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Pilot Weather Advisor System

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We are currently developing a system called the Pilot Weather Advisor, which will shortly provide pilots with graphical weather depictions using color laptop computers, and eventually will be a part of an advanced technology flight management system. Through the use of broadcast satellite communications the PWxA system provides near real-time graphic depictions of weather information in the cockpit of aircraft in flight. The purpose of this system is to improve the safety and utility of general aviation and commercial aircraft operations. The concept of providing pilots with graphic depictions of weather conditions, overlaid on maps with geographical and navigational information, is extremely powerful. We have demonstrated the feasibility of using satellite communications to provide significant amounts of weather data to aircraft in flight. We have also demonstrated the usefulness of providing weather data in graphic form, which increases efficiency and decreases pilot workload.

Introduction

CURRENTLY pilots can obtain verbal and textual weather information in flight through the use of voice communications and ARINC Communications Addressing and Reporting Service (ACARS). Dash and Crabill[1] contend that these procedures for acquiring and assimilating weather information require undue efforts on the part of the pilot, particularly under adverse weather conditions, and that an automatic broadcast is essential. They also contend that this weather data should be provided in a graphical format. Scanlon's[2] studies on the impact of graphic weather products on aircrew decision processes indicate that verbal or textual data systems are extremely difficult to visualize. This is rather alarming considering that pilots often make critical judgements based on this information. The Pilot Weather Advisor (PWxA) system has been designed with this important factor in mind. The idea is to provide easy to understand graphic products to aid flight crews in making strategic decisions enroute.

System Overview

The PWxA system has three functional task subsystems: 1) the ground processing system, 2) the satellite communications system, and 3) the airborne processing system. These systems and their interaction are illustrated in Fig. 1.

Ground Processing System

Weather data is first collected and analyzed at a central location. This data includes National Weather Service (NWS) radar summary, surface aviation observations, terminal forecasts, severe weather watch boxes, and lightning. The analysis of the data includes extraction of relevant portions of the data, data compression, and encoding. The analysis and decoding of the surface observation and terminal forecast data are depicted in Fig. 2. The observation and forecast elements are converted to meteorological condition displays that have shape and color translations to be shown on the aircraft display, which are discussed below.

Satellite Communications System

It may be noted that the PWxA system is a broadcast receive-only system. All the information for the entire Continental U.S. (CONUS) is broadcast over the satellite system and received by all aircraft within the satellite's footprint. The onboard processor selects the data needed for display based on the pilots actions described below. No two-way interaction between the aircraft and the ground system is required. This means that the communications system of the PWxA remains transparent to the pilot, and an unlimited numbers of users automatically receive all the data at the same time. On the other hand, in a request reply system some sort of time lag will be inherent, which is totally unacceptable for time critical information like weather. This time lag will grow when the weather is bad, as many users will have an urgent need for the data. Another advantage of the broadcast system over a request/reply system is that the pilot may not always have the knowledge or time to request a specific piece of information that may be critical for safe flight operations.

In the PWxA data is received by the antenna and satellite communications receiver on board the aircraft, and transferred via a RS-232 interface to the airborne processing system on the aircraft. During phase I (Ref. 3) of this project, we used a Qualcomm's OmniTRACS Mobile Communications System. This system consists of a mechanically steered antenna, and an Omnitracs Communications Unit. The data was

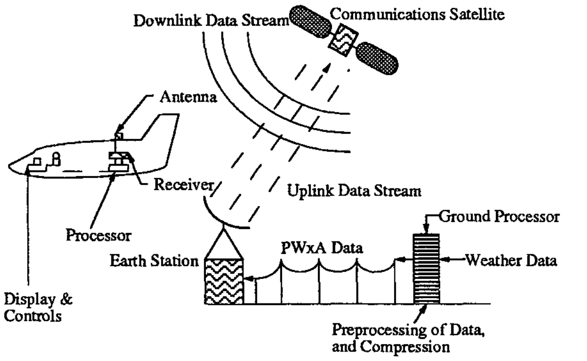

Fig. 1 Pilot Weather Advisor concept.

