaded free of charge from the download program (*Tools | Download Service Data*). Previous_Fav will only exist if you have favorites from the previous installation.

In the installation of version 7.50, you are prompted to locate the directory where your previous version of GrafNav/GrafNet is installed. This will automatically copy all of your user files (including your previously stored favourites) into version 7.50. You may follow these steps to manually copy your favourites into version 7.50:

Conversion from 6.02 to 7.50:
1. Copy the file Master.fav from your 6.02 (or earlier) directory (the same directory that contains the 6.02 version of wgrafnav.exe)
2. Paste into the new 7.50 directory (the same directory with the 7.50 version of wgrafnav.exe)
3. Load the Favourites Manager in version 7.50
4. Upon loading the favourites manager, a message will appear warning the old favourites are being read in the WGS84 datum and height coordinates as ellipsoidal. If this is not the correct coordinate format, you must change them individually by using the Edit button, which is described later.

Conversion from 6.03 to 7.50:
1. Copy the file User.fvt from your 6.03 directory (the same directory that contains the 6.03 version of wgrafnav.exe)
2. Paste into the new 7.50 directory (the same directory with the 7.50 version of wgrafnav.exe)
3. Load the Favourites Manager in version 7.50
4. Upon loading the favourites manager, version 6.03 favourites will now be loaded into the vesion 7.50.

2.8.2   Working with the favourites manager

What follows is a brief discussion of the buttons on the favourite manager interface.

Add Site, Add Group, and Remove
Often new groups are created when starting a new project to facilitate easy removal after project completion.

Info
If clicked on an entire group, returns the total number of sites contained in the folder.
If clicked on an individual station, returns position, height type and datum type.

Edit
Rename the entire group or edit the coordinates of individual stations using this function.

Add from File
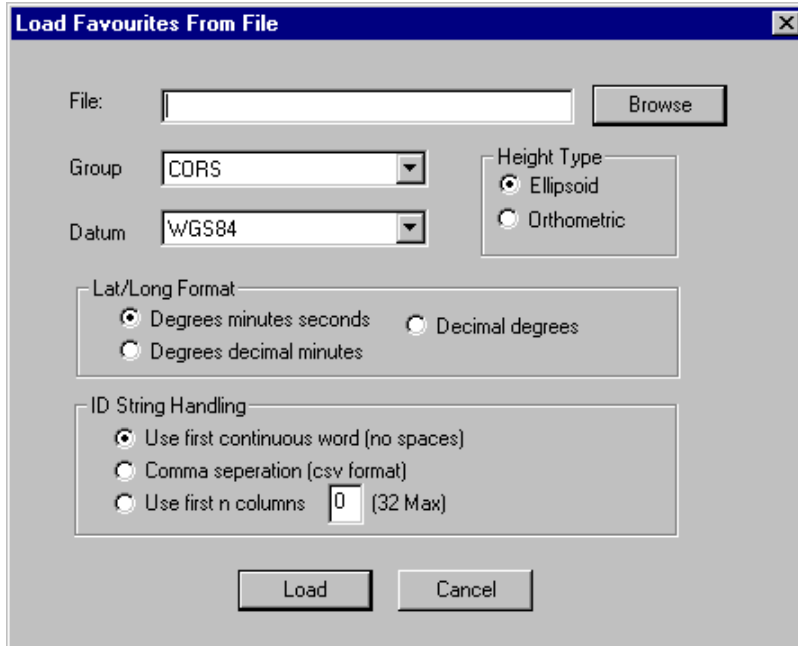
Figure 2.49 Load From Favourites File

Lists of coordinates can be directly read in from a file using this feature. Simply browse to the file, specify the input height type and Lat/Lon format of the file, and Load.

Rejected Sites
If only a few sites were rejected it could simply mean that the lines in the header were rejected (the program has no way of knowing what header information is, it will simply reject lines that do not conform to the expected input format). However, if no points were accepted, this is an indication of problems in the input file.

The input coordinates must be signed to indicate hemisphere, and must not have N/S or E/W preceding or following the coordinates. Another major cause of failure is the way the station name is read in, which is controlled by the ID string handling option.

The station name should precede the latitude, longitude, and height in the input file. If the station name is FRED1, the default option (Use first continuous word (no spaces)) should work, as there are no spaces in the name. If, however, you wish to specify the name as FRED 1, there must either be a comma after FRED 1 and the file read in as .CSV format, or you could choose to read in the first 6 columns for the ID string. If you chose the latter option, all the station names must also be fixed at six characters or less. Note all other fields should simply be separated by a space.

Examples of input file formats and how the ID strings cam be handled:

Use first continuous word (no spaces)

POINTONE 34 26 09.98731 -114 26 09.98731 12.01
POINT2 36 12 56.12154 -114 12 56.12154 14.23
POINTTHREE 52 12 00.00000 -56 00 23.01213 1112.45

Comma separation (csv format)
POINT ONE,34,26,09.98731,-114,26,09.98731,12.01
POINT 2,36,12,56.12154,-114,12,56.12154,14.23
POINTTHREE,52,12,00.00000,-56,00,23.01213,1112.45

Use first n Columns (in this case n = 7)
POINT 1 34 26 09.98731 -114 26 09.98731 12.01
POINT 2 36 12 56.12154 -114 12 56.12154 14.23
POINT 3 52 12 00.00000 -56 00 23.01213 1112.45

Section 9   Interactive Windows

2.9.1   Mapping Window
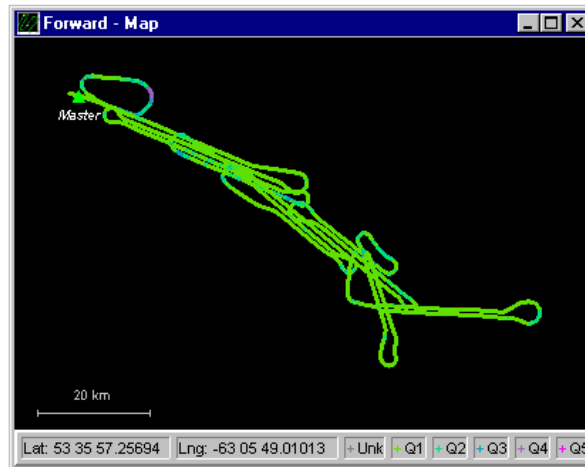
Figure 2.50 Mapping Window

This screen is a graphical representation of the project area. It shows the master station, the location of the remote station at each epoch, and station or event marks. The master station is represented by a solid green triangle. The event marks are shown as blue circles, and the station marks are shown as yellow triangles. The remote locations are shown as small crosses. The colour of the cross depends on the quality of the solution. The colours displayed are listed below:

Quality Number Description

Quality	Colour	Meaning	Accuracy (m)
1	Green	Fixed Integer	0.00 – 0.15
2	Cyan	Converged Float or Noisy Fixed Integer	0.05 – 0.40
3	Blue	Converging Float	0.20 – 1.00
4	Purple	Converging Float	0.50 – 2.00
5	Magenta	DGPS	1.00 – 5.00
6	Red	DGPS	2.00 – 10.00
Unprocessed	Grey	Has not been processed	N/A

Note: The accuracies given above are only guidelines. The actual accuracies may be very different, and in fact, much worse. The user should also check the standard deviation values, which are also a guideline.

2.9.2   Mouse Usage in Mapping Window

Positioning the cursor on a station or epoch mark and clicking with the left mouse button will bring up either the Station Information, or Epoch Information message boxes. Clicking the right mouse button instead of the left mouse button, the Object Menu will come up (see Section 2.5.5 User Defined Options).

2.9.3   Processing Window

This window appears during processing and it will show position, status, satellite and message information originating from the processing engine. Such various types of information are contained on different pages, which can be accessed by pressing the appropriate radio button, near the top of the processing window.

Also displayed on this window is a graphical quality bar. It ranges from 1 to 6, where 1 is best, and 6 is worst. The quality number is dependent on a number of factors but it is most sensitive to solution stability. If this bar jumps from 1 to 6, either a serious loss of lock has occurred or, unfixable bad measurements have incurred a Kalman filter reset in kinematic mode. At this point KAR will be engaged if enabled. Stable solutions are usually 1 or 2 for carrier phase processing. For code-only processing, the quality will range from 3 to 6.

This dialogue box has two checkboxes:

Split windows   This shows a two-window display. Users can select either window, except that when KAR engages, it will utilize the right page.

Show message log This displays the status messages written to the message log file. It updates in real-time. **Enabling this can significantly slow processing down!!!**
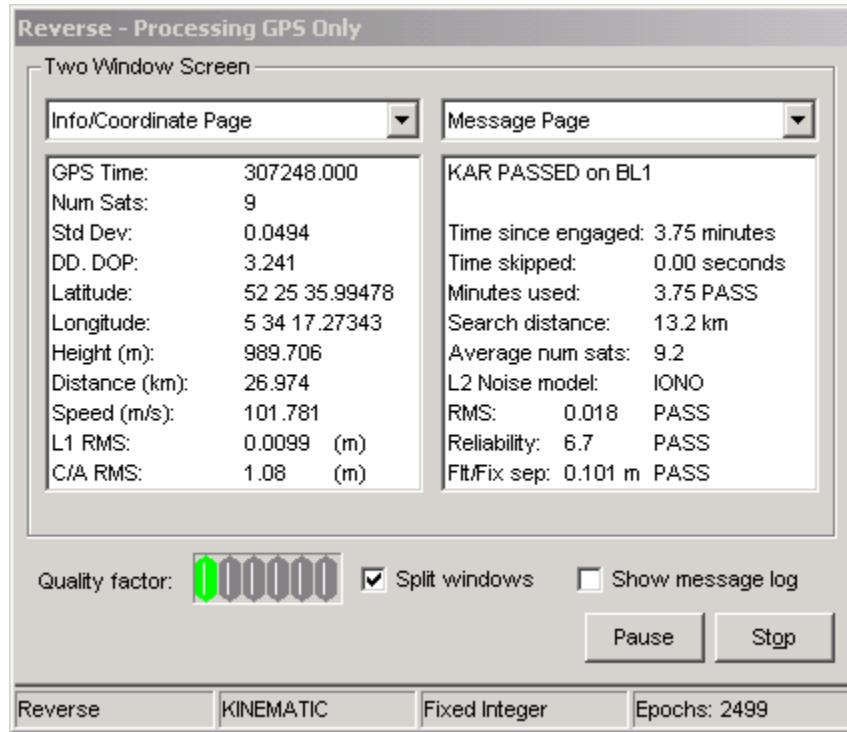
Figure 2.51 Processing Window

The status bar at the bottom of the processing window shows whether the current epoch is static, kinematic or if KAR is engaged. This status bar also indicates if the current process is using the forward or reverse direction. The static processing mode selected is also displayed. Lastly, the number of epochs that have been processed is shown. This screen is not updated every epoch rather, it is updated every *N* milliseconds. This update interval can be changed from the display options in both GrafNav and GrafNet, and the default is 500 milliseconds.

The meanings of the various parameters are given below:

Parameter	Description	Page
GPS Time	Epoch time given in seconds of the week, GMT hours, minutes, seconds time is also given.	Info/coordinate & Status
DD DOP	Instantaneous dilution of precision using double difference model. Large values indicate poor satellite geometry, which may cause position accuracy degradation. PDOP is approximately the square root of this value.	Info/coordinate & Status
Quality Number	Qualitative indicator ranging from 1 to 6 where 1 is best and 6 is worst.	Info/coordinate & Status
Latitude, Longitude, Height	Geographic position of remote at current processing epoch.	Info/coordinate
Speed	Vehicle instantaneous velocity vector in m/s. This value may be inaccurate for code-only processing.	Info/coordinate

L1 RMS	RMS fit of L1 carrier phase data should normally be <0.03m. However, larger values are acceptable for very long baseline processing.	Info/coordinate & Status
CA RMS	RMS fit of C/A code. This value is a good indicator of multipath. However, various receiver types will have different values. For example, precise correlation receivers should have values <3m, while some standard correlation receivers can have values >5m.	Info/coordinate & Status
Num Cycle Slips	Number of detected cycle slips. However, due to the lock time cut off, normally set to 8 seconds. This value may stay near zero.	Status
Num <4 Sats	Number of epochs less than 4 satellites	Status
Separation	Distance separation between base and remote stations expressed in km.	Status
PRN	Satellite vehicle number (1-31)	Satellite
Elev	Satellite Elevation (degrees)	Satellite
Az	Satellite Azimuth (degrees)	Satellite
DD Amts	Last few digits of double difference L1 carrier phase ambiguity. For accurate short baseline processing these values should be near integer.	Satellite

KAR display:
During processing, the message page will contain status of the last KAR solution. The following variables are displayed:

Time since engage	This is the number of seconds or minutes since KAR was engaged. KAR can be engaged for a number of reasons including loss of lock, poor geometry, data errors etc…
Time skipped	This is the time that KAR was unable to restore. Once KAR has a successful solution, it tries to go backwards as far as possible. This is the difference between the restore time and the original cycle slip time.
Minutes used	This is the time that KAR used for a solution. It is not the time since engagement.
Search distance	This is the distance when the ambiguity search was performed. This is not the distance when KAR was restored.
Avg. num sats	This the average number of satellites used to compute KAR statistics. It will always be greater than *or equal to* 5
Noise model	This is the model that KAR used to model L2 during processing. See Advanced KAR Options.
RMS:	This is the RMS fit of the KAR search and statistical testing of previous data. This number is in cycles. Values better than 0.04 usually indicate a correct

	solution. However, this number can be larger and still be correct. The tolerance for passing is 0.065 cycles.
Reliability	This is the ratio between the second best RMS and the best RMS. Ratios above 3-4 are usually a pass for dual frequency. The tolerance is variable depending on the float-fixed separation.
Float/fixed separation	This is the distance between the solved fixed integer solution and the float solution at time of search. Low numbers indicate a good correspondence between the two solutions.

Fixed solution display:

During processing, the message page will contain status of the last KAR solution. The following variables are displayed:

RMS(m)	RMS value computed by fixed solution (should be less than 0.02)
Reliability	This is the ratio between the second best RMS and the best RMS. Ratios above 3-4 are usually always a pass for dual frequency. The tolerance is 1.5. For single frequency, ratios are lower, but 2 or greater is usually correct. The tolerance for single frequency is 1.35.
Frequency	SINGLE or DUAL. Dual frequency receivers will try a single frequency solution if they fail on shorter baselines.
Time	Number of Hours:Minutes:Seconds used in the solution
Type	Fixed static solution type used. Continuous is the pre-version 6.00 type. It uses the best continuous block of data. NewFixed (multi-sat) uses all of the data. It may reject some satellite arcs (see Static/KAR summary file).

Section 10   Help Menu

2.10.1   Help Topics

Here the user can find online help topics similar to the ones published in this manual.

2.10.2   www.waypnt.com

Click this to open a web browser to Waypoint's homepage. Details on latest versions, patches, information on GPS/INS, and tech reports can be found on our webpage.

2.10.3   About GrafNav

Figure 2.52 About Box

This window displays information about the software version, build dates, copyright information, hardware lock key information, and dll information. User's can access the hardware key utility from this window by clicking 'Key Util (Upgrade)' if they need to upgrade their hardware lock. The dependent files window displays a list of executables and dlls associated with GrafNav. The date and time of the files are shown as well as a quick description of the file. Other programs (such as the convert utility, download service data, and GrafNet) have this feature as well.

By clicking 'Download latest manufacturer files' the user will automatically connect to Waypoint's download FTP site (internet connection required) and download the following manufact files:

manufact.adf – List of antenna profiles. See Section 10.3.2 for more details.

manufact.dn1 – List of base stations available for the download utility. This is usually updated monthly. This file can also be updated within the download utility, see Chapter 6 Section 9 for more details.

manufact.dtm – A list of datums, ellipsoids, and transformations between datums. See Chapter 10 Section 5 for details.

manufact.fvt – A list of favorites and the groups they are contained in. These only contain coordintes for stations available with the download utility. See Section Chapter 2 Section 8 for details.

manufact.grd – A list that contains available grids such as UTM, US State Plane, Gauss Kruger etc.   See Section 2.5.1 for more details.

manufact.svi – A file that associates a PRN number with a satellite type (Block II, Block IIA etc.) for purposes of determining the center of mass of the satellite. It assists in single point processing. This file should not be modified.

manufact.imu – Inertial Explorer Only. Contains a list of IMU error models tested and built into Inertial Explorer. See Section 5.4.5 for details on error modeling.

manufact.cim – Inertial Explorer Only. Contains a list of IMU profiles for the IMU convert utility. See Section 5.7.4 for details.

Most of these manufact files have an associated user file (e.g. user.fvt) where the user enters their own information to be saved. These files will not be modified when a user downloads the latest manufacturer files. It is important, for this reason, that users do not directly modify the manufact files as they will be overwritten if they choose to download the latest manufacturer files.

Chapter 3   Using GrafNet

Section 1   What is GrafNet?

GrafNet is a program developed by Waypoint Consulting Inc. that allows for quick processing of multiple static baselines. This is accomplished in a batch processing methodology. The user has only to load the observation (.gpb) files, define the coordinates of a reference (control) point, and start processing. GrafNet only processes static data and users wishing to perform kinematic processing should use GrafNav.

3.1.1   Common Definitions

Observation: A raw measurement file collected from a receiver set up over a stationary point. GrafNet only accepts .gpb files and other formats must be converted first. The acceptable formats are Allen Osborne Associates (Turbo Binary), Ashtech, Leica, NovAtel, Trimble, RINEX, CMC, and Motorola. This is accomplished using the Convert option from the File Menu. GrafNet also requires at least single frequency carrier phase data, but it will accept dual frequency if available. Users wishing to perform code-only processing should use GrafNav.

Station: A point where the GPS receiver was setup over and there might be multiple observation files for a single station. However, one set of position values will be produced for each station as a final product of GrafNet. There are several types of stations:

Ground Control Point (GCP): A reference station with known latitude, longitude and height coordinates. The user may also assign horizontal and vertical standard deviation for these values. There must always be at least one control point per project.

Check Point: A Station with known coordinates, but these coordinates are only used as a check against GrafNet's computed coordinates.

Tie Point: Such a point may also be called a loop tie closure, and it is formed when two or more sessions "point" to it. Thus, there is a redundant determination at this point.

Traverse Station: This is a point with no tie or control information. It might have two stations connected to it, but one is pointing to and one is pointing from.

Session: Concurrent period of time between two observation files at two different stations. One of the two stations will be remote and one the master. The arrow on the screen will be pointing from the master to the remote. The direction is determined by GrafNav in order to form loop closures as well as to minimize the number of legs from a control point. Each session will be processed individually and combined in either a network adjustment or traverse solution. A session can have different statuses and

colours depending on whether the tests passed or failed (see Section 3.7.1 Mapping Window).

Baseline: Connection between two stations with one or more sessions. Normally, a session and a baseline can be considered the same. However, in some cases there may be more than one session per baseline. This is called a duplicate session baseline, and it is plotted yellow on the screen.

Control Point: see station, ground control point.

3.1.2 What types of networks can be loaded into GrafNet?

GrafNet can be used to batch process any combination of static sessions. However there are two common types of networks employed.

Closed Loop Network
This style of network is shown in Figure 3.1, and surveyors often use it because of increased reliability. Due to the closing of the loops, any baseline determination errors will show up as tie point error. Such closure values can be seen from the View Traverse Solutions option in the Process Menu. If just two GPS receivers are employed, then a method called leap frogging can be used to collect the data. In this procedure, starting from a known point, the lead receiver is placed on the first point to be surveyed. After the first session is complete, the trailing receiver is moved ahead of the lead receiver so that it now becomes the lead. The next baseline is observed and this procedure is repeated until small (4-6) loops are closed.

Note: Antenna height measuring errors will often cancel with this method and should therefore be double-checked. Methods involving more than two receivers become quite complex, and are past the scope of this chapter.

Single Base Station or Open Loop Network
The previous method, though reliable, can be tedious as it involves moving receivers around. Regardless, other applications such as GIS do not need this high degree of reliability and productivity is more important. For these situations, open loop networks might be used. Figure 3.2 (base) shows an example of such a network. With this method, one receiver is left stationary over a reference (control) point. One of more remote GPS receivers are moved from point to point being surveyed.
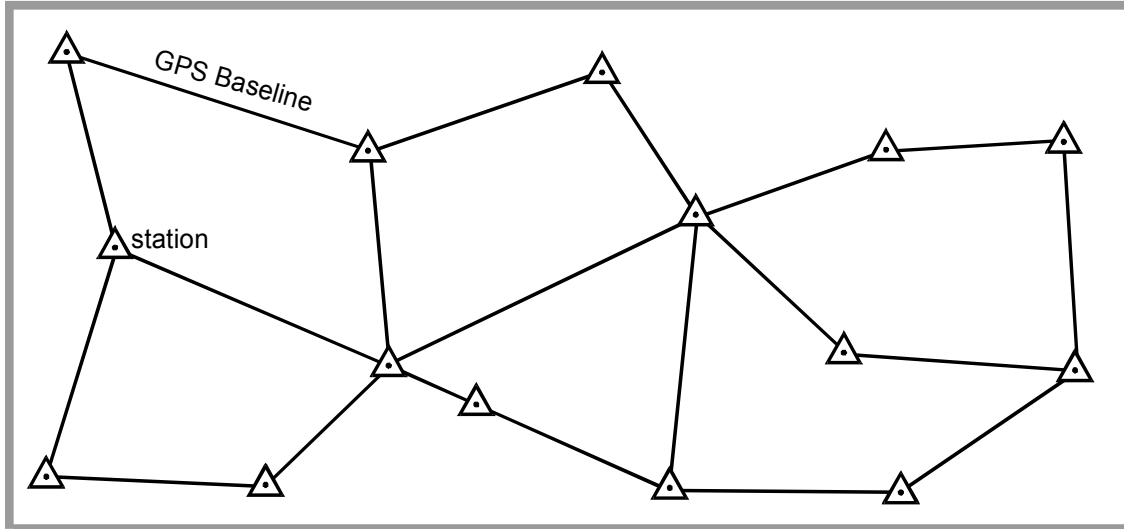
Figure 3.1 Close Loop Network
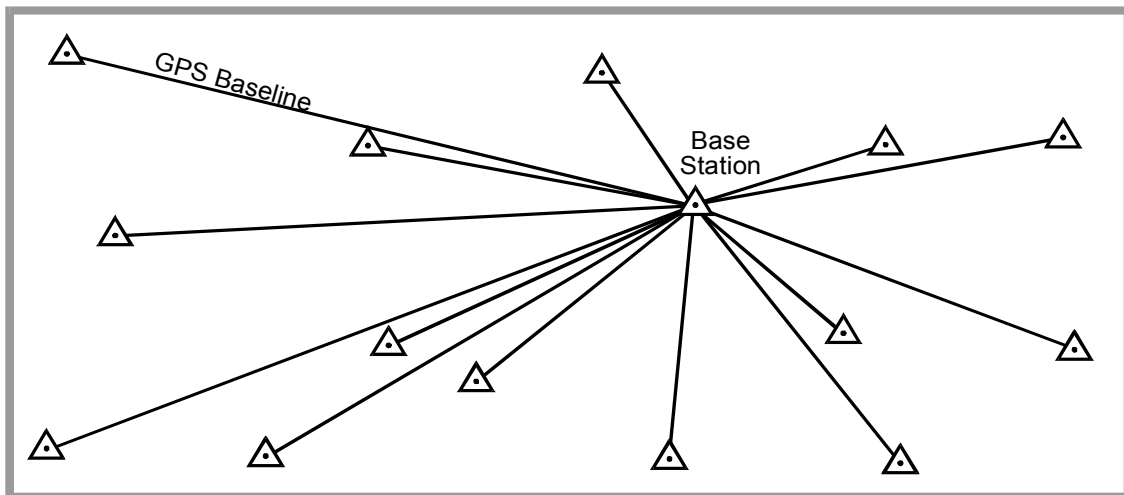
Figure 3.2 Open loop Network

3.1.3 How does GrafNet work?

GrafNet automatically determines concurrent sessions by examining the start and end times of the observation files. Using these sessions, stations and their connections will be formed. GrafNet will try and form sessions, using an extended time scale, which will resolve any ambiguities with different weeks. However, this requires that a valid ephemeris file (.epp) be present for each observation file (.gpb) with the same file prefix for both .epp and .gpb files. When such ephemeris files are present, the week numbering ambiguities will be resolved. For users with more than two receivers simultaneously collecting data, unwanted session connections can be ignored from within the Session Menu. Clicking with the right mouse button on the desired GPS baseline accesses the Session menu. The vector for each session is resolved independently. However, there are five modes of static processing:

Fixed Solution – This process uses single or dual frequency data, but assumes integer ambiguities. Therefore, this mode delivers the best accuracies and is also the default static processing mode. As a general rule, single frequency fixed solutions are best for 0-20 km baselines, while dual frequency will work up to 60 km. However, longer baselines will require longer observation times.

Float Solution – This method does not solve for integer ambiguities, and therefore, has no baseline length restrictions. Regardless, long single frequency baselines will have much poorer accuracies than their dual frequency iono-free counterparts. Normally, the float solution is only used when either the quick or fixed static solutions cannot be made to pass or for long single frequency baselines (20+km).

Iono-free – This is a float solution with the ionospheric effect largely removed from the carrier phase. This option requires dual frequency data at both stations. Iono-free should normally only be used on 50+km baseline lengths since the combined L1/L2 carrier phase noise is higher than L1 only, and will result in decreased accuracies if used on short baselines.

Automatic – chooses between the four processing modes by examining baseline length and the type of measurements available (single or dual frequency).

After processing, baselines will either show up green, if they passed, or red, if they failed. If an error occurred and only an approximate 1-5 metre solution was extracted, the baseline will show up as purple. Also, if the baseline shows up as blue, a serious error has occurred. Clicking the Session Info/Results button from within the Session Menu will display any return error messages. What to do if a baseline fails will be discussed later in this chapter (see Section 8 of this chapter).

After processing each session, GrafNet will transfer coordinates from the control points to successive stations in order to compute absolute coordinates. It is important that at least purple, red, or green sessions are computed for baselines on networks covering very large areas, otherwise distortions may arise.

3.1.4   How are coordinates computed for the stations?

Once the processing is complete, there are two methods to produce coordinate at the stations. First, the traverse solution is automatically computed and will start from known stations and transfer positions to neighboring stations one baseline at a time. A tie or closure will be computed for stations that already have coordinates transferred. Another way to produce station coordinates is by using a network adjustment. This takes all of the baselines into account into a single weighted least-squares adjustment. It will spread the errors out over the entire network and takes advantage of redundant baselines using covariance weighting to produce more accurate station coordinates. The network adjustment will flag erroneous measurements in that the residuals (calculated baseline vector minus observed value) will be unacceptably high to the user. This is most obviously displayed by the PPM (parts per million) value.

Section 2   Getting Started

3.2.1   How to start using GrafNet

Using the following procedure, a static network can be quickly processed with GrafNet. Further details of the individual menu items will be discussed in later sections.

1.   Give the Project a Name

- Select "New Project" from the File Menu or click the [ ] button.
- Go to the directory where the project files are to be located. Using a new directory can simplify matters as GrafNet creates a number of files during processing.
- Give the project a meaningful name.
- Click "Save".

2.   Convert receiver dependent files to .gpb

- If any of Waypoint's logging utilities were used (e.g. LOGGPS, LPCS) then this step can be skipped.
- From the File Menu, select *Convert | Raw GPS to GPB* (instructions for Convert are available in Chapter 7)
- Select the desired GPS receiver and convert the data file.

3.   Add observation files

- Select "Add/Remove Observations" from the File Menu or click on the [ ] icon.
- Select the directory containing the .gpb and .epp files. Note that you only need to select the .gpb files. The .epp files are assumed to have identical prefix names.
- Files can be added one at a time by clicking "Add" or all files in the directory can be added using "Add All". A dialogue box will appear requesting verification of the station ID and antenna height. With some receivers this information will be filled in automatically. Otherwise, GrafNet will extract the first four characters of the file and use the antenna height of 1.50m. The user should always ensure that the ID and antenna heights are correct.

Important! If a station is observed more than once, the station ID should be the same for each observation. Otherwise, two separate stations will be formed.

- Repeat these steps for each directory containing .gpb and .epp files that are to be added.
- Click on the OK button.
- Save Project from the File Menu.

4.   **Add at least one ground control point**

- Select "Add/Remove Control Point "from the File Menu or click the ![icon] button.
- Press the "Add" button.
- Enter the ID corresponding to the control point to be added. This ID can be selected from the list.
- Enter the latitude, longitude, and ellipsoidal height for that station. Important! These coordinates should be in the same datum as the selected one in the Datum Option under the Option Menu. The default datum is WGS84/NAD83.
- Press "OK".

5.   **Select "Static Processing Mode" and "Datum"**

- If fixed solutions and WGS84/NAD83 are desired, this step can be skipped. Otherwise:
- Select the desired static process mode. These modes are described in Section 3.5.1 Global Processing Options.
- Select the desired processing datum.

6.   **Process All Sessions**

- Select "Re-Process All Sessions" from the Process Menu or click the ![icon] button.
- Error ellipses should appear on each of the single session baselines after they have been processed. The processing window will also appear.

7.   **Verify that all baselines have passed.**

Passed baselines will be plotted in green, failed baselines in red, purple, or blue (see Section 3.7.1 Mapping Window). Duplicate (yellow) baselines do not show the pass/fail via colouring. Baseline statuses should be verified by clicking the right mouse button.

- Click on each failed baseline with the right mouse button.
- Press the " Info" or "Results" button to find out what the problem is. Section 8 Fixing Bad Baselines of this chapter explains in detail how to "fix" these sessions.
- If the user feels that the solution is correct despite failing GrafNet's statistical tests (appears a colour other than green), the statistics can also be overridden by pressing "Status" from within the Session Menu. However, such a change should only be performed for closed loop networks.
  Note: The traverse will transfer coordinates using failed baselines, while the network adjustment will not.

8.   **Run Network Adjustment**

- From the Process Menu, select "Network Adjustment".
- Press "Process"

- Select "OK" to view error ellipses or View Solution to view the ASCII output of the adjustment.
- You should see error ellipses on each of the stations.

9.   **Export Station Coordinates**

- From the Output Menu, select "Write Coordinates".
- Enter an output file name.
- Select the source for the coordinates (usually network).
- Select a projection, format, and units (see Section 2.6.3 Write Coordinates)
- Press "OK".

10.   **Clean up processing files (optional)**

- The user may wish to remove some of the intermediate processing files by selecting *File | Remove Processing Files | All but Static Summaries*.

3.2.2   Tips on Maximizing Accuracies

Chapter 10 Section 1 contains a valuable list of tips that can be helpful improving accuracies.

Section 3   File Menu

3.3.1   New, Open, Save, Save As Project

File | New Project/ Open Project/ Save Project/ Save As
These menu items allow the user to control .gnt projects. Their usage is very similar to other Windows applications. The Save and Save As operations saves the .gnt (project), .rep (session report), and .trv (traverse solution).

3.3.2   Print

File | Print
The user can print the current window or the map window. The orientation of the output can also be controlled and the colour scheme as well. Click 'Set Margins' to change the top, bottom, left, and right margins. By default they are 1 inch.

3.3.3   Add/Remove Observations

File | Add/remove Observations
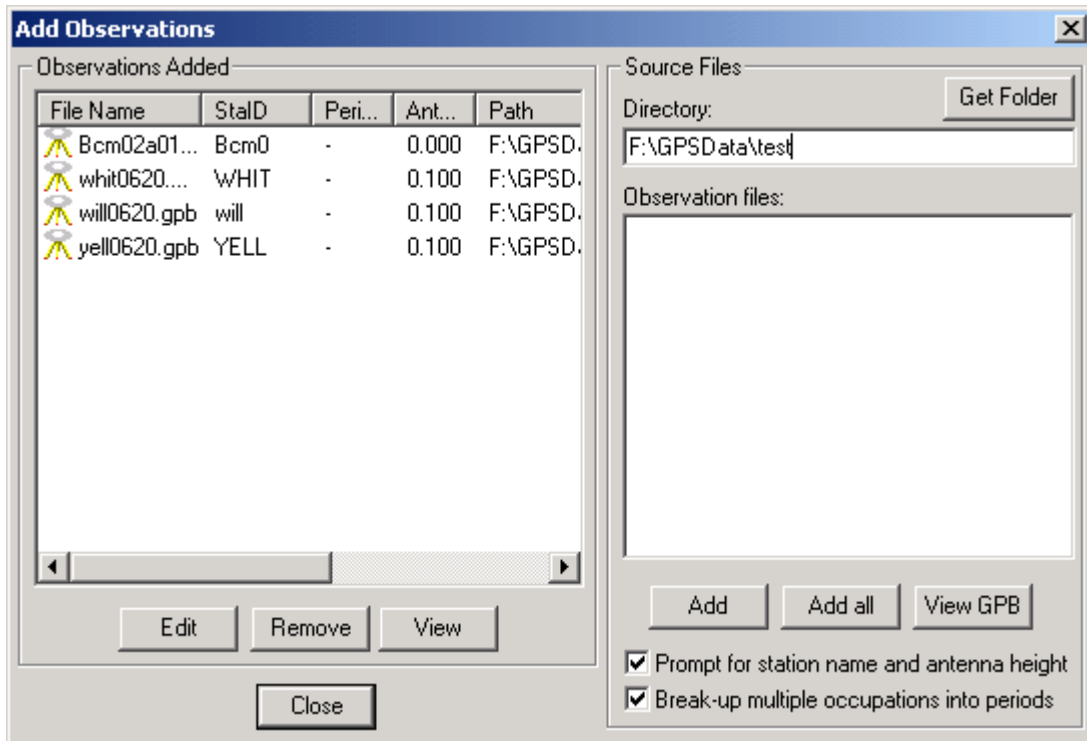
Figure 3.3 Observations Dialogue Box

This menu item is necessary to add observation files to GrafNet. Observation files must first be converted to .gpb/.epp files using the Convert utility from the File Menu. These files may have also been created directly by using Waypoint's data logging software.

If available, GrafNet will automatically extract the station name and antenna height values from the .sta file, which may have been created during the conversion process. For such a case, and if the user is confident that these values are correct, the check box titled "Prompt for Station Name and Antenna Height" may be unselected. This will cause observations to be added without user input. However, the user should still double check station names and antenna heights in the Observations Added List. The format in the list is File Name, StaName, and Ant Height. If there are any errors, they can be corrected by pressing the "Edit" button.

GrafNet allows users to select an Antenna Profile. When using profiles other than 'Generic', users should be cautions to match up the antenna height measurement to the expected measuring mark on the antenna (see figure below--Origin). This is because additional offsets to the L1 and L2 phase centres are added. In addition, if a slant measurement is selected, then a correction is applied based upon the size of the antenna ground plane. Again, be sure that the origin (i.e. measuring mark) is defined correctly.
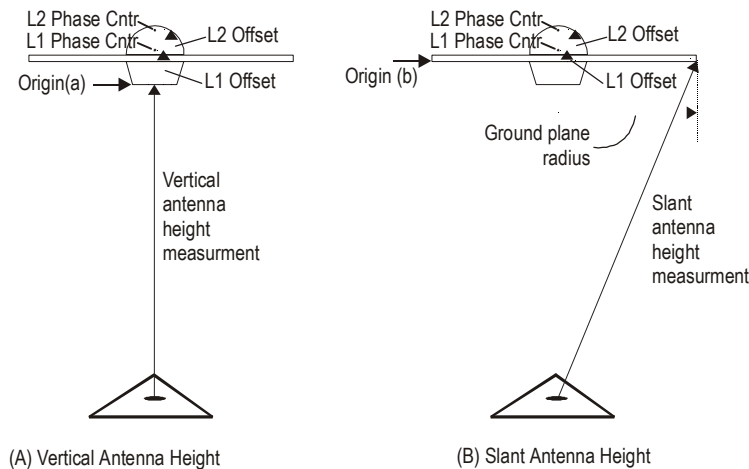
Figure 3.4 Antenna Profile Definitions

Adding observations will normally break-up observation files into multiple periods if a gap of 3 minutes more is detected. Whether or not this is done is controlled from the checkbox 'Break-up multiple occupations into periods'. Some RINEX files have gaps but are observed over the same point for the entire observation period. For such files, this checkbox should be disabled. For cases where the time gap is very short because the station to station movement is very fast, the minimum time gap for breaking up periods can be controlled from the Global Options 'Solution and Session' (see 'Minimum time span for breaking up observations into periods').

IMPORTANT: Station ID's must match those of all observations for a given same station and those of matching ground control points. Sessions associated with an observation should be reprocessed if the antenna height has been changed. This is performed by clicking on the station for that observation with the right mouse button. Select "Remove Processing Files", the select "Process All" from the Process Menu.

3.3.4 Add/Remove Control Points

File | Add/remove Control Points
At least one 3D ground control point must be added before processing can begin, and sessions will not be processed unless they are directly or indirectly connected to a 3D control point. Three types of control points can be entered, 3D, horizontal and vertical control.

After selecting "Add/Remove Control Points" from the File Menu, press "Add" to enter a new control point. The station ID should match that of the corresponding station.

IMPORTANT: The latitude and longitude coordinates should be in the same datum as the selected datum. The height can be entered as meters above the ellipsoid or above mean sea level. If height above mean sea level is used you will have to select a geoid file. If the geoid height corrections are desired, they can be implemented using "Write Coordinates" from the Output Menu. If a mean sea level or orthometric height is entered

here, then only an approximate geoid correction is applied. As stations become more distant from the control point, orthometric height errors will increase. If more than one control point is present, and orthometric (mean sea level) heights are entered, the height ties may be poorer as well.

Standard deviations can be entered at this stage. The default values are 5mm for horizontal and 5mm for vertical. The user may wish to change them to more realistic values. The standard deviations are only taken into account in the network adjustment. However, they can be very useful for combining high and low accuracy control points.

3.3.5 Add/Remove Check Points

File | Add/remove Check Points
Check points are useful for gauging how well the network fits the existing control fabric. They are added in the same manner as control points, except that standard deviations cannot be defined. As with control points, it is important that the processing datum matches the coordinates' datum.

3.3.6 Add/Remove Ephemeris

File | Add/remove Ephemerides
This option can be used to add additional precise or broadcast ephemeris files (.sp3 and .epp files). To load an ephemeris file, press the "Add" button. Move to the directory that contains the proper file. Select the file. Press "Open".

It is important that a precise ephemeris file covers the entire time span for each session. Although more than one .sp3 file can be loaded, only one can be used for processing each session and GrafNav will pick the proper file. However, if a session spans more than one .sp3 file, the .sp3 files must be concatenated together. Using MS-DOS copy command will work i.e. copy file.sp3 +file2.sp3 all.sp3. Be sure that the files are sequential and in chronological order. If a session is not fully covered by one .sp3 file, a message will appear providing the percentage covered by the precise ephemeris. Unless the percentage is in the high 90's, this baseline should be processed with start/end times. This can be accomplished by utilizing the GrafNav option from within the Session Menu (see Section 3.7.5 Session Menu).

3.3.7 View Raw GPS Data

File | View | Raw GPS Data
See Section 2.2.15 Viewing Raw Binary GPS Data.

3.3.8 Convert

File | Convert
See GrafNav Section 2.2.21 Converting GPS Data and Chapter 7 Convert.

3.3.9 Remove Processing Files

File | Remover Processing Files | All Files / All but Static Summaries
This menu item can be used to "clean up" a directory by removing the session dependent files. Solutions for static sessions are stored in the .fss for forward and .rss for reverse processed files. The .fwd/.rev and .fml/.rml are unnecessary and can be removed using the "All But Static Summaries" option. Selecting "All Files" will remove all files including the solution files. The user must reprocess for further analysis.

3.3.10 GPB Utilities

File | GPB Utilities
This menu item gives you access to a couple of utilities, provided with the software package, directly from GrafNet. The utilities (ViewGPB, GPB to RINEX Converter, and Concatenate, Slice, and Resample) and their locations are described in Chapter 6 Utilities.

Section 4 Process Menu

Generally, this menu is used to process all sessions and view solutions.

3.4.1 Process Unsuccessful Sessions

Process | Process Unsuccessful Sessions
Selecting this option will process sessions that do not have a good status (i.e. not green). Processing will start nearest to the control points and move outward. For processing problem sessions, it may be better to process from the Session Menu using GrafNav.

3.4.2 Re-Process All Sessions

Process | Re-Process All Sessions
This option will re-process all solutions regardless of status. It is a good idea to re-process all sessions after changing the global options

3.4.3 Rescan Solution Files

Process | Rescan Solution Files
This option merely rescans the .fss (forward static solution) or .rss (reverse static solution) files. When deciding whether to use the forward or reverse, it uses the one with the newest date/time. Under normal circumstances, solution scanning is automatic, but in a few instances, such as when using GrafNav in conjunction with GrafNet, the user may want to rescan manually.

3.4.4 Ignore Trivial Sessions

Process | Ignore Trivial Sessions

GrafNet defines trivial baselines as those that are unnecessary resulting from multiple receivers simultaneously running. The problem is that the baseline solutions computed by GrafNet are not independent and are correlated. Therefore, trivial baseline removal reduces these dependencies, while still maintaining a closed loop. Removing trivial baselines will also create a network where the standard deviations reflect the actual errors more accurately.

Consider the network in the figure below. The six points are surveyed with four receivers, during two one-hour sessions. During the first session, the points A, B, C, and D are observed. During the second session, the points C, D, E, and F are observed.
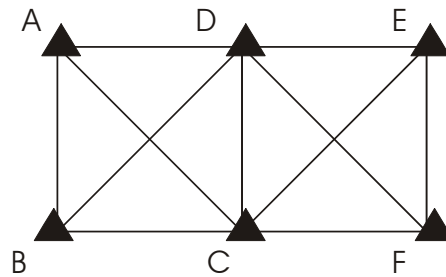
Figure 3.5 Trivial Baselines

This network can be divided in two sub-networks, namely the sub-networks formed by the first and second time periods respectively. Before the trivial baseline removal, every baseline in these two sub-networks is dependent on the other baselines. Such dependencies can cause the loop ties to be unnaturally low.

With four receivers or more collecting data at the same time, a sub-network is very over-determined. Using three GPS receivers, the network is still over-determined, but all baselines need to be included to form a closed loop. GrafNet attempts to remove these dependent or trivial baselines by creating a single loop that will connect all of the points in the sub-network. Form the example above, we can see that it is easy to remove such baselines. With four receivers, there are two dependent baselines in each sub-network. GrafNet will remove these trivial baselines for each sub-network individually. The diagram below shows two possibilities of what GrafNet might do with the first sub-network.
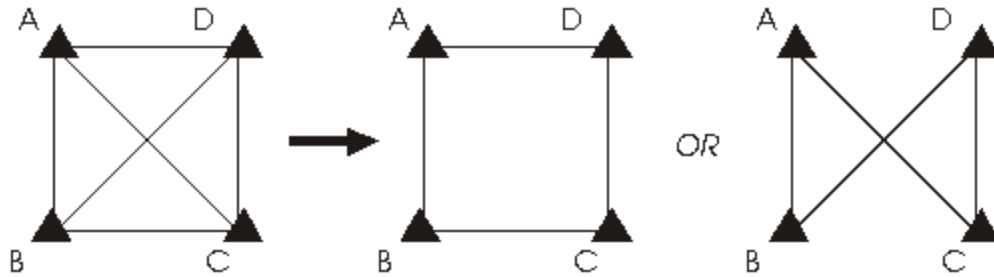
Figure 3.6 Removal of Trivial Baselines

GrafNet removes the trivial baseline by setting their session status to IGNORE. It is possible to un-ignore any session by simply changing its status back to UNPROCESSED from the Session Menu (see Section 3.7.5 Session Menu). GrafNet tries to keep the sessions that are of best quality. The criteria it looks at are:

- The amount of time the baseline was surveyed.
- The frequencies used in the surveying of the session.
- The length of the baseline.
- The number of connecting baselines to the two end-points.
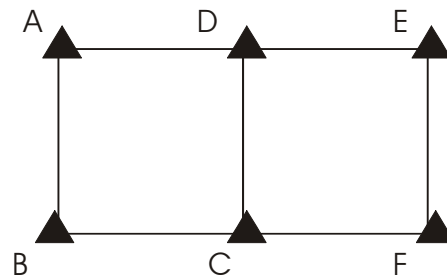
Figure 3.7 Network with Trivial Baselines Removed

As you can see, GrafNet automatically excluded AC, BD, CE, and DF. It then formed a single loop for each of the time periods. DC is a baseline with a duplicate session.

3.4.5 Unignore All Sessions

Process | Unignore All Sessions

Unignore All Sessions changes the status of all ignored sessions from ignored to the status they had before they were ignored.

3.4.6 View Traverse Solution

Process | View Traverse Solution

GrafNet computes a traverse solution automatically after processing each session. This option can be used to view traverse solution files (.trv).

Section 3.9.1 contains a detailed description or the Traverse Solution.

3.4.7 Network Adjustment

Process | Network Adjustment
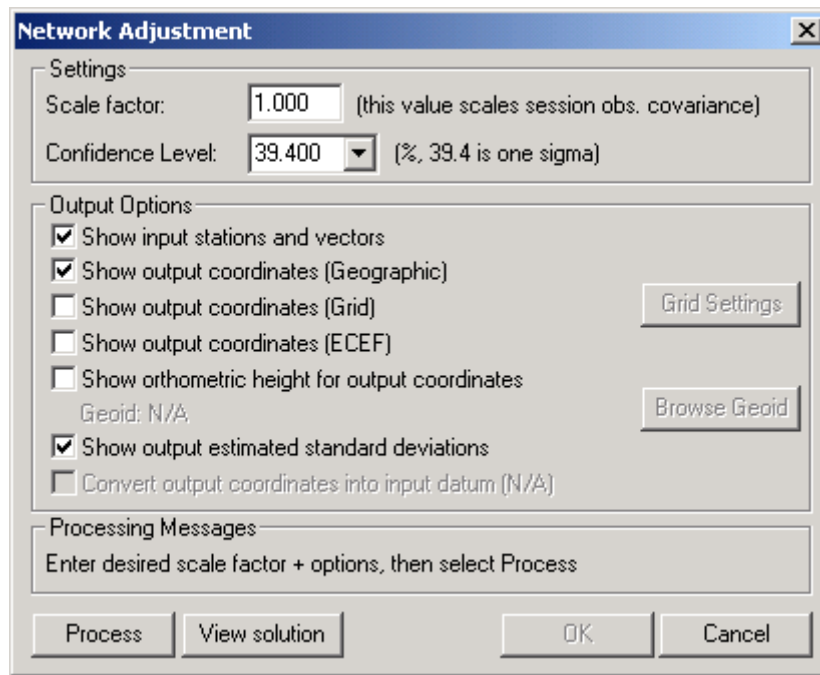
Figure 3.8 Network Adjustment Options

Executing this option allows the user to invoke the network adjustment contained within GrafNet. External network adjustments such as GeoLab also supports GrafNet's output format.

Before running the network adjustment, all baselines must have already been processed and only good (green) baselines will be used.

The Output Options let you control what is output in the network solution. The input stations and vectors are all the control and check points and their vectors. You can output the coordinates in three different forms. These forms include Geographic, Grid and ECEF. The option for orthometric height also exists. To use orthometric height you have to provide the geoid file. This geoid file can be selected by using Browse Geoid. Other output options include outputting the estimated standard deviations and converting the output coordinates into the input datum. The input datum is selected in *Tools | Datum Manager*.

To process the network adjustment, press the "Process" button. This step must be performed each time a project is re-loaded. To view the ASCII solution output, press "View Solution", otherwise press "OK".

Error ellipses should appear on the stations. The ellipses will be scaled by the Scale Factor. The level of confidence of the error ellipse can also be adjusted.

Section 3.9.2 contains a detailed description of the Network Adjustment including a description of scale factor and confidence level.

3.4.8   View Processing Report

Process | View Processing Report
This option displays the .rep file. This file displays information about the stations, sessions, baselines, and observations and gives a summary for each session processed.

3.4.9   View All Sessions

Process | View All Sessions
The Session Menu, which is described in Section 3.7.5 , can be accessed for all baselines by selecting this menu item. It can also be invoked for individual sessions by clicking on a baseline with the right mouse button. This is a useful way of ensuring all sessions have a good status.

3.4.10   View All Observations

Process | View All Observations
This option gives the information about each observation. The user can click on the "View" box, which will bring up a message box showing: file name, station name, antenna height, time range (in seconds and status information). Also, pressing the "View .gpb" button will access the .gpb file viewer.

Section 5   Options Menu

This section describes the items under the Options Menu.

3.5.1   Global Processing Options

Options | Processing (Global)
This dialogue box gives the user access to the global processing options. Global Options for all baselines can be accessed from the Options Menu. Otherwise, this menu can be accessed for individual sessions using the session menu.
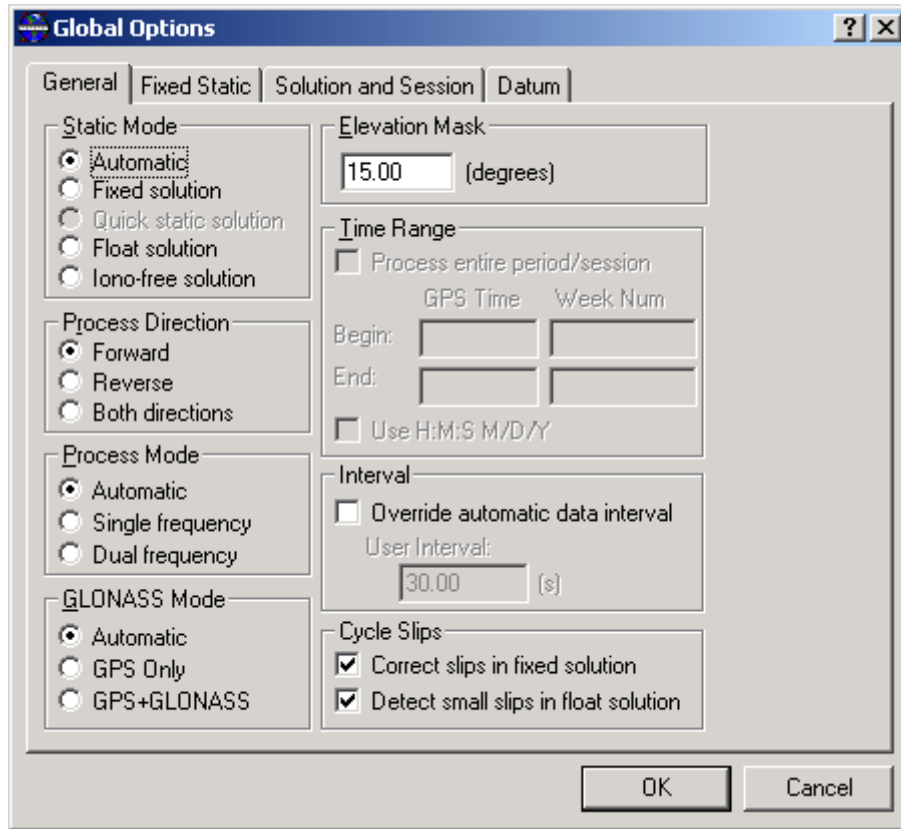
Figure 3.9 Processing Options

Static Process Mode
A simple table is given below to summarize usage, observation time lengths, and expected accuracies.

Mode	Frequency	Minimum Observation time (min)	Maximum Distance (km)	Approximate Accuracy
Fixed Solution	SF	15	15	5mm+1ppm
	DF	5	50	5mm+1ppm
Float	SF	--2	--3	10mm+2ppm
Iono-free	DF	--2	--3	10mm+0.5ppm
Automatic	Chooses between the fixed solution and the float (for SF) and iono-free float (for DF) depending on the baseline distance. The distance tolerance can be defined in the Solution and Session options.			

Notes:
1.   Observation times should increase for longer baselines. For single frequency, a good rule of thumb is 10 min + 1 min/km. For dual frequency, these times can be halved. Observation times should also be increased during poor satellite geometries (i.e. high PDOP).

2.   No minimum time is given, but accuracy improves with observed time. A few minutes of observation will only achieve sub-metre accuracies under very good operating conditions.

3.   For dual frequency receivers, use fixed quick, or float solutions for baselines less than 50 km, and Iono-free for more than 50 km.

4.   Accuracies are given for average occupation time. Accuracies will increase for longer times, and degrade with poor geometry or bad measurement quality.

5.   Use precise ephemeris for baselines longer then 150 km.

Elevation Mask – Satellites below this mask angle will be ignored. The default value for GrafNet is 15°. Setting this to a lower value will allow more satellites to be used, perhaps improving a solution with poor geometry.

Process Direction – This option can be set to forward, reverse, or both. GrafNet will use the solution file created last (i.e. file with latest date). Under normal circumstances the forward and reverse solution should provide roughly the same solution. However, in some circumstances, a reverse solution will pass when a forward has failed, or, solutions may differ because of different base satellite selections. If both directions are selected, the combination of the two solutions will be used. (See Section 2.4.3 Combining Forward and Reverse Solutions for more details).

Process Mode (Frequency type)
Single Frequency – forces single frequency (L1 only) processing.
Dual Frequency – forces dual frequency processing. This can be used if the auto detection is failing. However L1/L2 data must be present in all observation files.
Auto-frequency detect – auto-detect single or dual frequency processing for each baseline. This is the default process mode, and it should be used under most circumstances.

Interval –This option lets you choose the processing interval. The default interval is the interval the data was logged. If the logged data rate is high (e.g. 1 Hz), it is suggested that this interval be overrided with 15 seconds.

Time Range- This option is only available for individual baselines. The processing options for an individual baseline are accessed through the session menu.

3.5.2 Fixed Static Options
Options | Processing (Global) | Fixed Static Tab
See Section 2.3.7 Fixed Static Options.

3.5.3 Solution and Session Options
Options | Processing (Global) | Solution and Session Tab
Forward/reverse Process Direction Handling – This dialogue box allows the user to change the way forward and reverse solutions are chosen for use in the network. By default, GrafNet will load the latest solution (most recently processed). If however you wish to use a combined solution, you must check the combined solutions radio button. If

in the General Options dialogue box, you indicated that you want both directions to be processed, GrafNet will prompt you to change to the combined solution option.

Session Forming Options – Minimum observation time for forming a session controls the minimum number of seconds necessary to declare concurrent observation files as a session. The default value is 180 seconds or 3 minutes. For dual frequency data, it may be desired that this time is reduced, and for single frequency, this value may have to be lengthened to avoid short/low accuracy baselines. The ignore feature from the Session Menu "Change Status" can also be used to manually ignore short baselines. The minimum time span for breaking up observations into periods controls the time required between sessions for them to be recognized as two different sessions. The default is 3 minutes.

Time span for breaking up periods – This combined with the checkbox labeled 'Break-up multiple occupations into periods' in the Add Observations dialogue box controls how long of a gap in the data in needed to signify a new period. The default is 3 minutes (i.e. 180 seconds).

Distance tolerance for using fixed over float – This tolerance is used in combination with the Automatic Static Process Mode. If the baseline distance is longer then the tolerance, then a float solution will be used for single frequency, while an iono-free solution will be used in dual frequency mode. Otherwise, the fixed static solution is used.

3.5.4   Datum Options

Options | Processing (Global) | Datum Tab
Refer to Section 10.5.2 Datums for a discussion on datums.

3.5.5   User Defined Options

Options | User Defined
This command works identically to the one found in GrafNav. Please refer to Section 2.5.5 and Appendix A for a list of commands.

3.5.6   Grid Options

Options | Grid
See Section 2.5.1 Grid Options.

3.5.7   Display Options

Options | Display
Zoom Increment – changes amount of zooming between each (+) and (-). For the first three zoom levels, the following option can be set. Zero refers to the smallest scale with all objects plotted on one screen. Further zooming past two will use the values from two. Pressing the "Set Defaults" button will return values to their original state.

Text point size – size of station name text (points).
Symbol size – size of station triangles on the screen.

Ellipse scale – This is an important option as it changes the size of the error ellipses. Projects covering large areas may have unpleasantly large ellipses. This being the case, decreasing the values for all three zoom scales (0, 1, and 2) will make the ellipses smaller.

Map status information – This setting defines what is displayed at the bottom status bar of the mapping window. The session ID may not be implemented on early versions, but it gives the session name when the left button is clicked.

Error ellipse display – This controls if relative or absolute error ellipses are displayed. First, error ellipses can be displayed for session solutions. Second, ellipses can be displayed for the stations after a network adjustment is run. The crosses on the ellipse option merely shows the axes of the error ellipses.

Processing updates – this is an important display option because it can increase or decrease processing speeds. It defines how often the solution is updated to the Processing Window. Values of at least 250ms are suggested, and the default value is 500ms. Entering zero will force every epoch to be written to the screen.
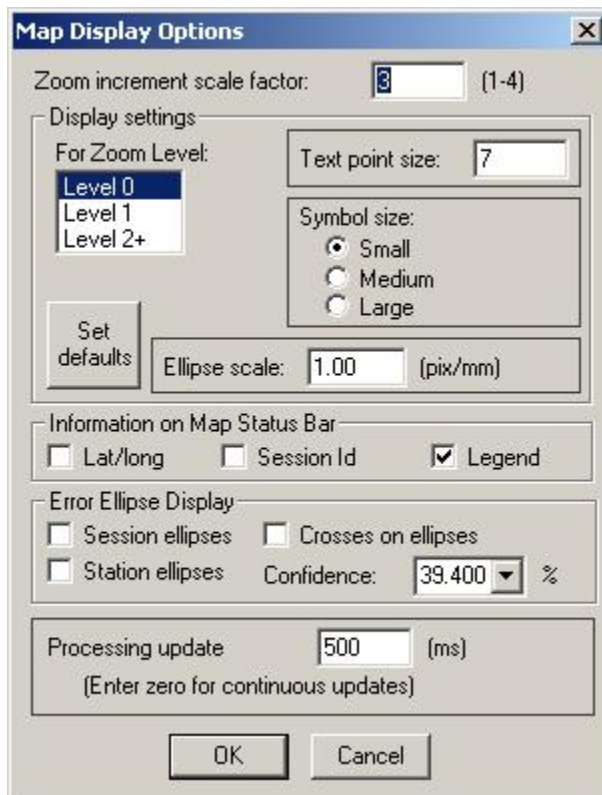
Figure 3.10 Display Options

Section 6   Output Menu

See GrafNav Sections 2.6.3 Write Coordinates, 2.6.4 View Coordinates and Section 7
Export Coordinates Wizard of Chapter 2 Section 7 .

3.6.1   Export to DXF

Options | Export DXF

The following figure shows the main dialogue box for Export to DXF. Most of the
options for this dialogue box are described in Section 2.6.5 Export to DXF. Only the
GrafNet specific options are described here. These options include station error ellipses,
baseline error ellipses and the error ellipse scale factor. Station error ellipses are only
available if a network adjustment has been done. The station error ellipse shows the error
ellipse around each of the stations. To use baseline error ellipses only the baseline needs
to be processed. The ellipse scale factor simply scales the ellipse so it will be visible. In
most cases if you use a small scale factor the error ellipses will not be visible. If you
want error ellipse and do not see any in the DXF file try increasing the ellipse scale
factor.
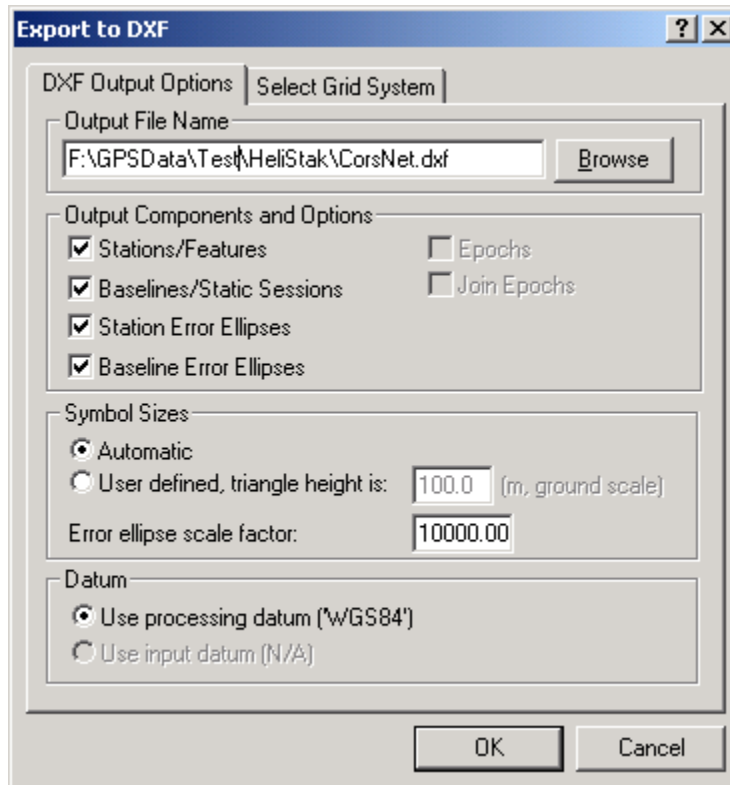
Figure 3.11 Export to DXF

Section 7 Interactive Menus and Screens

This section describes the Mapping Window, Processing Window, Station Menu, and Session Menu.

3.7.1 Mapping Window
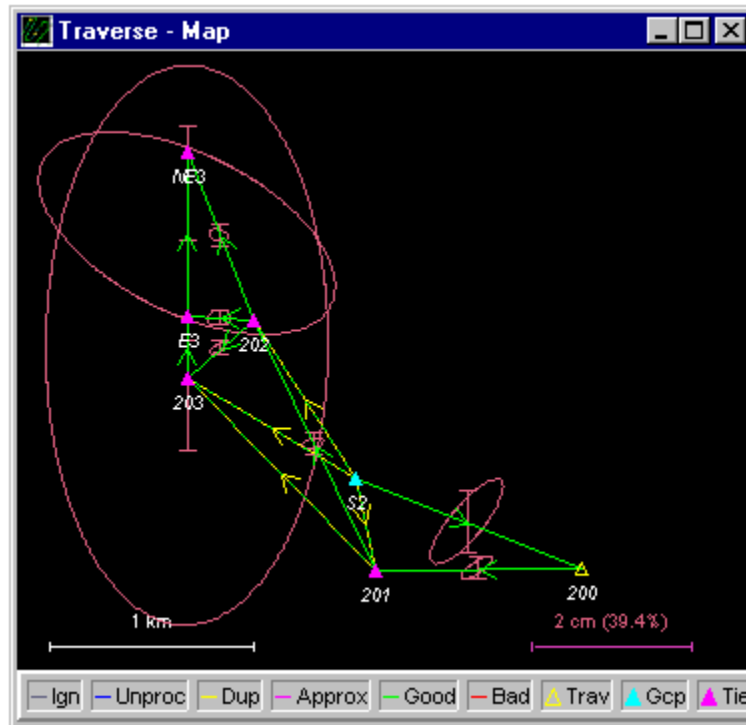
Figure 3.12 GrafNet Mapping Window

This mapping window screen is a graphical representation of the project area. It shows the stations and connecting baselines.

Baselines are plotted using the following colours.

Colour	Description
Blue	This is normally an unprocessed baseline. In some cases when processing quits prematurely, the colour may remain blue. The return error message can be viewed from the Session Menu by pressing the Session Info/Result button
Grey	Session is to be ignored
Yellow	This baseline has more than one session and it is called a duplicate baseline. This line is plotted with two colours: yellow, and the colour of the best solution type among all the sessions for the duplicate baseline.

Purple   An error has occurred during the processing and only an approximate (1-5m) solution was extracted. This solution is only useful for transferring an approximate position from base to remote and this session should either be reprocessed or ignored.

Red   Processing on this baseline has failed one or more tests, and it is considered bad. Press the "Session Info/Results" button under the Session Menu to determine the problem. If the user is confident that the solution is okay, the status can be changed from the Session Menu as well.

Green   This session has passed all tests or the user has set it to green.

Station triangles can be represented with the following colours that signify:

Colour	Description
Cyan (light blue)	Tie point. Two or more sessions are connected as remotes to this station via the traverse solution. The .trv file will show traverse ties.
Dark purple	Check point. This station has known coordinates available, but they will only be used as a check. Comparisons are found in the .trv file as well. The network adjustment output file (.net) will also show checkpoint errors.
Yellow (hollow)	Regular traverse point. No tie information can be computed for traverse solution.

3.7.2 Mouse Usage in Mapping Window

By positioning the cursor on stations and clicking with right mouse button or double clicking with the left mouse button, the Station Menu will be invoked. Performing the same procedure on baselines will bring up the Session Menu. Using the display options to perform the same procedure on the baselines will also bring up the Session Menu. Use the display options to also show the latitude and longitude position on the bottom station bar of the Mapping Window.

3.7.3 Processing Window

See Section 2.9.3 Processing Window.

3.7.4 Station Menu

Positioning the cursor on a station marker and clicking with the right mouse button or double clicking with the left mouse button can access the Station Menu. This menu allows the user access to coordinates computed by traverse or network adjustment solutions. However, it can also be used to view sessions and observations associated with this station. For the purposes of reprocessing only a portion of a project, files associated with a certain station may be deleted as well.

Right-clicking on a station marker and selecting the View Solution (processing datum) will bring up the following message box.
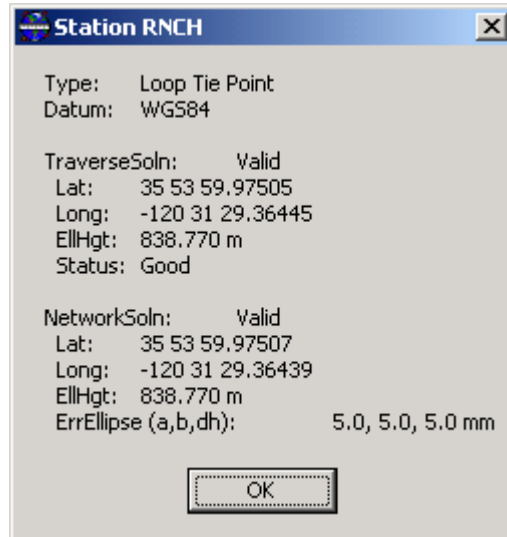
Figure 3.13 Station Solution

This message box shows the latitude, longitude, and height for that station for both the traverse and network adjustment solutions. For the network adjustment, error ellipse parameters are also given.

3.7.5 Session Menu

This dialogue box is often used as it gives access to session specific features. Such features include display of baseline processing results, editing of session specific options, changing of session result status (e.g. from bad to good), reprocessing directly or by invoking GrafNav, viewing of processing files and displaying of observation file info. Clicking with the right mouse button on a specific baseline easily accesses the Session Menu. All sessions within a range of a few pixels will be loaded and will show up in the "Select Session" window. Select the session that is of interest. Session names are defined as follows: FromID to ToID (#). From ID is the master station name, while ToID is the name of the remote. The # refers to the duplicate session index and will be 1 for baselines with only one session.
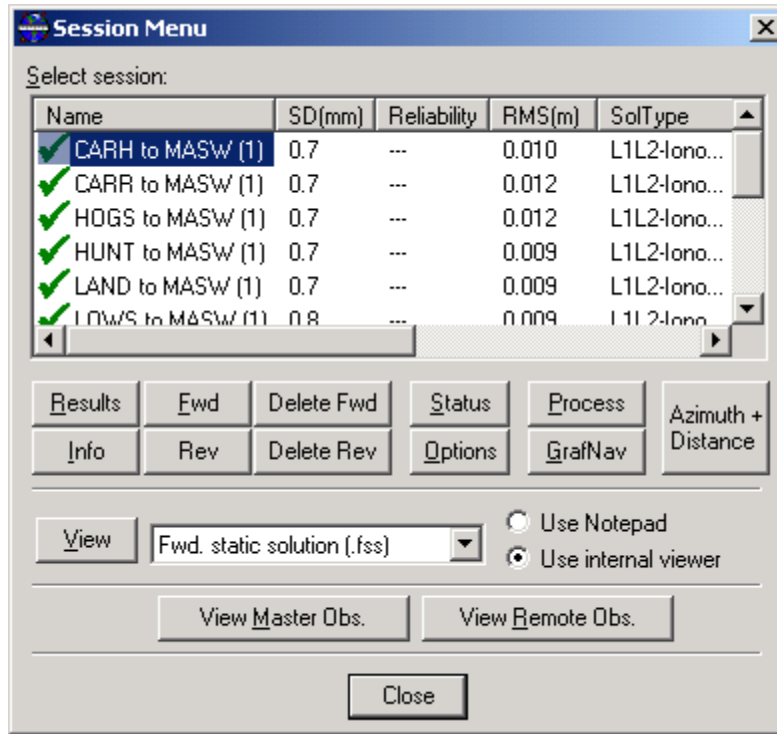
Figure 3.14 Station Session Menu

Results/Fwd/Rev Buttons – Displays information about the solution used by GrafNet, the forward solution, and the reverse solution respectively. The following information is displayed:

Parameter	Meaning
Result/Status	Good/Bad/Ignore/Approximate/Unprocessed
Soln Type	Defines whether a fixed, quick, or float solution is found in the static solution file. An Iono-free solution will show up as a float solution.
Direction	Forward, Reverse, or Combined solution used.
ECEF Vector	Earth centre earth fixed vector between base and remote.
Rel Err Ellipse	Relative semi-major (a), semi-minor (b), and height error values for baseline solutions. All values in millimeters.
Reliability	Result of the ratio test computed by dividing the RMS of the second best integer intersection by the best RMS.
Err Code	Return status from the GPS Engine used by GrafNet and GrafNav. Can be SUCCESS, FATAL ERROR, NON FATAL, ERROR, USER QUIT.
Err String	Message returned by the processing engine. Some of these messages are defined in the appendix.
Solution String	Message generated by GrafNet indicating if static solution tests have passed or failed.

Info button – Displays information about the data used in the session. The following information is displayed:

Parameter	Meaning
Master Obs/Remote Obs	Observation file names for From and To stations.
Start and End	Start and end of concurrent session between observation files.
Length	Session time length in seconds.
Result/Status	Good/Bad/Ignore/Approximate/Unprocessed
Err Code	Return status from the GPS Engine used by GrafNet and GrafNav. Can be SUCCESS, FATAL ERROR, NON FATAL, ERROR, USER QUIT.
Err String	Message returned by the processing engine. Some of these messages are defined in the appendix.
SolutionString	Return solution type. Can be Fixed or Float.

Options button – see Section 3.5.1 Global Processing Options and 2.3.2 General Options.

Status button – This is an important option with three uses:
Allows the user to ignore redundant or troublesome baselines.
Change session status to Good in the event that a session has failed tests, but the user is confident that the solution is in fact correct. Such a change should only be performed for closed loop networks.
Change the status back to Unprocessed so that "Process All" will reprocess it. Removing the solution files can also perform this.

Process button – Reprocess this session using new options. Due to the limited number of items within general options, GrafNav may have to be used for more troublesome baselines.

GrafNav button – All of GrafNav's features are made available to GrafNet by invoking GrafNav. This includes graphical plotting and extensive control over all options. For example, when controlling such parameters as the start /end times, GrafNav must be used. For details on using GrafNav, consult Chapter 2 .

Azimuth + Distance – Displays the Azimuth (from→to/to→from) and Distance (Ellipsoidal/Surface/Spatial).

Delete Fwd/Rev button – Removes the Forward or Reverse solution of the selected baseline.

View Master/Remote Obs. – View Master or Remote GPB summary and Raw GPS data.

Note: Solutions will be re-loaded into GrafNet when the Session Menu is closed. If the Session Menu is closed before GrafNav is finished processing, the solution files must be rescanned manually, which can be performed from the Process Menu. The forward or reverse solution with the latest date will always be used. Therefore, be careful to reprocess a forward solution if an undesirable result is achieved on the reverse solution. The same is true for vice-versa.

Section 8   Fixing Bad Baselines

See also Chapter 10 Processing Techniques for more hints for fixing baselines.

3.8.1   Fixing Bad GrafNet Baselines

A difficulty that may arise is that some baselines may appear red when running GrafNet. For the case of a duplicated baseline, it will stay yellow. However, when examining the baseline sessions from within the Session Menu, one or more sessions will have BAD indicators. This means that one or more tests have failed in the static solution. If a baseline is flagged as APPROXIMATE. Then it has also failed tests. In fact, the baseline was only able to achieve an approximate (1-5 m) solution. Such a baseline can also be considered BAD.

The purpose of this section is to assist the user in how to re-process this baseline in order to achieve better results. Unfortunately, there are many causes of a failed baseline, and not every solution is given. In some cases, not much can be done. In other cases, the correct solution has been found, but the statistics just fail. This indicates that GrafNet cannot label this baseline as correct for certain. However if there are loops that are closed, and the closure is very good, then the user may wish to change the status from bad to good using Change Status from within the Session Menu.

3.8.2   Using GrafNet to Fix a Baseline

A few changes can be made within GrafNet to improve a baseline. These options can be accessed for an individual session from within the Session Menu. Otherwise, it can be accessed globally for all sessions from within the Global Options in the Options Menu. The Advanced Options have not yet been implemented and GrafNav must be accessed for these. The user defined options found in options can also be used to avoid going into GrafNav. Refer to Section 2.5.5 User Defined Options and Appendix A Summary of Commands for more information on user defined options.

3.8.2.1   Fixed Static Solutions

If fixed solution fails, then you might have to switch to a float solution. However, float solutions are not very good at achieving centimetre accuracies unless you have many hours of data.

3.8.2.2   Forward / Reverse Processing

Another easy change that can be made within GrafNet is to switch from Forward to Reverse. Since the reverse solution may pick a different base satellite than the forward

solution, this solution can be different and may in fact pass. GrafNet will pick the forward or reverse solution with the latest date. Therefore, be sure to reprocess the forward solution if the reverse is unacceptable.

3.8.2.3 Changing the Elevation Mask

GrafNav by default uses a 15° elevation mask. This is because tropospheric and ionospheric errors increase significantly on low satellites. However, lowering the mask to 10° will allow more satellites into the solution, which will strengthen the geometry. The improvement in geometry may offset the increased atmospheric errors.

For long baseline dual frequency processing, the iono-free solution combined with a precise ephemeris can be a tremendous benefit. However, some shorter baselines are better off using a fixed solution. Therefore, it may be advantageous to re-process shorter baselines separately.

3.8.3 Using GrafNav to Fix a Baseline

GrafNet has limited access to processing options. However, GrafNav can be used to change a number of various settings. Therefore, GrafNav is a valuable tool in fixing a failed data set and can be invoked from within the Session Menu.

From within GrafNav, the most common options to change from a static baseline are as follows:

- The start/end times can be modified from within the General Options. Sometimes a data set can have parts that are unusable. A good indicator is the L1 Phase RMS Plot from within GrafNav. Entering the start and end times can eliminate these parts by selecting the appropriate times. Another way to find good sections of data is to view the .fss or .rss files. There is a section at the start showing numerous periods of cycle slip free data for various satellites, and it also shows which period was used. You might try entering the start/end times from another period exclusive to the one used.

- For a float solution, only a coarse cycle slip detection scheme is used, and it uses another means to detect small cycle slips. However, you may try engaging the fine static cycle slip detection from within Advanced Options. This will help to find small cycle slips.

