4.3 AVIATION APPLICATIONS OF TAMDAR AIRCRAFT DATA REPORTS

Richard D. Mamrosh NWS Green Bay, WI
Taumi S. Daniels NASA Langley, Hampton, VA
William R. Moninger Earth System Research Laboratory, Boulder, CO

1. INTRODUCTION

Meteorological data from regional commuter aircraft were utilized by meteorologists to make improved aviation forecasts during an experiment called the TAMDAR Great Lakes Fleet Experiment. TAMDAR (Tropospheric Airborne Meteorological Data Report) is an instrument package and communications system designed by AirDat, LLC as part of NASA and FAA aviation safety initiatives. Real-time weather data were collected during ascent, descent and cruise altitude by an instrument with temperature, humidity, icing, and pressure sensors. Wind and turbulence data were derived.

TAMDAR data were transmitted via satellite to an AirDat ground station, and then relayed to NOAA's Earth System Research Laboratory where they were made available to certain government, university, military and airline meteorologists via an interactive web page. Data were also made available to the public via an AirDat maintained internet site.

Meteorologists at many National Weather Service (NWS) Forecast Offices and Center Weather Service Units (CWSU) found TAMDAR to be valuable in forecasting ceilings, visibilities, thunderstorms and turbulence in Terminal Forecasts and Center Weather Advisories. Air Force Weather Agency (AFWA) meteorologists also found TAMDAR useful in forecasting icing. Several examples are presented to demonstrate how TAMDAR was valuable in forecasting different weather phenomena important to aviation.

* *Corresponding author address:*
Richard D. Mamrosh NWS
2485 South Point Road
Green Bay, WI 54313 (920) 497-8771
Richard.Mamrosh@noaa.gov

2. TAMDAR AND THE GREAT LAKES FLEET EXPERIMENT

NASA contracted with AirDat LLC to design, build and test an instrument to collect meteorological data from regional commercial aircraft. The resulting instrument (TAMDAR) was installed on 63 Mesaba Airlines Saab 340 aircraft flying over much of the central and eastern United States and Canada (fig. 1). Details on the development of the sensor can be found in Daniels, et al (2004).

A one year field evaluation of the data called the "Great Lakes Fleet Experiment" (GLFE) was conducted from January 15, 2005 to January 15, 2006. The purpose of the GLFE was to determine if data from regional aircraft could improve forecasts made by government, airline and military forecast offices, and numerical models run by NOAA and AirDat. Further details about the development of TAMDAR and the GLFE can be found in Moninger, et al (2006).

The NWS produced a training presentation that was made available to Warning and Forecast Offices (WFOs) and CWSUs in the GLFE area, and to other users upon request. A web page http://www.crh.noaa.gov/tamdar of flight schedules, reference documents and other resources was also created in support of the GLFE.

3. DATA ACCESS

Meteorologists in NWS WFOs, CWSUs, airline meteorology and military weather departments could access TAMDAR via the Aircraft Data Web hosted by ESRL (http://amdar.noaa.gov), or by a page hosted at AirDat (http://www.airdat.com). Some WFOs could also display TAMDAR on the Advanced Weather Interactive Processing System (AWIPS).

