PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

Doppler -- European Datum Transformation Parameters for the North Sea [and Discussion]

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Doppler – European Datum transformation parameters for the North Sea

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The positioning of platforms and other constructions at distances greater than 100 km offshore is usually carried out by using the Navy Navigation Satellite System (N.N.S.S.) if high absolute accuracy is required. For legal and technical reasons, these positions must be related to the local onshore geodetic datum, usually European Datum 1950 (ED 50). The relation between satellite datum, World Geodetic Datum 1972, and ED 50 must therefore be determined with adequate accuracy. When accuracies of better than 5 m are required, inconsistencies occur owing to a systematic deviation between the British and Norwegian primary order triangulation. This paper gives a review of existing parameters, mainly for the Norwegian side, and describes how they were determined, how they should be used and how errors can be avoided.

Introduction

Statements concerning the practical use of geodetic reference systems covering areas larger than national territories have not always been easy. Only 20 years ago, it was largely only scientific (shape and size of the Earth) and military usage which was apparent. This picture has changed totally during the last 10 years, owing to the birth of a type of industrial geodesy. By and large, two major advances were responsible: the breakthrough in using satellite technology for positioning, navigation and oceanography, and secondly the discovery and exploration of oil, gas and mineral deposits beneath the oceans. It is a general assumption today that we live in a transitional period between a past where localized classical geodetic methods and systems were used and a future where more global alternatives, based on satellite and inertial technology, will dominate. Consequently, the important task confronting us today is how we can best assure continuity by fixing the relation between the classical and the constantly developing new systems. Past and future exploration of the oceans, especially in our case the North Sea and the Norwegian Sea, requires, as far as industry is concerned, a highly dynamic attitude from the geodetic society, a group whose work is traditionally considered as long-term. A change in attitude is vital to meet the new requirement: delivery of the right geodetic information at the right time.

Requirements

The relation between the classical reference systems used in the United Kingdom and Norway and the satellite Doppler datums has to be known with differing degrees of accuracy, according to the particular need. Broadly speaking a distinction between legal, technical and scientific requirements can be made.

As far as legal needs are concerned, i.e. median line determination and the positioning of geophysical data relative to this median line, the highest possible degree of accuracy is required. However, as will be shown, this accuracy must to some extent be a psychological one, when the main goal is a just partition of the oil and gas resources in agreement with international law. Datum shift parameters are necessary since the median line has already been defined in European Datum 1950. This is a fictitious line that can only be physically located with sufficient accuracy in the satellite Doppler reference system by the use of the Navy Navigation Satellite System.

The location of oil and gas resources is given by the positions (related to the Doppler reference system) of seismic data and cannot be fixed with 1 m accuracy.

For technical purposes, such as pipeline laying, the best possible relative accuracy is required between the starting point and the final point. Special attention has to be given to the datum shift if the starting point is determined in the satellite Doppler system and the final point is given in the local, land-based datum. Best possible datum shifts have also to be used when an integrated system has been used for hydrography.

For general mapping and long-term relocation purposes the following accuracy requirements have been stated relative to the Norwegian land based system, European Datum 1950 (N.O.U. 1975): pipelines, structures on the seabed, 10 m; permanent structures (if used as bench marks), 5 m; well heads, 10 m; detailed seismology near boundary lines, half the distance between shot points, i.e. 12 or 25 m; preliminary surveys of the seabed, 100–10 m (dependent on local topography); surveillance, as accurate as possible (25 m).

For scientific purposes, the best possible accuracy is usually required as a matter of principle. Examples of this are the positioning project connected with the Seasat A North Sea altimetry test project currently in progress, and the establishment of reference stations for local determination of the relation between the old and new datums.

Transformation purposes and two-dimensional navigation suggest a further need, the demand for geoidal height information which relates to European Datum 1950.

Shore based reference systems

The datum commonly used in Norway is the NGO 1948 system. The fundamental point is at the Oslo Observatory and the spheroid used is a modified Bessel ellipsoid (a = 6377492.018 m; f^{-1} = 299.153). The British datums OSGB 36 and OSGB 70 (SN) have their fundamental point at the Royal Greenwich Observatory at Herstmonceux and the Airy ellipsoid is used (a = 6377563.396 m; f^{-1} = 299.325) (Williams & Bordley 1976), these datums being established for national use. As the median line between Norway and Britain is defined in coordinates relative to European Datum 1950 (ED 50), it is quite logical to use this datum as a reference system for the North Sea. ED 50 is not, however, the ideal system, being limited in its accuracy.

European Datum 1950 is based on an adjustment made by the U.S. Army Map Service (A.M.S.) in the period 1948–50. The international ellipsoid (Hayford, a = 6378388 m, f^{-1} = 297) is used with Potsdam as the datum point. It is unfortunate that only the southern part of Norway was included and Britain was not covered.

The A.M.S. adjustment for southern Norway includes baseline measurements, angular observations and Laplace points from the period 1905–48. During the 1960s the triangulation network was extended towards the west and north of Norway mainly by the use of modern distance (tellurometer) and Laplace measurements. These triangulations were adjusted later, keeping all coordinates of the A.M.S. main adjustment in Norway fixed and connected with ED 50 by giving scale corrections to the new parts.

OSGB 70 (SN) is the result of a readjustment of the retriangulation which includes more distance measurements than the previous OSGB 36. This result was transformed to ED 50 by using the connection measurements made across the English Channel to France (Weightman 1975).

In 1953 the A.M.S. measured the distances between three of the Norwegian and three of the British triangulation stations with the use of the Hiran method. High accuracy was attained ($0.5–1.0 \times 10^{-6}$). However, unexplained discrepencies of approximately 12 m in the distances to Hellisøy meant that these measurements were not used to strengthen the connection (Jelstrup 1958). Doppler measurements during the 1970s have found systematic errors of about 8 m between the triangulations (N.O.U. 1975). Therefore, if the highest order of accuracy is required, one should distinguish between ED 50, Norwegian version, and ED 50, British version.