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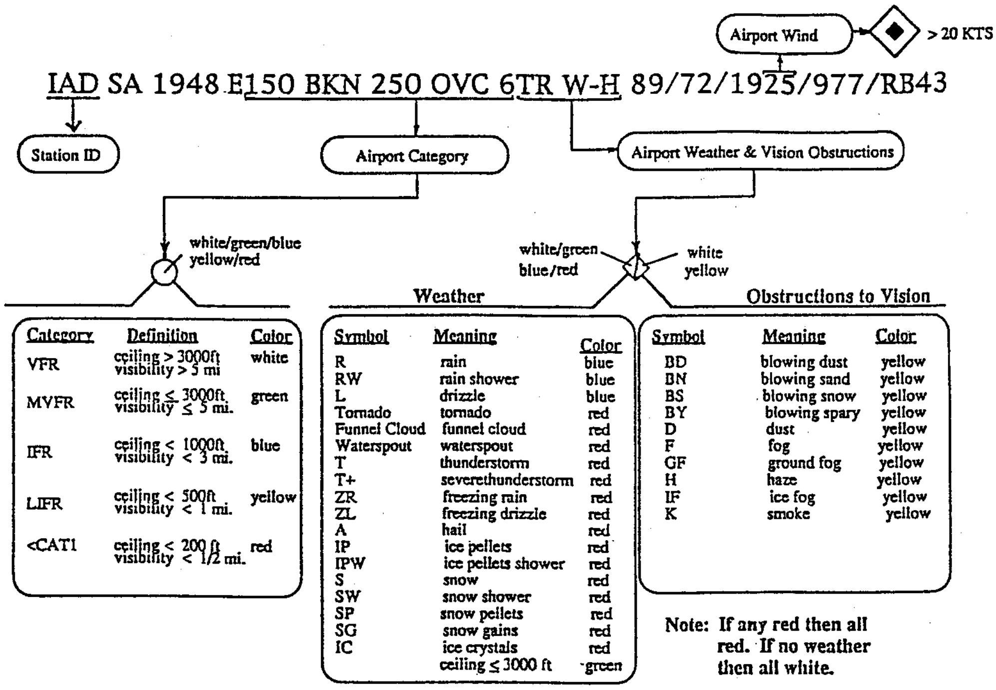

Fig. 2 Analysis of surface observation and terminal forecast data.

received using a Comstream Modem at 9600 bits per second (bps). We are currently working on an aerodynamic Ku-band microstrip antenna. The communication system has a low level of fault tolerance built into it, to detect and correct any faulty operations.

Airborne Processing System

The airborne system processes the ground system data into the required airborne display formats and stores these data for later use. The control system allows the pilot to retrieve and display the information in a user friendly manner without being distracted from the primary functions of piloting, navigation, and communication. The airborne system needs minimal interaction from the user, and is fairly fault tolerant.

The initial map displayed is a CONUS map with about 100 surface observation sites. Surface weather, ground based weather radar, and other products described below, can be shown on this map at the pilots discretion. The pilot then inputs the following information: 1) the departure airport, 2) the destination airport, and 3) an alternate airport.

With these inputs, a suitably scaled trip map, just accommodating the route, can be displayed, North-up, again showing about 100 sites. The global positioning system (GPS) or LORAN interface supplies the position of the aircraft. The system utilizes this positional information to display the aircraft position on the CONUS, TRIP, or LOCAL map, whichever is selected. These maps are updated every minute to display the map in accordance with the current aircraft position.

Currently, the plan is to update weather data at least four times every hour, although the system does have the capability of updates every 7 min. A display system looping function can depict the trend of the weather categories. The display is always North-up, and a history of the aircraft track information is an option. All the maps are displayed using a map projection that renders great circles as nearly straight lines, and very nearly shows areas in their true relative sizes.

Displays

The basic display strategy is to show the pilot past, present, and expected locations of those weather elements that the pilot needs to be aware of in order to make an informed strategic plan for the intended flight, and to monitor these elements during the flight, with minimum workload.

The weather elements to be displayed in map format are 1) the airport category, 2) the airport weather, 3) ground weather radar, 4) lightning locations, and 5) forecast locations and times of severe convective weather.

The airport category symbol depicts the five FAA ceiling and visibility combinations that define the conditions for visual flight rules (VFR), marginal VFR (MVFR), instrument flight rules (IFR), low IFR (LIFR), and less than LIFR (<Cat 1) as shown in Fig. 2. These five categories have precise legal connotations to pilots operating in less than perfect (unlimited ceiling and visibility) weather conditions. Pilots must ensure that the existing and forecast airport categories for their departure, destination, and alternate airports are appropriate to the planned flight in a legal sense as defined by the FAA. The pilot must also ensure that the weather conditions will permit the flight to be conducted safely and comfortably, within the limitations of the aircraft.