- Bad Doppler data can sometimes make data process poorly. This can be detected by plotting the L1 Doppler RMS. If there are any large spikes (5 or more times the size of the Doppler standard deviation), then this data may have problems. Try shutting the Doppler OFF for carrier phase processing from within the Advanced Options.

- A particular bad satellite will have many bad data warnings in the message log file (.fml or .rml). This satellite can be omitted from within the Advanced Options.

- For a float or iono-free solution, changing the standard deviations for both the L1 carrier phase and the C/A code can improve a solution. Suitable standard deviations can be obtained by viewing the plots for both the C/A code RMS and the L1 Phase RMS. A good standard deviation value to choose is generally one which about 90% of the RMS falls below. Realistic values allow the Kalman filter to perform better.

3.8.4   Unfixable Data

Sometimes bad data is just bad, and changing the options within either GrafNav or GrafNet cannot help. In this section, some of the possible causes of such data are given, and for some cases, advice for improving the solution is still offered.

An antenna that is not still will cause havoc with static processing. This can be caused by an operator not holding the antenna still, heavy winds, or a vehicle this is rocking. Theoretically, this data should be processed as kinematic and the position solutions averaged. However, GrafNet does not currently support this mode of processing. Therefore, such types of data should be avoided. If it needs to be processed, a float solution will perform best.

Heavy ionospheric activity can cause large carrier phase noise. A single frequency receiver cannot do much to alleviate the problem. However, dual frequency data will most likely process better with an iono-free solution rather than some of the fixed integer techniques, such as the fixed solution.

High multi-path mostly affects the C/A code. However, the carrier phase can also be affected and may cause a fixed solution to fail. Antennae placed near large metal structures are most easily affected. Moreover, locations on rooftops can also cause data to be much poorer. Such locations should be avoided. There is not much that can be done at processing time. The only suggestion is to reduce the size of the C/A code standard deviation from within the Standard Deviation Options.

Sometimes a GPS receiver just collects bad data. **Low power or a poor antenna connection** can cause this. If the problem is consistent with a particular GPS receiver unit, the manufacturer should check the GPS receiver.

Section 9   Traverse and Network Solution

3.9.1   Traverse Solution

After all of the baselines have been successfully processed, i.e. they will show up green. At this point the user will wish to produce coordinates for each of the stations. This is accomplished by using the traverse technique from known station to unknown stations. Using the Add GCP command under the File Menu, additional known (fixed) control points may be specified (Note that at least one GCP is needed per project before GrafNet

will process any data, but others can be added later). These known control stations are used to transfer coordinates to unknown stations in the network. In some ways, this is very similar to a conventional traverse survey. However, instead of instrument, backsight and foresight stations, this traverse technique only has an instrument and foresight station. Starting from the known stations, coordinates are transferred to the nearest stations. Then, the next nearest stations receive coordinates. This procedure is repeated until all connected stations have coordinates transferred. The arrow marker on the baseline shows which direction this transfer takes place.

The coordinates for a given station will be transferred from the minimum number of legs. The lengths of the legs are not taken into account which, in some cases, may result in an unfavorable transfer of position. In this case, the network adjustment will produce more accurate coordinates.

For stations that have more than two baselines connecting, a loop tie can be computed. This means that there is more than one possible transfer of coordinates to this point. The first transfer is used for coordinate generation. Subsequent transfers are used to compute loop ties. The loop ties are good for locating erroneous baselines. However, it should be noted that the loop ties are an accumulated error of many baselines to that point meaning that the last baseline in that traverse leg may not be the erroneous one. These ties also give a good indication of the accuracy of the network, but the magnitude of the errors will be larger than the network adjustment residuals. This is not saying that the network adjustment is that much more accurate than the traverse, rather, the traverse errors (closures) are accumulated while the network adjustment spreads these errors across the whole network.

3.9.2   Network Adjustment

3.9.2.1   What is the Network Adjustment?

The network adjustment is only available within GrafNet, and it is a means to more accurately compute each station's coordinates given the solution vectors computed for each session/baseline. Such an adjustment not only uses the X, Y and Z vector components, but it also utilizes the 3x3 covariance matrix (i.e. standard deviation values + coordinate to coordinate correlation). Using least squares, the errors are distributed based on a session's estimated accuracy. More weight will be placed on sessions with lower standard deviations.

3.9.2.2   Why use it?

In the traverse solution, each station's coordinates are determined using one session from one previous station. For networks with redundant measurements (usually the case), this can lead to a sub-optimal or even erroneous determination of a station's coordinates. The network adjustment does a much better job of distributing errors than the traverse solution. This makes it less sensitive to errors as long as a session's estimated accuracy is representative of actual errors. Thus, the network adjustment generally produces more accurate station coordinates.

Another advantage of the network adjustment over the traverse solution is that it assigns a standard deviation to each point. Estimated standard deviations should be used with caution, but they are a good tool for locating outliers. See 'What is the variance factor and how does it relate to the scale factor' for more information on scaling standard deviations to match the data accuracy.

3.9.2.3   How do I run the network adjustment?

After processing all of the baselines within GrafNet, and you are happy with the solutions (i.e. sessions are green), then the network adjustment can be accessed from the Process Menu. Select Network Adjustment. It should be noted that the network adjustment will only accept session data flagged as GOOD (i.e. green sessions). IGNORE, BAD or APPROX baselines will be ignored.

For the initial few runs of the network adjustment, the Scale Factor should be set to 1.0. This will not scale the final standard deviations to match observed session vector residuals (see 'What is the variance factor and how does it relate to the scale factor').

Select 'Process' to compute a network adjustment solution. This will display any errors encountered. If there are any "hanging stations", which are stations that are not attached to the network or are attached by a BAD baseline, the adjustment will fail. It is possible to change the status of the baseline to good from the session menu. Once complete, an ASCII .NET file will be created, which can viewed by selecting 'View Solution'.

Please note that the network adjustment must be re-run if you have reprocessed sessions or changed the station configuration.

3.9.2.4   Procedure for employing more than one control point

When multiple control points are present, it is important to initially use just use one. This will prevent errors in the existing control from causing otherwise correct session vectors not to fit. Therefore, large tie errors in the traverse solution or large residuals in the network adjustment can be attributed to GPS errors (see 'Interpreting the network adjustment output' below). Once you are happy with the quality of the GPS data and the fit of the session vectors, then additional control points may be added. This can be done from the File Menu by selecting Add or Remove Control Points. Control points can also be added by right-clicking on a station and selecting Add as Control Point.

Since the network adjustment is a least-squares adjustment, it will attempt to move control point coordinates to make the network fit better. This can be an undesirable effect for many applications. To avoid such movement, control points should be given very low standard deviations. The default value is 5 mm, which may need to be lowered if the network fit is poor. Lowering the standard deviation to 0.0001 m should force the control point to "stay put". A standard deviation of zero is not allowed. The standard deviation for control points can be changed from the File Menu in GrafNet (see *File | Add and Remove Control Points*). Select the desired control point and select Edit.

3.9.2.5 How do I use horizontal and vertical control?

GrafNet supports horizontal and vertical control points in addition to full 3-D control. To utilize such control, users must have available 1-10 m accurate coordinates for the unknown axes (i.e. Z for horizontal points and Latitude and Longitude for vertical points). These coordinates can be obtained either from the single point solution (in the absence of SA) or from an initial network adjustment run using just one 3-D control point. The latter method is normally used.

When the vertical and horizontal control points are added (using *File | Add and Remove Control Points*), it is important to de-weight the unknown axes. For vertical control points, the horizontal standard deviation is set to 100+ m. For horizontal control points, the vertical standard deviation is set to 100+ m.

3.9.2.6 How do I obtain orthometric (mean sea level) heights?

Orthometric heights are not available in the network adjustment output. To obtain these heights, you will need to use the Export Wizard or Write Coordinates feature from the Output Menu in GrafNet. This must be done after running the network adjustment. Important! Control point elevations must be entered as ellipsoidal heights.

3.9.2.7 The variance factor and the input scale

The variance factor can be found at the very bottom of the network adjustment output. It is the ratio between the observed residuals errors and the estimated session (baseline) accuracies. Ideally, the variance factor should be 1.0. This indicates that the estimated errors correspond well to observed errors. A variance factor less than 1.0 indicates that the estimated errors are larger than the observed errors (i.e. session standard deviations are pessimistic). A value greater than 1.0 denotes that observed errors are larger than estimated accuracies (i.e. session standard deviations are optimistic). The latter case most often exists unless the GPS data is very clean. Thus, low variance factors are normally desired. Very large variance factors 100+ normally indicate abnormally large session errors (i.e. a very poor network fit), and a user should try and investigate the source of the problem before using the coordinates produced.

The variance factor can also be used to scale the station standard deviations to more realistic values. The network adjustment is initially run with a unity Scale Factor. The resulting variance factor can then be inserted in the Scale Factor field from the first screen. After running the network adjustment with this new Scale Factor, you will notice larger or smaller standard deviations and that the new variance factor should now be ~1.0.

3.9.2.8 What is the confidence level and do I need to use it?

The confidence level (in percent) can be set from the first network adjustment screen. This uses a statistical 2-D normal distribution. Changing this value will not alter the final coordinates; rather it will scale the final standard deviations and covariance values. For example, 95% results in a standard deviation scale factor of 2.44.

3.9.2.9 Interpreting the network adjustment output

The network adjustment output is an ASCII file, which can be printed from GrafNet or another program like Notepad. This section describes each of the information blocks:

INPUT STATIONS
This is a list of each of the stations whose coordinates are being solved for. The TYPE is UNK if the coordinates are to be determined and (GCP) for ground control points. The Earth Centred Earth Fixed (ECEF) X, Y and Z coordinates are shown for control points only. SX, SY and SZ refer to the ECEF standard deviations.

INPUT VECTORS
This is the ECEF vector components for each of the sessions that have a GOOD status. The lower triangular of the ECEF covariance matrix is shown next to the vector components. The value in brackets is the standard deviation of the ECEF X, Y or Z axis in meters. The covariance values are not scaled by the Scale Factor entered at the start.

OUTPUT VECTOR RESIDUALS (most important!)
This is the most important section of the network adjustment output. It indicates how well the session vectors fit in the network. The residual values are shown in local level, where RE is the east axis residual, RN is the north axis residual and RH is the Z axis residual. These values are expressed in meters and ideally should be a few centimeters or less. Larger values may be acceptable for larger networks.

In addition to the residual values, a parts-per-million (PPM) value is shown. This indicates the size of the residuals as a function of distance. 1 PPM corresponds to a 1 cm error at a distance of 10 km. The baseline length is also shown in kilometers. Short baselines (i.e. < 1 km) can have large PPM values. This is because other errors such as antenna centering become an influencing issue. This may not indicate an erroneous session solution. The last value is the combined (east, north and up) standard deviation (STD). This will indicate sessions that have a float solution and/or poor satellite geometry (i.e. high PDOP) and/or short occupations.

CHECK POINT RESIDUALS
If check points have been added, this section will show how well the known coordinates compare to those computed by the network adjustment.

CONTROL POINT RESIDUALS
This section shows the adjustment made to control point residuals. When just one control point is used, then the adjustment will always be zero. With two or more points, the adjustment depends on the input control point standard deviation and the session vector standard deviations. See "What procedure should I use for employing more than one control point".

OUTPUT STATION COORDINATES
This shows the computed coordinates for each of the stations both in geographic and ECEF coordinate systems. The output datum will be that indicated by the DATUM

parameter at the top of this file. Note that the geographic height should be ellipsoidal. However, this is only true if the user entered an ellipsoidal height for the control point elevation.

OUTPUT VARIANCE/COVARIANCE
This section shows the local level (SE, SN and SZ) standard deviations along with ECEF covariance values. These standard deviation and covariance values will be scaled by both the input Scale Factor and the statistical (confidence) scale factor. If error ellipse parameters are desired, then the Write Coordinates feature should be used.

VARIANCE FACTOR
See "What is the variance factor and how does it relate to the scale factor?" discussed on the previous page.

Chapter 4   GrafNav Batch

Section 1   What is GrafNav Batch?

GrafNav Batch is a program that accompanies the GrafNav/GrafNet or GrafNav Lite version 7.50 software packages. This program allows the user to batch process both kinematic and static baselines using float-only, fixed static, KAR solutions, and other GrafNav processing options. Static-only baselines/networks are best processed using GrafNet. Users can easily load observation files (.gpb), process multiple baselines, process multi-base baselines, and export the output of numerous sessions into separate or concatenated files.
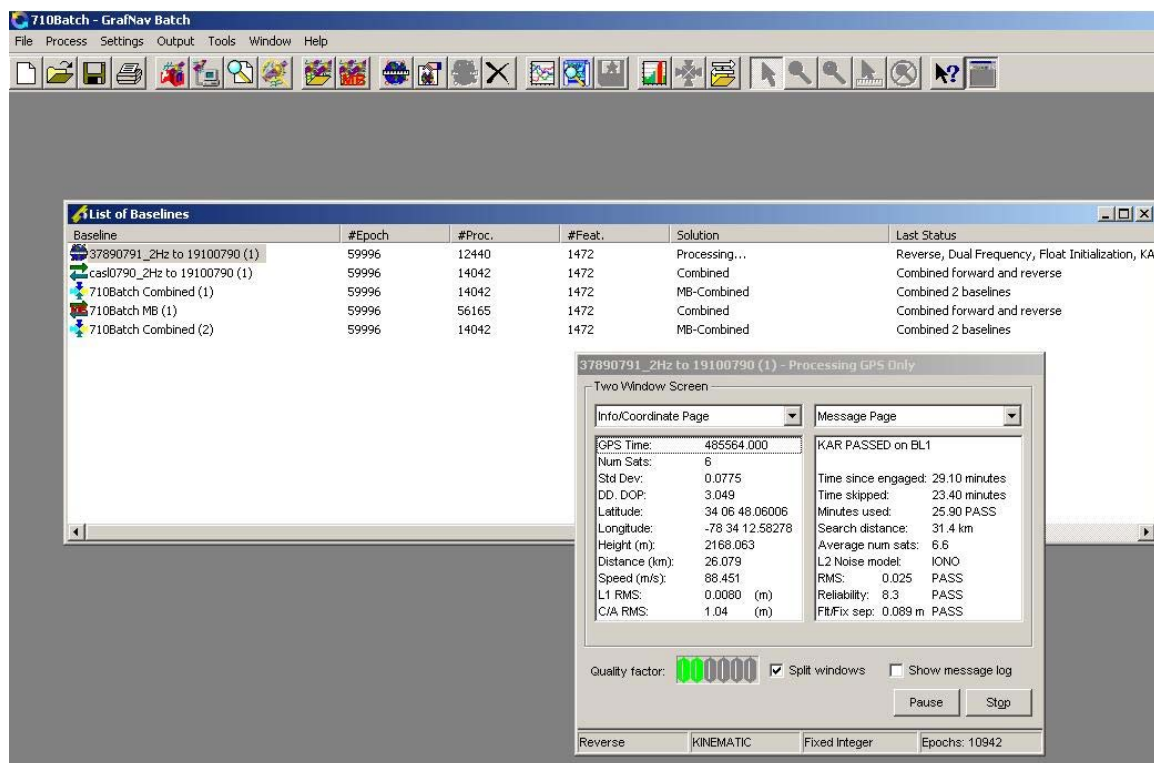
Figure 4.1 GrafNav Batch Processor

4.1.1   Getting Started

By following the procedure below, a user can quickly get accustomed to using GrafNav Batch, which can process multiple baselines with few operator steps.

1.   **Select a name for your project**

- Select New Project from the File Menu or click on the ▯ button on the tool bar.
- Change the directory to the one where the observation files are located. It is important that you save your project in the same directory as the observation files

because otherwise you will be prompted to locate each GPB file that is not in the same directory as your project when your project is reopened.

- Give the project a unique name.
- Save.

2.   Convert receiver dependent raw GPS data to Waypoint .gpb format.

- If the data logger WLOG (or another one of Waypoint's utilities i.e. LOGGPS) was used to log the observation files, this step may be omitted.

- The Convert utility can be accessed under the File Menu, or by clicking the button. For more information on the Convert utility see Chapter 7 .

3.   Add Many Baselines

- Choose Add Many Baselines from the File Menu or click the button.
- Select the appropriate directory containing the observation (.gpb) and ephemeris (.epp) files. Ephemeris (.epp) files should have the same prefix as the .gpb files. If not, then a corresponding .epp file will need to be specified for each individual baseline (use Edit Baseline).
- Select the option 'One base many remotes' or 'One remote many bases' depending on whether the same base or remote was used repeatedly for each baseline.
- Highlight one or more observation files containing GPS data for the master station(s) and click Add Base(s) in the dialogue box. Another dialogue will prompt the user for the geographic coordinates and antenna height of the base.
- If you wish to specify remote antenna heights, ensure that the box with the option 'Prompt for remote antenna height' is selected.
- Highlight all the remote station observation files and click the Add Remote(s) button.
- Click OK.

4.   Add Multi-base baselines

- Choose Add Multi-Base Baselines from the File Menu or click the button.
- Add the master files by clicking 'Add'. The remote file can be added by clicking 'Browse'. Locate the path of the .GPB files. Click 'Plot Coverage' to display the Static/Kinematic Coverage plot of the files added. Be sure that there is sufficient coverage available.
- A dialogue box will appear prompting the user for geographic coordinates and antenna height of the bases. Another dialogue box will prompt the user for the remote antenna height.
- Click OK

5.   Set Processing Options

Global Options
If you do not wish to specify individual processing options for each baseline, select
'Process All Baselines' from the file menu. You will be warned that using this option
will process all the baselines with the same options, thus overwriting any previously user
specified options for any individual baselines (such as processing time interval or user
defined C/A or L1 phase standard deviations).

Another way to specify global options is to select 'Global Options' under the Options
menu. Ensure that the processing datum corresponds to your project one. For more
information on datums, see Section 10.5.2 Datums.

Individual Baseline Options
Some baselines may require processing options that differ from others to obtain
satisfactory results. This can be for reasons as simple as some of the baselines in your
project are short and some are long. Specifying individual processing options for
baselines is accomplished by selecting the baseline(s) that you wish to change the

processing options and click the [button icon] button. Then, with all of your baselines selected
(those with and without special processing options), chose 'Process Selected' from the

file menu, or click the [button icon] button. This will process all of your baselines, while
preserving processing options for each individual baseline.

6.   Combined baseline solution

In the case where you have many base stations and one remote, or multi-base baselines,
you may wish to create a combined file that uses weighted observations from all of your
baselines. See Section 7   for information regarding combining baselines.

7.   Export data output into files

To export coordinates and other information from processed baseline sessions to ASCII

text files, select Export All from the Tools Menu or click on the [button icon] button.
Select the source for your output (epochs, features/stations, static sessions) and select a
predefined profile that comes with GrafNav (i.e. $GPGGA, Geographic, UTM, State
Plane, etc.) or select a user defined profile.
Click the Next button and choose the Break-up batch sessions into separate files only if
you want the output for each baseline in separate ASCII files. The user can also specify
how the output files are named and what file extension is used.
Click Next again to continue with the rest of the Export Wizard option menus.

8. **Save Project**

To save your configuration, select Save Project in the File Menu or click on the [icon] button. If processing one remote and many base stations, then refer to Chapter 4 Section 7 for information on combining multiple baselines into one solution.

Section 2   File Menu

4.2.1   New, Open, Save, and Save Project

These menu items help manage the GrafNav Batch/ GrafNav Lite Batch projects (i.e. .BNV files), and they are very similar to standard Windows applications.

4.2.2   Add Baselines

File | Add Baselines
Use this option to add independent single baselines to your project. Under the 'File Name' window tab, select which GPB files you want to add as master and remote. The user needs to select whether these separate baselines have 'One base many remotes' or 'One remote many bases'.
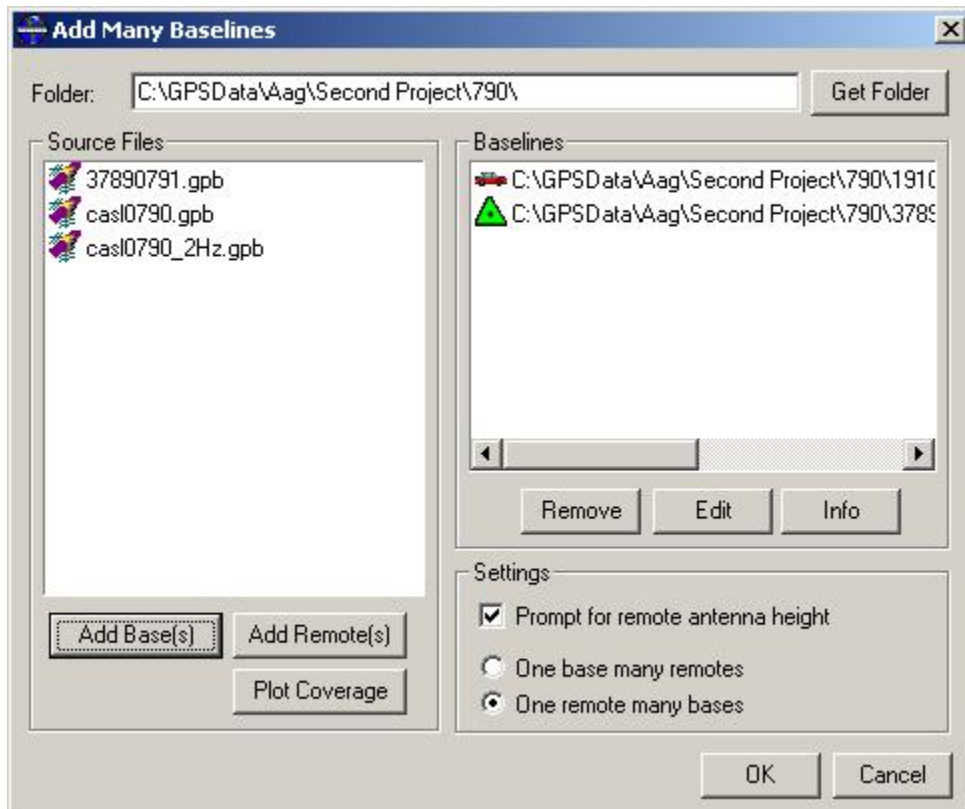
Figure 4.2 Add Baselines Dialogue

After pressing OK, the user will be prompted to enter the base station coordinates. Once a position for the base station has been entered, the coordinates may be added to the

favourites list to reduce the amount of retyping. Both the base station and remote station window tabs require an antenna height to be entered. A simple vertical antenna height is generally used; however an advanced antenna height model using an antenna profile is also available. The advanced antenna height profile is only used if horizontal distance from the antenna centre to the ground plane edge and vertical distances from the L1 and L2 phase centers are needed. For more information on advanced antenna profiles, please see Section 2.2.4 .

Figure 4.3 Base Station Information

The **'Remote Antenna'** dialogue box lets you change the antenna height and the antenna height model. Refer to Section 2.2.5 for more information on remote antenna options.

4.2.3 Add Multi-Base Baselines

File | Add Multi-Base Baselines
This option allows the user to add multi-base baselines, where the base stations will be processed together with the remote rather than independent single baseline processing.
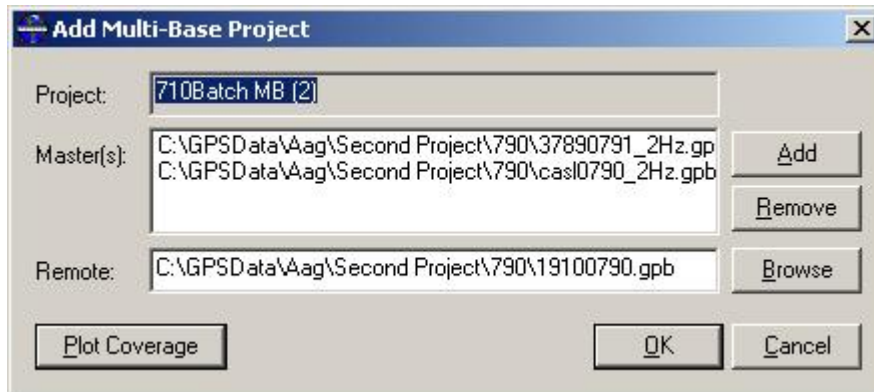
Figure 4.4 Add Multi-Base Baseline Dialogue Box

Add the master files by clicking 'Add'. The remote file can be added by clicking 'Browse'. Locate the path of the .GPB files. Click 'Plot Coverage' to display the Static/Kinematic Coverage plot of the files added.

Tip: This is best called after single base baselines are added.

4.2.4   Add Combined Baseline

This will add another 'combined' baseline to the list of baselines. A user may wish to combine more than one pair of baselines in one project. This option will allow the user to do so. New to version 7.50, the user can now combine 'combined' files and multi-base baselines as well. Highlight 2 or more baselines in the list of baselines to be combined, then select *Process | Combine Selected Multi-Base*. The dialogue box that opens contains information about the combine process and the user can select the 'combine' baseline from the pull down menu, see Section 7 for more details.

4.2.5   Edit Selected Baseline Settings

File | Edit Selected Baseline Settings
This option gives the user the ability to edit the path and file names that GrafNav Batch should be looking for, base station names, change the master station coordinates, or change the antenna heights or antenna height model being employed. If more than one baseline is selected, then any shared information can be changed. This could be the master position and antenna height, remote antenna height, or baseline options. Refer to Section 4.2.2 for more information on the edit options.

4.2.6   Remove Selected Baselines

File | Remove Selected Baselines
Remove Selected Baselines will remove highlighted baselines in the List of Baselines window and from the project file (.bnv). However, if the project is not saved afterwards, the project will still retain the deleted baseline. Configuration and processing files will be left over unless they are manually removed.

4.2.7 View ASCII file

File | View | ASCII File
See Section 2.2.14 Viewing an ASCII File.

4.2.8 View Raw GPS Data

File | View | Raw GPS Data
See Section 2.2.15 Viewing Raw Binary GPS Data.

4.2.9 Convert Raw GPS to GPB

File | Convert | Raw GPS to GPB
See Section 2.2.21 Converting GPS Data and Chapter 7 Convert.

4.2.10   Convert GPB to RINEX

File | Convert | GPB to RINEX
See Chapter 6 Section 5 GPB to RINEX (Windows).

4.2.11   Remove All/Selected Processing Files

File | Remove Processing Files | All/Selected
Use caution when choosing to remove all processing files, as all processing files in your working directory will be deleted, including those from other projects. If you wish to remove the processing files from only certain baselines, select these baselines then chose to remove only the selected baseline solutions.

4.2.12   GPB Utilities

File | GPB Utilities
See Chapter 6 Utilities.

Section 3   Process Menu

4.3.1   Process All/Selected

Process | Process All Baselines / Process Selected
These two options will process either all or only the selected baselines in GrafNav Batch. If Process All is selected, the individual processing options will be overwritten with the global processing options for all baselines. However, the user may wish to specify individual options for troublesome baselines. Do this by selecting the desired baseline and pressing the ![button] button. After changing individual processing options, select all the baselines with the mouse (while holding the shift or control key for multiple selections), and press the ![button] button or go File | Process Selected. The processing window and dialogue box for options are the same as GrafNav. Users should refer to Chapter 2 Section 3 Processing Options for more information.

4.3.2 GrafNav on Selected

Process | GrafNav on Selected
If the user needs additional options, tools, plotting and printing capabilities or the baseline solution needs improvement, GrafNav can be opened and used for processing the highlighted baseline using the GrafNav on Selected option.

4.3.3 View Selected Processing Summary

Process | View Selected Processing Summary
See Section 2.4.12 View Processing Summary.

4.3.4 Load All/Selected Solutions

Process | Load All / Selected Solutions
These two options will load all or selected solutions into GrafNav Batch, thus allowing the user to load existing solutions for plotting and exporting into output files.

Section 4   Settings Menu

4.4.1 Global/Selected Processing Options

Settings | Global Options/Selected Options | Processing Options
If global processing options are selected, the options will be copied to every single baseline and overwrite any individual options that have been set. Baselines that require individual options should be selected and then 'Selected Options' should be chosen from the Options menu. Users should refer to Chapter 2 Section 3 for more information on Processing Options.

4.4.2 Global Datum/Grid Options

Settings | Datum/Grid Settings
These options will affect all baselines. See Section 2.3.11 for datum options and Section 2.5.1 for grid options.

4.4.3 Alternate Ephemeris files

Settings | Global | Alternate Epehemeris Files
See Section 2.2.6 for details on adding precise ephemerides or IONEX files.

4.4.4 Edit Selected Baseline

Settings | Selected | Processing/Baseline Settings
See Section 4.2.5 and Chapter 2 Section 3 for processing/baseline settings.

4.4.5 Copy Processing Options

Settings | Copy Processing Options
Copy processing options lets the user copy the processing options from one baseline to another baseline. The baseline with the new processing options will have to be reprocessed for the processing options to take effect.

4.4.6 Manage Settings

Settings | Manage…
See Section 2.5.7 for loading pre-defined settings into a baseline.

4.4.7 Display Options

Settings | Preferences
See Section 2.5.2 for a list of the options available in GrafNav Batch.

Section 5   Output Menu

4.5.1 Plot Selected GPS Data

Output | Plot Selected GPS Data
This feature allows users to plot GPS data from a selected baseline. See Section 2.6.1 for more information on the types of plots available for GrafNav, GrafNet, and GrafNav Batch.

4.5.2 View Selected GPS Map

Output | View Selected Map
This feature allows the user to view a trajectory (in the case of kinematic data) or a static representation of the GPS data for any individual baseline. Note that only one map for one baseline can be viewed at a time.

4.5.3 Export All / Selected

Output | Export All / Export Selected
By using Export All and Export Selected, the user can export custom output files using the Export Wizard. Export Selected and Export All will export the selected data into one concatenated file if more than one baseline is selected and if the 'Break up batch sessions into separate files' option is not selected. If this latter option is selected, the user will be prompted to assign the method for naming the output files. Further information regarding the use of the Export Coordinates Wizard and its options can be found in Chapter 2 Section 7 .

4.5.4 View Export File

Output | View Export File
This option opens the ASCII viewer in GrafNav Batch for the user to view the last output file that was written using the Export Wizard. If the Export Wizard has the option 'Break up batch sessions into separate files' selected, View Export File will not work properly since it looks for the file name <project name>.txt in the current working directory. In this situation, try using the View ASCII file option in the File Menu or on the toolbar. See Section 2.2.14 Viewing an ASCII File.

Section 6 Tools Menu

4.6.1 Map Tools

Tools | Zoom In / Zoom Out / Zoom Reset / Distance & Azimuth Tool
These tools, also found in GrafNav and GrafNet, are provided to be used in the mapping window. In GrafNav Batch, this window is activated by selecting the desired baseline and selecting the 'View Selected Map' option from the Output menu. The distance/azimuth tool works by left clicking once on your "from" point, then right-clicking on your "to" point.

4.6.2 Find Epoch

Tools | Find Epoch Time
This tool is also used only in the mapping window, and is useful for kinematic data sets. When selected, the user is prompted to enter a time in GPS seconds of the week. GrafNav Batch will then highlight the chosen epoch by drawing a red circle around it. This can be useful in determining where in the survey bad epochs were recorded.

4.6.3 Datum Manager

Tools | Datum Manager
Use this tool to convert coordinates between datums. This is useful for converting base station coordinates before processing in the desired datum. See Section 10.5.2 Datums for more information.

4.6.4 Geoid

Tools | Geoid
If orthometric heights are of interest, use this option to change geoid models. Geoid heights can also be computed here. See Section 10.5.4 for information on Geoids.

4.6.5 Grid/Map Projection

Tools | Grid/Map Projection
Available grid systems include Gauss Kruger, US State Plane, and UTM. This option allows users to define their own grid system as well. Use this option to convert grid coordinates to geographic coordinates. See Section 10.5.3 Map Projections/Grids for more information.

4.6.6 Favourites Manager

Tools | Favourites Manager
Use this feature to avoid unnecessarily retyping coordinates that are used often. See Chapter 2 Section 8 Favourites Manager for more information.

4.6.7 Time Conversion

Tools | Time Conversion
This tool allows the user to convert both from GPS time to HMS and back. Note that this tool returns GPS week numbers from 0-1023. In some applications (such as downloading precise orbits) it is necessary to add 1024 to the week number returned by this tool.

4.6.8 Mission Planner

Tools | Mission Planner
To best prepare for a GPS survey, take advantage of this tool that indicates hourly conditions (number of satellites, DOP values) for your area of interest. See GrafNav Chapter 6 Section 8 Mission Planner for more information.

4.6.9 Download Service Data

Tools | Download Service Data
This is a convenient tool that will download GPS data from the IGS, CORS, AUSLIG, IGN, and GSI networks. These stations, if near enough to your project area to satisfy desired accuracies, can be used as base stations, or additional base stations if you already have one of your own. This can improve accuracies, and in some cases save a survey altogether. They can also be used to check the validity of base station coordinates. See Chapter 6 Section 9 Download Service Data for more information.

Section 7   Combining Multiple Baselines

This section covers the process of using GrafNav Batch to process between multiple bases, multi-base baselines, and a single remote. For instance, a typical scenario would be an aircraft covering a large area. In order to maintain accuracies, multiple base stations are required. As of version 7.50, users can now combine multi-base baselines and combined baselines as well. To add an additional combined baseline, see Section 4.2.4 .

The following procedure would be used:
1. To get started, follow steps 1 to 5 in Section 2 File Menu of this chapter.
2. Process each of the baselines to your satisfaction. This can be done either from within GrafNav Batch or GrafNav.
3. Add an additional baseline to the same remote (it does not mater which base station is used because this baseline will not be used for processing). The user may wish to change the name on this baseline, which is performed by right-clicking on it and selecting the Rename menu option. Change the name to something appropriate like: Multi-Base Combination.
4. You may wish to reject epochs that have poor statistics, specify remote initializations, or specify the solution to load (forward / reverse / combined). All of these options are found in the 'Multi-base' tab after selecting 'Edit Selected Baselines' from the File menu. From this dialogue box, epochs can be rejected for a number of reasons. In addition, an additive PPM and weighting value can be used to change the weighting with distance.

5. With all of the baselines still selected, select 'Combine Selected Multi-base' from the Process Menu. This will combine these baselines into a single solution. Outliers can be rejected based on two parameters:
    -   Error Tolerance – this is the minimum error before an outlier will be detected. Setting this correctly is important to prevent false errors from being detected.
    -   Sigma Tolerance – This is the number of standard deviations (of the computed position standard deviation) before an error is "deemed an error". You may wish to use 3-sigma to reduce the number of errors detected. The default is 2-sigma.
6. The additional baseline added will be used as a "holding place" for the combined solution. This is performed by enabling 'Send output to baseline (i.e. BED file)'. Select the baseline added (possibly renamed) e.g. Multi-Base Combination.
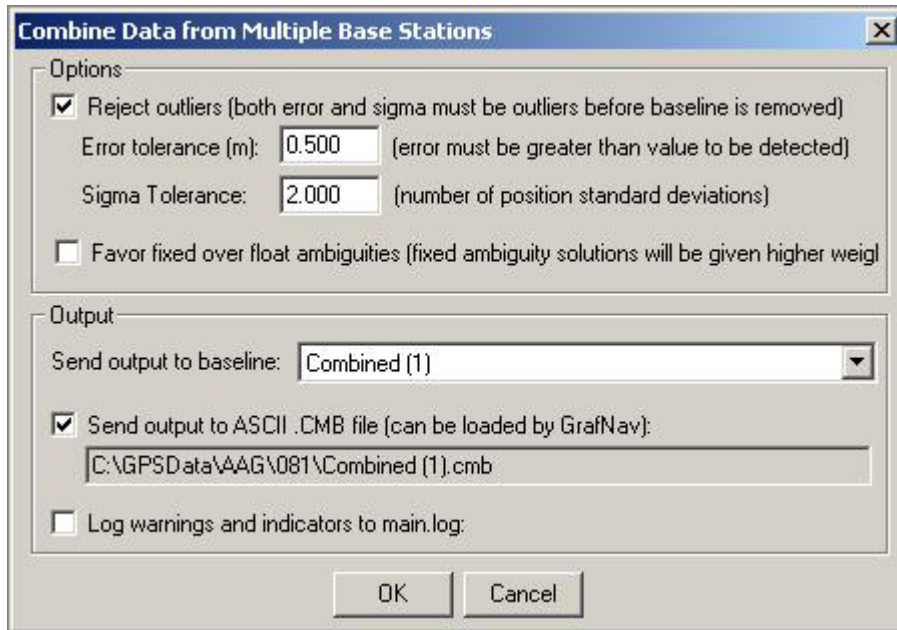
Figure 4.5 Combining Data from Multiple Base Stations

7. If camera event positions are desired, then select the next option labeled 'Send output to ASCII .CMB file' as well. This will allow you to load this solution into GrafNav, which supports the interpolation of camera event marks.
8. Press OK

When complete, the following screen will appear:
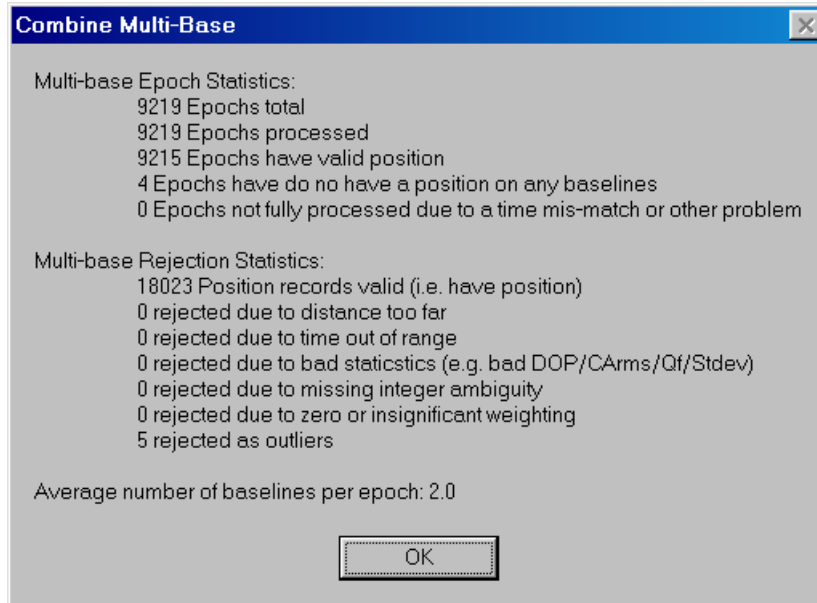
Figure 4.6 Combine Multi-Base Summary

This gives the user an indication of how many epochs were rejected.

To export the camera event pulses, load one of the baselines in GrafNav. From the File Menu, select *Load | Existing Solution*. Select the .CMB file created. You may also need to load the camera event pulses. Use either Write Coordinates or the Export Wizard to output the camera position.

<Important>: The user should monitor how many epochs were rejected – especially as outliers.

Chapter 5 Inertial Explorer

Section 1 Introduction

Inertial Explorer (GPSIMU) post-processing software suite is aimed at user's who wish to integrate rate data from six degrees of freedom IMU sensor arrays with GPS information processed via GrafNav which is included. Inertial Explorer is designed to utilize strapdown accelerometer (Δv) and angular rate ($\Delta \theta$) information to produce high rate coordinate and attitude information from a wide variety of IMU's including high accuracy navigation grade to inexpensive MEMS (Micro Electro-Mechanical Systems) sensor types.

The initial version of the GPS/IMU processor implements a loose coupling of the GPS and inertial data. Users must collect and process GPS data in a separate stream from the raw IMU Δv and $\Delta \theta$ measurements. It is the user's responsibility to time tag each set of inertial measurements to the GPS time frame during the data collection process. The GrafNav component of Inertial Explorer must be run first in order to process and store an optimal set of GPS coordinates, velocity and quality information in the standard GrafNav fwd/rev/cmb output files. Following this, the IMU component of Inertial Explorer can be invoked to perform alignment, mechanization of the rates and filtering. GPS coordinate and velocity updates are implemented by time matching and interpolating the inertial rate data with the closest GPS measurement epoch. Sensor bias calibration is also performed during the filtering process.

With this software package we hope to provide GPS / inertial processing for users who are not able to utilize available commercial GPS/IMU systems in their particular application for reasons of cost, package size or other parameters relative to specialized mission requirements. The IMU algorithms have been originally developed at the University of Calgary for their KINGSPAD program and have been proven in many applications. Waypoint is engaged in on-going IMU research activities with our partners at the University. The aim of this partnership is to help bring relevant and significant improvements to the Inertial Explorer package as time goes on.

Section 2 About Inertial Systems

To a significant extent, inertial navigation is about coordinate frames. Inertial sensors measure rate information relative to an inertial frame of reference. An inertial coordinate frame does not rotate or accelerate with respect a space-fixed system of reference. Accelerometers measure change of velocity with respect to an inertial frame. Gyroscopes

measure change of rotation with respect to inertial space. In other words, they are inertial sensors. If one can relate measurements made in this inertial frame to some chosen navigation frame, then inertial sensors can be used to realize both 3-dimensional coordinates (X, Y, Z) and 3-dimensional attitude (roll, pitch and yaw) in a world that makes sense to navigators.

Inertial Reference Frame (I-Frame)
A practical implementation of an inertial coordinate frame is to define the centre of mass of the earth as an origin. The z-axis of this system goes through the poles and is co-incident with the spin axis of the earth. The x-axis is tied to star systems and points at the equinoctial colure or the meridian where the sun apparently crosses the equator at the spring equinox. The y-axis completes a right hand triad. We assume that a system tied to the stars does not move for the duration of a typical survey.
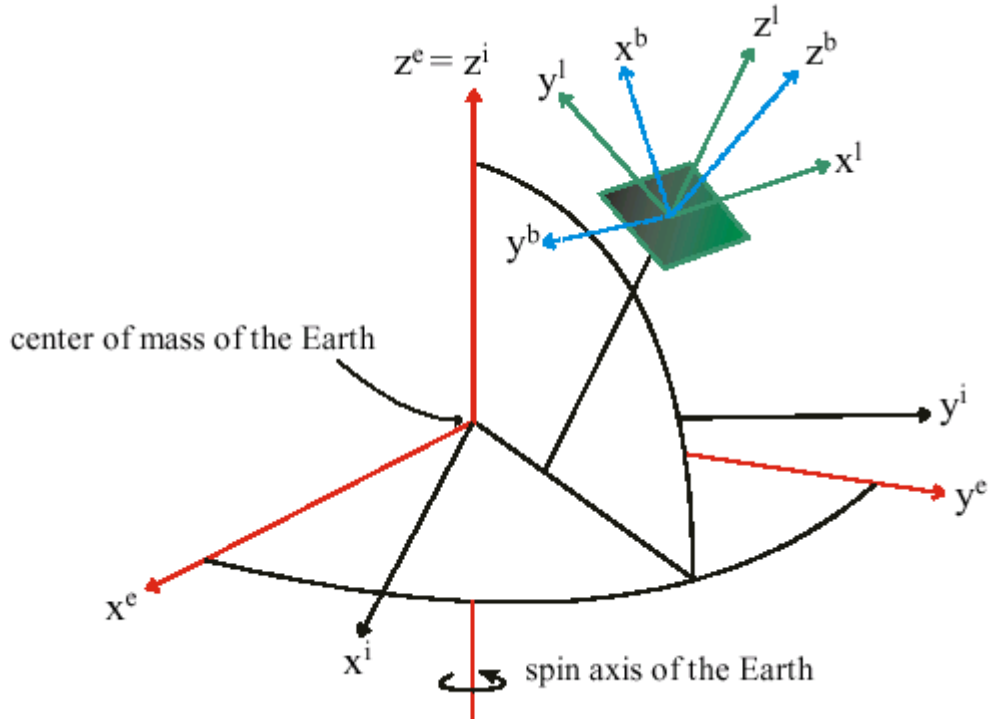
Figure 5.1 Coordinates Frames Utilized in Inertial Explorer

Figure 5.1 above[1] portrays the relationship of our practical inertial frame with a convenient ECEF computation frame ($X^e Y^e Z^e$) and a popular local level navigation frame ($X^e Y^e Z^e$).

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[1] Re-printed with permission of Dr El-Shiemy of the University of Calgary

Earth-Centred Earth-Fixed Frame (ECEF) or e-frame
The computation frame - Inertial Explorer performs its principle calculations for both GPS and inertial computations in the ECEF frame. The origin of this system is at the centre of mass of the earth – well-defined by observing the orbits of satellites together with gravity measurements. The z-axis is co-incident with the spin axis of the earth and co-incident with the z-axis of the I-frame defined previously. The x-axis of the ECEF system points through the Greenwich Meridian, while the y-axis completes a right hand orthogonal frame.

It can be assumed that the ECEF frame differs from an inertial earth-centred frame only by the amount the earth rotates.

Local Level Frame (LL-frame)
The navigation frame, included for the purposes of visualizing the navigation of a vehicle the Local Level frame, is an appropriate reference system to output coordinate and attitude information. Local Level enables coordinate output in north, east, up or latitude, longitude, height as well as attitude output in terms of roll, pitch and yaw (heading). The origin of this system is the centre of the sensor array. The z-axis is orthogonal to the reference ellipsoid at the sensor array, the y-axis points north, while the x-axis points east. When making computations in the local level frame, instabilities can develop near the poles due to convergence of the meridians. This is not a problem for Inertial Explorer because it uses the e-frame. However, other systems utilize the so-called Wander Azimuth system to compensate. This system maintains a so called grid north.

Body Frame (B-frame)
This sensor axis frame is aligned to the vehicles body. In the following discussion, we will assume that the accelerometer and gyro measurements are made in the body frame of the vehicle. This is the so-called "strapdown" approach to inertial navigation. The orientation of a vehicle's body frame is completely arbitrary from one epoch to the next. One of the principal challenges in any inertial survey is to properly compute the orientation of the B-frame with respect to your chosen computation frame at each and every measurement epoch. For instance, body to l-frame angles are roll, pitch and yaw.

The B-frame chosen for Inertial Explorer is depicted below. Note that the body frame definition for the user's inertial measurement unit may very likely be different from that shown below. A simple reflection of your body axes into the body axes given by Inertial Explorer will typically be all that is required to process data.
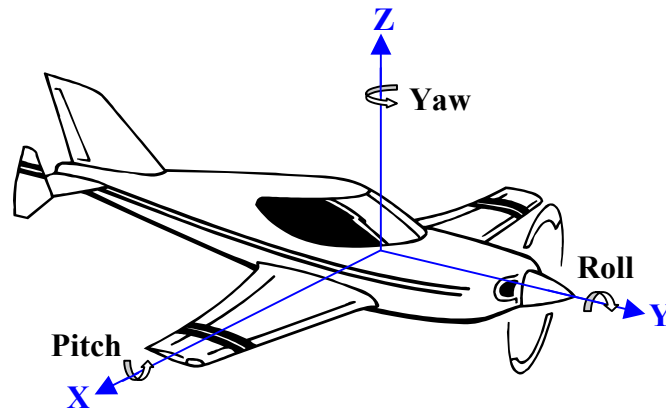
Figure 5.2 Body Frame Definition

The y-axis of the body frame is co-incident with the longitudinal axis of the vehicle. Its positive direction points out the nose of the vehicle. The y-axis may also be said to define the roll axis of the vehicle with positive roll being counter-clockwise in a right hand system. The positive x-axis of the B-frame points out the right side of the vehicle, when facing the rear. It will contain the vehicle pitch rate. The z-axis of the body frame points positive up. A counter-clockwise yaw rate is positive about the z-axis of the given b-frame.

Inertial Processing

To process measurements made in an inertial frame, the body frame needs to be re-oriented in such a way as to make it co-incident with the computation frame or eventually the navigation frame (if they are different). In other words, body frame measurements should be sensed directly in the desired computation frame. Furthermore, only those components, which are due to motion of the vehicle, are of interest. Hence, gravity earth rotation and the curved shape of the earth as sensed by the gyros (and accelerometers) must be eliminated. Any sensed accelerations can now come only from vehicle dynamics. For example in the e-frame, if accelerations along the north-pointing axis are integrated twice, there is a direct difference in northing from some known starting location. Similarly, differences in easting and height can be obtained by integrating twice along the other 2 accelerometer axes – provided these are properly oriented. If the initial coordinates at the centre of the sensor array are known at the start of a mission, our coordinate differences can be used to compute and output latitude, longitude, and height at each time epoch in the trajectory.

The problem is that sensor biases, measurement noise, errors in initial conditions and gravity modeling errors are integrated along with measurements. In attitude, the single integration results in the platform becoming misaligned to the computational system. In position, this misalignment causes the gravity vector to enter horizontal axes, while the double integration of these errors leads to an additional quadratic error. The end result is that significant errors can quickly be realized.

The rotation matrix required to take body sensed measurements and place them in the computation frame at any given epoch will be referred to here as the **attitude matrix**. The gyro triad is utilized to sense the change in vehicle rotation from one body frame orientation at one epoch to the subsequent body frame orientation at the next epoch. The direction cosine matrix which is defined in Inertial Explorer to go from body to navigation frame is a function of 3 consecutive rotations in yaw, pitch and then roll. Computation frame is ECEF, so the attitude matrix must be further rotated as function of latitude and longitude.

Changes in orientation (i.e. angular rates) must be integrated once in order to obtain angles. This implies 2 things. First of all, it is a requirement to solve for 3 initial constants for the integration process to be complete. Secondly, as with the accelerometers, errors are integrated as well as measurements. The integration process can then quickly build up errors from the gyros – as well as signal.

Error Models are more important for inertial processing than GPS processing. Some details on error models are provided in the section concerning our Error Model Dialogue Box (see Section 5.4.5 but it may be useful to make some mention of the topic here. First of all, by "error model" in the context of Inertial Explorer, it looks at the initial variances and a priori spectral noise densities required by the IMU Kalman filter. These are values which may be input through the Error Model dialogue box interface or User Commands. The dialogue box interface provides a number of "canned" error models appropriate to certain classes of IMU's. It also allows the user to build custom error models suitable to particular inertial measurement units or applications.

Unlike GPS, inertial computations are very sensitive to the input a priori stochastic information that is available for each inertial system. As a rule of thumb, the more expensive the IMU, the less likely you are to achieve poor results from a non-optimal choice of input statistical quantities. A poor choice of noise densities for a navigation grade inertial system may simply provide the user with a sub-optimal set of outputs, say for attitude. An inappropriate choice of noise densities for a MEMS array with a drift of 300 degrees/hour may mean that you obtain nonsense for attitude information! The process of choosing an appropriate variance and spectral densities for a particular system is called "**tuning**". Unfortunately, tuning can be something of an arbitrary process. The user may have to simply guess at the approximate magnitude of the noise densities which help describe the behavior of an inexpensive inertial system. This can be a tedious and unrewarding process. Definition of error models for various classes of IMU's will be an on-going program at Waypoint and with our partners at the University of Calgary. These will be included in a file called USER.IMU which can be found under your Program Files\WaypointGPS software directory. Waypoint will be attempting to update this file on a regular basis as we learn more about the different sensors coming on the market, especially in the MEMS category.

Alignment is the process of computing the initial values of roll, pitch, and yaw. Proper alignment is very important to IMU performance and processing because errors result in a direct attitude error and can take some time to correct by the Kalman filter. Alignment can either be static or kinematic.

Static alignment generally takes place in 2 stages; **coarse** alignment followed by **fine** alignment. Coarse alignment is a requirement for static alignment. Fine alignment is optional. If the user has GPS data immediately available for updates, the static fine alignment process can often be ignored.

Coarse alignment generally requires 1 to 2 minutes of static data. The default time for coarse alignment is Inertial Explorer is 120 seconds. The software will monitor the data and warn you if the data is kinematic. During coarse alignment the basic signal from a set of static accelerometers is the gravity vector. In this B-frame definition, roll is a function of acceleration measured in the x body axis. Pitch is a function of sensed acceleration in the y body axis. The approximate roll and pitch values computed from these measurements can then be used to define an approximate level plane. Initial heading still needs to be computed and this is where inexpensive IMU sensors tend to disappoint. Gravity is a strong signal and it can be sensed adequately by even MEMS grade accelerometers. Heading or yaw (which simply has the opposite sign to heading) must be computed by examining the output of the gyros for earth rate. For instance in an ideal stable platform system, the assumption was that one horizontal axis points due east. A gyroscope aligned along this axis will be in a no torque situation relative to the earth rotation. There will be no output. On the other hand, the north-pointing axis will sense the entire earth rate at that latitude. Consider the magnitude of the earth rotation rate at about 15 degrees per hour. MEMS rotation sensors can have drifts in the order of 100 to 300 degrees per hour and the user can see that computation of heading during coarse alignment with such sensors is impossible. In fact, any output from such a gyro during static alignment can be simply considered as bias noise. Systems at about 1 deg/hr should be able to gyrocompass to some degree of accuracy. Systems above this may require external aiding for azimuth determination.

Fine alignment is the process of using static data in the Kalman filter process to fine tune the initial roll, pitch and yaw computations. If GPS updates are immediately available following coarse alignment, many applications can choose to fine tune the attitude information from the GPS information available during navigation. For instance, an airplane taxiing down a runway may have sufficient time and update information to adequately perform a dynamic fine alignment. By the time the aircraft reaches the area where the mission will take place, the attitude matrix and associated sensor biases may very well be optimized as well as possible without static fine alignment. Note that for low grade IMU's, the GPS update process can also provide some approximation of heading during navigation. This works best in minimal crab environments.

In principle, it is also possible to transfer initial roll, pitch and yaw from another sensor while kinematic. Moving coarse alignments are even possible just from GPS update information. Users should be aware that the process of alignment is similar to the convergence process which must be undertaken for computation of GPS phase ambiguities. Unless the user has a very expensive IMU do not expect to obtain optimal values for attitude until some static and kinematic data collection has taken place. This will be in the order of minutes, not seconds. Analogous to GPS, kinematic IMU

alignments take longer than static alignments. Ideally, the first 5 to 10 minutes of the mission should be concerned with alignment (static and kinematic).

Data Formats

Inertial Explorer expects raw binary IMU data to have the following structure:

Word	Size (bytes)	Type	Description
Gpstime	8	real	time of the current IMU rate measurement in GPS seconds of the week.
GyroX	4	int	scaled x-body axis gyro measurement as an angular increment or angular rate
GyroY	4	int	scaled y-body axis gyro measurement as an angular increment or angular rate
GyroZ	4	int	scaled z-body axis gyro measurement as an angular increment or angular rate
AccelX	4	int	scaled x-body axis accel measurement as a velocity increment or acceleration
AccelY	4	int	scaled y-body axis accel measurement as a velocity increment or acceleration
AccelZ	4	int	scaled z-body axis accel measurement as a velocity increment or acceleration

Table 5.1 IMU Data Formats

Inertial Explorer directly decodes raw IMU binary measurements from a number of systems. These are listed below:
LTN90
LASERREF3
LN200
HG1700 (NovAtel BDS)
AG1700
GENERIC_IMU

These data formats are decoded if selected in the dialogue box shown in Inertial Explorer.
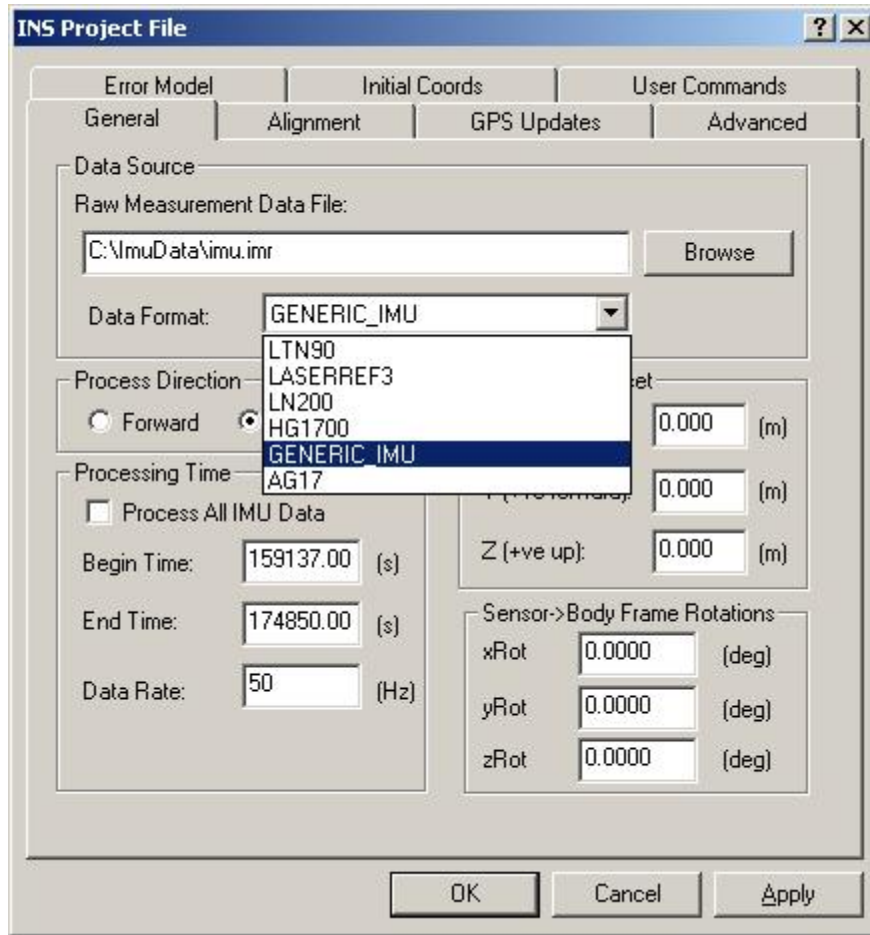
Figure 5.3 Data Formats Decoded in Inertial Explorer

Users can define their raw strapdown output in our Generic Format which has the same structure as shown in Table 5.1 above, where

Time is GPS seconds of the week,

Gyro output is in angular rate of 1/100 of an arc second per second, in other words, degrees per second scaled by 360000, and

Accelerometer output is in acceleration units of micro-metres per second^2 or metres per second^2 scaled by 1000000. Also see Section 5.7.3 Generic Binary Input Structure that provides the format for different generic binary input files. See Section 5.7.4 for converting raw IMU data into Waypoint's generic format (*.imr file).

Note that GPS time can either be the internal GPS receiver measurement time or it can be the so-called corrected measurement time. The difference between the two is the receiver clock bias. Users should be aware that GPS receivers which do not steer their clocks can have clock biases which are many milliseconds. It is up to the user to make sure that their IMU measurements are tagged with a meaningful time in GPS seconds of the week.

GrafNav outputs both the corrected time and nominal receive time. Inertial Explorer has a User Defined command which allows some accounting for this:

INS_GPS_TIME_FRAME = GPS_TIME_FRAME / RCVR_TIME_FRAME

The default is GPS_TIME_FRAME i.e. we are assuming that the IMU measurements have been time tagged with the corrected measurement time.

Kalman Filtering / GPS Updates
The IMU Kalman filter consists of 3 misalignment states, 3 position states, 3 velocity states, 3 gyro bias states, and 3 accelerometer bias states. The first 9 states are in the ECEF computation frame. They represent estimated errors in the realization of an ECEF computation frame from measurements made in the arbitrary vehicle body frame. The sensor biases are lumped states accounting for constant and time-dependent gyro and accelerometer measurement errors. This filter runs in conjunction with equations which "mechanize" the IMU rate data, that is propagate the attitude matrix and integrate coordinate differences between GPS updates.

The GPS data must be processed first. This produces ASCII .fwd and .rev files, as well as a .cmb file which represents the weight mean of the forward and reverse GPS processes. Inertial Explorer reads the .cmb file by default and stores the coordinate, velocity and associated covariance information in a binary image in memory. At IMU measurement time tags, and GPS epochs are generally not aligned. Therefore, Inertial Explorer interpolates the inertial records either side of the GrafNav time tag to line up a derived inertial measurement with the corresponding GPS time. At this derived point the mechanized inertial coordinates and velocities are differenced from the GPS computed quantities to obtain the error in the inertial information. These estimated errors are used as update information to the IMU Kalman filter. The covariance information from the GrafNav file is used as weighting in the update procedure.

Note that Inertial Explorer has a GPS Updates Dialogue Box (see Section 5.4.3), which allows the user to reject GrafNav information which is deemed unacceptable for updating purposes. Rejection tolerances can be based on ambiguity determination, standard deviation, or quality number. Tolerances will be based on the stand-alone navigation capabilities of your inertial system. Covariance can also be scaled.

Section 3   Getting Started with Inertial Explorer

Inertial Explorer contains full-featured static and kinematic GPS and inertial post-processing package using Waypoint's proprietary GPS processing engine, together with KINGSPAD IMU engine developed at the University of Calgary. Waypoint's GrafNav GPS-IMU is a single baseline processor that processes GPS data first, followed by processing IMU data using GPS updates to obtain a trajectory. This section goes over the basics of GrafNav GPS-IMU including a how to process inertial data in a step-by-step tutorial for first time users.

Step 1:   Start Inertial Explorer
Assuming that you have followed the installation instructions properly, you will have a program group called Waypoint Inertial Explorer 7.50. In this group, there will be a program called GrafNav GPS-IMU. Highlight and click GrafNav GPS-IMU to begin the program.

Step 2:   Convert and Process GPS Data
Refer to Section 2.1.1 How to Start Processing Baseline from Step 2 to Step 8 to obtain processed GPS data. Chapter 7 Convert contains details on how to extract inertial data from the Convert utility into a binary .imu file. Once GPS processing is complete, a .cmb file should be created automatically by Inertial Explorer, as it is needed as a source of GPS updates during the inertial processing.

Step 3:   Determine Static Time using Velocity Plot Profile
After processing the GPS data, static time is needed to determine the coarse and fine alignment parameters. Under the Output Menu, choose Plot GPS Data. From this list of options, click on 'intermediate' and scroll down to the bottom and click on "Velocity Profile". This plot shows the speed of the vehicle or aircraft in terms of North, East, and Height directions (based on the GPS data). To process the inertial data in forward and reverse, there needs to be periods of static alignment at the beginning and the end of the dataset. Static periods have zero velocity and should be clearly visible at the beginning and the end of the velocity plot, see Figure 5.4. Zooming in may help (right-click on the plot for options – See section 2.6.1 Plot GPS Data for details). Decide on a start time for static alignment at the beginning of the data (where velocity is near zero) and how long it will last. You can right-click on a point on the plot and 'Set IMU Processing Time', preferably during a time of static data at the beginning for forward processing. The same is required at the end of the dataset if you wish to process in reverse. Note that any significant movement will result in an error during static alignment.
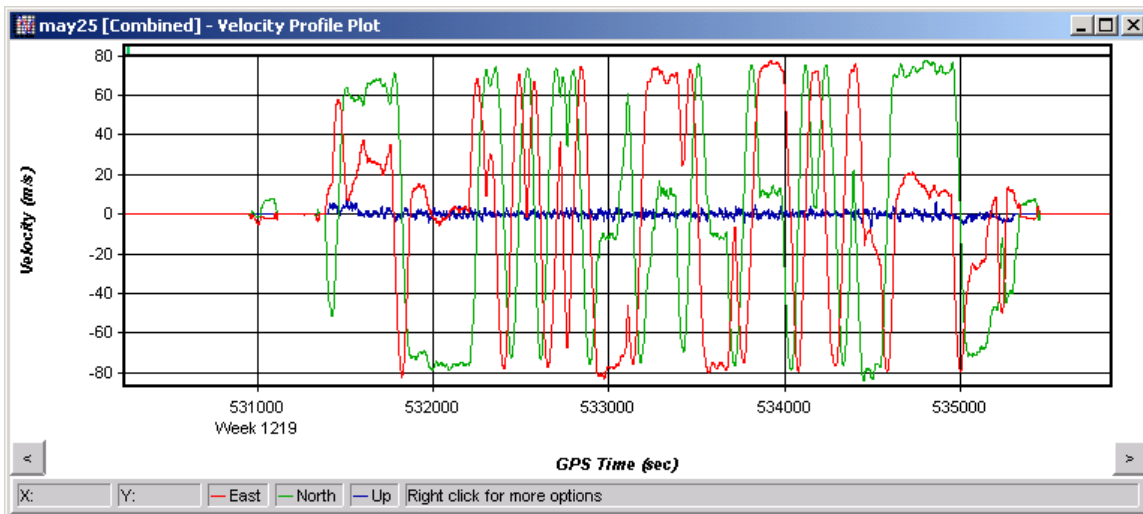
Figure 5.4 Velocity Profile Plot – Used to Retrieve static alignment periods

Step 4:   Process Inertial Data

If necessary the IMU data may need to be converted into generic Waypoint format (*.imr file) using the ConvertIMU utility. See Section 5.7.4 for more details. From the Process Menu, click Process IMU. A dialogue box will appear prompting you for more information. Under the 'General' tab, the path of the IMU data file should be in the Raw Measurement Data File box. If not, click the browse button to locate the path of the binary IMU measurement file. The data format should also be selected from the Data Format box. GENERIC_IMU is Waypoint format (*.imr file). For this tutorial, we will process in the forward direction only. All IMU data will be processed unless it conflicts with the static time that was determined in Step 3 above. Change the begin and end times if necessary. Under the 'Alignment' Tab, select Static Coarse Alignment Only for simple purposes of this tutorial. Under the Initial Alignment Period, set the *Coarse* time (in seconds) of the static alignment time that was determined in Step 3 above. For Figure 5.4 above, as an example, we can use 500 seconds in the forward direction for coarse alignment, although 120 seconds is sufficent. Note that the 'bump' around the 531000 time does not qualify as a static alignment period, so it is best to use the time before it. Next, click on the 'GPS Updates' tab, and under the Source of GPS Updates box, select Project CMB file as the Update File and the path should be displayed below. If the .cmb file is not in the local directory, select Browse External to locate it.

Upon selecting OK, the program will begin post-processing your inertial data. You will notice a window that displays various numbers which shows that your inertial data is processing.

Step 5:   Plotting and Quality Control

Under the Output Menu, choose Plot GPS Data. From the list of options you can show the following IMU plots:

Attitude (Roll and Pitch)	This plot shows the roll and pitch profile of the processed IMU data.
Attitude(Azimuth/Heading)	This plot shows the Heading/Azimuth of the IMU, as well as the GPS COG (Course-over-Ground).
Attitude Separation	If the inertial data was processed in forward and reverse, they need to be combined for this plot. Under the Process Menu, select Combine Solutions, then IMU Forward and Reverse. Plot the Attitude Separation, which will show the difference between forward and reverse inertial processing. Ideally, they should agree very well.
IMU GPS Position Misclosure	This plot shows the misclosure between the GPS solution and the IMU solution.

Step 6:   Export Final Coordinates

From the Output Menu, select Export Wizard. Select the source for the solution. Epochs will output the trajectory, while features will export any loaded features. For photogrammetry users wishing to export interpolated camera positions, event marks must be first loaded (see Section 2.2.10 Loading Camera Event Marks). After selecting a source, a profile must be selected. For Inertial Explorer users, select IMU data as the profile to export coordinates. Click Next. For the Datum screen just use the processing datum. Users may also be prompted for the geoid undulation file. The distribution CD contains a number of Geoids in the Geoids directory.

See Section 2.7.1 Creating Files and Profiles with Export Wizard for more information.

This was a brief overview on how to load a file and process the data. The following sections deal with the additional menus and options that are associated with the inertial software.

Section 4   Processing Options

5.4.1 General Options

Process | Process IMU | General
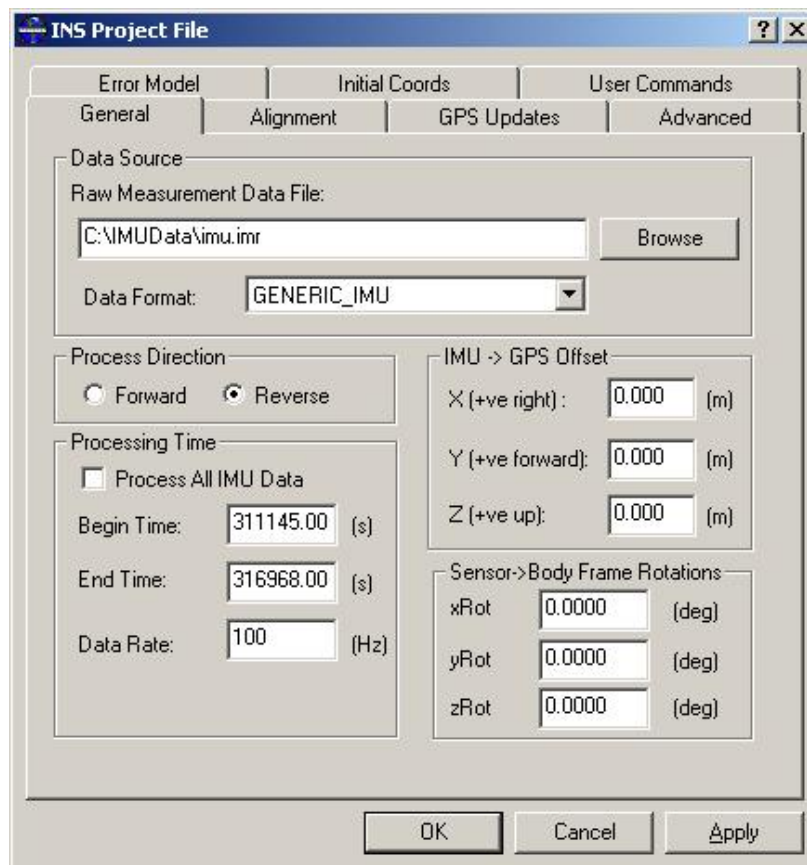
Figure 5.5 General IMU Processing Options

Data Source

Raw Measurement Data File

Contains the path\\filename of the binary IMU measurement file which has been collected from the mission and stored to disk. If not already filled in previously, the Browse button can be used to search for the correct IMU measurement file.

Data Format

Indicates which type of IMU measurement data has been collected. It is important to choose the correct IMU as each inertial unit has different scaling for the delta v and delta theta rate values, as well as different measurement collection intervals. Available data formats include:

LTN90
LASERREF3
LN200
HG1700 (NovAtel BDS)
AG1700
GENERIC_IMU

See page 204 for a general discussion on data formats.

Processing Direction

Forward/Reverse IMU processing is possible in Inertial Explorer. The default mode of processing is forward in time. Reverse processing (in time) is possible with most types of IMU data formats. As with GPS processing the forward/reverse separation of selected quantities can be plotted for analysis purposes.

Processing Time

Process All IMU Data

If this is checked, the software attempts to find the beginning and end times in the raw binary IMU file. These times will be GPS seconds of the week for typical GPS time-tagged applications.

There are some important things to note here:

For forward processing, *Begin Time* may not correspond to some GPS time in the GrafNav FWD/REV/CMB files. If it does correspond, Inertial Explorer will automatically use the GrafNav derived position at the time to seed the inertial processing in the forward direction. For alignment purposes, you may or may not wish to use the *Begin Time* that is automatically detected. There may be a more optimal GPS time at which to begin alignment. In such a case, this time should be entered. This will be mission-dependent and you will wish to choose your time to begin alignment with some care. A poor alignment will result in poor attitude and coordinate information for all or part of the survey.

For reverse processing, *End Time* will have the same considerations as above.

Data Rate
This is a critical value. This is the number of IMU epochs per second collected and time-tagged in your binary IMU measurement file. Inertial Explorer has built-in data rates for most IMU's, but this value should be checked. The integration interval for IMU processing will be 1.0/Data Rate. You will not obtain optimal or even correct results unless the Data Rate is correct. Therefore, it must be known.

IMU -> GPS Offset
It is a requirement to measure the distance in metres from the centre of the IMU sensor array to the centre of the GPS antenna for each mission, if you wish to correctly update GPS and IMU position and attitude information.
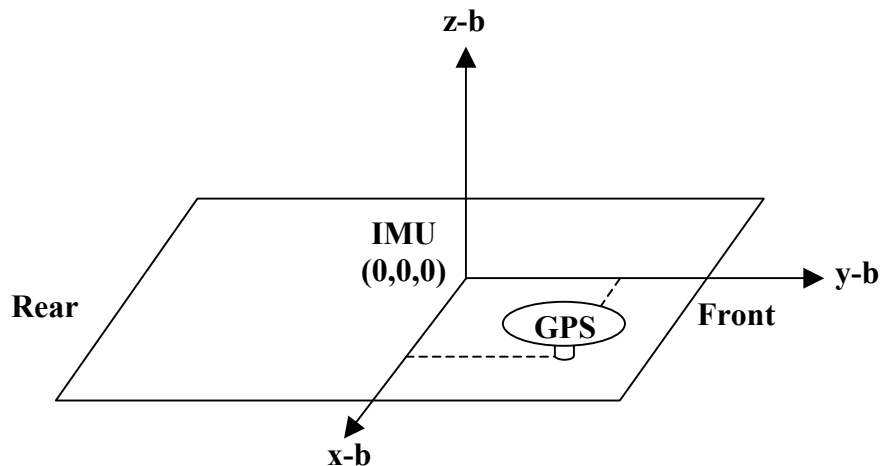
Figure 5.6 IMU - GPS in Body Frame Offsets in Vehicle Body Frame

Figure 5.6 illustrates the relationship Inertial Explorer uses to lever-arm coordinates from the IMU to the GPS antenna. Note the IMU is the local origin of the system.

X (+ve right)
This is the measured lateral distance in the vehicle body frame from the IMU to the GPS antenna out the ride side of the vehicle.

Y (+ve forward)
This is the measured distance along the longitudinal axis of the vehicle from the IMU to the GPS antenna.

Z (+ve up)
This is the measured height change from the IMU to the GPS antenna.

Initial Angular o/s (Usually Zero)
This set of values represents an additional "lever-arm" to the more general one described above. Many typical IMU installations have the surface of the IMU directly attached to for instance the floor of the vehicle, such that the roll, pitch and yaw of the vehicle are

directly experienced by the IMU (i.e. the sensor frame of the IMU) and the body frame of the vehicle are more or less aligned. Some IMU's may be installed in a tilted position with respect to the body frame of the vehicle. If you know these tilts in terms of roll, pitch and yaw, Inertial Explorer will compensate so that the attitude information produced is with respect to vehicle body frame, not the IMU sensor frame.