In 1947 it was decided to carry out a readjustment of the European network in three phases, phase 1 being concluded in 1974 and phase 2, including the majority of electronic distance measurements and Laplace observations, being completed in 1977. But new technology has overtaken the classical methods: any definitive result will have to include the Doppler satellite measurements which are available from the various observation campaigns. Moreover, an entirely new perspective has already been raised by the expected relative accuracy of 10 cm within 2000 km of the Navstar Global Positioning System which should become available during the next decade (Anderle 1978).

Satellite based datums

The establishment of a practical global reference system has been made possible by satellite technology. The Navy Navigation Satellite System (Black *et al.* 1976) has played a significant role in this new concept.

The Doppler satellite reference system is defined by the system in which the satellite orbit parameters are given (ephemeris). These parameters are based on the adopted station coordinates (station set) of a number of tracking stations and an adopted geopotential model (gravity model). These are passed on to the users in two ways: the predicted ephemeris is broadcast in real time and the precise ephemeris, which is confidential information, is distributed some months later. Consequently a terrestrial Doppler position is determined in the reference system which belongs to the ephemeris used, this being dependent upon the combination of station set and gravity model in use.

During the period 1968–75 the predicted ephemeris was in the APL Mk 4.5 system while the precise ephemeris, used for computation of Norwegian positions, was based (chronologically) on combinations of station-sets 8F, 9C and 9D and gravity models 9B and 10F. Station set 9D and gravity model 10F are known as the NWL 9D system.

The World Geodetic System 1972 (WGS 72) was introduced in July 1975. This global reference system is computed from data available before 1972 (Seppelin 1974), i.e. N.N.S.S.–Doppler data, Secor data, optical data from the worldwide satellite triangulation network (European stations in Tromsø, Hohenpeisenberg and Catania), S.A.O. Baker–Nunn camera data (European stations in Oslo, Helsinki, San Fernando and Athens), surface gravity data, astrogeodetic data and ground survey data for scale determination (i.e. the baseline Tromsø–Catania) (Anderle 1974).

From December 1975 the predicted ephemeris was based on the WGS 72 geopotential model and a newly defined station set (NWL 10D) for the four tracking stations. In addition, geoidal heights were given relative to the WGS 72 ellipsoid. No direct mathematical relation exists between positions computed in the APL Mk 4.5 system and those computed in the WGS 72 system. The position shift on a global basis varies by up to 15 m. Therefore if an accuracy of better than 5 m is required, it is recommended that those stations positioned before conversion to WGS 72 be repositioned (Holland *et al.* 1976).

Positions in the NWL 9D system, obtained by users of the precise ephemeris, can be converted mathematically to WGS 72 as there is a relation between NWL 9D and NWL 10F, the latter being consistent with the WGS 72 system (Anderle 1975; Ashkenazi *et al.* 1977). These relations represent a rotation and a scale correction of the NWL 9D system and the conversion to an ellipsoid with other dimensions.

The accuracy (1σ) of the precise ephemeris is estimated to be within 1–3 m, the predicted ephemeris being in the range of 5–10 m. Resulting multi-pass position accuracies are respectively of the order of 1 m and 2–5 m (Kouba 1976).

Determination of datum shifts for the North Sea

It is now possible to summarize some of the important factors concerning datum shift determination: there are different accuracy requirements for the parameters; there is a need for rapid information; ED 50 is only to some extent a homogeneous network; there are several Doppler satellite reference systems, with different degrees of accuracy.

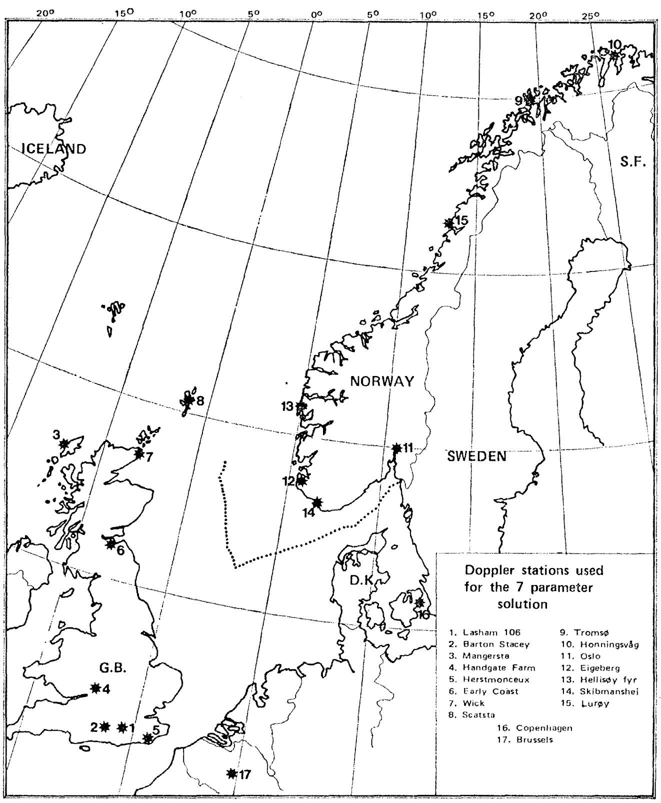


Figure 1

Some of the projects used for datum shift determinations can be described in brief.

Single point positioning by DMA (1971, 1974). Eight stations in Britain and seven stations in Norway were positioned with the Geoceiver and computed in the NWL 9D system by the U.S. Defense Mapping Agency. Accurate datum shift parameters could thus be attained at an early stage (figure 1).

