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3.1 TAMDAR JET FLEETS AND THEIR IMPACT ON RAPID UPDATE CYCLE (RUC) FORECASTS

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1. INTRODUCTION

Commercial aircraft now provide more than 180,000 observations per day of winds and temperature aloft over the contiguous United States. The general term for these data is AMDAR (Aircraft Meteorological Data Relay, Moninger et al. 2003). These data have been ingested into the Rapid Update Cycle (RUC) for more than a decade, and have been shown to improve forecasts.

One weakness of the current AMDAR data set is the absence of data below 25,000 ft between major airline hubs and the almost complete absence of water vapor data. To address this weakness, a sensor called TAMDAR (Tropospheric Airborne Meteorological Data Reporting, Daniels et al. 2006), developed by AirDat, LLC, under NASA sponsorship, has been deployed on several fleets of U.S. regional aircraft. Like the rest of the AMDAR fleet, TAMDAR measures winds and temperature. But unlike most of the rest of the fleet, TAMDAR measures humidity, turbulence, and icing. By late 2009, AirDat expects to have more than 400 aircraft equipped with TAMDAR sensors in the contiguous U. S. and Alaska.

Over the past 4 years, NOAA/ESRL/GSD has evaluated TAMDAR's data quality (as compared with traditional AMDAR measurements) and its impact on RUC forecasts. To measure TAMDAR impact we run two identical RUC cycles in real-time: one with TAMDAR and one without—otherwise both use the same input data. These cycles use up-to-date assimilation/model techniques (generally corresponding to the NCEP operational 13-km RUC, but run at 20-km resolution), and incorporate all observation types (as used in the RUC13) except radar reflectivity. The observation types include GOES cloud-top pressure and METAR ceiling height and present weather (to construct an initial cloud analysis), full METAR assimilation accounting for boundary-layer depth, GOES and GPS precipitable water, all other aircraft, profilers (NOAA and 915-MHz boundary layer), and rawinsondes. With its hourly assimilation and full use of other observations, the RUC provides a framework for a stringent assessment for forecast value added by TAMDAR. The parallel models are strictly controlled to isolate the effects of TAMDAR data, including a resetting of common initial conditions every 48 h to ensure a full control.

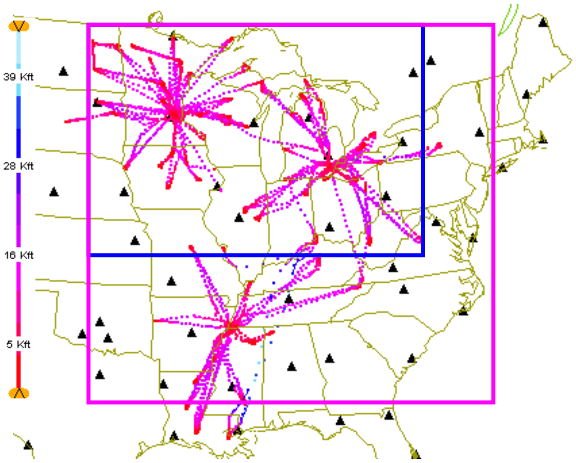

Fig. 1. TAMDAR-Mesaba observations for 31 Dec 2008. Verification areas are shown for blue rectangle (Great Lakes area – 13 RAOBs) and violet rectangle (eastern US area – 38 RAOBs)

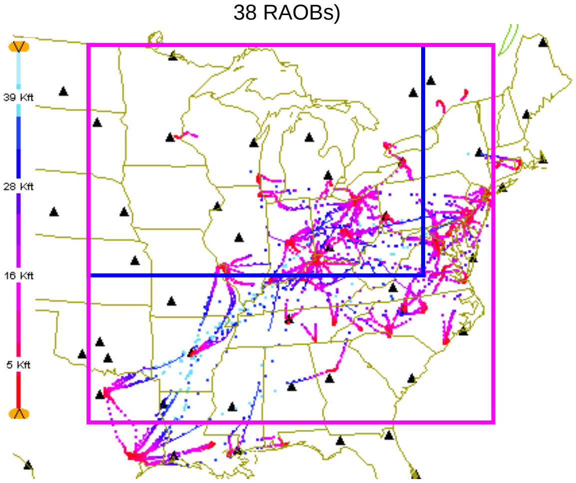

Fig. 2. As in Fig. 1 except for TAMDAR-Chautauqua observations. Note the higher flights than in Fig. 1, indicated by the cooler colors.

For the first 3.5 years, we evaluated the data quality and impact of approximately 50 TAMDAR-equipped turboprop aircraft flying over the Midwest on Mesaba airlines. Data from these aircraft improve RUC forecasts of temperature, humidity, and wind. These sensors continue to report data and are now an operational part of the National Weather Service data stream. As of 16 Dec 2008, TAMDAR-Mesaba data are being ingested into the operational RUC run

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at NCEP. Fig. 1 shows TAMDAR-Mesaba coverage for 31 Dec 2008.