5.4.2 Alignment Options

Process | Process IMU | Alignment
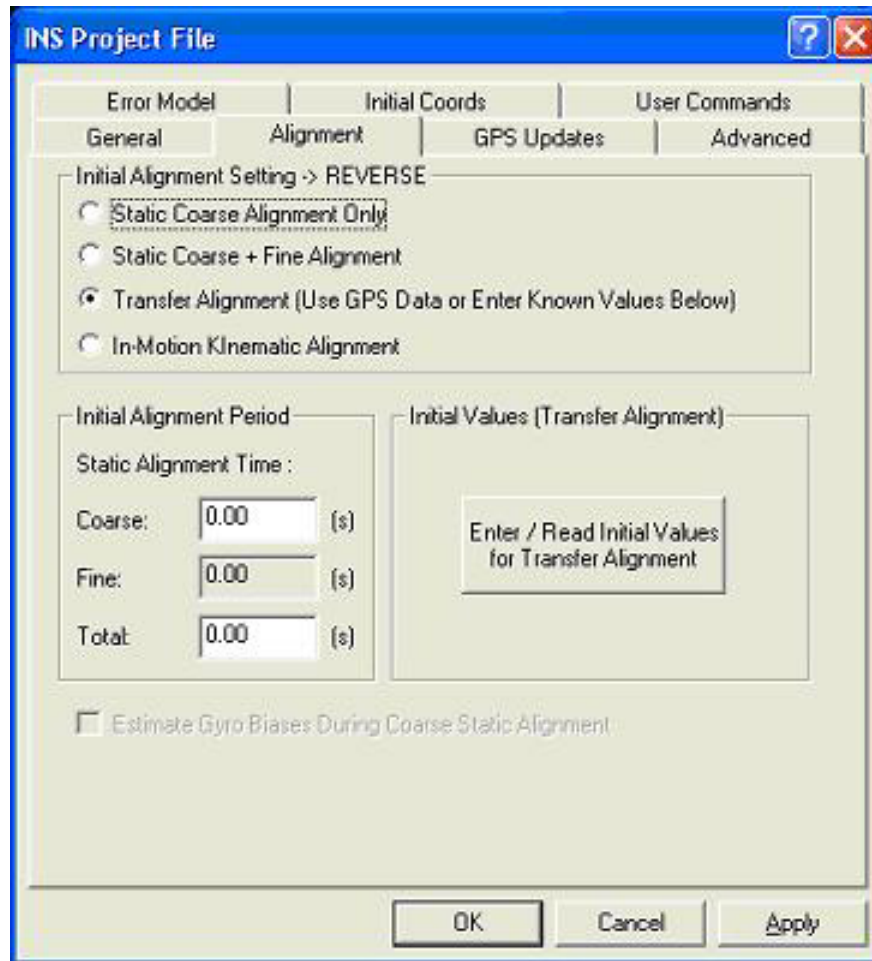
Figure 5.7 Alignment Options

Initial Alignment Setting -> FORWARD or REVERSE
Initial alignment, whether processing forward or reverse, is used to determine the initial roll, pitch and yaw of the IMU sensor axes. These values are used as integration constants in continuously updating the attitude information throughout the mission. These initial values should be determined as carefully as possible in order to insure optimal attitude information for the remainder of the survey. Inertial Explorer provides you with 3 choices, largely depending on how much static IMU data is present at the beginning or end of the survey.

Static Coarse Alignment Only
As this implies, this data must be static in nature. If sufficient motion is detected, a warning will be given the user about it, but it is the responsibility of the user to choose a Begin Time (General Options) which is in a static data period. One of the simplest ways to do this is to plot the Velocity Profile from GrafNav and check where the GPS velocity components are very near zero. Coarse alignment is normally performed for the first 30 – 120 seconds of static IMU data collection and is used to provide a seed value for attitude information for either fine alignment or navigation. Coarse alignment uses the sensed gravity vector components to estimate roll and pitch. It uses sensed earth rate to provide an initial estimate of the yaw of the IMU sensor array. Note that most low accuracy (e.g. MEMS) sensors can more or less measure gravity components, but earth rate (which is 15 arc seconds/second at the equator) may be buried in gyro noise. For inexpensive sensors, Inertial Explorer may consider any sensed gyro rate during coarse alignment to be a bias and uses the data for a coarse calibration.

Note that for many applications involving constant GPS updates, coarse alignment may be sufficient to start kinematic IMU navigation. Coarse alignment only is the default mode for Inertial Explorer.

Static Coarse + Fine Alignment
This may invoke if the IMU is in static mode for any period significantly longer than 120 seconds. Note that 120 seconds is a guideline value only, but many high precision IMU applications recommend about 2 minutes of coarse alignment followed by 8 or 10 minutes of fine alignment. Given constant GPS updates, fine alignment may or may not be necessary. Within say 5 to 10 minutes the GPS updates should provide enough information for the IMU to provide attitude information consistent with the accuracy level achievable by the accelerometer / gyro triad – with or without fine alignment. This will depend on the type of IMU and the user's experience and requirements in their application. After the roll, pitch and yaw are roughly estimated for coarse alignment attitude information to a better level of precision. Again, it is a large mistake to invoke fine alignment if kinematic data is present during the alignment period.

Transfer Alignment (Use GPS or Transfer Known Values Below)
This should be checked if insufficient static data is present in the IMU measurement data. If constant GPS updates are available and the IMU data is of reasonable quality, the attitude information should be determined through GPS updates, even if the initial roll, pitch and yaw are completely unknown (i.e. roll, pitch and yaw are entered as zeroes). It will take longer to converge to highest attitude accuracy, however. How much longer will be a function of the mission type, GPS accuracy and IMU type. If roll, pitch and yaw are known apriori, these values can be entered as initial integration constants and navigation can proceed from these known quantities. Click 'Enter / Read initial values for Kinematic Alignment', see Figure 5.8. If a user processed in the forward direction, and needs attitude values for reverse kinematic alignment processing, clicking this button will scan to the 'End Time' (General options) in the .fim file. It will enter the attitude and velocity and their standard deviations automatically from the 'End Time' epoch. If the time is not available, the user needs to enter the attitude values manually or set the

'End Time' to an epoch that exists in the .fim file. The same idea applies to forward processing, if a .rim file exists. If attitude is unknown for kinematic initialization, leave roll, pitch and yaw as zero and expect sub-optimal results for your survey, especially for the first n minutes of data processing.

Figure 5.8 Input values for transfer alignment

In-Motion Kinematic Alignment
If no static data is available and no a-priori attitude information is available, the user may try to align the vehicle while in motion. The user must choose a short period of time while the vehicle is relatively level and moving in a more or less straight line. The time period can be anywhere from 4 to 40 seconds, depending on the dynamics at the chosen start time. This feature can be useful if large data gaps have been experienced during a mission for some reason. To data, Inertial Explorer has been successful at aligning tactical grade systems in this mode. There is no guarantee that less grade IMU's can be used in this way. It might even be necessary to pick a different Error Model in order to prevent instabilities arising in the Kalman filter. We do continue to recommend a static alignment if possible.

Initial Alignment Period / Static Alignment Time
Coarse and *Total* Alignment Time must be entered in seconds. Begin Time and End Time from General Options must be chosen to correspond to the starting GPS time of the static alignment session. The user must have some knowledge of how many seconds the IMU remained stationary following the begin and end time. Plotting the GrafNav Velocity Profile (see Section 2.6.1 Plot GPS Data) may help here.

The number of seconds of coarse versus *Fine* alignment time depends on what is entered for seconds of coarse align time and total align time. The program subtracts total – coarse to obtain *Fine* align time, should Static Coarse + Fine Alignment be checked. If Kinematic Alignment is checked, the times will simply be zeroed. If Coarse-only is checked the Coarse Time can range from zero to any value up to several hundred seconds. A suitable default mode of operation for Inertial Explorer is Static Coarse Alignment Only with 120 seconds of Coarse Time. Please note that this is somewhat arbitrary. It is the responsibility of the user to determine optimal alignment procedure for their system and task.

Initial Attitude Values (Transfer Alignment)
By clicking 'Enter / Read initial values for Kinematic Alignment' the user can enter the known attitude values for the beginning (forward processing) and/or the end (reverse processing). If the user has already processed in one direction and needs to use kinematic alignment in another direction, this option will scan the epoch output file and automatically fill in the attitude, velocities and standard deviations.based on the start or end times in the General tab. Sometimes the user may need to change the start/end times if they do not exist in the .fim or .rim files.

Estimate Gyro Biases During Coarse Static Alignment
If static mode, any medium or lower accuracy gyro outputs a signal which consists of earth rate plus the bias error for that gyro axis. This can be used by Inertial Explorer to perform a rough calibration of the gyros.

5.4.3   GPS Updates Options

Process | Process IMU | GPS Updates
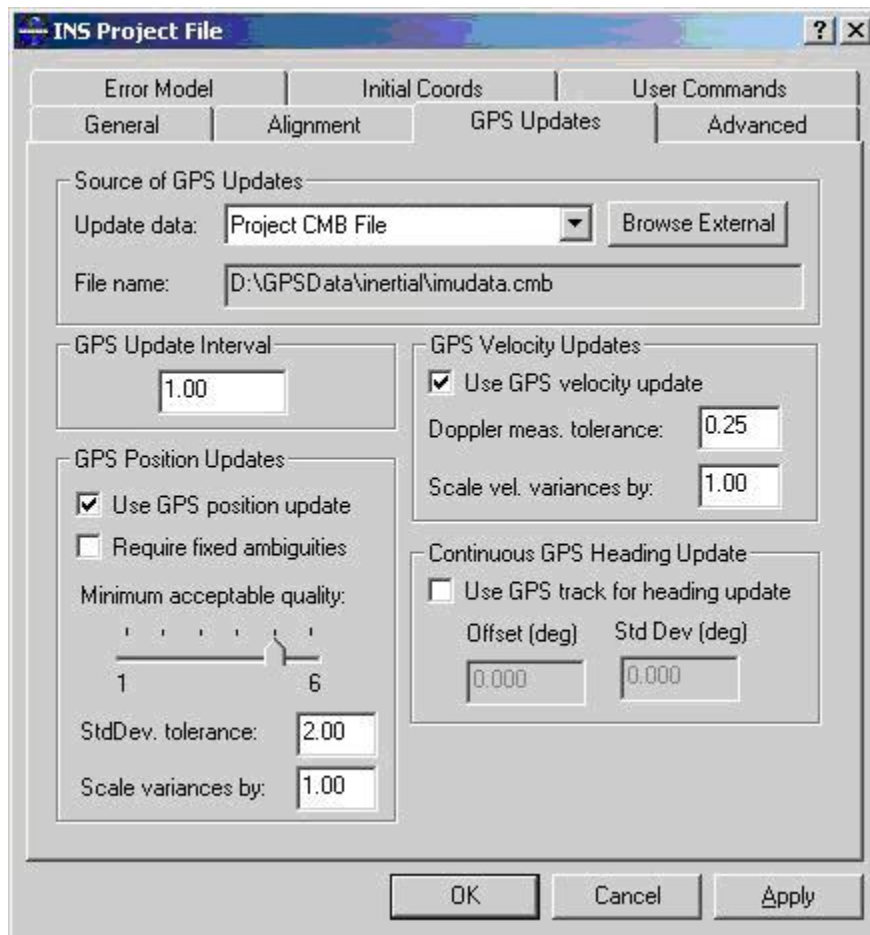
Figure 5.9 Options for GPS Updates

Source of GPS Updates
Inertial Explorer uses previously processed GPS data to update the IMU information.
The format must be GrafNav's ASCII epoch output (e.g. .FWD, .REV and .CMB format).
The default file used to update the IMU is the combined trajectory (GrafNav .CMB file)
for the current GPS/IMU project. This filename is automatically inserted in the *Update
Data* and *File name* box.

Update Data
This indicates which GrafNav FWD/REV/CMB file the user wishes to update the IMU
with. Data can come from the current project or an external FWD/REV/CMB file from a
different project. The drop down list provides choices for this. If External is chosen, the
BROWSE button is un-grayed and the FWD/REV/CMB file can be found through the
standard file dialogue box.

File name
This shows the path\\filename of the FWD/REV/CMB file used to provide IMU coordinate, velocity or azimuth updates.

GPS Update Interval
This is the interval that the GPS updates will take place. The default update interval is 1.00 second but if the GPS data was collected at a higher rate (e.g. 10Hz) then this value can be set to a lower value (e.g. 0.10 seconds) to have more frequent GPS updates.

GPS Position Updates
Use GPS position update
This is checked by default. To process IMU information alone, this box should be unchecked. It should be noted that low accuracy (MEMS type) sensors are not usually reliable unless constant GPS position updates are employed.

Required fixed ambiguities
This should be checked if the user wishes to use only GPS information where KAR has produced Fixed Ambiguities. In general, the IMU has an internal weighting scheme for updates such that low quality GPS updates get correspondingly low weights in the update process. Hence this box can be left unchecked, in principle.

Minimum acceptable quality
This uses the GrafNav quality number to filter out unacceptable GPS update information. The default setting is a 5, which typically indicates GPS coordinate information at the one metre level. Any GPS information with a quality number of 5 or lower is used to update the IMU at any given time match. The quality number used is application dependent and should be determined by the user based on requirement and precision of the IMU. For MEMS sensors, 5 make some sense whereas for navigation grade IMU's a better quality number should most likely be chosen.

StdDev tolerance
This reflects the standard deviation of the GPS coordinates as determined by GrafNav. GPS determined coordinates with a standard deviation (trace of the covariance matrix) above the given value will not be used for IMU updates. Tolerances used will depend on mission and grade of IMU.

Scale variances by
Allows the user to increase or reduce the variances determined by GrafNav. This variance information is used by the IMU filter in is Kalman update routines to weight the GPS position update. It is recognized that the covariance information produced by the GPS filter is generally optimistic and this is a simple way of providing the IMU filter with a more realistic update variance for the input position information from GrafNav.

GPS Velocity Updates
Use GPS velocity update
This is checked by default. If you do not wish to have the IMU filter use GPS velocity information as update information, uncheck this box. GPS velocity updates are optional.

GrafNav uses Doppler information to compute GPS-derived velocity components. It should be pointed out that Doppler accuracies vary significantly from receiver to receiver. The Doppler RMS can be viewed (after processing GPS) via the Advance Plotting Screen. In addition, the Doppler Measurement Std. Dev. used by the GPS Kalman filter can be controlled from the standard deviation tab of the different GPS processing options. The default value may not be optimal. *Doppler meas. tolerance* is set by default to 0.25 m/sec. Any GPS velocity information with an RMS residual value of less than 0.25 m/sec is used as velocity update quantities in the IMU filter. The IMU filter will not use GPS derived velocities from data with RMS values above this value.

Scale vel. variances by
This is used to reduce or increase the covariance information related to GPS velocity. See the explanation for Position Updates.

Continuous GPS Heading Update
Use GPS track for heading update
GPS course over ground (COG) can be computed from the GPS velocity components. If the forward pointing axis of the IMU is more or less aligned in some known orientation with the longitudinal axis of the vehicle, GPS COG can be used as a direct azimuth update. Care should be taken when using direct azimuth updates, as it may be difficult to guarantee the IMU is aligned with the vehicle body axis. Aircraft crab angles are one example of errors which can produce significant differences. On the other hand, some low accuracy (MEMS) sensors may not produce meaningful heading information in any case and this may be a useful update.

Offset (deg)
This option allows the user to enter a known constant offset between the forward axis of the IMU sensor triad and the forward axis of the carrier.

Std Dev (deg)
This is the estimated error in the constant value given in the Offset box.

5.4.4 Advanced Options
Process | Process IMU | Advanced
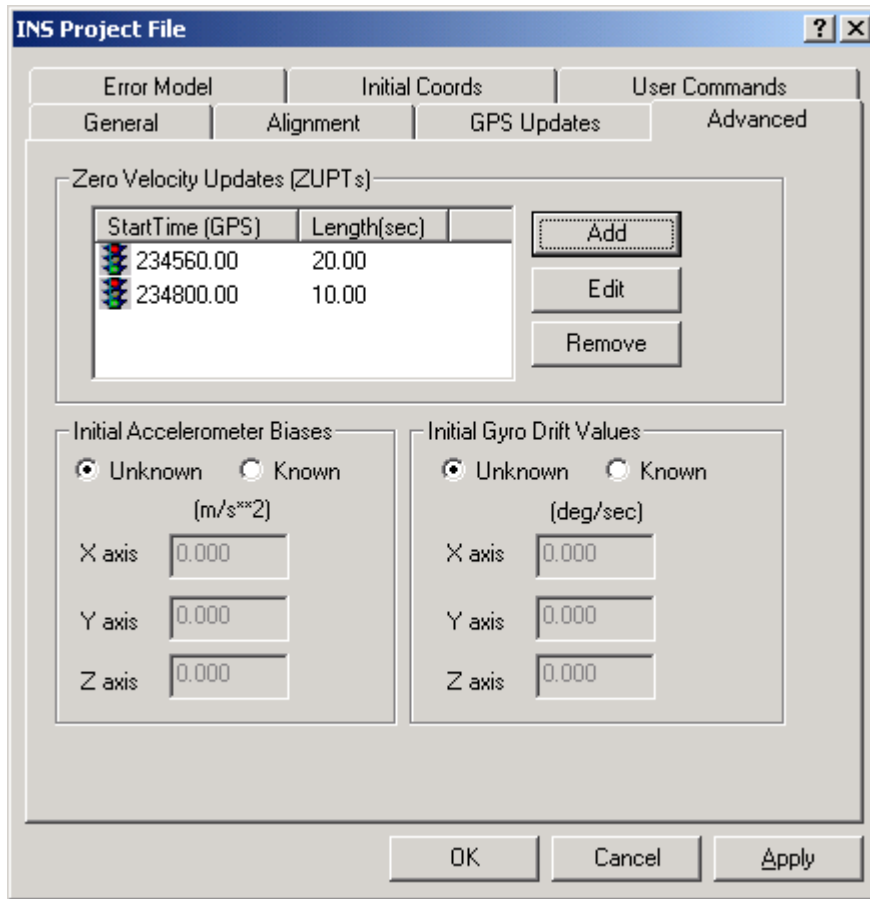
Figure 5.10 Advanced IMU Options

Zero Velocity Updates (ZUPT**s)**
Inertial Explorer can take advantage of zero velocity updates as long as the user marks the start time of the ZUPT while in the field, along with the duration of the ZUPT. As illustrated in Figure 5.11, the start time of the ZUPT must be in GPS seconds of the week (presuming that you have time-tagged the IMU to GPS time), while the duration of the ZUPT is simply the number of seconds of static occupation. 10 seconds is the minimum recommended time for a ZUPT.
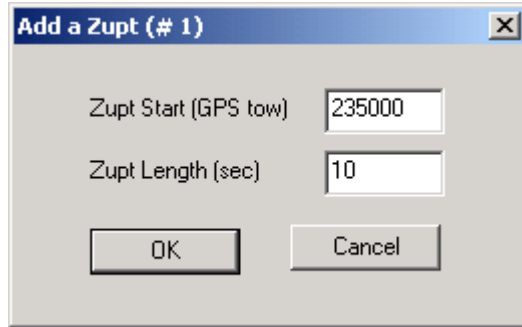
Figure 5.11 Adding a ZUPT in Advanced Options

When Inertial Explorer reaches the 'ZUPT Start (GPS tow)', it will assume static data is present for at least 'ZUPT length' seconds and will use zero velocity as an update. ZUPTs are probably redundant for data sets with constant GPS updates of good quality. For GPS data sets in tree cover or urban canyons, ZUPTs can still be a valuable way of bounding inertial error.

Initial Acceleration / Gyro Drift Biases
Inertial sensors tend to have biases in their sensors which can be defined as a long-term constant. These values may be calibrated by manufacturers especially for tactical or navigation grade units and can be subtracted during processing from each delta v and delta theta measurement. The user may or may not have access to these values. If so, they may be entered here. Users may also wish to perform their own calibration on one mission, and use the values for subsequent ones.

Inertial Explorer does not expect the user to have any knowledge of constant biases. Instead, it attempts to calibrate the sensors through the alignment and update process throughout the mission. Hence these values will usually be zero for most applications.

It should be noted that highest accuracy would be achieved for inertial units with predictable and known turn-on to turn-on biases. However, the procedures for rigorously calibrating inertial sensors with off-line procedures involving rate tables and so on are outside the scope of the Inertial Explorer software.

If you do have knowledge of the accelerometer and/or gyro drift biases they may be entered in metres/sec^2 and decimal degrees/sec. It is important to note the definition of the axes here. Inertial Explorer defines:

The *X-axis* is positive out the right side of the vehicle (facing the rear) and defines pitch rate.
The *Y-axis* is positive out the nose of the vehicle and defines the roll rate.
The *Z-axis* is positive up and defines yaw rate.
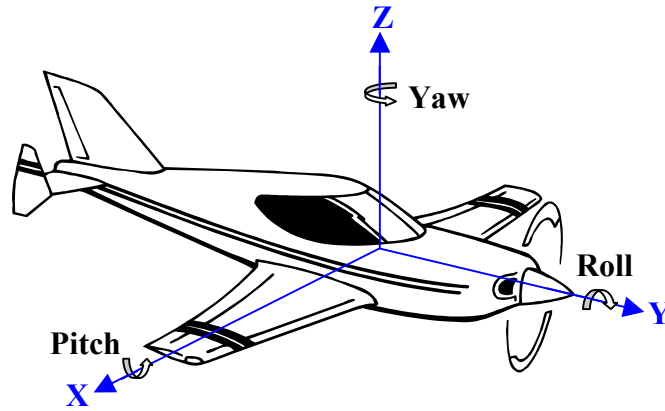
Figure 5.12 XYZ-axis Definition

If your IMU has a different X, Y, Z sensor frame definition, this should not represent a problem. Just note which of your axes measure pitch rate and enter this in our X-slot, with the appropriate sign – and similar for roll and yaw.

5.4.5 Error Model Options

Process | Process IMU | Error Model

Figure 5.13 Building and Saving Error Models for Different IMU Types

Set IMU Kalman Filter Error Model Values
This is one of the most important aspects in IMU processing. In general, the more inexpensive the sensor package, the more "tuning" will have to be performed to find initial variances and spectral densities that work optimally for your particular IMU. For some MEMS sensors, it is critical that you choose spectral densities that match the sensor noise of your system. In some cases, IMU processing will not work at all without a properly chosen error model. You can choose one of the error models provided they can build an error model of their own and save it under *Add IMU Type* and *Set Values*. Building an error model can be a trial and error process and may be required for custom IMU packages. More expensive tactical or navigation grade systems will need much less tuning and for many applications the error models provided are sufficent.

In general, the poorer the sensor the larger the spectral density required for the misalignment, gyro, and accelerometer noise process. Recall that spectral densities add

noise to the covariance propagation process prior to filtering. The higher the density, the more emphasis is placed on the update measurement during filtering. The less precise the sensor, the more we will rely on GPS updates to carry the IMU process.

IMU Type
This drop down-list box shows the list of error models that come with Inertial Explorer. These models really consist of an identifying name together with lists of variances and spectral densities.

Navigation (High Precision)	Contains Kalman filter parameters suitable for systems such as the Honeywell LaserRef. IMU's such as this have gyro dirft rates at the level of 0.01 degreee/hr or better.
Tactical (Medium Precision)	It stores values corresponding to medium grade systems such as the LN200 from Litton or the HG1700 from Honeywell with drift rates listed at 1 – 10 degrees/hr.
Automotive (Low Precision)	Relates to lower grade units than Tactical. This error model may also be useful for situations where alignment is poor or non-existent and the user wishes to allow the filtering process to "loosen-up" to compensate for poor field conditions.

Custom error models may be added and stored for later use, as explained in the following sections.

Add IMU Type
User-defined error models may be added by clicking the Add IMU Type button. The dialogue box shown in Figure 5.14 will appear.
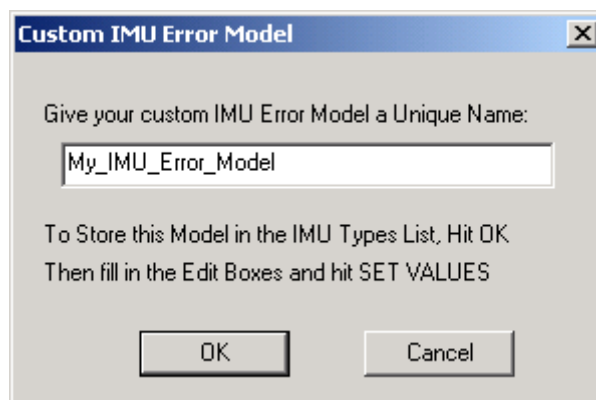
Figure 5.14 Adding a Custom Error Model Name to the IMU Types List

Type in a name which suits the particular IMU or application. This name will be stored in the IMU Type list in the file called User.imu, provided the user click Set Values button after filling in the Initial Standard Deviation and Spectral Density values.

Initial Standard Deviation
Misalignment
In general this relates to the difference between the computed direction cosine matrix relating the IMU body frame to the computation frame (ECEF in the case of Inertial Explorer) and an error free idealized direction cosine matrix or attitude matrix. The initial Misalignment Standard Deviation in arc seconds represents the best estimate on the ability of the user's sensor package to estimate roll, pitch and yaw during the coarse alignment period (if any). Roll and pitch are estimated from the sensed gravity components in the horizontal axes of the accelerometer triad, while yaw is computed from the sensed earth rate around the leveled gyro axes. Typically, even MEMS sensors can make some estimation of roll and pitch. Earth rate is buried in noise on any IMU's lower than tactical grade. In any case, the initial misalignments in x and y (the horizontal axes corresponding to pitch and roll) may be an order or magnitude less than in z (corresponding to yaw). If in doubt, simply make these large values in the order of thousands of arc seconds. The IMU Kalman filter will eventually estimate some reasonable values for misalignment uncertainty (i.e. error in the computation of the "attitude matrix").

Accel Bias
Represents an initial uncertainty in your knowledge of the constant bias errors in the accelerometer triad. This value is in metre/second^2 and will be dependent on the precision of each sensor array. Recall that we often enter the accelerometer bias as zero (i.e. unknown and the initial uncertainty should reflect this).

Gyro Drift
In arc seconds per second pertains to knowledge of initial uncertainty in sensor drift in the gyros. Again, the assumption that the gyro drift is unknown and large values are acceptable here to reflect this. The IMU filter will attempt to resolve accelerometer and gyro biases on-the-fly.

Spectral Densities
Misalignment
A Misalignment noise density in arc seconds squared per second becomes a covariance when multiplied by some time interval δt. If the sensor triad has problematical ability to provide you with an accurate attitude matrix or you have poor alignment capabilities for whatever reason, you may have to introduce large spectral density values for misalignment. These spectral components will add noise to the computed Kalman covariances for misalignment. This in turn will force the update computations to rely more heavily on the GPS coordinate and velocity information at each update epoch. This in turn will hopefully help compensate for large errors in the direction cosine matrix.

Accel Bias
Accel Bias densities when multiplied by the prediction time interval act as additive noise to the accelerometer bias states. Larger accelerometer noise densities may aid in compensation of large biases in these sensors.

Gyro Drift
Gyro Drift densities similarly act as additives to the covariances computed for the gyro drift states. In many cases, larger gyros densities are necessary for inexpensive gyro sensor blocks.

Tuning a Kalman filter with correct noise values is extremely important especially for MEMS sensors. It may be necessary for custom IMU packages to experiment with widely varying values for the spectral quantities. Once, you have determined optimal values for your sensor package, name, and store the Error Model.

Remember – to store a custom model, user must click the Set Values button, after filling in the specific entries for variances and densities.

5.4.6 Initial Coords Options
Process | Process IMU | Initial Coords
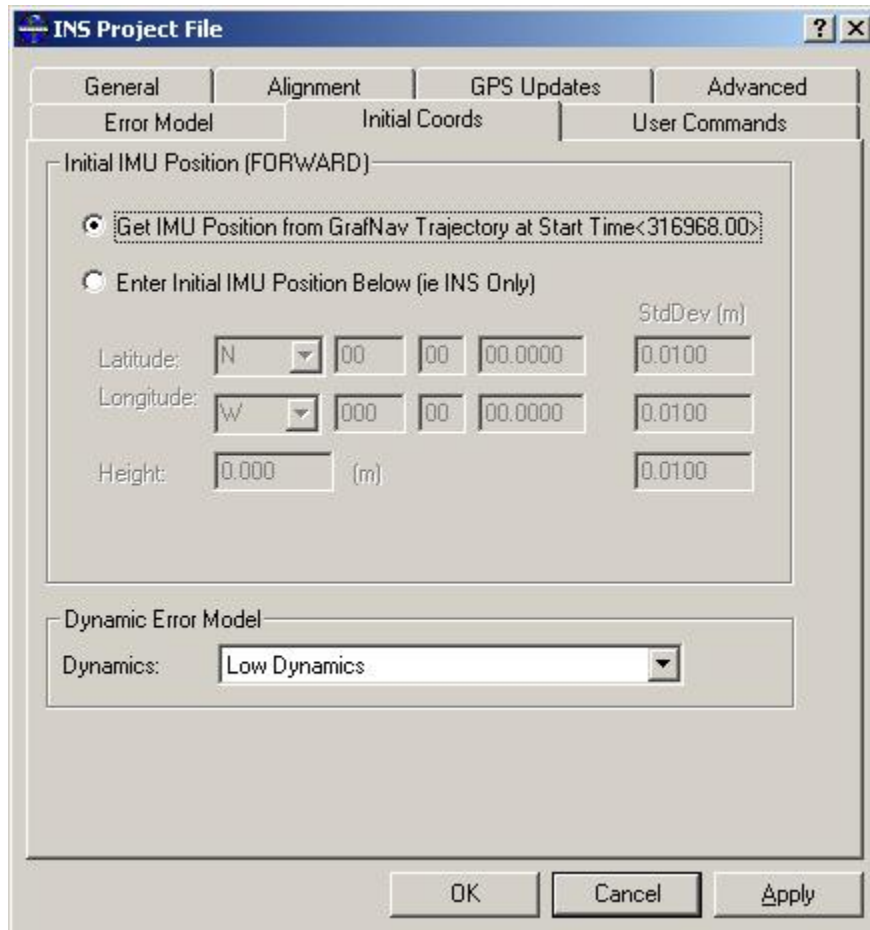
Figure 5.15 Initial Coords Options

Initial IMU Position (Forward/Reverse)
The initial position of the IMU sensor array must be known for the inertial integration process to begin. Inertial Explorer will automatically lever arm derived GPS coordinates from the GrafNav fwd/rev/cmb file, provided the IMU Begin or End Time specified under General Options can be found in the GrafNav file. Alternatively, user can enter the initial coordinates manually or change the Begin and End time. Be careful when entering custom coordinates in kinematic applications. If the start/end time is changed, the coordinate will beed to be altered as well.

Dynamic Error Model
This value can be left at *Low Dynamics* for most applications. *High* or *Extreme Dynamics* really provide a higher spectral density for the coordinate and velocity states. These would not be invoked unless the user is unsure about the coordinate updates for timing or other reasons.

5.4.7 User Commands
Process | Process IMU | User Commands
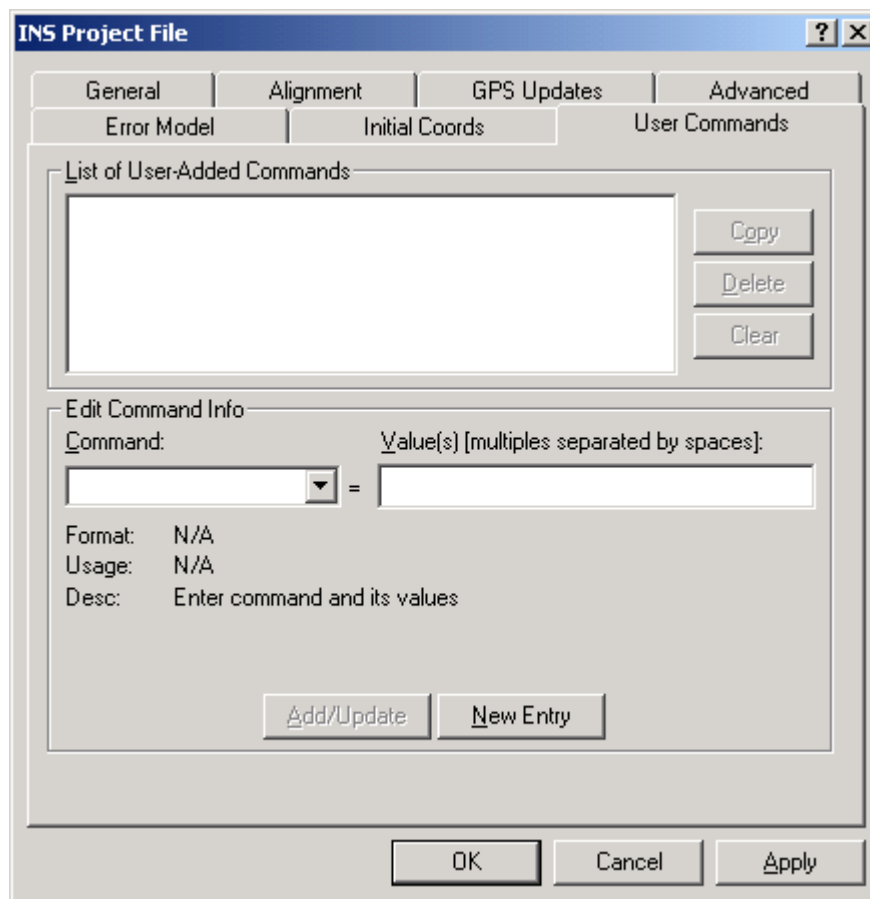
Figure 5.16 User Entered Commands

Some Inertial Explorer options may not be available from the dialogue boxes provided. A full list of configurable options is available under User Commands and may be invoked by users whos wish to try special features or overwrite defaults.

For an explanation of all Inertial Explorer commands, please see the Appendix.

Section 5   IMU Processing Display

After choosing the OK button on the Ins Project File wizard described in detail above, the following screen will appear with processing output displayed.
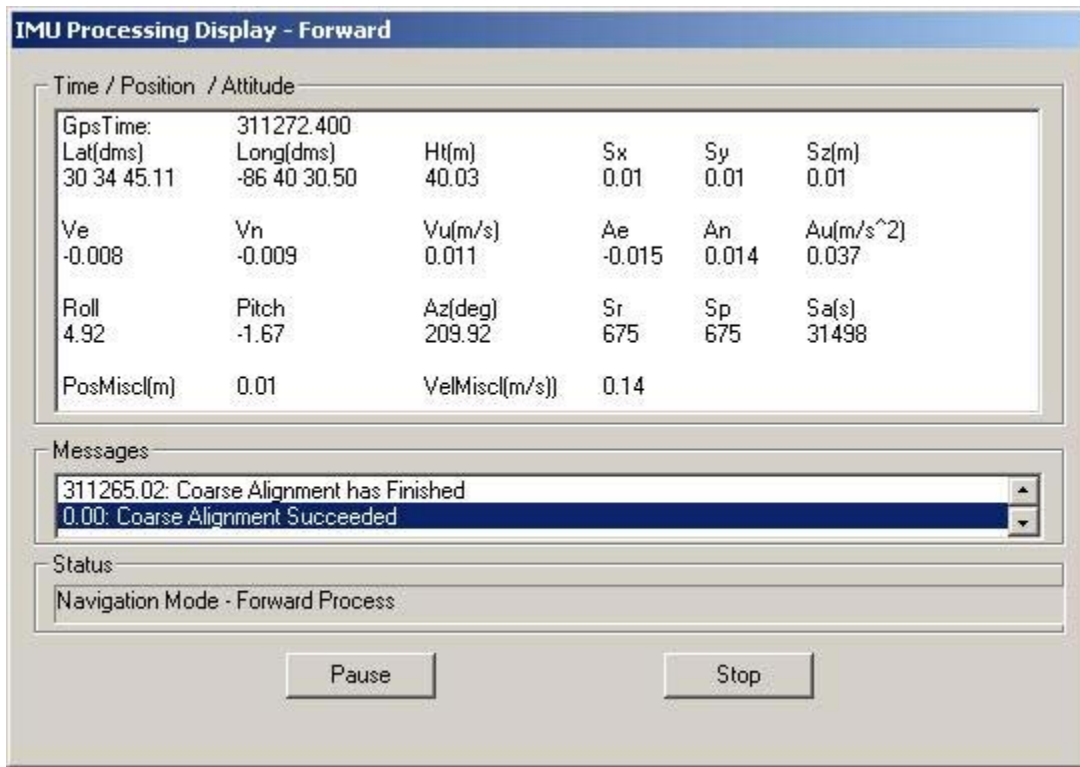
Figure 5.17 IMU Processing Display

Time / Position Atttitude
GpsTime shows the current GPS seconds of the week for the IMU record being processed.

Latitude, longitude and height are shown in degrees, minutes and seconds in the first 3 columns. The next 3 columns show the associated standard deviation of the processed IMU coordinates respective to latitude, longitude and height in metres.

Ve, Vn and Vu represent the inertially derived velocity components in east, north and up directions in m/s. The next 3 columns are the current local level accelerations with

gravity and Coriolis effects removed. These are then the vehicle accelerations in the east, north and up directions along with residual bias effects not removed by the Kalman filter. Units are m/s^2.

Roll, Pitch and Yaw are presented in degrees, along with standard deviation in the same units. The roll and pitch values should be assessed as you process.   If your IMU has been placed on a level surface, these should reflect reasonable values relative to the motion of the vehicle. Invalid roll and pitch values, especially for inexpensive IMU's can be the result of an incorrectly chosen Error Model. Incorrectly decoded binary data files can also cause inappropriate values to appear here.

PosMisc in metres and VelMisc in metres/second display the current difference between the GPS derived coordinates and velocity and the corresponding mechanized IMU quantities. These misclosures between GPS and IMU represent a good idea of the stand-alone capability of your inertial system over the time interval between GPS updates.

Messages can be watched for events or errors in the IMU processing DLL.

Status provides an idea of whether you are in alignment or navigation mode or have completed processing.

Section 6   List of Available IMU Plots

Attitude (Roll and Pitch)   **Novice**
Plots the Roll and Pitch values from GPS/INS processing.
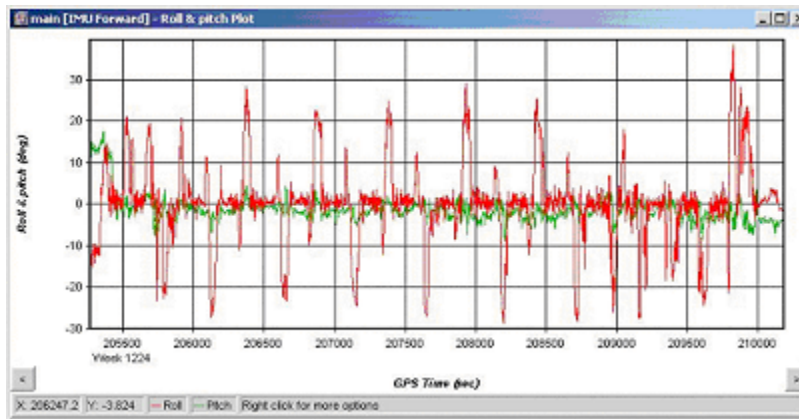
Figure 5.18 Roll and Pitch Plot

In airborne data, it is common to see roll values between ± 30 degrees and pitch values of around ± 10 degrees, depending on the flight pattern of the aircraft itself.

Attitude (Azimuth/Heading)   **Novice**
Plots the heading and GPS COG (Course-over-Ground) that was computed from the GPS/INS processing. Effects of crabbing will be visible in this plot if the GPS COG is constantly offset from INS heading. The *IMU Heading COG Difference* Plot shows the difference between these two heading values.
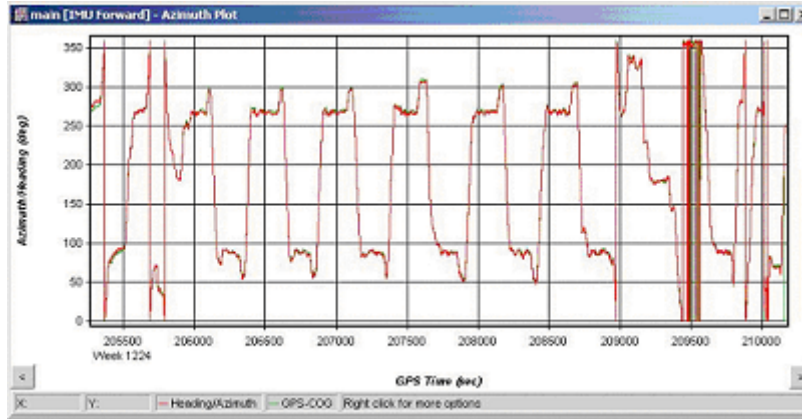
Figure 5.19 Heading/Azimuth Plot

Any transitions between a heading/azimuth of 359 degrees and 0 degrees will show up as a vertical bar in this plot.

Attitude Separation   **Novice**
This plot requires forward and reverse IMU solutions to be combined. To combine forward and reverse IMU solutions, select the *Process | Combine Solutions | IMU Forward and Reverse*. Basically, this plot shows the difference between the combined solutions in terms of Roll, Pitch, and Heading.
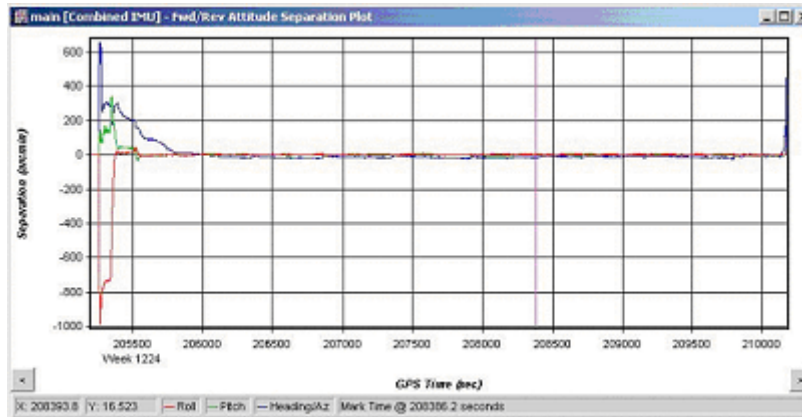
Figure 5.20 Attitude Separation Plot

Ideally, a zero separation means a match in solutions in the forward and reverse IMU processing. It is common to see spikes at the beginning and the end of the data, as the ambiguities are being resolved into integers at those times.

Estimated Attitude Accuracy   **Novice**

This plot shows the estimated accuracy (standard deviation) computed in the GPS/INS Kalman filter in terms of Roll, Pitch, and Heading.
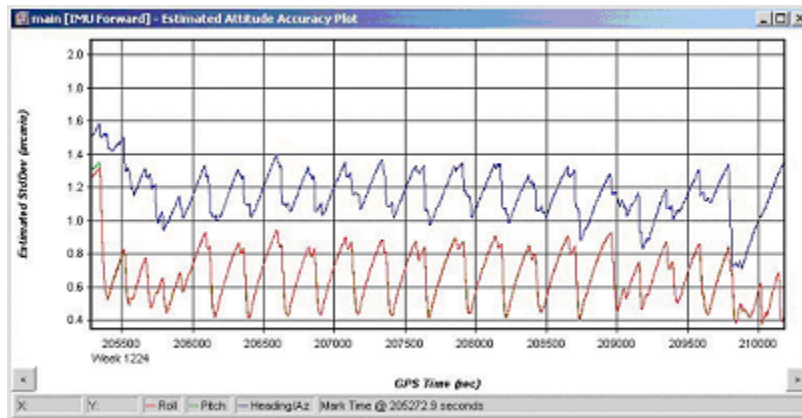
Figure 5.21 Estimate Attitude Accuracy Plot

Estimated Gyro Drift Accuracy   **Intermediate**

This plot shows the estimated standard deviation of the gyro drift rate. This plot generally decreases with time. It is plotted in terms of the X (right direction), Y (forward direction), and Z (up direction) of the INS body.

Figure 5.22 Estimated Gyro Drift Accuracy Plot

Estimated Accelerometer Bias Accuracy   **Intermediate**

This shows the estimated standard deviation of the accelerometer bias. It is plotted in terms of the X (right direction), Y (forward direction), and Z (up direction) of the INS body.
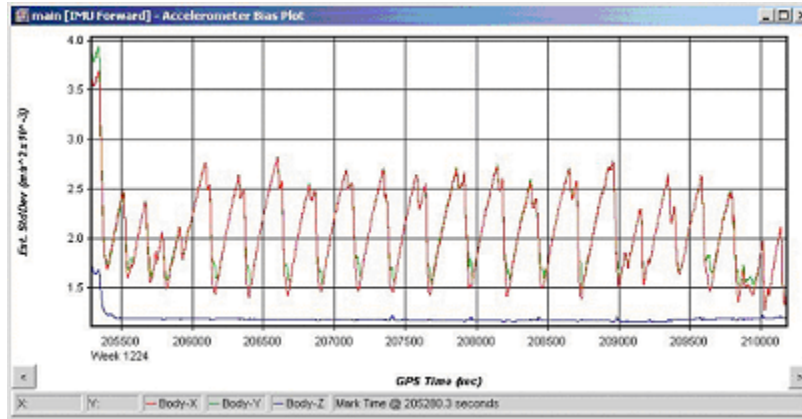
Figure 5.23 Accelerometer Bias Accuracy Plot

IMU Accelerometer Bias   **Intermediate**

This is the apparent output in acceleration when there is no input acceleration present. It is computed by the GPS/INS Kalman filter and the effects may be sinusoidal or random. It is plotted in terms of the X (right direction), Y (forward direction), and Z (up direction) of the INS body. Generally they should stabilize after the alignment period and agree when processed in both directions.
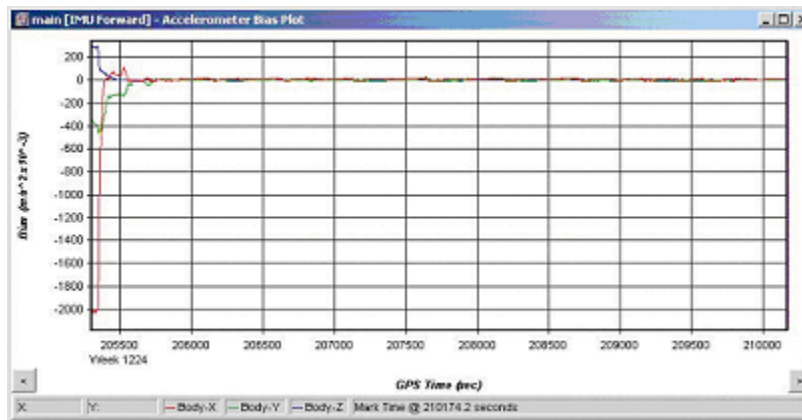
Figure 5.24 Accelerometer Bias Plot

IMU Angular Rates   **Advanced**
This plot shows the gyroscope rate of change of attitude in the X, Y, and Z axes of the
IMU body with the drift removed. This plot is used to check the gyros.
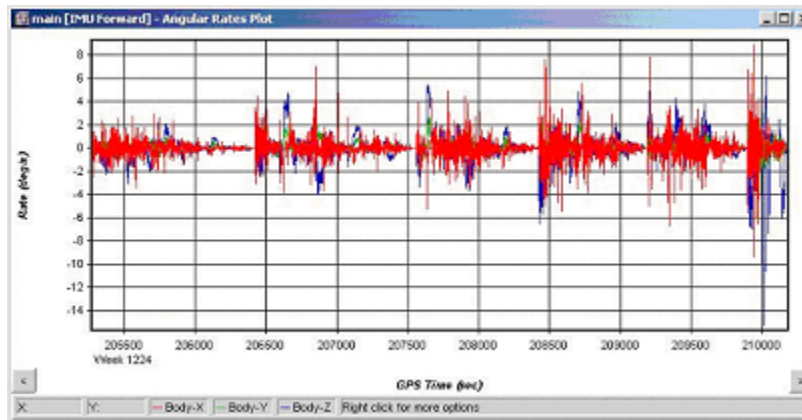
Figure 5.25 Angular Rates Plot

IMU GPS Position Misclosure   **Intermediate**
This plot shows the difference between the GPS solution and the mechanized INS
positions obtained from the GPS/INS processing. This is a good analysis tool used to
check the GPS/INS solution as well as checking INS stability. Large jumps or spikes
may indicate a bad INS solution.
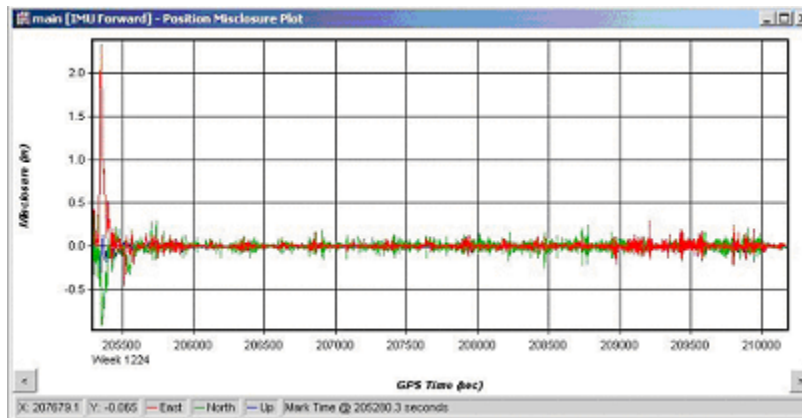
Figure 5.26 IMU/GPS Position Difference Plot

A near zero separation will confirm the GPS solution.

IMU GPS Velocity Misclosure **Intermediate**

This plot shows the difference between the GPS calculated velocity and the mechanized INS velocity obtained from the GPS/INS processing. Another good analysis tool used to check INS stability.
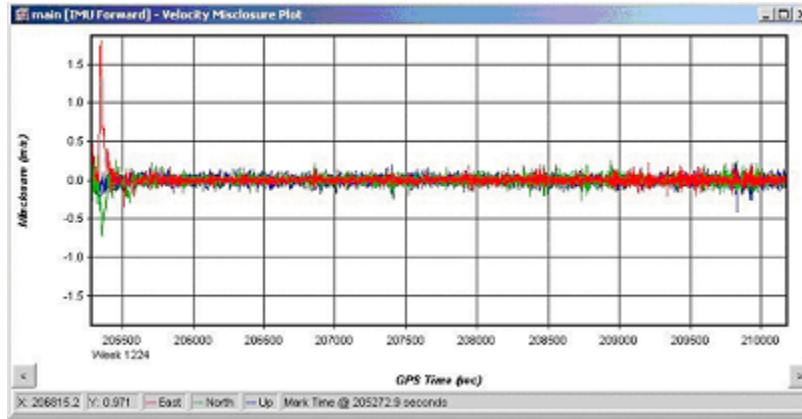
Figure 5.27 IMU/GPS Velocity Difference Plot

IMU Gyro Drift Rate **Intermediate**

This is the apparent change in angular rate over a period of time. It is computed by the GPS/INS Kalman filter and the effects are usually random. It is plotted in terms of the X (right direction), Y (forward direction), and Z (up direction) of the INS body. Generally they should stabilize after the alignment period and agree when processed in both directions.
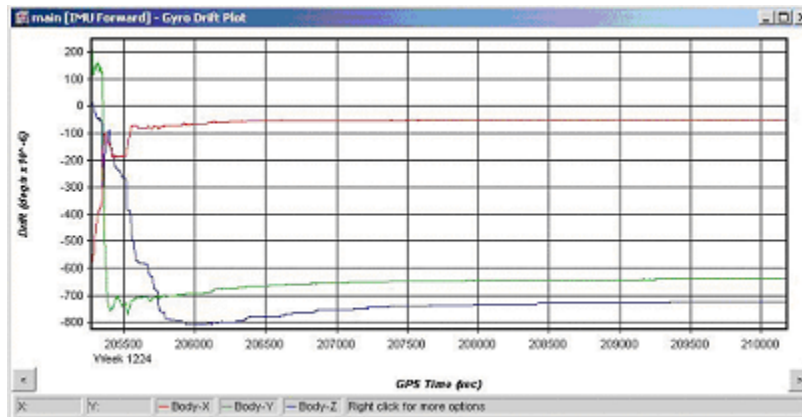
Figure 5.28 IMU Gyro Drift Plot

IMU Heading COG Difference   **Advanced**
This plot is the difference between the IMU heading and the GPS Course-over-Ground values. The absolute IMU heading/GPS COG can be seen in the Attitude (Azimuth/Heading) Plot.   Effects of crabbing will show up as a direct bias in this plot.
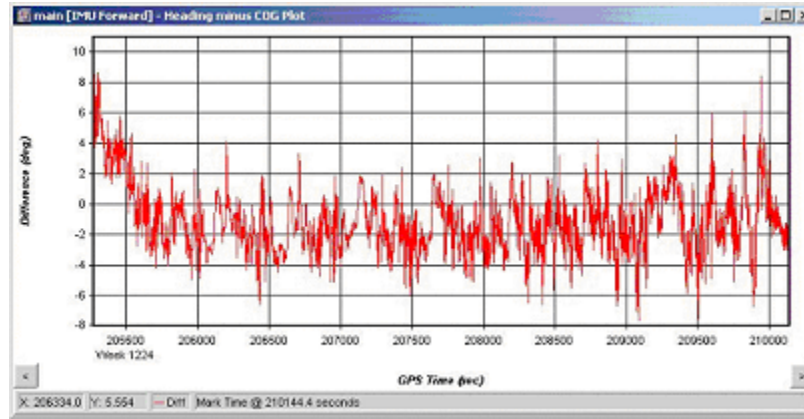
Figure 5.29 IMU Heading/COG Difference Plot

Section 7   IMU File Format

5.7.1   .FIL or .RIL file

The message log file simply echoes all error and warning messages sent to the message window during INS processing. Some example messages are shown here:

Coarse Alignment Succeeded on attempt #1
Coarse alignment was successful.

Reading GrafNav Record: 1000
Scanning the GPS/IMU data before processing.
Warning: Coarse Alignment has used up all of the Align Time. Will Continue Processing anyway...
INS processor used all the coarse alignment time entered.

Warning - GUPT Missing in GPS data -> DT: 0.200
Gap in GPS data of time DT seconds – the processor cannot use this time as a GPS update.

Warning: Trace of Body-Earth matrix < 0 after update
Check on Fix: 1-tr{C} of transform matrix (0.056389)
Mathematical computation warning.

5.7.2 .FIM or .RIM or .CIM file

This is the output format common to other Waypoint output files. Note that the first line of the output file always begins with $OUTREC, and is followed by the version number, the processing engine, and the type of output. An example is given below as the first line:

$OUTREC Ver1.00 INSDLL Forward InsOutput
An example of the output format is shown below. A description of the variables and the units are also shown, followed by a numerical example.

```
$OUTREC Ver1.00 INSDLL Forward InsOutput
Eg {
Tim: InsGpsTime InsGpsTime GpsWeek#                          ; Gps_seconds_of_week
Geo: latitude(dms) longitude_ins(dms) ht_ins(m)
Loc: d_east(m) d_north(m) d_ht(m) vel_east(m/s) vel_north(m/s) vel_up(m/s)
Var: Cee Cnn Cup Cve Cvn Cvup TraceCpos                      ; m² m²/sec²
Att: Roll(deg) Pitch(deg) Azimuth(deg) Roll_sd(deg) Pitch_sd(deg) Azimuth_sd(deg)
Drf: GyroX(deg/sec) GyroY(deg/sec) GyroZ(deg/sec) GX_sd(deg/sec) GY_sd(deg/sec)
GZ_sd(deg/sec)
Bia: AccelX(m/s²) AccelX(m/s²) AccelX(m/s²) AX_sd(m/s²) AY_sd(m/s²) AZ_sd(m/s²)
Rat: Gx(deg/sec) Gy(deg/sec) Gz(deg/sec) Ax(m/s²) Ay(m/s²) Az(m/s²)
Ecf: ECEF_X(m) ECEF_Y(m) ECEF_Z(m)
Kal: MisalignX(arcsec) MisalignY(arcsec) MisalignZ(arcsec) dX(m) dY(m) dZ(m) dVx(m/s)
dVy(m/s) dVz(m/s)
Mis: GPS-IMU_east(m) GPS_IMU_north(m) GPS-IMU_up(m) GPS-IMU_ve(m/s) GPS-IMU_vn(m/s) GPS-
IMU_vu(m/s) GPS_Course_over_ground   Acc: AccelEast(m/s²) AccelNorth(m/s²) AccelUp(m/s²)
Ang: RollRate(deg/s) PitchRate(deg/s) YawRate(deg/s)

}


Out {

Tim: 594669.000 594669.000000 1135
Geo: 51 06 01.50907 -114 01 16.90259 1065.3495 0.000
Loc: -0.428 344.213 -0.620 0.084 37.222 -0.121
Var: 4.23411e-004 3.88634e-004 2.95252e-004 8.91871e-001 -4.08521e-008 -1.32678e-005
1.10730e-003
Att: -1.5958 2.6190 0.3802 1.89049e-002 2.52198e-002 7.65137e-002
Drf: 1.14593e-006 -1.36657e-007 -1.76144e-008 2.68329e-005 2.68407e-005 2.68488e-005
Bia: -1.29293e-002 -2.65716e-003 3.38231e-003 3.23914e-003 2.83102e-003 1.17864e-003
Ecf: 108.816 245.212 215.669
Kal: 15.2 -22.9 9.2 -0.023 -0.021 -0.013 -0.007 -0.006 -0.004
Mis: -0.028 -0.068 0.017 -0.037 0.020 -0.008 0.180
Acc: 0.077 0.265 0.242
Ang: 0.1364 0.2175 0.0864

}
```

5.7.3 Generic Binary Input Structure

GENERIC RAW DATA FORMAT

Waypoint puts all custom IMU raw binary formats into a generic format which is read from Inertial Explorer following the decoding process in CONVERTIMU (see Section 5.7.4 for further details). The first 512 bytes of the Generic IMU Data Format is a header which must be filled in and must be read and interpreted as it contains vital information for reading and decoding the data.

In a C/C++ structure definition, the generic format header has the following fields:

```
typedef struct
{
  char   szHeader[8];        // $IMURAW[0] -> NULL terminated string
  char   bIsIntelOrMotorola; // 0 - Intel (little endian) - default
                     // 1 - Motorola (bit Endian) - swap bytes for IExplorer
                     // This can be set for any user who directly writes in our
                     // format with a big endian processor. IExplorer will swap
                     // the bytes
  double dVersionNumber;     // ie 2.00
  int    bDeltaTheta;        // Default 1 which indicates the data to follow
                     // will be delta theta's meaning angular increments
                     // ie scale and divide by fDataRateHz to get degrees/second
                     // If the flag is set to 0, then the data will be read directly
                     // as scaled angular rates
  int    bDeltaVelocity;     // Default 1 which indicates the data to follow
                     // will be delta V's meaning velocity increments
                     // ie scale and then divide by fDataRateHz to get metres/second**2
                     // If the flag is set to 0, then the data will be read directly
                     // as scaled accelerations
  double dDataRateHz;        // ie 100.0 records for second
                     // if you do not know it, set this to zero
                     // then fill it in from the interface dialogue boxes
  double dGyroScaleFactor;   // Scale (multiply) the gyro measurements by this to get
degrees, if iDeltasOrRates=0
                     // Scale the gyros by this to get degrees/sec, if iDeltasOrRates=1
                     // if you do not know it, then the data can not be processed !!
                     // Our default is to store the gyro data in 0.01 arcsec increments
                     // or 0.01 arcsec/sec, so that
                     // GYRO_SCALE = 360000
  double dAccelScaleFactor;  // Scale (multiply) the accel measurements by this to get
metres/second, if iDeltasOrRates=0
                     // Scale the accels by this to get metres/second/second, if
iDeltasOrRates=1
                     // if you do not know it, the data can not be processed
                     // Our default is to store the accel data in 1e-6 m/s increments
                     // or 1e-6 m/s/s, so that
                     // ACCEL_SCALE = 1000000

  // defines in INSDLL.DLL
  // IMU_TIMEFRAME_GPS   0  -> raw data file uses GPS sow
  // IMU_TIMEFRAME_UTC   1  -> raw data file uses UTC - convert to GPS
```

```
    int    iUtcOrGpsTime;      // are the time-tags in UTC or GPS seconds of week
                               // 0 - do not know (our default is GPS)
                               // 1 - UTC
                               // 2 - GPS


    // defines in INSDLL.DLL
    //  IMU_GPS_TIME_FRAME  0 -> GPS timetags are corr_time
    //  IMU_RCVR_TIME_FRAME 1 -> GPS timetags are rcv_time

    int    iRcvTimeOrCorrTime; // are the GPS time tags in the nominal top of the second
                          // or are they corrected for receiver time bias
                          // 0 - do not know (our default is corrected time)
                          // 1 - receive time on the nominal top of the epoch
                          // 2 - corrected time ie corr_time = rcv_time - rcvr_clock_bias

    double dTimeTagBias;       // default is 0.0, but if you have a known
                          // millisec level bias in your GPS->INS time tags
                          // enter it here


    // space reserved
    char Reserved[447];        // total header size is 512 bytes

} ImuGenericHeaderType;
```

where

szHeader[] is a NULL terminated ASCII C string - $IMURAW[0]. This must be present.

bIsIntelOrMotorola – 0 indicates Intel format. If a 1 is filled in, all bytes will be swapped in both the header and data records.

dVersionNumber – ie 1.00.

bDeltaTheta – if 1, then Inertial Explorer will expect the gx, gy, and gz gyro.measurements to be delta theta's ie angular increments not angular rates. If 0, Inertial Explorer will assume all gyro measurements are given as angular rates.

bDeltaVelocity– if 1, then Inertial Explorer will expect the ax, ay, and az accelerometer measurements to be delta v's ie velcocity increments not accelerations. If 0, Inertial Explorer will assume all accel measurements are given as accelerations.
dDataRateHz – this is the data rate at which the inertial measurements have been stored ie 100.00

dGyroScaleFactor – when Inertial Explorer reads the 4 byte gx, gy, and gz gyro measurement values it will scale by this number to go from long integer to either a gyro increment in degrees or an angular rate in degrees/second.

dAccelScaleFactor – when Inertial Explorer reads the 4 byte ax, ay, and az accelerometer measurement values it will scale by this number to go from long integer to either a velocity increment in metres/second for the given time period or an acceleration value in metres/second/second.

iUtcOrGpsTime – time frame for the IMU time tags - if 0, unknown and Inertial Explorer assumes GPS time frame, if 1 UTC time frame is used in processing the data, if 2 then 0Inertial Explorer assumes GPS time frame for the binary IMU measurement tags.

iRcvTimeOrCorrTime – the GPS receiver time frame – if 0, unknown and Inertial Explorer assumes the GPS time tags have been corrected for receiver clock bias, if 1, it is assumed the GPS time tags are at the nominal top of the GPS epoch (uncorrected), if 2 Inertial Explorer assumes the GPS time tags have been corrected for receiver clock bias.

dTimeTagBias – if there is a known offset in the GPS->IMU time tagging system, it can be entered here. This would be typically at the millisecond level. Inertial Explorer will SUBTRACT this value from all time tags in the measurement structures. **Note that the default is 0.0000 and should be filled in as such.**

Reserved[] bytes for future use. It is suggested that these bytes be zeroed.

The single header is followed by a structure of the following type for each IMU measurement epoch.

```
typedef struct
{
  double Time;       // gps time frame – seconds of the week
  long   gx,gy,gz;  // delta theta or angular rate depending on flag in the header
  long   ax,ay,az;  // delta v, or acceleration depending on flag in the header

} INS_type;         // this is the binary structure type expected in GPSIMU
```

Time is given in GPS seconds of the week. The angular increments or rates gx, gy, and gz are scaled long integers. The scale factor to obtain a double precision word must be supplied in the header. Similarly, the accelerations or velocity increments are signed 4 byte words and must be scaled by a double precision variable given in the header.

5.7.4   Waypoint IMU Data Conversion

wconvertimu.exe is a Win32 application program that converts custom formats into a GENERIC raw IMU data format. The generic format that we use is described in Section 5.7.3 . To convert IMU data to Waypoint's GENERIC raw IMU data format, click the

 icon in Inertial Explorer or click File > Convert > Raw IMU data to Waypoint Generic (IMR). See Figure 5.30 below.
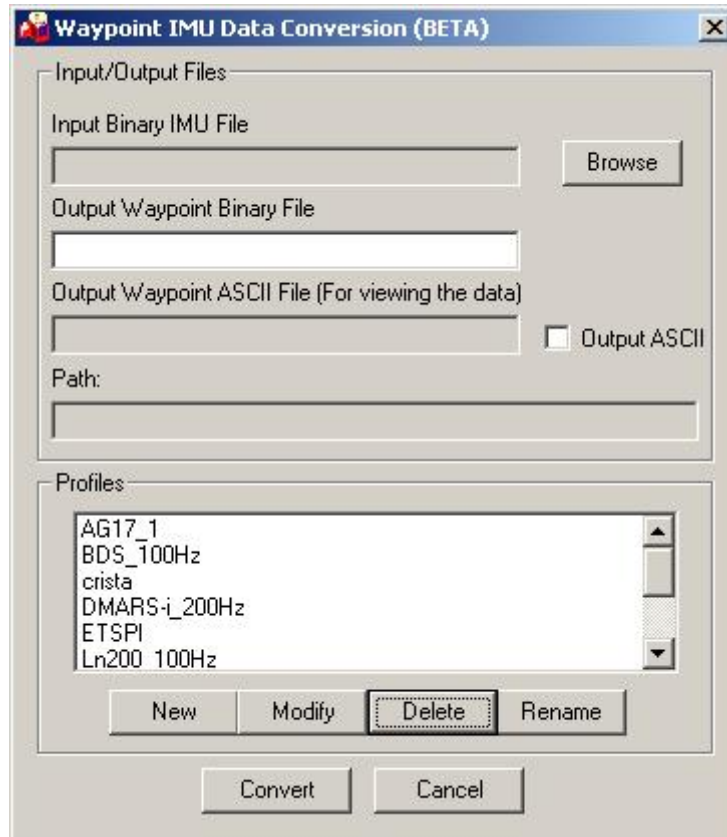
Figure 5.30 wConvertIMU interface

Click Browse to locate the path of the input IMU file to be converted to Waypoint's GENERIC format. The binary output file will be in the generic format and will have an .imr extension. An ASCII output file (.out) can be generated if the Output ASCII option is enabled. This will output the first 10000 epochs showing the GPS time, XYZ Gyros and XYZ acceleration. It is useful to check after converting to observe if there are any errors while converting or if the correct scale factor was used. Select a profile that applies to the input IMU data and click convert to begin converting the data. If the profile of the IMU type is not in the list, a new profile will need to be created.

5.7.4.1   Creating a new profile in wConvertIMU

For users who have their own scale factors, data rates, and orientations in their raw data files can create a profile to convert their unique format to Waypoint's Generic format. Open wConvertIMU and click 'New'. See Figure 5.31 below.
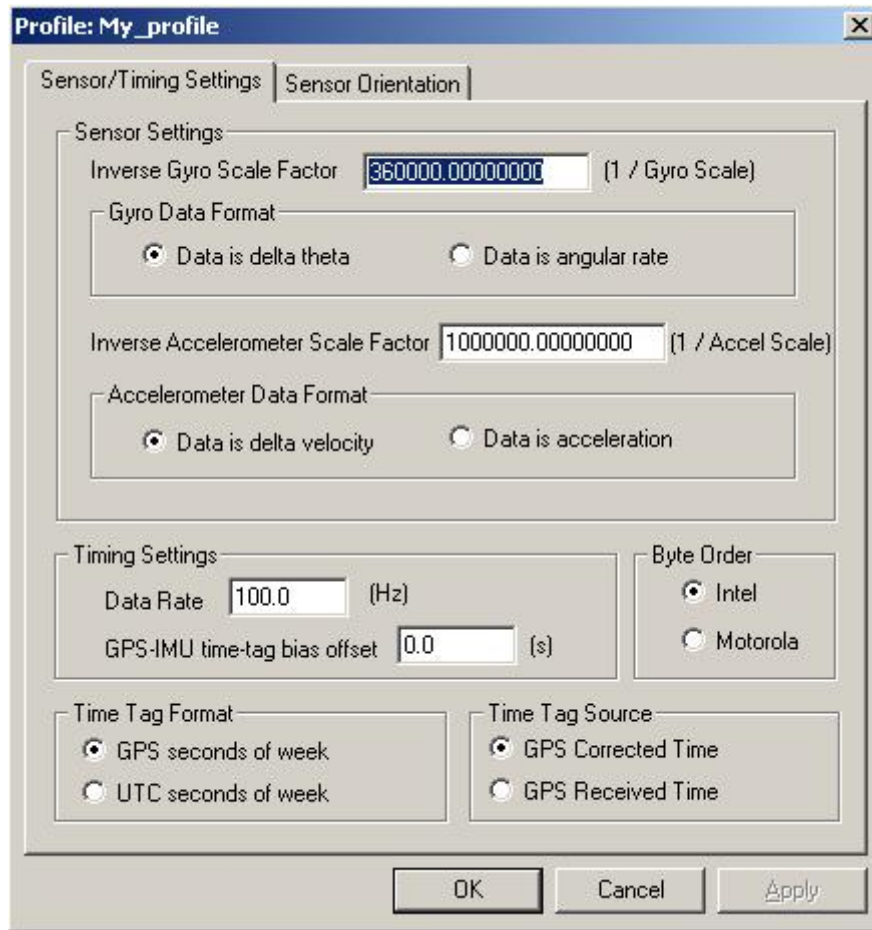
Figure 5.31 Creating a new profile in wConvertIMU

The scale factors can be entered at this point. Note that the INVERSE value of the scale factors must be entered (e.g. if the scale factor is 0.0004 = 1/2500, so enter 2500). The format of the gyros can be delta theta (angular increments) or the angular rate. The accelerometer can be delta velocity (velocity increments) or acceleration.

The data rate of the IMU can be entered as well as any time tag offsets between the GPS and the IMU. It is important that the correct byte order is set as either Intel or Motorola otherwise the decoding phase will report errors. The time tag format can either be GPS seconds of the week or UTC seconds of the week. The time tag source can be the GPS corrected time or the GPS received time.

To define the orientation of the IMU, click on the sensor orientation tab, as shown in Figure 5.32.
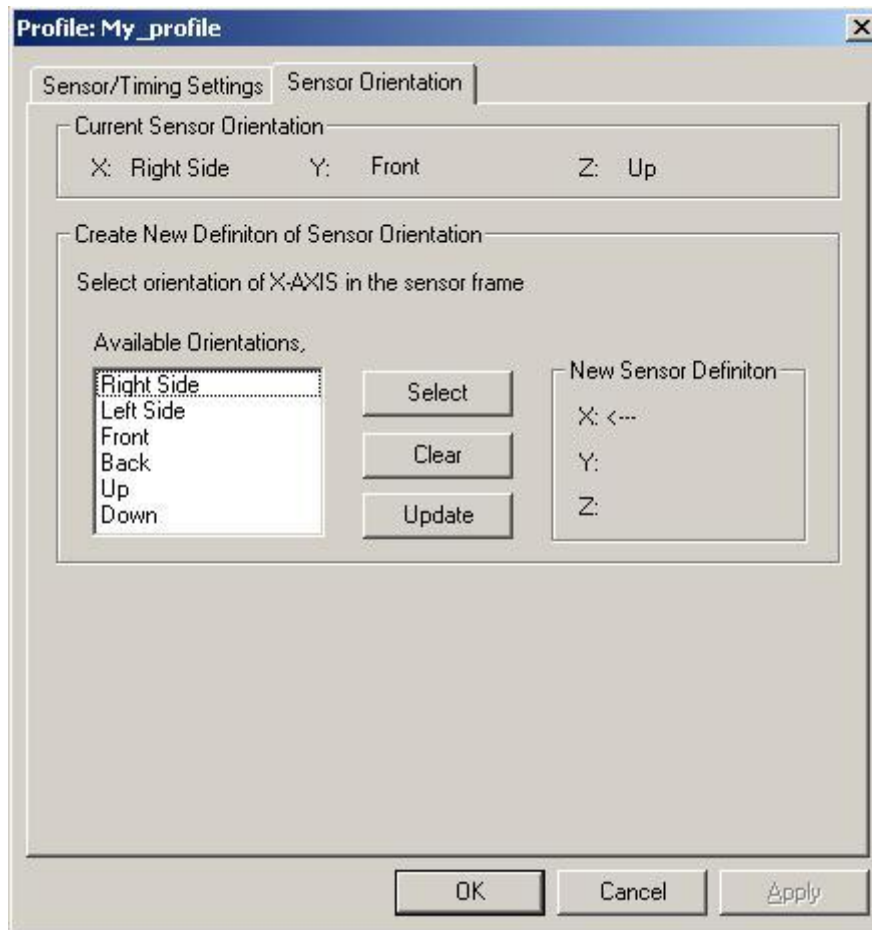
Figure 5.32 IMU Sensor Orientation Dialogue Box

The current sensor orientation is shown at the top of the window. To define a new sensor orientation, follow these steps (note that the orientation will always be right handed):

- The X direction will be selected first. Pick the direction that corresponds to the X-axis of the sensor frame. Click 'Select' to set that direction to the X-axis.
- The Y direction will be selected next. Pick the direction that corresponds to the Y-axis of the sensor frame. Click 'Select' to set that direction to the Y-axis.
- The right handed frame will complete itself automatically at this point. Click 'Update' to apply the new sensor orientation. If a mistake was made, click clear to start over.

Click OK to set the new profile. It should now be in the list of profiles to convert the IMU data.

5.7.5 Binary INS Data Files .BIF, .BIR (Output)

A .imu file is the raw binary measurement data file that contains the INS data. For more information, see Table 5.1 IMU Data Formats.

The following is the data structure for a binary .bif and .bir files:

```
typedef struct              // holds latitude, longitude and height
{
    double  phi,lamda;          // degrees
    float  ht;                  // metres
}   plh_type;

typedef struct
{
    double x,y,z;
}   xyz_type;

typedef struct
{
    float x,y,z;
}   fxyz_type;

typedef struct
{
    signed long iRoll, iPitch, iYaw;          // sf=1.0e-6
}   iatt_type
```

```
typedef struct
{
    char    Str[16];                // $IMUOUT (see IMU_HDR_STR above)

    long    HdrSize;                // size of this header
    long    IsExtended;             // true if exended format used (use later)
    long    RecSize;                // size of this record
    long    Reserved1;              // for later, zero
    double  Interval;               // data interval (s)
    char    ProgramName[32];        // program name that created this file
    char    VersionName[32];        // version that produced file
    char    Direction[16];          // "Forward","Reverse" or "Combined"
    char    Reserved2[392];         // reserved space for additional information (zero at
creation of new file)

}   imu_hdr_type;

// normal record defininition
typedef struct                 // 80? bytes
{
    double  GpsTime;           // GpsTime of this record (0-604800)
    short   WeekNum;           // week number
    short   Reserved;          // reserved for future flags

    plh_type  GeoPos;     // geographic position of this record (deg/m)
    fxyz_type LLVel;      // local level velocity (m/s)
    fxyz_type LLAcc;      // local level acceleration (m/s^2)

    iatt_type LLAtt;           // local level attitude (deg) (scaled)

    //fxyz_type LLPosSd;   // Position standard deviation
    //fxyz_type LLVelSd;   // velocity standard deviation
    //iatt_type LLAttSd;     // standard deviation of attitude values

    float   fPosTrace;   // trace of position covariance (m)
    float   fVelTrace;   // trace of velocity covariance (m/s)
    float   fAttTrace;   // trace of attitude covariance (deg)

}   imu_outrec_type;
```

Chapter 6   Utilities

Section 1   COMPARE

The 'Compare' utility is a Windows command line utility that compares multiple .LAT files. It is located in the GrafNav distribution directory, which is usually "C:\Program Files\WayptGPS". 'Compare' can also be found in the 'DosUtils' directory on the GrafNav\GrafNet CD-ROM. It is useful for comparing solutions from different base stations or solutions using different processing options. The easiest way to use the utility is to write the coordinates using geographic and decimal degrees. It will only compare epochs, and it will not compare stations (features).