The Frigg field positioning project (1976). The objective of this project was the determination of datum shift constants for the Frigg field area and the accurate positioning of a fixed oil platform relative to the median line (Blankenburgh *et al.* 1977, 1978). Two stations in Britain and three stations in Norway were positioned simultaneously, together with the platform. The translation parameters as determined from the five shore stations were averaged and accepted as the official datum shifts.

Reference station Trondheim (1975–8). In order to monitor the N.N.S.S. system and to check its long-term stability, measurements have been undertaken regularly at the same station (Moum 1978; Blankenburgh & Coldevin 1976).

The Statfjord A positioning project (1977). The determination of the fixed platform was required with an accuracy of better than 5 m relative to ED 50, Norwegian version. Results had to be available within 14 days after the start of the observations. The use of datum shift constants was avoided here by applying the simultaneous observation method (rigorous translocation) and by using the Trondheim station as a reference point (Blankenburgh 1977, 1978).

The European Doppler Observation Campaign, EDOC-2 (1977). EDOC-2 was mainly undertaken to establish a zero order network of reference points for Western Europe (Wilson *et al.* 1978). As three Norwegian and three British stations were included, the resulting transformation parameters ED 50–WGS 72 will be able to check the previously determined datum shifts.

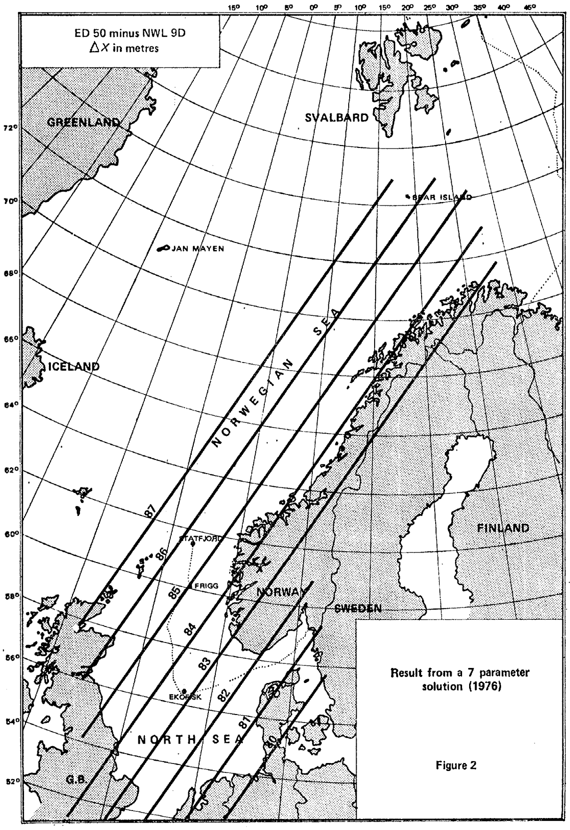
Datum shift parameters

The relation between ED 50 and Doppler satellite datum can be defined by seven parameters: three translations, three rotations and a scale factor. In 1976 the DMA positioning results of 16 stations (figure 1, excluding station 13) were referred to the NWL 10F system and transformation parameters were computed, neglecting the inhomogeneity of ED 50 (Mathisen 1976). The following significant results were attained, by least-squares adjustment, for the scale correction and the rotations:

scale (S)	-1.78 parts/10^6;
X-axis rotation (R_x)	-3.59 parts/10^6 ($-0.74''$);
Y-axis rotation (R_y)	3.30 parts/10^6 ($0.68''$);
Z-axis rotation (R_z)	6.06 parts/10^6 ($1.25''$).

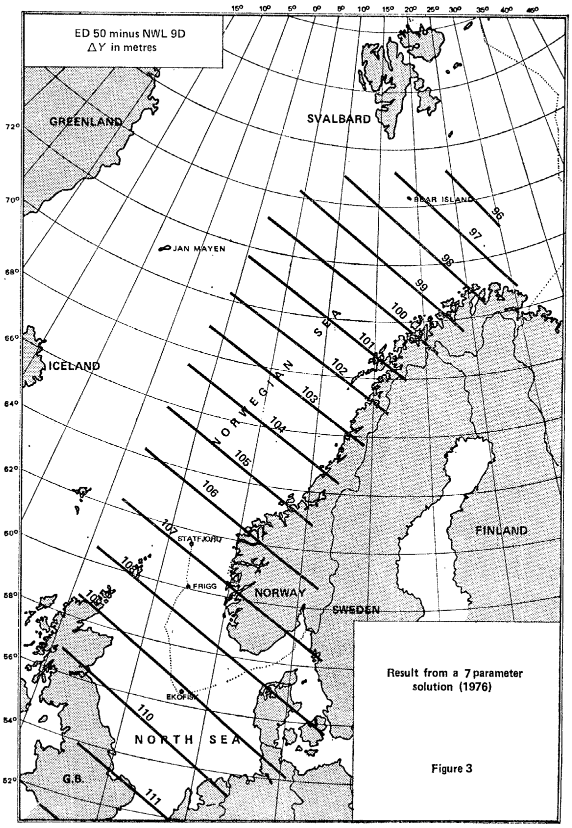
Figures 2, 3 and 4 give a graphical representation of the translation parameters NWL 9D to ED 50 (Blankenburgh & Mathisen 1976).

In 1977, additional information became available and the parameters were computed from 17 stations, which showed the following results for WGS 72 to ED 50 (O. Mathisen 1978, personal communication).



