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Highlights of the TAMDAR AERIBago Validation Experiment (TAVE) in Memphis, Tennessee

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1. Introduction

The first phase of TAMDAR AERIbago Validation Experiment (TAVE) was recently conducted by the University of Wisconsin Cooperative Institute for Meteorological Satellite Studies (CIMSS) scientists from February 22 to March 8, 2005 in Memphis, TN. TAVE is an effort sponsored by NASA to understand the relative accuracy of a new aircraft instrument called the Tropospheric Airborne Meteorological Data Reporting (TAMDAR) system. The TAMDAR sensors were developed by Georgia Tech Research Institute and AirDat L.L.C. and are currently mounted on 64 Mesaba Airlines Saab 340 aircraft (Figure 1). The TAMDAR sensor measures pressure, humidity, wind speed, wind direction, temperature, icing and turbulence at altitudes below 25,000 feet, with the measurement location, time, and aircraft altitude provided by Global Positioning System technology. These sensors are in continuous operation throughout the entire aircraft flight, which provide valuable upper-air measurements at times and locations between the two normally scheduled National Weather Service radiosonde launches at 0000 and 1200 UTC.

2. AERIBago and Dataset Description

The SSEC Mobile Weather Laboratory, also known as the AERIbago, played a prominent role in this validation effort, as it carries a suite of instruments for measuring atmospheric temperature and water vapor profiles (Figure 2). The AERIbago was deployed at the Tennessee Air National Guard base near the end of one of the primary runways of Memphis International Airport. A total of six CIMSS scientists were deployed during TAVE, with numerous others providing technical support at UW-Madison. CIMSS scientists spent most of the days during TAVE working inside the AERIbago vehicle, preparing for radiosonde launches and ensuring that other instrumentation was operating properly.

Figure 1: A Saab 340 Aircraft owned by Northwest Airlines and operated by Mesaba Airlines (left). A detailed photo of the TAMDAR sensor (right).

Figure 2: The SSEC "AERIbago" deployed during TAVE. The GPS signal reciever lies in the foreground. The anemometer, radiosonde signal antennae, surface temperature, and moisture sensors are mounted on a tower at the rear of the AERIbago.

Of special interest to weather forecasters are TAMDAR datasets containing vertical temperature, moisture, and wind profiles that are collected as a plane ascends or descends. At the Memphis International airport, a Mesaba Airlines hub, an average of 55 vertical profiles are collected daily. The frequency of the profiles provides

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forecasters with valuable data to monitor atmospheric characteristics such as thermodynamic stability for predicting the timing of thunderstorm formation, temperature inversions and the height of the freezing level for predicting winter precipitation type, and low-level wind shear aviation hazards. At the Minneapolis and Detroit airports, greater than 100 profiles a day are collected by the TAMDAR instruments, providing an even greater time resolution between profiles (Figure 3).

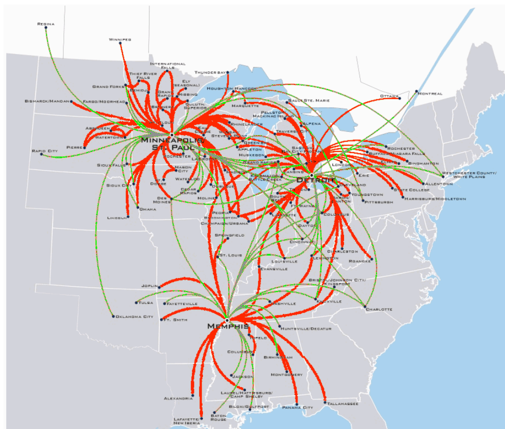

Figure 3: Mesaba Airlines routes, with Saab-340 routes highlighted in red.

3. TAMDAR Validation Details

In order to understand the relative accuracy of the TAMDAR sensor, TAVE scientists were tasked with collecting an independent set of direct measurements that can be compared to measurements collected by TAMDAR. Datasets collected by TAVE scientists include: 1) vertical temperature, moisture, wind speed, and wind direction profiles measured from radiosonde balloon launches (Figure 4 shows a CIMSS scientist performing her first ever balloon launch), 2) radiances from the AERI instrument that are used to retrieve temperature and moisture profiles up to 3 km in clear or partly cloud skies, 3) cloud-base measurements from a ceiliometer that are used to improve AERI retrievals, 4) temperature, relative humidity (RH), and pressure at the surface which are needed for both the AERI retrieval algorithm and as a quality check for the radiosonde profiles, and 5) GPS signal delay, measured by a GPS signal receiver antenna, that can be used to calculate the total amount of water vapor in a vertical column of the atmosphere. Through the combination of the radiosonde, AERI, and GPS measurements, highly accurate temperature and water vapor profiles are produced which are compared to the water vapor and temperature measurements from TAMDAR.

Figure 4: Sarah Bedka of CIMSS performing a radiosonde balloon launch.

Five radiosonde instrument packages were launched on a normal day during TAVE, closely coordinated with Saab 340 takeoffs and landings. Through this process, CIMSS scientists are able to directly compare what the TAMDAR measures to the actual state of the atmosphere sampled by the radiosondes. Figure 5 provides an example of such a comparison, where data from one TAVE radiosonde launch and all TAMDAR profiles collected within 30 minutes of the radiosonde launch are displayed.

