5.1 THE TAMDAR GREAT LAKES FLEET EXPERIMENT

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1. INTRODUCTION

The TAMDAR (Tropospheric Airborne Meteorological Data Report) project is a joint venture between NASA, Airdat LLC, Mesaba Airlines, NOAA and the FAA. It is the result of NASA aviation safety initiatives designed to reduce weather related aircraft accidents and delays. The purpose is to design, test and manufacturer an inexpensive instrument to measure temperature, moisture, pressure, wind, ice accretion and turbulence from commuter aircraft that fly to small and medium size airports.

The Great Lakes Fleet Experiment (hereafter referred to as GLFE) began on 1 December, 2004 and will continue into the summer of 2005. It is being conducted to determine if the use of TAMDAR data will result in numerical model and forecast improvements. TAMDAR units were installed on 64 Mesaba Airlines (Northwest Airlines Regional Airline) Saab 340 aircraft. These aircraft fly to around 80 cities across the central and eastern United States and southern Canada. These data are sent via satellite to Airdat's data center in Raleigh, North Carolina. They are processed and delivered in real time to internet web pages hosted by NOAA's Forecast Systems Laboratory (FSL) and Airdat. They are also available to NWS meteorologists via the Advanced Weather Interactive Processing System (AWIPS) and to FSL as input to retrospective runs of the Rapid Update Cycle (RUC) model.

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Meteorologists will use TAMDAR in forecasts and warnings, and evaluate the accuracy, timeliness and usefulness of these data. In addition to the use of TAMDAR in field offices, FSL will run the Rapid Update Cycle (RUC) model with and without TAMDAR, to determine if there are forecast improvements as a result of the inclusion of these data.

2. TAMDAR SENSOR DETAILS

TAMDAR units were designed by Airdat to measure temperature, relative humidity, pressure and icing. When combined with data from the aircraft avionics, it is possible to calculate pressure altitude, ground relative winds and turbulence. Figure 1 shows the TAMDAR unit and Figure 2 is an associated schematic.

Figure 1. TAMDAR unit

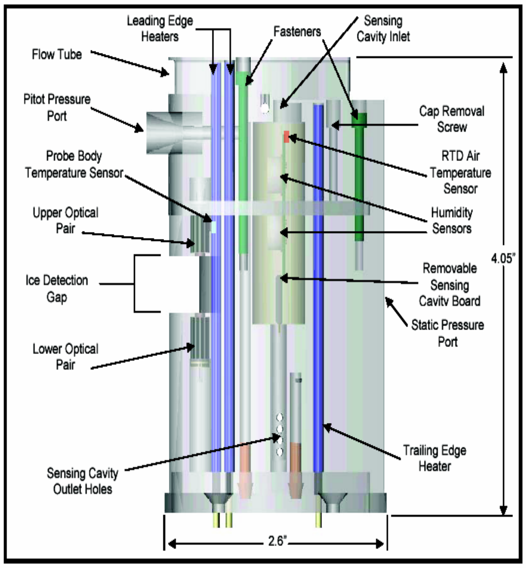

Figure 2. Schematic of TAMDAR

The temperature measurement device has a design accuracy of +/- 1C. The capacitive humidity sensors are designed to be accurate to +/- 5% relative humidity below mach .4, and to +/- 10% at higher speeds. Pressure is designed to be accurate to within 2 hPa. Further details of the TAMDAR sensors can be found in appendix A and in Daniels, et. al (2004).

TAMDAR was tested at University of North Dakota and other wind tunnels, and on NASA, NOAA and University of North Dakota research aircraft. TAMDAR was also compared to NWS rawinsonde data in an evaluation in Aberdeen, South Dakota. These experiments indicated that TAMDAR achieved the designed accuracy. Details of the wind tunnel and flight tests may also be found in Daniels, et. al. (2004).

3. GREAT LAKES FLEET EXPERIMENT

3.1 Aircraft installation and route structure

After FAA certification, TAMDAR units were installed on 64 Mesaba Airlines Saab 340 (see illustration Fig. 3) beginning in September 2004. Each aircraft required the installation of a TAMDAR unit, an aircraft avionics interface, a transceiver and a satellite antenna.

Figure 3. Mesaba Airlines Saab 340 aircraft

Mesaba flies these 64 aircraft to about 80 destinations in the central and eastern United States and Canada. Figure 4 shows the routes of TAMDAR equipped aircraft.

Figure 4. TAMDAR routes colored in green

3.2 Data density and distribution

The aircraft average seven flight segments per day, each with an ascent and descent sounding. Therefore, the 64 aircraft fleet provide about 900 soundings per day. Some destinations have just a few soundings, while others have a dozen, or more, each day. Hub airports such as Minneapolis and Detroit have over 100 soundings daily. In fact, during the busiest periods, there are sometimes two or three soundings each minute! The aircraft generally cruise at altitudes between 10,000 and 20,000 feet MSL, providing excellent flight level wind data between 400 and 700 hPa.

3.3 Data distribution

TAMDAR data are sent from the aircraft to the ground via satellite short message service. After receipt at Airdat's data center, they are quality controlled and distributed to a company web page and to the FSL. The FSL provides TAMDAR to NWS forecast offices via a data stream to AWIPS, and through a restricted web page with other aircraft (ACARS, MDCRS, etc.) data. Airdat will permit public access to TAMDAR data for the duration of the GLFE on their web page (http://www.airdat.com).

The Airdat and FSL web pages allow display of TAMDAR text data, as well as soundings and upper air wind plots. Users can also manipulate soundings and produce stability parameters such as lifted indices and convectively available potential energy.