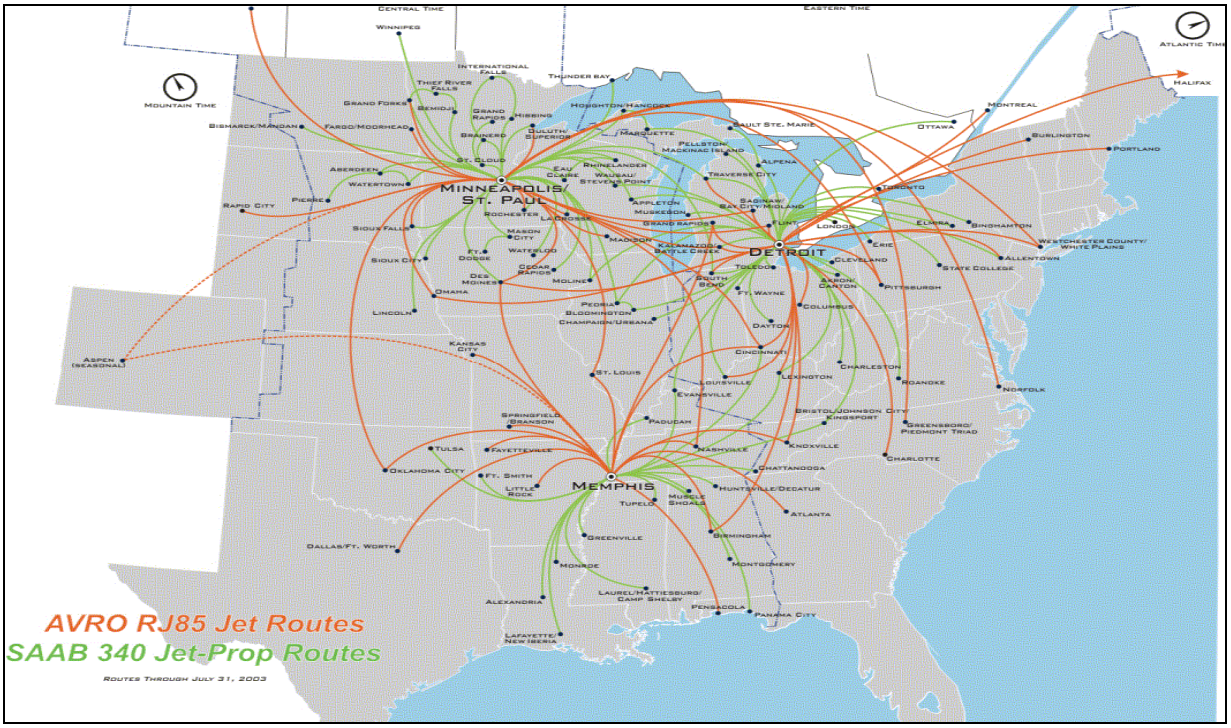

Figure 1. TAMDAR routes shown in green.

4. AVIATION APPLICATIONS

Much of the difficulty in producing accurate aviation forecasts is due to the lack of timely upper air data in the vicinity of the airport. Even the few airports that are near NWS radiosonde locations only receive two atmospheric soundings each day. Data from commercial jet aircraft (Often referred to as AMDAR, MDCRS or ACARS) provide some additional upper air reports, but these are generally available only near the large airline hubs.

As a result, meteorologists in WFOs are often reliant upon model guidance to produce both aviation Terminal Forecasts (TAFs) and Route Forecasts (TWEBs). While numerical models are generally quite good, there are many instances where occurrence, arrival, intensity and duration of a phenomenon are poorly forecast. If an erroneous numerical model was used in the production of the TAF or TWEB, a poor quality forecast is the result.

TAMDAR was designed to supplement data from the radiosonde network and the existing aircraft data from large commercial jets. The purpose is to provide real time upper air data in the vicinity of small and medium sized airports, with the goal of improving aviation and other forecasts.

a) Prior aviation applications of aircraft data

Real time data from commercial aircraft (AMDAR, MDCRS or ACARS) flying to large airport hubs have been available for more than a decade. The United Airlines meteorology department in Chicago began using automated weather data reports from their aircraft in the early 1990s. They found them useful in forecasting low clouds and fog at their hubs in Denver and Chicago, and for finding favorable flight level winds for transoceanic flights. They also faxed these reports to the Chicago WFO, where they were plotted on skew-T diagrams. Forecasters there found these data useful for route and terminal forecasts (TWEBs and TAFs, respectively) in northern Illinois. Data were also used to evaluate the potential for lake effect snow, low clouds, and low level wind shear (Mamrosh, et al, 2001).

The WFO in San Diego has also been one of the leading NWS users of aircraft data. They found the soundings very useful in determining the height of the marine layer along the coast of California. The presence and character of the marine layer is a determining factor as to whether low clouds and fog develop in coastal and interior sections of the state (Martin 2000). Meteorologists there have improved forecasts of fog and low clouds along the coast and in the interior valleys, largely due to the availability of aircraft data from airports in San Diego, Los Angels and Ontario.

b) Aviation applications of TAMDAR

The ingenuity of airline, government, and military meteorologists has resulted in many aviation applications of TAMDAR data.

- Air Force Weather Agency-

The AFWA in Omaha uses TAMDAR to forecast icing in areas where pilot reports (PIREPS) are sparse or missing. In one example, the MM5 model valid at 18UTC on January 19, 2005 forecasted icing at 5,000' in parts of the Ohio Valley north through Michigan into Ontario (fig. 2.) PIREPS from the area (fig. 3) corroborated the icing forecast over the Ohio Valley, but not further north.