Compare.exe can be used as follows:

Usage: compare file1 file2 outfile [-i interval] [-ecef] [-xyz] [-d]

Where,

-i interval	force comparison on this interval [default=use all]
-neh	read north east height instead of decimal degrees
-ecef	read in XYZ ecef and do comparison by rotating using the coordinates from file1 using WGS84 ellipsoid
-d	Compute slope distances
-s	N,E on one file, E,N on the other, switch the first one
-c	Contain decimal degrees to -180 - 180

Section 2   DUMP

DUMP is a command line utility that can be used to log data from any serial source in a dumb fashion. That is, it will log byte for byte any data originating from the source. DUMP is called as follows. DUMP is located in "DosUtils" directory on the GrafNav/GrafNet CD-ROM.

Usage: dump [Fname] [-h] [-a fname] [-l fname] [-b baud] [-p port] [-n]
          [-nmea] [-r str interval] [-u ioaddr irq] [-f seconds]

DUMP will NOT log to file unless a logfile is specified on the command line. DUMP will prompt for the baud rate and COM port. Parity is assumed to be none. Data bits is 8. Stop bits is 1. The following commands can be issued within DUMP.

where,

fname	same as -l option
-h	this help screen
-l fname	log to file named fname
-a fname	append to file named fname

-n	do not ask for port parameters use [com1: 9600-n-8-1]
-b baud	overwrite -n baud rate to baud
-p port	overwrite -n comport number to this number (1-4)
-r str interval	request nmea record (e.g. GGA) at specified interval
-u ioaddr irq	com6: user port assignments (-n option)
-w	start watchdog timer
-e echo_port	echo GGA out receiver port n (usually 2)
-c echo_baud	echoed data goes out at this baud rate
-f seconds	re-open the files every n seconds [default =300.0]

Section 3   GPBView

GPB files are in a binary format, and thus cannot be viewed with a normal text editor. GPBView allows you to both view your data, and edit it in limited ways. A picture of the program is shown below.
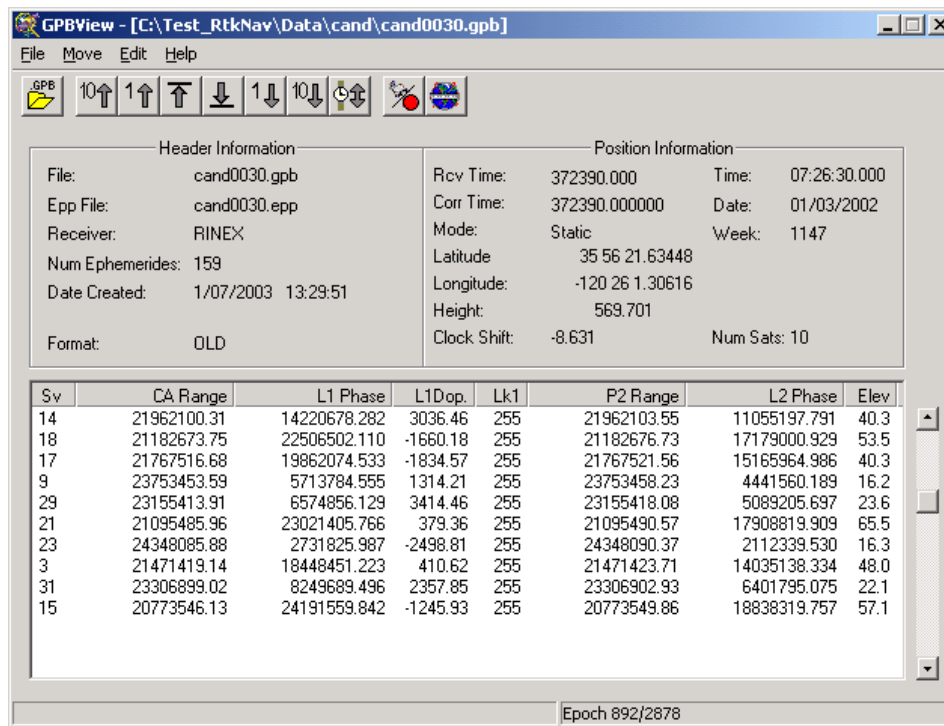
Figure 6.1 GPB Viewer

6.3.1   Why Use GPBView?

If you were unable to switch the remote data from KINEMATIC to STATIC or vice-versa while collecting data, you can change the kinematic marker in the binary file. This is also useful if you did not use the real-time logging software provided. This is important if you wish to process kinematic data. Go to the epoch where the kinematic/static is to start. To change the process mode, go to the Edit Menu and choose Switch Static/Kinematic, select From Current Location, Specified Epochs, and enter the

number of epochs that you wish switched. Choose whether the data will be switched to Static or Kinematic. If you know the start and end time, just select Specified Time Range and enter the start and end times. Note that if you want to convert the entire file, simply select All Epochs and From Start.

- If you have cycle slip problems, you can go to the epoch with the problem by using the Search option under the Move menu, which allows you to search by Second, Epoch or H.M.S. By examining the phase and phase rate (Doppler measurement) at the previous epoch, you can compute what the phase measurement at the present epoch should be.
  Phase$_t$ = phase$_{t-1}$ + phase_rate$_{t-1}$ * time_interval + Δ + clockcorrection

- If a data record is corrupt, simply because the serial data was bad or the receiver clock jumped for one epoch, you can eliminate this record. From the edit menu, choose Disable Satellite(s). This will zero pseudoranges for one or more epoch(s) for a given satellite and will remove this/these epoch(s) from processing.

- Add and remove cycle slips on the receiver. These cycle slips can be edited using the Add/Remove Cycle Slips from the Edit Menu. Cycle slips can be removed by selecting Remove Cycle Slip. The cycle slip can be added by selecting Add Cycle Slip.

- Recompute position and clock correction records. This option can be found under the Edit menu, Recalculate Position. This is useful for:
  - Computing a position where one did not exist, or
  - Correcting erroneous or bad clock shift data causing processing data errors. NOTE that ephemerides must exist - use the file/ephemeris option to specify another file containing the proper ephemeris.

- Recompute Doppler can be found under the edit menu. If the velocity during or after processing seems flawed (e.g. extremely high values), the Doppler may be corrupted. To fix this is to recalculate the Doppler values in GPB Viewer. Select to recompute by C/A if the data is kinematic or by the ephemeris if the data is static.

- Edit Meteorological Values. This feature will allow the user to edit the GPB file pertaining to the environmental conditions for better troposphere modeling. A .trp file will be created that the processor will look for when processing GPS data. Information regarding the new troposphere parameters will appear in the forward/reverse message log after processing. Meteorological values should be entered for both stations (i.e. master and remote). If not, the post-processor will utilize the entered values of one of the stations for both. Only the effect of height difference will be accounted for. It is suspected whether this is better than using the internal estimated values.

6.3.2 How to Use GPB View?

The File Menu allows you to open or close a .GPB file. The Load Alternate Ephemeris command is useful to print proper GMT H:M:S times or to recalculate position and clock shift. Also, the ephemeris file must be loaded in order to search for H:M:S.

The Move Menu is used to move through the list of epochs. The choices are Forward 1 epoch, Forward 10 epochs, Backward 1 epoch, Backward 10 epochs, Home (start of file) or End of File. Search is useful when searching for a specific Second, Epoch or H.M.S.

The Edit Menu edits the .GPB file. This includes switching from static to kinematic and vice-versa. Add or remove cycle slip. Disable Satellite(s), zeroes pseudoranges for one or more epochs for a given satellite. Recalculate Position recalculates receiver position values using a single point GPS solution. Recalculate Doppler will fix bad Doppler values. Edit Meteorological values edits a .trp file for troposphere modeling.

Before any changes are made to the .GPB file, GPBView will confirm that you want to make the changes. These changes are PERMANENT, so it is advisable to keep a backup copy of the observation file.

6.3.3 How To Move Through a GPB File

There are two ways to move through a .GPB file. The first is to use the tool bar. The second is the use the arrow keys, and the paging keys (Page Up, Page Down, Home, and End keys).

6.3.4 Fix Corrupted GPB File

GPBView will automatically fix up corrupted GPB files, simply open the file with GPBView.

6.3.5 Convert to Old or New GPB Format

 In GPBView, user can convert to the old format by selecting Save As under the File menu. Old format can also be converted to the new format by selecting the same option.

Section 4   Concatenate, Slice, Resample Utility

This utility can be called from the GPB Utilities sub-menu under the File menu in either GrafNav or GrafNet. As its name suggests, this utility can be used to concatenate multiple files into one new file, take a small portion of one file and make a new file with that portion, or create a new file from data sampled at a lower data rate from an original file. The program also allows you to interpolate from a lower data rate to a higher data rate.
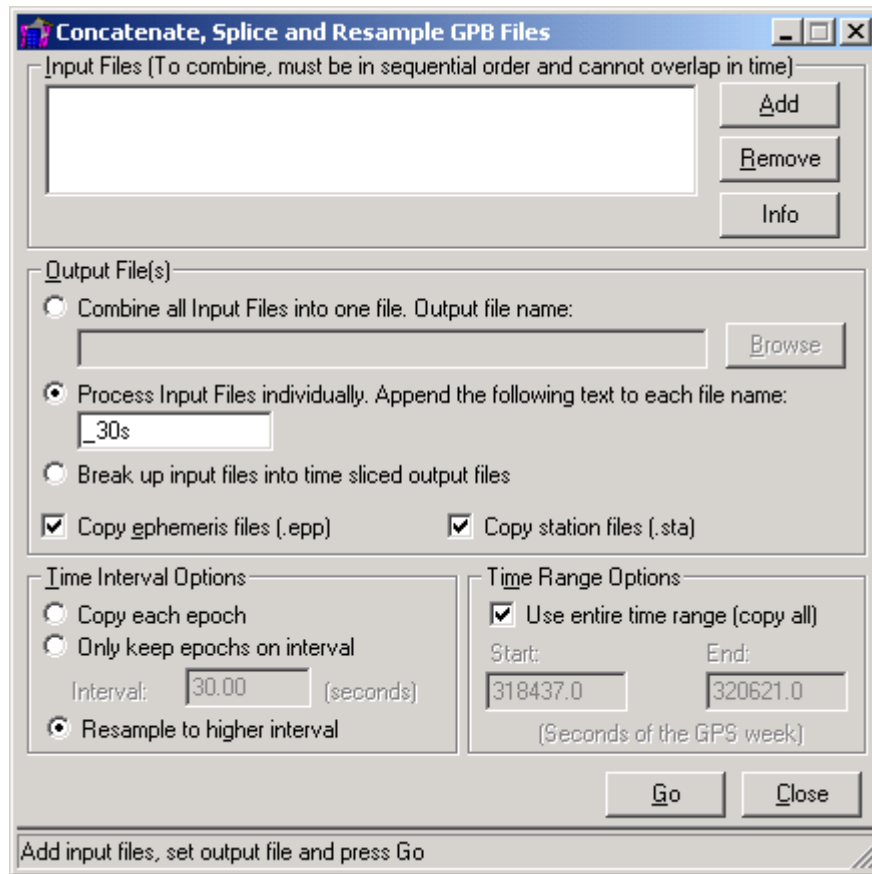
Figure 6.2 Concatenate, Splice and Resample GPB Utility

Use the Add and Remove buttons to select the files that you wish to use as original files. Note that multiple files can be selected during Add. From the "Time Interval Options" box, select the "Copy each epoch" radio button to simply splice a file, or select the "Only keep epochs on interval" to resample the file. If you wish to concatenate two or more files, either radio button may be selected depending on whether you want to resample the data as well as concatenating it. Use the "Time Range Options" to set the times that will be used to create the new file.

This utility also allows GPB data to be resampled to a higher data interval. This is best performed on static data because in the kinematic case it will also attempt to interpolate vehicle motion, which is not very well characterized by the polynomials used. Note that this functionality is available directly within GrafNav too.
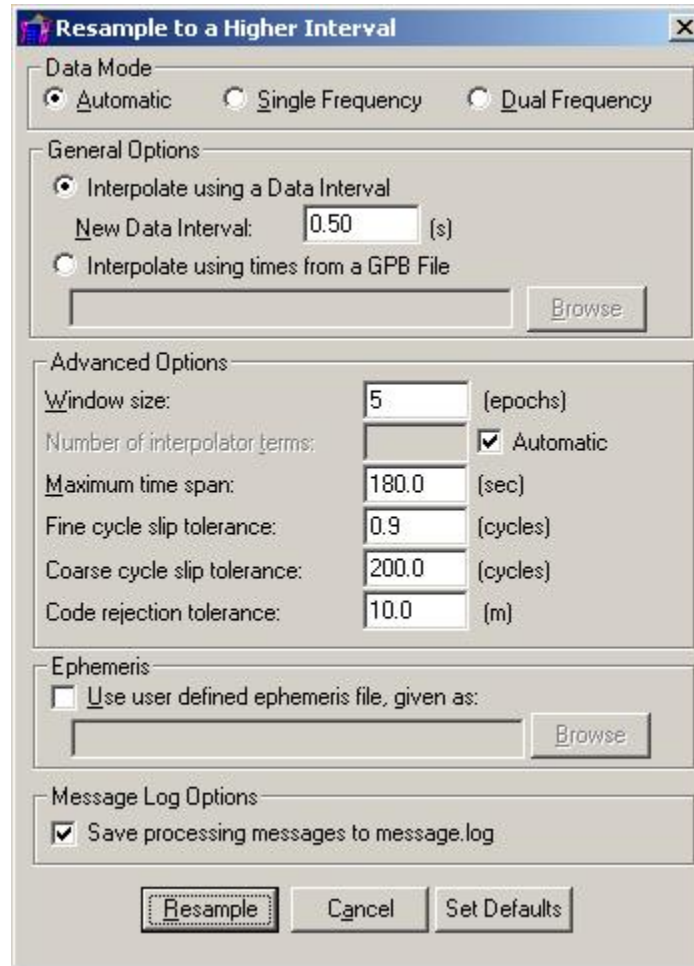
Figure 6.3 Resample to Higher Interval

An additional dialogue box appears with the following options:

- The data mode defines what measurement quantities are to be interpolated. It is important to set this properly.
- For kinematic data, results will be unreliable. However, if the user wishes to try it, make sure that the kinematic box is selected.
- Window size in epochs is the range of data used for interpolation. The window size should normally be set between 4 and 6. Very large windows will have problems, especially with data files that have large data intervals.
- The data interval is the interval that will be resampled to. It should be finer than the original input interval.
- The number of polynomial coefficients is the number of Chebychev polynomial coefficients used for the interpolation. Normally a value close to the Window size is acceptable. This value cannot be larger than the window size.
- The maximum time span prevents the interpolator from using data across too high of an interval. Currently, 3 minutes is the default. However, larger

values are required for large interpolation windows with coarse input data
rates.

- Cycle slips can cause the interpolation to have problems. Therefore, a coarse
  detector is implemented. This value cannot be lowered too much, since then
  pseudorange noise will be mixed up with carrier phase errors (a minimum
  value of 50 cycles should be used).
- The GPB resampling utility needs GPS ephemeris data. Normally, the
  ephemeris from the input files is used. If these ephemerides either do not
  exist, or they are incomplete, then use the alternate ephemeris option.

This utility can also be used to resample the times of one GPB file onto those of another.
This has application when the remote file is not on the whole epoch (e.g. Sirf, Parthus
GSU-II).

Interpolation adds 1 to 2 cm of noise for 30 second data. Five second or higher data has
almost no added error. When processing 30 second interpolated data, KAR may not
work. In addition, for the Advanced KAR Option 'Exact Interval (for interpol. data)', a
value of 30 seconds should be used.

Section 5   GPB to RINEX (Windows)

This program will convert a .GPB file into a standard format RINEX version 2.0 or 2.10
file. You can convert multiple files in succession by simply adding them all to "Files to
Convert" list. Each time you add a file, you will be prompted for a station name, an
antenna height, and whether an alternate ephemeris should be used.

The type of data that will be written to the RINEX files can be selected with the radio
buttons in the "Data Types to Export" box. If Auto-Detect from this box is selected, then
the program will export all available data. Regardless of what button you press, only data
that exists will be exported (columns of zeroes will not be created for missing data).

The GPB to RINEX converter allows you to set the week number the observations were
made on. If the Auto-Detect button in the "GPS Week" box is chosen, then the week the
observations were made will stay the same. You can also set the week by choosing the
Set Week button. Occasionally, de-code data is given an incorrect week when it is
converted from a receiver format to a .GPB file. These errors can be corrected by
converting the .GPB data into RINEX data with the correct week, and then back to .GPB
data.

Section 6   Insert Static/Kinematic Markers

This utility can be called from the GPB Utilities sub-menu under the File menu in
GrafNav. This utility can be use to convert data to static or kinematic.
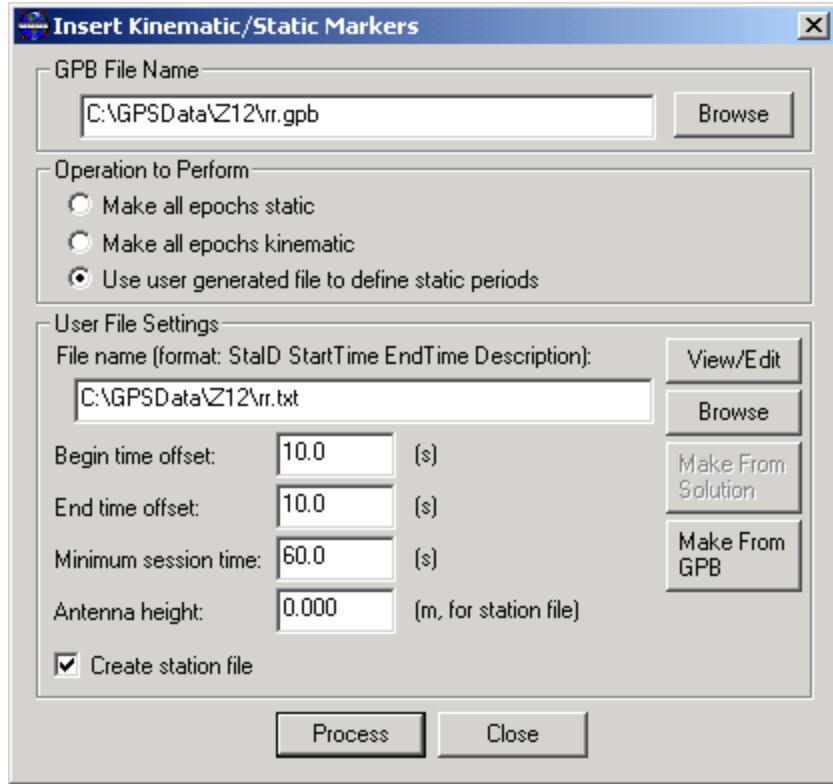
Figure 6.4 Insert Kinematic/Static Markers Utility

Selecting the option "Make all epochs static" will change all the epochs in the selected GPB file into static mode. "Make all epochs kinematic" will change all the epochs into kinematic.

Selecting the option "Use user generated file to define static periods" will allow the user to change particular areas to static. The file has to follow the following format:

```
StaID      StartTime        EndTime    Description
    :          :                :            :
```

The diagram in Figure 6.5 describes some of the options.
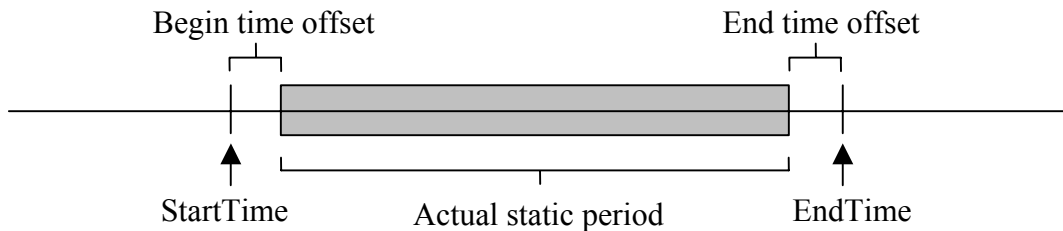
Figure 6.5 Time Offset

If "Create station file" is selected, all the static periods will be listed in the STA file.

Section 7   MAKEGEOID (Command Prompt)

This utility can be used to convert ASCII geoid file to Waypoint Geoid Format (WPG). A bitmap file (BMP) file is also created to give a visual of the geoid. The input file is as follows:

LatVal   LonVal   UndulationVal
   :   :   :

Note that Latitude and Longitude is in decimal degrees and Undulation is in meters. **Be sure to use at least 12 decimals for latitude and longitude values**. In addition, positive latitude is northern hemisphere while negative is southern. For longitude, positive is eastern while negative is western hemisphere.

Usage: MakeGeoid InFile [-o OutFile[.wpg/bmp]] [-rlt] [-rln] [-d datum]
                        [-g "Geoid name"] [-r "Region name"] [-h]
Where,
 InFile - Input file name, Format:
 -o   - output file [default=InFile.wpg/bmp]
 -rlt   - Reverse sign on latitude values [default=off]
 -rlm   - Reverse sign on longitude values [default=off]
 -d   - Datum name [default=WGS84]
 -g   - Geoid name [default=Unknown]
 -r   - region name [default=Unknown]
 -h   - help screen

Section 8   Mission Planner

6.8.1   What is the Mission Planner?

Tools | Mission Planner
The Mission Planner is a feature that was added to GrafNav/GrafNet version 6.02. This tool allows the user to investigate satellite geometry, satellite count, and dilution of precision values for the GPS constellation. Mission planning is normally performed prior to the mission, but it can also be used to compare the theoretical constellation to that observed during processing. The Mission Planner requires an almanac file. Two formats are supported:

- YUMA almanac which can be downloaded from the NAVCEN web site (see below)
- .EPP file that contains almanac records. Currently, only a few decoders (e.g. NovAtel) support the decoding of almanacs. **.EPP files that do not contain an almanac cannot be used.**
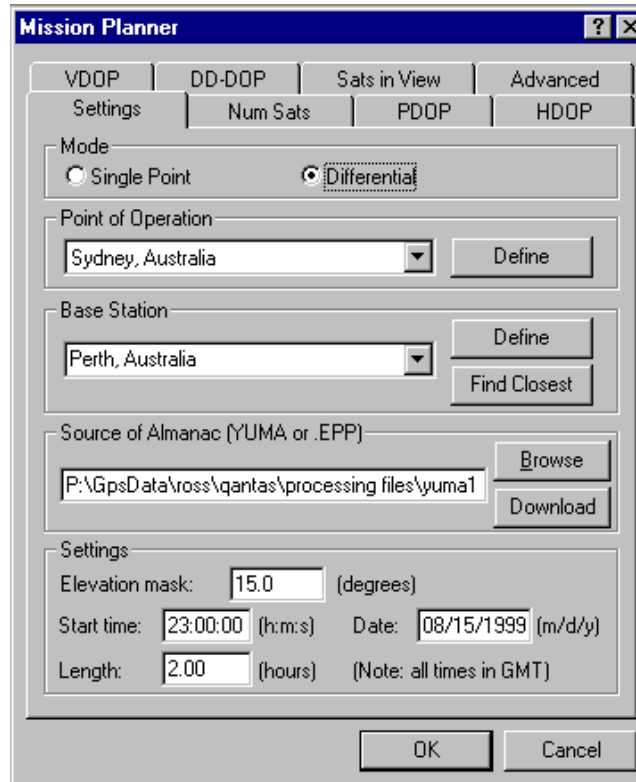
Figure 6.6 Mission Planner – Settings Tab

The Mission Planner relies on almanac files for information on the orbital parameters for each satellite PRN and the geographical coordinates of cities (point of operation) in mission planner city (.mpf) files to estimate the number of satellites, satellite geometry (satellites in view), double difference DOP, PDOP, HDOP, and VDOP. A base station must be defined for differential computations. YUMA almanac files (.txt) or Waypoint ephemeris files (.epp) can both be used with the Mission Planner. The only requirement for the ephemeris files is that the almanac record be included in the .epp format. At present, only the NovAtel almanac format is supported in the ephemeris files. YUMA almanac files can be downloaded from
http://www.navcen.uscg.gov/ftp/GPS/almanacs/yuma/

6.8.2 Getting Started

The following section will guide a new user in how to use the Mission Planner and obtain output for flight mission.

1) Open up GrafNav and select Mission Planner from the Tools Menu.
2) Select either Single Point or Differential Mode.
3) Choose a Point of Operation. If the menu is blank, click on Define and then on Change List File and select a mission planner city list (i.e. world.mpf or north_am.mpf for cities with coordinates already defined). If the city is not in either of the predefined lists, custom entries can be added to the MissPlan.mpf which is the default list upon installation. When adding custom cities, an .mpf file other than

world.mpf or north_am.mpf should be used to prevent entries from getting lost upon re-installation.

4) Choose a Base Station in the same manner as choosing a Point of Operation if differential mode was selected. The closest base station to the Point of Operation can be found by using the Find Closest button; however, this function works best when the cities are chosen from two different city files, otherwise it will just find the point of operation city.

5) Next, either browse through (or type the path name) and select the almanac file in your directories, or download a YUMA almanac file from one of the URLs in Section 6.8.1 What is the Mission Planner?. The following dialogue box will appear once the default web browser for GrafNav has been selected. Follow the instructions on how to download the YUMA almanac, and then select it using Browse.
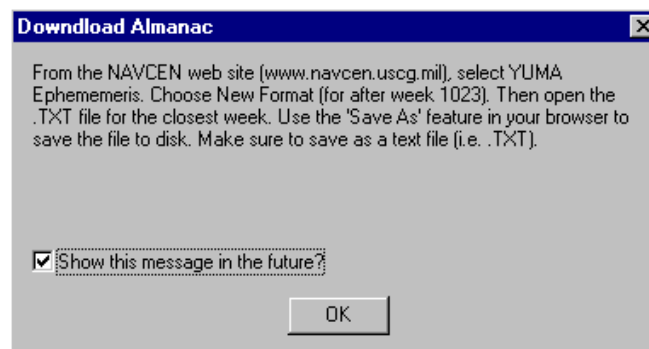
Figure 6.7 Download Almanac Instructions Dialogue Box

6) Leave the elevation mask at 15° to ensure that low satellites, which can have a poor signal, will not degrade the solution. If there are not enough satellites to find the geometry of the position, lower the elevation mask to 10°.

7) Enter in the start time, date, and length of the flight mission in H:M:S.

8) Decide upon which plots are necessary for predicting and planning the flight, and click on each tab and change the option from None to either Line Graph or Bar Chart. If you wish to place all the DOP charts being plotted on one graph, select line graph and then change the option in the Advanced tab. The default charts that are plotted are the Number of Satellites and PDOP bar charts.

9) If you would like to see the elevation of all the satellites in view, select the option Satellite Lock Plot in the Sats in View tab.

10) An output file containing a log of the mission planner output in ASCII can be saved by selecting the option from the Advanced tab of the Mission Planner.

11) Press OK and all the graphs and/or mission planner log file will open in GrafNav.

6.8.3 Options for Mission Planner
Settings

Mode	
Single Point	The mission planner will provide results for the area surrounding the single point chosen. Differential mode should be used for long baselines or to closely match values computed during post-processing.
Differential	The mission planner results will be for an area between the base station and point of operation

Point of Operation	
Define	Define allows the user to select the city file containing geographic coordinates for their point of operation. GrafNav comes with 2 default city coordinate files called north_am.mpf, and world.mpf (i.e. North America and the World). The default .mpf file used is MissPlan.mpf which is blank upon installation. Coordinates for other cities should be added to MissPlan.mpf to prevent overwriting the north_am and world mpf files during re-installation. **Figure 6.8 List of Point of Operations window** Select will choose the highlighted city as the Point of Operation in the Settings Tab, while the Change List File allows the user to select a different .mpf file. The commands Add, Edit and Remove will edit and change the current .mpf file loaded. Add and Edit will launch a dialogue box to change the name, latitude, and longitude of a selected point. **Figure 6.9 Define (Add and Edit) Point Dialogue Box**
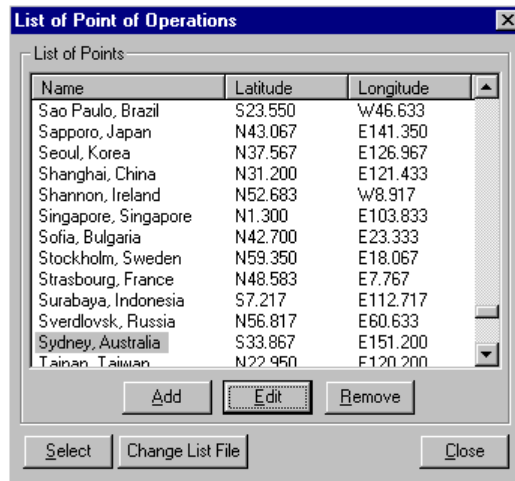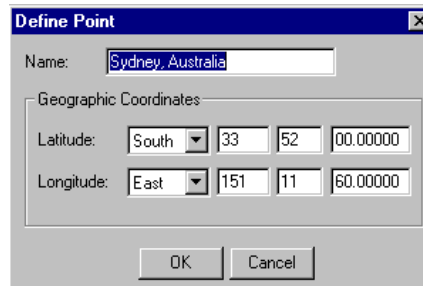
Base Station	
Define	See Point of Operation: Define
Find Closest	Find Closest will find the closest city defined in the Base Station .mpf file compared to the city selected in the Point of Operation .mpf file. This option works best when there are two different files used for Base Station and Point of Operation.
Source of Almanac (YUMA or .EPP)	
Browse	The user can browse the directory structures on their hard drive(s) to find existing YUMA or .EPP almanac files. **Note that .EPP file must contain an almanac record to work. For most decoders this record will not be included.**
Download	This will open up a new browser window and the URL site for downloading YUMA almanac files. If this option has never been used, a dialogue box will prompt the user to select a web browser (i.e. Netscape or Internet Explorer) to open. Once the proper YUMA almanac is found, save the file as a text file by selecting File > Save As…
Settings	
Elevation Mask (°)	This option sets the cut-off elevation for the mission planner. The default value for the mission planner is 15 degrees. However, users may wish to use larger values to simulate conditions of satellite blockage lower on the horizon (e.g. aircraft turns, buildings, or trees).
Start Time (h:m:s)	The start time of your mission in h:m:s GMT time.
Length (hours)	The length of your mission in hours.
Date (m/d/y)	The date of your mission in m/d/y format.

Number of Satellites, PDOP, HDOP, VDOP, and DD-DOP
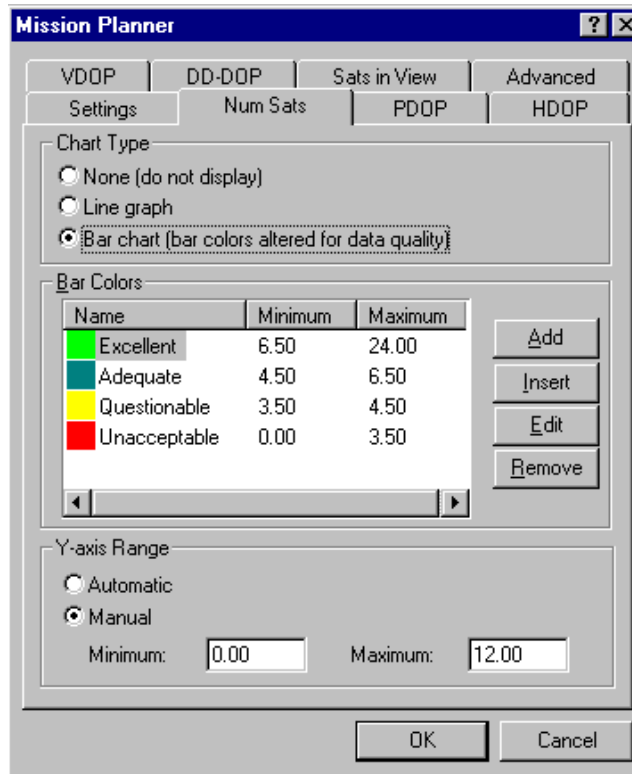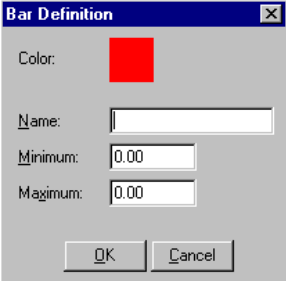
Figure 6.10 Mission Planner: Number of Satellites tab

Chart Type (for each one)	
None	No chart/graph will be plotted onto the display when this option is selected.
Line Graph	A line graph will be displayed with when this option is selected. The line graphs are very similar to the ones plotted in the Plot GPS Data tool.
Bar Chart	The bar graph allows for more interpretation of the results since the values of the Number of Satellites, Satellites in View, and DOP values are categorized in to Excellent, Adequate, Questionable, and Unacceptable categories where each graph has default maximum and minimum values. A maximum of six bar colours are allowed for each bar chart.
Bar Colours(only applicable for bar charts)	
Add, Insert, Edit, Remove	The Add option will add a bar colour to the selected bar chart at the end of the list of colours. Insert will add a bar colour to the bar chart ahead of the highlighted bar colour in the colour list. Edit allows the user to modify the Name, and Maximum and Minimum values defining the chosen colour category. Remove will automatically delete the colour from the list. If a colour is accidentally deleted, press Cancel so that the changes are not saved to the WPMissPlan.ini file. **Figure 6.11 Bar Definition (Add, Insert, Edit) window**
Y-axis Range	
Automatic	This option allows the Mission Planner to automatically scale the Y-axis for the line graph or bar chart.
Manual (max, min)	The maximum and minimum values in the Manual setting allow the user to customize all the graphs to a user-defined value regardless to the chart values.

Satellites in View

Chart Type	
None	No chart/graph will be plotted onto the display when this option is selected.
Satellite Lock Plot	The graph displayed on the screen is a satellite lock plot showing each SV tracked with its elevation. This graph is similar to the Lock Plots for the Master and Remote station in GrafNav.
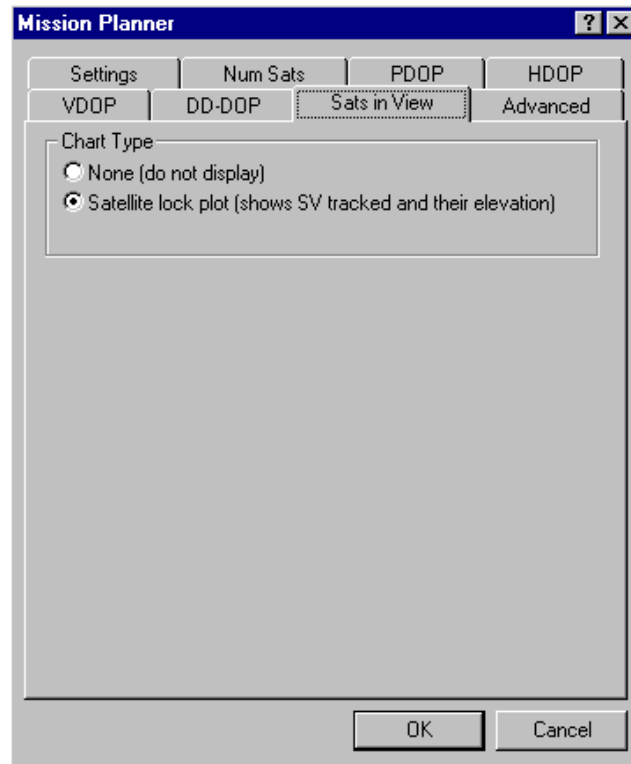
Figure 6.12 Mission Planner Satellites in View tab

Advanced
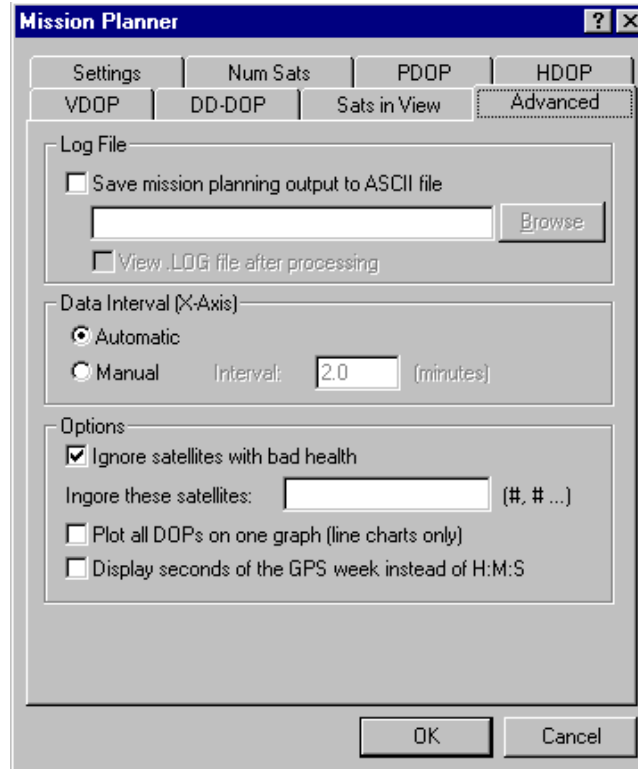
Figure 6.13 Mission Planner: Advanced Options tab

Log File	
Save mission planning output to ASCII file, Browse	Users can either directly type in a directory path for where they would to save the mission planner output, or they can use the Browse button to define a path.
View .LOG file after processing	If you would like to view the mission planner output immediately after processing, select this option and the ASCII viewer will open the log.
Data Interval	
Automatic	This option will automatically compute a data interval suitable for the most recent plot window size.
Manual	Users can manually define a data interval to improve the resolution.
Options	
Ignore satellites with bad health/ Ignore these satellites	The Mission Planner will check the almanac file for any sick satellites if this option is selected. If certain satellites that are causing problems and are not labeled as sick in the almanac file, the Mission Planner can be manually set using Ignore these Satellites to ignore specific PRNs.
Plot all DOPs on one graph (line graph only)	This option will plot all the DOP plots that have line graph mode selected (except for DD-DOP) onto one line graph plot. Note that each of the DOP charts must be set to line type.
Display seconds of the GPS week instead of H:M:S	Users can change the format of the X-axis labeling between GPS seconds of the week or H:M:S. This is used for comparing to post-processing data plots.

Note that if there are changes in the options that are unknowingly saved, default options and settings for the Mission Planner can be reset by deleting the WPMissPlan.ini file in your Windows directory.

Section 9   Download Service Data

6.9.1   About the Download Program

The Download Service Data utility allows you to automatically download RINEX data from different services and convert the data into Waypoint's .GPB format. Optionally, GPS data can be resampled to a higher interval. Services are internet web and ftp sites which continually store data from a number of GPS sites. This data can be downloaded for free. The services currently supported are CORS, IGS, AUSLIG, IGN, GSI, BKGI (EUREF), ASI, CDDIS, and OLG. Users can also add their own services (see Section 6.9.3 Adding Stations and Services).

6.9.2   Downloading Service Data

Tools | Download Service Data

Figure 6.14 shows the main download screen. This feature can be accessed from GrafNav, GrafNav Batch and GrafNet via **"Tools > Download Service Data"**. The 'List of Stations' shows the stations you have selected to download and their associated service. Distance is only present if the 'Add Closest Stations' option was used, which is described later. The 'Path' is the path where the final GPB files will be placed. 'Date and Time Range' is the date and time of the data in GMT time. Note that the date is in month/day/year. 'Output data interval' lets you either leave the data as found or select a new interval. Note that interpolation to a higher interval will add roughly 1-2 cm of additional error in the measurements depending on the original data and the interval to which you are interpolating.
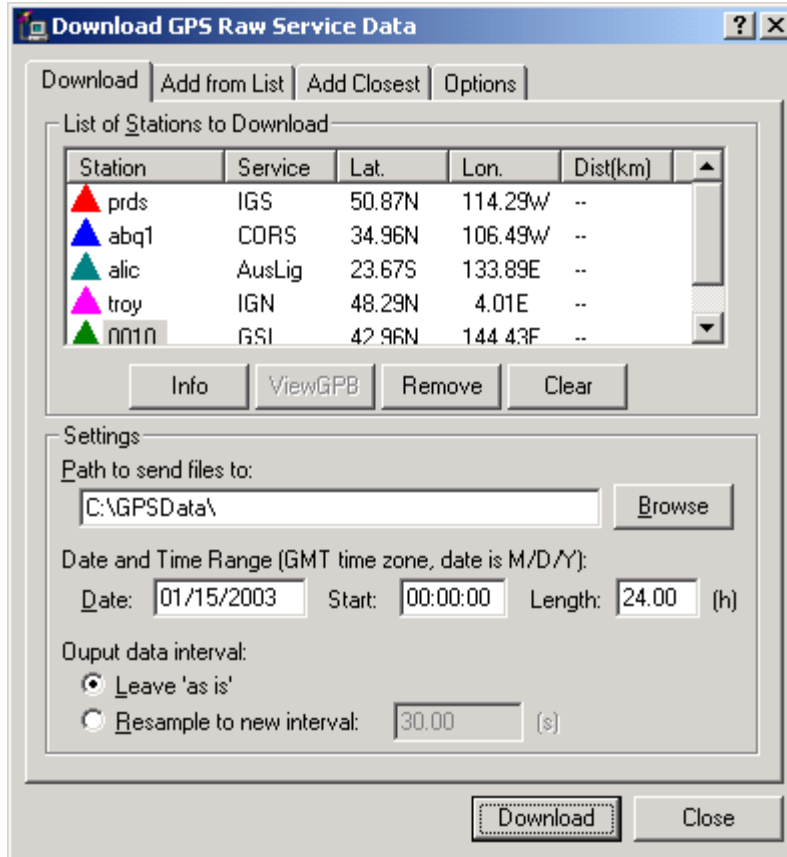
Figure 6.14 Main Download Service Data Screen

Figure 6.15 shows the 'Add from List' feature. 'Add from List' allows you to add a station from the list of pre-defined stations, and is useful if you know exactly which station you would like to download. Highlighting the station and selecting the 'Add' button will add the station to the list of stations to be downloaded (on the main screen). Station information can be obtained by highlighting the station and selecting the 'Info' button.

It should be noted that this list of stations may not be complete due to the continual addition and removal of CORS stations. Additionally, every so often a service will change its directory structure, thereby making the download program useless for that service. Both of these problems can often be solved by selecting the "Download Latest List" option from the "Add From List" tab. This will download Waypoints latest list and station list and will also update the service directory paths that the Download Program searches for. In the event that our list (which is updated every few months) does not contain some very recently added CORS, IGS, AUSLIG, IGN, GSI, BKGI (EUREF), ASI, CDDIS, or OLG stations and you would like to add these yourself, consult the Adding Stations and Services section.

It should also be noted that the coordinates provided are not guaranteed. Every effort has been made to maintain correctness; however it is recommended that you look

up the coordinates on the services web page. The coordinates you will usually want are for the L1 Phase centre (those stored in the favourites manager are ARP's). The services web pages are provided below.

Service Name	Web Address
IGS	http://sopac.ucsd.edu/
CORS	http://www.ngs.noaa.gov/CORS/cors-data.html
AUSLIG	http://www.ga.gov.au/
IGN	http://lareg.ensg.ign.fr/RGP/index.html
GSI	http://www.gsi.go.jp/
BKGI (EUREF)	http://www.epncb.oma.be/
ASI	http://geodaf.mt.asi.it/
CDDIS	http://cddisa.gsfc.nasa.gov/
OLG	http://gps.iwf.oeaw.ac.at/olgdc1.htm
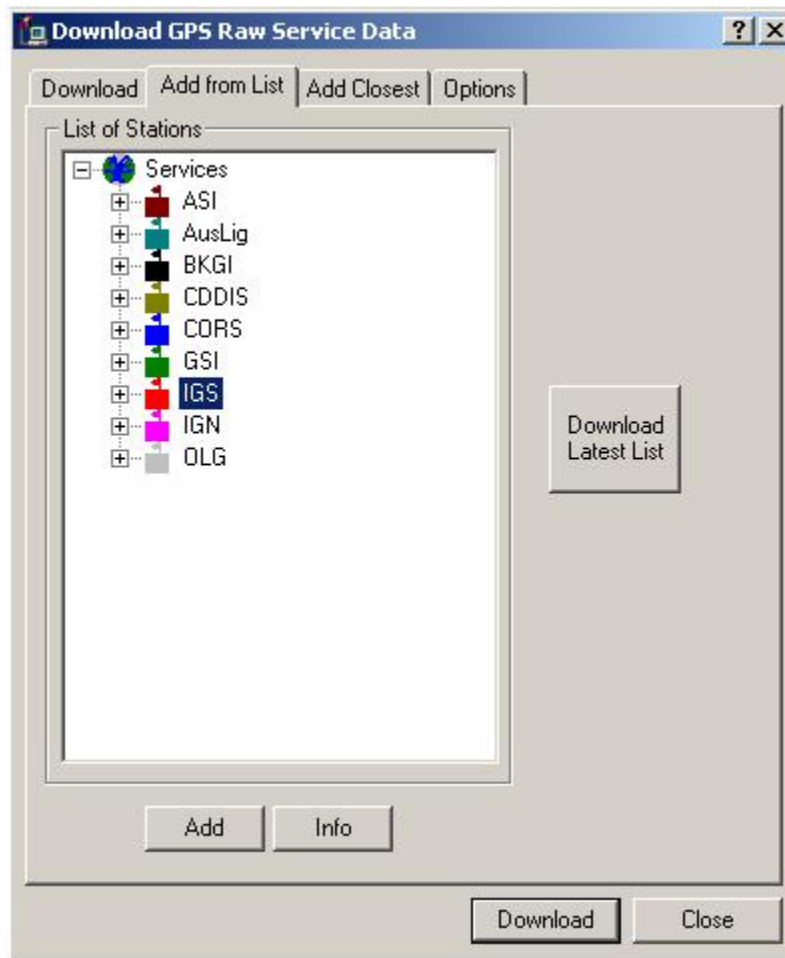
Figure 6.15 Add From List

Figure 6.16 shows the 'Add Closest' feature. This feature shows a list of all the closest stations based on the latitude and longitude position entered. Two settings that can be

controlled are the 'Maximum Distance' and 'Maximum Number' of stations. 'Maximum Distance' prevents stations further than this constraint from being added to the list. Maximum number of stations sets the maximum size of the list. If no stations appear in a search then you'll have to increase the maximum distance.
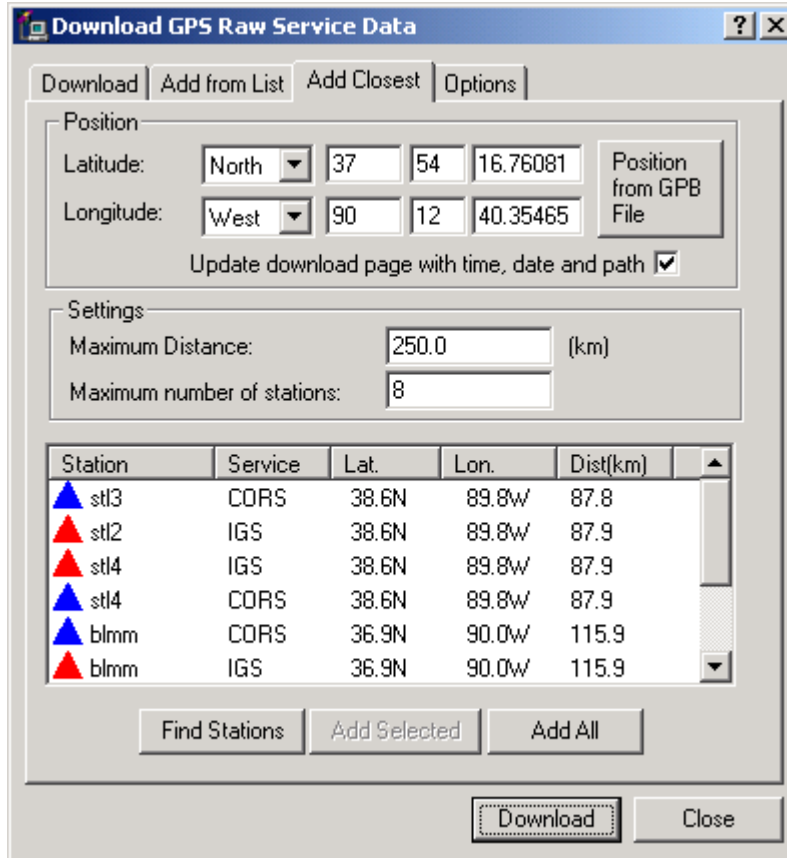
Figure 6.16 Find Closest Station

'Download' first places all files in a temporary directory. Where the files are uncompressed and converted from RINEX to GPB. If the program quits unexpectedly you can check the temporary directory for the files. To change the temporary directory you can go to the options tab as shown in Figure 6.17. It is important to note that the temporary directory cannot be the same as the final directory.

If a file exists in the destination directory with the same name as the file being downloaded the file will be overwritten if the option "Overwrite existing files with newer ones" is enabled. However, if the 'Append' option is enabled the new file will have an A,B,C etc appended to the file name. If you would like to use the Doppler value from the RINEX file enable 'Use D1 in observation file if available'. If you would like to keep the RINEX files enable the option 'Leave raw RINEX files in TEMP directory'. The files will then be available in the temporary directory for other packages to use. By default the RINEX file will be converted into the new GPB format. To convert to the old GPB format, disable 'Use New GPB format'. Some of the FTP sites require the user to input a

valid email address before giving permission to download GPS data. Note that your
email address is not used for any other purpose than a password.

If you would like to download the precise ephemeris, enable 'Download SP3 files'. Final
precise orbit ephemeris will be downloaded if available. If it is not available, rapid orbit
would be next. The final precise orbits are available at 12 days latency and the rapid
orbits are available with approximately 17 hours latency. Precise orbits are located at:
Final: ftp://igscb.jpl.nasa.gov/igscb/product/<week>/igs<week><d>.sp3.Z
Rapid: ftp://igscb.jpl.nasa.gov/igscb/product/<week>/igr<week><d>.sp3.Z
Where <week> is the gps week and <d> is day of the week.
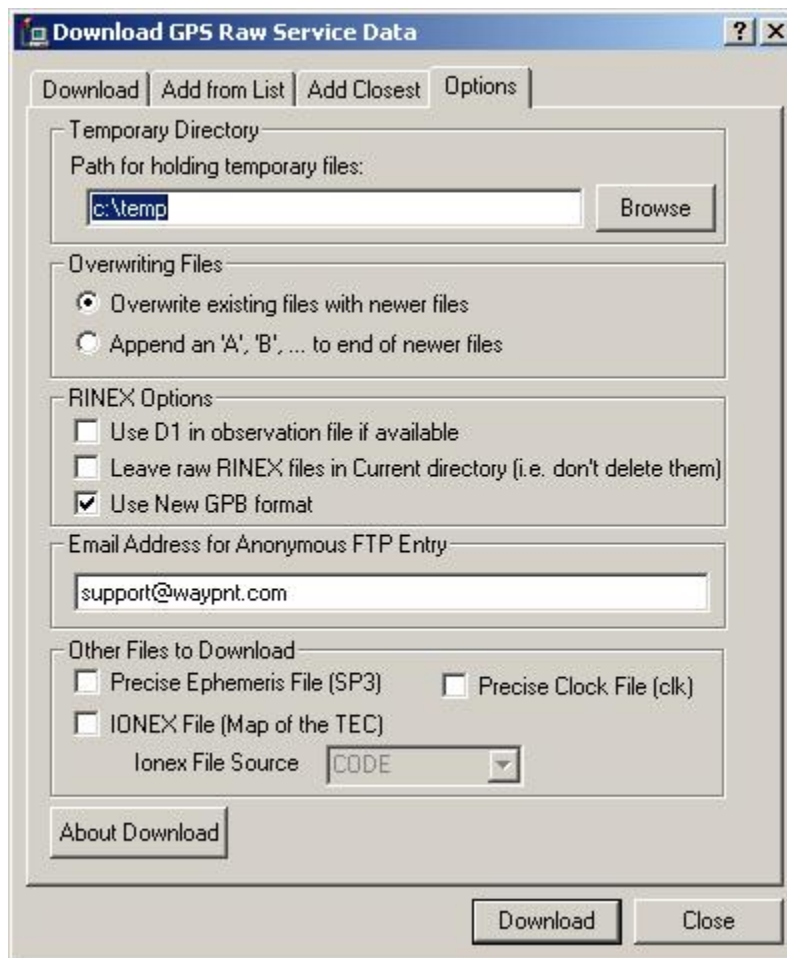
Figure 6.17 Download Options

IONEX (Ionosphere Map Exchange) files contain information relating to the Total
Electron Count (TEC) of the ionosphere on a given day. They can be used in single
frequency or single point processing to aide in the ionosphere modeling process. These
files can be downloaded from various producers:

CODE – Center for Orbit Determination (http://www.aiub.unibe.ch/igs.html)
NRCan – Geodetic Survey Division of Canada (http://www.geod.nrcan.gc.ca)

ESA – European Space Agency (http://www.esa.int)
JPL – Jet Propulsion Laboratory (http://www.jpl.nasa.gov)
UPC – Technical University of Catalonia (http://gage1.upc.es)

Precise clock files (.clk files) contain information of clock biases in a particular GPS satellite. These files are also used to support single point positioning. They are obtained from the NGS/NOAA producer (http://sopac.ucsd.edu). For details on how to implement them in GrafNav, see Section 2.2.6 .

6.9.3   Adding Stations and Services

Download lets you add new stations and services for downloading. To add either a station or service you need to open users.dn1 found in your Waypoint directory. If the file does not exist, you might have to create it using the format is listed below. To add a station record, copy the last station record in the file and paste it at the end. Then edit the fields of the new record as explained below. Note that you will also find a file, manufact.dn1, in the directory as well. This is the file that gets updated when "Download Latest List" button is clicked.

sName: The station name on the ftp server. Max 4 characters (case sensitive).
lat: Station Latitude in DMS. N – North and S – South.
lon: Station Longitude in DMS. W – West and E – East.
ht: Station Height.
serv: Service name of the service that the station belongs to. You will have to look at the service records to find the Service name ("ServId:"). Note that this is case sensitive.

An example station record is shown below:

Station { sName: prds
lat: 50 52 16.8672 N
lon: 114 17 36.5856 W
ht: 1247.94
serv: IGS
}

Adding a service requires you know the services ftp address, directory structure and file type (i.e. Z, gz, or zip). To add a service, copy and paste one of the service records at the beginning of manufact.dn1. Then edit the fields of the new record as explained below.

ServId: The name of the service. This can be whatever you choose maximum 8 characters

ftpAd: Address of the ftp server.

oFile: The directory structure and name of observation data files. The directory structure is how the folders are organized to find a certain file. For example, to find one file, you might have the path: /pub/obs/1998/128/prds1280.98n.Z. Then another file for

the same service may have the path: /pub/obs/1999/032/alic0320.99n.Z. On this example service, the files are organized by year and Julian day. The directory structure would look like the following: /pub/obs/<YYYY>/<JJJ>/<XXXX><JJJ>0.<yy>n.Z, where <YYYY>, <JJJ>, <XXXX> etc are directory structure commands.

The following is a list of these commands:

<JJJ>   Julian Day eg 006 or 365
<YYYY> *   Year eg 2000 or 1999
<XXXX>   Station id   eg prds
<week>   gps week eg 1075
<wkrl>   gps week - 1024 eg 1075 would be 0051
<yy>   *   last two digits of the year eg 99 or 01
<d>   Day of the week eg 3
<MN>   Month Number eg 11
<DM>   Day of the month eg 31

Note that commands with an * are case sensitive. All the directory commands are inside the brackets < >. For more information, look at some of the ftp services in manufact.dn1 and examine their directory structure for examples.

nFile: This is the directory structure of the navigation file. Same commands as for oFile.

dFile: This is the directory for compressed RINEX files.   This field does not need to be present if the service does not have any compressed RINEX files.

Ftype: This is the type of compression on the file. The file types include Z, gz and zip.

Datum: This is the datum of station record coordinate.

color: This is the colour of the symbol in download for the service. This option also does not need to be present but allows you to select a unique colour for the service and station symbols. The following colours are available: red, green, blue, magenta, cyan, gray, wine, black, gold, darkgray, darkgreen, darkblue, lightcyan, and darkmagenta.

An example service record is shown below.

```
Service { ServId: igs
        ftpAd: lox.ucsd.edu
        oFile: /pub/rinex/<YYYY>/<JJJ>/<XXXX><JJJ>0.<yy>o.Z
        nFile: /pub/nav/<YYYY>/<JJJ>/<XXXX><JJJ>0.<yy>n.Z
        dFile: /pub/rinex/<YYYY>/<JJJ>/<XXXX><JJJ>0.<yy>d.Z
        Ftype: Z
        Datum: WGS84
        color: red
}
```

Chapter 7 Convert

The data conversion utility included with GrafNav/GrafNet 7.50 decodes raw GPS data from over twenty different GPS receivers by choice or auto-detect. CONVERT is located in the distribution directory (i.e. C:\Program Files\WayptGPS750), and it can also be accessed from the Start Menu in Windows 95/98/2000/XP/NT 4.0. The conversion utility can also be called from within GrafNav, GrafNav Batch or GrafNet in the menu File -> Convert -> Raw GPS to GPB.

Similar conversion utilities for DOS can be found in the \DosUtils directory on the GrafNav/GrafNet CD-ROM. Older style Windows utilities can be accessed from the GrafNav and GrafNet interfaces. It is suggested to use the conversion capabilities within CONVERT over the others as they are the most up-to-date.

Section 1 CONVERT Interface/Functionality

7.1.1 How to Use Convert

After opening CONVERT from GrafNav or the Start Menu, raw GPS data files can be easily converted to Waypoint's custom GPB format using the following procedure.
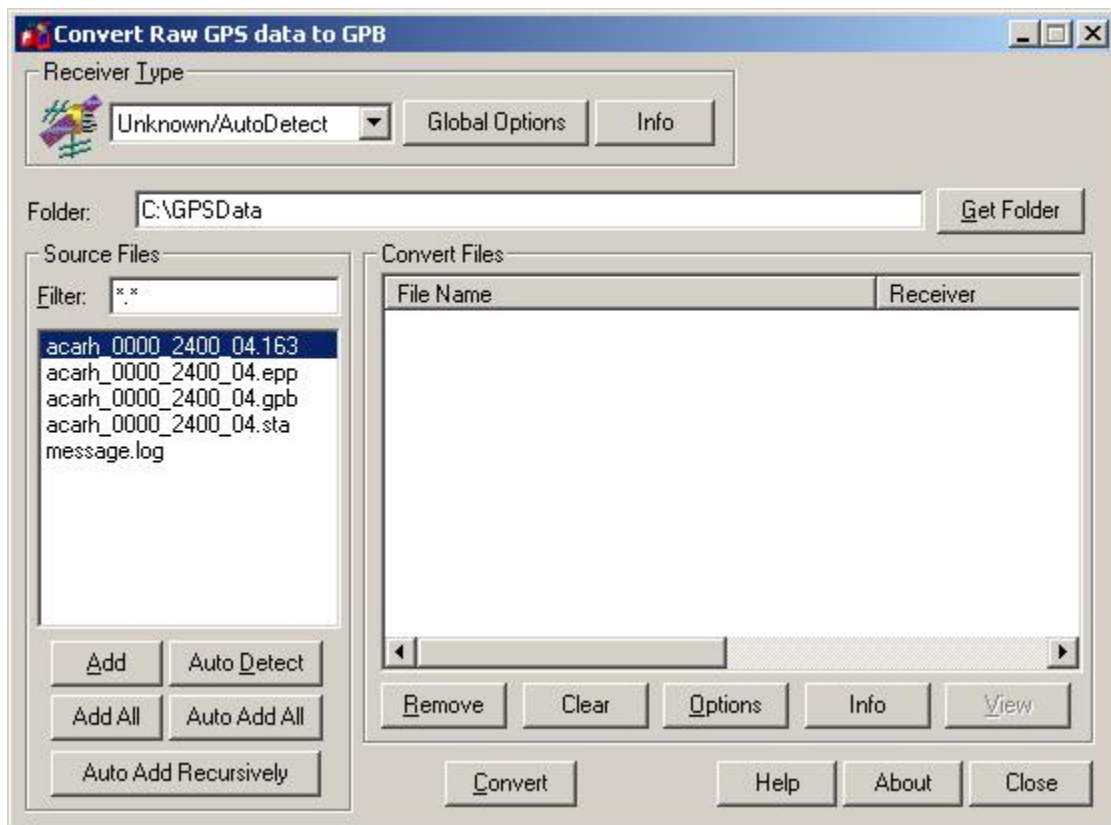
Figure 7.1 Convert's receiver type options

For example, How to Convert your NovAtel data:
- Under the File Menu choose File -> Convert -> Raw GPS to GPB
- A dialogue box will appear as follows:
- Choose the NovAtel receiver type from the pull down menu.
- Select the appropriate path name for the folder containing the Raw GPS files or use the Browse button.
- You can either add files individually using "Add" or add all files using the "Auto Add All" button or the "Auto Add Recursively" button which searches all subfolders in the directory as well.
- Set global options required.
- Press the Convert button.

7.1.2 CONVERT Interface Options

Receiver Type
- If you know which receiver you used to collect the data, choose it from the drop box menu. Otherwise, leave the selection at Unknown/AutoDetect.

Global Options
- Gives specific options for each receiver listed and allows the user to define data conversion
- Modifying the global options for a given receiver will alter the options for all of the selected convert files. These changes will also be saved for the future.
- There are no options for unknown or auto-detect

Info
- Provides information on the status and version of the receiver's DLL file and whether it is loaded and allows auto-detection

Folder
- The user can type in a folder path name into a dialogue bar if it is known

Get Folder
- A browsing feature that allows the user to look through the directories on the system and select the desired folder

Source Files
- The Source Files window lists all the files with filtered extensions from the folder path given

Filter
- Lists the associated file extensions for the selected receiver, separated by a semicolon. Use *.* to view all files.

Add
- Adds the highlighted file in the Source Files window to a list of files to be converted
- If a receiver type is not selected, add will try to auto-detect the highlighted file

Add All
- Tries to add all files in selected folder to be converted

Auto Add All Files
- Adds all the files in the Source Files window to the list of files that will be converted
- This function will always attempt an auto-detect on each file
- Only files with a detected receiver type will be added

Auto Detect
- Allows CONVERT to automatically detect the receiver type of the file highlighted

Note, not all receiver formats have auto detection available; Auto detection may not work on all variations of a receiver format

Auto Add Recursively
- Will automatically detect and add files to be converted in the immediate folder as well as all subfolders. This will continue to add files up to a maximum of 128.

Convert Files
- The Convert Files windows lists the selected convert files

Remove
- Removes a highlighted file from the list of files waiting for conversion

Clear
- Removes all files from the Convert Files window

Options
- Displays the options dialogue box for the selected receiver. Options will <u>not</u> be saved – use global options if changes are to be permanent.

Info
- Provides information on the file name, receiver type, and status of conversion

View
- After converting the raw GPS file to GPB format, pressing View will open the converted file in ViewGPB

Convert
- Starts converting all of the selected files

About
- Provides copyright information and information relating to the .dlls used in the utility. See Section 2.10.3 for more details.

Close
- Exits CONVERT

Section 2   Messaging Options

While a binary GPS data file is being decoded, a message dialogue box will appear to display the status and progress of the conversion.
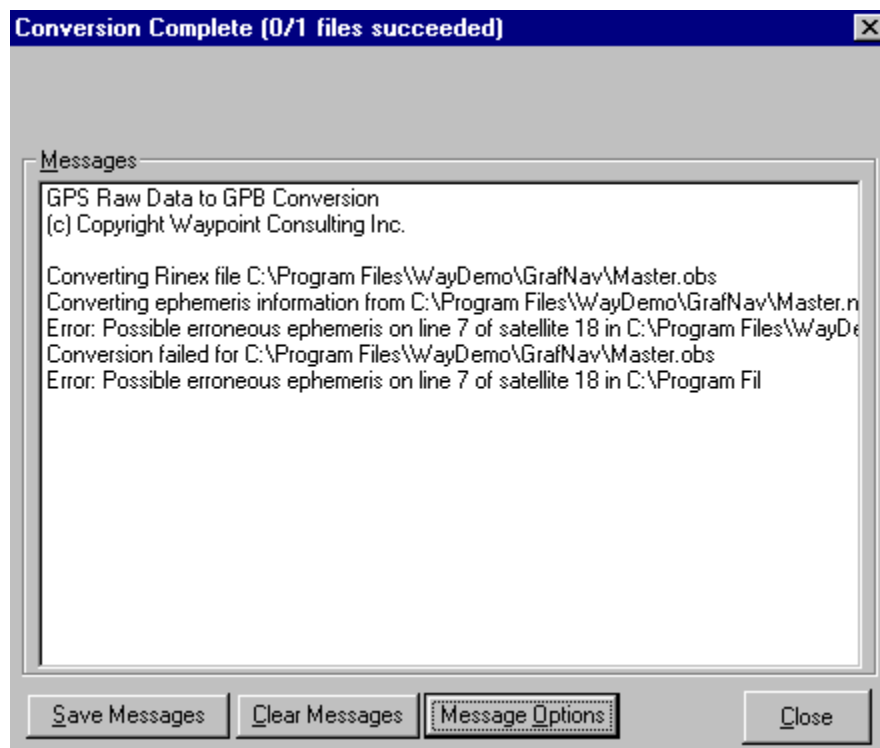
Figure 7.2 Message Log Dialogue Box

Save Messages
- Prompts the user with a dialogue box to save the message log to a file

Clear Messages
- Clears the message log from the dialogue box; once the button is pressed, the message log cannot be recovered if it has not been saved

Message Options

Maximum number of messages
- o Maximum number of messages allowed to appear in the message log

Use FAST message addition (less flickering)
- o Causes less flickering in the dialogue box window and updates the window every # of milliseconds

Automatically log messages to file
- o Automatically saves the message log to a user defined file name in the same directory as the converted data files
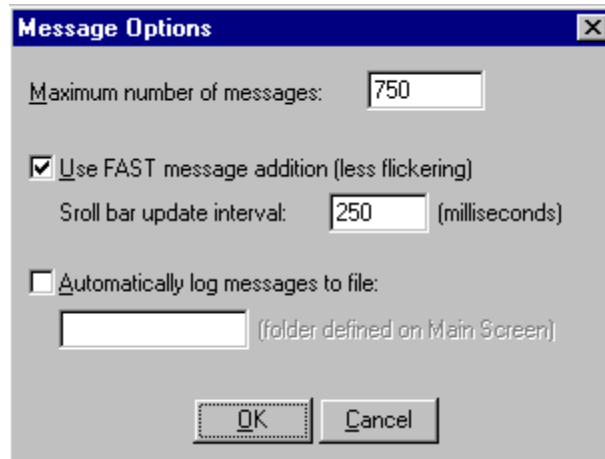
Figure 7.3 Messaging Options Dialogue Box

Section 3   Receivers

7.3.1   Allen Osborne Associates (AOA version only)

Turbo Binary (.TB) files can be converted to .GPB using CONVERT. This decoder is only available for AOA versions. Normally, one .TB file will contain data from many sessions (or even days). Therefore, this decoder must split the files up to be compatible with GrafNav/GrafNet. This decoder looks at the Begin and End session marks within the .TB file. The user creates these when they mark the beginning and end of a session. The session name entered in the receiver will be the name of the file, except that the Julian day number will be appended.

Data Required

File	Type	Comments
*.TB	Measurement/Ephemeris/ Station	
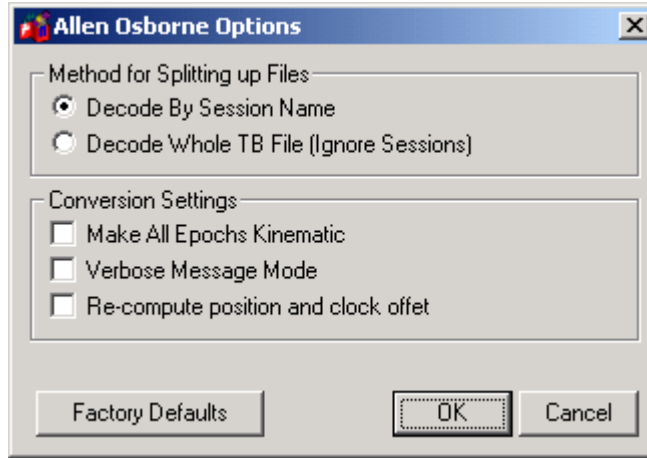
Options

Figure 7.4 Allen Osborne Associates Options Dialogue Box

Decode by Session Name	Decodes the TB file based on session marks inputted into the receiver
Decode Whole TB File (Ignore Sessions)	Decodes the entire TB file with the assumption that all the data collected was from one session
Make All Epochs Kinematic	Use this to make every epoch kinematic, otherwise, will be static; use ViewGPB to switch individual or groups of epochs between static and kinematic
Verbose Message Mode	Alerts the user of additional warnings and errors that have occurred
Re-compute position and clock offset	GrafNav requires clock shift to perform data processing, while GrafNet needs the position record. If the position record is not available, choose this option to use the decoder algorithms
Factory Defaults	Restores the original settings for AOA format processing

7.3.2 Conexant Jupiter

Because of timing issues, the carrier phase on this receiver is not usable. Hence, this is basically a code-only receiver. Ephemeris measurements are contained in record #1102, while record #1000 can be used for position measurements.

Options
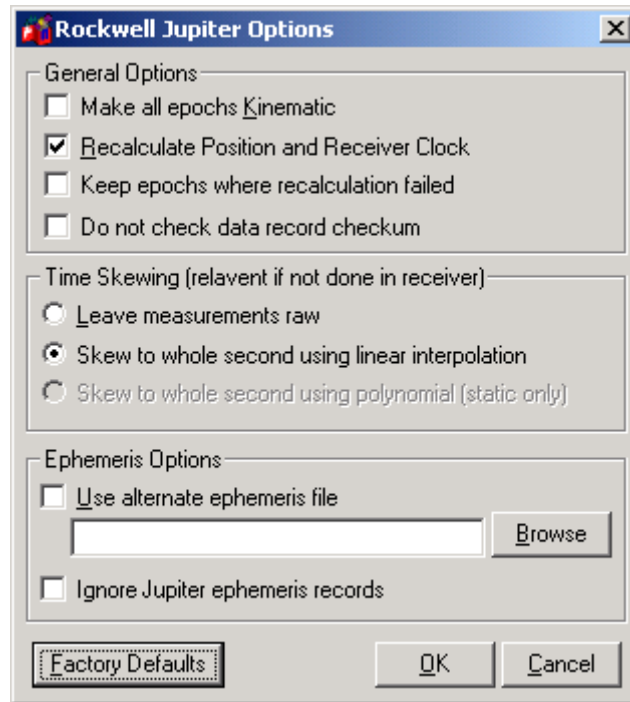
Figure 7.5 Conexant Jupiter Dialogue Box

General Options		
	Make all epochs Kinematic	Use this to make every epoch kinematic, otherwise, will be static; use ViewGPB to switch individual or groups of epochs between static and kinematic
	Recalculate Position and Receiver Clock	GrafNav requires clock shift to perform data processing, while GrafNet needs the position record. If the position record is not available, choose this option to use the decoder algorithms
	Keep epochs where recalculation failed	If time recalculation failed, measurement may cause problem. Use this to ignore these records
	Do not check data record checksum	Use this setting to ignore record integrity checks

Time Skewing		
	Leave measurements raw	Leave time 'as is'
	Skew to whole second using linear interpolation	Shift to integer second
	Skew to whole second using polynomial (static only)	Shift to integer second
Ephemeris Options		
	Use alternate ephemeris file	Utilize ephemeris records from another source
	Ignore Jupiter ephemeris records	If many corrupted records exist, the ephemeris in record #1102 may be unuseable
Factory Defaults		Restores the original settings for Conexant Jupiter

7.3.3 Conexant NAVCOR
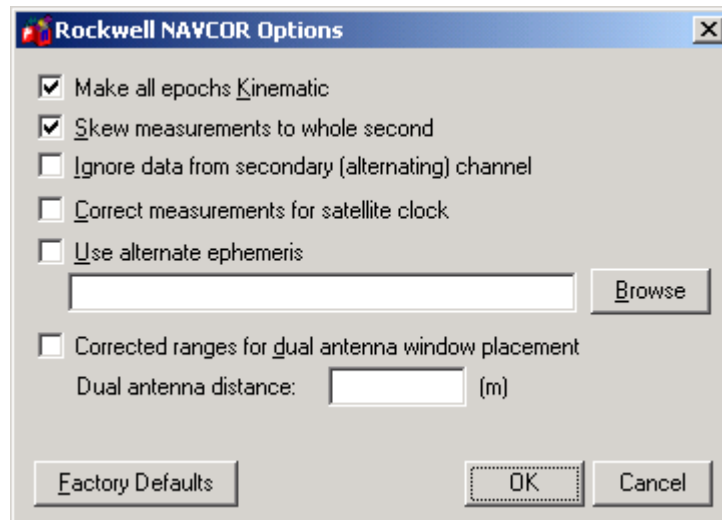
Figure 7.6 Conexant NAVCOR Dialogue Box

Make all epochs kinematic	Use this to make every epoch kinematic, otherwise, will be static; use ViewGPB to switch individual or groups of epochs between static and kinematic
Skew measurements to whole second	Shift to whole second
Ignore data from secondary (alternating) channel	5th channel on this receiver alternates between remaining satellites. Enable this to ignore

Correct measurements for satellite clock	Should be off
Use alternate ephemeris	Use if ephemeris is missing
Corrected ranges for dual antenna window placement	For CSSI users only
Factory Defaults	Restores original settings for conversion process

7.3.4 CSI SLX/DGPS-MAX

Convert data from DGPS-MAX receiver to GPB

Data Required

Record	Type	Comments
96	Measurements	
1	Position	
95	Ephemeris	

Options
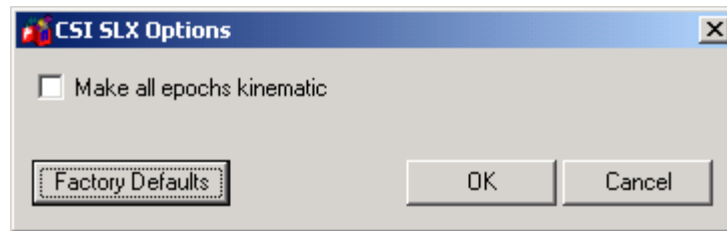
Figure 7.7 CSI SLX/DGPS-MAX Dialogue Box

Make all epochs kinematic	Use this to make every epoch kinematic, otherwise, will be static; use ViewGPB to switch individual or groups of epochs between static and kinematic
Factory Defaults	Restores original settings for conversion process

7.3.5 Javad/Topcon

The Javad decoder in CONVERT will decode the binary data from any Javad receiver into .gpb format. This includes both the GPS and GPS/GLONASS receivers.

