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A CEILING AND VISIBILITY PREDICTION SYSTEM SUITABLE FOR ANTARCTIC FLIGHT OPERATIONS

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1. INTRODUCTION

Aviation forecasts of ceiling and visibility are of vital importance to the aviation community worldwide, with pilots relying on these forecasts to inform them of the landing conditions expected at their destination. These forecasts become especially critical for flights into remote locations with rapidly changing weather conditions, primitive aircraft navigation systems, and few divert landing options (e.g., Antarctic research stations). A ceiling forecast gives the height of the cloud base above the runway and a visibility forecast gives the visual range along the runway. Both are key components of Terminal Aerodrome Forecasts (TAFs) issued four times per day by operational forecasters. Several studies have shown that 3-hour and 6-hour ceiling and visibility forecasts are generally not better, and often worse than persistence (Zurndorfer et al. 1979; German and Hicks 1981; Goldsmith 1993). This performance is generally attributed to the difficulties in predicting cloud cover. In a more recent study, Dallavalle and Dagostaro (1995) found no signs of improvement in recent years for 6-hour ceiling and visibility forecasts. If TAF ceiling and visibility forecasts can be improved, this advancement would directly influence both flight safety and efficiency.

U.S. Antarctic Program forecasters issue TAFs for research stations (e.g. McMurdo and South Pole) and a large number remote field camps four times per day (0300, 0900, 1500 and 2100 UTC). For each TAF location, a forecaster manually analyzes the available data and generates the forecasts. The amount of relevant data available for individual TAF locations generally is highly variable. TAFs generated for research stations and remote field camps not only provide critical information to pilots, but also play a key role in the near-term planning of flight operations.

This paper describes an objective aviation ceiling and visibility forecast system, and the procedures necessary to modify this system to generate TAF forecast parameters at Antarctic research stations and remote field camps. Because of local climate differences, unique terrain factors, and widely varying data coverage and quality associated with each TAF location, a unique, customized algorithm must be developed for each location.

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2. METHODOLOGY

We have developed and validated an objective aviation ceiling and visibility forecast system in an effort to improve the operational efficiency of a forecaster issuing a TAF and to improve the accuracy of the forecasted TAF parameters. This forecast system was developed in consultation with lead forecasters at the National Weather Service Forecast Office, Pleasant Hill, MO., and is described in Pan et al. (2000). The ceiling and visibility forecast system has been developed as an automated guidance tool for forecasters generating forecasts out to 1, 3 and 6 hours. This ceiling and visibility forecast system has been developed to provide the greatest accuracy with low ceiling and/or low visibility conditions – conditions that are most critical to aviators and flight operations.

The forecast system generates 1, 3 and 6 hour forecasts for ceiling and visibility using either multiple linear regression (MLR) or fuzzy logic algorithms. The set of predictors was chosen based on forecaster experience. This set of predictors includes multi-spectral satellite data, available surface and upper air observations, and numerical weather prediction (NWP) model forecast fields. Algorithms are customized for specific locations, with the algorithms trained on about 40-50 previous cases of low ceiling and low visibility conditions. Using MLR, the predictant is modeled as a linear combination of predictors x_n as

$$y = a_1x_1 + a_2x_2 + \ldots + a_nx_n \qquad (1)$$

The coefficients a_n are calculated to minimize the squared error between the predicted and observed values of y. The algorithm generates ceiling and visibility forecasts by ingesting the required data, and provides the results to the forecaster for use as a guidance tool. Application of this forecast system to two low visibility and low ceiling events in December 1999 is described in Braaten et al. (2000).

3. SYSTEM ADAPTION TO POLAR REGIONS

While the aviation ceiling and visibility forecast system described above was developed for middle and low latitude regions, the forecast system is flexible and can be readily adapted to the conditions and operational weather data sources in polar regions. Within these high latitude regions, geostationary satellite data are not available, and therefore, the forecast system must rely on polar orbiting satellites. The density of meteorological stations in polar regions is generally very low, and in addition, the spatial distribution of these stations is far from optimum. The limited number of meteorological stations and upper air observations in polar regions also impacts the performance of numerical models in polar regions.

Implementation of the aviation ceiling and visibility forecast system in polar regions would require multi-spectral data from polar orbiting satellites. These currently include NOAA and DMSP series satellites (NOAA-12, NOAA-14, NOAA-15, DMSP F-12, DMSP F-13, DMSP F-14). During most of the 24-hour day, satellite coverage of polar regions is adequate. For McMurdo Station, Antarctica, NOAA and DMSP series satellites make a total of 54 passes per day, with the temporal coverage ranging from one pass per hour to 5 passes per hour (Bromwich et al., 2000). However, there is a gap in the daily coverage cycle of these satellites over McMurdo Station. The gap occurs between 2130 and 0400 UTC (1030 and 1700 local time), which unfortunately coincides with the period of greatest aviation activity. Over the next few years this data gap is expected to be ameliorated with the launching of new polar orbiting satellites.

Surface and upper air meteorological observations over a broad region are important in forecasting ceiling and visibility. The small number of upper air observations currently available in polar regions will increase dramatically in the next few years with the commencement of the COSMIC (Constellation Observing System for Meteorology, Ionosphere and Climate) program in 2004 (Kuo et al., 2000). COSMIC is a Taiwan-led initiative, with support from the U.S. (NSF, NASA, NOAA, Navy, and Air Force), and consists of a constellation of six micro-satellites carrying advanced Global Positioning System (GPS) receivers. COSMIC uses the radio occultation technique for atmospheric profiling, and will provide upper air meteorological soundings with a very even spatial/temporal distribution over the globe, including polar regions. The availability of these data will provide sufficient temporal and spatial coverage to significantly benefit the upper air data requirements of the ceiling and visibility forecast system.

We have found numerical weather prediction model forecast fields such as 950 mb relative humidity and 700 mb vertical velocity to be important parameters in the aviation ceiling and visibility forecast system (Braaten et al., 2000). We expect that several model forecast fields will also be important in applications of the forecast system in polar regions. Forecasters in Antarctica have access to several operational global NWP models (NOGAPS, AVN, UKMET, and ECMWF). Forecast fields from these models can be used by the ceiling and visibility forecast system without modification.

4. CONCLUSIONS

An aviation ceiling and visibility forecast system has been developed, and its application in polar regions has been outlined. While the forecast system shows potential for improving the accuracy of ceiling and visibility forecasts in the central United States, adaptation and testing of the forecast system in polar regions still needs to be performed.

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