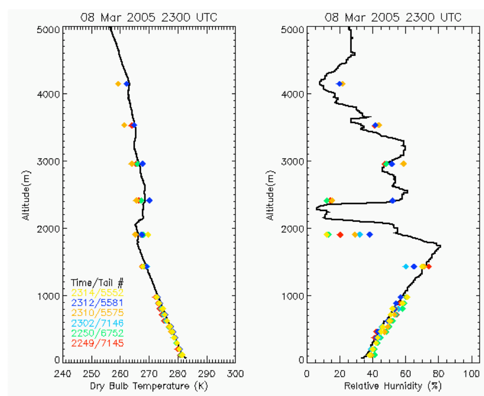

Figure 5: A comparison between a TAVE radiosonde temperature (left in black line) and relative humidity (right) profile at 2300 UTC on 8 March 2005 and several profiles from nearby TAMDAR sensors (colored diamonds).

A comparison of the radiosonde and TAMDAR temperature observations shows good agreement between the 2 sensors. The RH plot shows good agreement at low levels, with some spread occurring above the 1.5 km level. These differences should not necessarily be considered errors, but instead result from the characteristics of the different sensors and the validation methodology. The TAMDAR-equipped aircraft and radiosondes often travel in differing directions, with the TAMDAR progressing linearly toward or away from an airport and the radiosonde being carried along by the wind flow. Therefore, the 2 sensors may not be sampling the exact same location in the atmosphere, which can lead to discrepancies in measurements collected at the same time. Figure 6 provides a three-dimensional view of TAMDAR flight paths and radiosonde launches for 5 March 2005, illustrating the disparities in location between the two measurement systems. One TAMDAR sensor may be traveling through a small cloud or rain shower and would detect higher RH, while the other TAMDARs and radiosonde instruments remain in clear sky and detect lower RH. For this and other reasons, TAVE scientists can only determine the "relative", but not exact, accuracy of TAMDAR.

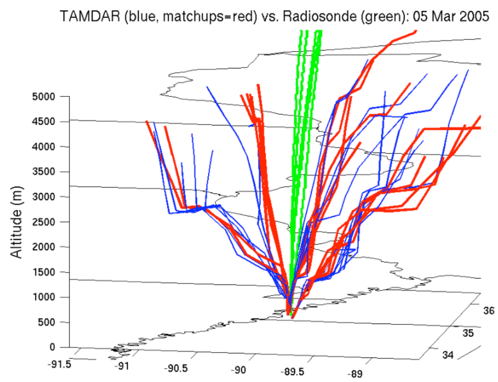

Figure 6: A plot of the flight tracks of all TAMDAR-equipped aircraft (blue) and TAVE radiosonde launches (green) on 5 March 2005. Aircraft takeoffs or landings within 30 minutes of a radiosonde launch are highlighted in red.

Another TAVE validation dataset are vertical temperature and moisture profiles collected by AERI. Figure 7 provides a comparison of retrievals using AERI radiances to profiles measured by TAMDAR. Similar results exist for this validation dataset, where good agreement exists in the temperature field with some differences present in the moisture field. One point to note with this figure is that AERI observations are collected every 10 minutes, whereas a period of greater than 2 hours can pass without a TAMDAR takeoff or landing. This can lead to discrepancies in the comparison of these datasets, as the structure of the atmosphere can change quite a bit in two hours time.

Nevertheless, despite the minor issues mentioned above, the comparisons provided in Figures 5 and 7, coupled with other preliminary analyses, suggest that the TAMDAR sensor provides accurate, reliable meteorological data that can be used to nowcast aviation hazards such as severe thunderstorms, visibility, and icing in locations not frequently sampled by conventional radiosonde data. More information about TAVE and NASA's TAMDAR program can be found on the Web at: http://cimss.ssec.wisc.edu/tamdar/.

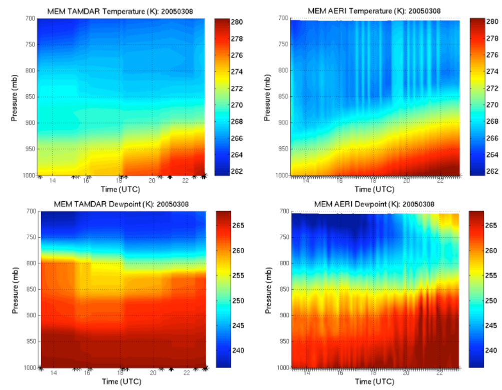

Figure 7: A comparison of TAMDAR and AERI temperature (top panels) and dewpoint (bottom panels) cross-sections on 8 March 2005 during TAVE. The times of actual TAMDAR and AERI measurements are highlighted by asterisks along the "Time" axis. Interpolation is performed between TAMDAR observations to obtain an approximation of the atmospheric conditions at those times.

4. Acknowledgements

The authors would like to acknowledge the support of Taumi Daniels at NASA Langley Research Center, Lt. Norvel Atkins of the Memphis Air National Guard, and Bill Wagner of the FAA. Funding for this research was provided by NASA, grant number NNL05AA09G.

Web links:

TAMDAR Great Lakes Fleet Experiment:
http://www.crh.noaa.gov/tamdar/
University of Wisconsin TAVE homepage:
http://cimss.ssec.wisc.edu/tamdar/
NOAA Forecast Systems Laboratory data viewer:
http://acweb.fsl.noaa.gov/java/