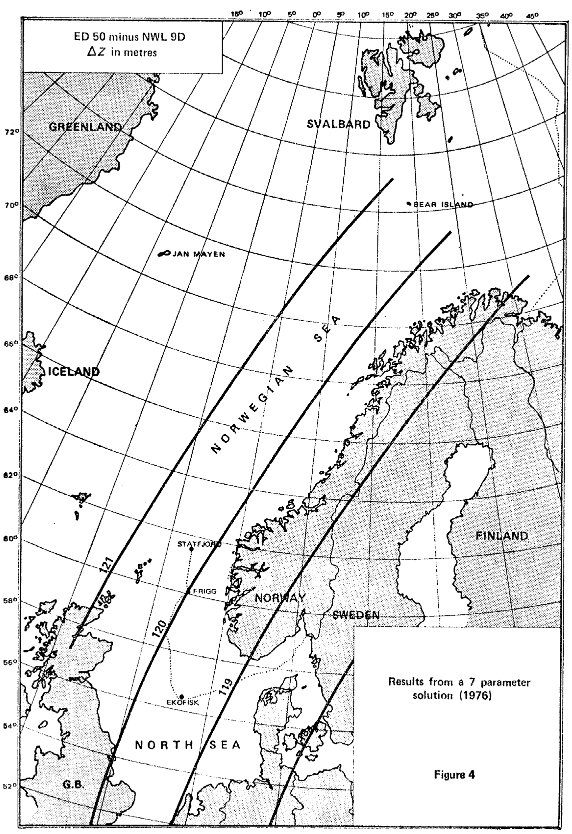
Result from a 7 parameter solution (1976)

Figure 2



Result from a 7 parameter solution (1976)

Figure 3



Results from a 7 parameter solution (1976)

Figure 4

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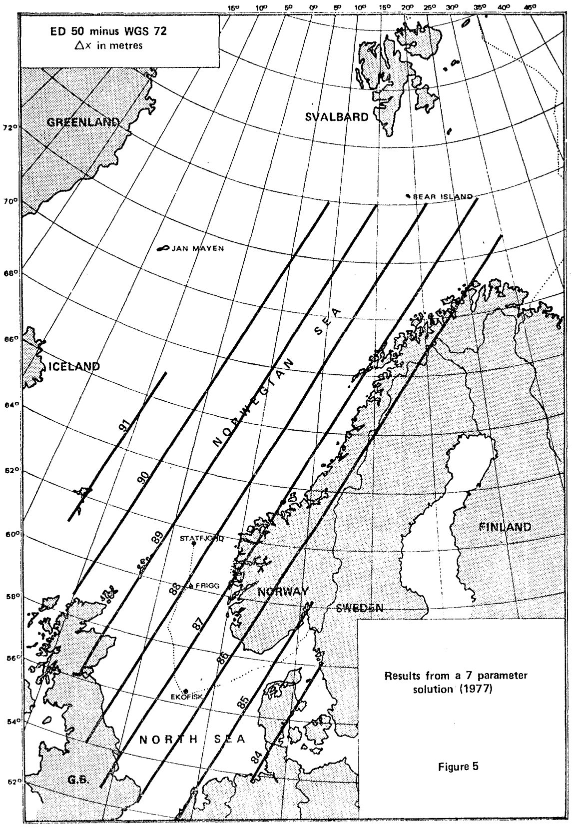
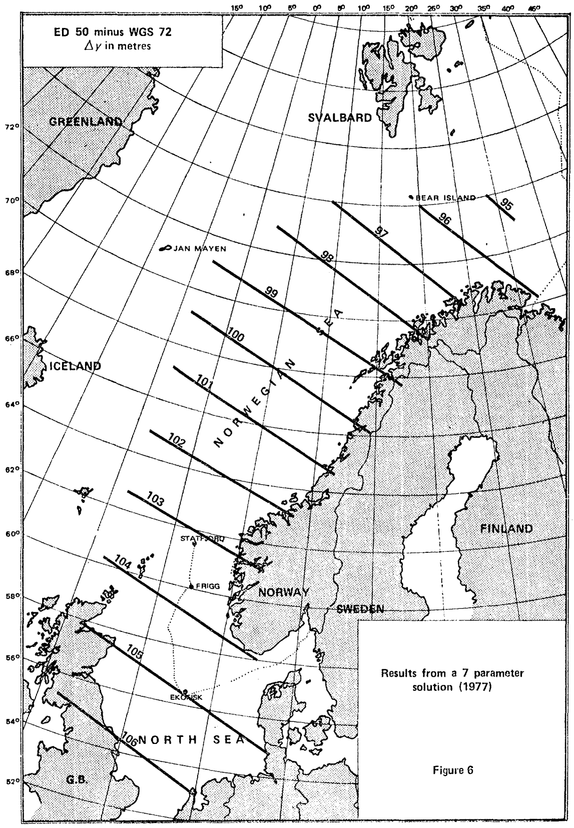


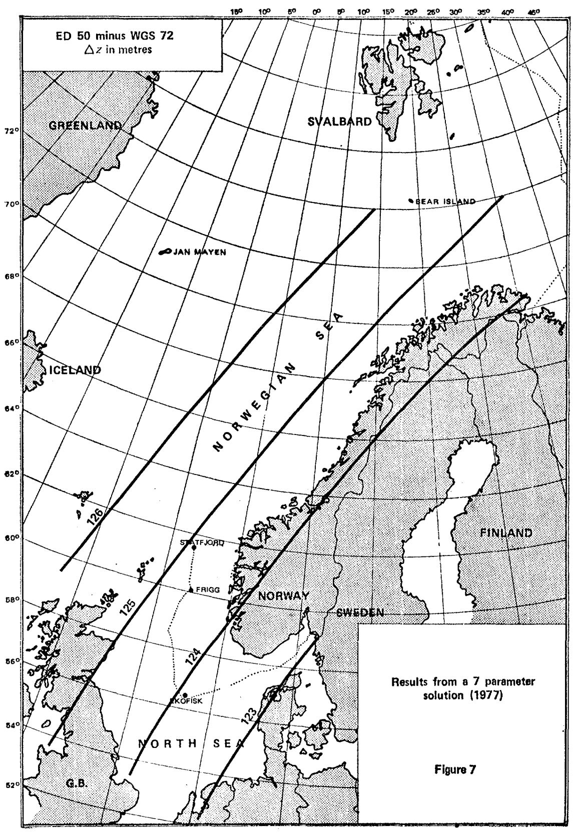
Results from a 7 parameter solution (1977)