The airport weather symbol provides the pilot with a first-order assessment of the existing and forecast weather conditions at airports in terms of the presence of hazardous weather such as thunderstorms, tornado, hurricane, or any solid precipitation, or winds at the surface greater than 20 kt, liquid precipitation, or any obstruction to vision such as fog, haze, blowing snow, dust, etc., also shown in Fig. 2.

In addition, displays of precipitation aloft as detected by the NWS ground weather radar in three levels of intensity are shown together with lightning location data from airborne or ground-based detectors. The anticipated locations and times of severe convective weather are shown by "weather watch boxes" as predicted by the NWS.

These display elements are combined into the two map-type data sets shown in Figs. 3 and 4, to illustrate to the pilot what the legal definition of the weather is and what weather elements are causing these conditions, without requiring the pilot to select the individual display elements. The purpose is to keep the operation of the PWxA as simple as possible during flight operations. This is particularly important for single pilot IFR operations, and especially so in situations of adverse weather conditions.

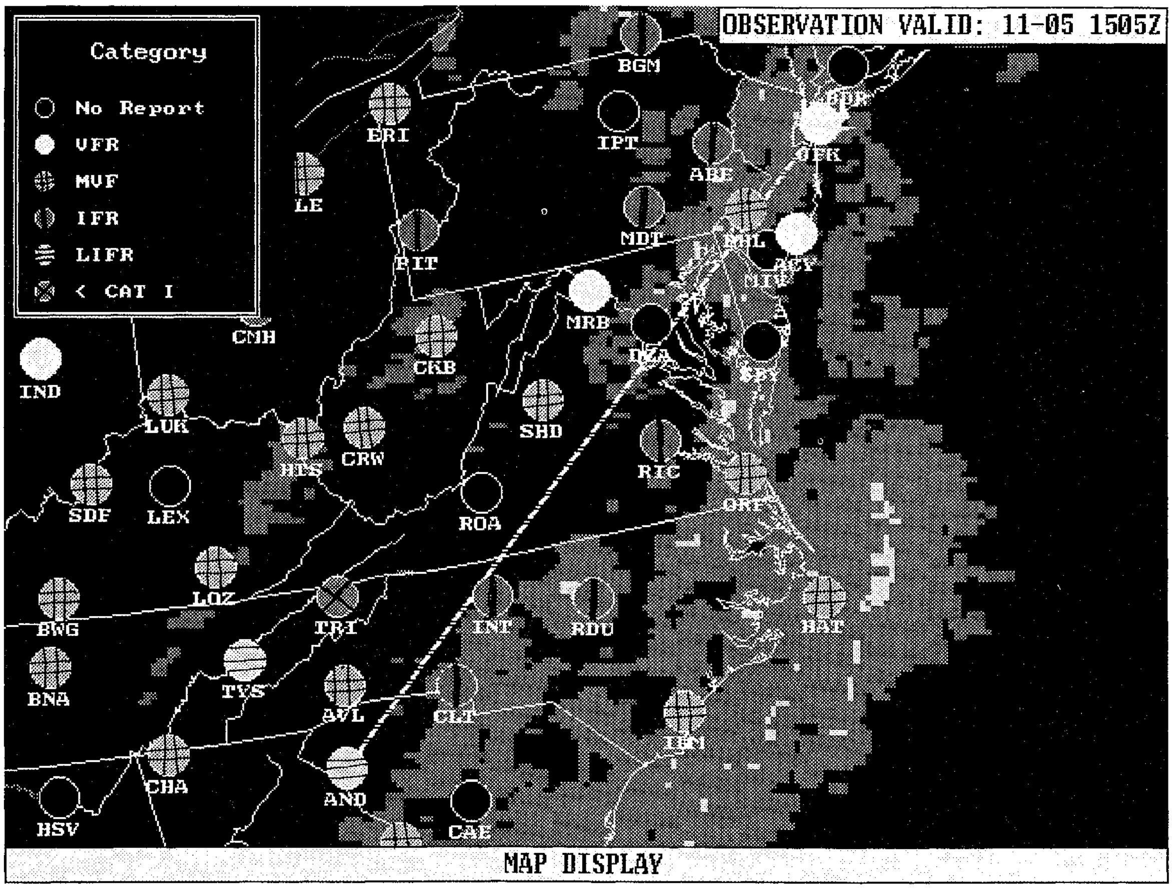

Fig. 3 Trip map with airport category, and ground weather radar.