Data Required

Record	Type	Comments
RC, rc	C/A Code Measurement Block	RC suggested
R2, r2, 2R, 2r	L2 P Code Measurement Block	2R suggested
PC, pc, CP, cp	L1 Phase Measurement Block	CP suggested
P2, p2, 2P, 2p	L2 Phase Measurement Block	2P suggested
DC	L1 Doppler Measurements	suggested

GE	GPS Ephemeris	
NE	GLONASS Ephemeris	
TO	Clock Offset	
TC	Locktime	
PO	Position	
SI	PRN List	
RD	Receiver date	
OEM	Measurement	Compressed record which is more robust

Options
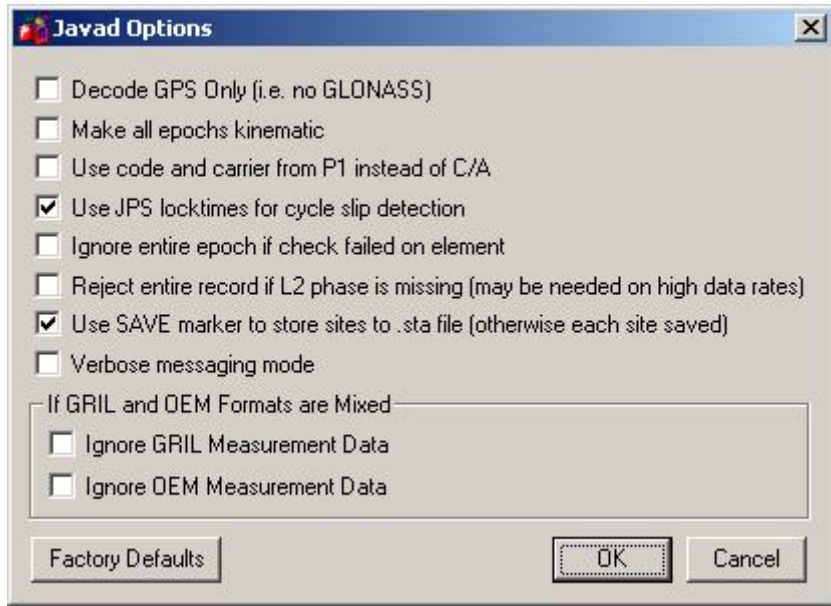
Figure 7.8 Javad Options Dialogue Box

Decode GPS only (i.e. no GLONASS)	This option causes the decoder to ignore all GLONASS data (i.e. GPS only)
Make all epochs kinematic	Use this to make every epoch kinematic, otherwise, will be static; use ViewGPB to switch individual or groups of epochs between static and kinematic
Use code and carrier from P1 instead of C/A	P1 code is currently encrypted with Y code , but once SA is off, it is expected that L1 phase from P1 code will be more accurate

Use JPS locktimes for cycle slip detection	Locktimes from the Javad receiver will be used instead of the ones computed by the decoder; currently, the Javad has a problem with the locktime counter, however, this may change with future firmware versions
Ignore entire epoch if check failed on element	If enabled, GPS data for the entire epoch is ignored if a checksum error is reported for any of the incoming records. Otherwise, only the affected data is ignored.
Use SAVE marker to store sites to .sta file	Markers will be saved to .sta file
Reject entire record if L2 phase is missing (may be needed for high data rates)	
Verbose messaging mode	Allows the user to see additional warning messages

If GRIL and OEM Formats are Mixed		
	Ignore GRIL Measurement Data	Ignore GRIL record information and only utilize OEM
	Ignore OEM Measurement Data	Ignore OEM and only use GRIL
Factory Defaults	Restores original settings for conversion process	

Notes

Current JPS default messages are: RC, CP, 2P, DC, and 2R or some set of equivalent records.

7.3.6 Leica SR and MX

Leica raw GPS measurement data can come in two types of formats. The MX series data files are produced by the MX 4200 and 9200 receivers while the SR series data formats are produced by the SR-299, 399, 9400, 9500 sensors. The SR files usually start with DS. The decoder in CONVERT will automatically detect if the files are from the SR or MX series.

Data Required

SR series

File	Type	Comments
DS*.OBS	Measurements	
DS*.EPH	Ephemeris	

or

MX series

Record	Type	Comments
2	Measurements	Raw data for 6 channels
3	Measurements	Raw data for 12 channels
8	Position	
200	Ephemeris	
201	Ephemeris	
202	Ephemeris	
203	Ephemeris	

Supported Files (SR only)

File	Type	Comments
DS*.CMP	Position	SR series
DS*.TTP	Station	SR series
DS*.EVT	Event Mark	Produced by SR-9400 & 9500 sensors -> MRK file
DS*.INT	Station	SR series
DS*.CHN	Static Chains	SR series
.EV0	Event Mark	ASCII files produced by ASCOT system with MX series; read by GrafNav directly
.TDU	Event Mark	ASCII files produced by TDU units running in conjunction with SR sensor series (SR-299,399); read by GrafNav directly
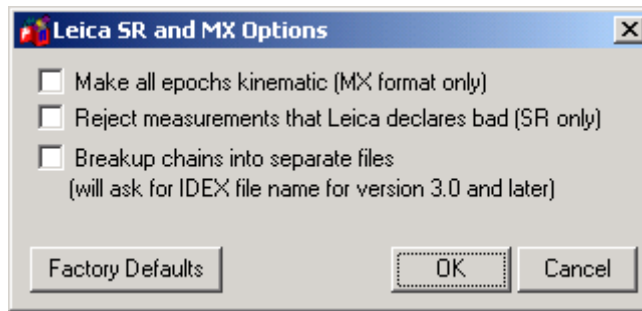
Options

Figure 7.9 Leica SR and MX Options Dialogue Box

Make all epochs kinematic (MX format only)	Use this to make every epoch kinematic, otherwise, will be static; use ViewGPB to switch individual or groups of epochs between static and kinematic; only works for MX format

Reject measurements that Leica declares bad (SR only)	The Leica rejection flags are very sensitive; better results can often be obtained by ignoring them; however, if bad measurements are a problem, try this option
Breakup chains into separate files (will ask for IDEX file name for version 3.0 and later)	For SR files that contain more that one static session (chain) per file, enable this option to split the chains up into separate .gpb files; see note below
Factory Defaults	Restores original settings for conversion process

Tips/Notes
One current limitation of the SR decoder is that it does not copy alphanumeric station names properly since only the numeric index is retained. This occurs in the newer firmware versions (i.e. versions 3.0 and later). The value retained is in an index of a list of station names that are contained in the Leica file system. To circumvent this, an IDEX file can be loaded into GrafNav (for kinematic processing) or into the decoder directly (for static chains). See Section 2.2.11 for instructions on creating an IDEX file.

7.3.7 Leica System 500

Use this decoder for Leica files from the newer System 500 or SR530 series receivers.

Data Required

Record	Type	Comments
19, or	Measurements	Compacted observation data
20	Measurements	Full observation data; not fully tested as of June 4,1999; Use this record if Doppler measurements are desired
15	Ephemeris	

Additional Files

Record	Type	Comments
10	Position	
13	Station/Event Mark	
9	Antenna Height	

Options
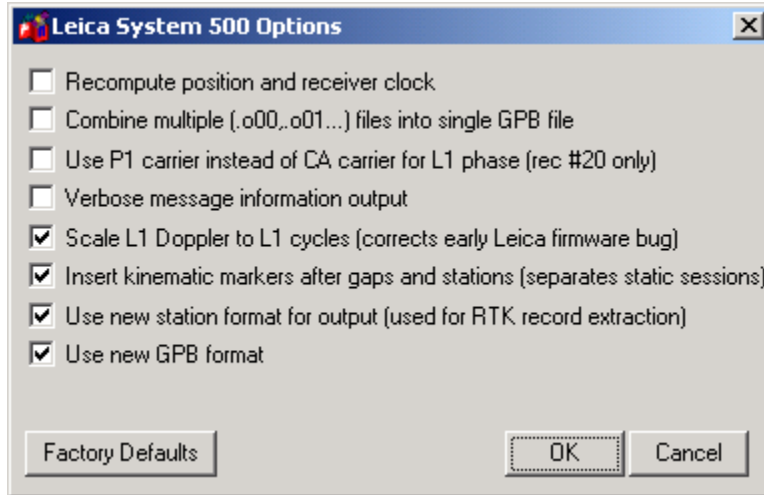
Figure 7.10 Leica System 500 Options Dialogue Box

Recompute position and receiver clock	GrafNav requires clock shift to perform data processing, while GrafNet needs the position record. If the position record is not available, choose this option to use the decoder algorithms
Combine multiple (.o00,.o01…) files into single GPB file	The Leica SR530 receiver writes all of its data into separate files from one session with different extensions; this option allows the user to combine files from one session into one .gpb file
Use P1 carrier instead of CA carrier for L1 phase (rec #20 only)	P1 code is currently encrypted with Y code, but once SA is off, it is expected that L1 phase from P1 code will be more accurate
Verbose message information output	Alerts the user of additional warnings and errors that have occurred
Scale L1 Doppler to L1 cycles	Recalculates Doppler, corrects for early Leica firmware bug
Insert kinematic markers after gaps and stations	Ensures that static sessions are properly created
Use new station format for output	Utilizes new more detailed format
Use new GPB format	Converts data into the new GPB format
Factory Defaults	Restores the original settings of the decoder for processing

7.3.8 Magellan ProMark

Decodes ProMark data format.

Options
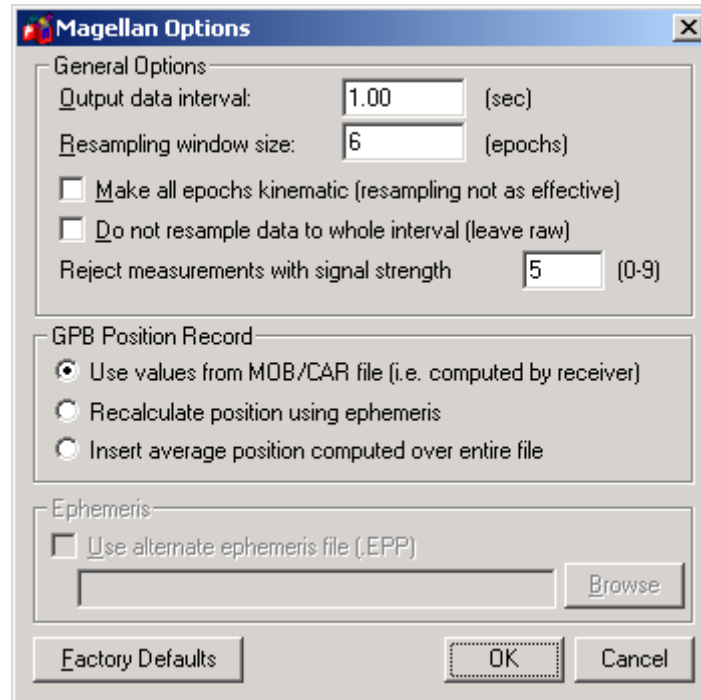
Figure 7.11 Magellan Dialogue Box

General Options		
	Output data interval	Resample to this data interval
	Resampling window size	Number of epochs used for resampling operator
	Make all epochs kinematic	Use this to make every epoch kinematic, otherwise, will be static; use ViewGPB to switch individual or groups of epochs between static and kinematic
	Do not resample data to whole interval (leave raw)	If data is kinematic, it is better to resample to base station using GPBCat
	Reject measurements with signal strength	Reject very poor measurements (see ProMark documentation)
GPB Position Record		
	Use values from MOB/CAR file	Utilize position computed by receiver

	Recalculate position using ephemeris	Recompute position by decoder
	Insert average position computed over entire file	Use average of values compiled by receiver
Ephemeris		
	Use alternate ephemeris file (.EPP)	Use if ephemeris missing or imcomplete
Factory Defaults		Restores the original settings for Magellan ProMark

7.3.9 Motorola Oncore

CONVERT will decode 6 and 8 channel data from the Motorola VP Oncore to .gpb and .epp format from the binary Motorola files.

Data Required

Record/File	Type	Comments
@@Ea or	Position	8 channel
@@Ba	Position	6 channel
@@Eg or	Measurements	8 channel
@@Bg	Measurements	6 channel
@@Bf	Ephemeris	

Options
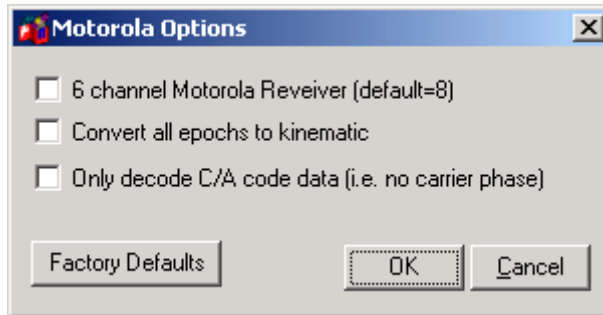
Figure 7.12 Motorola Oncore Options Dialogue Box

6 channel Motorola Receiver (default=8)	Select the receiver type that was used to collect the data
Convert all epochs to kinematic	Use this to make every epoch kinematic, otherwise, will be static; use ViewGPB to switch individual or groups of epochs between static and kinematic
Only decode C/A code data (i.e. no carrier phase)	Perform a code only extraction, thereby ignoring carrier lock information
Factory defaults	Restores the default settings for processing

Tips/ Notes
The VP Oncore has been discontinued. The GT Plus is its replacement and does not have raw data output capabilities. Its data can only be corrected via position correction methods.

7.3.10 NavCom

Will decode binary data from all of NavCom's receivers.

Data Required

Record/File	Type	Comments
0xB0	Measurement	
0xB1	Position	
0x81	Ephemeris	
0xB4	Event Marker	

Options
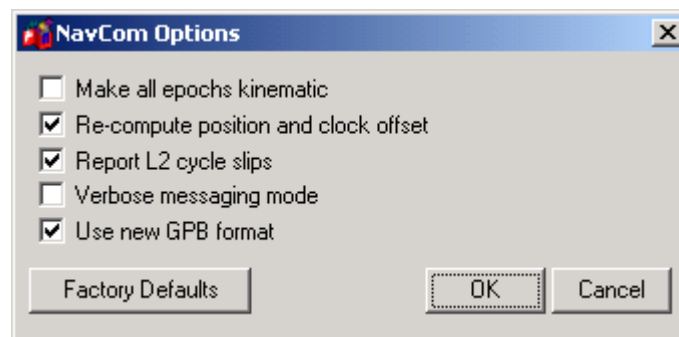
Figure 7.13 NavCom Dialogue Box

Make all epochs kinematic	Use this to make every epoch kinematic, otherwise, will be static; use ViewGPB to switch individual or groups of epochs between static and kinematic
Re-compute position and clock offset	GrafNav requires clock shift to perform data processing, while GrafNet needs the position record. If the position record is not available, choose this option to use the decoder algorithms
Report L2 cycle slips	Print message if L2 cycle slip encountered
Verbose messaging mode	Allows the user to see additional warning messages
Use new GPB format	Converts data into the new GPB format
Factory Defaults	Restores original settings for conversion process

7.3.11 NovAtel CMC

Raw data from the NovAtel CMC All Star and Super Star can be converted to .gpb using this receiver type in CONVERT. Waypoint also has logging software available that will log directly from the CMC All Star receiver.

Data Required

Record	Type	Comments
ID#20	Position	Should be last record requested
ID#22	Ephemeris	
ID#23	Measurements	This measurement record is recommended for better results
ID#13	Measurements	Old style measurement record (not suggested)
ID#14	Measurements	Old style measurement record (not suggested)
ID#15	Measurements	Old style measurement record (not suggested)
ID#16	Measurements	Old style measurement record (not suggested)

Options
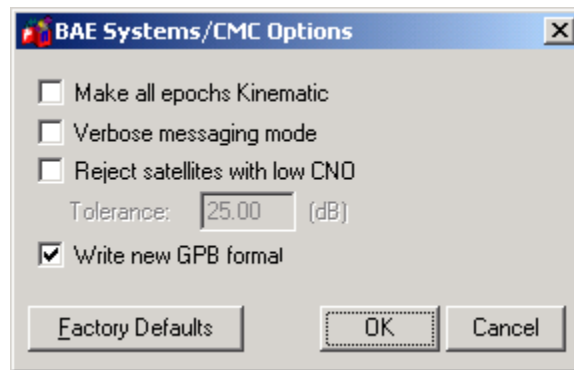
Figure 7.14 CMC All Star Options Dialogue Box

Make all epochs Kinematic	Use this to make every epoch kinematic, otherwise, will be static; use ViewGPB to switch individual or groups of epochs between static and kinematic
Verbose messaging mode	Allows the user to see additional warning messages
Reject satellites with low CNO	Satellites with low CNO will not be decoded
Write new GPB format	Converts data into the new GPB format
Factory Defaults	Restores original settings for conversion process

7.3.12 NovAtel OEM2/3/SoftSurv

This utility converts raw binary NovAtel data to a .gpb file. The real-time data is formed when data logged externally from the receiver using a utility such as DUMP, WINSAT, or another simple logger. If you wish to convert NovAtel ASCII data, then use NovAtel's convert utility.

Note: There are two decoders:

       a) NovAtel OEM2/SoftSurv decoder
       b) NovAtel OEM3 decoder supporting new GPB format

Data Required

Record	Type	Comments
RNGB (use one of the following measurement records), or	Measurements	2100 Series; Ontime; outdated
RGED, or	Measurements	3100 Series; Ontime (suggested)
RGEC, or	Measurements	3100 Series; Ontime
RGEB	Measurements	3100 Series; Ontime
REPB	Ephemeris	2100, 3100 Series; Onchanged or Ontime 600

Additional Records Supported

Record	Type	Comments
POSB	Position	To see your position when GrafNav starts, either log POSB or use position computed algorithms
MKTB	Event Mark	CONVERT will automatically decode this record into a *.MRK file
MKPB	Event Mark	CONVERT will automatically decode this record into a *.MRK file
CLKB	Clock Info	Standard correlator receivers should log the CLKB record or recompute the position and clock correction; the clock correction (offset) is needed; this record is also suggested if you log data right from power up

File	Type	Comments
*.orb	Ephemeris	SoftSurv Ephemeris file for processing

Options
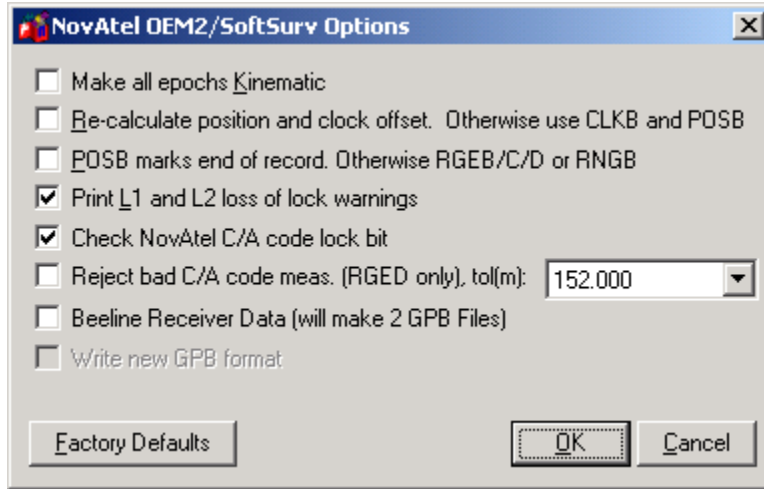
Figure 7.15 NovAtel Options Dialogue Box

Make all epochs Kinematic	Use this to make every epoch kinematic, otherwise, will be static; use ViewGPB to switch individual or groups of epochs between static and kinematic; SoftSurv files may have static / kinematic detected automatically
Re-calculate position and clock offset. Otherwise use CLKB and POSB	If no POSB record is present, use this option to recalculate the position and time; REPB ephemeris record must be present; epochs collected before REPB will not be recompiled and may cause problems, use ViewGPB to check
POSB marks the end of record. Otherwise RGEB/C/D or RNGB	If POSB record is requested after the RGEB/C/D or RNGB record, select this option to ensure that the POSB time record matches the RGEB; otherwise, request RGEB/C/D or RNGB first; this would ONLY be used if an RTK or DGPS position is to be preserved
Print L1 and L2 loss of lock warnings	Alerts the user of phase loss of lock problems in the status window
Check NovAtel C/A code lock bit	Prevents measurements that the NovAtel receiver has detected as having bad C/A code from entering the GPB file

Reject bad C/A code meas. (RGED only), tol(m)	In the RGED format, the PRN range record has 4 bits that determine the pseudorange standard deviation. Each possible code (out of a possible 16) represents a range of standard deviation. The user can use the code in the record as a tolerance for which C/A code measurements to reject.
Beeline Receiver Data (will make 2 GPB Files)	Split Beeline data into two files for primary and secondary antennas
Write new GPB format	Converts data into the new GPB format
Factory Defaults	Restores original settings for conversion process

Tips/Notes

- Ask for the ephemeris once, then ask for onchanged later on
- Use RGEC or RGED since they are much smaller records
- Make sure your baud rate is high enough to log 12 channels and the records requested; note that GPS and GPS/GLONASS MiLLennium has 24 channels
- Use either MKTB or MKPB, but not both
- If logging CLKB, request for it before RGEB/RGEC/RGED
- If no static data was collected, remember to enable the Make all epochs Kinematic option since it is important to make the epochs where the vehicle is moving kinematic
- User may need to recompute position and time in GPBView if clock adjustment not available at start

7.3.13 NovAtel OEM4

Decode data from NovAtel's OEM4 product line.

Data Required

Record	Type	Comments
43	Measurement	RangeB Expanded format
140	Measurement	RangeCmpB Compressed
64000	Measurement	Waypoint Ultra Compressed *

* Please obtain OEM4 on-board program from Waypoint.

Additional Records Supported

Record	Type	Comments
73		AlmanacB
42		BestPosB Position info
8		IonUtcB Iono correction and UTC offset
181		MarkedPosB Position of event (no time)
71		PRPCLKMODELB clock info
41		RAWEPEMB Ephemeris

231		MARKTIMEB Event time
74		RAWALM Raw almanac data

Options
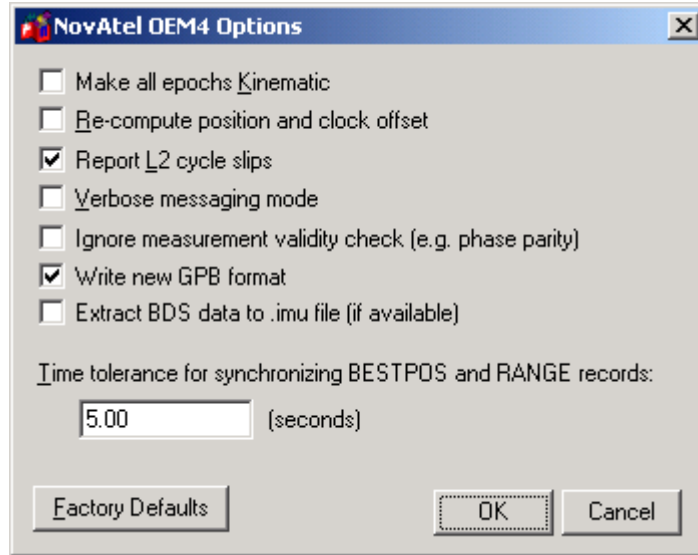
Figure 7.16 NovAtel OEM4 Dialogue Box

Make all epochs Kinematic	Use this to make every epoch kinematic, otherwise, will be static; use ViewGPB to switch individual or groups of epochs between static and kinematic
Re-compute position and clock offset	GrafNav requires clock shift to perform data processing, while GrafNet needs the position record. If the position record is not available, choose this option to use the decoder algorithms
Report L2 cycle slips	Alerts the user of phase loss of lock problems in the status window
Verbose messaging mode	Allows the user to see additional warning messages
Ignore measurement validity check	Utilizes more measurements by ignoring NovAtel data validity checks
Write new GPB format	Converts data into the new GPB format
Extract BDS data to .imu file	Extracts inertial data if available

Time tolerance for synchronizing BESTPOS and RANGE records	Assigns position to GPB record if time difference between measurement and position record less than tolerance. Note, decoder uses measurement record to compute record and save to disk
Factory Defaults	Restores original settings for conversion process

7.3.14 RINEX

The CONVERT utility will change the RINEX format into the .gpb format. RINEX (Receiver INdependent EXchange) is a format that uses ASCII in two files for measurement and ephemeris data. The .nav/.yyn file contains the ephemeris data while the .obs/.yyo contains the GPS measurement data for each epoch.

RINEX is a very flexible format and it has been sometimes interpreted differently by various receiver manufacturers, software developers and government agencies, which produce RINEX files. Due to this reason, RINEX has occasionally caused problems, and sometimes the altering of options is necessary to get the RINEX files to convert properly.

The RINEX decoder also supports Hatanaka/Compressed RINEX observation files.

Data Required

File	Type	Comments
.yyo (i.e.*.99o), *.obs, .0?o, *.rxo, *.0?d	Measurements	
.yyn (i.e.*.99n), *.nav, *.rxn	Ephemeris	

Options
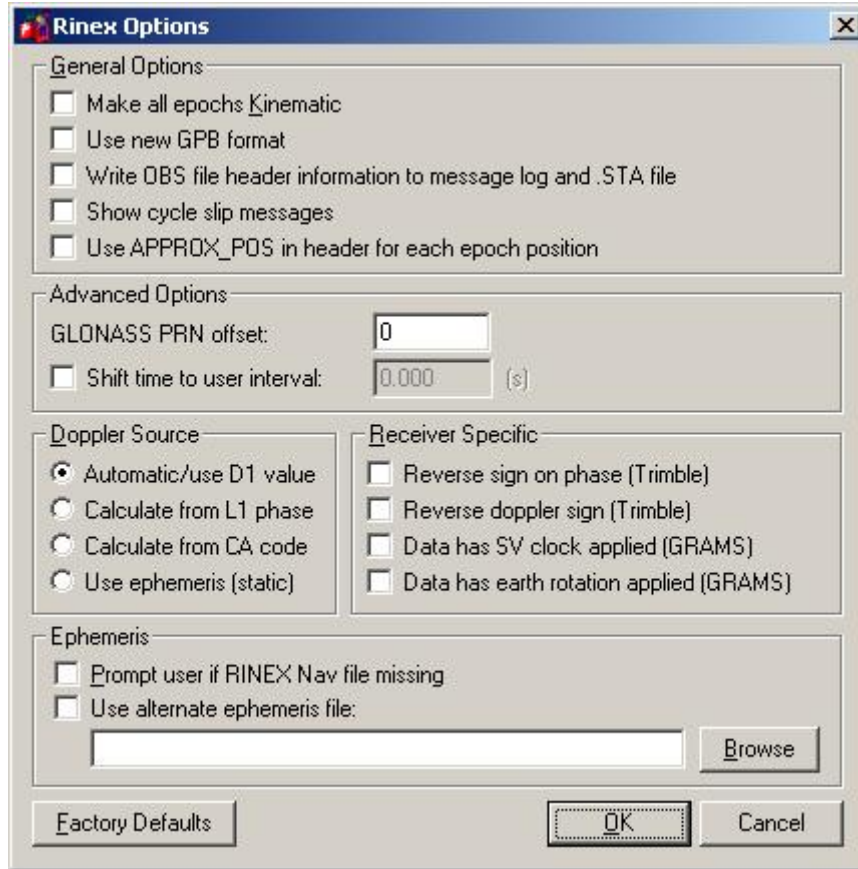
Figure 7.17 RINEX Options Dialogue Box

General Options		
	Make all epochs Kinematic	Use this to make every epoch kinematic, otherwise, will be static; use ViewGPB to switch individual or groups of epochs between static and kinematic
	Use new GPB format	Converts data into the new GPB format
	Write OBS file header information to message log and .sta file	Saves content of observation file header to message log and station file. Can be useful for determining receiver and antenna type
	Show cycle slip messages	Prints L1 and L2 cycle slip messages to message log

	Use APPROX_POS in header for each position	Uses approximate position in observation header for each epoch's position
Advanced Options		
	GLONASS PRN offset	Shifts PRN number of GLONASS satellites by this number (>32)
	Shift time to user interval	If data interval determination (from header or file scanning) fails, use this to correct data interval
Doppler Source		
	Automatic/use D1 value	Uses D1 value for Doppler or auto-detect if missing; auto-detection will use Calculate from CA code for < 10 second intervals, or otherwise Use ephemeris (static)
	Calculate from L1 phase	If the Doppler signal is missing or unstable, use L1 phase to calculate Doppler
	Calculate from CA code	If the Doppler signal is missing or unstable, use CA code to calculate Doppler; this will create fewer problems than the L1 phase method but velocity accuracies may be worse
	Use ephemeris (static)	Assume still site and compute Doppler from satellite velocities; Doppler will have SA effects (0.5 m/s)
Receiver Specific		
	Reverse sign on phase (Trimble)	Some RINEX older Trimble formats have the incorrect sign on the phase
	Reverse Doppler sign (Trimble)	Some RINEX older Trimble formats have the incorrect sign on the Doppler signal
	Data has SV Clock applied (GRAMS)	
	Data has earth rotation applied (GRAMS)	

	Receive time is GPS time (GRAMS)	
Ephemeris		
	Prompt user if RINEX Nav file is missing	If a nav file is missing or has a different name than the obs file, the user will be prompted to select a different broadcast ephemeris
	Use alternative ephemeris file	User defines ephemeris path name manually; this will override the prompting for a missing nav file
Factory Defaults		Restores the original defaults for RINEX data processing

Tips/Notes
- Be sure that data interval is determined properly
- Watch out for incorrect sign on carrier phase and Doppler

7.3.15 Rockwell PLGR/MPE12 (Rockwell version only)

CONVERT also decodes Rockwell Jupiter binary data into the .gpb files. Older versions of Jupiter firmware did not make measurements on the even second; therefore to enable GrafNav to use the data, the measurements need to be skewed to the even second by using Doppler measurements. Newer versions of the firmware can make the measurements on the even second if enabled so that skewing is no longer necessary.

Data Required

| Record	Type	Comments
1102	Measurement/Ephemeris	To extract the ephemeris from the 1102 file, a record for each second is needed
1000	Position	Contains position and clock offset

Options
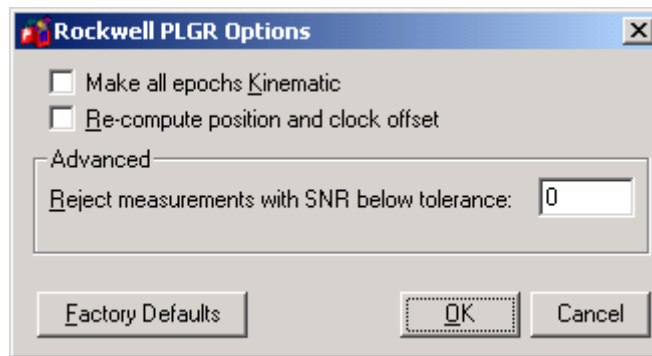
Figure 7.18 Rockwell Jupiter Options Dialogue Box

General Options		
	Make all epochs Kinematic	Use this to make every epoch kinematic, otherwise, will be static; use ViewGPB to switch individual or groups of epochs between static and kinematic
	Re-compute position and clock offset	GrafNav requires clock shift for processing; if these are incorrect, unstable or missing from the original data file (i.e. no record row), use this option for the decoder algorithms to re-calculate
Advanced		
	Reject measurements with SNR below tolerance	Satellites with low CNO will not be decoded
Factory Defaults		Restores the original settings to allow for processing

7.3.16 Septentrio SBF

Data from the Septentrio SBF format can be converted into GPB format.

Required Records

Record	Type
5889 *	Measurement record
5890 *	Compressed measurement record
5891	GPS Nav (Ephemeris)

* Either record 5889 or 5890 is required.

Supported Records

Record	Type
5904	PVT Geodetic

Options
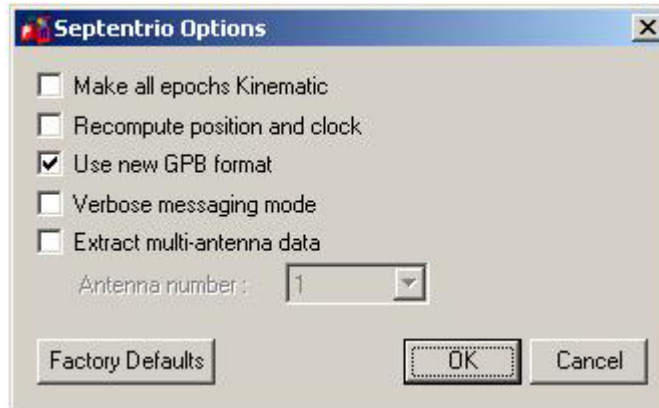
Figure 7.19 Septentrio Dialogue Box

Make all epochs Kinematic	Use this to make every epoch kinematic, otherwise, will be static; use ViewGPB to switch individual or groups of epochs between static and kinematic
Recompute position and clock	GrafNav requires clock shift for processing; if these are incorrect, unstable or missing from the original data file (i.e. no record row), use this option for the decoder algorithms to re-calculate
Use new GPB format	Converts data into NEW GPB format
Verbose messaging mode	Allows the user to see additional warning messages
Extract multi-antenna data	Should only be used for multi-antenna applications

7.3.17 Sirf Binary

Converts binary data from Sirf GPS receivers or receivers using Sirf chipset.

Data Required

Record	Type	Comments
28	Measurement	Navlib measurement record
2	Position	
15	Ephemeris	
7	Clock offset	

Options
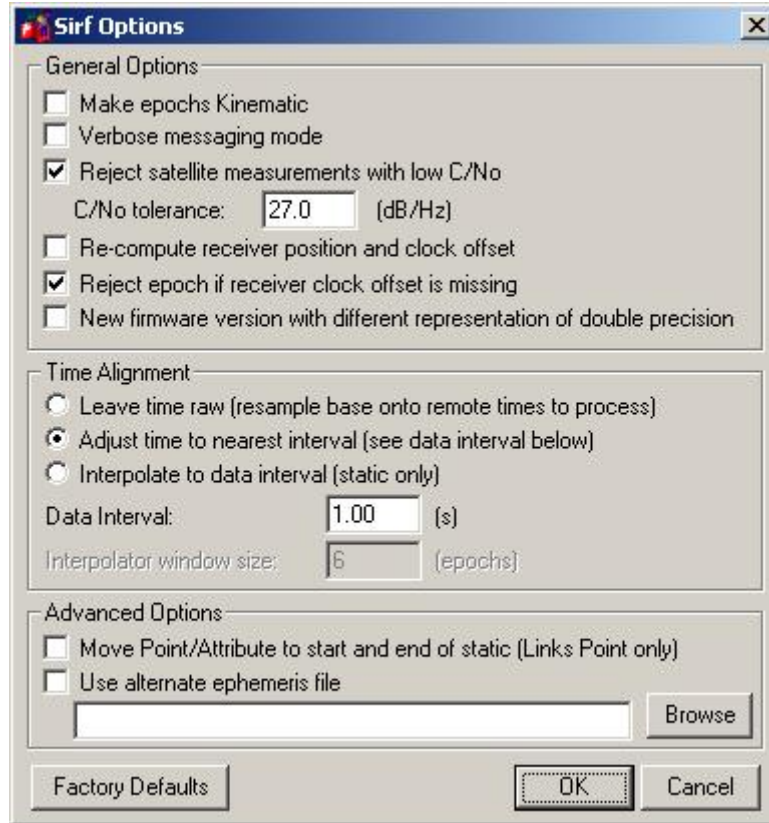
Figure 7.20 Sirf Dialogue Box

General Options		
	Make epochs Kinematic	Use this to make every epoch kinematic, otherwise, will be static; use ViewGPB to switch individual or groups of epochs between static and kinematic
	Verbose messaging mode	Allows the user to see additional warning messages
	Reject satellite measurements with low C/No	Satellites with low C/No will not be decoded

	Re-compute receiver position and clock offset	GrafNav requires clock shift for processing; if these are incorrect, unstable or missing from the original data file (i.e. no record row), use this option for the decoder algorithms to re-calculate
	Reject epoch if receiver clock offset is missing	Data is unusable if clock offset is missing. However, clock offset can be re-computed using GPBView
	New firmware version with different representation of double precision	
Time Alignment		
	Leave time raw	Use for kinematic or single point. Master data can be interpolated on to remote using GPBCat
	Adjust time to nearest interval	Kinematic/code-only shift to a interval equal to base data interval
	Interpolate to data interval (static only)	Static only, interpolate Sirf data onto regular data interval
Advanced Options		
	Move Point/Attribute to start and end of static	Links Point only
	Use alternate ephemeris file	Use if ephemeris is missing but recompute or interpolation selected
Factory Defaults		Restores the original settings to allow for processing

Tips/Notes

- Sirf does not measure on whole epoch; either master or remote must be interpolated to make work. Contact Waypoint for help.

7.3.18 Thales Download (B-File Format)

CONVERT will decode Thales data downloaded using their receiver download utility. This data will have been logged into internal receiver memory. Thales receivers such as the Super C/A, Sensor or G12 must use the Thales Real-Time format type in CONVERT (described in 7.3.19).

Data Required

File	Type	Comments
Bssssayy.jjj	Measurements	Measurement file where ssss = site name, a = session, yy = year, jjj = Julian day

Additional Records Supported

File	Type	Comments
Essssayy.jjj	Ephemeris	GPS+GLONASS ephemeris
Sssssayy.jjj	Station	Static site info (antenna height)
Dssssayy.jjj	Station	Kinematic station information
PHOTO.DAT	Event Mark	Camera events; must be loaded by GrafNav directly
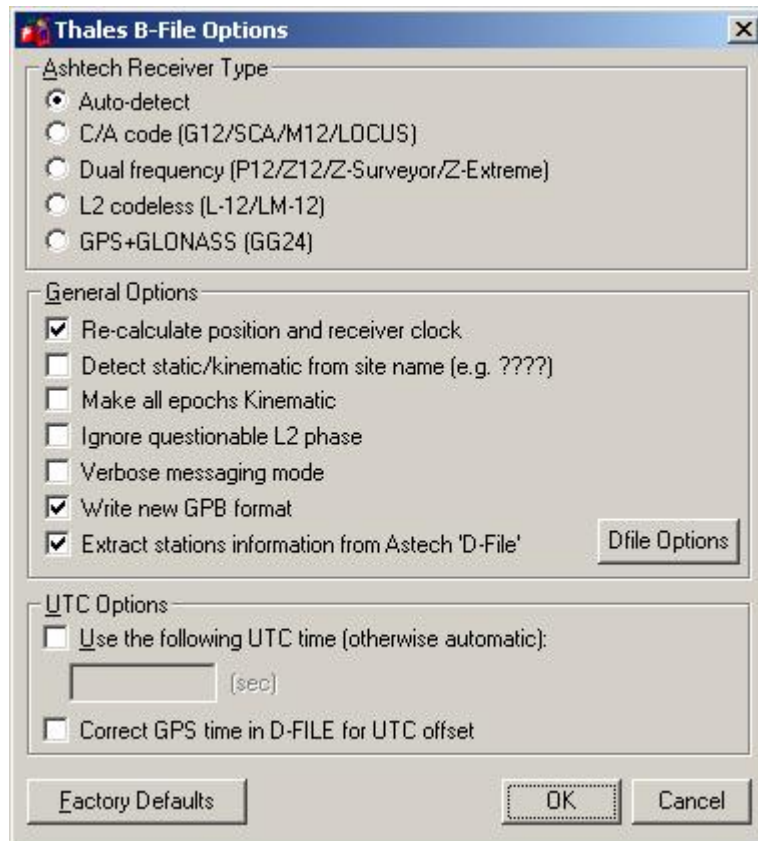
Options

Figure 7.21 Thales Download Options Dialogue Box

Ashtech Receiver Type		Select the Thales receiver used to collect the data; if auto-detect does not work, try selecting your receiver type manually
General Options		
	Re-calculate position and receiver clock	Used to correct incompatible clock correction sometimes computed by a Thales receiver; it is suggested that this option be used since GrafNav requires clock shift for post-processing; GrafNet requires both position and clock shift
	Detect static/kinematic from site name	Looks in Thales B-File for data tagged as static or kinematic using (????) site ID
	Make all epochs kinematic	Use this to make every epoch kinematic, otherwise, will be static; use ViewGPB to switch individual or groups of epochs between static and kinematic
	Ignore questionable L2 phase	Allows for processing of highest quality L2 data only; enable this if KAR is having difficulties
	Verbose messaging mode	Allows the user to see additional warning messages
	Write new GPB format	Converts data into the new GPB format
	Extract stations information from Ashtech 'D-File'	Various Thales handheld controllers can output a D-File which contains information regarding features and antenna heights. Enable this checkbox to utilize this information.
UTC Options		
	Use the following UTC time (otherwise automatic)	Changes the GPS to UTC time offset from the current nominal value to user defined value; this is normally used for GLONASS processing if no UTC is contained in the data
	Correct GPS time in D-FILE for UTC offset	Thales D-files can have GPS or UTC time; changes time to GPS if in UTC

Dfile Options		
	Chain Repeated Station Marks into 1 Static Session	Enabling this setting causes sessions repeated in the Seismark software to be combined into one session
	Do NOT Chain Marks that are more than # seconds apart	This value controls the time tolerance used in the previous setting. Basically, if two static periods marked less than this time amount apart, they will be combined
Factory Defaults		Restores the original decoding options for Thales Download

Tips/Notes
- Antenna heights may need to be altered within the feature editor if not kept constant as the Thales format only allows one value
- Re-calculate position and time may need to be used if many cycle slips exist
- User may need to select receiver type manually

7.3.19 Thales Real-Time

This receiver type converts Thales Real-Time (DG16, G12 and Super C/A) data to a .gpb file. The real-time data is formed when data is logged externally from the receiver using a utility such as WLOG (raw format) or another simple or custom data logger. The DLL for this decoder forms two files: .gpb and .epp.

Data Required

Record	Type	Comments
MBN (use one of the following measurement records) or	Measurements	Preferable record for G12
MCA or	Measurements	
MPC or	Measurements	Dual frequencies (i.e. Z12)
MCL or	Measurements	L2 codeless
MACM or	Measurements	Preferable record for G12; can facilitate high data rate applications of 10 or 20 Hz w/o bandwidth limitations
ITA	Measurements	G8 measurement record, code only
CT1	Measurements	C/A code
CT2	Measurements	C/A code, L1 carrier
CT3	Measurements	C/A code, L1 carrier, L1 doppler
SNV	Ephemeris	
PBN	Position	Marks end of record
SNG	Ephemeris	GLONASS ephemeris

Options
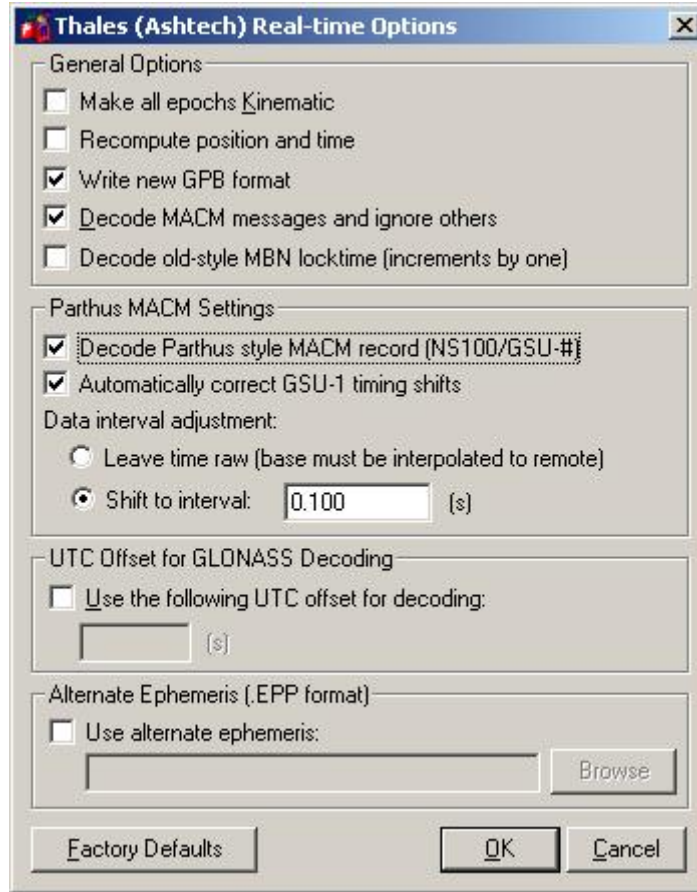
Figure 7.22 Thales Real-Time Options Dialogue Box

General Options		
	Make all epochs Kinematic	Use this to make every epoch kinematic, otherwise, will be static; use ViewGPB to switch individual or groups of epochs between static and kinematic
	Recompute position and time	GrafNav requires clock shift to perform data processing, while GrafNet needs the position record. If the position record is not available, choose this option to use the decoder algorithms
	Write new GPB format	Converts data into the new GPB format
	Decode MACM messages and ignore others	New Ashtech measurement record; ignore other measurement records if both MBN/MCA and MACM records exist.

	Decode old-style MBN locktime (increments by one)	Some older units (e.g. Sensor II) output the locktime with a different resolution. Use this option to properly output the locktime value.
Parthus MACM Settings		
	Decode Parthus style MACM record (NS100/GSU-#)	Parthus units (NS100, GSU-1 and GSU-2) utilize the MACM record. However, due to timing differences, its implementation is not compatible. Therefore this checkbox should be selected.
	Interval	The GSU-1 benefits greatly by having the correct data interval entered, while the GSU-2 is best processed with the raw time and having the base interpolated onto these times (see GPBCat)
UTC Offset for GLONASS decoding		
	Use the following UTC offset for decoding	Allows the user to define their own UTC offset rather than using the nominal or detected value; needed for GLONASS processing
Alternate Ephemeris (.EPP format)		
	Use alternate ephemeris	Utilize this option if recompute is selected but there are ephemeride missing (e.g. Parthus, GSU-2)
Factory Defaults		Restores the original settings for Thales Real-Time

7.3.20 Thales DNSP

Data Required

Record	Type	Comments
Measurement Q (hex 51)	Measurements	Receiver time record (recommended)
Measurement R (hex 52)	Measurements	Satellite time record
Measurement E (hex 45)	Ephemeris	

Options

Figure 7.23 Thales DNSP Options

Make all epochs Kinematic	Use this to make every epoch kinematic, otherwise, will be static; use ViewGPB to switch individual or groups of epochs between static and kinematic
Recompute position and time	GrafNav requires clock shift to perform data processing, while GrafNet needs the position record. If the position record is not available, choose this option to use the decoder algorithms

7.3.21 Trimble DAT

This utility converts Trimble 4000 – 5800 data to Waypoint's custom format by forming a .gpb and .epp file. The Trimble data files (.DAT) are formed when data is logged internally in the receiver. CONVERT should be able to handle most variations in the Trimble 4000 – 5800 series including event marks.

Data Required

File	Type	Comments
*.DAT	Measurement/Ephemeris/ Station	
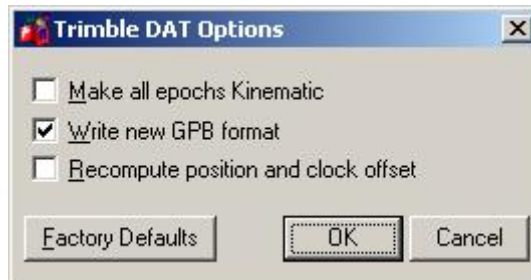
Options

Figure 7.24 Trimble DAT Options Dialogue Box

Make all epochs kinematic	Use this to make every epoch kinematic, otherwise, will be static; use ViewGPB to switch individual or groups of epochs between static and kinematic
Write new GPB format	Converts data into the new GPB format
Recompute position and clock offset	GrafNav requires clock shift to perform data processing, while GrafNet needs the position record. If the position record is not available, choose this option to use the decoder algorithms
Factory Defaults	Restores the original settings of the decoder for processing

Tips/Notes
The antenna height extracted by the converter may be the slant distance which needs to be corrected to get the vertical distance. Trimble SSF files must be converted to either .DAT or RINEX to be processed with GrafNav or GrafNet.

7.3.22 Trimble Real-Time

Data captured directly from a Trimble 4000-5800 receiver can also be converted to GPB using this decoder.

Data Required

Record	Type	Comments
0x0	Measurement	Concise and expanded
0x1	Position	
0x2	Ephemeris	

Options
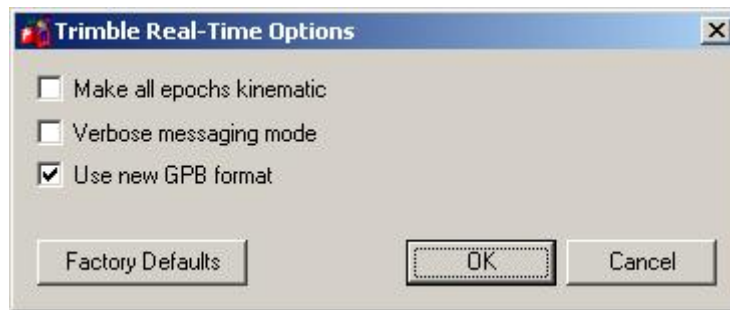
Figure 7.25 Trimble Real-Time Dialogue Box

Make all epochs kinematic	Use this to make every epoch kinematic, otherwise, will be static; use ViewGPB to switch individual or groups of epochs between static and kinematic

Verbose messaging mode	Allows the user to see additional warning messages
Use new GPB format	Converts data into the new GPB format
Factory Defaults	Restores the original settings of the decoder for processing

7.3.23   Trimble TSIP

Data in Trimble's TSIP format can be converted using this decoder. Receivers include Ag20, MS-750 and MD-950.

Data Required

Record	Type	Comments
0x9A	Measurement	
0x6t	Measurement	With carrier
0x5A	Measurement	Not suggested
0x4A	Position	Single precision
0x8A	Position	Double precision
0x58	Ephemeris	

Options
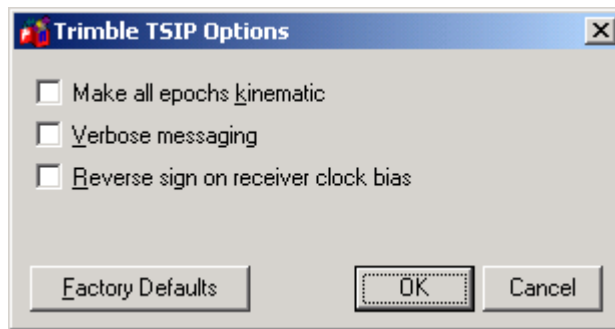
Figure 7.26 Trimble TSIP Dialogue Box

Make all epochs kinematic	Use this to make every epoch kinematic, otherwise, will be static; use ViewGPB to switch individual or groups of epochs between static and kinematic
Verbose messaging	Allows the user to see additional warning messages
Reverse sign on receiver clock bias	Opposite sign will be aplied to receiver clock bias
Factory Defaults	Restores the original settings of the decoder for processing

7.3.24 Trimble TIPY

Used by Force 5 receiver.

Data Required

Record	Type	Comments
0xAE	Measurement	
0x84	Position	LLA
0x99	Ephemeris	
0x44	DOPS	May not be used in post processing

Options
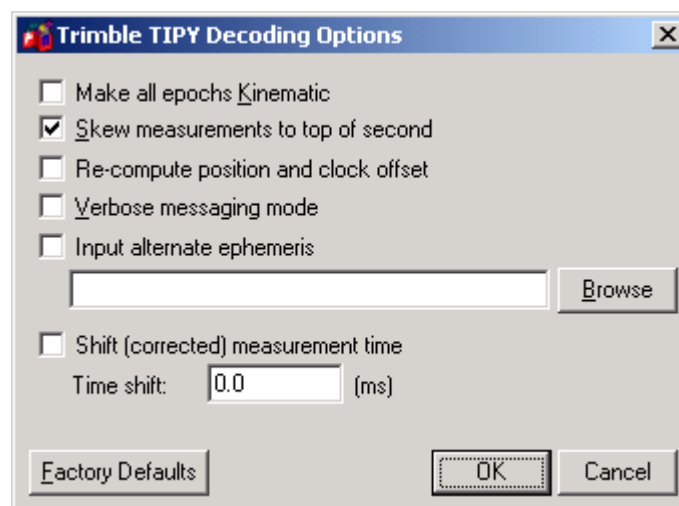
Figure 7.27 Trimble TIPY Dialogue Box

Make all epochs kinematic	Use this to make every epoch kinematic, otherwise, will be static; use ViewGPB to switch individual or groups of epochs between static and kinematic
Skew measurements to top of second	Shift times to whole second to make differential possible *
Re-compute position and clock offset	GrafNav requires clock shift to perform data processing, while GrafNet needs the position record. If the position record is not available, choose this option to use the decoder algorithms
Verbose messaging mode	Allows the user to see additional warning messages
Input alternate ephemeris	If ephemeris missing or imcomplete, use this setting to specify another ephemeris source file

Shift (corrected) measurement time	Apply time correction to measurements (used to correct old firmware bug)
Factory Defaults	Restores the original settings of the decoder for processing

* consider also leaving raw and using GPBCat to interpolate Master to Remote times.

Tips/Notes

- Force 5 carrier phase may not be usable.

7.3.25   U-Blox

Data Required

Record	Type
ID# 02	Position
ID# 22	Clock
ID# 10	Measurement
ID# 31	Ephemeris

Options
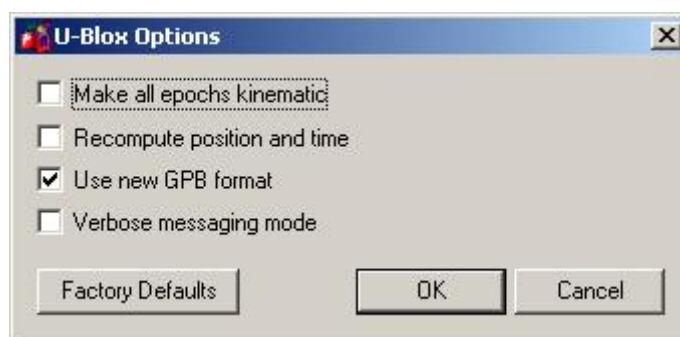
Figure 7.28 U-Blox Options

Make all epochs kinematic	Use this to make every epoch kinematic, otherwise, will be static; use ViewGPB to switch individual or groups of epochs between static and kinematic
Re-compute position and clock offset	GrafNav requires clock shift to perform data processing, while GrafNet needs the position record. If the position record is not available, choose this option to use the decoder algorithms
Use New GPB Format	Converts data into NEW GPB format
Verbose messaging mode	Allows the user to see additional warning messages
Factory Defaults	Restores the original settings of the decoder for processing

Chapter 8   Data Logging Utilities

Section 1 discusses the Windows data logger, and Section 2 covers the new Windows CE data logger.

Section 1   GPS Data Logger (Windows)

Waypoint provides a WIN95/98/2000/XP/NT data logger, which currently supports NovAtel, Ashtech, Trimble, Marconi, Rockwell Jupiter, Javad (Topcon), Parthus CSI, Navcom, and Garmin receivers. The data logger configures the GPS receivers, logs the measurement data and converts it into Waypoint's GPB / EPP, measurement / ephemeris format. Adjunct features include waypoint navigation, satellite and scatter plot capabilities. In addition, stations and events can be marked and written to .STA files compatible for post-processing by GrafNav/GrafNet.

The data logger is shipped with its own device driver for WIN95/98 users. This driver is called WPCOMM.VXD and should be placed in your WIN95 System Directory or in the current directory from which the data logger runs. On Windows 2000/XP/NT machines, the data logger uses the 2000/NT device driver.

8.1.1   Getting Started

To start using WLOG you simply follow the New Project Wizard to begin logging data. The New Project Wizard can be started either from the menu options or "quick started" from the toolbar by selecting NEW. Setting up a new project with the Wizard consists of the following steps:

Step 1 of 10
1.   Choose File > New Project to start the wizard
2.   Type in a Project Name, if you wish to store data to disk. The Project File stores the various settings used for logging data. Click Next once a project name has been selected.

Step 2 of 10
3.   Select the appropriate receiver type.
4.   Select a data interval at which data will be recorded. Note that this number is in units of data interval / second, thus a data interval of 0.5 means 2Hz.
5.   Select the appropriate Receiver Com Port.
6.   Check the "Request Camera Marks" box if you want camera marks. Note this option is only available for certain NovAtel, Ashtech and Javad receivers, and will be disabled otherwise.
7.   The most common usage of the option "re-compute position" is to force your data logger to output position at the data interval that you specified. Some receivers may log data at 10 Hz, but only output position at 1Hz.

Figure 8.1 Selecting Receiver Options

Step 3 of 10
8. NovAtel and Ashtech receiver users have the option to send ASCII commands to the receiver. This can be used to shut off commands or over-ride various receiver commands. Refer to your receiver manual for information on these commands.

Step 4 of 10
9. If you are using network for receiving data from the GPS receiver, choose TCP/IP in the "Receive Data by" box. Otherwise, select "Serial Port".
10. If using serial communication to obtain data from the GPS receiver to your computer-select the computer com port that the receiver is connected to.
11. Choose a baud rate from the list.
12. Select the parity, which for most receivers is none.
13. Select the bits for the receiver, which for most receivers is 8.

   Note: Refer to your receiver manual if you are not sure about the baud rate, parity or the bits for the receiver.

14. Choose the network protocol, and the port number. If using MultiCast protocol, type in the Multicast group IP address. UDP and Multicast protocols can be used for communication over local networks (i.e. within the same office), while TCP is used for wide area communication in the same manner as internet. You must choose a port number which does not conflict with those reserved for standard network purposes. Numbers starting at 1024 are usually considered safe. Ports can range to values of

65536. For Multicast groups, both the sender i.e. the GPS receiver and the receiver i.e. the computer must have the same IP address. For Win32, Multicast IP addresses range from 224.00.00.00 to 240.00.00.00. Select Next to proceed to the next step.
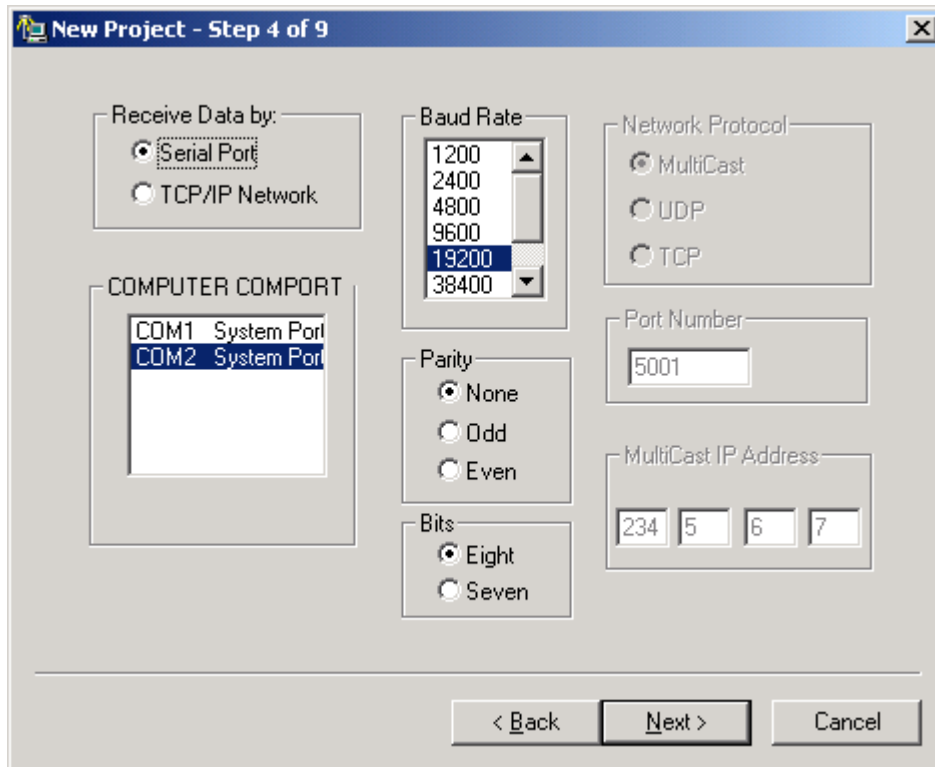
Figure 8.2 Computer/Receiver Configuration

Step 5 of 10

15. Select the radio button indicating how you would like the data to be saved. Data can be saved directly in Waypoint format i.e. GPB files or the data can be saved to disk byte by byte and decoded later with Waypoint's Convert utility.
16. If you want the data to be saved to disk then enter an appropriate file name. All data files will adopt the file prefix given in the Edit box seen above.
17. Select if you want all the data to be logged or if you want data within a certain time to be logged. Note if you are using defined start or end times then you will have to enter the GMT offset. Select Next to proceed to the next step in the wizard.
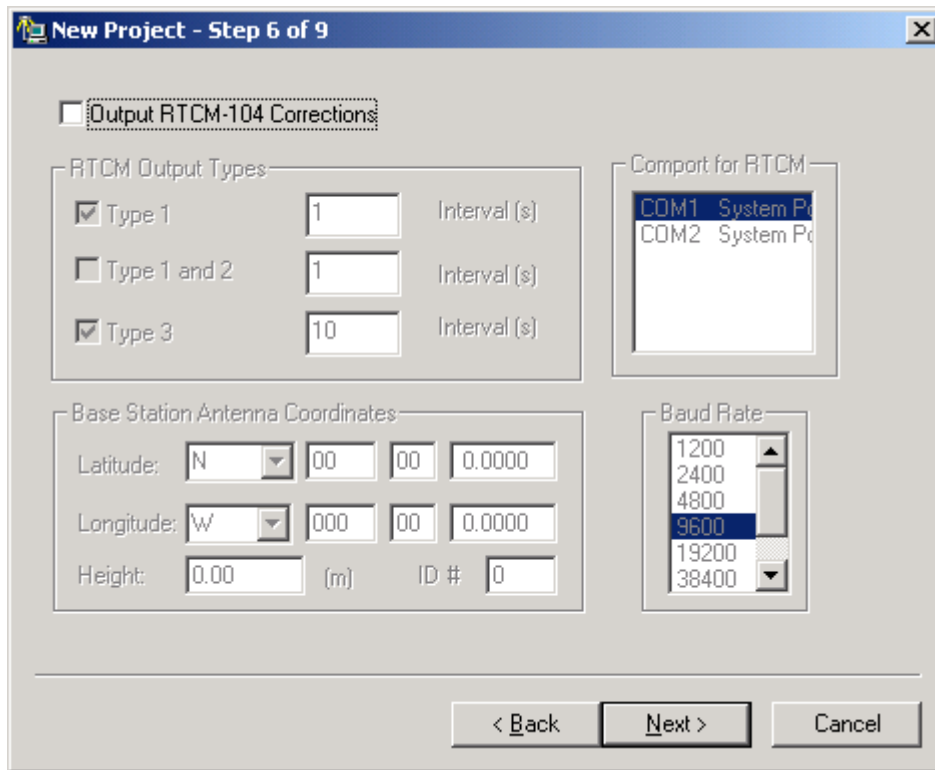
Figure 8.3 Generating RTCM Corrections (Optional)

Step 6 of 10
18. RTCM-104 corrections are the updated differential corrections. Check the "Output RTCM–104 Corrections" box if you want RTCM corrections to be displayed. If you are not displaying RTCM corrections then you are finished the setup.
19. Select the type of RTCM output you would like and the interval for each.
> Type 1: includes time, PRN, $\delta\rho$ and $\delta\rho$ rate.
> Type 2: has the last IODE (issue of data ephemeris).
> Type 3: gives position.
20. Select the comport you would like to use for the RTCM output.
21. Enter the base station coordinates for the Antenna.
22. Select the baud rate.

Step 7 of 10
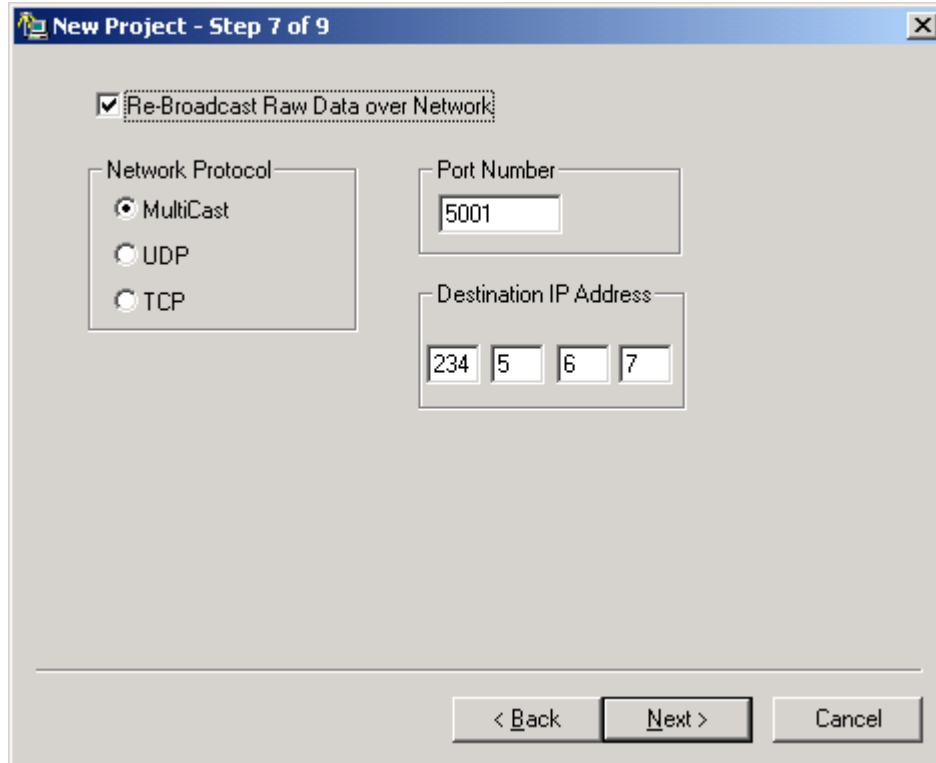
Figure 8.4 Re-broadcast GPS data over a Network (Optional)

23. GPS data collected by direct link to the GPS receiver can be rebroadcast over a local or wide area network. An example of this is as follows. Computer #1 collects GPS data on a serial port from the GPS receiver. It rebroadcasts this GPS data on Multicast port #5001, group IP 234.5.6.7 (see above). Computer #2 is in a different section of the building and of course is not directly linked to the GPS unit. Referring to Figure 8.4, Computer #2 elects to receive the re-broadcast data through TCP/IP on Multicast port #5001, IP address 234.5.6.7. Thus 2 different computers in different locations can collect data from one GPS receiver and view that data in real-time, even though only one computer is directly linked to the receiver. In principle, this technique can be used to re-broadcast data using TCP protocol over existing internet connections.

Step 8 of 10
24. Another optional feature of WLOG is the ability to send a GPGGA NMEA string out a secondary serial port of the computer – assuming another serial port is available. This would be useful in the case where some external device such as an echo sounder may require position input from GPS on its serial port.
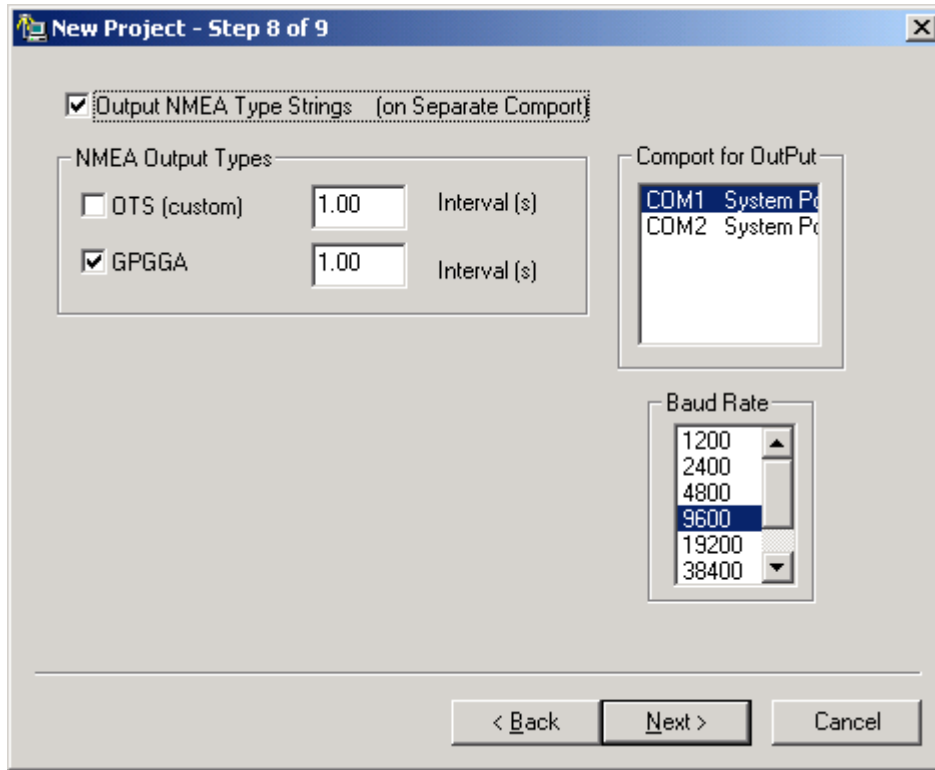
Figure 8.5 Output GPGGA NMEA strings (Optional)

Currently only GPGGA is supported. NMEA string descriptions can be found in the main PLGR manual.

Step 9 of 10

25. In the case of a base station occupation it is unlikely that waypoint navigation will be a useful feature. If navigating with a roving receiver, inputting a list of waypoints to navigate to may be very useful indeed, as ROCKLOG will provide a text and graphical display of the distance and bearing from the current GPS location to the selected waypoint. ROCKLOG will also display across and along-track information for navigation between any 2 selected waypoints.
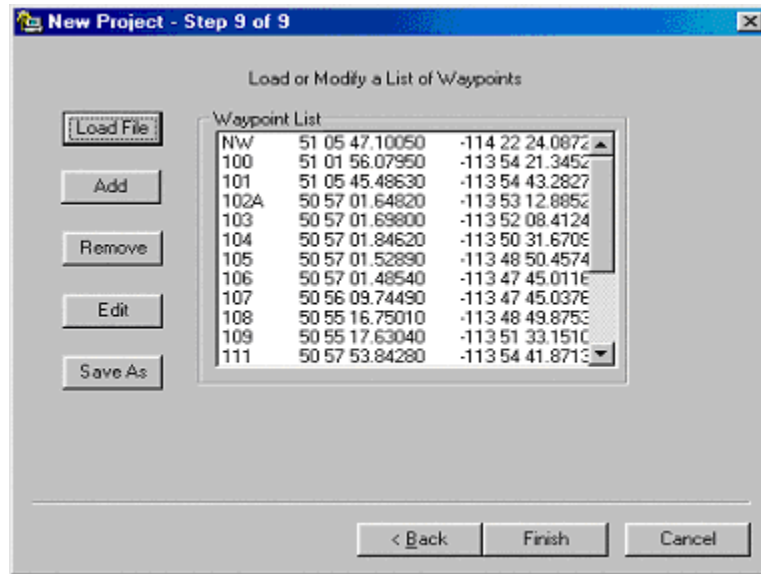
Figure 8.6 Adding a Waypoint List

Waypoints can be added in two ways. Firstly, an ASCII file can be loaded with the format shown below. The first element is a station descriptor of up to 7 characters, followed by latitude in degrees minutes seconds and longitude in degrees minutes seconds.

NW 51 05 47.1005 -114 22 24.0872 0.000
100 51 01 56.0795 -113 54 21.3452 0.000
101 51 05 45.4863 -113 54 43.2827 0.000
102A 50 57 1.6482 -113 53 12.8852 0.000

Alternately, waypoints can be added from the dialogue launched by the ADD button. These waypoints can be edited, removed and/or saved to a file of their own for later use.

Step 10 of 10
26. The user can make requests for position, ephemeris, and satellite visibility records while logging. They will be displayed on the main window. The user can also display the time in HMS in GPS time, UTC time, or Local time. UTC and Local time require the number of leap seconds to be entered as UTC time is a non-linear time system, unlike GPS time. For more information on leap seconds, please see http://tycho.usno.navy.mil/leapsec.html
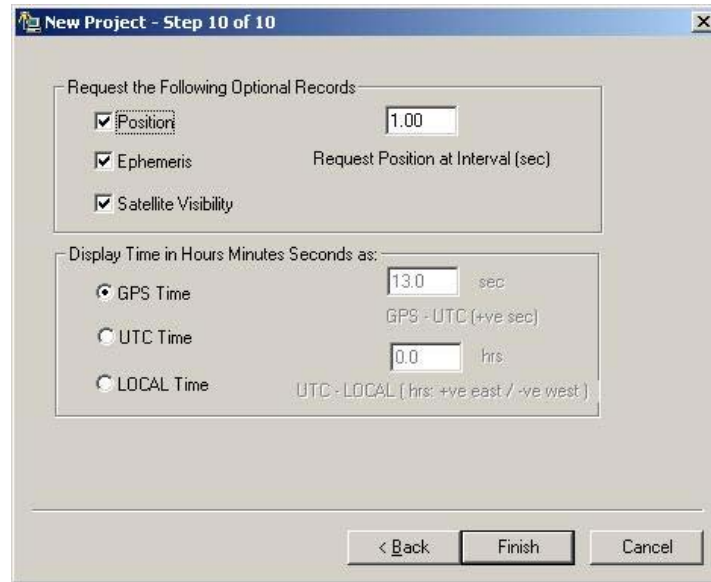
Figure 8.7 Optional Records and Display Time

8.1.2 Logging data

Once a project has been opened and the COM port has been initialized, the GPS receiver will send binary data to your computer to be logged. The following screen as seen in Figure 8.8 should appear.

8.1.3 Basic Logging Display

The text appearing in the figure below should be fairly self-explanatory. It should be noted that GPS time is not synched to UTC, currently by 13 seconds. The Mode item appears as Static by default. This can be changed to Kinematic by hitting the F3 key or using the Events Menu option. This is important if the data is meant to be post-processed by our GrafNav/GrafNet modules.
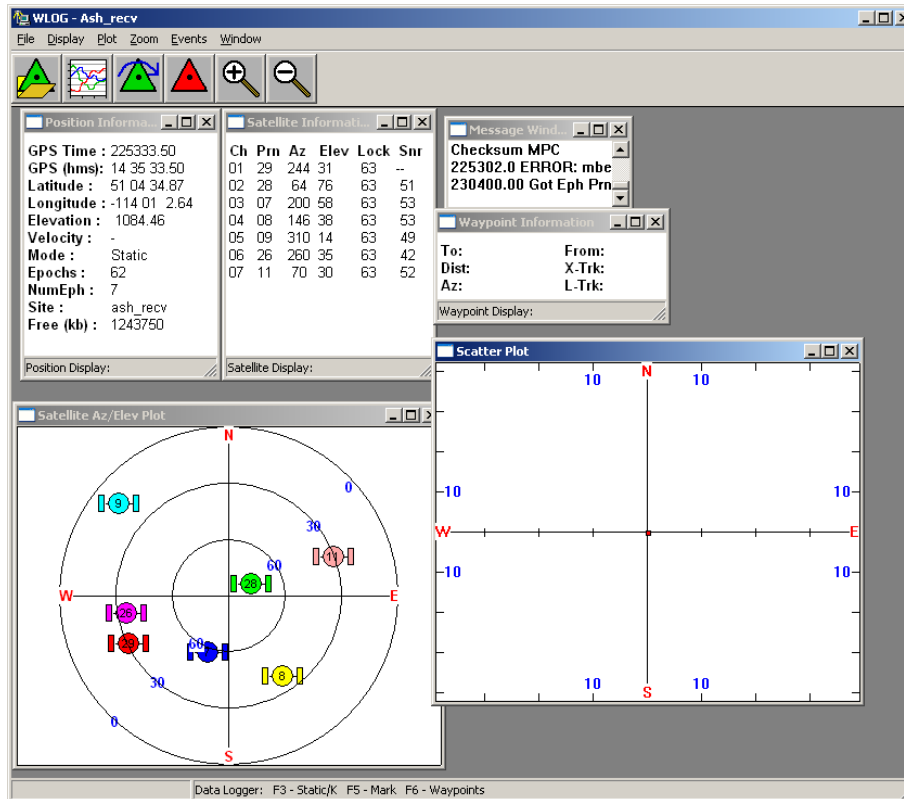
Figure 8.8 WLOG Logging Data

An extended logging display including waypoint navigation features can be invoked from the Plot menu option or from the Plot Tool button.