Figure 5



Results from a 7 parameter solution (1977)

Figure 6



Results from a 7 parameter solution (1977)

Figure 7

$$S = -1.27 \text{ parts}/10^6$$
$$R_x = -3.07 \text{ parts}/10^6 \ (-0.63'')$$
$$R_y = 2.10 \text{ parts}/10^6 \ (0.43'')$$
$$R_z = 5.86 \text{ parts}/10^6 \ (1.20'')$$

The relation WGS 72 to ED 50 (in metres) can accordingly be computed from:

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix}_{\text{ED 50}} = \begin{pmatrix} X^1 \\ Y^1 \\ Z^1 \end{pmatrix}_{\text{WGS 72}} + \begin{pmatrix} 86.7 \\ 103.9 \\ 124.2 \end{pmatrix} + \begin{pmatrix} S & -R_z & R_y \\ R_z & S & -R_x \\ -R_y & R_x & S \end{pmatrix} \cdot \begin{pmatrix} X^1 - 3312594.5 \\ Y^1 - 218908.1 \\ Z^1 - 5366776.8 \end{pmatrix}.$$

A graphical representation is given in figures 5–7. Datum shifts for WGS 72 to ED 50 in curvilinear form are given in figures 8 and 9.

By taking the corrections for scale and rotation into account, the r.m.s. of the residuals for the 17 stations used was reduced from 2.3 m for X, 3.2 m for Y and 1.5 m for Z to, respectively, 1.3, 1.3 and 1.3 m. The 7 parameter solution gives the following datum shifts for the main offshore fields (metres).

	X	Y	Z
Ekofisk	86.5	104.9	123.9
Frigg	87.8	103.8	124.6
Statfjord	88.2	103.3	124.8

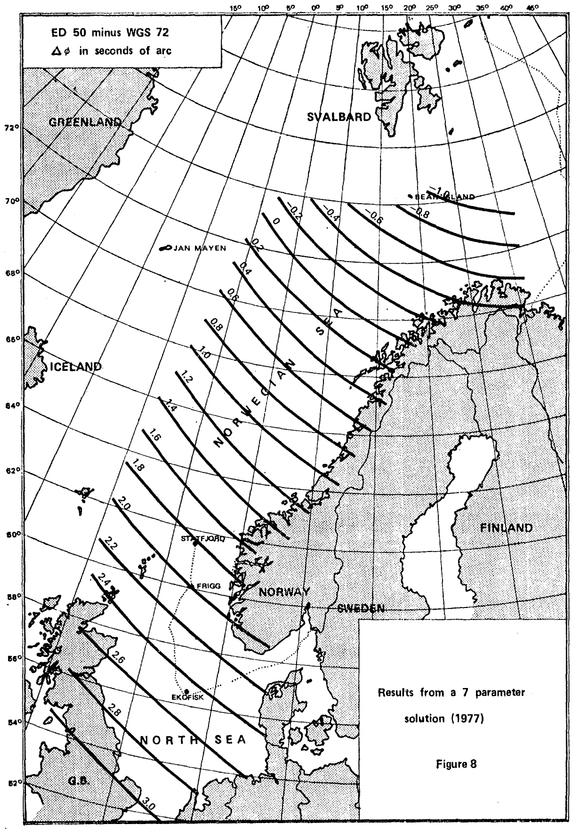
Local distortions of the ED 50 are averaged. The datum shifts that are recommended by the official authorities south of 62° N are now (Nesbø 1977): $X = 87$; $Y = 105$; $Z = 124$. Though these constants have limited accuracy ($\sigma \approx \pm 3$ m), they are more suited for use in the North Sea than the general values ($X = 84$, $Y = 103$, $Z = 127$), which have been used by many operators before. The latter values are derived from eight stations that are representative for ED 50 as a whole. The corresponding accuracy is consequently much less: $\sigma \approx \pm 10$ m (Seppelin 1974).

At the shore stations, the datum shifts have been determined with an accuracy of $\sigma \approx \pm 1$ m relative to the local ED 50. Within 200 km from these reference stations the influence of rotations and scale are at maximum 1.8 m with respect to the parameters above. Therefore, when highest accuracy is required, these local values can be advantageously used while considering the ED 50, Norwegian version, and the ED 50, British version.

The values for some representative stations (figure 1) are shown in table 1.

