9.7 TAMDAR EVALUATION WORK AT THE EARTH SYSTEM RESEARCH LABORATORY GLOBAL SYSTEMS DIVISION: AN OVERVIEW

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1. INTRODUCTION

AMDAR (Aircraft Meteorological Data Relay) is a worldwide program providing automated real-time reports of atmospheric conditions from commercial airliners. AMDAR data have been available, and used by weather forecasters and in weather models, for nearly two decades. For a full discussion of AMDAR, particularly its U.S. component, see Moninger, et al. (2003).

AMDAR has improved weather forecasting, but the data from the commercial jetliners that comprise the bulk of AMDAR-producing aircraft leave data gaps. Over the contiguous United States these gaps are generally below 20,000 ft. between major airline hubs.

In an attempt to fill these gaps, the NASA Aviation Safety Program funded the development of a sensor called TAMDAR (Tropospheric AMDAR) by AirDat, LLC, of Raleigh NC, designed for deployment on aircraft flown by regional airlines (Daniels et al., 2004, 2006). For the past year (15 January 2005 to 15 January 2006), with the support of NASA and the FAA, these sensors have been deployed on 63 aircraft flying over the U. S. Midwest in an experiment called the Great Lakes Fleet Evaluation (GLFE).

The Global Systems Division (GSD) of the Earth Systems Research Laboratory (ESRL) has played a central role in the evaluation of TAMDAR data, and in distributing the data to others at NWS and elsewhere for their evaluation. We provide here an overview of ESRL efforts; several individual presentations in this special TAMDAR session and at the 12th Aviation Conference provide more details.

2. ESRL/GSD Tasks Performed

2.1 TAMDAR Data Ingest

ESRL/GSD has been ingesting AMDAR data from US and international sources for more than a decade. In December 2004 we began receiving TAMDAR data from AirDat, LLC. We routinely monitor this data flow, which has been highly reliable for the duration of the GLFE.

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2.2 Quality Control and Data Merging

The TAMDAR data received from AIRDAT are merged with data from other AMDAR sources to form a single data stream with uniform characteristics. Although only TAMDAR data provide winds, temperature, humidity, turbulence, and icing, other fleets provide subsets of all these variables, and it is therefore convenient for data from all of the AMDAR fleets to have the same format. The data in this stream are then subjected to rudimentary quality control (Moninger et al., 2003), and passed on for further processing and display.

2.3 MADIS Distribution

The unified AMDAR data stream--which now includes TAMDAR--is made available through GSD's Meteorological Assimilation Data Ingest System (MADIS, Miller et al., 2005) to authorized users. The TAMDAR data themselves would be freely available, and indeed are freely available from AirDat, but because the data stream includes traditional AMDAR data that the providing airlines view as proprietary, access is restricted. Details about the access restrictions on the data may be found at http://amdar.noaa.gov/FAQ.html.

For the TAMDAR evaluation, MADIS created an additional output format that allows the AMDAR data to be displayed on AWIPS, the NWS forecaster workstation in both plan view and as soundings. Although traditional AMDAR data from U. S. airlines are available for display at NWS offices through official NWS channels, MADIS is the only way TAMDAR and foreign AMDAR data can be displayed on AWIPS.

The MADIS program also created and distributes the documentation and software necessary for NWS forecast offices to ingest the data into AWIPS, by using their Local Data Acquisition and Display (LDAD) system.

2.4 AMDAR Web Display

For more than a decade, GSD has maintained a web display of AMDAR data (http://amdar.noaa.gov/). The real-time portions of this display are restricted as described above. This display provides plan views of AMDAR data and sounding plots as either SkewT's or Tephigrams. Tephigrams were developed at the request of Environment Canada, which is participating in the TAMDAR evaluation (Zaitseva,et al., 2006).

Several upgrades were made to our displays to support the GLFE. These include:

- Displaying all of the variables wind, temperature, dewpoint, turbulence, and icing for TAMDAR aircraft when the mouse cursor is over a data point.
- Adding the choice to display *only* TAMDAR data.
- Showing GPS altitude from TAMDAR. Only TAMDAR provides geometric (GPS) altitude as well as pressure altitude, and the differences between the two can be meteorologically meaningful. The GPS altitude is shown to the right of the pressure altitude by the cursor for TAMDAR observations.
- Displaying true airspeed, a variable particularly important in evaluating TAMDAR behavior.
- Changing the criteria used to differentiate flights to accommodate the very rapid turn-around times of the TAMDAR-equipped aircraft.
- Changing the criteria used to identify soundings to accommodate the relatively low cruising altitude of TAMDAR-equipped aircraft.

2.5 Parallel Real-Time RUC Models

Since January 2005 we have been running parallel versions of the RUC assimilation cycle, one with TAMDAR (called "dev2") and one without (called "dev"). These cycles are scheduled to run at the same time each hour so that they ingest identical data, with the exception of TAMDAR. Moreover, their background fields are set equal every 48 hours to ensure that the effects of spurious gravity waves do not cause the two cycles to diverge in ways that are not due to TAMDAR data.

Plan view analyses and forecasts from these cycles are available (http://ruc.noaa.gov/), as are soundings (http://www-frd.fsl.noaa.gov/soundings/java/). The latter may be compared with actual aircraft soundings by users authorized to view the aircraft data.