8.1.4 Extended Logging Display

The extended display has two functions. The first is to display the azimuth and elevation of the satellites being tracked by the receiver and the second is to plot the current track of the static or kinematic antenna. The scatter plot of a static antenna will basically be an indication of selective availability. A more useful feature of the Scatter Plot window is that it allows the user to follow the track of a vehicle to waypoints read from a simple text file. In Figure 8.9 below, the waypoints are indicated by triangles while the current position of the GPS receiver is shown as a dot. The Zoom menu option or tool buttons allow you to set a scale, which is congruent with the situation that you are in. The Waypoint Information box is invoked from the Display menu option.

8.1.5 Using Waypoints

An ASCII "waypoint file" must be loaded in order to plot waypoints on the screen. To load an ASCII waypoint file, you must first build the file with a text editor. Each line in the waypoint file must look like:

Station_name latitude(deg min sec) longitude (deg min sec)

For instance, part of the file read in for the figure below is simply:

NW   51 05 47.1005   -114 22 24.0872
100 51 01 56.07954 -113 54 21.34525
101 51 05 45.48627 -113 54 43.28268
and so on…….

To actually load the waypoint file, look under the file menu option or click on the Load Waypoints tool button.
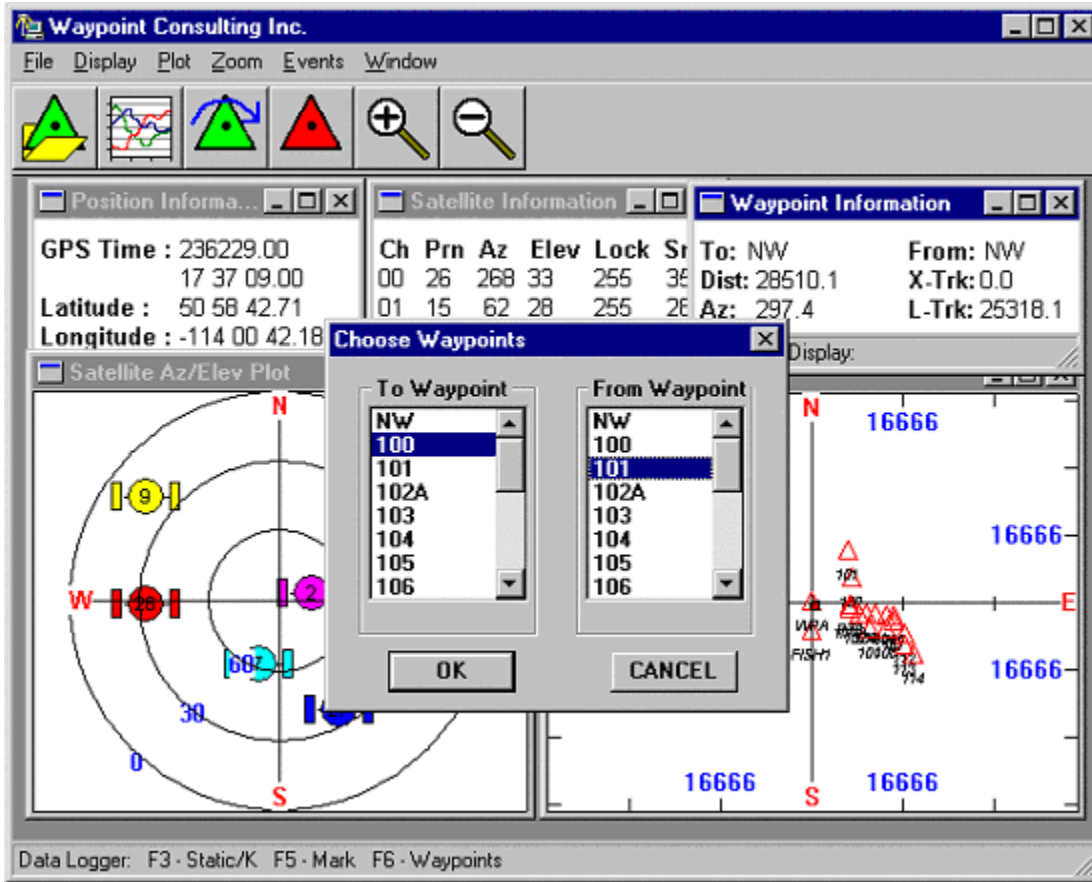
Figure 8.9 Loading Waypoints

It can be seen from the Waypoint Information Box that the current To Waypoint is station 100, while the current From Waypoint is station 101. The distance and bearing that must be traveled from the current receiver position to station 100 is 9533 m at an azimuth of 50.9 degrees. If one was to attempt to drive in a straight line from station 100 to 101, it can be seen that the current dot on the screen is 7746 m left of line. The along track distance indicates that there are 12656 m left to travel along the line.

To dynamically choose To and From Waypoints from the ASCII waypoint file, choose the Events / Next Waypoint menu option or click on the Choose Waypoints toolbutton or hit the F6 key.

8.1.6 Marking Events

Currently, two kinds of events can be marked. The first event is the Static/Kinematic mode sequence, which indicates that the antenna is either motionless or static. The second is the Station Mark Event, which allows the user to mark the GPS time at which the antenna was over some significant point. The static/kinematic marks are placed both in an ASCII .STA file, and in the binary GPB measurement file. The data logger creates these files for each project you have. The station marks are placed in the ASCII .STA file. GrafNav/GrafNet will read the station marks in the .STA file and plot these in the GrafNav environment.
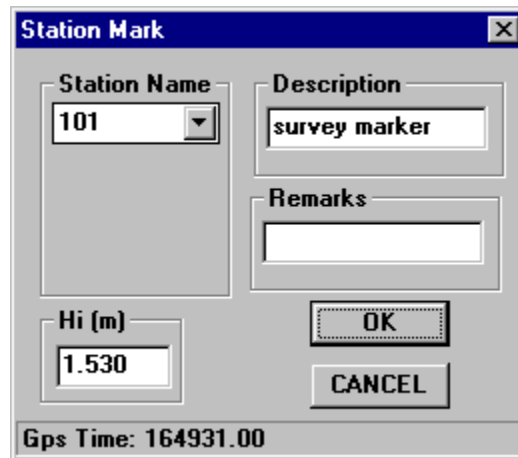
Figure 8.10 Station Marks

The information in the dialogue box shown above is stored in the ASCII .STA file. Note that the GPS time in the status bar of the dialogue box is the GPS time current at the time that the dialogue box has been invoked by hitting the F5 key or using the Events menu option. The Mode has been toggled to Kinematic by hitting the F3 key or using the Events / Static/Kinematic menu option.

8.1.7 Output Files

If a project name has been entered into the Log Data? dialogue box, the data logger will output measurement files in Waypoint's binary .GPB format, ephemeris files in an ASCII .EPP format and .STA files which are ASCII files associated with event marks.

Section 2   GPS Data Logger (Windows CE)

8.2.1 The CE Data Logging Software

There are 3 components to the WinCE data logger. CELOG.EXE which is the graphics interface, SIOGPS.DLL which performs serial/network communications and data decoding and VARDISP.WPD. VARDISP.WPD is a script file which can be built or

modified with a text editor to enable the user to build or change their own text display windows.

CE data logging devices come in a variety of flavours. They have different CPU's and form factors. This makes a generic data logger very difficult to write. CELOG has been developed on the TDS Ranger - a CE unit which has a 320x200 screen pixel size and an ARM processor. CELOG and SIOGPS can be compiled for other CPU's. The VARDISP script file allows the user to define text display windows with an ordinary text editor. This will allow each user to custom build text screen output windows to fit their display size. The VARDISP file and script format are described Section 8.2.6 Building or Modifying the VARDISP Script File to Display Data, which will focus on getting started with the features of the CE data logging software.

8.2.2   Installing the CELOG Logger

To install the CE data logging software, you must simply copy three files to the root directory of your CE device using Active Sync or whatever generic file transfer service is provided to you by the CE manufacturer. The three files required are CELOG.EXE, SIOGPS.DLL, and VARDISP.WPD. For those users who wish to display State Plane coordinates, STPLN83.BIN will also be required in the root directory.

8.2.3   Getting Started with CELOG

1.   Following installation of the three files mentioned above, click on CELOG.EXE. You should see the following display (more or less depending on the CE device):
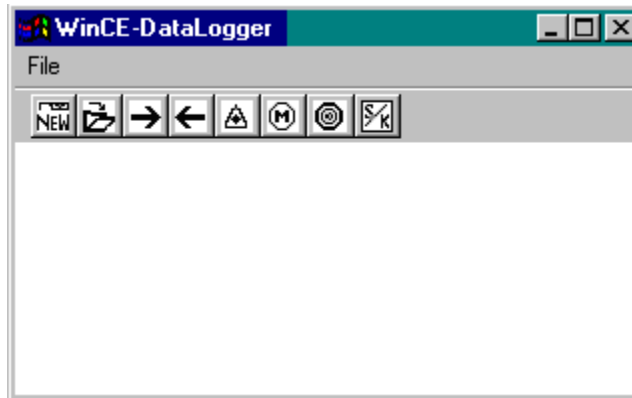
Figure 8.11 Initial CE Logger Display

2.   Choose New Project (the first toolbutton) to start and build a new project file. The project file will be stored as a .IN file. If you have an existing project, use the Existing Project toolbutton (the second toolbutton).

The New Project toolbutton launches a Wizard which guides you step-by-step through the process of creating a project. The Wizard becomes a Property Sheet when choosing the Existing Project mode. For the sake of simplicity, the pages of the New Project / Existing Project are presented below in Property Page mode. The explanation of each

page is valid whether you are choosing a New Project or Editing an Existing Project. Note that you can Edit an Existing Project while logging data by hitting the Existing Project toolbutton. To start another new project, you must quit CELOG and start it up again.

> 2a) Type in a name for this project. The given name will end with a .IN suffix. All of your chosen parameters will be stored in this file. You can bring the Project file up for quick starting another GPS data collection session. If choosing Existing Project, you may want to change the Log File Name to make sure that you do not overwrite existing files.
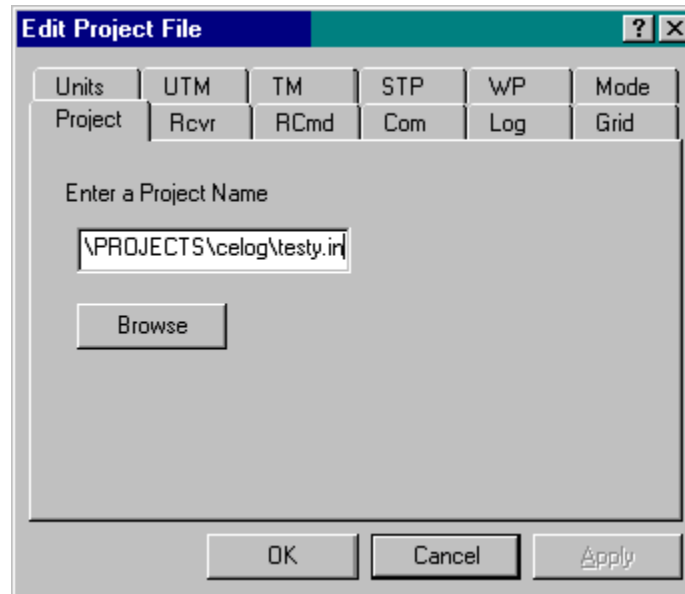
Figure 8.12 Enter a Name for this Project File

> 2b) Choose one of the supported receiver types. Make sure to enter the data interval that you wish to log at. Also, you are given a choice of whether to utilize one of two serial ports on the GPS receiver (provided the unit has multiple ports).

CELOG will send the necessary configuration commands in order to force any of the given receivers to send measurement and position data out the chosen port. This binary data will be decoded by CELOG into Waypoint's GPB format or can be stored as is byte for byte to disk. The byte for byte data can be decoded later from the GrafNav/GrafNet environment.
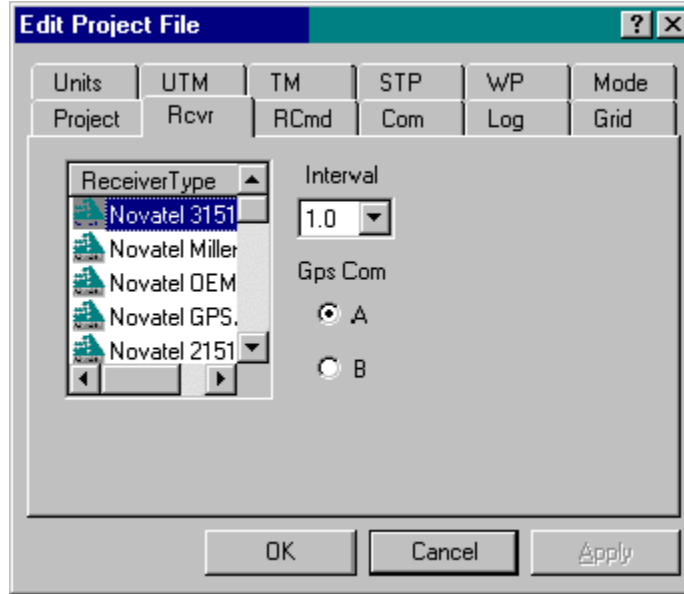
Figure 8.13 Choose a Receiver Type

2c) The third step in starting or editing a project may be skipped for any receiver type that does not support an ASCII command set. However, NovAtel and Ashtech receivers support ASCII commands. Any extra commands which CELOG does not send the receiver may be entered here. CELOG will send its normal configuration for that command set and then transmit any extra commands typed here. Below is an example for the Ashtech G12 receiver.
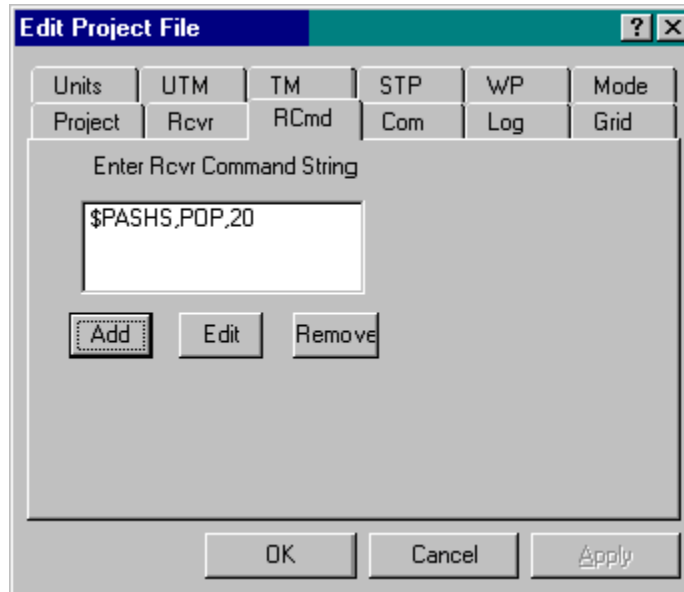
Figure 8.14 Adding an ASCII Command to Send to an Ashtech Receiver

2d) Setting up the serial or network communication parameters for logging data from the GPS unit is an important step. In most cases, data transfer will be via serial cable. 8 bits, no parity is assumed. Baud rates up to 115200 baud are supported.
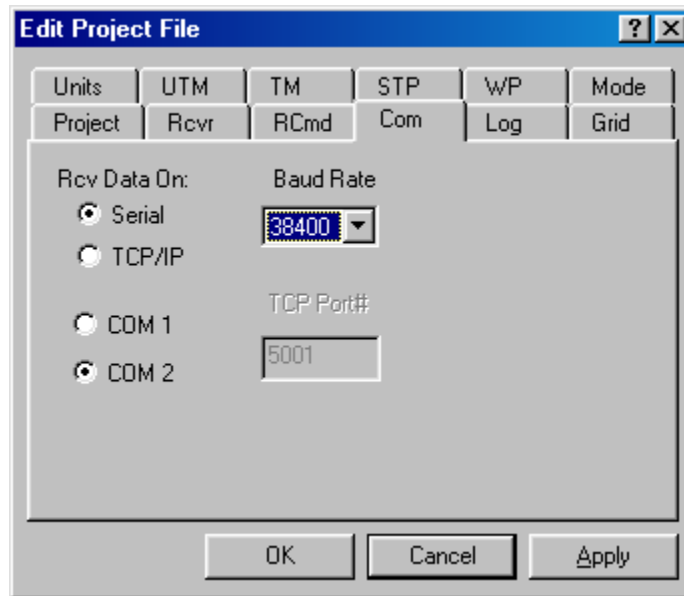
Figure 8.15 Setting the COMM Parameters

Note that TCP network protocol is also supported in the event that GPS data is input via a standard network connection.

2e) The fifth step in starting or modifying a project is to enter a name for the data files that you wish to store for post-processing.
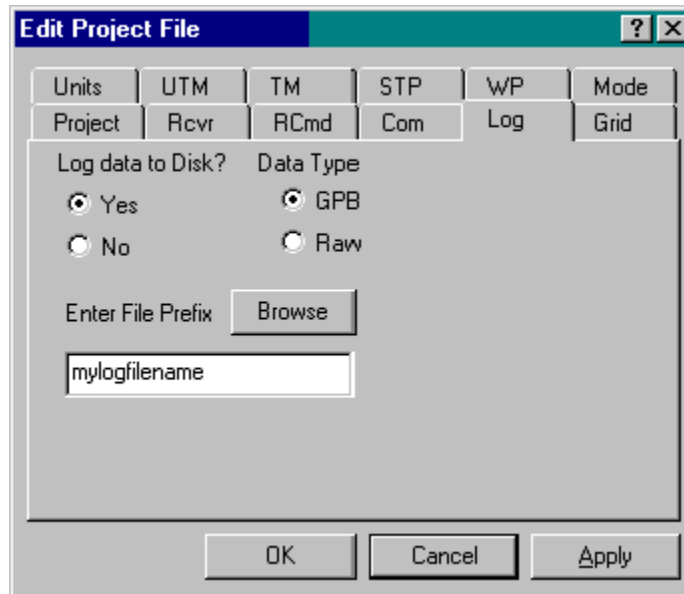
Figure 8.16 Choose a Prefix for the GPB,LOG,STA,EPP Files

Note that you may wish to "quick start" CELOG by using existing project with the same project file, but it is likely that you will need a different name for your data files as saved to disk. CELOG saves three different files.

Either a GPB or a LOG (Raw) file will be saved containing the measurement and position information generated by the receiver. This depends on your choice in the above wizard page. LOG files contain simply whatever comes across the serial or network port. These have to be decoded later from the GrafNav environment. GPB files are files decoded in real-time into Waypoint's proprietary binary format.

STA files are ASCII files generated from the CELOG environment by marking stations. Station marks contain the GPS time that a station was occupied and information regarding that point.

EPP files are ASCII files containing ephemeris information as transmitted by the receiver.

> 2f) CELOG supports a number of different coordinate grids. Please note that currently these are only supported in the WGS84 datum.
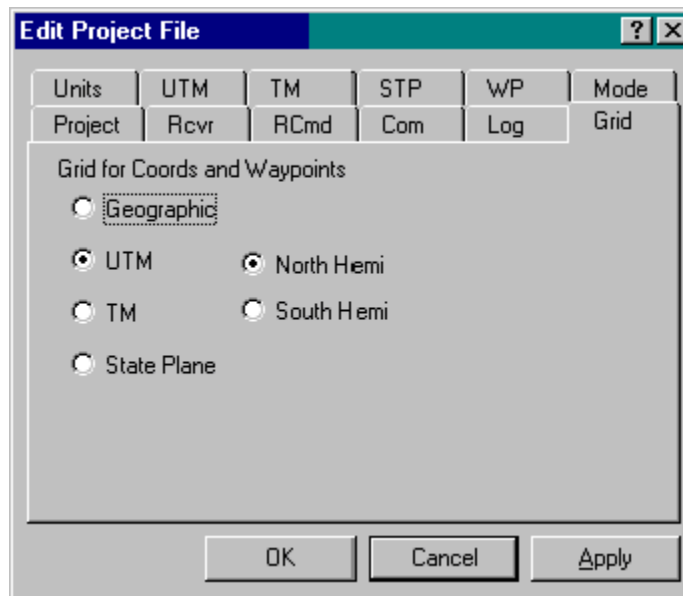
Figure 8.17 Choosing a Framework for Coordinate Output

Geographic coordinates are always available from the GPS receiver, however depending on the gird chosen, geographic coordinates can be converted in real-time to UTM, TM or the State Plane coordinate systems. Please notify CELOG whether you are in the northern or southern hemisphere prior to reading in a waypoint file.

If you are reading in a waypoint file or entering waypoints manually, CELOG assumes that the grid chosen above will also be the coordinate framework associated with your

waypoint file. For the example shown in Figure 8.17, CELOG will assume that any waypoint file will be in UTM north and east.

The VARDISP.WPD file allows display of a "north" and "east" variable. These values will be associated with the grid coordinate frame chosen in this dialogue box.

  2g) If a coordinate frame is defined as anything other than simple geographic, that grid must be defined with relevant parameters. This is accomplished through invoking the Units Property Page and the property page corresponding to the chosen coordinate reference:
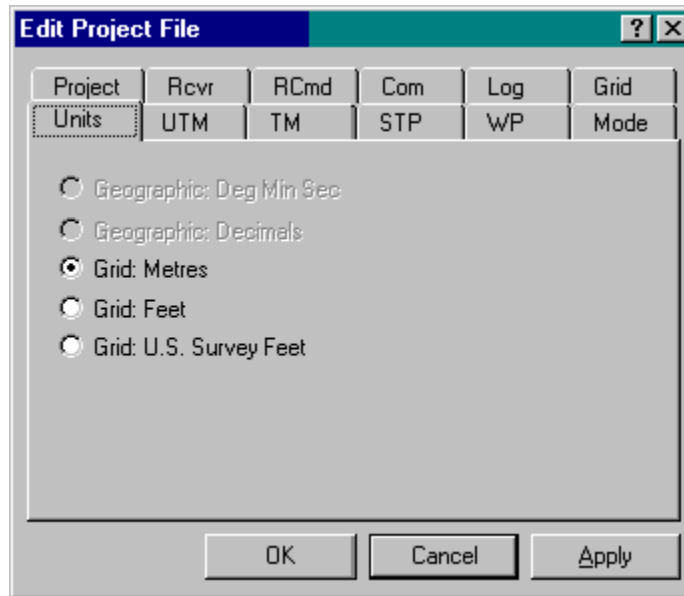
Figure 8.18 Gird North / East Can be displayed as Meters, Feet or US Feet

If UTM grid coordinates are desired, just enter your zone number. To calculate a UTM zone number from a Central Meridian use:

Zone_number = (CM +183) / 6

For instance, for CM –117, the zone number is 11.

For specific TM or Transverse Mercator grids such the 3TM grid, a number of parameters must be known, as shown in Figure 8.19.
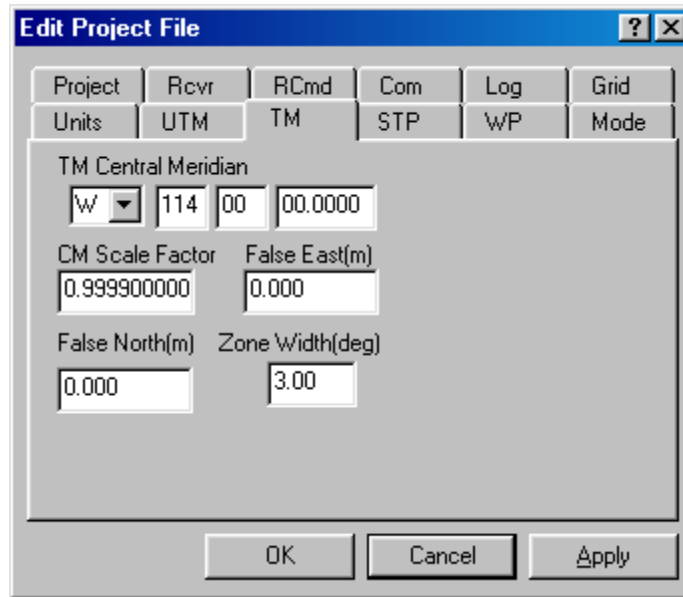
Figure 8.19 UTM only Requires a Zone Number

NAD83 State Plane coordinates can be converted from geographic or read in from a waypoint list simply by choosing the State Plane zone that you are concerned with.
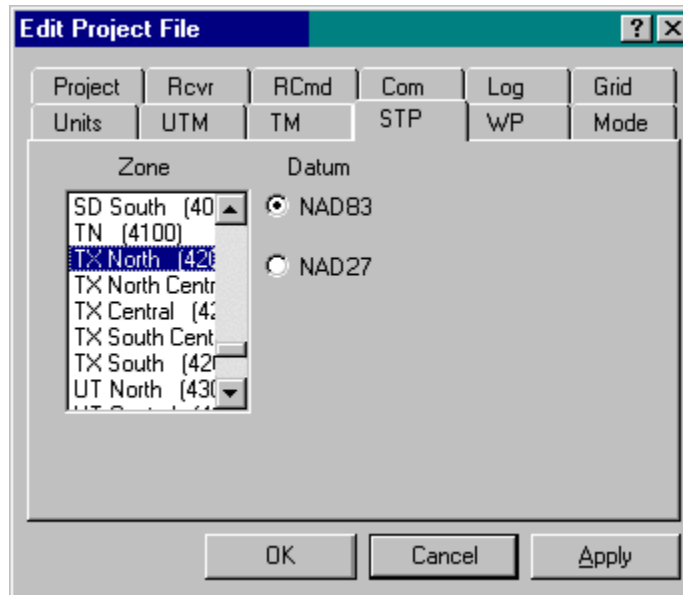
Figure 8.20 Choose a State Plane Zone

Please note: STPLN83.BIN must be in the root directory of the CE device. NAD27 is NOT currently supported.

2h) Waypoint lists can be entered manually at the window shown in Figure 8.21, and/or read in from ASCII files created by a text editor. Any waypoints so entered can be removed or edited. The modified file can be saved to disk.
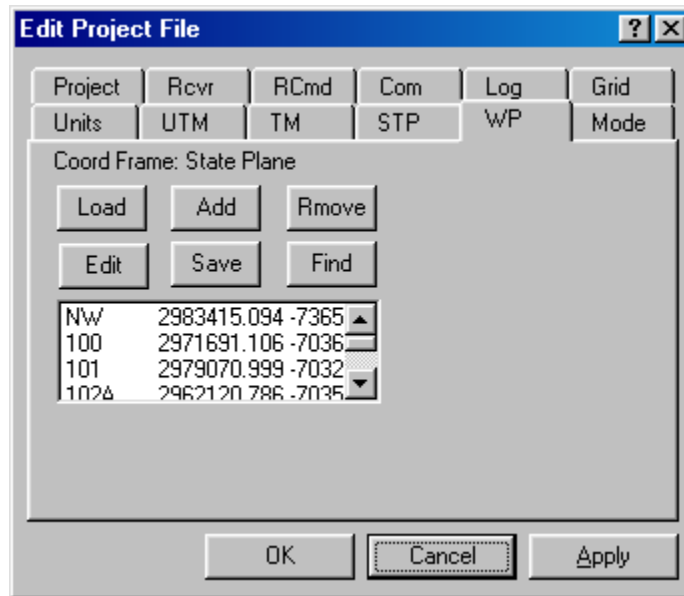
Figure 8.21 The Waypoint Property Page

Waypoint File Formats:
Waypoint files are simple ASCII files. Geographic coordinates can be entered as degrees, minute, seconds or decimal degrees. UTM, TM or State Plane coordinates can be entered in meters, feet or US Survey Feet. Examples are given below:

a) **Example Waypoint File – Geographic, degrees, minutes seconds**

$WAY GEO
NW 51 05 47.1005 -114 22 24.0872
100 51 01 56.0795 -113 54 21.3452
101 51 05 45.4863 -113 54 43.2827

b) **Example Waypoint File – Geographic, decimal degrees**

$WAY GEO
    ant-a   51.00000000 -114.00000000
    ant-b   50.97861111 -114.01166667

c) **Example Waypoint File – UTM Coordinate Input**

$WAY UTM
    NW   5663828.559   683914.631
    100   5657966.778   716937.210

Note that the UTM Zone is defined in the corresponding project (.IN) file.

d) Example Waypoint File – State Plane Coordinate Input

```
$WAY ST
    NW    462374.437  3211340.969
    100   475344.388  3245597.245
```

Again, the State Plane zone is defined in the associated project file.

Waypoints can also be entered manually using the ADD button. Any list of waypoints can be saved using the SAVE item.

     2i) The final page of the start-up wizard allows the user to define a static occupation period. This feature would typically be used for a tree cover survey where you would like to place some static occupations in a kinematic survey. Static occupations of at least 2 minutes are recommended for surveys under tree canopy. The static occupation feature displays a dialogue box during data logging which indicates a "count-down" until the session is finished.
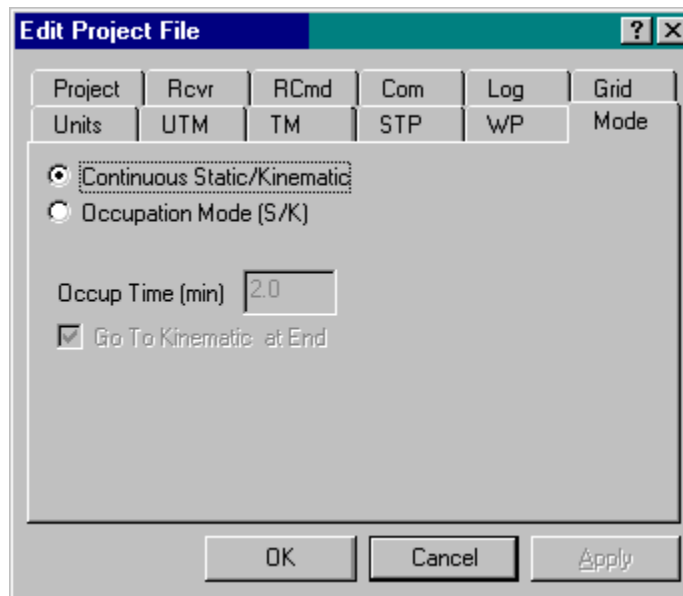
Figure 8.22 Survey Modes

Continuous static/kinematic is the normal mode of operation where the surveyor would perform a static occupation to start and then go to kinematic status for the remainder of the mission. Any marked points would be marked while in kinematic mode and typically occupied for only a few seconds. Occupation mode allows the user to set up at a station for some given length of time. At the end of the n minute period, CELOG shows the user a dialogue box which prompts the user to quit the static session and go directly back to kinematic mode.

8.2.4   The Variable Display File (WPD File)

There are 3 components to the WinCE data logger:

- CELOG.EXE: the graphics interface
- SIOGPS.DLL: performs serial/network communications and data decoding
- VARDISP.WPD: a script file which can be built or modified with a text editor to enable the user to build or change their own text display windows.

The reason for allowing users to build or modify display windows is that a number of different screen sizes are used by various manufacturers of CE products. Hand-held CE units tend to be 320x200 pixels or alternately 200x320 pixels. Palm-top CE devices are usually in the order of 640x200 pixels. Other variations may exist.

The VARDISP script file not only defines the text display for CELOG, but can be modified by the user to display a given list of variables in any position on any defined window. By definition CELOG only allows the user to display one window at a time. The window size is the default window size given by the CE device being used. For instance, those owning CE units with 200x320 displays may wish to output variables which are ordered in long columns and short rows. Alternately, users with 320x200 displays may wish to build windows which display items as long rows with relatively short columns. Users can modify VARDISP.WPD with a text editor to accomplish this.

The list of variables which you are allowed to display is set at the bottom of the VARDISP file. Do not change this variable list. Variable which are allowed in the text display window are listed below with a short definition of each.

8.2.5   Variables Given in the VARDISP File

The following variables can be invoked by the user for use in any text window that they wish to define. Note that the variables below are NOT case sensitive in the context of CELOG. For instance, the user can type in the Gpstime variable as "GPSTIME", "gpstime", or "GpsTime" in the VARDISP.WPD file. CELOG will not care.

- Gpstime -GPS seconds of the week
- Latitude - Latitude in degrees, minutes, seconds
- Longitude - Longitude in degrees, minutes, seconds
- Height - Elevation as output by the GPS receiver
- Epochs – Number of measurement epochs since data collection started
- Diskspace – Number of free mgbytes remaining on your device
- Elev – Elevation of the satellite in degrees above the local horizon
- Prn – PRN number of the given satellite
- Az – azimuth of the satellite in degrees with respect to local north
- Locktime – number of seconds of valid phase lock for a particular PRN – resets to 0 on loss of lock
- East – Easting as given by the defined grid. Grids can be UTM, TM or State Plane

- North – Northing as given by the chosen grid
- Tosta – If waypoints have been entered or read in from a file, this is the chosen waypoint ID which you are navigating to
- Fromsta – If a waypoint list is present, this is the waypoint you are navigating from. The line between the Tosta and the Fromsta defines an along track / across track reference frame
- Acrosstrack – the distance left or right of a line joining the current Tosta and Fromsta waypoints
- Alongtrack – the distance along a line given by the Tosta and Fromsta
- Todist – the current distance from your position to the chosen Tosta waypoint
- Toaz - – the current azimuth from your position to the chosen Tosta waypoint
- Surveymode – static or kinematic. You must define this from the CELOG menu or toolbar if you are performing kinematic surveys
- Station – If marking a point for static or kinematic occupation, this will be the name that you give to that marked point
- Static_epoch – If using Occupation Mode for marking a station, this is the number of measurement epochs that the user has occupied that station

Once again, please do not edit the variable list in the VARDISP.WPD file.

8.2.6   Building or Modifying the VARDISP Script File to Display Data

CELOG is meant to present one text window at a time to the viewer. The text windows are defined completely by the window elements in the VARDISP.WPD script. If the file is not present or corrupted, you will not get a display. These text windows can be changed during operation of CELOG by pressing the side arrow keys on the keyboard or the toolbar. The content of the windows is defined by the user through the script file both in terms of which variables are displayed and where those variables are placed within the window region. All of the following rules must be followed exactly, if you wish to build or modify your VARDISP file with a text editor. Modifying the VARDISP file may be useful or even necessary depending on the Win CE device screen size that you have.

1.   Defining a New Window

Up to 12 text windows can be created in VARDISP.WPD. Each new window is built by using the following form:

DISPWINDOW {

}

Remember these are text windows only. They are designed to display the variables listed above in any particular format as designed by the writer.

2.   To Define a Window Title

Each window may have some theme as given in the title. To add a title to a new window use:

DISPWINDOW {
Title: "My Position Information Window"
}

3.   To define a line of text, add the Line command:

DISPWINDOW {
Title: "My Position Information Window"
Line: $"Latitude:"
}
where the $ indicates text to follow. The text must be enclosed in double quotation marks. The $" " format allows the use of spaces with text. Spaces may be interpreted as delimiters by some basic C programming functions. In this case, we would like to use the spaces as part of the text string to be displayed.

4.   To Embed a Variable or Variables in a Line of Text

DISPWINDOW {
Title: "My Position Information Window"
Line: $"Latitude:" &latitude
}

where the & sign MUST be followed by one of the variable names given in the list above. Variable names are NOT case sensitive. &latitude and &LATITUDE are equally valid.

5.   To Separate Variables or Text Strings by Spaces

DISPWINDOW {
Title: "My Position Information Window"
Line: $"Position:" &latitude $"   " &longitude #s#s#s#s#s &height
}

Spaces can be defined as text strings by using a line of text as $"   " or spaces can be given by type in #s#s#s, where each "#s" represents one space. In the example above the text word "Position:" will be displayed in the My Position" window followed by the current latitude, longitude and height i.e.:

Position 51 00 43.652   -114 00 42.234   1015.45
Is output by the CELOG program.

6.   Separating Variables or Text by Tabs

Using spaces as delimiters is not as exact as using TABS. Single tabs can be used in the
VARDISP script by simply inserting a TAB of 4 spaces using a "%t" format:

DISPWINDOW {
Title: "My Position Information Window"
Line: $"Position:" &latitude %t &longitude %t &height
}

Once again,

Position 51 00 43.652   -114 00 42.234   1015.45

Is output by the CELOG program in the "My Position Information" window.

7.   Separating Variables or Text by Percent Screen Sizes

One of the most exact ways of delimiting text is to organize text and associated variables
in columns which start at certain percent values ACROSS the screen. For example you
may wish to start displaying a certain column of variables exactly ½ way across the
current window i.e. 50% of the way across the screen. For example:

DISPWINDOW {
Title: "My Position Information Window"
Line:
Line: $"Latitude:" &latitude %50t &prn[0] %t &locktime[0]
Line: $"Longitude:" &longitude %50t &prn[1] %t &locktime[1]
Line: $"Height:" &height %50t &prn[2] %t &locktime[2]
Line: $"" %50t &prn[3] %t &locktime[3]
Line: $"" %50t &prn[4] %t &locktime[4]
Line: $"" %50t &prn[5] %t &locktime[5]
Line: $"" %50t &prn[6] %t &locktime[6]
}

In the example window above, the first column of values are single variables such as
longitude and height. These variables are displayed in the first column of the window.
The PRN numbers are output half way across the window in a column and their
corresponding LOCKTIME values, one tab from the PRN numbers.

**Note that the second column that is the %50t column must be preceded by any value
including a space in the first column.**

8.   Displaying Array (Channel) Variables versus Single Item Variables

Variable such as latitude, longitude and height are defined here as single item variables. On the other hand, values given to prn numbers, locktimes, azimuth and elevation and so on are per channel variables. These are given in arrays – up to 12 values corresponding to each channel of a 12 channel GPS receiver.

Array or channel variables can be output in two ways. The first method is to simply define the channel variable by its name with no index. For example let us add another window to the VARDISP file.

DISPWINDOW {
Title: "My Channel Information Window"
Line: $"Prn   Azimuth   Elev   Locktime "
Line: &prn %t &az %t &elev %t &locktime
}

The above window will automatically display all n channels at each epoch. CELOG will recognize the variable prn, az, elev and locktime as array variable requiring n channel rows to be displayed.

Note that you can not put %t's in the sub-title string,(Prn Azimuth..etc) but must space this header "manually".

The second method of outputting per channel variables to a text window is to define each element of the channel array variable explicitly with a zero-based index. An example of this is seen in one of the previous Position Information windows.
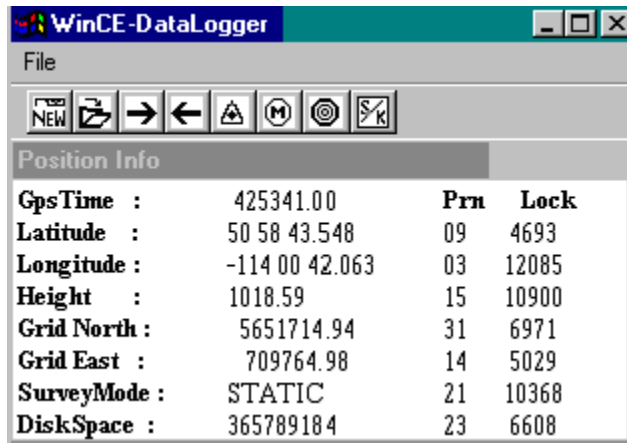
DISPWINDOW {
Title: "My Position Information Window"
Line:
Line: $"Latitude:" &latitude %50t &prn[0] %t &locktime[0]
Line: $"Longitude:" &longitude %50t &prn[1] %t &locktime[1]
Line: $"Height:" &height %50t &prn[2] %t &locktime[2]
Line: $"" %50t &prn[3] %t &locktime[3]
Line: $"" %50t &prn[4] %t &locktime[4]
Line: $"" %50t &prn[5] %t &locktime[5]
Line: $"" %50t &prn[6] %t &locktime[6]
}

Of a possible 12 channels, only 7 (0 – 6 inclusive) are explicitly output to the text screen. For those users with CE screens which are wider than longer, you may wish to display array variables as:

DISPWINDOW {
Title: "My Channel Information Window"

Line: $"Prn" &prn[0] %t &prn[1] %t &prn[2] …… %t &prn[n]"
Line: $"Locktime" &locktime[0] %t &locktime[1] %t &locktime[2] %t &locktime[n]"
}

This will display at most n channel values across the page with one tab delimiting each variable. Each line is prefaced in the first column with a text string indicating the nature of the variable.

Figure 8.23 Typical Window Created from the VARDISP Script

See Below for the Actual Script Used

```
DISPWINDOW {
Title: "Position Info "
Line: $"GpsTime   :" %35t &GpsTime     %70t $"Prn"  %t $"Lock"
Line: $"Latitude   :" %35t &latitude  %70t &prn[0] %t &Locktime[0]
Line: $"Longitude :" %35t &longitude   %70t &prn[1] %t &Locktime[1]
Line: $"Height     :" %35t &height   %70t &prn[2] %t &Locktime[2]
Line: $"Grid North :" %35t &north      %70t &prn[3] %t &Locktime[3]
Line: $"Grid East   :" %35t &east      %70t &prn[4] %t &Locktime[4]
Line: $"SurveyMode :" %35t &surveymode %70t &prn[5] %t &Locktime[5]
Line: $"DiskSpace  :" %35t &diskspace   %70t &prn[6] %t &Locktime[6]
Line: $"" %70t &prn[7] %t &Locktime[7]
Line: $"" %70t &prn[8] %t &Locktime[8]
Line: $"" %70t &prn[9] %t &Locktime[9]
}
```

Note that lines in the window can be COMMENTED OUT, by prefacing the Line: with a semi-colon. CELOG will ignore these lines.

Chapter 9 File Formats

Section 1 Output Files

This section discusses some of the different output files that are created by GrafNav.

9.1.1 .FML or .RML File

The message log file simply echoes all error and warning messages sent to the message window during processing. Some common example messages are shown and explained here.

Reading ephemeris files...
Processing ephemeris file 'C:\GPSData\urk_.epp'
Detected 40 GpsEph, 0 GlonassEph, 0 GpsIono and 0 GpsAlmanac records
This message is shown at the start of the file. It's a good message to check to see how many ephemerides were loaded.

Best base on BL1 is PRN 17 with 4 points and elevation of 62.1 degrees
Second best on BL1 is PRN 16 with 2 points and elevation of 51.7 degrees
This message indicates the base satellite (and its elevation) selected after a base change or at outset. The second best base is also shown. Base satellite selection is based on a point system that includes a number of factors such as elevation above the horizon, whether it is rising or falling, and ambiguity determination accuracy.

Prn 15 dropped out for 2.0 s on baseline BL1--ambiguity reset
Prn 23 dropped out for 2.0 s on baseline BL1--will try to save ambiguity
These message are displayed when an individual satellite drops out for a short period. Whether the first or second message is displayed depends on if the 'Save ambiguities on satellite drop-outs' check box is selected under the Advanced option. For some data sets, this saving process may be folloed by data errors ($$$). In such a case, try de-selecting this option.

Detected bad Phase measurement. Rms is 2.091 m (Worst Prn is 10 on B/L BL1 with residual of 2.325)
This is almost always caused by one or more undetected cycle slips. In most cases, the software will be able to correct for the problem by removing the affected cycle slip. If not, a cycle slip will be induced to all satellites.

Skipped 83 epochs or 76.1 % due to long distance (used 26 epochs or 23.9 %)
This message shows up if the KAR option 'Utilize all data whose distances are less than tolerances' is enabled. It indicates what percentage of the data is shorter than distance tolerance – hence it is used.

Performing KAR search at 525 seconds on baseline BL1
KAR used 525.0 s (PASS) with average of 7.1 sats over average distance of 21.9 km
RMS is 0.0809 cycles (FAIL), Reliability is 1.2 (FAIL), Float/fixed sep. is 0.47 m
(PASS)
KAR failed 2 out of 4 tests, will try again in 15.0 seconds
Message printed for an unsuccessful KAR search. Indicates various statistics.

KAR failed on baseline BL1 after 30.1 minutes--too much time used and starting
over
Printed if KAR went too long. The tolerance is generally 30 min., and can be set from
the KAR option.

Note: KAR cannot be engaged at this distance (68.6 km) on baseline BL1
Printed if distance too long for KAR to engage. The software will wait until it gets
closer.

Epoch rejected due to poor satellite geometry--DD_DOP of 918.0 too large
This message warns that an epoch has been rejected because of poor satellite geometry.
The default DOP tolerance is 100.0. This can be changed in the user defined options with
the command DOP_TOL.

Doppler L1 cycle slip on PRN 24 of 1575419.57 cycles on baseline BL1
Indicates that a large change in carrier phase has been encountered which is interpolated
as a cycle slip. If this message appears continoually, the doppler may need to be
recomputed (see Chapter 6 Section 3 GPBView).

Locktime cycle slip on PRN 4 of -5.92 cycles on baseline BL1
Cycle slip has been reported by base or remote receiver. Size of cycle slip is on
approximate.

Inserted L1 cycle slip due to locktime reset for PRN 4 on baseline BL1
Receiver cycle slip counter has reset at some time in the past but was not caught.
Therefore, slip inserted now.

Less that four satellites at startup--Will try next epoch(s)
Software needs at least 4 satellites and good measurement quality at start. It will
continue until this goal has been achieved.

Warning: Epoch with less than 4 good satellites (Cycle slips)
This message warns about an epoch with less than 4 satellites. Usually the result of cycle
slips.

Locktime cycle slip on PRN 26 of -41.31 cycles on baseline BL1
Small L2 cycle slip on PRN 26 of 0.65 cycles on baseline BL1
Both messages warn of cycle slips on L2. The DPH is an indicator of the size of the
cycle slip. It shows the difference in phase. If you have a lot of L2 cycle slips in your

data it will make for a bad ionospheric free solution. If you have a lot of L2 cycle slips try using the relative ionospheric solution.

Prn 15 is below mask angle of 10.0 degrees
This message indicates that a satellite has gone below the elevation mask.

Satellite 7 is rising or re-appearing
This message is usually caused from a satellite on the horizon.

*** KAR engaged due to total loss of lock
*** KAR now engaged because distance became lower than tolerance
'***' followed by a message indicates if and why KAR was engaged.

Prn 27 disappeared for 33.0 seconds on baseline BL1
Indicates that as satellite dropped out and is reappearing, a new ambiguity will be solved.

Calculating fixed solution
Calculating RMS values
Continuous fixed solution reliability: 7.43 (PASSED), RMS: 0.0372 m (PASSED), STD: 0.0014 m
Continous fixed solution position is: 39 01 23.54716, -84 36 21.25817, 259.7909 m
Computing New Fixed solution
This message shows the results from the multi satellite fixed solution. The reliability is the ratio between the second best RMS and the best RMS. The minimum reliability for a pass is 1.35. The RMS is the RMS fit of the fixed solution. This number is in meters and the maximum value to pass is 0.025 m + 1PPM for dual frequency and 0.015 + 1PPM for single frequency.

Warning: No precise available for prn 21
Message warns that precise ephemeris messing for a satellite. You may want to try another precise ephemeris file (if available) to try and better the results.

$$$ GPS data errors detected--will try and reject measurements, baselines or satellites
Error messages starting with '$$$' indicated bad carrier or code measurements encountered. The above message should be following another message indicating what residuals are out-of-range and which satellite has the largest value. This indicated satellite may not be the actual problem one because the Kalman filter distributes the errors around. A number of tests will be performed to isolate the problem data and satellite. Therefore, this message is followed by the messages shown below.

C/A code tested OK (CaRms is 2.1 m)--The problem must be due to the carrier phase
Indicates that the C/A-only tested OK and a problem is very unlikely to be a problem. If the C/A was invalid then another message will be printed.

On code, worst PRN is 20, RMS is 1.46 m (PASS), reliability is 1.84 (FAIL)
A further test on the combined code-carrier solution to ensure that the code is OK.

On phase, worst PRN is 28, RMS is 0.0949 m (PASS), reliability is 1.19 (FAIL)
This test will generally indicate if a missed cycle slip to other carrier phase problem was fixed by removing a particular satellite. The above message indicates that the problem could not be fixed, and will generally be followed by a filter reset message. See below. The reliability must be greater than 4.0 to be signaled as a pass. You may wish to investigate the clock offset information (see GPBView) at this epoch to see if the problem epoch is due to an incorrectly computed clock shift.

Could not fix Kalman filter by rejecting a satellite--Failed 2 out of 4 tests
Unable to correct bad GPS data--issuing filter reset
This message indicates that a data problem could not be repaired.

$$$ Engaging filter reset--Accuracy is severily reduced
This is printed when the filter reset is being engaged. It should be preceded by a message indicating why the filter reset was issued. A filter reset is when a cycle slip is issued to all satellites and the position is reset to startup values.

*** KAR enaged due to occurance of filter reset
Printed when a User-KAR record is being implemented and the 'Engage Filter Reset' flag has been enabled.

Locktime and doppler cycle slip on PRN 30 of -307.64 cycles on baseline BL1
Indicates that a cycle slip has occurred and it has been detected by both the locktime and a large changed in the carrier phase.

%%% PRN 18 was omitted for time range 488400.0-488500.0 s on ALL baselines
%%% ALL satellites were omitted for time range 8000.0-8100.0 s on baseline mast
'%%%' followed by a message indicates when and how long a baseline and/or prn was omitted from processing.

'@@@' followed by a message indicates if a position fix was processed. Position fixes can originate from fixed static or from user entered remote initialization.

9.1.2 .FSS or .RSS File

The Static Session Summary file presents a summary of the float, fixed static and KAR processing. The FSS file is created in the forward direction processing while the RSS file is created in the reverse direction. You will find the project configuration and processing settings at the beginning of the file and return status at the end of the file. The following is an example of the project configuration and processing settings.

```
-------------------------------------------------------------------
  Configuration and processing settings
-------------------------------------------------------------------
```

Project settings:
           # Antenna Type   AntHgt FileName..........
 Master Info   : 01 Generic   0.008 C:\Temp\Test\carh1050.gpb
 Remote Info :   Generic   0.486 C:\Temp\Test\carr1050.gpb
 Master Position: 01 35 53 18.17873 -120 25 50.94840 480.276
 Broadcast Eph. : Automatic, (406 GPS and 0 Glonass ephemerides)
 Precise Eph. : (none)
 Direction   : FORWARD
 Process Mode : Dual frequency carrier phase
 Static Initial.: Fixed
 Use KAR   : Yes
 Use Glonass   : No

General Options:
 Elevation Mask : 10.0 degrees
 Data Interval : 30.00 s
 Fixed Interval : 15.00 s
 Time Range   : (use entire range)
 Datum   : WGS84 using conversion 'WGS84 to WGS84 (Same)'
 Split Static   : No

Advanced Options:
 Base Satellite : (auto)
 Model Tropo. : Yes, using Saastamoinen model
 Locktime Cutoff: 4.0 s
 Use Doppler   : Yes
 Dynamics Model : No
 Cycle slip checking:
  Doppler   : Yes, using 150.0 cycle tolerance
  Locktime   : Yes
  Static tol. : 0.40 cycles
  Save ambig. : Yes, (on satellite drop-out)
 Bad data control:
  Filter Reset : Yes
  Write Bad   : No, (Yes if epochs containing bad data to be written)
  Skip Bad   : No, (Yes if epochs with bad statistics to be skipped)
 Output Format : Normal
 Write Sat Resid: Yes
 Print Slip Warn: Yes

Standard Deviation Options:
 C/A StdDev   : 7.00 m
 C/A Rej Tol   : 25.00 m
 Carrier StdDev : 0.0200 m
 Carrier Rej Tol: 0.1000 m
 Doppler StdDev : 1.000 m/s
 Doppler Rej Tol: 25.000 m/s
 Additive PPM : 1.0 ppm

Dual Frequency Options:
 Use P-Code   : No
 Use L2 for Amb : Yes

Iono Correction: No
Small L2 Slip : 0.40 (tolerance)
Corr. Code Iono: No

General KAR Options:
 Minimum Time   : 1.00 minutes
 Additive Time : 1.50 minutes/10-km
 Search Region : Adaptive, using StdDev scale factor of 3.00
 Maximum Time   : 30.00 minutes
 Max. distance : 30.00 km
 Use More Data : No, (if Yes, use all < max. distance)
 Start in Static: No
 Engage on Time : No

Advanced KAR Options:
 Strict Rel. Tol: Yes
 Strict RMS Tol : No
 Distance Weight: Yes
 Fast KAR   : No
 Fast KAR (5SV) : No
 Refine L1/L2   : Yes
 Maximum DOP   : 9.00
 Engage Bad DOP : No
 Data Filter   : 5.0 s
 Exact Interval : No
 Search Interval: 15.0 s
 L2 Noise Model : AUTO, (iono. distance tolerance is 5.0 km)

The processing settings will not be display if 'Print input settings to static/KAR summary' under the Advanced option is turn off. The following is an example of the return status.

```
------------------------------------------------------------------------
  Program finished, return status
------------------------------------------------------------------------
Finish {
    Status:    "SUCCESS"
    RetValue:  -101 "Successful program completion--end time reached"
    ErrMsg:    "Endtime Reached"
    NumEpochs: 2781
    UsageTime: 13.74 s
}
```

The file may look slightly different if static or kinematic processing is done. In static output are the final coordinates and various statistics associated with those coordinates. In kinematic processing the KAR summary record is the only output. If you're doing kinematic processing without KAR you will not see these output in the .FSS or .RSS file. The following is the output satellite tracking list. This output is only displayed on fixed static solutions. It shows which satellites are tracked when, how long, and the status of the satellite. The status is important because it will show if any satellites are rejected. This output can also be seen for all data types in the plot 'Satellite Lock'.

PRN	START	END	DT(SEC)	BASE	BESTRMS	INDEX	RMS @0	NUM RMS	NEP OCH	STATUS
14	259220	273645	14425.0	21	0.012	0	0.012	2881	2881	OK
20	271235	273645	2410.0	21	0.020	0	0.020	483	483	OK
22	272315	273645	1330.0	21	0.020	0	0.020	267	267	OK
29	259220	273645	14425.0	21	0.013	0	0.013	2881	2881	OK
30	263495	273645	10150.0	21	0.013	0	0.013	2031	2031	OK
7	298205	302400	4195.0	27	0.050	0	0.050	840	840	Rejected
14	273660	279775	6115.0	25	0.018	0	0.018	1224	1224	OK
28	279815	280650	835.0	25	0.047	0	0.047	168	168	OK

```
-------------------------------------------------------------------------
 Satelites used/rejected in New/multi-satellite fixed solution
-------------------------------------------------------------------------
```

PRN	START	END	DT(SEC)	BASE	BESTRMS	INDEX	RMS@0	NUM RMS	NEPOCHS	STATUS
14	259220	273645	14425.0	21	0.012	0	0.012	2881	2881	OK
20	271235	273645	2410.0	21	0.020	0	0.020	483	483	OK
22	272315	273645	1330.0	21	0.020	0	0.020	267	267	OK
29	259220	273645	14425.0	21	0.013	0	0.013	2881	2881	OK
30	263495	273645	10150.0	21	0.013	0	0.013	2064	2031	OK
7	298205	302400	4195.0	27	0.050	0	0.050	810	840	Rejected
14	273660	279775	6115.0	25	0.018	0	0.018	1224	1224	OK
28	279815	280650	835.0	25	0.047	0	0.047	168	168	OK

Following are the final coordinates that are output in a static solution. This is not seen for kinematic data. The difference between the Fixed and Float output is the Fixed will have an RMS and Reliability output. The RMS is the RMS fit of the fixed solution. This number is in meters and the maximum value to pass is 0.025 m + 1PPM for dual frequency and 0.015 + 1PPM for single frequency. The reliability is the ratio between the second best RMS and the best RMS. The minimum reliability for a pass is 1.35.

```
-------------------------------------------------------------------------
   Final FIXED static position for Station STATIC_01, Base BL1
-------------------------------------------------------------------------

Static {
     ToSta:     "STATIC_01"
     FromSta:   "BL1"
     IsBest:    Yes
     AntHgt:    0.486 m

     StartTime: 401050.00 1284  15:24:10.0 08/19/2004
     EndTime:   403315.00 1284  16:01:55.0 08/19/2004
     TimeLen:   37 minutes, 45 seconds

     Latitude:   51 08 19.52307
     Longitude: -113 32 25.26474
     EllHeight:  965.8063
     SolType:   L1-Fixed
     IsFixed:   Yes
     RMS:       0.0074 PASS   ; m
     Reliability: 3.0   PASS   ; RMS ratio
```

```
    StdDev:     0.0005 0.0008 0.0009   ; m (e,n,h)
    EcefVec:    5180.8939 -287.3737 1462.3952  ; m
    EcefCov1:   2.47516461e-007
    EcefCov2:   2.90900665e-008  3.64201228e-007
    EcefCov3:   2.69447236e-008 -4.06613700e-008  9.45815104e-007
    AvgDDDop:   3.39
    AvgPDop:    1.70
    AvgNumSats: 6.8
    Quality:    1

    SlopeDist:   5390.997   ; m
    HorizDist:   5390.182   ; m
    SurfaceDist: 5390.183   ; m
    Azimuth12:    64 24 48.00207
    Azimuth21:   244 28 02.69245
}-------------------------------------------------------------------------------
```

The only output from Kinematic processing is the KAR summary record as shown below. If kinematic processing is used without KAR no output will be shown in the fss/rss files.

```
 -------------------------------------------------------------------------
    KAR summary records for succeeded solutions
 -------------------------------------------------------------------------
Kar {
    EngageTime:  343269.00 1272  23:21:09.0 05/26/2004
    RestoreTime: 343270.00 1272  23:21:10.0 05/26/2004
    SearchTime:  343329.00 1272  23:22:09.0 05/26/2004
    TimeSkipped: 0.0    s
    TimeUsed:   60.0   s  PASS
    RMS:        0.010  cyc PASS
    Reliability: 6.2       PASS
    FloatFixSep: 1.42   m  PASS
    SearchDist:  0.02   km "HIGH L2 noise model"
    AvgDist:     0.02   km
    AvgSats:     7.0
    SearchSats: 7        "13 3 19 1 28 27 31"
    RestoreSats: 7       "13 3 19 1 28 27 31"
    RestoreDop:  2.6
    RestorePos:  -21 10 09.12638 149 11 00.32129 58.989
    Message:     "KAR success!"
}
```

9.1.3 .FWD or .REV

This section explains the trajectory output, which has entries for each epoch. The first line of the output file always begins with $OUTREC, and is followed by the version number, the processing engine, and the type of output. An example of the first line is given below.

$OUTREC Ver7.50 NGPS32 Forward Extended

The output format is shown below. Text that has been italicized indicates a description of the variables, or the units that the variables are in. A numerical example is also given.

Note that entries in the format marked as optional may not appear, depending on which processing options were used. The default processing output is Normal; however, to get full output (the optional output) go to the 'Advanced' tab in the processing options and change the option 'FWD/REV File Format' from Normal to Extended. Extended output is required for some output types in the Export Wizard and for some of the advanced plots.

```
Out {  Tim: even_sec_time corrected_time WkNum        GPS seconds of the week, week number
       Geo: latitude longitude height anthgt           Degrees minutes seconds, metres
       Loc: d-east d-north d-height v-east v-north v-height   local level pos+vel, metres, m/s
       Sta: quality amb_drift dd_dop pdop hdop vdop     1-6, cycles/sec, dops
       Rms: L1Rms CARms P1Rms D1Rms L1Std CAStd D1Std       m, m/s Rms=RMS of resid,
Std=meas std-dev
       Var: cee cnn czz cve cvn cvz cpos        Position + velocity variance + trace with ppm, m^2, m^2/s^2
       Flg: S/K L/F NumGps NumGlonass SolType     (S)tatic, (K)inematic, f(L)oat amb., (F)ixed amb.
                        SolType: (S)-SF carrier, (D)-DF carrier, (I)-IonoFree, (R)-RelIono, (C)-C/A Only
       Cov: cne cze czn cvne cvze cvzn          Position and velocity covariance
       Ecf: dx dy dz                           ECEF base->remote vector
       Acc: ae an au                           Local level accelerations (m/s^2)
       Gln: TimeOffset ToffSd NGps NGln         m
}

Out {  Tim: 343277.000 343276.999962535 1272
       Geo: -21 10 09.16196 149 11 00.34808 58.9045 0.000
       Loc: -2.454 18.834 0.804 -0.002 0.022 0.045
       Sta: 4 0.118066 2.59 1.55 1.19 1.00
       Rms: 0.0060 0.545 0.000 0.028 0.0379 4.200 1.050
       Var: 5.89495e-001 7.70540e-001 4.04788e+000 2.80134e-001 3.47242e-001 9.18255e-001
5.40791e+000
       Flg: K L 7 0 I
       Cov: 3.91145e-002 3.03102e-001 5.10459e-002 1.38708e-002 5.89769e-002 6.98362e-004
       Ecf: -5.228 5.976 17.272
       Acc: -0.020 0.037 0.038
       Gln: 0.000 1000000.0000 0 0
}
```

9.1.4 .FBV or .RBV

These are binary values (BV) that provide additional baseline and satellite output statistics mostly used for plotting. A BV file will be proved under the following circumstances:

    a)   Multi-Base processing
    b)   User selects 'Write MB binary values/satellite residuals' under Advanced 1 Settings.

A BV file will contain the following:
    a)   For each baseline:
        i)   Code, carrier and Doppler RMS values
        ii)   Code, carrier and Doppler SD values
        iii)   Code and carrier phase separation values (see MB Plots)
        iv)   DOP values
        v)   Ambiguity drift

        vi)   Effective weighting
    b)   For each satellite:
        i)   PRN
        ii)   Baseline
        iii)   Rejection + base satellite flags
        iv)   Code, carrier and Doppler residual values
        v)   Code, carrier and Doppler SD values

Please contact Waypoint if the file format is required. In the future, an ASCII converter may become available.

Section 2   .CFG file

The .CFG file stores all the options in a project. It is rare that you will need to edit a .CFG manually; however one situation in which you will need to do so is when using callgps (the command-line processor). When editing a .CFG file you have to be careful to follow the exact syntax. To learn the commands of .CFG files look at a few files created by GrafNav and refer to Appendix A for a list of all the commands and their meanings.

Section 3   Binary GPS data files

Binary measurement data is stored in our custom .GPB format. This format is receiver independent and only stores necessary information to minimize disk space requirements. This format contains a position record and num_sats measurement record for each epoch. GPBVIEW is a useful utility to inspect and modify this file.

   i. Position record: contains the receiver computed latitude, longitude, height and clock offset. It also contains the correct GPS time (seconds since Sunday), and status bits for position validity and process mode (STATIC or KINEMATIC). The process mode is used to switch the processing program from static to kinematic mode and vice/versa. This record requires 68 bytes.

   ii. Measurement record: contains the measurements for each satellite. It contains the PRN number, CA code range, L1 phase, L1 phase rate (Doppler), L2 phase, P code range and locktime. For those fields that do not exist, zero is present. This record requires 44 bytes per satellite.

Section 4   Station Files

9.4.1   New Station File Format (.STA/.NST)

In Version 6.03 Waypoint Consulting Inc. changed the format of the station files. The old station file format is still compatible with Version 6.03, 7.00 and 7.50; however, any

changes to that station file will be saved in the new format. The new format has two possible file extensions; .NST and .STA. The new station file format is described here.

Every station file must have the input at the top of the file.

$STAINFO

If this string is not present in the file it will not load. The station file may have a header record. The header is optional and will not be present in most cases. The following is a description of the header format.

```
Hdr {
    Proj:    "Name of project"    field project name
    User:    "User Name"          name of field operator
    Time:    hh:mm:ss LOCAL/GMT    Start time
    Date:    mm/dd/yyyy            start date
    RxName:  Ashtech              receiver type
    RxSub:   GG24                 receiver sub type
    Hi:      Hi_m VERT/SLANT      start antenna vertical or slant
    Ant:     V_Offset H_Offset "Name"   antenna info (V=offset to phase centre, H-to meas. point)
     if position fixed
    Pos:     phi lamda ht [ELL/ORTHO]   computed position (of antenna)
    Mode:    SP/DGPS/RTFL/RTFX/RTK/FIX  Mode of solution (RTFL=float, RTFX=fixed,
RTK=float/fixed not known)      SP-single point, DGPS-DGPS, FIX-KNOWN
}
```

The following is the format for the stationary station marks. Many options are available in this output; however, only the options with an * are required.

```
Sta {
*   ID:      "Station ID"
*   GTim:    SecOfWeek [WeekNo]      GPS Time
    UTim:    SecOfWeek [WeekNo]      UTC Time could be used instead of GTim but this is not
recommended and often not supported.
    Pos:     phi lamda ht [ELL/ORTHO]   computed position (of antenna)
    Mode:    SP/DGPS/RTFL/RTFX/RTK/FIX  Mode of solution (RTFL=float, RTFX=fixed,
RTK=float/fixed not known)
                        SP-single point, DGPS-DGPS, FIX-KNOWN (user entered)
    Std:     SdE SdN SdH          standard deviation in meters
    Hi:      Hi_m VERT/SLANT      ; start antenna vertical or slant (vertical offset to ground)
    Ant:     V_Offset H_Offset "Name"   antenna info (V=offset to phase centre, H-to meas. point)
    OffR:    Range(m) TrueAzimuth(deg) DH(m,+UP)   offset to actural point
    OffL:    DE DN DH             ; offset in local level frame, meters (+UP)
    OffB:    DX DY DZ             ; body frame offset X-RightWingPos, Y-FOrwardPos, Z-UPPos (m)
    Att:     roll pitch heading   attitude in degrees
    Desc:    "description"
    Rem:     "remarks"
    Nsv:     NumSats NumGPS NumGlonass
    Dop:     PDOP HDOP VDOP
    Rms:     L1Phase CACode
    Age:     Sec                  age of last correction (or RTK receipt)
    Enable:  1/0                  used in grafnav
}
```

The new station file format also handles event marks. Saving a project with event marks loaded will bring the event marks into the station file. Currently no decoders will load event marks into the station file, but future decoders will. The following is the event mark format. The required fields are marked with an *.

```
Mrk {
*   Event:   Number              event number or name (no spaces)
    Desc:    \"Name\"            roll name
*   GTim:    SecOfWeek [WeekNo]     GPS Time
*   UTim:    SecOfWeek [WeekNo] UTC Time could be used instead of GTim but this is not
recommended and often not supported
Pos:     phi lamda ht [ELL/ORTHO]   computed position
Mode:    SP/DGPS/RTFL/RTFX/RTK/FIX ; Mode of solution (RTFL=float, RTFX=fixed,
RTK=float/fixed not known)
                        SP-single point, DGPS-DGPS, FIX-KNOWN (user entered)
    Std:     SdE SdN SdH          standard deviation in meters
    Vel:      VE VN VH            m/s
    Att:     roll pitch heading      attitude in degrees
    Rem:      "remarks"
    Nsv:      NumSats NumGPS NumGlonass
    Dop:      PDOP HDOP VDOP
    Rms:      L1Phase CACode
    Age:     Sec              age of last correction (or RTK receipt)
    Enable:  1/0               used in grafnav
}
```

GIS marks are also available in the new station file format. GIS marks can only be created by using Waypoint's logging software (WLOG).

```
Gis {
   Count:    counter
   Feat:     "name"
   Attrib1:  "name"
   Value1:   "name"
   Attrib2:  "name"
   Value2:   "name"
   Attrib3:  "name"
   Value3:   "name"
   Rem:      "remarks"
   Type:     featuretype position direction
         POINT/LINE/POLYGON NONE/START/END/NODE NONE/CW/CCW
   GTim:     SecOfWeek [WeekNo]      GPS Time
   UTim:     SecOfWeek [WeekNo]      UTC Time
   Pos:      phi lamda ht [ELL/ORTHO]   computed position
   Mode:     SP/DGPS/RTFL/RTFX/RTK/FIX   Mode of solution (RTFL=float, RTFX=fixed,
RTK=float/fixed not known)
                        SP-single point, DGPS-DGPS, FIX-KNOWN
   Std:      SdE SdN SdH          standard deviation in meters
   OffR:     Range(m) TrueAzimuth(deg) DH(m,+UP)   offset to actural point
   OffL:     DE DN DH             offset in local level frame, meters (+UP)
   OffB:     DX DY DZ              body frame offset X-RightWingPos, Y-FOrwardPos, Z-UPPos (m)
   Hi:      Hi_m VERT/SLANT        start antenna vertical or slant
   Ant:     V_Offset H_Offset "Name"   antenna info (V=offset to phase centre, H-to meas. point)
```

```
    Nsv:    NumSats NumGPS NumGlonass
    Dop:    PDOP HDOP VDOP
    Rms:    L1Phase CACode
    Age:    Sec            age of last correction (or RTK receipt)
    Enable:  1/0            used in grafnav
}
```

Another new data type handled in the station format is an RTK epoch, where every epoch can be recorded. This is not currently implemented but is described here for future reference.

```
RTK {
*   GTim:   SecOfWeek [WeekNo]     GPS Time
*   UTim:   SecOfWeek [WeekNo]     UTC Time
*   Pos:    phi lamda ht [ELL/ORTHO]  computed position
    Mode:   SP/DGPS/RTFL/RTFX/RTK/FIX  Mode of solution (RTFL=float, RTFX=fixed,
RTK=float/fixed not known)
                            ; SP-single point, DGPS-DGPS, FIX-KNOWN (user entered)
    Std:    SdE SdN SdH        ; standard deviation in metres
    Vel:    VE VN VH           ; m/s
    Att:    roll pitch heading    ; attitude in degrees
    Nsv:    NumSats NumGPS NumGlonass
    Dop:    PDOP HDOP VDOP
    Rms:    L1Phase CACode
    Age:    Sec            ; age of last correction (or RTK receipt)
    Enable:  1/0            ; used in grafnav
}
```

9.4.2 Station Old Format 6.02 and older (.STA)

Feature points can be loaded into GrafNav via a station file. This station file is an ASCII file from which station names, GPS times, antenna heights and related information is read. GrafNav will select the nearest epoch time to extract the position, and will not interpolate in this situation. For interpolation the user should see the Load Camera Marks option. The station file can contain two feature type as follows:

1.   A named station has the following format:

        STA: * GPSTime * StaName * AntHeight * Description * Remarks   [CR][LF]

Where,
        GPSTime   Time of feature mark, defined in GPS seconds of the week
        StaName   Alpha-numeric station identifier [16 chars max]
        AntHeight   Height of the range pole or tripod in meters
        Description Description of station [32 chars max]
        Remarks   Remarks for the station [32 chars max]
        [CR][LF]   Carriage return + line feed to end line
        '*'   Field separator, there cannot be any '*'s in the text

2.   The second feature is called a GIS feature mark and has the following format:
        GIS: * GPSTime * Counter * AntHeight * Attribute [CR][LF]

Where,

GPSTime	Time of feature mark, defined in GPS seconds of the week
Counter	Numeric counter which normally increments
AntHeight	Height of the range pole or tripod in meters
Attribute	Feature name + attribute string
'*'	Field separator, there cannot be any '*'s in the text

Section 5   Ephemeris Files

GrafNav/GrafNet use a custom ASCII file format for the ephemeris records. These records are created in real time with the data logger or from the various conversion utilities. Since this file format is ASCII, a simple text editor can be used to combine ephemeris records from multiple concurrently collecting receivers. This is useful if some ephemeris records were missed from some stations. Duplicate records will be automatically removed in GrafNav.

Chapter 10   Processing Techniques

Section 1   Tips on Maximizing Accuracies

This is a valuable section to pass on some of Waypoint's processing knowledge to the user along with a few tricks that can vastly improve certain data sets. It should be noted that as you have the ability to bring a static baseline from GrafNet into GrafNav, many of the tips listed in GrafNav can equally apply to baselines in GrafNet.

10.1.1   Helpful GrafNav/GrafNet Tips

10.1.1.1   Avoid Re-Typing Master Station Coordinates

Every time a new project is created from New File or Auto Start, the user needs to input the Master Station Coordinates. If certain base stations are being used repeatedly, it is easier to store the station coordinates by using 'Add to favorites' in the Master Position Coordinate Options, and loading the master station coordinates using 'Load from favorites' when needed. This method is faster and less typing errors are induced.

Stations from network or traverse solutions can also be added to the favorite stations list using GrafNet. Once a network solution has been processed and the user right-clicks the mouse on the station (on the map), a pop-up menu appears with the 'Add point to Favorites' option. Stations added from GrafNet will also be available for use in GrafNav. Note that if no network solution is loaded, the user will be prompted to see if a traverse solution should be used or not. A list of coordinates can also be loaded from the Favourites Manager.

It is worth noting here that CORS, IGS, AUSLIG, IGN, and GSI control points are pre-loaded into the Favorites Manager. It is important to note that these coordinates should only be used as guidelines, as they are subject to change. Additionally, be careful to note the datum of the coordinates found in the Favourites Manager. For instance, IGS coordinates are given in WGS84.   If high accuracies are desired, the exact coordinates should be read from the Internet.

By selecting the datum prior to pressing 'Select from Favorites', coordinates in this datum will be favored. This has application for stations that are part of two networks (e.g. CORS and IGS). CORS coordinates will be NAD83 while IGS is ITRF/WGS84.

10.1.1.2   Custom Output Formats

The Export Coordinates Wizard (see Chapter 2 Section 7) is present to allow the user more control over output format. Export Profiles can now be customized and saved for reuse. Along with more access to different variables for output, the Export Wizard can also vary in format with user defined header/footer files, strings, error/warning messages, and a processing summary.

10.1.1.3 Missing a Base Station?

GrafNav now supports single point processing which is accurate to 1-3 (or worse) meters with precise ephemeris, dual frequency and good quality code measurements (on both frequencies).

Generally, a more accurate solution is to use the download program that can be launch form GrafNav, GrafNet or GrafNav Batch via *Tools | Download Service Data*. Currently there are 2400 stations from around the globe loaded into the software. Download will:
1. Go onto the Internet and download selected stations
2. Decompress
3. Convert from RINEX to GPB
4. Concatenate files if time span covers two or more days
5. Optionally resample to a higher data interval

See Chapter 6 Section 9 Download Service Data for more information.

10.1.1.4 Use Pre-configured Options Profiles

Version 7.50 now comes with pre-loaded configuration combination (see *Options | Default Settings | Load Settings From*). Users can also add their own. Using these makes the life of choosing settings easier. Selecting either these or Factory Defaults is especially important for processing projects from previous versions.

10.1.2 General Tips for Kinematic (GrafNav)

10.1.2.1 Use Pre-Loaded Options Profiles

Before processing, consider selecting an options profile (e.g. 'Airborne', 'Low Cost Receiver', etc…). This can be accomplished directly during 'Auto-Start' or after a project has been created or loaded by selecting *Settings | Load Settings From | Profile*.

10.1.2.2 Combine Forward and Reverse Solution

For carrier phase processing, accurate ambiguity determination is the most important goal. The forward/reverse combination is a fast and easy check on this determination. Selecting 'Combine Forward/Reverse' from the process menu after both directions have been processed performs this. Plotting the forward/reverse separation shows the difference, and gives an indication of the reliability of the solution. This difference is not necessarily the errors and the weighting of these two solutions can be plotted as well.