Starting on 3 April 2008, we began receiving data from TAMDAR sensors that have been installed on (now) 58 regional jet aircraft operated by Chautauqua Airlines in the Gulf Coast, southern Midwest and Eastern U.S. (Fig. 2). Ultimately 67 Chautauqua jet aircraft are expected to carry TAMDAR sensors. These jet aircraft fly higher and faster than Mesaba turboprops do.

This study is an update on our previous TAMDAR studies (Moninger et al. 2007a,b, 2008) that includes these new aircraft, with particular emphasis on relative humidity measurements above 20,000 ft (460 hPa). We consider both data quality, as measured with respect to RUC background fields, and TAMDAR impact on RUC forecast quality.

2. PARALLEL REAL-TIME RUC CYCLES TO STUDY TAMDAR IMPACT ON FORECASTS

Two parallel experimental versions of the RUC have been run at ESRL/GSD since February 2005, with the following properties:

- ‘Dev’ (or ‘development version 1’) assimilates all hourly non-TAMDAR observations.
- ‘Dev2’ is the same as dev but assimilates, in addition, TAMDAR wind, temperature, and relative humidity observations in the RUC domain.
- The same lateral boundary conditions, from forecasts made by NCEP’s North American Mesoscale analysis and forecast system (NAM), are used for both dev and dev2 experiments.
- These RUC experiments are run at 20-km resolution, but using latest 13-km-version code, with the exception that dev and dev2 do not ingest radar reflectivity data.

The 20-km resolution was used to save computer resources. From June-October 2006, TAMDAR data were also assimilated into experimental 13-km RUC versions at ESRL/GSD, with similar (but not greater) TAMDAR impact, confirming that use of 20-km resolution in the dev and dev2 RUC cycles has not masked potential TAMDAR impact.

A summary of the characteristics of the June 2006 operational RUC13 is available at http://ruc.noaa.gov/ruc13_docs/RUC-testing-Jun06.htm. More details on the RUC assimilation cycle and the RUC model are available in Benjamin et al. (2004a,b, 2008). Other details on RUC TAMDAR experimental design are described in Benjamin et al. (2006a,b).

3. REAL-TIME RUC FORECAST SKILL WITH AND WITHOUT TAMDAR DATA

In this section we present an update of TAMDAR impact on forecasts of temperature, wind, and relative humidity.

3.1 Temperature

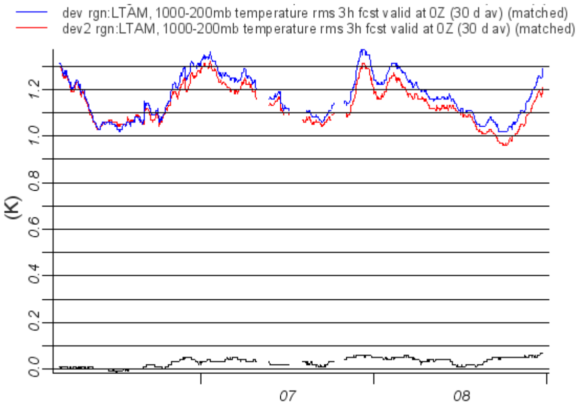

Fig. 3. Time series of 3-h temperature forecast errors (RMS difference from 00 UTC RAOBs) for dev (no TAMDAR, blue) and dev2 (TAMDAR, red), and dev-dev2 difference (black), for the eastern U.S. region, in the layer between the surface and 200 hPa. The time period covered is 2006 through 2008; 30 day running averages are shown. Positive differences indicate a positive TAMDAR impact.

Figure 3 shows TAMDAR impact on temperature forecasts. The RMS temperature differences show the common seasonal variation with larger values in winter and smaller ones in summer when day-to-day temperature changes are reduced and the lower troposphere is more commonly well mixed with a deeper boundary layer. TAMDAR impact is greatest during winter, when RUC (and other model) temperature errors in the lower troposphere are larger. We consider only 00 UTC RAOBs because this is the time when we expect to see the maximum TAMDAR impact, given the schedule (11-03 UTC, primarily daylight hours) of the TAMDAR fleets.