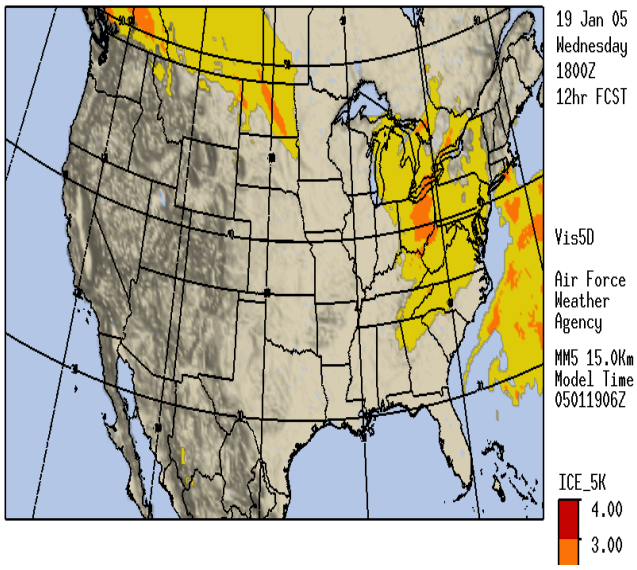

Figure 2. MM5 model icing forecast at 5,000'

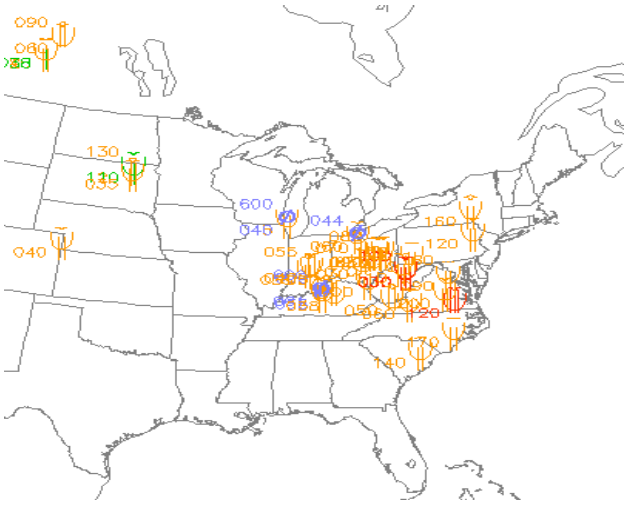

Figure 3. PIREPS for icing at all levels from 1743-1926UTC on Janury 19, 2005.

TAMDAR aircraft reports (fig. 4) show that there is indeed icing (indicated by red flight track) further north in northern Lower Michigan.

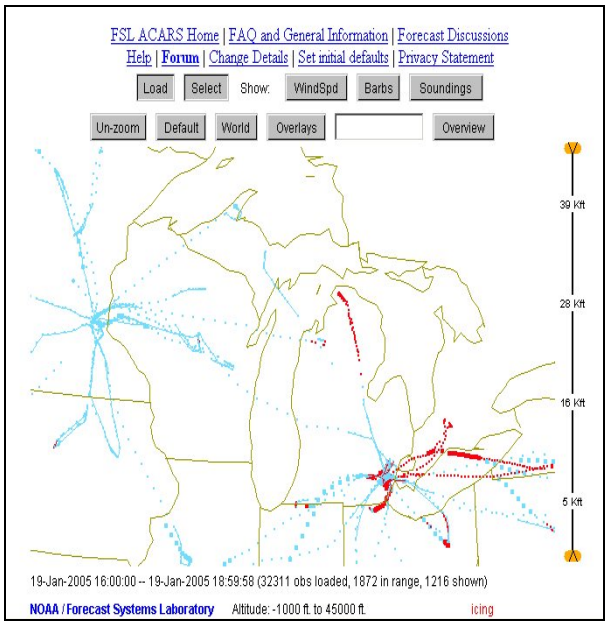

Figure. 4 TAMDAR icing reports from ESRL aircraft data web page

- National Weather Service -

- CWSUs -

CWSU meteorologists stationed at FAA Air Route Traffic Control Centers monitor the weather in their airspace and alert controllers of aviation hazards such as icing, turbulence and thunderstorms. Meteorologists at the CWSU in Indianapolis frequently use TAMDAR to determine atmospheric moisture content needed in stability index calculations used to forecast areal coverage of thunderstorms (Alexander, personal communication, 2005). The CWSU in Cleveland uses the data in forecasting icing, convective initiation and low level wind shear (McKinley, personal communication, 2005).