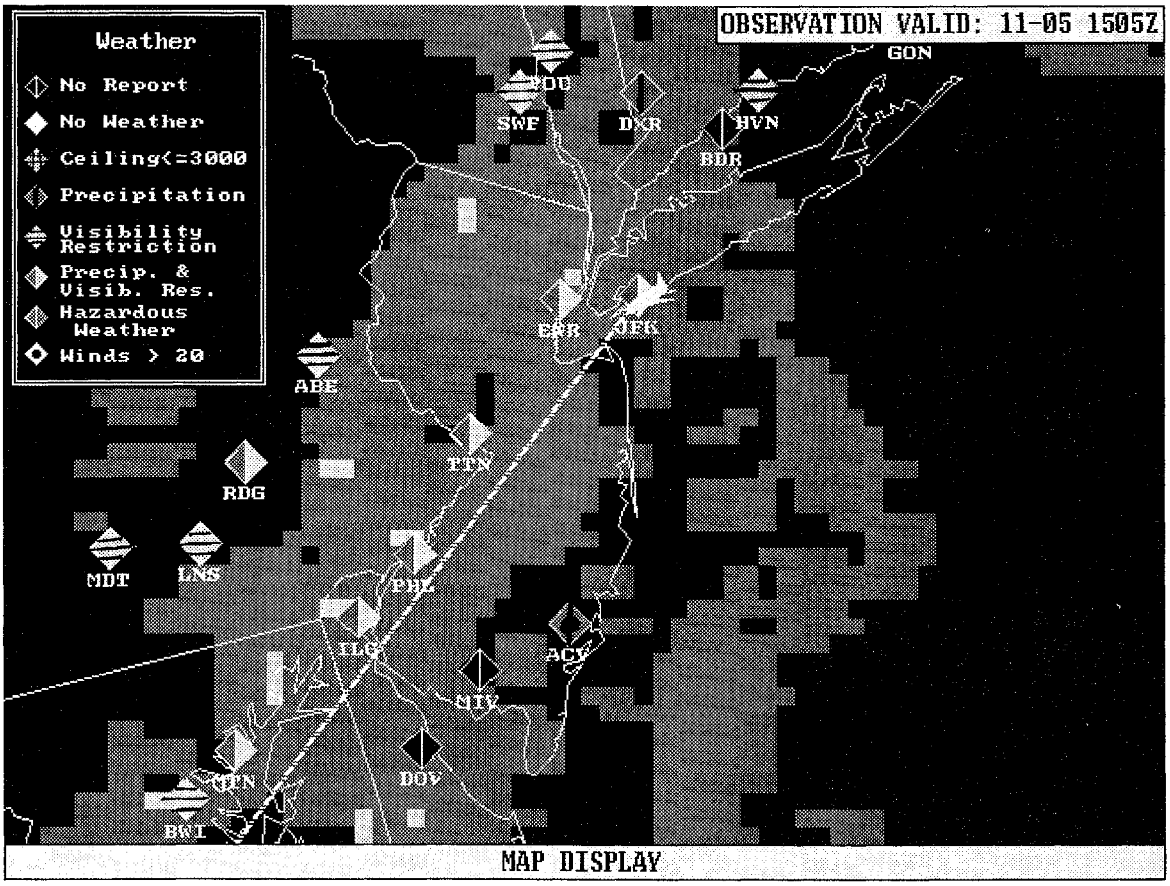

Fig. 4 Local moving map with airport weather, and ground weather radar.