Figure 4 shows a vertical profile of temperature RMS errors for dev and dev2 3-h forecasts for November 2008. The dev2 RUC has lower errors for all levels between the surface and 300 hPa. The maximum RMS error difference between dev and dev2 occurs at 900 hPa and is about 0.22 K. Because the analysis fit to RAOB verification data is about 0.5 K as described in Benjamin et al. (2006a,b, 2007), the maximum possible reduction in RMS error difference would be about 0.8 K (the difference between the ~1.3 K RMS shown for dev in Fig. 3 at 900 hPa and the 0.5 K analysis fit). Thus, **TAMDAR data result in about a 28% reduction in 3-h temperature forecast error at 900 hPa**. This may be compared with the TAMDAR impact of 36% in the smaller Great Lakes region (not shown here, but shown in Moninger et al. 2008). The impact shown here is less, but is over a substantially larger region.

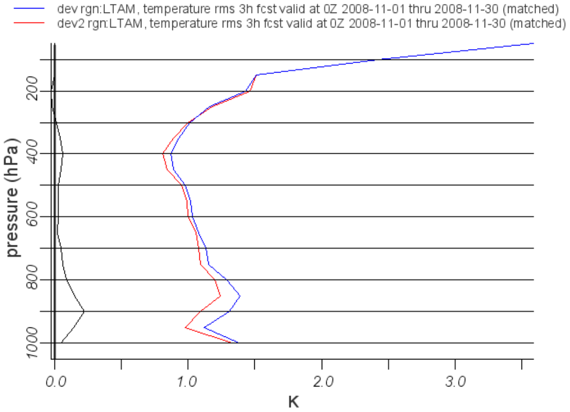

Fig. 4. Vertical profile of 3-h temperature forecast errors (RMS difference from 00 UTC RAOBs) for dev (no TAMDAR, blue) and dev2 (TAMDAR, red), and dev-dev2 difference (black). For the large TAMDAR region, Nov. 2008.

3.2 *Wind*

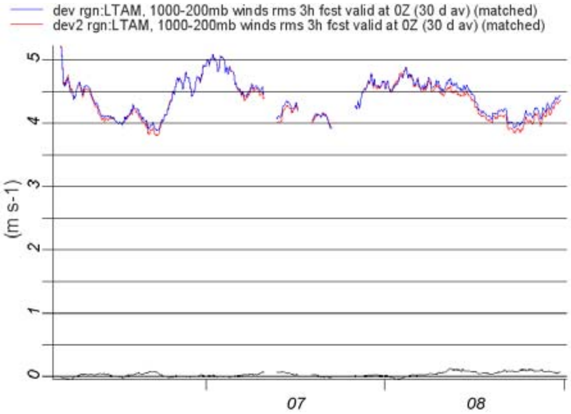

Fig. 5. As for Fig. 3, but for 3-h wind forecasts

Figure 5 shows TAMDAR impact on winds for the three years, averaged over the surface-200 hPa layer. The impact is small but consistently positive, and it increases in April 2008 when the Chautauqua fleet started providing data.

Figure 6 shows the corresponding vertical profile, for November 2008. The TAMDAR impact on winds shows a broad peak between 350-950 hPa, with a maximum at 750 hPa. At this level, the RMS reduction due to TAMDAR is about 0.17 m/s. This represents about **a 10% reduction in 3-h wind forecast error due to TAMDAR** since the analysis fit to RAOB winds is about 2.15 m/s in this altitude range. (The TAMDAR wind impact in the smaller Great Lakes Region is about 15%, as shown in Moninger et al. 2008.)

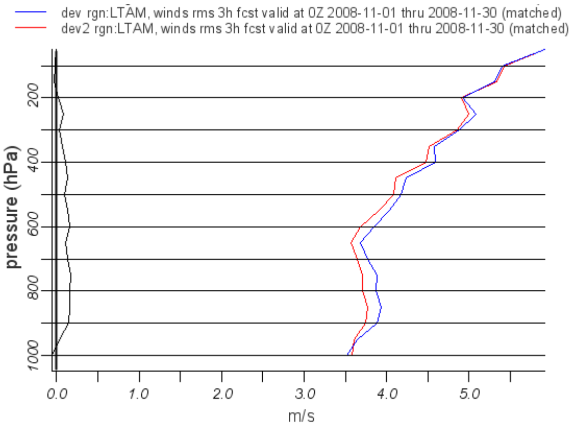

Fig. 6. As for Fig. 4, but for 3-h wind forecasts.

3.3 *Relative Humidity*

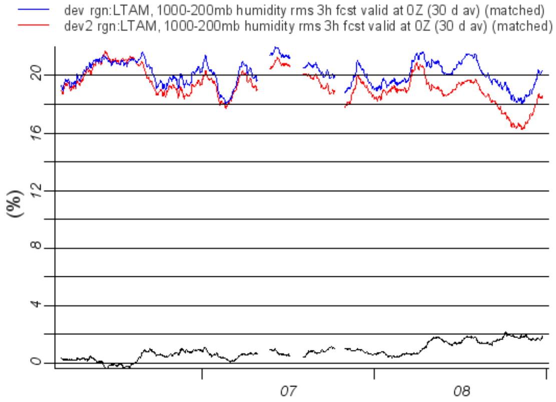

Fig. 7. As for Fig. 3, but for 3-h Relative Humidity forecasts.