With version 7.50, problem periods such as incorrect integers determined in either the forward or reverse direction can be blocked. See *Process | Combine Solutions | Combine Settings*.

10.1.2.3 Use Static/Kinematic Flag

GrafNav keeps track of Static and Kinematic processing, and accuracies are better in Static than Kinematic. Therefore, if a user has longer period of static (i.e. more than 5 minutes), then it is beneficial to make that data static. It is even more important to set portions of the data where the antenna is moving to kinematic. Even if the movement is 5

centimeters, that portion should be set to kinematic. This is performed via the GPB Viewer (see Chapter 6 Section 3 GPBView).

To make use of this flag, it is important to first properly identify which data is static and which is kinematic. An easy way to separate the static from the kinematic is as follows:

- Make entire remote data kinematic (see GPBView, Chapter 6 Section 3 or use *File | GPB utilities | Insert Static/Kinematic markers*).
- Process with float solution (i.e. no KAR or fixed solution).
- Plot the Velocity Profile from the Plot GPS Data function within the Output Menu.
- Static data is normally where the velocity is very near zero (e.g. < 0.2 m/s). Always be cautious about slow movements which can be shrouded in the measurement noise.
- Use Raw GPS Data Viewer to switch these periods from kinematic to static. It is generally a good idea to start the static 10-20 seconds after movement stops, and stop the static a similar amount before movement begins (again Insert Static/Kinematic Markers feature can also be use).
- GPS receivers that make an accurate Doppler measurement facilitate easier static/kinematic identification.

10.1.2.4 Eliminate Problem Satellites

Sometimes a single problem satellite will introduce considerable error in the solution. Two techniques to identify and eliminate problem satellites are briefly discussed here. One way is to examine the message logs after processing, and look for repeated warnings concerning specific satellites. If one satellite has many warning, you may wish to either eliminate this satellite for the entire data set, or for specific time periods (as indicated in the message logs).

A second method to identify problem satellites is to process in the forward direction only, with the option 'Write MB binary values/satellite residuals' on, which is located in the Advanced Options. Enabling this setting will allow you to plot the C/A code and the L1 phase satellite residuals (see 'Individual Satellite Statistics' under Section 2.6.1 Plot GPS Data). Problem satellites will usually have large spikes or generally stand out from the other SV plots, and omitting these satellites will generally improve results.

If large spikes appear in every SV plot, examining which satellite is the worst offender (that is, which has the largest satellite phase residuals) just prior to the filter reset, and omitting these satellites (up to just after the total loss of lock) will often not result in the total loss of lock induced by the filter reset option, and improve results considerably.

10.1.2.5 Set the Proper Standard Deviation for Kinematic Convergence

The standard deviation on the C/A code is set to 4 meters by default. This is to satisfy the requirement of all GPS receivers. However, many receivers produce more accurate C/A code measurements by using narrow correlation or smoothing technologies, while other low-cost units have much poorer C/A code accommodations. Setting proper

measurement standard deviation values will improve float accuracies and also increase KAR reliability.

To determine a new C/A code standard deviation, process once in float mode (i.e. no fixed solution or KAR). After processing, plot the C/A Code RMS from the Plot GPS Data option from the Output menu (see Section 2.6.1 Plot GPS Data). Note that the current standard deviation value should be plotted as well. Pick a value that nicely represents a good overall RMS for the C/A. Pessimistic values are better than optimistic ones. Set the C/A code standard deviation to this new value from the Standard Deviation options from the Options menu, and reprocess. The C/A code RMS can also be obtained via the Processing Summary (select View Processing Summary from the Process Menu). When using this value as a standard deviation (see Measurement Processing Settings), a problem can be that it is too optimistic, and the methodology discussed previously in this paragraph is better.

A similar methodology can be used for the carrier phase. However, instead of lowering the value, it is often raised to account for increased error. Note that the carrier phase standard deviation value may be higher than the entered value due to the checkbox 'Adjust for Iono' being set.

Setting proper standard deviation values is especially important for single frequency data sets, and can do more to help than just about anything else. The L1 phase standard deviation may need to be raised (e.g. 0.05-0.10 m). This is performed under the Measurement Options. Setting proper standard deviations is also helpful for dual frequency processing.

10.1.2.6 Bad Data Control

When GrafNav sees very high residuals (i.e. code and/or carrier RMS), it tries to correct the problem by removing a measurement (i.e. doppler or P2 code), baseline (MB processing only), or satellite. In some cases, if it cannot correct the problem, it will issue a cycle slip to all satellites. This is known as a filter reset and can be observed by a sharp increase in estimated position accuracy (in forward or reverse direction), and a '$$$' message will be printed to the message log.

The user can control how GrafNav handles bad data in the 'Outlier detection/rejection' section of the Measurement processing settings. Specifically, a looser carrier phase 'level' will prevent fewer resets from happening, while a stricter carrier phase 'level' will be more energetic in finding errors at the risk of issuing more resets.

10.1.2.7 Avoiding Missing Epochs

After processing with GrafNav, epochs can be missing for a number of reasons:

- Either the base or remote .GPB files are missing one or more epochs. Use the GPBView (View Raw GPS Data) and check the epochs in question. If this is the case on the remote, then there is nothing that can be done here. However, master

gaps can be "filled in" by selecting *View | GPS Observations | Master ___ | Resample*. See 2.2.7

- By default, GrafNav ignores the first 4 seconds of data after a satellite rises. This is to avoid any possible half-cycle problems in determining the carrier phase that are more likely during the first few seconds of lock. The tolerance is known as the Locktime cut-off, and can be altered from the Advanced Options. If missing epochs are a problem, try lowering this number.
- If an epoch has been determined to be "bad", data is not written to the .FWD or .REV files and thereby not received by GrafNav. This is to protect the user from receiving very bad data. However, if data quantity is more important than quality, then these epochs can be written by setting the "Write epochs containing bad data" checkbox from within the Advanced 1 Options.
- There may also be less than 4 satellites in common between base and remote. GrafNav requires at least 4. If there are no obstructions, then check for Missing ephemeris messages in the Message Log File (.FML/.RML). If there are not enough ephemerides, then broadcast ephemeris files can be downloaded from the NGS-CORS (http://www.ngs.noaa.gov/CORS/cors-data.html) or obtained from a service provider. Convert the RINEX ephemeris to .EPP using the provided RINEX Converter.

Otherwise, coordinate interpolation is the only other option. GrafNav can interpolate missing epochs from within the Export Wizard or the Write Coordinates feature, which can both be accessed via the Output Menu. Interpolation is permitted in the Export Wizard from the screen titled "Select Epoch Sampling Mode". Likewise, interpolation is permitted in the Write Coordinates feature by selecting Epoch Format. At the bottom of this dialogue box, enable missing epoch interpolation, and select the desired data interval.

10.1.2.8 Avoid RINEX for Kinematic Data

Most GPS receivers attempt to detect cycle slips at a data rate much higher than the recording rate, and their native formats indicate such slips. Although RINEX has a loss of lock character, RINEX converters do not always use it. Therefore, use the receiver specific converter if possible.

10.1.3 Tips for Using KAR

10.1.3.1 Detecting and Fixing Incorrect Integer Intersections

Incorrect intersections are caused by KAR when it picks the wrong solution. This error exhibits a near constant offset in the combined forward/reverse separation.

Step 1—Confirm that the large forward/reverse separation is due to a bad KAR fix
After plotting the combined separation, which will show the times when the forward/reverse separation is poor, also plot the 'Float/Fixed Ambiguity Status'. This will show when there is zero, one or two fixes available for an epoch. Incorrect KAR intersections are most apparent when there are two fixes (i.e. for both forward and reverse). These areas show up as green. This does not mean that an incorrect fix cannot occur when there is just one fix. In this situation, you are comparing a float solution to a

fixed. The large bias is usually due to the float solution, but this is not always the case. In such a case, plotting the standard deviation of the float solution can be very helpful.

Step 2—Determine processing direction of bad solution
It is always a good idea to determine which processing direction is the cause since only that direction needs to be reprocessed. This is significant because in Step 3, you will be changing many options. It is important to only make these trails on the bad direction as you would not want to corrupt the good direction.

The fastest way to determine which direction is bad is to load each individually. After each is loaded, plot the L1 Phase RMS. The incorrect fix normally exhibits a linear growth to the carrier phase RMS. There may be jumps as GrafNav is trying to correct the problem by removing satellites. After some time, it may stay low if a filter reset has been issued.

Another way to determine the likelihood of a bad KAR fix is to view the Static/KAR summary file (.fss/rss). There will be records for each KAR fix. Look for fixes with poor RMS (>0.05 cycles), low reliabilities (<2-3) and/or large float-fixed separations (>1 m).

Step 3—Correcting the Problem
A bad KAR fix is normally a very easy problem to correct. It just requires one or more of the following settings to be changed. The first ones are more likely to help then the last.

a) Enable the 'Stricter RMS tolerance' and/or the 'Stricter reliability tolerance' checkboxes in the Advanced KAR options.
b) Lengthen the minimum KAR time. As KAR uses more time, it usually rejects bad fixes better
c) Try disabling 'Refine L1/L2 KAR search' (Advanced KAR option).
d) If the auto-reduce KAR search area is used for dual frequency, try increasing the scale factor, or switch to the constant search region size.
e) Consider re-engaging KAR manually after the bad fix. Be sure the checkbox 'Reset Kalman Filter' is checked on the Manual KAR Engage record.
f) Use the KAR_SEP_TOL command to force KAR to only accept intersections that are close to the float solution. For instance, use a value of 1 m).
g) Lower the Maximum Engage Distance for KAR. Users may also wish to use the KAR_USE_DIST command and set the distance to a lower value as well.
h) If poor geometry is a concern, try lowering the 'Maximum allowed DD_DOP' from the Advanced KAR Options.
i) If all else fails, disable this time period during combination (see 10.1.2.1).

10.1.3.2   Using KAR With Interpolated Data

If the Download Service Data function was used to download CORS or IGS data, you have the option of interpolating to a higher interval. In such a case, the epochs not on the

original interval (usually 30s), has errors of ~1 cm. If KAR uses this data, it will often fail. Therefore, under the Advanced KAR options, set the 'Use on interval:' value to the original data interval of your data (e.g. 30 s). In addition, enable the 'Exact interval (for interpolated data) option. This will cause KAR to only use the data on the exact 'n' second interval. The minimum KAR time may need to be increased to compensate for less data being used by KAR.

10.1.3.3 KAR Options – Could Not Find a Solution

Resolving this problem is usually more difficult than resolving the problem of picking a wrong solution. This is because the inability to pick a solution is most often related to noisy carrier data on L1 and/or L2. Usually, playing with the KAR time and search region size is all that can be done. Consider disabling the strict reliability tolerance as well. For dual frequency, switching to other noise models can help if there is a problem with L1 or L2. With single frequency KAR, the L1 phase needs to be very clean, and there has to be a period of at least 10 minutes without a loss of lock. These conditions are not always possible in many environments.

For dual frequency data on short baselines (< 8 km), try using Fast KAR (Advanced KAR option). The '5 satellite' option is not suggested.

For dual frequency GPS data with good C/A code, the following tricks can be used.

- Set the C/A standard deviation to 2-3 meters. This is done under the Standard Deviation Options.
- Change the size of the KAR Dual Frequency Search Region size to 1.5 meters. Use KAR Options.
- Raise the KAR Minimum Time for Dual Frequency to 3 or more minutes. Use the KAR Options as well
- From the Options Menu, select User Defined Options. Enter the command: KAR_SEP_TOL=0.75

Using this procedure will help in finding a solution but may increase the chance of a false intersection as well. Therefore, it is important that FWD/REV solutions agree.

10.1.3.4 Taking Advantage of GrafNav's Improved KAR (for long baselines)

Most of these tips are available primarily to dual frequency users due to the ionospheric modeling.

Iono Noise model removes ionospheric error to improve reliabilities and also seeds the ionospheric correction (when engaged). The Auto Noise model chooses between the High and Iono noise models based upon the distance when the search is performed. The distance tolerance for choosing between the two noise models (i.e. High and Iono) can be specified in the Advanced KAR Options. In most cases the Auto setting works best. However, forcing either the Iono or High models has its advantages. For example, the High noise model is less reliant on L2, which can make it more reliable if L2 is noisy.

The iono model seeds the iono-free and relative ionospheric models, which can produce a more accurate final solution.

KAR can also be engaged in static mode (see KAR Options – Engage Settings). This means using the fixed static solutions can be avoided, which simplifies processing. Normally though, the fixed static solution is more reliable, and fixed solution fixes can be solved for each of the static periods in the data.

Using the option 'Utilize all data whose distances are less than tolerances' (see KAR options) has a great effect on airborne long distance data where the aircraft is continuously flying within and outside KAR distance tolerances. Enabling is generally a good thing as more data is used. However, sometimes this can result in the incorrect integer being chosen if a carrier slip is missed while the aircraft was far away.

10.1.3.5 KAR – Improving Upon a 20-30cm Combined Separation

On long baseline airborne processing, 5-10 cm accuracies are sometimes needed (e.g. large photogrammetric scales or LIDAR). However, after initial processing, the forward/reverse separation may only show 20-30 cm. The forward/reverse separation is not an absolute indicator of accuracy, but a very tight separation provides for a very nice level of comfort. This section describes how 20-30 cm separations can be improved. If it took a great deal of effort just to achieve 20-30 cm, then your outlook for improving upon this can be bleak. Otherwise, here are some tips:

a) Make sure that a fixed integer (ambiguity) solution is obtained for as much of the mission as possible because fixed integers solutions (i.e. KAR or the fixed static solution) are usually necessary achieving 5-10 cm accuracies. This can be observed by plotting the Float/Fixed Ambiguity Status plot for both the forward and reverse directions. If there is a larger separation and only one of the solutions (i.e. forward or reverse) has the fixed ambiguity solution, then this is not a significant problem if you are sure that the fixed integer solution (i.e. KAR/fixed static) is correct.

b) Use manual KAR engage at times where base or remote distance is small but forward-reverse separation is outside tolerance.

c) Enable the 'Engage on poor DOP' option under the Advance KAR Options. This will be helpful if large DOPs are observed (plot the DD_DOP variable where DD_DOPS over 15-25 can cause instabilities). You may also need to check the message log file, as epochs with extremely poor DOPs are skipped and not visible on the data plots.

d) In MB processing especially, try engaging when close to a base station (see *KAR 1 | Engage if distance < tol1, reset if distance > tol2*).

e) Increasing either the KAR time or the KAR add time (i.e. # min/10 km) can help as well, since KAR can sometimes pick the wrong L1 or L2 lane resulting in a 10-20 cm error.

f) Try enabling the stricter RMS tolerance check box in the Advanced KAR Options. This will make KAR less likely to accept a bad solution.

g) Try forcing the use of the Iono L2 noise model (or lower the Auto distance) in the Advanced KAR options. This causes ionospheric corrections to be more properly estimated.

h) Try using a stricter carrier phase 'level' in the Outlier Detection/Rejection section of the Measurement Processing Settings.

i) If static data is available, using the fixed static solution can be helpful.

j) Try both the Iono-free, relative models and combinations for forward and reverse

10.1.4   General Tips for Static (GrafNet)

If there is a problem with a static baseline, it is a good idea to right-click on it and select "GrafNav", which will bring the baseline into GrafNav. This allows you to control many more processing options, and gives you access to plot options for a more detailed analysis. Once inside GrafNav, many of the above techniques for GrafNav are equally as applicable here.

10.1.4.1   Use GrafNet for Static Batch Processing

If you have numerous static baselines even with a single base, use GrafNet as it is much faster to setup and process the project. If problems develop with the receiver at your base station, try downloading the nearest CORS/IGS station, or even the nearest few CORS/IGS stations, and use the Batch processor to get a combined solution from multiple base stations (see Chapter 4 for more information on the Batch Processor).

10.1.4.2   Use Kinematic Processing on Static Baselines

If data has static sections defined, and there is even a small amount of movement, the L1 carrier will suffer. This may cause a fixed solution to fail or a float/quick to deliver poor results. To compensate for the small movement, the user may want to process the data in kinematic mode, which will give better results if there was movement in the antenna. Changing the entire remote file to kinematic can be accomplished within the GPB viewer (see Chapter 6 Section 3 GPBView). Alternatively, the user can process in static mode, but select the option "Engage KAR while in Static mode". KAR is very reliable for dual frequency data but can only be engaged in kinematic mode.

10.1.4.3   Optimizing the Fixed Static Solution for GrafNet or GrafNav

Like in KAR, an ionospheric L2 noise model is available. This can greatly increase the range of fixed integer solutions—especially with longer observations. With such longer occupations, enabling the iono-free solutions (under GrafNav) can further improve accuracies. Under GrafNet this is performed by default for the iono noise model (use Fixed Static Options).

For both GrafNav and GrafNet, the automatic noise model works very well. However, on days with heavy ionosphere, switching to the iono L2 noise model can be helpful. Having longer static occupation times can be extremely helpful under these conditions.

On longer baselines, fixed solutions usually fail as a result of RMS rejections. Conversely, reliability failures are usually the cause of failure on short baselines. In

either situation, engaging the Auto-reduce feature can be helpful. This is possible for both GrafNav and GrafNet using the Fixed Static Solution Options. If the float or iono-free float is fairly accurate (e.g. +/- 10 cm), then using a user search area site (see Fixed Static Solution Options) can be helpful as well. Values as small as 20 cm can be used.

10.1.4.4   Adjust Refine L1/L2 Option for Dual Frequency Data

The setting 'Refine L1/L2' in the fixed solution option can be beneficial for obtaining the proper static fix. However, sometimes it can actually result in the one or more satellite resolving the incorrect integer. Try using with and without selected.

10.1.4.5   Using a Larger Interval for Static Processing

Users may have collected data at a high data rate such as 1 Hz. Such high data rates, while necessary for kinematic positioning, are detrimental to static processing. The reason is that carrier phase measurements are correlated over time periods of 10 or more seconds. Since each epoch is considered an independent set of measurements in the static computation, time correlation is not modeled. The gist of the previous text is twofold. Firstly, statistics are overly optimistic with the higher data rate. This can be explained with the following abstract example. Ten independent measurements are more accurate than one. However, if these 10 measurements have a systematic bias that is much larger than the random error (i.e. epoch-to-epoch white noise), which is possible on GPS signals over short periods, one measurement is essentially as good as 10. The second repercussion is a result of the first. The floating solution will converge too quickly, making it very sensitive to erroneous measurements at the start.

The solution is very easy. Just use an interval of 15 or 30 seconds. This will give you essentially the same coordinate value as with a higher data interval, but with a much more accurate estimated standard deviation. In GrafNet, the network adjustment's variance factor will be much closer to unity. Both GrafNav and GrafNet have options for setting the interval.

10.1.5   Long Baseline/Dual Frequency Processing in GrafNav/GrafNet

10.1.5.1   Processing Long Kinematic Baselines

For dual frequency processing on long baselines, it is important to process with L2 ionospheric processing. This option is set under the Dual Frequency Options. Enable the checkbox labeled "Use L2 for ionospheric processing". The checkbox "Use L2 for ambiguity resolution" should also be enabled.

Once L2 ionospheric processing is enabled, there are two ionospheric processing methods:

   i.   The iono-free method works well when the remote initializes far from the base. This method creates a carrier signal "free" of ionospheric error. However, a cycle slip on L2 will induce a total loss of lock for that satellite. In some cases, the

iono-free method may do better than the Relative even if initialization is close. It is often good to try both. Generally iono-free works better than the relative model.

ii. The Relative model works by only applying an ionospheric correction to the L1 signal. If initialization is close, then an initial correction of zero is accumulated as the remote vehicle travels away from the base. The relative model tends to have a higher L1 phase error (see Plot GPS Data) than the iono-free. This is because the relative model is only an approximation. However, cycle slips on L2 do not reset the ambiguity like the iono-free solution. Hence, accuracies may be better if L2 cycle slips are present in large quantities. For days with high ionospheric activity, the "Engage Distance" may need to be lowered (found in the Dual Frequency Options tab in the processing options). If a static initialization is performed close to the base, which is suggested, then it may be beneficial to make the Engage Distance longer than the initialization distance. Raising the rejection tolerance and/or the PPM value in the standard deviation options will stop GrafNav from mixing up big ionospheric corrections with carrier phase errors. This is performed within the Standard Deviation Options. Using 0.2 m for the L1 rejection tolerance is normally good.

Although KAR can be used with both ionospheric methods, a KAR fix will have some ionospheric error if the iono noise model is not used (found in Advanced KAR Options). It may also have difficulties on longer baselines. Therefore, setting the "Maximum Distance for Engaging KAR" dual frequency value from within the KAR Options is important. Normally, values between 20 and 60 km are realistic.

On very long baselines, the C/A code can be corrected if P2 code is available. In many cases, this will simply add more noise, but the noise is very white, and overall improvements can be observed. This is enabled from the Dual Frequency Options. It is often good to try with and without.

For single frequency, it is important that the standard deviations be set properly on the C/A code and L1 carrier phase signals (see Section 10.1.2 General Tips for Kinematic (GrafNav)). This can do more to help than just about anything else. The L1 phase standard deviation may need to be raised (e.g. 0.05-0.10 m) as well as the rejection tolerance (e.g. 0.2-0.5 m). This is performed under the Standard Deviation Options. Setting proper standard deviations is also helpful for dual frequency processing.

10.1.5.2 Processing Dual Frequency Data During Ionospheric Storms

Ionospheric activity peaks in 1999-2000, and data over even 10-15 km can sometimes be hard to process if ionospheric activity is high. Since the effect of the ionosphere on electromagnetic signals is frequency dependent, dual frequency data can be used to combat ionospheric problems very effectively. By default, both GrafNav and GrafNet do not use L2 phase data to correct for the ionosphere because noise can be added to shorter baselines. Ionospheric processing must be enabled from within the options. A dual frequency receiver is required at both ends of the baseline to perform such processing.

In GrafNav, ionospheric processing is enabled from the Dual Frequency Options. Make sure the checkbox labeled "Use L2 for ionospheric processing" is enabled. There are two modes of ionospheric processing. The relative model assumes that the remote starts very near to the base and that the initial ionospheric error is zero. As the remote travels it transfers the ionospheric correction. On the other hand, the iono-free model forms a phase measurement, which is a combination of L1 and L2 and free of ionospheric error. This method is more effective for static positioning or if the remote starts far from the base. One of the disadvantages of the iono-free model is that a cycle slip on L2 will induce a cycle slip for that satellite. This is not the case for the relative model. Regardless, for many kinematic data sets, both should be tried. For the relative model, it may be advantageous to lower the "Engage distance" during high ionospheric activity. It is 4.0 km by default.

In GrafNet, only the iono-free model can be used. It is enabled from the General Options by selecting the Ionospheric Free Solution for the Static Process Mode. This is a float solution, which means that non-integer ambiguities are solved. The effect of this is that observation times of at least 30 minutes should be used. On longer baselines, many hours are suggested. It is also suggested that if short and long baselines are combined in a GrafNet network, a Fixed Solution can give better results on the shorter baselines.

To detect if there is bad ionospheric data, process with a float static solution and use single frequency (this is best done from GrafNav). Make sure KAR is turned OFF. Once the data is processed, plot the L1 Phase RMS from Plot GPS Data under the Output Menu. If the data looks like a cross-section of the Rocky Mountains with peaks over 0.05 meters, then there may be ionospheric problems. The ionosphere should not show up on baselines less than 5 km.

10.1.5.3   Processing Long Static Baselines

Fixed solutions may be susceptible to ionospheric errors that are produced on long baseline lengths. This may result in a failed solution (e.g. high RMS value and/or low reliability) or an incorrect fix. In such cases, the iono-free solution or float solution should be used for dual and single frequencies respectively.

The maximum distance for fixed solutions varies from data set to data set. For dual frequency, maximum fixed solution distances are usually 30-60 km, but may be less during ionospheric storms. For single frequency, this distance is more like 10-20 km. In both cases, longer fixed solution distances can be achieved but with varying degrees of success.

For single frequency, the float solution is the only alternative. It should be used if the fixed fails in both forward and reverse directions. If not, then the solution must be manually re-processed from the Session Menu (right-click on the baseline). The float solution is more accurate if the fixed solution has determined an incorrect integer ambiguity solution.

For dual frequency, the iono-free solution is normally superior to the float. The only time that this is not the case on long baselines is if the L2 signal from the GPS receiver has either many slips or data errors. In such a case, the float solution is better. For long observation periods on very long baselines, the iono-free may in fact be more accurate than the passed L1/L2 fixed solution. This is because the ionospheric error has been removed. On short baselines, the iono-free solution should not be used.

For either frequency, the inclusion of the precise ephemeris is also important. This can be downloaded at no charge from the web site http://www.ngs.noaa.gov/GPS/GPS.html. Make sure to select the .SP3 files, which can be imported into GrafNav by using the Select Alternate Ephemeris option from the File Menu. Normal precise ephemeris files take approximately one week to become available, and are the most accurate. However, slightly less accurate rapid orbits are also available in about 1½ day.

The different modes of processing are selected in the General Options located from the Options menu item. If long and short baselines are mixed, then it may be necessary to process the short baselines with a fixed solution and the long ones with the iono-free or float solution.

Section 2   Multi-Base Processing

Many GPS post-processing applications utilize multiple base stations, and processing can be handled in two ways:
- a)   Sequential manner where baselines are processed separately and combined after-the-fact. This requires GrafNav Batch, and is the pre-version 7.50 manner of processing that is still supported.
- b)   Process all bases simultaneously in a combined multi-base Kalman filter (MB-KF). This is a new feature, and processing is possible from both GrafNav and GrafNav Batch.

In this Section, the words 'base', 'base station' and 'baseline' are often interchangeable. This is because GrafNav only supports one remote file. This means that each base station produces one corresponding baseline (which is a base-remote pair).

10.2.1   Which mode of processing should I use?

Generally, the user has several options:
- i)   Use the *older* sequential method (a) exclusively
- ii)   Use the *newer* combined MB-KF method (b) exclusively
- iii)   Use both which is possible in GrafNav Batch
- iv)   Use the Combined MB-KF (b) first, and follow up with the sequential method (a) if needed

Generally, option (iv) is preferable. In general, the sequential method, although requiring less CPU effort to compute a solution, does require more operator intervention— especially in terms of analysis and the number of user iterations required to reach an

optimal solution. Secondly, since the MB-KF uses all of the bases at once, KAR can be much more effective if lock is lost in the project area. Finally, cycle slips on base receivers (although not that common) are much better handled by the MB-KF as well. For these three reasons, the older method (a) should only be used if necessary.

10.2.2 How important are base station coordinates?

VITAL! Incorrect base station coordinates is the most common error in MB processing. The averaged coordinate values are not acceptable for processing.

Latitude, longitude and height errors (especially for MB-KF processing) must not be larger than 5 cm, and accuracies should be much better than this. In addition to correct coordinates, the correct antenna height must also be entered. <u>All values should be double checked</u>. The best approach is to utilize GrafNet to quickly run a network adjustment using the all the base station data. Use the iono-free float if baseline separations are longer than 20 km. Process at a longer interval (15 or 30 s) and check each of the coordinates given. Be sure the antenna heights in GrafNet match those in GrafNav.

The effect of incorrect coordinates depends on the method and is as follows:
    a)   For the sequential method, one of two phenomenon will occur:
          i)   smaller errors will show up as a bias in the separation plot for the combined baseline
          ii)   If the error is larger, this the outlier rejection algorithm will reject one (but not necessary the same) baseline. For this reason, it is important to check the number of outlier rejections after combining multiple baselines in GrafNav Batch.
    b)   For the MB-KF, the effect is much more obscure, and it is most apparent in the MB carrier phase RMS plot. A very obvious ramping or "saw-tooth" effect is visible. See Figure 10.1 for an example. For this reason, it is very important to always view this plot in addition to the separation.
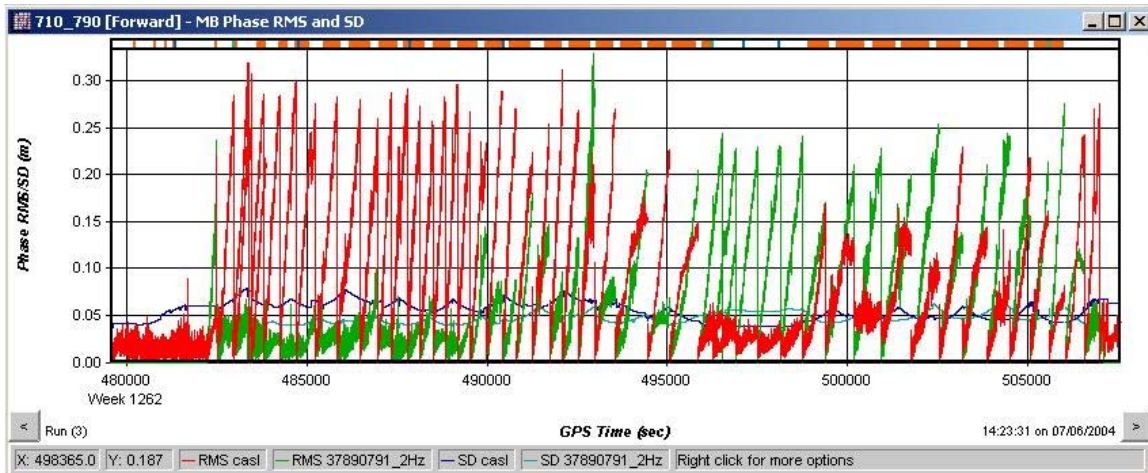
Figure 10.1 MB Carrier Phase RMS using bad base station coordinates

10.2.3   How do I use the MB plots?

When using the MB-KF methodology, a number of new plots are available. These utilize the FBV/RBV files that are produced in addition to the regular ASCII outputs. Binary Value (BV) files contain statistics for each baseline and satellite. The Output|Plot MB menu selection shows the baseline values. Some of the more common plots are (in order of usefulness):

a) **Carrier Phase RMS/SD** – shows carrier residuals for each baseline along with measurement standard deviations. This plot indicates how well the carrier phase fits with the overall solution. It also shows errors in base position, and it can be used to determine if one baseline is worse than another.

b) **Number of Baselines** – Shows how many baselines are used for processing. This is important to check as it will indicate if any baselines are ignored or rejected during data line-up.

c) **Distance Separation** – Shows distances from remote to each of the base stations.

d) **Effective Weighting** – This number is computed after the fact as is an approximate indicator of how much weight each baseline has. This value is not used to compute the solution, but it can be very helpful in indicating which baseline has the most weight. It is most affected by proximity, but the number of satellites can have an effect as well.

e) **Carrier Separation** – shows the difference between combined KF solution and individual baseline solutions using code+carrier. It is not really a measure of accuracy, but it does indicate how well multiple baselines fit to each other.

f) **Number of Satellites/DOP** – The user can plot the number of satellites and/or DOP values. This will show if one base is tracking fewer satellite than another. For very large areas, it may also show the effect of different satellites being above the elevation mask.

10.2.4   Do all of the masters need to utilize the same data interval?

In theory, no, but practically, the answer is yes. The MB-KF methodology can handle data with varying data rates without problems. The constant dropping in and out of base data will result in closer bases possibly not being used when they should. In the sequential method, processing is not affected, but a jumpy trajectory can be produced after combining.

For these reasons, both GrafNav and GrafNav Batch can now resample data right within the interface. See *View | GPS Observations | Master ___ | Resample / Fill Gaps using | Processing Interval*, and be sure to set the processing interval to the remote data interval before performing this operation (see *Settings | Processing | General*). Users can also select *View | GPS Observations | Master ___ | Resample/Fill Gaps using | Remote File Times*, which will resample to each exact epoch in the remote file. If only one remote file

is processed, this is works well. If many remotes are present for the same time, then data gaps in the remote used for resampling will cause dropouts in the resampled master.

10.2.5   How about data drop-outs at the master, will this affect processing?

Isolated data gaps are not as severe as differences in the interval. However, depending on the frequency, side effects can be present as well. For this reason, GrafNav will prompt the user to resample the master data if small gaps are detected (while creating a new project). This process will fill in these gaps if the user selects 'Yes'. Resampling can always be performed in the manner described in Section 10.2.4 . This operation is suggested if a significant number of drop-outs are present. To determine how many data gaps there are, select *View | GPS Observations | Master ___ | Show Time Gaps*.

10.2.6   Which base stations should be included?

In general, only base stations that are within the project area should be included. This is because farther away stations will hinder rather than help results as it just adds increased errors (due to tropospheric and ionospheric effects). A general rule of thumb is if a base never becomes the closest station, it is too far. In addition, using two stations very close together adds nothing over just using the one. If they track different numbers of satellites, pick the one that tracks the best.

10.2.7   What do I do about problematic baselines?

Poor baselines can be defined as following:
   a)   One baseline continuously tracking fewer satellites than the others (see Plot MB, Number of Satellites)
   b)   Having a larger carrier phase or C/A code RMS plot (see Plot MB, phase/code RMS/SD)
   c)   KAR regularly resolving incorrectly (or not resolving at all) on one baseline but not the others
   d)   Numerous bad data messages (that start with $$$) are present in message log, and seem to stem only to one base station.
   e)   Numerous cycle slips in the message log stemming only from one base (note that Slip warning must be enabled in the Advanced 1 Processing Settings).

For cases (a), (c), and (e) eliminating the baseline only from KAR should be sufficient. This is performed from the General Processing Settings (press 'Omit …' button). Reject all satellites, on the isolated baseline for the entire time, but just for KAR/Fixed Static.

For case (b), there are two approaches. The easiest is to disable it, and in most cases this works best. Disabling can be performed a number of ways, but the easiest is to right-click on the baseline, and select 'Edit'. Check the disable checkbox. The baseline symbol should now have a red 'X' on it. The other alternative is to de-weight it, which is done from the Measurement Processing Settings. From the 'Values are for' list, select the problematic baseline. Uncheck the 'Use main settings' checkbox. Then enter code

and carrier phase standard deviations more representative of the data for this baseline. You may also wish to disable this baseline from KAR as well (see previous paragraph).

For case (d), disabling is the best approach (see previous paragraph).

10.2.8   How is KAR best used with MB-KF processing?

In general, very little is different. By default, KAR uses the closest baseline for resolving KAR (or all those < 8 km). After the KAR fix, the other baselines will be fixed to the same location as well. There are two KAR settings that relate to MB processing.

      a)   The 'Search only closest base' setting under KAR 2, when checked, causes KAR to only use the base station that is nearest, or it use all base stations that are within 8 km. In general, the user would leave this checked. If a base station is causes bad fixes, it is better to disable it (see Section 10.2.6).

      b)   A useful setting (for corridor work especially) is the 'Engage KAR if distance < *tol1*, reset if distance > *tol2*' checkbox. It will engage KAR on the first occurrence the proximity to each base is less than *tol1*. KAR engagement will be reset if distance is greater than *tol2*. The values *tol1* and *tol2* (in km) may need to be refined for a particular data set.

            This feature is a useful means to take advantage of close periods to base stations in order to improved fixed integer accuracies. The only disadvantage of using this method is that KAR may engage in the middle of the flight line which can cause a position shift, which is not necessarily desirable during image, laser or SAR data capture. The only alternative is to manually fix KAR during the turns, and this latter approach is more time consuming.

10.2.9   How about using the fixed static solution?

KAR is the most common way to resolve fixed integer ambiguities, but the fixed solution works well too and can often be more accurate. It obviously needs a stationary (static) period of a few minutes for dual frequency. Longer times are needed for longer baselines (see Section 10.1.5). For MB-KF processing, this process becomes more complex because GrafNav attempts to compute a fixed solution to all baselines. It will disable those where the distance or time is too long and short respectively (see Advanced 2 Processing Settings).

For each static period, only one fixed solution will be utilized for "fixing". A number of criteria are used to pick the best one, including distance, RMS, reliability and estimated standard deviation. The fixed solution used, will be signaled as 'BEST' in the GrafNav interface.   To view the solutions, right-click on the static sessions (or select *View | Objects | KAR/Static*). Select the 'View' button for the desired static session. All of the static sessions will be shown. For combined solutions both forward and reverse will be shown. In addition, a 'combined' static solution may also be computed. This is signaled as PRIMARY, and these solutions are only used for exporting and do not affect processing. In summary, each static session has one BEST solution for each direction,

which is used to fix the kinematic trajectory. Each session will then have one PRIMARY solution used for exporting. In some cases, the BEST and PRIMARY will be the same.

If the BEST fixed solution used is deemed in incorrect from the forward/reverse separation or other means, then it can be disabled from the fixed solution. To do this, first note the start/end times of the static session by selecting Edit from the Object Menu. From the General Processing Settings, select 'Omit …'. After pressing 'Add', disable all satellites from the erroneous baseline for the noted time period. Select be sure to KAR/Fixed static radio button.

10.2.10 How can I speed up processing?

MB-KF processing can be much slower due to the increased numbers of states and observations. For example, 12 satellites on 4 bases will result in 50 states and 132 observations on every epoch! Therefore, here are some tips to cut down processing time (other than buying a faster computer):

a) Disable any bases that are far outside of the project area, as they will add very little to final accuracies, and they may even hinder them.

b) Consider disabling the Doppler measurement from processing. This is performed from the Advanced 1 Processing Settings. Under the Velocity/Doppler Group, uncheck Doppler from phase processing. If accurate velocity is needed, enable it again in the final stage.

c) Reduce the data interval for preliminary analysis to something like 2 seconds. One of the problems is that the 1, 2 (or more) Hz data can result in different effects and problems. This can be helped by forcing KAR to use the same data, which is accomplished by entering an interval value common to 2 s and your final data rate (e.g. 4 s) in the KAR 2 settings. The value is entered in the 'Search on data interval' edit box. Be sure also to check 'Only search on exact interval'. This will help to make 2 second and high data rate data produce similar results, but it is best not to continue on this low data rate too long.

d) Utilize only the closest base for fixed solution. Consider lowering the maximum distance (for using fixed static) in Advance 2 processing settings.

Section 3   FAQ

This section contains general information and instructions on how to perform some of the tasks that was not covered in previous sections.

10.3.1 Determine the Quality of Final Solution

The best method to check the quality of the final solution would be to analyze the plots.

This can found under the 'Output' menu or press F7 or click . The following are some of plots that might be useful:

1. **Combined Separation Plot**
   This should be the one of the first plot to look at. It shows the difference between the forward and reverse solution. An ideal solution should have *separation* of zero as this indicates that the carrier phase ambiguities have been determined to be exactly the same value in both directions. This plot gives the user an idea of what kind of accuracy they are getting. Looking at Figure 10.2, the accuracy seems to be approximately 5 cm. For a combined baseline in GrafNav Batch, this plot will always be positive as it shows maximum minus minimum value, and the user may wish to also view the 'Combined RMS' plot.
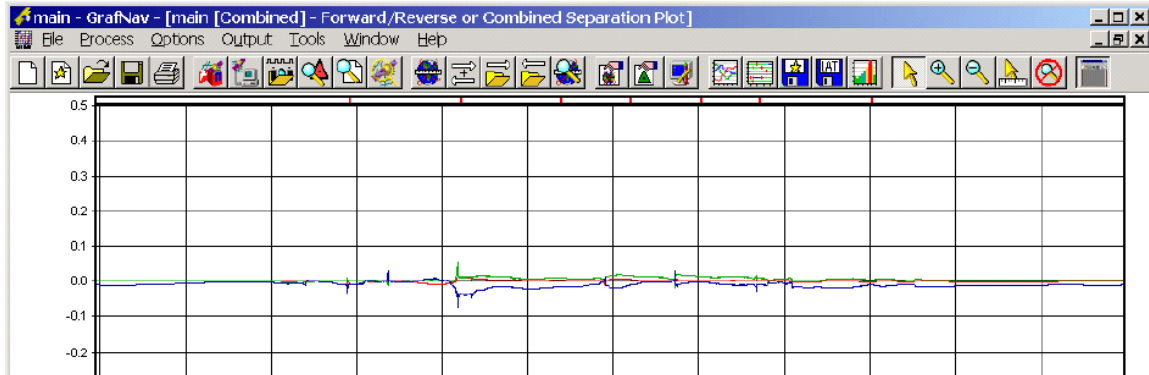
Figure 10.2 Combined Separation Plot

2. **Float or Fixed Ambiguity Status Plot**
   This plot shows if the solution is float or fixed. Fixed integer ambiguities generally have better accuracies (usually < 20 cm accuracy). Ideally, the plot should show *fixed* (green) as this indicates a fix in both directions. Furthermore, the separation plot shown in Figure 10.2 is the most meaningful. A fix in just one direction (cyan) is generally okay too, but it cannot be verified via the combined separation plot as well. Sometimes, a trajectory will lose its fixed status because the DD_DOP became too poor (see FF_DOP_TOL). In such a case, the separation may not be as badly affected as a loss of lock.
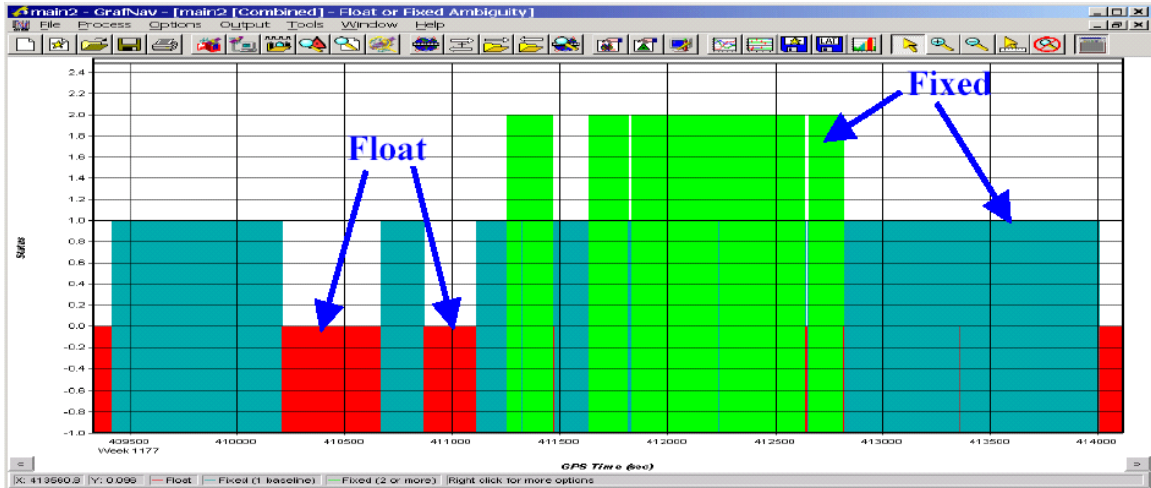
Figure 10.3 Float or Fixed Ambiguity Status Plot

3. **Quality Factor Plot**
    This plot shows the quality of the solution. There are five different quality factors:
    - Quality 1 – Fixed Integer (Green)
    - Quality 2 – Stable Float (Aqua)
    - Quality 3/4 – Converging Float (Blue)
    - Quality 5/6 – DGPS or worse or single point (Red)

    Increasing quality factors indicate a worse solution. This is not a perfect indication, but it can be useful to isolate problem areas. See Section 2.9.1 for a description of Quality Factor.
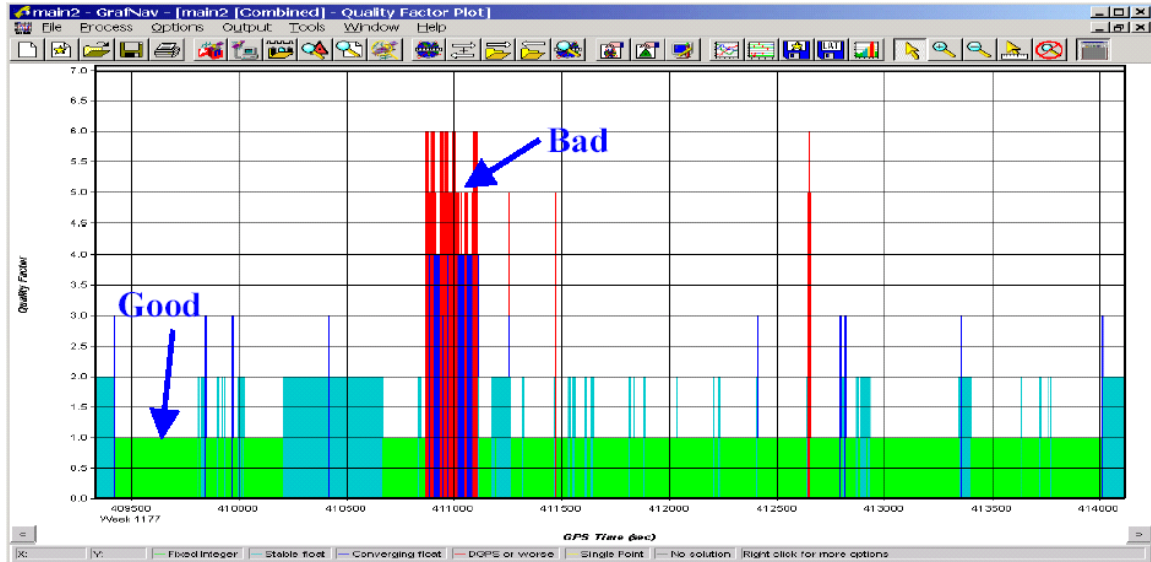
Figure 10.4 Quality Factor Plot

10.3.2   Antenna Profiles

For correction antenna errors, data made available by the NGS is used. Unfortunately, they generally do not use the same measuring point than marked on the equipment. They normally use the base of the antenna. For this reason, users are best to create their own profile if they have knowledge about the antenna characteristics (see below).

Figure 10.5 Antenna Profile

This software assumes that one of three measurements is made:
a) Vertically directly to L1 phase center (select 'Measurement directly to L1 phase centre' or use simple antenna model)
b) Vertically to measurement point (or origin).
c) Slant measurement to some point offset perpendicular to measurement point.
d) Vertical measures to L1 phase center but antenna profile to base. In this case, a new profile can be created or select 'Measurement directly to L1 phase centre').

For b and c the L1 and L2 offsets are use to compensating antenna height for separation between measurement point and phase center. For c, the antenna radius is further used to correct the slant measurement via Pythagoras.

To create your own antenna profile you must have knowledge of three parameters:
a) Vertical offset from measuring point to L1 phase center
b) Vertical offset from measuring point to L2 phase center (see existing antenna profile for difference between L1 and L2 offsets)
c) Horizontal radius of antenna from measuring point (used only for slant measurements).
d) Elevation based antenna errors (optional)

Once you have these values, press the 'Define' button next to the Antenna profile name under 'Use advanced method'. Then select 'Add Empty', give the antenna a meaningful name and enter values for (a), (b) and (c) described above (note that order is different!).

In addition, an antenna height model can be created using correction values from that of another. Select the model to copy from and press 'Add From'. The vertical distance values may need to be modified. Be sure that the relationship between the L1 and L2 vertical offset is unchanged.

To further answer your question, each antenna profile has its own origin and you may specify it wherever you would like. If you have multiple origins for one antenna, then you will need to create profile for each origin definition.

10.3.3 Copy User Files

User files such as Export Wizard profiles, favorite points, and antenna, datum and grid definitions can be copied or backup. There are two ways to do this:
1. Running Copy User Files program.
2. Manually copy the files.

The following are the list of files that are copied by the Copy User Files program or if the user chooses to manually copy. Note that not all the files will be available.
- User.prf – Export Wizard profiles
- User.fvt – Favorite points (from Favorites Manager)
- User.dtm – Datum definitions
- User.grd – Grid definitions
- Local.fav – Local Coordinate Favorites
- Missplan.mpf – Cities defined in Mission planner
- User.dn1 – Download user file
- User.adf (**) – Antenna definitions (new format)
- *.Defopt (**) – User defined project/option settings
(**) These files are only available on v7.50.

1. **Running Copy User Files Program**
    Copy User Files program will automatically run at the end of the installation. You may also run the program yourself from the Windows Start button | Waypoint GPS | Utilities. The program will let you set the path of the source directory. The destination will automatically set for you. If you would like to set your own destination, then go to method 2. Manually copy the files.
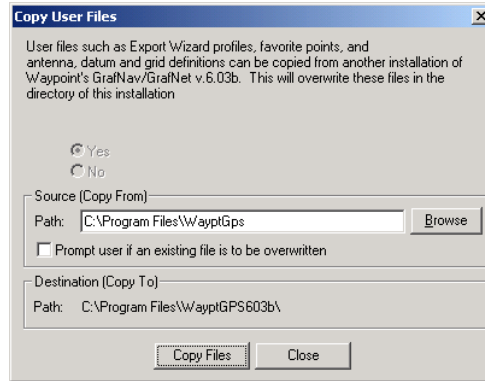
Figure 10.6 Copy User Files

2. **Manually Copy the Files**
   To manually copy or backup the files, just simply copy the list of files above to your destination.

10.3.4 Updating Manufacturer Files

The preloaded datums, station coordinates (favorites), download stations, grid definitions and IMU definitions may change from time to time. Waypoint periodically updates these values on its FTP site*. The user can download these via the About Box in GrafNav, GrafNet, GrafNav Batch, Download or Convert. Select *Help | About*. Then select 'Download latest manufacturer files' at the bottom. Be sure to restart program so that changes will take effect.

*Note that new manufacturer files may not be updated for older versions outside of support period. This feature is only supported by version 7.01 and later.

10.3.5 Shifting Coordinates to Local Plane (XYZ Translation)

Our objective is to shift the coordinate (Northing, Easting) that is relative to the Master (Green) station to coordinate relative to the Known Point (pink).
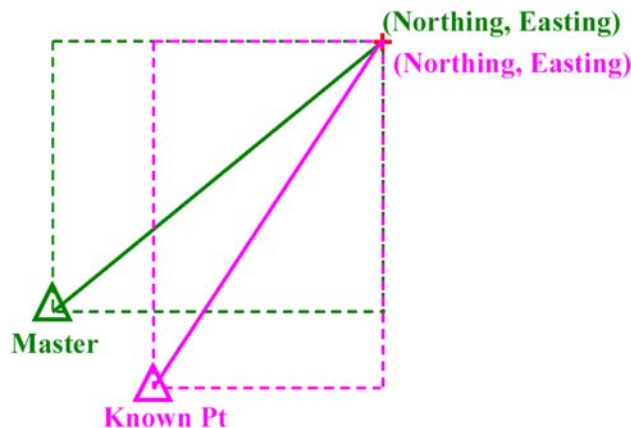
Figure 10.7 Master to Known Point

Step 1: Create and Define Transformation
1) First we need to define the transformation. This can be done under the 'Tools' menu, select 'Grid/Map Projection' and then 'Define', refer to Figure 10.8.
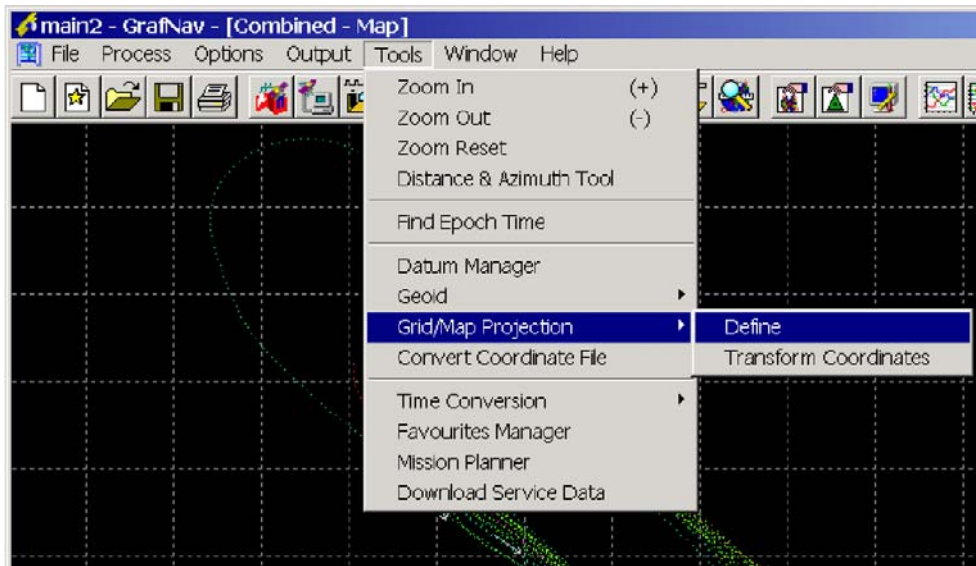
Figure 10.8 Tools Menu

2) You will come to the following screen, click 'New':
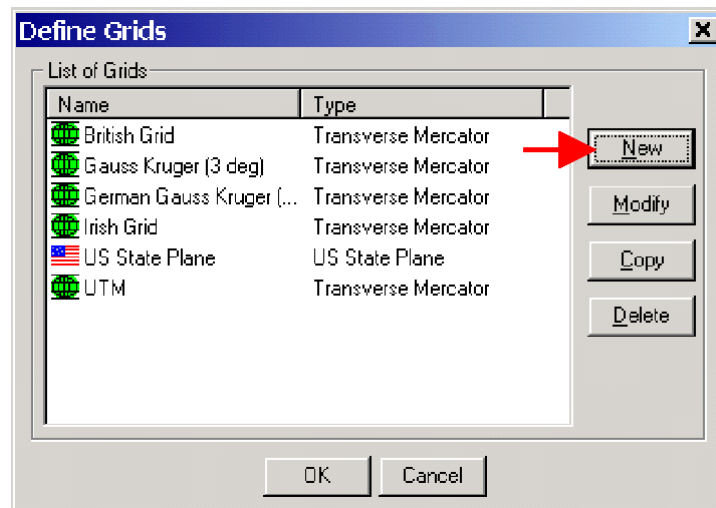
Figure 10.9 Define Grids

3) You will be asked to provide a name; in our case we will call it "TM_Custom". Select 'Local Cartesian (ECEF rotated to local level)' then click 'Next'.
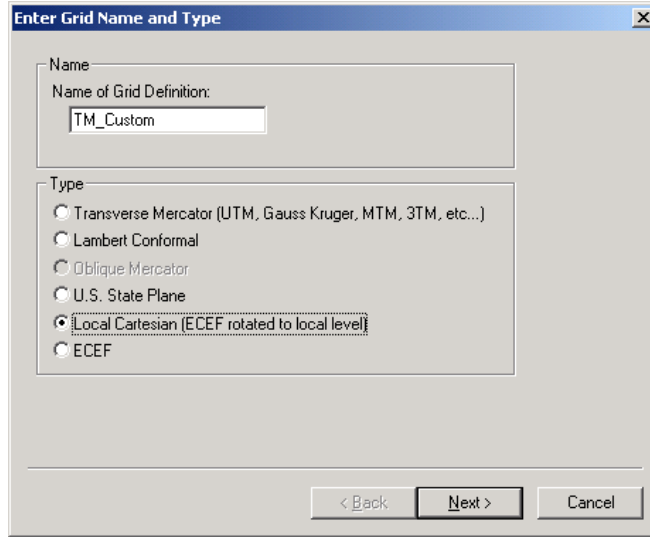
Figure 10.10 Enter Grid Name and Type

4) You will then come to the 'Transverse Cartesian Settings' dialogue box (Figure 10.11).
   a. Enter Latitude of the known point
   b. Enter Longitude of the known point
   c. Enter the Ellipsoidal Height of the known point
   Click Finish.
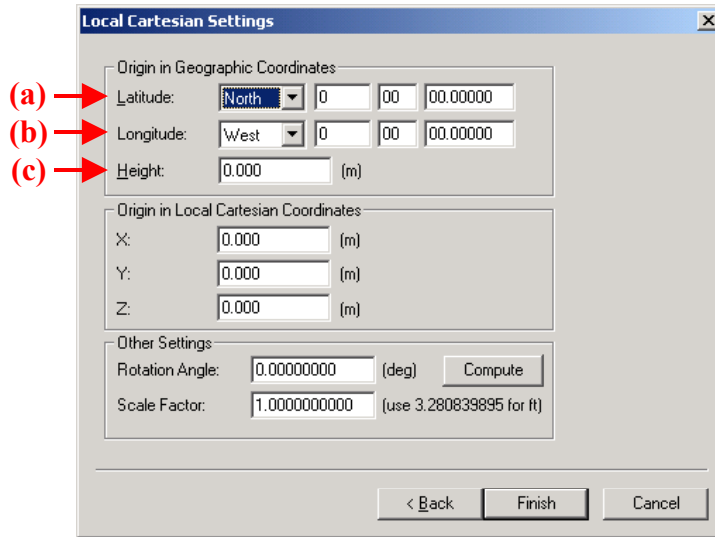
Figure 10.11 Local Cartesian Settings

Step 2: Export Wizard/Output
You may output the shifted coordinates (easting, northing) using 'Export Wizard'. The coordinates can be found under the variables are named 'Selectable Grid-East' and 'Selectable Grid-North'.
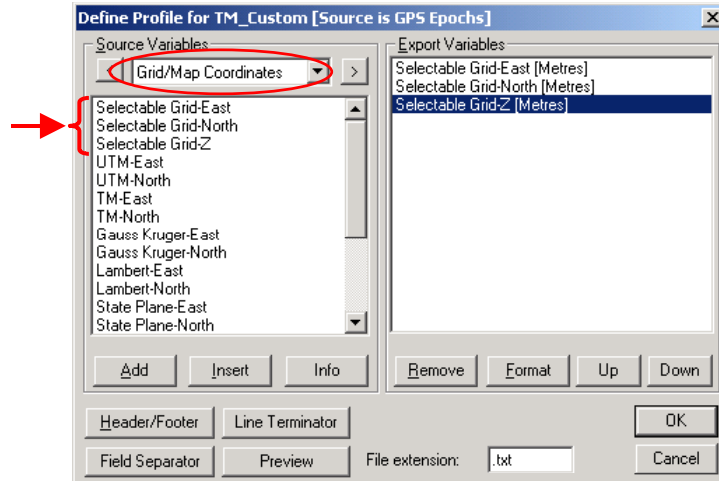
Figure 10.12 Export Wizard

When you reach the 'Select Grid System and Settings', make sure you select the transformation grid that you created in Step 1.
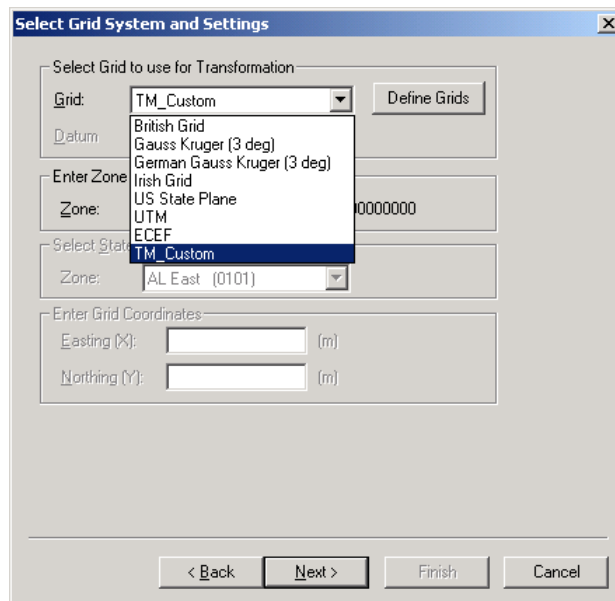
Figure 10.13 Select Grid System and Settings

10.3.6   Epoch Sampling

A. Interpolate to higher sampling rate

GrafNav has an option that enables the user to output data at higher sampling rate. An example of this would be if the user would like to output data between the times 12:00:01 and 12:00:02 that is 1 Hz (1 second interval). This can be done with the 'Export Wizard'. It can be found under the Output menu.
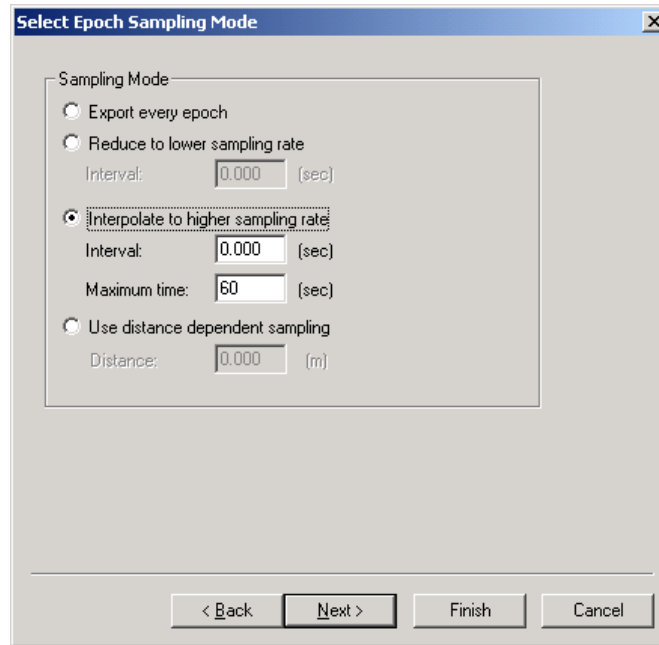
Figure 10.14 Select Epoch Sampling Mode

Figure 10.14 shows the window that will be seen near the last step in the 'Export Wizard'. If the user would like two data point between two epochs that is 1 Hz (1 second interval), they would enter 0.33333 sec in the Interval box under the 'Interpolate to higher sampling rate'.

B. Reduce to lower sampling rate
To reduce the sampling rate, repeat the same steps as *Interpolate to higher sampling rate* except select 'Reduce to lower sampling rate'. For example if the user would like to output data that is 1 second interval, but needs only data every 10 second, they would enter 10 second in the Interval box under 'Reduce to lower sampling rate'.

C. Use distance dependent sampling
'Use distance dependent sampling' is an option under the 'Export Wizard' that enables the user to output data that is distance interval rather than time interval. For example if the user would like to output data that is every 10 m, they would simply just enter 10 m in the Distance box under 'Use distance dependent sampling'.

10.3.7   Processing Aerial Survey with Camera Event Marks

Camera Event Marks
After adding the master and the remote, you'll have to load the Camera Event Marks for some GPS files. For others, they will load automatically. To load event marks manually, select *File | Load | Camera Event Marks*. See Section 2.2.10 for details.

Settings
Select *Settings | Load Settings From | Airborne* to utilize a parameter set well suited for airborne data. In addition, if you interpolated your data, make sure the option 'Exact

interval (for interpolated data)' is checked, and enter the original interval (under KAR 2 Processing Options). See section 2.5.4 on page 83.

Process
You may now start processing. Look at the Combined Separation plot (under the Output menu, Plot GPS Data). Preferably we want the plot to be around zero.

Output (Export Wizard)
When processing is done the next step is to output the solution. This can be done using the Export Wizard (under the Output Menu).

Select the option Features/Stations and the profile that you prefer. You will then be asked to enter the Camera-Antenna offset. GrafNav define xyz as forward, left-wing, and up respectively. This can be seen in the following figure:
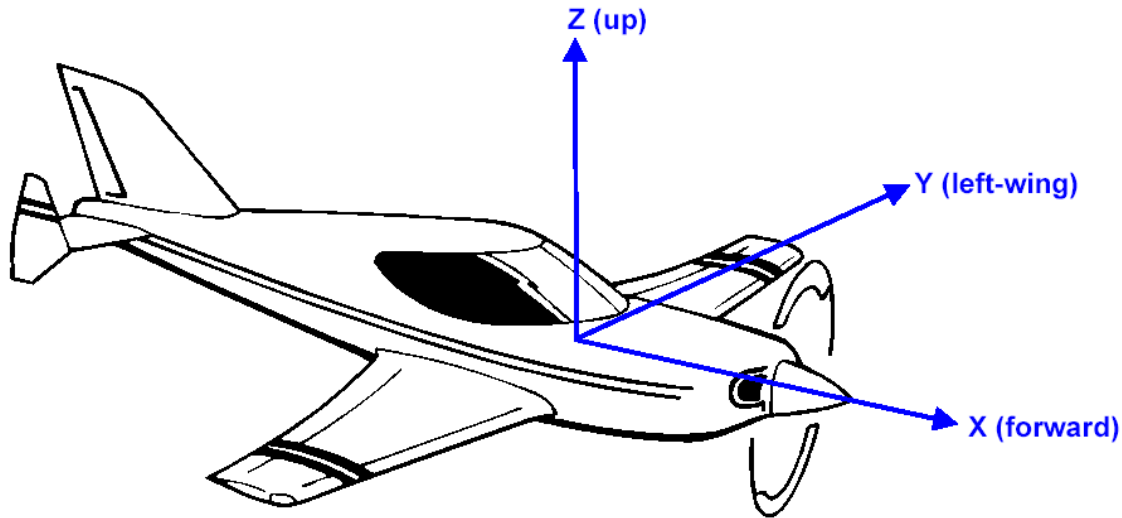
Figure 10.15 Forward, Left-wing, Up

Section 4   Digital Elevation Models

This section goes over the implementation of DEMs into GrafNav and how to obtain some over the Internet for the United States. DEMs are optional when processing GPS data.

10.4.1   What are Digital Elevation Models?

A Digital Elevation Model (DEM) is a representation of the height of the ground. There are two ways they can be stored:

i)   Regular grid with constant density (i.e. spacing). The DEM is stored as an array to minimize memory usage. Access is very fast, but flat areas require an unnecessarily high number of points.

ii)   Irregular point distribution where density generally increases with increased relief. This type is represented by a Triangulated Irregular Network (TIN).

GrafNav uses type (ii). It can theoretically handle both types of DEMs (although type (i) will be handled much less efficiently).

10.4.2   Why should I use a DEM?

There are two main reasons for using GrafNav's DEM capabilities:

a)   The vehicle is traveling over a surface (e.g. road, runway, etc…) and the ground height is to be used for quality control purposes. GrafNav has two plotting tools that help. The 'Height Profile Plot' shows the height of the ground as well as remote station height. If the GPS antenna is a constant vertical offset above the ground, it should be entered as the remote antenna height. The 'Height Above Ground' plot shows the difference between kinematic GPS and ground heights. The ground surface height (at each GPS position) can be exported as well. DEM precision and accuracy is very important here.

b)   In aerial photogrammetry, mapping is often performed on the map projection. This leads to an incompatible scale used for horizontal and vertical axes. The vertical scale factor (VSF) correction compensates for this, but usually only accepts a constant ground height. A more accurate compensation can be employed by using the height of the DEM under each image frame. In high relief areas, the DEM can improve this correction significantly. The amount of improvement depends on the size *and variation* of the scale factor in the project area and variation of the ground height. DEM accuracy is not as important as a 25 m DEM error will result in a very small final error in VSF height for UTM and an insignificant error for most state plane zones.

10.4.3   How can DEMs be obtained?

There are many sources, but for VSF correction purposes, 1:250,000 (1-degree) DEMs are sufficient. In the US, these can be obtained free of charge from the internet (See http://edc.usgs.gov/products/elevation/dem.html and then http://edc.usgs.gov/geodata/).

For the US, you will need to determine the following:
i)   Go to http://edc.usgs.gov/geodata/ and click on the 1:250K button at the top. Select 'FTP via Graphics'.
ii)   Determine map sheet(s) that cover your area. You may need to enter latitude / longitude values into MapQuest (or a similar mapping program/site) if you do not have any information about the state and county of the GPS observations.
iii)   Download these map sheets from USGS ftp site. For each file, use the utility DEM2XYZN (which can be downloaded from http://data.geocomm.com/dem/dem2xyzn/) to convert these files to a listing of geographic points. The output will be Longitude, Latitude, Height where Lat/Lon are in arc-seconds while height is expressed in metres.

iv) Concatenate files of desired size together (e.g. from the command prompt type copy file1.pts +file2.pts +file3.pts filecombine.pts

v) Follow the steps in section 6 for importing the DEM

10.4.4 How is the geoid handled and what formats are supported?

DEMs (after loading) are expressed in ellipsoidal height. Therefore, if the DEM is mean-sea-level (which is usually the case), the geoid undulation must be subtracted from the elevation values. This is performed automatically during the import process but it requires that a geoid be available (see Section 10.4.4).

GrafNav only supports DEMs stored in ASCII where the each elevation point is a separate record in the file. The full position must be made available for each point. This means that many gridded files must be expanded before importing. The following formats are supported:

i)	[ID]	Grid-East(m)	Grid-North(m)	Height(m)
ii)	[ID]	Grid-North(m)	Grid-East(m)	Height(m)
iii)	[ID]	Grid-East(usft)	Grid-North(usft)	Height(usft)
iv)	[ID]	Grid-North(usft)	Grid-East(usft)	Height(usft)
v)	[ID]	Lat(deg min sec)	Lon(deg min sec)	Height(m)
vi)	[ID]	Lat(deg min)	Lon(deg min)	Height(m)
vii)	[ID]	Lat(decimal-deg)	Lon(decimal-deg)	Height(m)
viii)	[ID]	Lon(arc-sec)	Lat(arc-sec)	Height(m)
ix)	Specialized formats…			

The [ID] term is an optional identifier that may be present. It is not necessary. **Format (viii) is created by the DEM2XYZN utility.**

10.4.5 Importing DEMs

Importing a new DEM should be performed after processing the desired area of interest. For instance, if the airport is some distance away, it may be preferable to limit the scope of processing to just the mapping area by setting start/end processing times. The purpose of doing this is to limit the scope of the DEM to just the observation area, which saves memory and improves speed.

To import the DEM, select from the main menu **File | Load | Digital Elevation Model | Import DEM Points**.

The following dialogue box will appear in Figure 10.16:
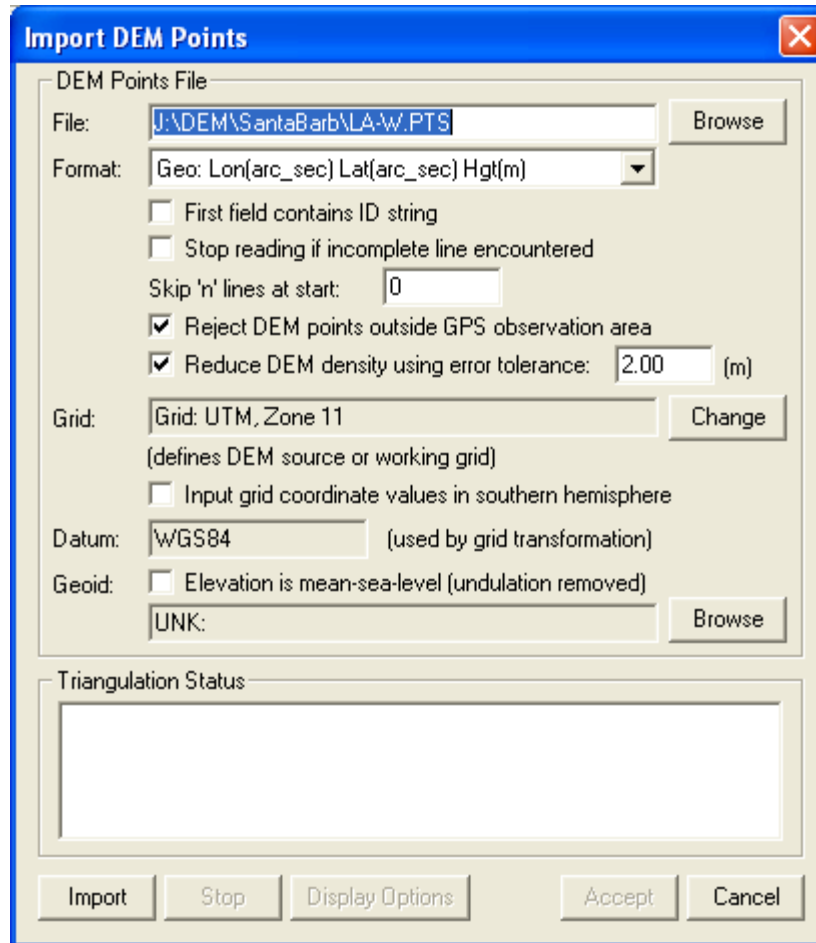
Figure 10.16 Importing DEMs

File   Enter the file name of your DEM points

Format   Enter if suitable format. If none exits, then you will need to convert your DEM to one of these formats.

Select the following:

i)   'First field contains ID string' if an point name leads each line

ii)   'Stop reading if incomplete line encountered' if multiple data types are in the file and you wish to only extract the first type

iii)   'Skip N lines at start' to skip past any header lines in the file

iv)   **'Reject points outside DEM area'** to limit the size of the DEM to just the GPS observation area. **This is highly suggested.** It requires that valid GPS position data be available either from the GPS receiver or via processing.

v)   Select **'Reduce DEM density using error tolerance'** if you have either a gridded DEM or a large high density DEM that will give GrafNav memory or speed troubles. Points will be rejected if their height is estimated from nearby ones with the error tolerance defined. Tolerances of 5-10 m are acceptable for VSF purposes. Larger error tolerances will reduce densities.

Grid   If the DEM horizontal coordinates are in a map projection such as UTM or state plane, then GrafNav needs to know the details of this exact projection. If the DEM is stored in geographic, then a working map projection (grid system) is required. Any system will do, but UTM is normally the easiest.

Datum   This is the processing datum and should match the datum that the DEM values are stored in. Only the ellipsoid component of the datum is used, so NAD83 and WGS84 can be used in place of each other for most applications that do not require the utmost DEM accuracy.

Geoid   Generally, a geoid model should be selected, as DEMs are generally always stored in mean-sea-level. This requires a waypoint WPG file, NRCAN or NGS geoid. NGS geoids are also available in WPG on the distribution CD.

Next, press the Import button. Forming the TIN model can take some time, so be patient. Finally, once the geoid is formed, press Accept and a .tri file will be saved. In addition, the DEM will be displayed in GrafNav. If no contour lines are visible, then the DEM might be out of the area.

After a DEM has been imported, the TIN model does not need to be re-formed. Just load the .tri file as follows: **File | Load | Digital Elevation Model | Load Triangulation (.tri)**. This is a much faster operation than importing.

10.4.6 Handling Large DEMs

Digital elevation models can become very large. GrafNav's ability to handle them is very functional but is not designed for extremely dense data sets. DEM's greater than half a million points will become very slow within the software. They also will require a significant amount of memory. A half million point DEM will utilize an additional 157 MB in GrafNav (not including contours). This requires a fast computer with at least 512 MB of memory. For VSF applications, DEM accuracy is not paramount, so DEM thinning is highly suggested (which can be performed right within the import DEM step).

Some helpful hints to speed up GrafNav with large DEMs:
a)   Select the 'Reduce DEM density using error tolerance' checkbox during the Import DEM procedure. This will cause the TIN formation to take longer, but GrafNav will operate much quicker afterwards. This is especially important for regular grids.
b)   Before importing, create a GPS trajectory composed of just the project area. Use the start/end processing times to achieve this. Ensure that the checkbox labeled 'Reject points outside DEM area' is selected.
c)   Disable contouring from the Options > DEM Plotting/Display Options or select a very coarse contour interval (see Section 2.5.3 for plotting options.)
d)   Disable ground height plotting on height profile plot in Options > DEM Plotting/Display Options.

In GrafNav Batch, care should be taken to only load the DEM into one baseline, as an instance will be created for each baseline.