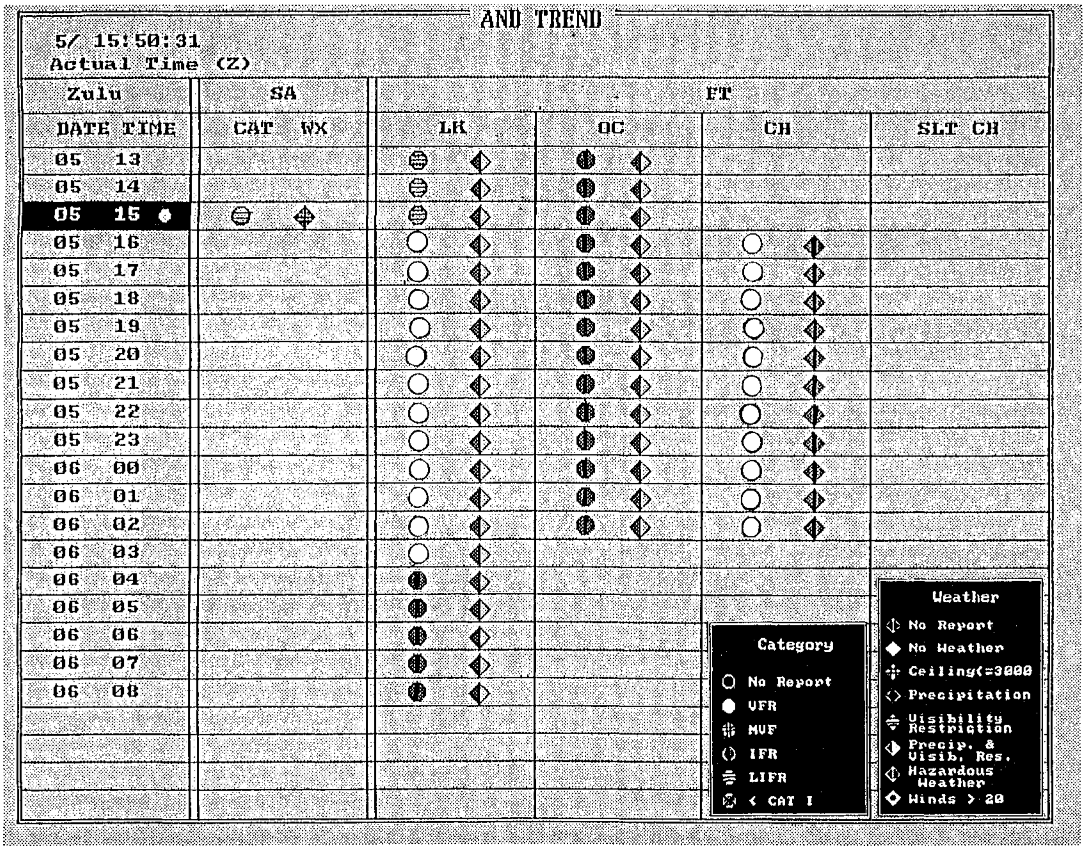

Fig. 5 Trend depiction for Anderson, South Carolina.

The trend depiction in Fig. 5 shows for each hour, the listing of the airport category and airport weather symbol for each airport with surface observations. In addition, for airports with aviation terminal forecasts, the airport category and weather symbols are shown at each hour for the likely, occasional, chance, and slight chance parts of the forecast. Thus, the actual airport category and weather can be compared with the forecast airport category and weather at a glance without having to sort through voluminous alphanumeric products. If there are serious adverse discrepancies, the pilot has a basis for forming an estimate of the likely weather.

Future Enhancements

The PWxA system as described here is designed to provide basic weather information to the enroute pilot for strategic planning purposes. The system could also be used preflight, to quickly obtain an overall view of the weather without having to read pages of alphanumerics. In the future, the depictions could be displayed directly on navigation moving maps to provide a powerful integrated weather/navigation flight management tool. As the NWS modernization program unfolds, we will be able to provide near real-time data such as winds and temperatures aloft, three-dimensional radar products, automated pilot reports (PIREPS), on turbulence and icing, etc. With slightly more computation power, we may even be able to provide trip profiles, by showing cross sections of the trip with the winds, temperatures, and radar. Our satellite communications link could be stretched to update data eight times an hour instead of four. The limiting factor is not the PWxA system, but the weather acquisition and dissemination systems.

We have also begun considering how to use this information with an expert system to provide a continuous recommendation to the pilot for the course and altitudes he should fly, based on both the current observations and the forecast. We believe the forecasts have to get considerably better, and the expert system formulation will have to get much more complex before such a system can provide reliable answers.

We demonstrated the PWxA concept in flight in 1991 on a Piper Malibu aircraft as part of our phase I work on a NASA Small Business Innovative Research contract.[4] We are presently in phase II of that contract, developing the operational prototype.

Acknowledgments

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