4. NWS FIELD OFFICE PARTICIPATION

TAMDAR is available in the forecast areas of 37 NWS Forecast Offices and 10 NWS Center Weather Service Units.

4.1 Forecast Applications

NWS Meteorologists will use TAMDAR data in forecast situations that would benefit from a spatial and temporal increase of upper air data. These data will be especially useful in evaluation of the boundary layer. Applications of TAMDAR data include forecasts of

- Convective initiation
- Precipitation type
- Wind shear
- Cloud and Fog formation
- Icing

TAMDAR will also be useful to compare with other upper air data sources such as rawinsondes, wind profilers, GOES soundings, etc. These data will also be useful in verifying model forecasts of upper air features. Several NWS offices will use TAMDAR as input into local models.

Meteorologists will provide feedback by utilizing a TAMDAR forum hosted by FSL, by completing periodic surveys, and by mentioning the use of TAMDAR in their forecast discussions.

4.2 FSL PARTICIPATION

The FSL ingests and quality controls TAMDAR data, and uses it as input for retrospective runs of the RUC model. For details, see Moninger, et. al (2004). Real time RUC model output *may* be available during the later part of the GLFE. The FSL also formats TAMDAR for distribution to NWS offices as described above.

5. GOALS

The first goal of the GLFE is to determine if TAMDAR is a cost effective, robust and accurate means of acquiring additional upper air data. The second goal is to determine if these additional data can be used to produce more accurate numerical models and weather forecasts.

5.1 MEASUREMENTS OF GOALS

Airdat's engineering and data centers will monitor TAMDAR units in real time to determine the reliability of the sensors, associated electronics and communications network. Failure rates of the instruments and network will be monitored and calculated so that hardware and software changes can be made, if needed.

The NWS will use the retrospective RUC output to determine whether the inclusion of TAMDAR results in a significant improvement to the model fields. Any improvements that result will be compared to those that result from the use of other upper air data sets.

The NWS will also use surveys and verification scores of aviation and public forecasts in order to establish the impact of TAMDAR on these forecasts. In addition, qualitative evidence will also be gathered from NWS Forecast Offices and Center Weather Service Units.

6. FORECASTER RESOURCES

NWS meteorologists were provided with a training presentation about TAMDAR and the GLFE. The NWS also has an internet site http://www.crh.noaa.gov/tamdar that is available to everyone. It contains links to the data, reference articles, a forum, a TAMDAR data schedule, and the training presentation.

7. REFERENCES

Daniels, T. S., Anderson, M., Moninger, W. R., and R. D. Mamrosh, 2004: Tropospheric Airborne Meteorological Data Reporting (TAMDAR) Sensor Development. *11th Conf. on Aviation, Range, and Aerospace Meteorology,* Hyannis, MA, Amer. Meteor. Soc.

Moninger, W. R., Daniels. T. S., Mamrosh, R. D., Barth, M. F., Benjamin, S. G., Collander, R. S., Ewy, L., Jamison, B. D., Lipschutz, R. C., Miller, P. A., Schwartz, B. E., Smith, T. L., and E. J. Szoke: TAMDAR, The Rapid Update Cycle, and the Great Lakes Fleet Experiment. *11th Conf. on Aviation, Range, and Aerospace Meteorology,* Hyannis, MA, Amer. Meteor. Soc.

APPENDIX A: TAMDAR SENSOR SPECIFICATIONS

Parameter	Range	Accuracy	Resolution	Latency (See Note 1)	Comments
Pressure	10 -101 kPa	2 hPa	0.05 hPa	10 sec	See Note2.
Temperature	-70 to +65°C	±1°C	0.1°C	10 sec	
Humidity	0 to 100%RH	±5% (typical) ±10% (typical)	1% (RH > 10%) 0.1% (RH < 10%)	10 sec	Below Mach 0.4 Mach 0.4 - 0.6 (RH from 2 separate sensors is reported)
Heading	0-360°	±3°	0.1°	10 sec	@ < 30° pitch & roll
Ice Detection		0.020 inch			

Table 1 Measured parameters

Parameter	Range	Accuracy	Resolution	Latency	Comments
Pressure Altitude	0 – 25,000 ft.	±150 feet	10 feet	10 sec	See Note 2
Pressure Altitude	25,000 – 50,000 ft.	±250 feet	10 feet	10 sec	See Note 2
Indicated Airspeed	70-270 knots	±3 knots	1 knot	10 sec	See Note 2
True Airspeed	70-450 knots	±4 knots	1 knot	10 sec	See Note 2
Turbulence (eddy dissipation rate--$\epsilon^{1/3}$); Peak and Median	0-1 $m^{2/3}$ sec^{-1}			3 sec	See Note 3. Reported as single encoded character (see TAMDAR Downlink Data Format).
Winds Aloft		± 6 knots vector magnitude error	1 knot, 1 deg	10 sec	See Note 4. Accuracy depends on relative magnitude and direction of vectors.

Table 2 Derived parameters

Not all parameters are included in the TAMDAR data output stream.

Notes:

1. 10-second latency is caused by digital filtering of the data as recommended in the AMDAR Reference Manual, 2003.
2. Accuracy specified for angles of attack less than +/-8° from nominal except for winds aloft whose accuracy depends on the heading sensor used.
3. Turbulence determination: calculation of eddy dissipation rate in accordance with MacReady. Atmospheric Calculated from 32 point DFT of TAS (3 sec block).
4. Winds aloft calculation will require use of GPS and magnetic heading.