- WFOs -

Meteorologists at NWS WFOs have found many applications of TAMDAR in aviation forecasting. A few are presented here.

Fog forecasting

The WFO in Detroit found TAMDAR to be useful in forecasting a dense fog event on the evening of February 4th, 2005. Soundings showed that there were light winds in the boundary layer, moisture near the surface and dry air above. These are normally suitable conditions for the formation of low clouds or fog. Figure 5 depicts a sounding from Detroit Metro airport at 2229UTC, showing moisture increasing with height (circled area) and a low level inversion.

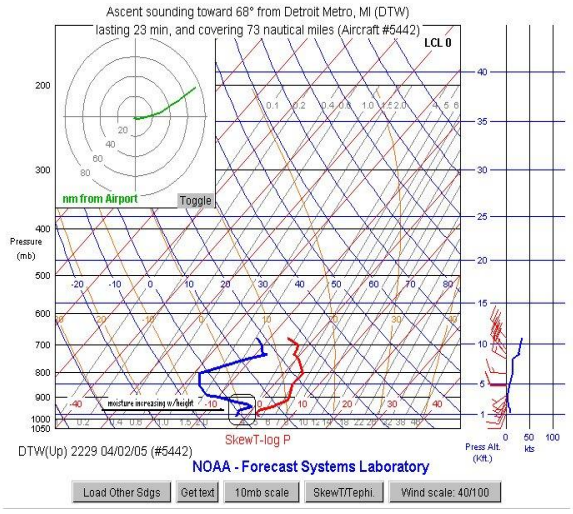

Figure 5. TAMDAR sounding from Detroit at 2229UTC on February 4, 2005

The forecaster on duty wrote an area forecast discussion (Fig. 6) describing how the TAMDAR data were useful in forecasting dense fog that night.

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AREA FORECAST DISCUSSION
NWS DETROIT/PONTIAC MI
AFDDTX 1021 PM EST FRI FEB 4 2005

TAMDAR SOUNDING ANALYSIS OUT OF DTW
OVER THE LAST COUPLE OF HOURS SHOW A
NEARLY UNIFORM MOISTURE PROFILE OVER
THE LOWEST 50MB... WITH VERY DRY AIR
ATOP THIS MOIST LAYER. THIS COUPLED
WITH CLEAR SKIES... TODAYS SNOWMELT
AND SOME REMAINING SNOW COVER WILL
SPELL IDEAL CONDITIONS FOR FOG
FORMATION TONIGHT.
```

Figure 6. Area Forecast Discussion issued by WFO Detroit on February 4, 2005.

The Detroit WFO issued a terminal forecast calling for visibilities to fall to ½ mile after 0600UTC, and to linger into the following morning. Surface observations confirm (Figure 7) that visibilities dropped to as low as a ¼ mile, with Runway Visual Ranges below minimums for many aircraft.

Surface Observations
Kdtw 0532z 00000kt **2sm br** clr
Kdtw 0739z 17003kt **1 3/4sm br** r04/1000v3500
Kdtw 0936z 17004kt **1/4sm fg** r04/0500v0600
Kdtw 1154z 16004kt **1/4sm fg** r04/2800v0600

Figure 7. Surface observations for the morning hours of February 4-5, 2005.

Timing of Thunderstorms

Warm, humid air covered much of the western Great Lakes on October 5, 2005. Thunderstorms were initially expected to form around noon in central Wisconsin and move east during the afternoon. The TAF (fig. 8) for Wausau, Wisconsin (AUW) issued around 1130UTC included a forecast of thunderstorms after 1800UTC in a TEMPO group.