Section 5   Datums, Projections and Geoids

This section outlines how processing with GrafNav and GrafNet can be optimized with the various datums, projections and geoids available. To start out, some definitions are in order. For the novice user, this text can be read disregarding the formulae.

10.5.1   Introduction and Definitions

A datum defines where the absolute coordinate values are referenced. For instance, WGS84, NAD83 and ED50 are datums. A datum is composed of an ellipsoid and a reference frame. The ellipsoid is a geometrical approximation of the earth's sea level surface, and it is needed to compute geographic or map projection coordinates. A semi-major axis (a) and a semi-minor axis (b) define the size of the ellipsoid. A flattening value (f) may also be used in conjunction with the (a) parameter for this definition as well. The relationship between f, a and b is given by

$$f = (a - b)/a. \tag{2}$$

The reference frame defines the location and orientation of the geocentric coordinate axes (i.e. the origin). The absolute location of the reference frame for a given datum is not accurately known. However, differences between datum reference frames are often known precisely. These "datum conversions" can be represented as follows:
  * 3-parameter (Molodensky) - This includes shifts in the ECEF X, Y and Z axes.
  * 7-parameter (similarity) - Includes 3 shifts, 3 rotations and one scale.
  * 10-parameter (7-parameter + temporal rotational velocities) - Includes 3 shifts, 3 rotations and one scale + rotational rates (referenced to a certain year). This is useful for datums that move with respect to each other.
  * Horizontal grid based method (e.g. NADCON) - This methodology does not try to use an analytical formula. Rather, it uses a grid of localized corrections to latitude and longitude to transform one horizontal datum to another. Normally, does not include corrections to the ellipsoidal height.

A map projection is the representation of the earth's spherical surface on a flat surface. Map projections are also sometimes referred to as grids. UTM is one of the most common map projections. GrafNav and GrafNet currently support two types of map projections:

  * Transverse Mercator - This employs a cylinder placed horizontally around the earth. Transverse Mercator (TM) has little distortion in the north-south direction, but the scale factor deviation from unity grows along with the convergence with distance from the central meridian. UTM starts a new zone every 6 degrees to circumvent this.
  * Lambert Conformal - This utilizes a cone placed over the north (or south) poles. Distortion is minimal in the east west direction, while the limitations are in the north south direction.

US State Plane uses either the Transverse Mercator or the Lambert Conformal. The one exception is the Alaska Pan Handle, which uses Oblique Mercator (which is currently not supported).

The geoid is the level of the sea surface (equipotential surface under landmasses). For instance, a spirit level (surveyor's level) would follow the geoid, and because of this, vertical datums are based upon the geoid. Maps are also based on the geoid, as this prevents any contour lines from forming on level surfaces such as lakes. GPS can only make measurements on the ellipsoid (ellipsoidal height), and GPS elevations must be corrected to reference the Geoid. The height above the geoid is known as an orthometric or mean-sea-level height. The difference between the geoid and the ellipsoid is the geoid height or undulation value, and it changes across the earth by 100 m. Luckily, many government agencies put out geoid undulation grid files (i.e. Geoid99 in US) that can be used to convert ellipsoidal to orthometric heights. The relationship between the orthometric, ellipsoidal, and geoid height is given by

$$h = H + U \tag{3}$$

where h is the ellipsoidal height, H is the orthometric height, and U is the undulation (geoid height).

10.5.2   Datums

See introduction from Section 10.5.1 Introduction and Definitions.

10.5.2.1   What capabilities are available?

The following capabilities are available:
- Built-in support for most of the world's datums using the NIMA (DMA) shift values.
- Users may select between multiple conversions between the same datum.
- Better support for 7 parameter transformations.
- Support for 10 parameter transformations (7-param. + rotational velocity). This is useful for datums that are shifting with respect to each other due to tectonic movement.
- Support for the NADCON grid transformation (e.g. NAD27-NAD83 conversion)
- Ability to combine two conversions (e.g. ITRF97->NAD83 = ITRF97->WGS84 + WGS84->NAD83)
- Much improved ability for users to add their own transformations. For instance, users can now add their own 7-parameter transformations.
- Coordinate transformation tool.
- Datum conversion computation tool (3- and 7-parameter conversion).

10.5.2.2   How does GrafNav/GrafNet handle datums other than WGS84?

WGS84 is the datum that GPS satellite orbits are referenced to. GLONASS is in PZ-90, but GrafNav/GrafNet takes care of the difference. WGS84 has undergone a number of

changes over the last 10 years, and it is now referenced to ITRF96…ITRF2004. ITRF## are global datums, which means that they are moving with respect to most of the world's datums due to plate tectonics. Such movements can be as large as several centimeters per year. For these reasons, WGS84 is not a suitable datum for publishing coordinates in.

GrafNav/GrafNet supports two methods for handling other datums:
Transform satellite coordinates into local datum - This is a very seamless methodology for supporting local datums. It requires only that the datum transformation be applied once, which minimizes the danger of mixing up conversions. Users need only to select the correct datum during processing and enter the base station coordinates in the local datum. For this reason, this method is highly suggested.

Process in WGS84 - Input coordinates are transformed into WGS84, which is the same datum that processing is performed in. This methodology allows users to use very localized or grid based datum conversions. It is not possible (or not suggested) to transform the very distant satellite coordinates (like method (a) does) using such localized conversions. Normally, final coordinates are also desired in the "input datum". Therefore, care must be taken to convert the coordinates from WGS84 to the local datum using the same transformation.

10.5.2.3 How do I make my datum visible in the list?

GrafNav/GrafNet has over 100 built-in datums. Most of the transformations from these datums to WGS84 are from the NIMA document: http://164.214.2.59/GandG/pubs.html (see also http://www.nima.mil). For simplicity, only a few of these datums are initially displayed in the processing options and other datum selection tools. Therefore, users may wish to enable the datums that are going to be used frequently and disable the rest. This is performed from the 'Datum Manager', which can be selected from the 'Tools Menu'. From the 'Datums' tab, the entire list of datums is displayed. By 'double clicking' on datums, the enable/disable status will be toggled.

10.5.2.4 How do I enter my own 7-parameter transformation?

When using 7-parameter transformations, be careful of the rotation angles, as there is no standard definition for the sign. The sign convention used by GrafNav/GrafNet is as follows:

$$
\begin{pmatrix} X \\ Y \\ Z \end{pmatrix}_{To} = (1+scale) \begin{pmatrix} 1 & -\theta_z & \theta_y \\ \theta_z & 1 & -\theta_x \\ -\theta_y & \theta_x & 1 \end{pmatrix} \begin{pmatrix} X \\ Y \\ Z \end{pmatrix}_{From} + \begin{pmatrix} \Delta X \\ \Delta Y \\ \Delta Z \end{pmatrix} \tag{4}
$$

Recent analysis shows the opposite sign tends to be more frequent. If your transformation uses the opposite sign (i.e. θ_x, θ_y, θ_z have the opposite sign in front of them) then check the 'Use reverse sign for rotations' box. The best way to determine which sign should be used is to inquire with the agency producing the transformation. Matching the overall transformation to an existing datum conversion can also be a method (see step 13). However, extreme caution should used here.

To ensure that datums to be converted between are available, use the following steps:
1. From the 'Tools Menu', select 'Datum Manager'. Select the 'Datums' tab.
2. Make sure that your FROM and TO datums exist. In addition, both datums should be enabled (i.e. box is checked). Double click on a datum to enable/disable it.
3. Step 3: If a datum is not enabled, select the 'Add' button. Enter the datum's name and select the ellipsoid used from the list. Check the 'Enable' box.

To add a datum conversion, do the following:
4. Select the 'Datum Conversions' tab so that you can enter the transformation between two datums.
5. Step 5: In the box labeled 'Show conversions between these datums', select the FROM and TO datums for the conversion. Normally but not necessarily, one of the two datums will be WGS84. It does not matter which one is WGS84. It is best to match the datums to the conversion values. For example, if you have conversion parameters for ED50->WGS84, FROM should be ED50 and TO should be WGS84.
6. Step 6: Press the 'Add' button, the following screen will appear. If the Add button is grayed, then the FROM and TO datums have not been selected properly.
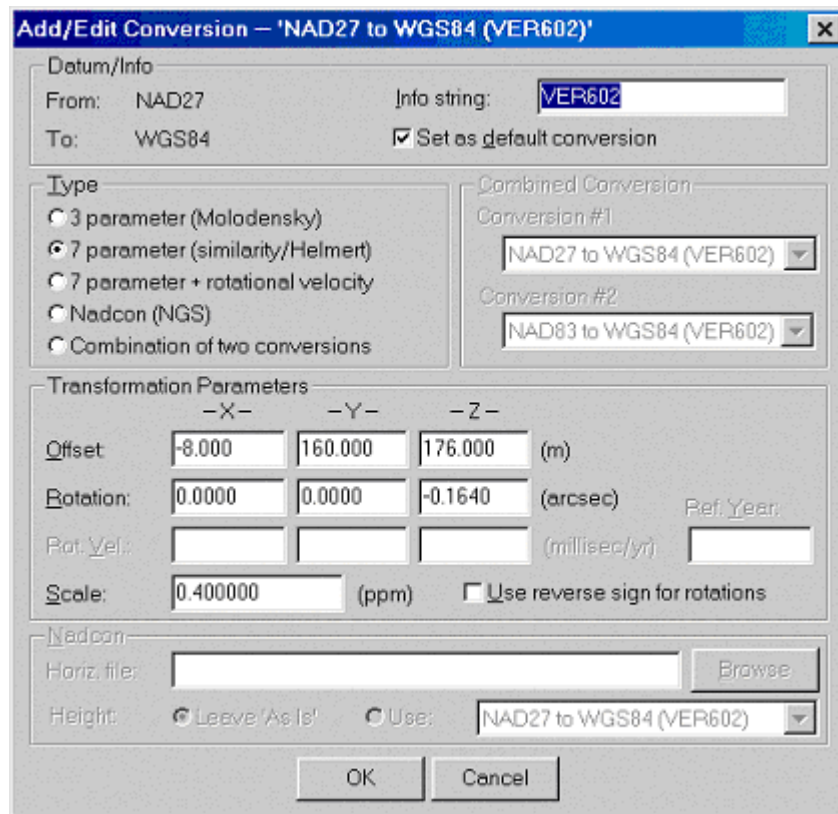
Figure 10.17 Add/Edit Conversion – NAD27 to WGS84

7. In the 'Info string' field, type a meaningful reference name. Only alphanumeric characters are allowed (i.e. a-z, A-Z and 0-9). Dashes '-' and underscores '_' are also allowed. You may also wish to check the 'Set as default transformation' box to ensure that this transformation is used for transforming between these two datums.

8. In the Type box, select the '7 parameter (similarity/Helmert)' radio button.
9. Enter the shift values in meters.
10. Enter rotations in arc-seconds and not milli-arc-seconds (mas) as they are sometimes expressed in. If the opposite sign formula is used (see above), check the 'Use reverse sign for rotations' box. Watch out that the proper sign definition is used.
11. Enter scale in parts-per-million (i.e. ppm_value x 10-6).
12. Check your transformation using the 'Coordinate Transformation' tool. At this stage, you can also compare the overall transformation to that of another datum conversion.
13. Press OK

10.5.2.5   How can I use NADCON conversion files?

NADCON are the datum conversion files produced by the National Geodetic Survey (NGS) in the United States. This conversion is expressed as a grid of corrections to latitude and longitude. For the most part, this correction is used for NAD27-NAD83. However, some other countries have also adopted this format. In addition, the NGS has corrections between NAD83 and NAD83(HARNS). The NGS files can be obtained from http://www.ngs.noaa.gov/TOOLS/Nadcon/Nadcon.html. The latitude correction is located in the .LAS file, while the .LOS file contains the longitude correction.

To add a NADCON datum conversion, use the same procedure (steps 1-7) as defined previously. After that:
1. In the Type box, select the 'Nadcon (NGS)' radio button.
2. Select the .LAS file for the region that you wish to use. The .LOS file need not be defined as it is loaded automatically.
3. Choose how the height is to be treated.
4. 'Leave As Is' means that there will be no transformation to height. Care must be taken when importing/exporting coordinates. In the export wizard, choose the option 'Do not convert elevation (leave in processing datum)' on the Datum page. In addition, Make sure that you combine the datum transformation with a geoid height correction since only the orthometric height may be valid in this datum.
5. Using another 3 or 7 parameter transformation for height can be a safer alternative, but it can be more difficult to incorporate a geoid model as there may not be one for NAD27 (for example).
6. Check your transformation using the 'Coordinate Transformation' tool.
7. In the datum options, make sure that you use the option 'Convert input coordinates to processing datum (for Nadcon and localized datums)'. This means that the button labeled 'More Datum Options …' must be selected from the General Options, or the Datum Options must be referenced directly. In addition, make sure that WGS84 or NAD83 is selected as the processing datum.
8. Press OK

10.5.2.6   How can I prevent datum conversion errors from corrupting my final coordinates?

In many cases, datum transformations can have errors of several meters or more. Users should be cautious about using any transformation in an absolute sense. Transformations should only be used for relative corrections. Care should also be taken that the same correction be used throughout. Here are several tips on minimizing these effects:

- Process in your local datum (e.g. NAD83, ED50, etc…) as much as possible. This methodology effectively uses a relative datum correction and minimizes the possibility of using multiple datum conversions. Processing in your local datum is performed by selecting the processing datum from the list of datums in the General Options in GrafNav. Selecting the Datum tab from the processing options in GrafNet or using the Datum Options from GrafNav, GrafNav Batch or GrafNet will bring up the Datum Options dialogue box. Select the processing datum from this screen.. In addition, make sure that the radio button labeled 'Use processing datum by setting processing datum to local datum' is selected from the 'Input Coordinate Datum' box.
- For localized datums (i.e. datums with large rotations, scale or shifts) or for NADCON corrections, processing should use a more global datum (e.g. WGS84 or NAD83). It is very important that the same conversion be used in the coordinate input and for the Export Wizard. This means checking the conversion used. In addition, avoid using the Write Coordinates feature to export coordinates, as it does not support input datums different from the processing datum.
- If using a newer version of GrafNav or GrafNet, or if examining an old project, be sure that the default conversion has not changed.
- If you use an external program to transform coordinates to the processing datum (e.g. WGS84), then use the same program to convert your final coordinates back to the local datum.
- Be cautious with geoids. Geoids designed for one datum may not be compatible with another.

10.5.2.7   How do I compute my own datum transformation?

Some users may wish to determine their own 3 or 7-parameter transformation/conversion. In such a case, a list of points with geographic coordinates in both datums must be available. The height values must be present and are ellipsoidal.

GrafNav has the ability to solve for a 3-parameter and a 7-parameter transformation. The 7-parameter can also have the scale constrained to unity, which effectively results in a 6-parameter transformation with 3 translations and 3 rotations. 7-parameter transformations should only be used for larger areas (i.e. >300 km across). This is because solving such transformations over small areas can make the solved parameters very sensitive to coordinate errors. In some cases, 7-parameter transformations are necessary due to a slope in the local datum. This is considered a 'very localized datum'. See the previous section for information on dealing with such datums.

To solve for a transformation or *datum conversion,* use the following steps:

1. Isolate the ToDatum and the FromDatum to be used. Normally, one of the two will be WGS84, while ITRF is also common. However, this feature could be used to convert between any two datums. It does not matter which datum is 'from' and which is 'to', as long as the coordinate files correspond. The datum conversion will take care of properly applying the conversion.

2. Create a text file that contains the geographic coordinates of the points in the FromDatum (e.g. NAD83, ED50, etc…). Coordinate systems other than geographic (degrees minutes seconds) are not supported. The format for the coordinate file is as follows:

   PointID Lat_deg Lat_min Lat_sec Lon_deg Lon_min Lon_sec EllHgt Flag

The PointID may not contain any spaces and must match the PointID in the ToDatum file that will be created in Step 3. The Lat_deg (latitude) term is +ve for the northern hemisphere and −ve for the southern. The Lon_deg (longitude) is +ve for the eastern hemisphere and −ve for the western. This means that North America needs −ve terms for the longitude. The EllHgt is in meters and is the height above the ellipsoid. The Flag term is optional. It indicates whether this point should be used for computing the transformation. Valid values are either 1 or 0, and 1 is assigned if the Flag is not present. Users may wish to use the Flag to either prevent suspect points from corrupting the solution, or they may wish to use some points as an independent check.

3. Create a text file corresponding to the ToDatum (e.g. WGS84, ITRF??, etc…). The format for this file is the same as for the FromDatum, except that the Flag term is ignored. Be sure that the PointID's match.

4. From the Tools Menu, select the Datum Manager. Click on the 'Solve Conversion' tab. The following screen will appear:
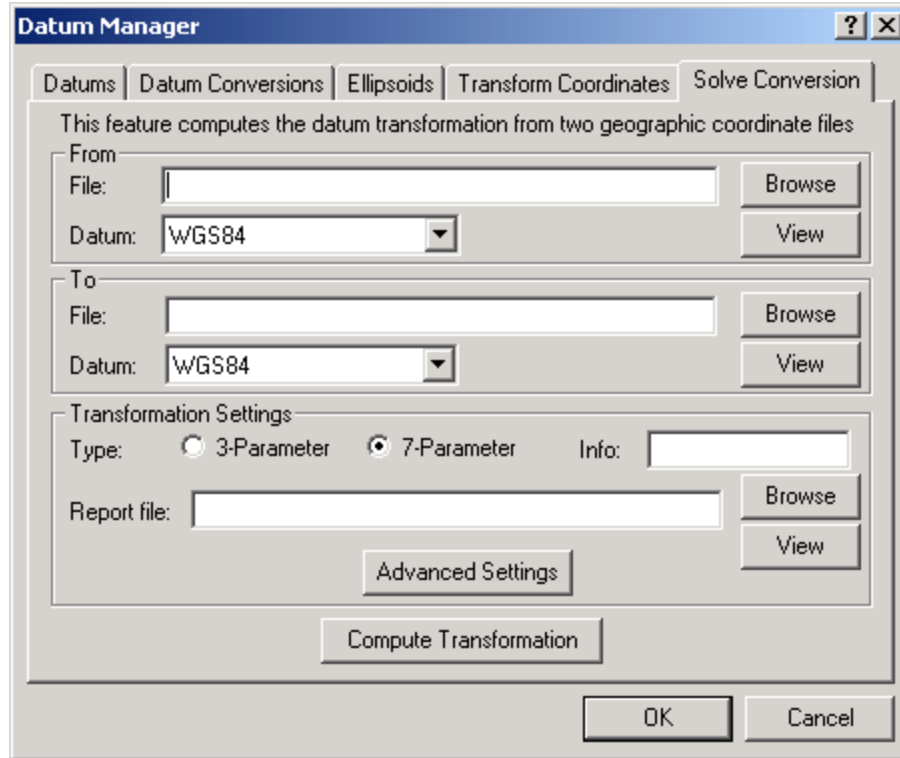
Figure 10.18 Datum Manager

5.   Press Browse to select the coordinates file corresponding to the FromDatum. Select the FromDatum from the list. If the datum does not exist, it will need to be enabled or added. The procedure for doing this is described earlier on in this section.
6.   Browse for the file corresponding to the ToDatum. Select that datum as well.
7.   Select the transformation type (i.e. 3 or 7 parameter). Enter a meaningful Info string. This will appear in the datum conversion (e.g. 'FromDatum to ToDatum (Info)').
8.   Select a meaningful output file name. This is a report that is generated from the computation process. It will contain the compute transformation parameters along with the residuals (i.e. fit).
9.   (Optional) Select the 'Advanced Settings' button. The following screen will appear:
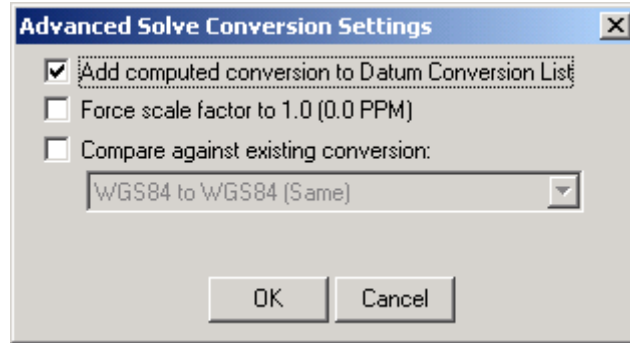
Figure 10.19 Advanced Solve Conversion

'Add computed conversion to Datum Conversion List' will cause the computed
conversion to be added to the list of conversions on the 'Conversions' tab in
the Datum Manager and Datum Options. This will allow the conversion to
be used by the software.

'Force scale factor to 1.0' will constrain the PPM scale to zero (scale factor=1.0). This is
only applicable for the 7-parameter transformation and effectively causes a
6-parameter transformation to be solved.

'*Compare against existing conversion'* This will compute residuals for an another
existing conversion in the Datum Conversion list. This is useful for
determining if the newly computed conversion fits better than the existing
one.

10.   Select the Compute 'Transformation' button. A message proclaiming success
should appear afterwards. If not, act on the message. For some failures, a partial
report file may be created. Press OK.

11.   Press the View button next to the Report file to use Windows Notepad to view the
processing report. This report will show the following:

Parameters—This is a reflection of the options on this dialogue box

Raw Differences—These are the raw differences between the ECEF coordinates of the
matched points in the two files. Only points that have a match found will
be processed. The USED column indicates if points are to be used in the
solution or not and refers to the Flag in the FromDatum file.

Transformation Parameters—This shows the parameters computed by the solve process.
If a comparison is made, then this will show the parameters from the
datum conversion. If the transformation needs to be inverted due to
opposite from and to datums, then the reversed values are shown.

Residuals using …—Shows difference between raw FromDatum coordinates and the
ToDatum coordinates transformed into the FromDatum. Root-mean-
square values are shown at the bottom. Note that the residual values are
oriented to local level (east, north and up).

For more information on this utility refer to Section 10.5.5.4 Creating your own datum
transformation from ASCII files.

10.5.3   Map Projections/Grids

See introduction from Section 10.5.1 Introduction and Definitions.

GrafNav/GrafNet supports two manners of map projections:
1.   Direct selection (e.g. UTM, TM, Gauss Kruger, State Plane, Lambert, etc…)
2.   Pre-defined and user-defined grid definitions using the Grid Manager.

For coordinate output, both methods can be used in the Export Wizard (use Selectable Grid-East and Selectable Grid-North variables in Export profile; see section 2.7.2). For Write Coordinates, only direct selection is possible.

For coordinate input (i.e. base station in GrafNav and control points in GrafNet), only grid definitions (#2) can be used. Another advantage with using grid definitions is that users can manage multiple user definitions more easily (i.e. for each country or region).

10.5.4   Geoids

GrafNav and GrafNet support geoids in three different formats including the U.S. National Geodetic Survey's .GEO format, the Geodetic Survey of Canada's .BIN/.SLV format and Waypoint's own Waypoint-Geoid (.WPG) format.

The distribution CD contains geoids in the .WPG format for the world with EGM-96, for the U.S. (including Alaska) with Geoid96/Geoid99 and for Australia with AusGeoid93. For Mexico, Mexico97 is included. Canadian Geoid03 files must be obtained from the GSC website, but a conversion program is also provided to convert to WPG. Otherwise, the .BIN/SLV files can be used directly with GrafNav and GrafNet. A geoid file is also provided for Japan. To obtain the latest Japanese geoid, please notify Waypoint that the geoid has been purchased from the government agency. More information about these geoids is found in ReadMe.txt in the \Geoid directory of the CD.

The relationship between ellipsoidal and orhtometric (mean-sea-level/MSL) height is:

$$h = H + U \tag{5}$$

When correcting ellipsoidal heights to produce orthometric heights, it is very important that the geoid and processing datums match. For example, if EGM-96 is used, then the base station coordinates should be in WGS84, and this datum should also be used for processing. Moreover, users should be cautious about using the same geoid model as used on the control sheets. This lessens the likelihood of differential errors developing.

For each of the geoids supported, the following datums are used. A web site is also given if further information is required.

Geoid	Datum	Web Site
Gsd95-Canada	NAD83	http://www.geod.nrcan.gc.ca/products/html-public/GSDinfo/English/factsheets/gpsht_fact.html
Geoid99-ContUS	NAD83	http://www.ngs.noaa.gov/GEOID/GEOID99/
Geoid99-Alaska	NAD83	http://www.ngs.noaa.gov/GEOID/GEOID99/
AusGeo98-1M	GDA94	http://www.auslig.gov.au/geodesy/ausgeoid/
EGM96-World	WGS84	http://cddisa.gsfc.nasa.gov/926/egm96/egm96.html
Mexico97	ITRF94 (1996)	see NGS site
Geoid96-Japan	WGS84	No known web site
RAF98-France	WGS84	http://www.esgt.cnam.fr/fr/recherche/geoide.htm
Geoid99-PuertoRico	NAD83	http://www.ngs.noaa.gov/GEOID/GEOID99/
Geoid99-Hawaii	NAD83	http://www.ngs.noaa.gov/GEOID/GEOID99/
Geoid03-ContUS	NAD83	http://www.ngs.noaa.gov/GEOID/GEOID03/

In some cases, the user may wish to process in a datum different than the one the geoid uses (e.g. NAD27 in North America or AGD84 in Australia). For this case, accurate results can still be obtained by using the geoid model in a relative fashion. The slope should be roughly the same between ellipsoids. With NAD27, there is up to 200-metre difference in geographic coordinates between it and NAD83. In areas with very high relief, this may result in a few centimeters of orthometric height error. The same can be said for other datums with large shifts (e.g. TOKYO and ED50).

In GrafNav, conversion to ellipsoidal can be performed as the master coordinate is entered. When exporting with the Export Wizard, the geoid undulation will be subtracted for.

For GrafNet, the process is similar. This is because users can convert orthometric heights to ellipsoidal as they enter the control/check point coordinates. The ellipsoidal/orthometric height flag must be entered correctly!!! Please note that elevations are always stored as ellipsoidal inside GrafNet. Conversion to orthometric will only take place at coordinate output/export. In many cases the default output is ellipsoidal height, so care should be taken when exporting elevation values

For more information on converting geoid to WPG format, please refer to Chapter 6 Section 7 MAKEGEOID (Command Prompt).

10.5.5 Transforming Coordinates

In GrafNav/GrafNet, there are several ways to transform coordinates. What follows are procedures for:

1. Performing a datum conversion between for a single coordinate
2. Performing a grid transformation on a single coordinate

3. Applying datum, geoid and coordinate transformations to and ASCII file.
4. Generate your own datum conversion from ASCII coordinate files.

10.5.5.1 Single Point Datum Conversions

Tools | Datum Manager | Transform Coordinates Tab
This tool allows you to quickly transform a coordinate from one datum to another. This is frequently used to transform base station coordinates of a project to another processing datum. Note that you can directly select a point that is in your favorites to be converted, as well as save any transformed point to your favorites. Specifying the week number of the coordinate will only have an effect on the final result if the selected conversion is a 10 parameter conversion.

10.5.5.2 Single point Grid Transformations

Tools | Grid/Map Projection | Transform Coordinates
This tool allows you to quickly transform a single coordinate from geographic to gird, or grid to geographic. It is important that users note the option "point is in Southern Hemisphere" which by default is not selected. It is also worth noting that once coordinates are converted from grid to geographic; they can be directly added to the user favorites.

10.5.5.3 Datum, Geoid, and Coordinate Transformations from ASCII files

Tools | Convert Coordinate File
Although the above mentioned methods are convenient for single point conversions, it quickly becomes tedious if you have a large list of coordinates to convert. Additionally, you may already have the list of coordinates in ASCII format. In this case it is best to use this tool, as entire files can easily be converted. This is a very flexible tool and can be used for converting between datums, changing the height system used (ellipsoidal, orthometric), and/or changing to grid or ECEF coordinates. It could also be used to simply change a list of coordinates to another format, such as from decimal degrees to DMS. The first step in this process is shown below.
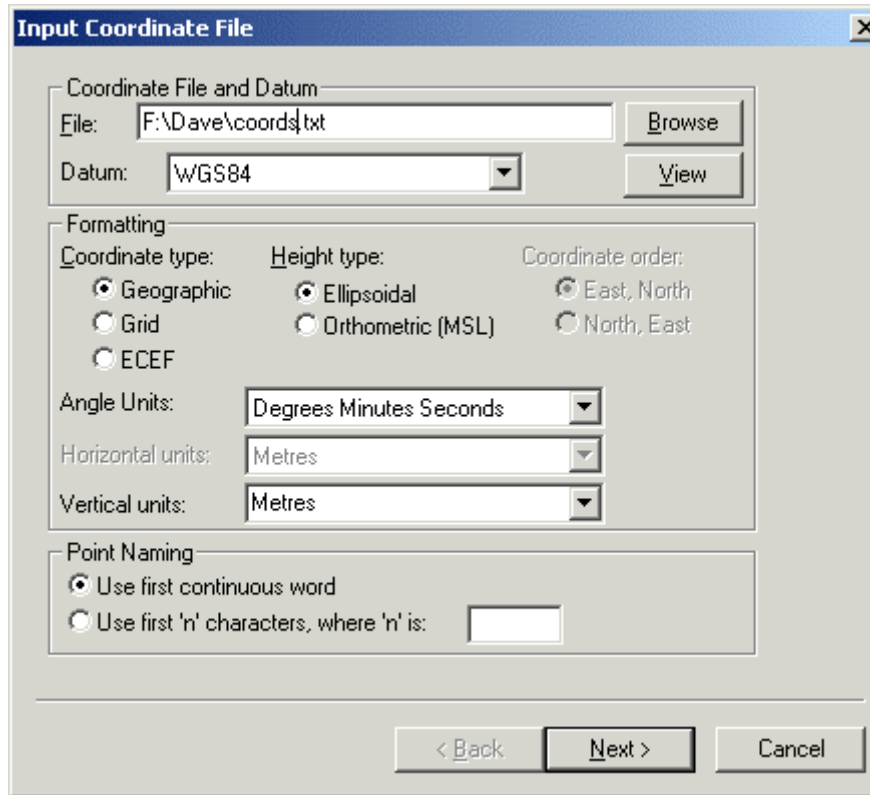
Figure 10.20 Coordinate Transforms step 1 of 3

The first step of the wizard requires the name of the input file, the datum and the format of the input file. Each line of the input file should contain the station name followed (on the same line) by the coordinates. This tool can handle station naming in two different ways. If the name of each station is always one continuous word and there are never spaces in any of the names, you can use the "use first continuous word" option. Otherwise, if station names contain spaces, you can specify a width of "n" characters. This will read the first "n" characters as the station name and include any spaces in the name. Geographic coordinates use +/- to indicate the hemisphere (i.e. latitude is positive in the northern hemisphere and negative in south, while longitude is positive for East and negative for West).

The next step requires the name, datum and format you want for the output file. The 'Naming' box is disabled as it will copy the names in the output file exactly as they have been read in from the previous step.

After pressing next, you may be prompted for grid definition settings if grid coordinates were selected. Otherwise, the same page as above will re-appear for the Output Coordinate definition.

The final page to appear is shown below. It will allow you to specify the datum transformation to be used if the input and output datums are different. In addition, a geoid file can be specified (if required).
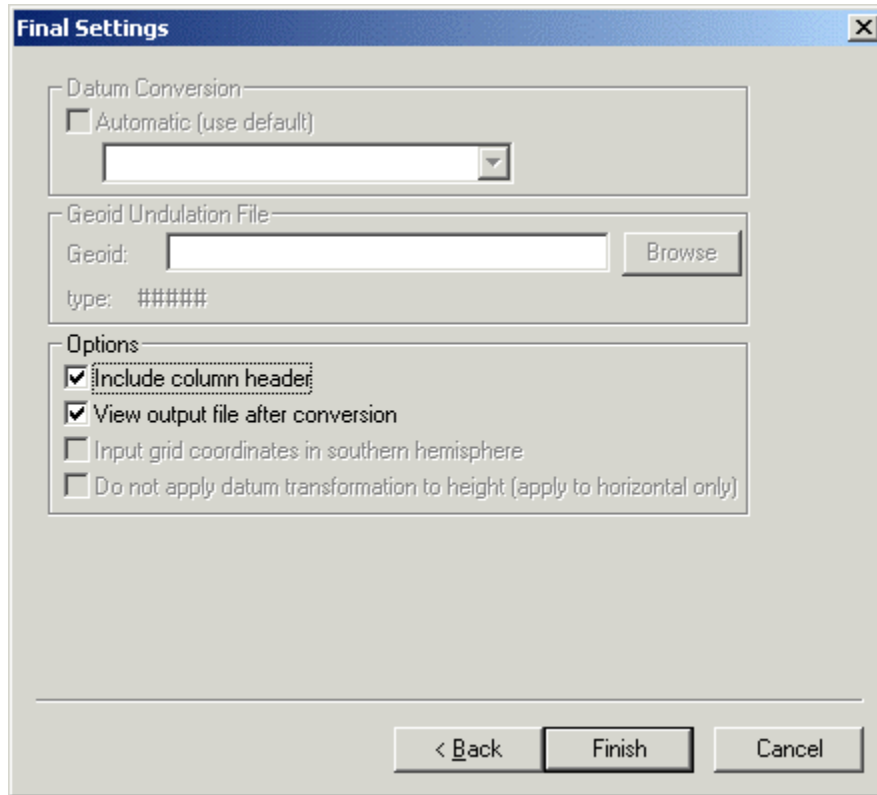
Figure 10.21 Coordinate Transform step 3 of 3

Finally, options are available for the following:

Include column header: Selected by default, this will conserve the header information in the input file.
View output file after conversion: Will automatically open the output file after you press "finish".
Input grid coordinates in southern hemisphere: Only necessary if your input data has grid coordinates and your project area is in the southern hemisphere
Do not apply datum transformation to height: This option is useful if you are outputting orthometric heights, as no datum transformation should be applied in this case.

10.5.5.4 Creating your own datum transformation from ASCII files

Tools | Datum Manager | Solve Conversion Tab
This feature allows you to solve your own datum transformation. This can be used if you have a list of control points with coordinates in both datums. From these point pairs, you can create a locally best fitting datum transformation for your region or project area. This function is also described in Section 10.5.2.7 How do I compute my own datum transformation?. The two lists must be in ASCII format and all points in each file must be common to both files and have identical point names. The order the points appear in each file, however, is not important.

The required format of each coordinate file is as follows:

ais1	55	4	8.66252	131	35	-58.3228	32.17
amc2	38	48	11.2486	104	31	-28.5327	1911.4
aml5	35	9	12.8258	101	52	-42.4693	1098.11
anto	29	29	28.3605	98	34	-35.9089	263.841
aoml	25	44	4.88865	80	9	-43.9141	0.1
arl5	32	45	32.5197	97	3	-37.0182	142.825
arp3	27	50	18.0664	97	3	-32.2452	-16.603

That is, the coordinates must be in signed DMS format. Latitudes in the southern hemisphere and longitudes in the western hemisphere must have negative values.

Be careful to specify what type of transformation you want to compute (3 or 7 parameter). The 3 parameter transformations will only compute a 3-D shift in the ECEF coordinates, whereas 7 parameter transformations will compute a 3-D shift in origin, a rotational shift about each axis and a scale factor. 3 parameter transformations are useful for small areas or if point errors are large.
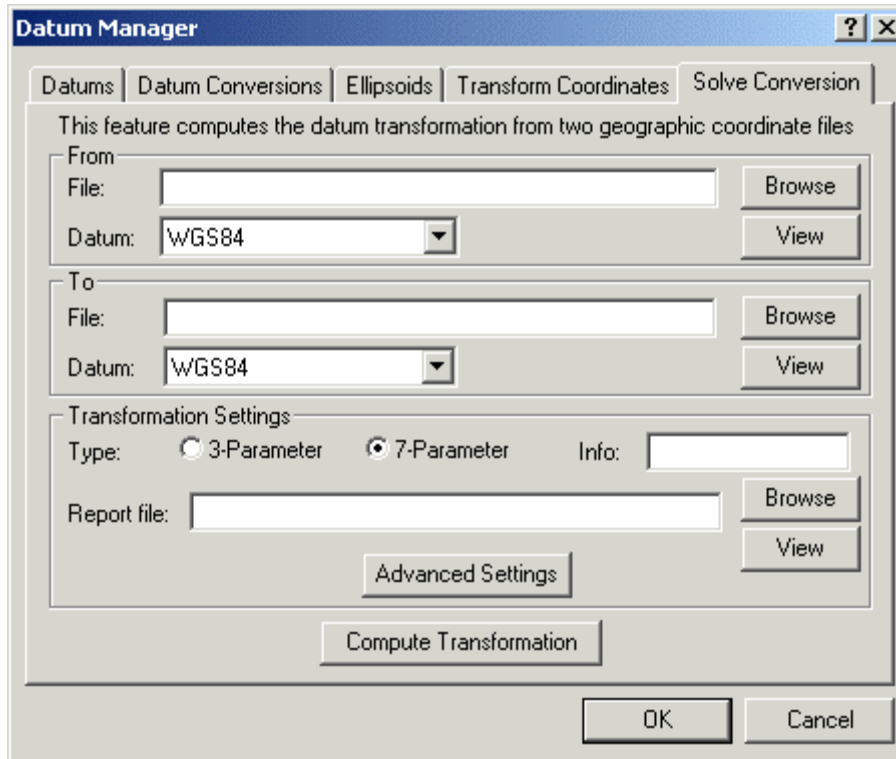
Figure 10.22 Solve Conversion

After specifying the path of the coordinate files and the corresponding datums, simply click "Compute Transformation". A message box will then appear either reporting that the transformation was successfully computed, or an error message.

Info
This is a required field and the transformation will not be computed unless text is entered here. Text that is put here will be appended to the type of transformation that will appear in the datum transformation list under the "Datum Conversions" tab. It is helpful to put a comment such as "7PCONTUS", which could mean a 7 parameter transformation of the continental US. Providing you were converting between NAD83 and WGS84, the full name of the datum conversion would read: NAD83 to WGS84 (7PCONTUS). It is important to note that the new transformation will only be added to the list if this option is enabled from the "Advanced Settings".

Advanced Settings
By default, only the "Add computed conversion to Datum Conversion List" is selected. This will allow GrafNav to utilize this conversion. The option "Force scale factor to 1.0" simply will not solve for a scale factor in a seven parameter transformation. "Compare against existing conversion" acts as a check on your conversion. If this option is selected, residuals are computed for each point using both the newly computed conversion and a conversion that already exists.

For more information on this utility refer to Section 10.5.2.7 How do I compute my own datum transformation?

Appendix A Summary of Commands

The following lists the available commands and a short description of their usage. Any subset of the following may be used for your particular input file. Note that the required format, status, and a description of each command in given after selecting the desired command and clicking on the 'values' field. User commands can also be observed via the User Defined Options dialogue box from the Options menu in GrafNav. Note that any spaces in file names, datum names, etc..., are substituted with the '*' character. Many of these commands are used by GrafNav's options. See User Defined Options to determine if this is the case.

Command	Description
ALT_FILE = fname EPP/SP3/CLK/IONEX ENABLE/DISABLE	
	This specifies the alternate ephemeris file (.epp file), or precise ephemeris (.sp3), or IONEX file (.yyI), or Satellite Clock file (.clk). They are set to ENABLE once added to the project. DISABLE will disable the processor from using the file.
APPLY_ANT = ON/OFF	Set to ON if elevation based antenna corrections are to be employed. Note that an antenna profile must also be specified for master and/or remote receivers. This is ON by default; use OFF to disable antenna correction.
ATMOS_FILE = *Filename[.atm]*	This will output atmospheric values computed by GrafNav into a .atm file.
AZ_DETERM = ON/OFF Dist DistSD	GrafMov only. Used to enable azimuth computation using an antenna distance constraint. Distance and standard deviation are in meters. Typical standard deviations are 2-3 cm.
BASE_SAT = *sv_num*	Satellite PRN number of base satellite used for differenced computations. Normally, this value should be left at 99, which will cause the program to automatically choose the best satellite using a number of criteria. The default value is 99.

CYCLE_TEST = *mode*	This can be LOCKTIME, DOPPLER, or BOTH, and determines the manner in which cycle slips are detected in kinematic mode. In general, either BOTH or DOPPLER should be used. Basically, using DOPPLER will disable LOCKTIME check.
CYCLE_TOL = *tol*	Tolerance used to detect cycle slips on the L1 phase in kinematic mode. These tolerances generally vary from 1 - 500 cycles, and depend on receiver type, vehicle dynamics and type of Doppler. Numerous cycle slips reported may indicate that CYCLE_TOL is too low. A value of 0.0 will cause cycle slip tolerance to be computed automatically from data interval. This value is also subsequently multiplied by 30 [default is 0.0].
DATUM = *ProcDatum [Wgs84Conv]*	This is the datum that processing is to be performed in, and the satellite coordinates are transformed into this datum. See GrafNav for a list of available datums. *WGS84Conv* is the conversion to be used. Use *WGS84Conv*=AUTO to allow NGPS32.DLL to select the best datum. Note that datums are read from manufact.dtm and user.dtm located in the same directory as the DLL.
DETAILED_SUM = ON/OFF	ON if detailed parameter info is to be printed at the start of the static/kar summary (.fss/rss) file.
DOP_TOL = dd_dop_tol	Epochs with DD_DOP above this value are not printed to .FWD/REV files as the geometry is deamed too poor. Default value is 100.0.
DOPPLER_TOL = *tol*	No longer supported.
DUAL_FREQUENCY = *on/off on/off off/relative/free on/off/smoothed*	OFF/ON - Use P-code for long baseline processing. No longer used; see USE_PCODE command.

OFF/ON - Use L2 phase for ambiguity resolution (should be ON).

OFF/RELATIVE/FREE – Use relative ionospheric correction or long baseline L3 iono-free baseline processing

ON/OFF/SMOOTHED – Apply ionospheric correction to C/A. SMOOTHED applies a low pass filter to the raw ionospheric corrections before implementing them.

DYNAMICS = *EnableFlag DynFlag*

This parameter controls the vehicle dynamics model that can be employed in the Kalman filter. *EnableFlag*=ON/OFF/AUTO, while *DynFlag*=LOW/MEDIUM/HIGH. Generally AUTO should be used, which means that dynamics constraint is off if Doppler is employed or ON if no Doppler is used. If ON, HIGH dynamics is used. If ON, use *DynFlag* to set vehicle dynamics.

ELEV_MASK = *angle*

Cut-of elevation for excluding satellites from the computations. This value is expressed in degrees. This *elevation mask* value may have to be increased to 15 degrees or more in high multi-path environments or during ionospheric storms. Some data tracked under 10 degrees may exhibit noise characteristics. Default value is 10.0.

FF_DOP_TOL = *dop_tol*

DD_DOP Tolerance over which a fixed integer solution is deemed "float". Allows user to control how easily a fixed changes to a float solution. Does not affect processing. Default is 25.

FIX_AUTO = *Min DtL2 MaxLenL2 MinDtL1 MaxDtL1 ON/OFF*

Controls automatic fixed static solution usage on static sessions. Use 'ON' to enable, or "OFF' to always use. Note that fixed static must also enabled in processing settings. *MinDt* is minimum ime length in seconds while *MaxLen* is maximum allowable distance in km.

FIX_CORRECT_SLIP = ON/OFF   ON if whole cycle slips are to be corrected forming a continuous phase in fixed solution. By default this option is ON.

FIX_CUBE = *mode L1User L2User*   *mode* is AUTOREDUCE, NORMAL, or USER. Sets the search region size for fixed solution. *L1User* and *L2User* are the sizes of the search are to be used for USER mode. Default is NORMAL. Although, AUTOREDUCE often works very well.

FIX_INTERVAL = *DataInterval*   Data interval in seconds to use for fixed static processing. Default is 15 seconds.

FIX_IONO_DIST = *dist*   Used in the AUTO fixed solution L2 model for deciding between IONO and NORMAL L2 noise models. *dist* is in kilometers. Default is 5 km.

FIX_L2_NOISE = IONO/NORMAL/AUTO
                                            Selects L2 noise model for processing fixed solution. IONO performs iono correction, NORMAL does not, AUTO selects between the two based on the FIXED_IONO_DIST command.

HGT_MODEL = *EstFlg KalFlg KarFlg ZOff/USEHI HgtSd [KarTol]*
                                            Controls DEM height constraint (Sportvision version only!)
                                            EstFlag = NAV / ALL / OFF
                                            Kar/KalFlag = ON / OFF

INITEX = *type time snap dir windowsize stdev anthgt phi lamda ht*
[[staname or ss_index] anthgt ELL/ORTHO]
                                            Used to set the remote position at a given location. See GrafNav user interface.

INTERVAL = *DataInterval*   This specifies the processing interval in seconds. It should be equal to or greater than the recording interval for proper time length computations. If this value is larger than the recording interval, then this new value will be used for processing. Use 0.0 to process all epochs. The default value is 0.0.

IONO_DIST = *dist_in_km*

Baseline distance in km at which relative iono-free processing will begin. Default is 5 km.

IONO_PPM_TOL = *tol*

Reject KAR or fixed static solutions if computed ionospheric error is greater than *tol* in PPM. Default value is 10 PPM. This setting is not in GrafNav's dialogue boxes.

ISSUE_KAR_DIST = ON/OFF *DistKm1 DistKm2*

This will engage KAR on first occurrence of dist < dist1 and reset the distance check when dist > dist2.

ISSUE_KAR_DOP = ON/OFF *doptol*

Engage KAR every time DD_DOP goes above *doptol*.

ISSUE_KAR_TIME = ON/OFF *NumMin*

Engage KAR every '*NumMin*' minutes.

KAR_COV_L2 = ON/OFF *sf offset*

Determines KAR search area using ambiguity variances. Search area is computed to be *SearchArea=+/- sf*AmbVar + offset.* This option only works for dual frequency processing.

KAR_CUBE = *cube_size_l1 cube_size_l2*

Size of kinematic ambiguity resolution (KAR) search *cube* in meters. A cube +/- *cube_size/2* will be searched from the initial approximate position, which is obtained from the program following the loss of lock. The default value is 2.0 m. This value should be increased if it is suspected that the remote position is outside of the search cube. However, larger values increase the possibility of an incorrect intersection found.

KAR_DISTANCE = *l1_dist l2_dist*

Do not <u>engage</u> KAR if distance is greater than value. Distances are defined in km. After KAR is engaged, it will search farther. Use KAR_USE_DIST to prevent KAR from utilizing data past a certain distance.

KAR_ELEV_MODEL = ON/OFF

Default is ON. KAR uses the KAR_TWOSTAGE_SAT highest satellites for its ambiguity search.

KAR_EPOCH_FILTER = *epoch_size*	Interval between storing epochs for KAR. *epoch_size* specified in seconds. This controls how much data KAR will use.
KAR_EPOCH_SIZE = *epochs_l1 epochs_l2*	Number of epochs between KAR ambiguity searches if L1 only or L1/L2. This controls how often KAR will search.
KAR_EXACT_INTERVAL = ON/OFF	Only use epochs exactly on KAR_EPOCH_FILTER in KAR.
KAR_FAST = ON/OFF	ON to enable 'Fast KAR'
KAR_IONO_DIST = *dist_in_km*	Used in auto L2 noise model for choosing between HIGH and IONO.
KAR_L2_NOISE = AUTO/HIGH/IONO/MEDIUM/LOW	Model used for KAR L1/L2 ambiguity search. Default is AUTO.
KAR_MAX_DOP = 7.0	Tolerance for allowable DOP during a KAR solution. Default is 9.0.
KAR_MAX_TIME = *30*	After this number of minutes, KAR will restart searching
KAR_MB_NEAREST = ON/OFF	If this option is turned ON, KAR will use the nearest base station to engage (Multi-baseline processing only).
KAR_MIN_ADD = *NumMinutes*	Minutes added to the minimum KAR time for every 10 km in baseline length. Default is 1.5 minutes.
KAR_MIN_TIME = *L1time L2time*	Minimum number of minutes for single and dual frequency processing before KAR is searching begins.
KAR_OUTPUT = ON/OFF	TRUE if KAR is to output additional information for FWD/REV files.
KAR_RELTOL = *tol*	Reliability is calculated by dividing the lowest intersection RMS by that of the second lowest. Reliable intersections should

	have values of 1.5 or higher and preferably greater than 2.0. Default is 1.5.
KAR_RMS_TOL = 0.075	Tolerance for KAR statistical test on the RMS phase. Default is 0.065 cycles.
KAR_RMSKEEPTOL = *tol*	If the RMS from a KAR solution is higher than this tolerance (cycles), then a warning will result. If there are still 4 good satellites *(see KAR_MAXSV)*, this solution will not be used. Default value is 0.06 cycles.
KAR_RMSUSETOL = *tol*	This is the tolerance (cycles) with which intersections will be kept in the list. This value should be 0.20 or higher. The default is 0.20 cycles.
KAR_SEP_TOL = 2.0	Tolerance for allowable separation between the float and fixed KAR solutions. This option can be used to "kick out" solutions with large float/fixed separations.
KAR_STATIC = ON/OFF	Turn ON to engage KAR in static mode. By default this option is OFF.
KAR_STRICT_TOL = *rmsflag relflag*	*rmsflag=ON/OFF* and enables stricter RMS tolerance for rejecting bad KAR solutions. *relflag*=ON/OFF and it enables stricter reliability tolerance.
KAR_TWOSTAGE_SATS = 6	Use this maximum number of satellites in the KAR ambiguity search routines.
KAR_USE_DIST = ON/OFF *MaxL1Dist MaxL2Dist*	
	ON to prevent KAR from using long baseline data. Tolerances for single and dual frequency processing are in km. Normally computed automatically from KAR_DISTANCE.
KAR_USE_FAR = ON/OFF	ON if KAR to use all data less than distance tolerances. OFF will just use data until maximum distance exceeded. Default is off.
L2_LOCKTIME = ON/OFF	ON to use L2 locktime for cycle slip detection. For some receivers (e.g.

	Ashtech), this can lead to more cycle slips being detected than really do occur.
L2_MAIN = ON/OFF	If turned ON, GrafNav will only use P2/L2 for single frequency processing (special applications only).
L2_SLIP_TOL = 0.20	Tolerance in L2 cycles at which an L2 cycle slip will be assumed. Default is 0.4 cycles.
LOCKTIME_CUTOFF = 8	Phase data will be ignored for the first 8 seconds after locking onto the satellite. Change this value to 0 to process all phase data or a large value to ignore the first n seconds of lock. This gives the phase lock loop a chance to stabilize.

MB_MASTER_ANT = *L1VertHgt* [*L2Corr MeasDist SlantFlag(1/0) ProfileName*]
MeasToPC

This is the extended version of the antenna height for a multi-base master station. Only first two parameters and ProfileName used by processing engine.

MB_MASTER_DISABLE = ON/OFF	ON if the master station is to be disabled from processing.
MB_MASTER_FILE = *Filename*	The name of the multi-base master file (.GPB file). Use * as spaces.
MB_MASTER_INDEX = *iIndex*	Index of the master file in the project. Note that this starts at 0. It must proceed MB_MASTER_??? commands which refer to this location.
MB_MASTER_NAME = *StaName*	This is the name of the master station used in multi-baseline processing for identification and baseline settings matching. This name is also displayed on the map and used to refer to station/baseline specific settings.

MB_MASTER_POS = *LatDeg LatMin LatSec LonDeg LonMin LonSec Ht(m)*

These are the coordinates of a master station. The latitude and longitude <u>must</u> be entered in *degrees minutes seconds* with

spaces in between. For those just interested in differential vectors between the stations, a rough pseudorange position is sufficient. This can be found using the VIEWGPB utility **or** selecting interactive input from the first menu and selecting an averaged position. If the antenna height (meters) is not present, this value will be assumed to be *zero*. Latitude is positive in the Northern Hemisphere and negative in the southern. Longitude is positive in the Eastern Hemisphere and negative in the western (Americas).

MOVING_BASE = ON/OFF

Moving Baseline Option Only. If ON, this indicates to the GrafMov module that the base station is in dynamic mode as well as the remote. If MOVING_BASE=OFF, conventional processing is performed.

MOVING_BASE_FILE = *Filename*

No longer supported.

NAV_TOL = *dist_in_m*

Distance before using DGPS based navigation approximation. Affect Kalman filter convergence for slowly moving objects.

NOWRITE_HIGH = ON/OFF

Does not export epochs to the .FWD/.REV if statistics are too poor (if ON used).

OMIT = KAR/PROC *$name*/ALL *sv#*/ALL RANGE/ALL *[start end]*

This controls omitted objects (such as baselines and satellites) from GrafNav processing. KAR = remove from KAR/fixed static; PROC = remove from all processing; *$name* is baseline name (or use ALL); use *start end* to define RANGE of times to omit.

OUTPUT_MODE = NORMAL/EXTENDED

Determines output format for the ASCII .FWD and .REV files. EXTENDED includes velocity and ambiguity values.

POS_DENSITY = 1.0

This is the spectral density of the position states. You may want to increase this value

	to 10 *or more* under high dynamics. This value should be left at 1.0 (default).
PROCESSDESC = *Description*	This is the processing description. By default it uses Run(1) and increments after each processing run. The information is stored in the processing history. Use * for spaces.
PROCTIME = *Time Date*	Time (hh:mm:ss) and date (mm/dd/yy) of processing.
PROCUSER = *Name*	User's name or intials stored before processing. It is stored in the processing history (by GrafNav) and is outputted in ASCII and binary files.
PROCESS_DIR = *direction*	Processing direction is either FORWARD or REVERSE. Reverse processing can be useful if there are a major series of (fatal) cycle slips during a kinematic run. All features supported under forward processing are supported under reverse processing.
REMOTE_ANT = *L1AntHgt [L2Offset ...*	Vertical offset from ground location to L1 phase centre. Second value is offset from L1 to L2 phase centre. Additional values used by GrafNav for internal use (see MB_MASTER_ANT).
REMOTE_FILE = *[path]file_prefix[.gpb]*	This is the name and location of the remote station binary GPS data file. This data must be in the .GPB format. If your data is not in this format, use one of the conversion utilities supplied. If this value is not entered, the program will prompt for it. Make sure to replace all spaces with '*' characters.
REMOTE_POS = *lat. long. ht*	These are the coordinates of the remote station. The latitude and longitude <u>must</u> be entered in *degrees minutes seconds* with spaces between. The processing engine now computes a differential pseudo-range solution at the start of the program if REMOTE_SD is greater than 1.0 meters.

This means that this position can be many kilometers out and still work. Entering the position is not necessary. Latitude is positive in the Northern Hemisphere and negative in the Southern. Longitude is positive in the Eastern Hemisphere and negative in the Western Hemisphere (e.g. Americas). See also INITEX command.

RMS_MODE = NEW/OLD   No longer supported.

SAVE_AMB = ON/OFF   ON if ambiguities are to be saved if a satellite drops out in the file but it's locktime is not reset. Disable if too many filter resets are occurring because of missed cycle slips.

SF_IONO_MODE = OFF/ON/BROADCAST/IONEX

Turned ON for automatic selection between IONEX and ICD-200 broadcast ephemeris corrections to be applied when processing single frequency data, or select type of correction manually. Such corrections will only help on very long baselines.

SHOTGUN = ON/OFF   No longer supported.

SKIP_EPOCH = *ON/OFF MASTER/REMOTE/BOTH NumSats*

Currently, not supported in Version 7.01

SKIP_NOREPAIR = *CaVal L1Val*   Maximum number of seconds of skip if bad data observed and could not be corrected on either L1 or C/A. Defaults are 10 s for C/A and 0.0 s for L1. Values are in seconds.

SPLIT_SS = ON/OFF *dt*   Set ON to break up static sessions if a time gap of greater than *dt* is observed. *Dt* is in seconds. By default, this setting is OFF.

SP_???   Single point processing settings. Ignored by NGPS32.dll.

STANAME = *name*   Used by GrafNet to set the station name for display in output files.

STATIC_SLIP_TOL = *val*   Static cycle slips are declared if greater than *val*, which is in cycles.

STATICSESS = *ID AntHgt StartTime EndTime IsSec80 UseFix 0*

Define information about a static session. For instance, *ID* gives it's name (use '*' for spaces); *AntHgt* allows the antenna height to be changed (value in m); *Start/EndTime* define time range in TOW or seconds since 1980 (see IsSec80 flag); *IsSec80=on/off*; *UseFix* indicates whether fixed static solution is to be used (0=off, 1=use, 2=check distance and time, see FIX_AUTO command)

STD_MODE = AUTO/ELEV/CN0/STANDARD

This is the type of weighting mode that the measurements will use in terms of statistical handling.

STD_REF = *REFCN0 REFELEV CN0_V*   These are the reference values that the measurement standard deviation's refer to. V in SD = $V+10^{-cno/10}$ (note: scaled by REF_CN0)

STD_DIST = LOW/MEDIUM/HIGH/OFF/MANUAL [*ManHzPPM ManVPPM*]

This is the magnitude of distance dependent errors. The distance effect can be low, medium, high, or off. The user can override these settings and enter their own horizontal and vertical PPM manually.

STD_PPM = *RejectPPM*   This is only used if the user command STD_DIST = OFF above.

STD_REJECT = *Type CedeRej PhaseRej DopRej CedeReset PhaseReset*

TYPE=MANUAL/NORMAL/STRICTALL /STRICTPHASE/STRICTCODE/LOOSEA LL/LOOSECODE/LOOSEPHASE, values are nSD (i.e. number of standard deviations). If type is MANUAL, the user needs to enter the rejection and reset tolerances.

STD_SKIP = *MaxRejSec nSkipCodeEpochs nSkipPhaseEpochs*

These are the advanced reset settings.

STD_PHASE = *SD_m* ON/OFF

This is the standard deviation for the carrier phase. ON/OFF refers to if the standard deviation will be adjusted for additional ionospheric noise.

STD_CODE = *SD_m*

This is the standard deviation for the C/A code and P code.

STD_DOPPLER = *SD_m/s* ON/OFF

This is the standard deviation for the Doppler. ON/OFF refers to the auto-doppler flag (used in GrafNav only).

STD_BL = *Name UseMain*(ON/OFF) [*CodeSD phaseSD dopplerSD*]

These are baseline specific values. Name refers to master; values in m or m/s.

STD_RELTOL = *Value*

This is the reliability tolerance for rejecting outliers.

TIME_CORR = 0.0   0.0

seconds. Time correction to master and remote files. This may be useful if a receiver has logged data in UTC time rather than GPS time. It is not suggested that this command be used unless there are errors in your GPS data timing.

TIMERANGE = ALL/RANGE *StartSec EndSec Flag ShowHmsMdy*   Processing

time range. Replaces START_TIME and END_TIME commands. ALL processes entire data set. *StartSec* is time at beginning (regardless of forward or reverse processing). *EndSec* is time at end of processing period. Times can either be seconds of the GPS week or seconds since 1980 (see *Flag*). *Flag* is 0 for time not valid, 1 for seconds of the week, and 2 for seconds since 1980. *ShowHmsMdy* is only used by GrafNav for display purposes (1=show H:M:S …).

TROPO_MODEL = OFF/SAAS

Default is SAAS, which is the Saastamoinen model. OFF can be used with GPS simulators that have troposheric correction disabled.

USE_DOPPLER = *ForCarrier ForCode*	*ForCarrier* uses Doppler for carrier phase (ON/OFF); *ForCode* uses Doppler for code only processing (ON/OFF).
USE_PCODE = *P1forCA*(ON/OFF) *P2*(ON/OFF)	This will enable P-code and requires dual frequency processing.
USERKAR = *gpstime* FORWARD/REVERSE/BOTH	Engage KAR at this time for the direction(s) specified, may be multiple entries. *gpstime* is in seconds of the GPS week.
VEL_DENSITY = *density*	Spectral density for velocity states (m^2/s^2).
VERBOSE = ON/OFF	ON prints additional information to FWD/REV/FML/RML files.
VERSION = *#.#.#*	Ignored by .dll. It is used by GrafNav to indicate version number producing CFG file.
WRITE_BAD_EPOCHS = OFF/ON	Default is OFF. Use ON to write bad data to the .FWD/.REV files. This option is useful if the user wishes to view data at epochs where the RMS_TOL values are exceeded. Normally, data which is greater than RMS_TOL is not written to file.
WRITE_RESIDUALS = ON/OFF	default OFF. If ON, then write out each L1 phase and CA-code residual for each satellite to a .RL1 and .RCA file.
WRITE_SLIP_MSG = ON/OFF	ON if cycle slip and other satellite rising/falling warning messages to be written to message log.

GPS-IMU User Commands

ACCEL_BIASES = *x y z*	x,y,z, accel biases in m/sec
ACCEL_NOISE = *sd1 sd2 sd3*	spectral density of the accel bias states (m**2/s**5)
ACCEL_SD = *x y z*	a priori Kalman std dev for x,y,z accel biase states (metres/sec**2)

ALIGNMENT_MODE = *mode*

0-coarse+fine align, 1-coarse align only, 2-no alignment (transfer or on-the-fly alignment)

ASCII_OUTPUT_INTERVAL = *Interval*

ASCII IMY Output to FIM or RIM files (default is 1 second)

COARSE_ALIGNMENT_MODE = *mode*

0-static coarse align,1-enter the az,2-transfer alignment

COARSE_ALIGNMENT_TIME = *time1 time2*

seconds of coarse align for fwd/rev processing (def 120 sec)

CORRELATION_TIMES = *gyro_time accel_time*

correlation time for Gauss-Markof gyro / accel bias states (seconds)

DATA_RATE = *rate*

data rate for IMU:
64 Hz for LTN90
50 Hz for LRF3
50 Hz for LN200
100 Hz for HG1700

DYNAMICS_MODE = *mode*

0 - low, 1 - high, 2 - extreme

ERROR_MODEL_IMU = *Name*

Error model name from manufact or user.imu files.

GPS_COVARIANCE_SCALE = pos vel

Scale GPS Kalman co-variances for POS and VELOCITY by this amount (default 1.0)

GPS_HEADING_UPDATES = OFF/ON const StdDev

ON/OFF - use GPS heading updates / Const offset in degrees / std dev of offset angle in degrees(default OFF)

GPS_INS_OFFSETS = dx dy dz

(m) Lever Arm measured in body axes system with the IMU considered as the origin

GPS_INS_UPDATE_TOL = FLOAT/FIXED sdev Q D_rms

only use GPS updates when these conditions are met:

GPS_POSITION_UPDATES = ON/OFF	ON/OFF - use or not use GPS velocity updates (default ON)
GPS_TRAJECTORY_SOURCE = source	GrafNav solution file -> 0-cmb, 1-fwd, 2-rev, 3-external file
GPS_VELOCITY_UPDATES = ON/OFF	ON/OFF - use or not use GPS velocity updates (default ON)
GPS_UPDT_INT = n	GPS updates every n seconds FIXED/FLOAT (ambiguities -> def FLOAT) std_dev_GPS_coord (def -> 2m) Qfactor (1-6 -> def 6) DopplerRms(m/s)
GRAFNAV_FILE = filename1 filename2	name of FWD, REV, CMB GrafNav file for GPS updates (fwd and rev processing)
GYRO_BIASES = x y z	x,y,z, gyro drifts in deg/sec
GYRO_NOISE = sd1 sd2 sd3	spectral density of the gyro drift states (arcsec**2/sec**3)
GYRO_SD = xsdev ysdev zsdev	a priori Kalman std dev for x,y,z gyro drift states (arcsec/sec)
INITIAL_ATTITUDE_KNOWN = att	ATTITUDE_KNOWN, HEADING_KNOWN, ATTITUDE_UNKNOWN - validity of the initial roll, pitch, yaw values
INITIAL_ATTITUDES = rowfwd pitchfwd azfwd rowrev pitchrev azrev	if known input Roll,Pitch,Azimuth (decimal degrees) for fwd/rev alignment
INITIAL_INS_POSITION = latfwd lonfwd htfwd latrev lonrev htrev	INS position for fwd / rev processing (D.M.S / metres)
INITIAL_POSITION_SOURCE = source	0-cmb/fwd/rev file, 1-manual entrry of position
INITIAL_VELOCITIES = vefwd vnfwd vhfwd verev vnrev vhrev	if known input East,North,Up velocities (m/s) for fwd/rev alignment

INS_BODYFRAME_OFFSETS = roll pitch yaw   (degrees) constant angular offsets from the IMU axes to vehicle body frame axes in roll,pitch,yaw (usually zero)

INS_DATAGAP_TOL = *Num_consectutive_epochs_missing*   Exit on a single data gap that is larger than this number.

INS_FILE_NAME = filename   name of IMU binary measurement file

INS_GPS_TIME_FRAME = GPS_TIME_FRAME/RCVR_TIME_FRAME
default GPS_TIME_FRAME (rcv_time - rcvr_clock_bias) / RCVR_TIME_FRAME (nominal rcv_time)

INS_LOWPASS = 0/1   0 or 1 -> if 1, use low pass filter on raw data (def = 0)

INS_PROCESS_DIR = FORWARD/REVERSE   FORWARD/REVERSE direction INS processing

INS_PROCESS_MODE = mode   GPS_INS (default) or INS_ONLY

INS_TIMERANGE = start end   start / end times for IMU processing and process ALL / PARTIAL data set

INS_TYPE = type   LTN90, LRF-3, LN200, HG1700, JAMI_IMU, GENERIC_IMU (*.imr)

INS_VERBOSE = ON/OFF   ON/OFF - write extra messages to FIL and RIL files (default OFF)

MISALIGNMENT_NOISE = sd1 sd2 sd3   spectral density of misalignment states (arc_sec**2/s)

MISALIGNMENT_SD = esddev nsddev hsddev   a priori Kalman std dev for east, north, up misalignment states (arc seconds)

NUM_STATES = number   Kalman filter states (def=15)

POSITION_MEAS_VAR = cov   variance (R-matrix) of Kalman CUPT observation (m**2)

POSITION_NOISE = sd1 sd2 sd3   spectral density of the coord states (m**2/s)

POSITION_SD = esdev nsdev usdev	a priori Kalman std dev for east, north, up coordinate states (metres)
PREDICTION_RATE = n	Kalman filter prediction every n sec (def=0.5)
TIME_OFFSET = offset	correction in seconds (if any) to GPS times in the IMU binary file (def -> 0.0)
TOTAL_ALIGNMENT_TIME = time1 time2	seconds of coarse + fine alignment (def 600 sec) NOTE: if total_align_time = coarse_align_time, no fine alignment is performed
VEL_MEAS_VAR = var	variance (R-matrix) of Kalman ZUPT observation (m**2/s**2)
VELOCITY_NOISE = sd1 sd2 sd3	spectral density of the velocity states (m**2/s**3)
VELOCITY_SD = sdev1 sdev2 sdev3	a priori Kalman std dev for east, north, up velocity states (metres/sec)
WRITE_BINARY_OUTREC = ON/OFF	ON/OFF - write binary structure to disk at Mechanization Rate for fwd/rev combination
ZUPT_ALIGN_INTERVAL = interv	length of time for a ZUPT during fine alignment (def -> 10 seconds)
ZUPT_AT = start end	start_time(GPS sec) end_time(GPS sec) incremental_number
ZUPT_OPTION = num	type of ZUPT = 0 or 1 -> one epoch or best fit over zupt_length seconds (default 1)
ZUPT_TIME = time	minimum length of time for a ZUPT (def -> 10 seconds)
ZUPT_VEL_TOL = tol	reject a ZUPT with velocity above this tol (m/s)

Appendix B Moving Baseline Upgrade (GrafMov)

This appendix describes the moving baseline upgrade, which is an add-on to Waypoint's GrafNav/GrafNet GPS post-processing software package. The purpose of the moving baseline software is to facilitate relative processing between two moving antennae.

To run the Moving Baseline version of GrafNav, select the Start button from Win95/NT. Then select Program and GrafMov from the Waypoint GPS folder. Make sure not to use GrafNav from the Desktop in Windows 95 since it will not process moving baseline files.

Important considerations when using GrafMov:

Make sure that the base and remote data are set to kinematic.

With the regular version of GrafNav, it is very crucial that static (stationary) and kinematic (moving) periods are properly defined for the remote GPB file, while the base stays static. This is important because GrafNav treats remote kinematic and static data differently, and if kinematic data is set to static, then large errors will develop. Even small movements on the antenna can cause problems in static mode, and such data should be switched to kinematic. On the other hand, static data that is incorrectly set to kinematic will cause a reduction in accuracies. This is especially true for single frequency data.

Most of the decoders make the entire data static or optionally kinematic. Switching between static and kinematic can be performed epoch-wise[2] within the GPB File Viewer (see Section 2.2.15). If WLOG is used to log the raw data, switches between static and kinematic can be performed in real-time by pressing F3.

For the GrafMov, it is important to ensure that <u>both the base and remote stations</u> are also set correctly (i.e. static or kinematic). Again, this is best performed from within the GPB File Viewer. The GPB File Viewer can be accessed a number of ways:
From the File menu, select View and View Raw GPS Data
From the File menu, select GPB Utilities and View Raw GPS Data
From the Process menu, select View Raw GPS Data, select either View Master or View Remote. For these to work, a project must be loaded.
From the Waypoint GPS programs, select GPB Viewer

If the user is not sure when the data is static and when kinematic, then make the entire file kinematic. It is much safer.

Make sure that the master GPB file has position data.

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[2] Multiple epochs can be changed between static/kinematic as well

For relative processing in kinematic mode, the movement of the base must be tracked, and GrafMov will extract this position from the Master GPB file. Normally, the receiver computes this position in real-time, but some of the decoders re-compute position during conversion. Examples are Ashtech Hose, Rockwell Jupiter and RINEX. With the exception of DGPS method, coordinates will have the effects of S/A that can be up to 100 m. This will not cause a problem since only the relative information is desired, which is not effected by S/A. However, it is important to ensure that the master GPB file has proper coordinates. This is best performed from the GPB File Viewer (see Section 2.2.15 Viewing Raw Binary GPS Data). Ensure that there is a geographic position in the top-right window.

Extracting Local Level Coordinates
Once processing is complete, the relative coordinates between the base and remote antennae are usually required. The local level system is very compatible with geographic coordinates and is often used. This system has the y-axis pointing north and the x-axis pointing east, while the z-axis is vertically oriented.

However, due to a convergence of the meridians the north axis at the base is different from the remote. The local level coordinates computed in GrafMov and GrafNav use the north axis of the base to define the y-axis. The base position is also the origin of the coordinates system. Although local level coordinates can be extracted from the .MOV file, they are better obtained using the Write Coordinates feature from within GrafMov. This allows forward and reverse solutions to be combined. This is performed by selecting Local Level coordinates as the Output Format. The local level velocities will also be written (units are m/s).

Extracting Relative Earth Centred Earth Fixed (ECEF) Coordinates
The local level coordinate system in not Cartesian, which is due to a different formation of the horizontal and vertical axes. These coordinates should not be used in conjunction with rotation matrices. For this purpose, the relative ECEF vector is better suited. ECEF is a coordinate system with its origin at the centre of the earth. The ECEF x-axis pierces the Greenwich Meridian, while the y-axis intersects longitude +90°. The z-axis intersects the North Pole. The relative ECEF coordinate system will have the same orientation, but the origin will be centred at the base antenna.

ECEF output requires the following steps:

1. Export the absolute ECEF coordinates for the remote. This is performed from Write Coordinates within the Output Coordinates menu, as follows:
2. Enter a meaningful file name (e.g. REMOTE)
3. Select Epochs as the Source
4. For the latest version, make sure that the Time Format is GPS seconds of the week and NONE of the Correction Values are selected. Otherwise, make sure Corrected Time is NOT enabled.
5. Select XYZ-ECEF as the Coordinate Type

6. Use the ASCII Output Format
7. Horizontal and Vertical Units should be Meters
8. Do NOT apply the Geoid correction
9. Press the OK button

Export the ECEF coordinates for the base station. This is also performed from Write Coordinates. These coordinates will have the effects of S/A but so will the REMOTE coordinates from (a). They will cancel. Use the following steps:

1. Enter a meaningful file name (e.g. MASTER)
2. Select Single Point Solution (.gpb file) as the Source
3. Select XYZ-ECEF as the Coordinate Type
4. Use the ASCII Output Format
5. Horizontal and Vertical Units should be Meters
6. Do NOT apply the Geoid correction
7. Press the OK button
8. Select Master .GPB File
9. Press the OK button

Files for both the base and remote ECEF coordinates are now available. Each is given extensions of .XYZ. However, the coordinates need to be differenced to generate the relative ECEF vector. This is performed using the COMPARE.EXE program that is supplied with the Waypoint GPS Software. It should be located in the following directory:
C:\Program Files\WayptGPS

>   Compare is executed as follows:
>   Compare MASTER REMOTE outfile.xyz -neh

Do not use the –ecef option as it will compute Cartesian local level coordinates.
The file output.xyz will contain the ECEF coordinates for each GPS epoch.

ECEF velocities are not available, and the local level values must be used.

Moving Baseline Options
GrafMov has only one option. This is whether Moving Baseline Processing is enabled or disabled. By default, this option is enabled. Disabling it will allow GrafMov to process like GrafNav. However, it is suggested that GrafNav be used for this purpose.
This option can be found under Options > Moving Baseline Options. If moving baseline is enabled, the azimuth determination feature must also be selected, see Figure B1 below.
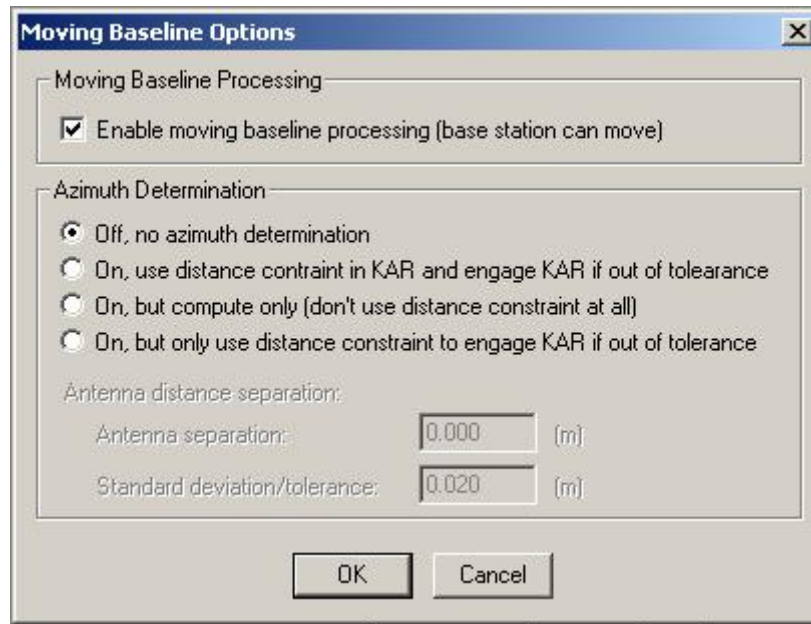
Figure B 1 - Moving Baseline Options

If the user knows the distance constraint between the two antennas, they can use the second option to ensure the stability while processing the data. The tolerance value is used to engage KAR if the distance between the two antennas becomes too far or close together. It may be a good idea to process with the azimuth determination off first to see the quality of the solution. If the quality is quite good then using the second or the fourth option will work. Selecting a lower tolerance may cause GrafMov to engage KAR continuously, resulting in a possible infinite loop or very long processing time. By default it is set at 2cm, but the user can change this after they have processed first without azimuth determination. Generally if the user just needs straightforward azimuth, or if the quality of the data is not good for using KAR, the third option should be used (compute only).

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