Mesoscale forecasting system with Commercial Aircraft (TAMDAR) Observations

What and Why TAMDFAR

Mesoscale (10 - 2000 km) meteorological data assimilation and prediction are challenging partly due to the sparseness of observations, especially in the upper-air atmosphere. In the past 15 years, a number of measurement platforms, e.g. wind profilers, commercial aircraft reports, satellite measurements, and others, have been developed to enhance the upper-air observations. Despite these advances, the present systems are not sufficient for mesoscale data assimilation and prediction. Recently, AirDat LLC., a Denver-based company, has been working with NASA, to develop and implement a new sensor, called TAMDAR (Tropospheric Airborne Meteorological Data Reporting) system.

The TAMDAR system uses the regional airlines to produce massive weather observations in the lower troposphere (Daniels et al. 2006). These data provide more accurate, and more complete mesoscale weather information with much higher time and space density than other data sources. In collaboration with AirDat LLC., NCAR/RAL developed a TAMDAR-based mesoscale forecasting system. This system is built around the NCAR/ATEC (Army Test and Evaluation Command) real-time multiscale, rapid-cycling, four-dimensional data assimilation and forecast (RTFDDA) system (Liu et al. 2002). The objectives of this project include evaluation of the TAMDAR data to advance the mesoscale weather analyses and short-term (0 – 48 hour) forecasts and exploration of opportunities for applying the data and the model system in various weather-critical governmental and industrial practices.

GLFE and RTFDDA Modeling

In the late 2004, a pilot demonstration TAMDAR field program over the Great Lakes area, named the Great Lakes Field Experiment (GLFE), was jointly conducted by NASA, NOAA/FSL, NWS (National Weather Services), FAA, NOAA, Mesaba Airlines and AirDat. During GLFE, AirDat equipped 63 Mesaba Airlines' turboprop SAAB 340 aircrafts with TAMDAR sensors that measure both conventional meteorological variables including temperature, pressure, winds and humidity as well as icing, turbulence and GPS heights. In a typical day, these instrumented aircraft make about 400 flights a day, providing about 800 soundings at the regional and major airports in the region (See Figure1).

To explore the potential of TAMDAR in improving regional short-term forecasts, a RTFDDA system was developed and has been operational on an AirDat Linux cluster. The forecast system has three domains, with 36, 12 and 4-km grid sizes respectively. The 12-km mesh covers all Mesaba Airlines regional flight airports and the neighboring regions affected by TAMDAR data (See Figure 2). In order to better resolve the regions of interest, a movable 4-km domain is nested in the 12-km domains. Owing to the

limitation of the computation capability of the available cluster, the model system has been operated mostly with the two coarse domains (36/12-km) during GLFE.

Two identical forecast systems are running in parallel, with one system ingesting the extra TAMDAR data and the other using standard RTFDDA data only. Both systems are running in real-time with 3-hr cycles with 12-hr forecasts in each cycle. The boundary and the initial conditions at cold-starts are provided using NCEP NAM (North America Model) model data. A data quality control procedure based on Liu et al (2004) was adapted to assure TAMDAR data quality, which not only prescreened problematic and unrepresentative data, but also provided valuable information for real-time TAMDAR quality assurance upstream of the TAMDAR data collection and dissemination. The model products are provided in real-time to AirDat and others in the communities.

Data Impact Study

Aside from modeling system engineering, NCAR/RAL has been focusing on TAMDAR data impact studies using the operational GLFE model configuration and TAMDAR data. Subjective and objective verification of the operational parallel, with and without TAMDAR, RTFDDA forecasts were conducted by comparing the model with radar, radiosondes and surface observations. Comparisons of the precipitation forecasts of TAMDAR-based RTFDDA model forecasts with the national operational models, RUC (Rapid Update Cycle) and NAM, running at similar resolutions were conducted. In addition, the TAMDAR data impact on wintertime massive cold-air process forecasts to an extended forecast length of 48 hours were conducted with the same model operational system. Tests were conducted through data-denial numerical experiments with a summer severe convective case to determine the value of TAMDAR data relative to other existing upper-air measurement platforms, including the standard radiosonde network, NOAA NPN (National Profiler Network) and CAP (Cooperative Agency Profiler) profilers, NESDIS GOES satellite wind products and the WSR-88D radar VAD. The details of the experiments described herein and the preliminary findings are summarized in Liu et al. (2005), Jacobs et al. (2006) and Liu et al. (2006).

Briefly, for the winter season, TAMDAR data generally leads to positive impacts on the mesoscale analyses and forecasts, and in some cases, the data can improve the forecast of upper-air weather variables by 25 – 35%. However, the domain average of surface forecast errors seems to be insensitive to TAMDAR data, partly due to the generally stable winter weather regime, partly to the strong controlling roles of the underlying land surface and soil properties, and partly to outliers of the stations. A subjective comparison of the model precipitation analyses and forecasts with radar observations indicated that, in some cases, the TAMDAR data are able to improve meso- and small structures and timing of the model precipitation systems (see Figure 3). A comparison of the TAMDAR-based RTFDDA forecasting system displays apparent advantages of the RTFDDA model for a 0–12 hr forecast of precipitation systems, especially severe summer convections, over the RUC and NAM operational forecasts (see Figure 4). A comparison of the impact of TAMDAR data with other available upper-

air measurement platforms displays the unique value of TAMDAR data due to the high density and completeness report of weather variables.

On-Going Research and Developments

As the TAMDAR project is in its d_but stage, there are many issues and opportunities for NCAR/RAL scientists and engineers to solve and explore. For example, although TAMDAR data display an overall positive impact on mesoscale weather prediction with the RTFDDA system, there are cases in which few negative impacts were found. This happens even more often for summer convective weather processes. It is not clear if this result is due to potential TAMDAR quality problems or inadequate use of TAMDAR data in the data assimilation. In the next few years, NCAR/RAL will continue to work with AirDat and the government agencies to further explore the value of the TAMDAR data system and enhance the TAMDAR-based mesoscale forecast capabilities.

In FY06, NCAR/RAL and AirDat will work jointly on optimization of TAMDAR data weighting in the RTFDDA data assimilation system. Special attention will be focused on convective scenarios when TAMDAR data from the aircrafts (which tend to fly around convective cells) require special weighting structure. An OSSE (Observation System Simulations Experiments) testbed will be developed to study any potential impact of the anticipated future full-scale TAMDAR fleets over the CONUS and also to provide guidance to AirDat, in order to choose immediate next fleet(s) to install the TAMDAR sensor so that it can quickly enhance the system. The OSSE testbed will also provide an effective tool to study data quality issues, including representative errors and their impacts on model analyses and forecasts. To ascertain the quality of the data, optimizing the data usage in the model (by developing best weighting) is more appropriate. Furthermore, the OSSE testbed will provide guidance for engineers to refine data sampling schemes for a given model system and guidance for modelers to refine the model configurations for given TAMDAR data schemes..Finally, NCAR/RAL will continue to refine and customize the TAMDAR-based RT

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Figure Captions:

Figure 1: None

Figure 2: Location of the NCAR/AirDat RTFDDA model Domain 2, a 12-km mesh, superposed over Mesaba Airline flight route map. The green legs mark SAAB 340 Jet-prop routes where TAMDAR data are provided.

Figure 3: Comparison of RTFDDA analyses of radar reflectivity of a snow event with and without use of TAMDAR data, and radar observation verification.

Figure 4: Comparison of very short-term rain forecasts of summer convective events from RTFDDA, FSL/RUC and NCEP NAM models. The NCEP Stage IV surface rain analysis is also shown for verification.