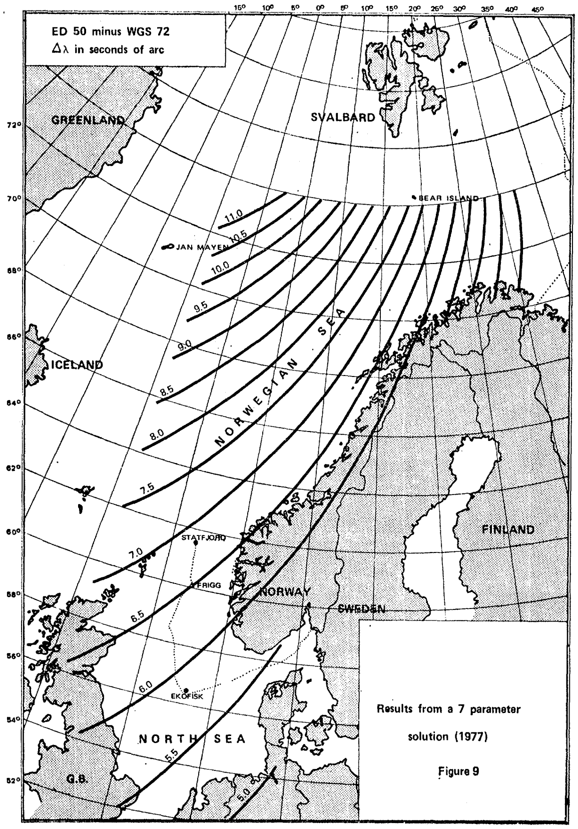
Table 1. Datum shift values

	X/m	Y/m	Z/m	
Early Coast (6)	89.1	106.0	124.4	
Wick (7)	89.8	104.6	124.5	
Scatsta (8)	91.5	105.4	125.8	
Eigeberg (12)	82.9	105.4	121.3	
Hellisø (13)	83.7	105.5	121.2	
Skibmannshei (14)	83.6	104.9	121.4	
averages				
northeast Britain	90.1	105.3	124.9	(ED 50 British)
southwestern Norway	83.4	105.3	121.3	(ED 50 Norway)



Results from a 7 parameter solution (1977)

Figure 8



Results from a 7 parameter solution (1977)

Figure 9

The accuracy of the datum shifts from the 7 parameter solution for this area (X_7, Y_7, Z_7) can be estimated by comparing them with the corresponding local values (X_L, Y_L, Z_L). Assuming $\sigma = \pm 1$ m for these values gives $\sigma_{x7} = \pm 2.5$ m, $\sigma_{y7} = \pm 1.7$ m and $\sigma_{z7} = \pm 2.1$ m.

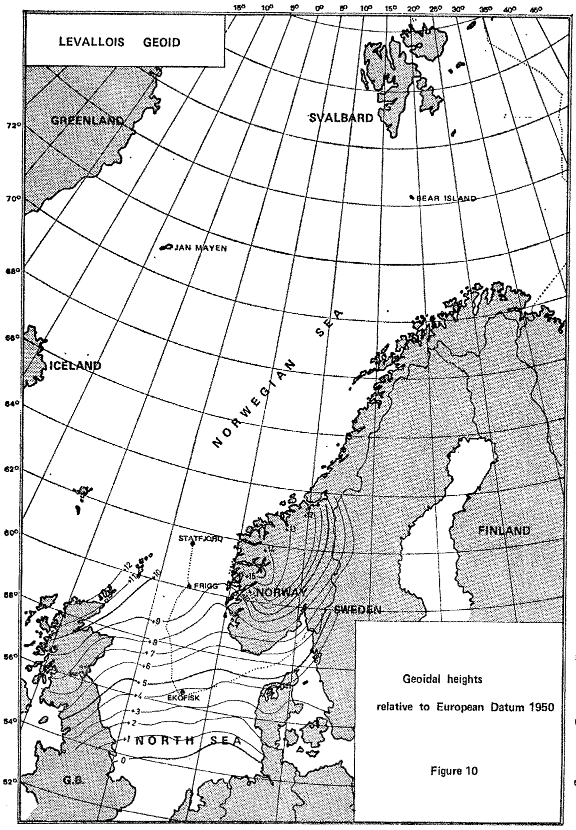
However, it should be emphasized that the method that can be most highly recommended for use with the predicted ephemeris is Doppler positioning in the simultaneous mode (translocation, short arc, etc.), thereby avoiding datum shifts entirely (Wells 1976).

Geoidal heights

So far no attention has been paid to the relation between the physical reference system, the geoid, and the mathematical one, the ellipsoid. When transformations have to be made from the curvilinear system (ϕ, λ, h), which is normally used in practice, to the geocentric system (X, Y, Z), it should be borne in mind that h is the height above the corresponding ellipsoid. The height above the geoid can be measured directly with some precision as the sea surface topography corresponds to some extent with the geoid. However, the geoid–ellipsoid separation can only be determined from extensive and complicated investigation.

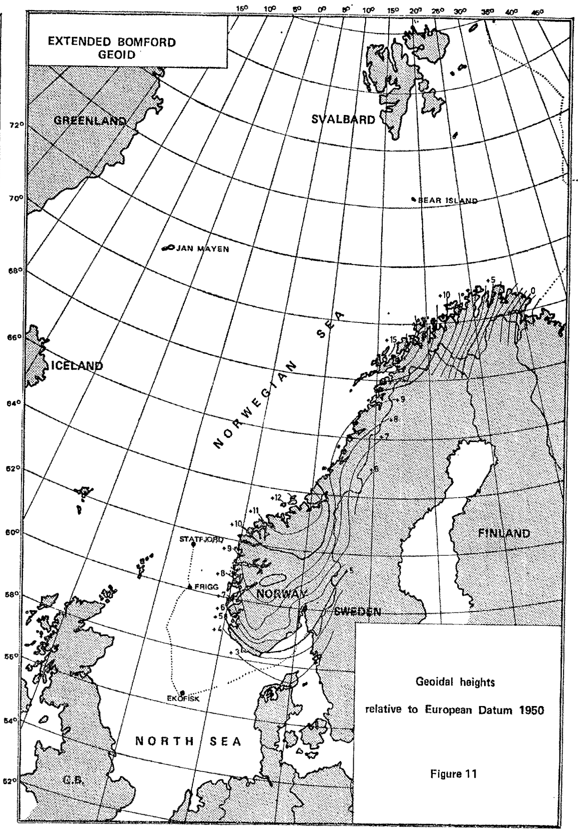
The relation between the WGS 72 ellipsoid and the WGS 72 geopotential model can be determined mathematically. However, this model is not available for the usual offshore users so the geoidal height information has to be taken from the existing global WGS geoidal height map which only has limited accuracy, especially in the northernmost areas.