Benjamin et al. (2006a,b) present a detailed discussion of the comparative skill of these two models in this session. In brief, these results are:

- TAMDAR improves lower tropospheric forecasts of temperature and winds, and during the summer months, relative humidity at 850 mb.
- The key areas of improvement have been in low clouds, precipitation, frontal zones, and convective forecasts.
- Through close interaction between GSD and AirDat, some systematic observation problems have been identified and fixed.
- However some problems remain which AirDat is actively working to fix. The data suggest that TAMDAR will have a larger impact on RUC forecasts once these problems are corrected.

2.6 CIMSS Soundings

The University of Wisconsin Cooperative Institute for Meteorological Satellite Studies (CIMSS) team conducted two intensive evaluations of TAMDAR together called TAVE (TAMDAR AERIbago Validation Experiment, Feltz et al., 2006). As a part of this, many balloon soundings were taken, collocated with TAMDAR ascents and descents at Memphis, TN.

To facilitate near real-time comparison with the TAMDAR data, GSD ingested these sounding data and made them available on the AMDAR web display, and also on our soundings display page at http://www-frd.fsl.noaa.gov/soundings/java/. Using this capability, viewers are able to overlay the CIMSS soundings on the corresponding TAMDAR sounding. This was helpful to the CIMSS team in the field, and also to others evaluating TAMDAR.

2.7 Case-Study Evaluations of TAMDAR

ESRL/GSD has used the tools mentioned above to study cases in which TAMDAR has played an important part in forecasts made by humans and/or by models. Szoke et al. (2006) describe these case studies. In addition, the Green Bay, WI NWS Forecast office has used GSD's tools to perform case studies in an operational setting (Mamrosh et al., 2006).

2.8 AMDAR-RUC Database

GSD is maintaining a database of AMDAR observations, including TAMDAR, and 1h forecasts interpolated to the AMDAR observation point from several RUC models, including "dev" and "dev2." This enables us to calculate bias and standard deviations of AMDAR wind, temperature, and relative humidity with respect to the RUC. We make this information available on the web in several ways at http://amdar.noaa.gov/ruc_acars/.

In particular, the 3-day and 7-day average, and interactive time-series statistics for each aircraft have been helpful to us, AirDat personnel, and others in identifying problems with individual sensors. In fact, AirDat is automatically downloading information from the time-series statistics page and ingesting it into their quality assurance system (Andersen, 2006).

In addition we have used this database within GSD to perform detailed studies of the error characteristics of various aircraft and fleets. One such study, an analysis of TAMDAR error characteristics compared with those of traditional AMDAR fleets is presented in Moninger et al. (2006).

2.9 AMDAR-RUC Web Display

With support from the FAA Aviation Weather Research Program's Quality Assessment Product Development Team (Mahoney and Brown, 2006), we have substantially upgraded an interactive web display that shows AMDAR data with interpolated RUC 1h forecasts. Because this display shows current data, it is restricted just as the AMDAR web display is (see Section 2.4).

The display, at http://amdar.noaa.gov/ruc_acars/plan_view/, allows AMDAR data over the RUC domain (somewhat larger than the contiguous United States) to be displayed in several ways. For instance, temperature or vector wind differences between the AMDAR observation and the RUC can be displayed by color and by wind barbs. Also, the data can be sub-sectioned in great detail, as follows:

- By the magnitude of the AMDAR-RUC difference in temperature, or wind
- By sensor type (vapor or non-vapor)
- By flight phase (ascent, descent, or other)
- By RUC error status (good, on reject list, or failed RUC QC)
- By airline

Overall bias and RMS of AMDAR-minus-RUC differences in temperature and wind (vector difference) for the data points selected are shown in the status window below the plot.

This page has already proven very helpful within GSD and NWS in identifying errors with individual airline fleets, and gathering statistics about the contributions of various data providers.

2.10 Icing and Turbulence Data Compared with Voice Pilot Reports

Working with colleagues at NCAR, we are comparing TAMDAR observations with manual reports of turbulence, clouds, and icing generated by the pilots of the aircraft carrying the TAMDAR sensors. This work is reported by Braid et al. (2006) later in this session.

2.11 Hosting NWS Forecaster Questionnaire

At the request of the Green Bay NWS Forecast Office, we hosted an on-line questionnaire on which NWS forecasters could report the ways in which they used TAMDAR, and the impact TAMDAR data had on their forecasts. More than 45 responses were received from forecasters at several different offices. These responses have been analyzed and are reported in Mamrosh et al. (2006).

3. PLANS

TAMDAR data availability after the 15 Jan 2006 end of the GLFE is uncertain at this time. **If AirDat chooses to continue to make their data available as they have during the course of the GLFE**, the data will be available in the following ways.

- Directly from AirDat (http://www.airdat.com/)
- Via web displays operated by GSD (http://amdar.noaa.gov/). However, because the web displays contain data from other airlines as well, access to the real-time portions of this site are restricted as described at http://amdar.noaa.gov/FAQ.html.
- Via GSD's Meteorological Assimilation Data Ingest System (MADIS) (http://madis.noaa.gov/).

Regardless of AirDat's decision about future data availability, archival data from the GLFE will remain available from the MADIS program. Data may be requested at http://madis.noaa.gov/data_application.html.

4. CONCLUSIONS

ESRL has been pleased to play a central role in the evaluation of TAMDAR in particular, and the worldwide AMDAR fleet in general. We are gratified that our work has helped facilitate the substantial body of TAMDAR evaluation results that are being reported at this conference.

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