```
FTUS80 KAUW 051200
KAUW 051155Z 051212 21009KT P6SM SCT050 SCT120
     FM1500 18012G20KT P6SM SCT050 BKN120
      TEMPO 1822 3SM TSRA BKN030CB…
```

Figure 8. TAF for AUW issued at 1130UTC

A few hours later, meteorologists at the NWS in Green Bay looked at TAMDAR soundings from airports in central Wisconsin and saw that convective temperatures were between 79F and 83F. In particular, a TAMDAR sounding from the Central Wisconsin Airport (about 10 miles from AUW) at 1541 UTC (fig. 9) showed a convective temperature of 82F.

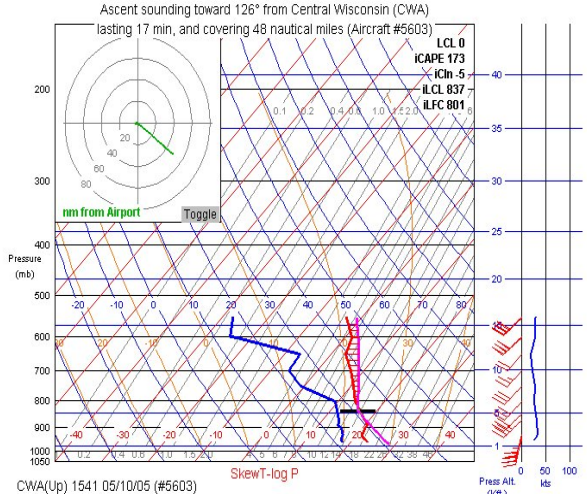

Figure 9. TAMDAR sounding from Central Wisconsin airport from 1541 UTC

Since these temperatures were not expected to be reached until later in the day, they were able to update the TAFs at 1555 UTC (figure 10) for three airports in that part of the state, predicting the arrival of the thunderstorms three hours later.

```
FTUS80 KAUW 051555 AAA
KAUW 051551Z 051612 18012G20KT P6SM
     SCT050 BKN120
      TEMPO 2124 3SM TSRA BKN030CB
```

Figure 10. TAF for AUW updated at 1555UTC

Surface observations at AUW show that the updated forecast was correct. Thunderstorms began as air temperatures reached the lower 80s, arriving at AUW just before 2100UTC (fig. 11)

```
METAR KAUW 051854Z AUTO 20018G24KT 9SM BKN040
27/18 A2985
METAR KAUW 051954Z AUTO 18018G23KT 8SM BKN043
OVC055 26/18 A2984
SPECI KAUW 052038Z AUTO 25008KT 220V310 5SM
VCTS RA BKN043 OVC050 24/19 A2985
METAR KAUW 052054Z AUTO 27008G20KT 10SM TS
SCT027 OVC039 21/18 A2985
```

Figure 11. Surface observations at AUW showing arrival of a thunderstorm around 2100UTC

Low level wind shear

Non-convective low level wind shear is another aviation hazard that meteorologists have found TAMDAR to be useful for. TAMDAR wind reports show a good amount of detail in the lowest few thousand feet above the ground. This permits forecasters to determine if there is sufficient directional and speed shear to include the mention of LLWS in the TAFs and TWEBs in that area.

The WFO in Detroit used TAMDAR data from the early morning hours of September 13, 2005 to forecast LLWS in area TAFs. Their area forecast discussion (fig. 12) states that TAMDAR and WSR-88D VAD Wind Profiler data support LLWS, but that RUC model soundings were too weak in this case.

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AREA FORECAST DISCUSSION
NATIONAL WEATHER SERVICE
DETROIT/PONTIAC MI
748 AM EDT TUE SEP 13 2005

.AVIATION...

BASED ON 11Z TAMDAR SOUNDINGS VICINITY
OF DTW...ADDED LOW-LEVEL WIND SHEAR TO
ALL THE TAFS THIS MORNING. AIRCRAFT
SOUNDINGS SHOW 1KFT WINDS OF 250/30KTS.
THIS IS ALSO SIMILAR TO DTX VWPS OVER
THE LAST 30 MINUTES...WHICH INDICATE
30KTS AT THE LOWEST CUT /2KFT/. 09Z RUC
IS TOO WEAK WITH THE LOW-LEVEL JET
COMPARED TO RECENT OBSERVATIONS.
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Figure 12. Area Forecast Discussion from NWS Detroit from September 13, 2005

TAMDAR is especially useful in the early morning hours for production of the 12 UTC TAFs, as data from NWS radiosondes are generally not available until around 1300 UTC.

5. SUMMARY AND CONCLUSIONS

The use of TAMDAR by meteorologists in the NWS and military weather offices suggest that they find the data to be valuable in aviation forecasting. This is borne out by a survey of NWS meteorologists in August 2005. More than 90 percent replied that TAMDAR helped them make improved warnings and forecasts.

Aviation forecasters in WFOs found TAMDAR most useful in forecasting the formation and dissipation of fog and low clouds, timing of thunderstorms, and LLWS. AFWA and CWSU meteorologists use TAMDAR largely to determine areas of icing and turbulence. They particularly find it useful in areas where PIREPS are not available.

6. ACKNOWLEDGEMENTS

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