Recent efforts have been directed towards the construction of a geoidal height map directly



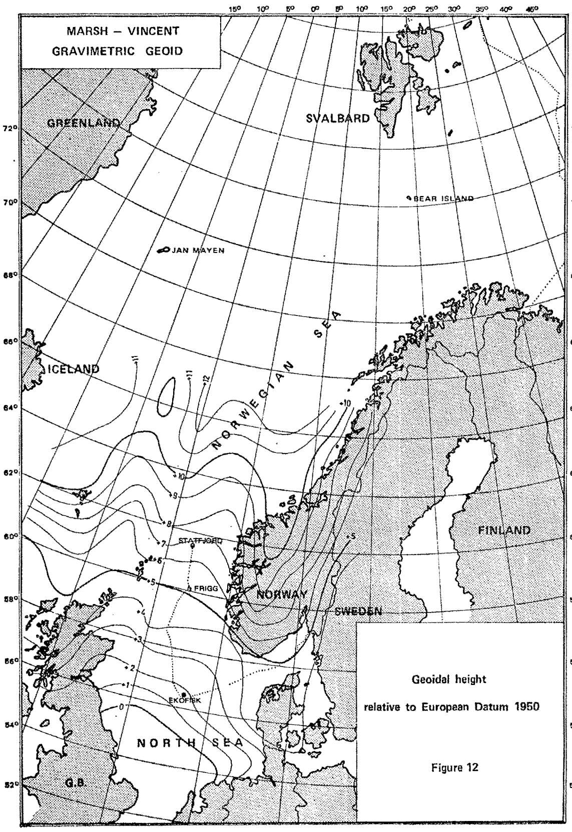
Geoidal heights relative to European Datum 1950

Figure 10



Geoidal heights relative to European Datum 1950

Figure 11



Geoidal height relative to European Datum 1950

Figure 12

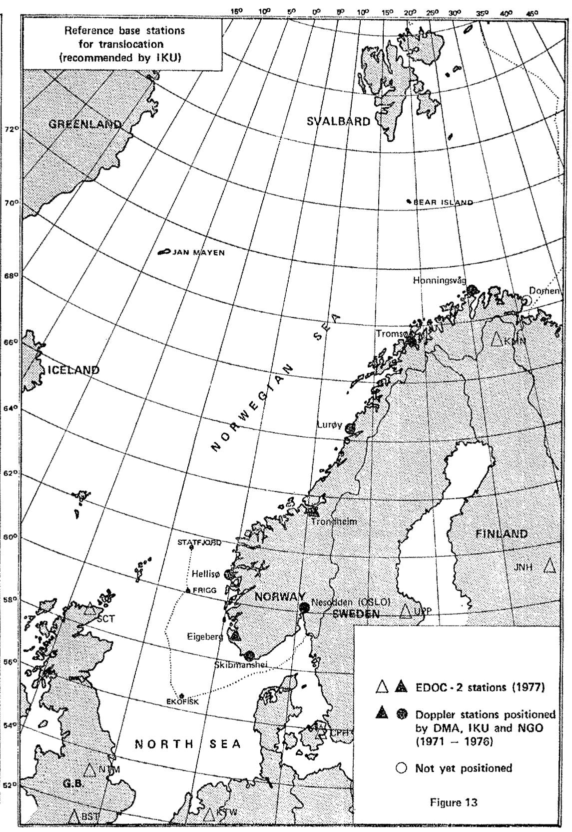


Figure 13

related to ED 50 for the whole Norwegian continental shelf area. The results to date can be summarized as follows:

(i) The Levallois geoid up to 60° N (figure 10).

(ii) The Bomford geoid, provisionally extended by the Geographical Survey (O. Mathisen) to cover the land area (figure 11).

(iii) The Marsh–Vincent geoid transformed to ED 50, covering land and sea areas up to 67° N. The transformation parameters were derived from a comparison of the gravimetric geoid with the Levallois geoid (J. Marsh 1977, personal communication) (figure 12).

A comparison of these maps gives some impression of the uncertainties. The accuracy of the geoidal height information for the marine areas is estimated to be $\sigma = \pm 2$–3 m.

The Grim II geoid is also transformed to ED 50. The datum shift parameter formula as given above was used in the definition of ED 50 (G. Weber 1978, personal communication). Results are not yet available.

Conclusion

The following conclusions may be drawn concerning the use of the above mentioned datum shift parameters for the North Sea.

(1) For *legal* requirements a 7 parameter solution should be used, based upon all the available positioning information from shore stations around the North Sea ($\sigma \approx \pm 2$ m).

(2) For *technical* requirements the officially recommended datum shift parameters should be normally used for the area south of 62° N ($\sigma \approx \pm 3$ m). Further north, the transformation formula from the 7 parameter solution could be used. If best possible accuracy is required relative to the local datum, local values ($\sigma \approx \pm 1$–2 m) should be used. However, the translocation method is preferable as it avoids any error in the datum shift.

(3) For *scientific* requirements the results of the Edoc-2 campaign should be used in combination with a critical analysis of the triangulation networks involved ($\sigma \approx \pm 1$ m).

(4) For transformation of geocentric coordinates and for two-dimensional navigation purposes, either the WGS geoidal height map ($\sigma_h \approx \pm 5$–10 m) or the ED 50 maps could be used, depending on the accuracy requirements ($\sigma_h \approx \pm 2$–3 m).

(5) If the translocation method is used, attention should be given to the quality of the reference station coordinates. The selected stations, which are recommended for use, are shown in figure 13 (Blankenburgh 1976). These reference stations will also determine the relation between present and future datums.

The author wishes to thank the following scientists for their assistance in the preparation of this paper: O. Mathisen, at present director of the Institute of Computer Sciences, Agricultural University, Ås, for his helpful suggestions and for making the 7 parameter solutions available; J. Marsh, Goddard Space Flight Center, for making the geoidal information available; G. K. Hygen, Continental Shelf Institute, for preparing the geoidal contour charts at the desired scale and projection. Finally, the Geographical Survey of Norway requires recognition for its cooperation in the Doppler positioning and geoidal height projects.

References (Blankenburgh)

Anderle, R. J. 1974 Transformation of terrestrial survey data to Doppler satellite datum. *J. geophys. Res.* **70** (35).

Anderle, R. J. 1975 Error model for geodetic positions derived from Doppler satellite observations. *NSWC/DL tech. Rep.* no. TR-3368.

Anderle, R. J. 1978 Geodetic applications of the Navstar Global Positioning System. In *Second Int. Symp. on Problems Related to the Redefinition of North American Geodetic Networks*, Washington. (In the press.)

Ashkenazi, V., Gough, R. J. & Sykes, R. M. 1977 Satellite-Doppler Positioning. Seminar, University of Nottingham, Dept of Civil Engineering.

Black, H. D., Jenkins, R. E. & Pryor, L. L. 1976 *The Transit system*, 1975. Technical Memorandum APL/JHU TG 1305.

Blankenburgh, J. C. 1976 *The importance of satellite geodesy for activities on the Norwegian continental shelf.* Continental Shelf Institute, Report P-118-F21.

Blankenburgh, J. C. 1977 *Statfjord A – satellite positioning project.* Continental Shelf Institute, Service report O–57.

Blankenburgh, J. C. 1978 *Some achievements and research projects based on the use of satellites.* Continental Shelf Institute, Report P-118-F42.

Blankenburgh, J. C. & Coldevin, A. J. 1976 *Results of Dopplersatellite test measurements in Norway: how consistent was APL Mk 4.5 Datum?* Continental Shelf Institute, Report P-118-F20.

Blankenburgh, J. C., Fossum, B. A., Torsen, H. O. & Østerholt, P. A. 1977 Norwegian marine geodetic projects. *Mar. Geod.* **1** (2), 125–145.

Blankenburgh, J. C. & Mathisen, O. 1976 *Datumshift-constants from TRANSIT Dopplersatellite datum to European Datum 1950.* Continental Shelf Institute, Report P-118-F19.

Holland, B. B., Eisner, A. & Yionoulis, S. M. 1976 The effect of WGS-72 geopotential in NNSS on station surveys. In *AGU Fall Annual Meeting*, San Francisco, 6–10 December.

Jelstrup, G. 1958 Første ordens triangulering og dens geodetiske problemer. Lecture, 14 April 1958, Geographical Survey of Norway.

Kouba, J. 1976 Doppler levelling. *Can. Surv.* **30** (1), 21–32.

Mathisen, O. 1976 *Transformation from Doppler NWL-10F Datum to Norwegian European Datum.* Continental Shelf Institute, Report P-118-F20, F21.

Moum, J. (ed.) 1978 *IKU surveys and related activities* 1976–1977. Report, Continental Shelf Institute.

Nesbø, I. 1977 *Positioning of Ekofisk by Satnav.* Preliminary report, Geographical Survey of Norway.

N.O.U. 1975 *Navigation/positioning on the Norwegian Continental Shelf.* Norwegian Official Reports, Ministry of Industry and Handicraft, Report no. NOU 1975: 62.

Seppelin, T. O. 1974 The Department of Defense World Geodetic System 1972. *Can. Surv.* **28** (5), 496–506.

Weightman, J. A. 1975 Doppler ties to European Datum and the European geoid. Commonwealth Survey Officers Conference 1975, paper no. B4.

Wells, D. A. 1976 Concept of satellite Doppler positioning using translocation techniques. In *Proceedings Int. Geod. Symp. on Satellite Doppler Positioning*, Las Cruces.

Williams, W. B. P. & Bordley, R. F. 1976 The Median Line and position fixing in the North Sea. *Automation in offshore oilfield operation*, Bergen.

Wilson, P., Boucher, C., Paquet, P. & Dejaiffe, R. 1978 EDOC-2: status report with a summary of some preliminary results of second European Doppler Observation Campaign. In *Second Symposium On the Use of Artificial Satellites for Geodesy and Geodynamics*, Athens.

Discussion

P. G. Sluiter (*c/o Shell, E.P./12, P.O. Box 162, The Hague, Netherlands*). Who are the authorities that established the 'official' datum shifts south of 62° N ($\Delta X = +87$ m, $\Delta Y = +105$ m, $\Delta Z = 124$ m)?

J. C. Blankenburgh. These values are official in Norway, as reported by the Geographical Survey.

(Subsequent discussion with Mr Bakkelid and Mr Leppard confirmed that the above shifts to convert from WGS 72 to European Datum 1950 in the North Sea south of 62° N have been accepted by Norway, the United Kingdom and also Denmark for geophysical exploration only, not for precise positioning. The values depend on data available in 1976, and should be dated as such.)

P. Melchior (*Observatoire Royal de Belgique, Brussels, Belgium*). Platforms at sea would probably move more than the 'decimetres' quoted in the paper.

P. G. Sluiter. Do I understand it correctly that platforms firmly attached to the seabed, e.g. by piles, would more move than the Earth-tide on land?

P. Melchior. Yes, this is due to crustal movements caused by the changing surface load of the water mass. I believe that these movements could be in the 1 m range.