Figure 7 shows TAMDAR impact on RH. The impact of the new Chautauqua data is particularly evident here in that the RH impact increases from approximately 0-1% RH to a little less than 2% RH in April 2008, when Chautauqua data first became available.

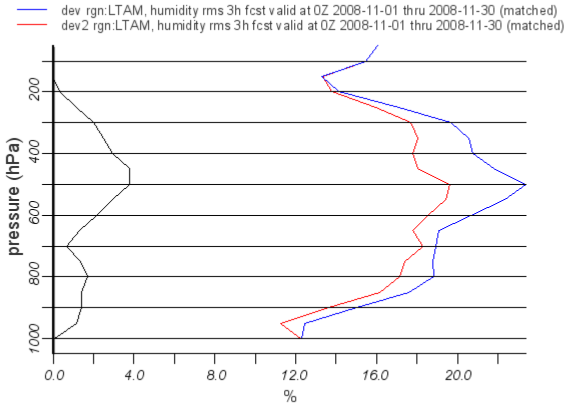

Fig. 8. As for Fig. 4, but for 3-h Relative Humidity forecasts.

Figure 8 shows the corresponding vertical profile. The RH impact has a peak of 4% RH at 500 hPa. Since the analysis error at this altitude is 14% RH, this represents about **a 45% reduction in 3-h RH forecast error due to TAMDAR.** To make this reduction clearer, consider Fig. 9, which shows the RMS RH error for the dev, dev2, and the dev2 analysis.

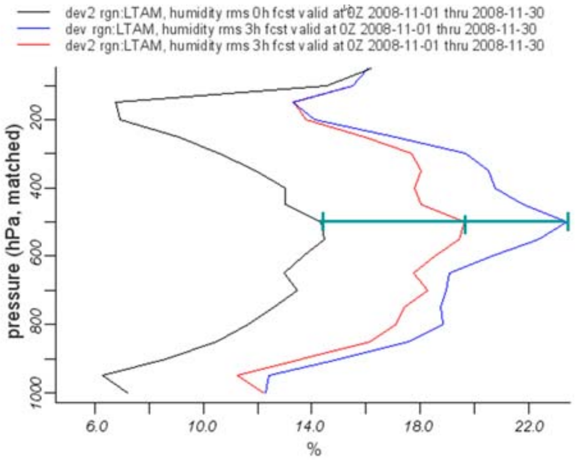

Fig. 9. Dev2 (black) RH analysis RMS difference with 0 UTC RAOBs in the eastern U.S. region, Nov. 2008, along with dev (blue) and dev2 (red) 3-h RH forecasts. The green line indicates the differences between dev2 3-h forecast, dev 3-h forecast, and dev2 analysis errors at 500 mb.

The RMS difference from the RAOBs for the dev2 analysis varies between 7 %RH and 14 %RH, and is approximately 14% at 500 hPa. Thus, the 4% reduction in RMS due to TAMDAR moves the 3-h RMS about 45% of the way to the analysis fit (as indicated by the green line). *[This section updated 29 January 2009 to show a 45% TAMDAR impact (with respect to the dev2 analysis), rather than a 50% impact (with respect to the dev analysis).]*

This is a major impact, largely due to the Chautauqua fleet. For comparison, we look at November 2007, before the Chautauqua fleet was flying, in Fig. 10.

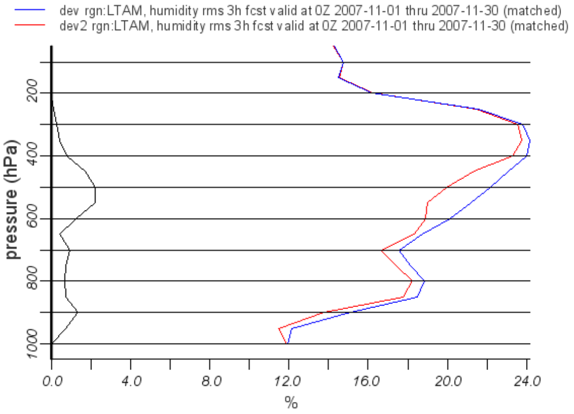

Fig. 10. As for Fig. 8, but for November 2007.

Comparing Fig. 10 with Fig. 8 shows that the RH impact is substantially less at all altitudes in 2007, but particularly less above 600 hPa. This is not surprising because the Mesaba fleet, comprised of turboprops, seldom flies above 550 hPa, whereas the Chautauqua jets fleet flies up to 200 hPa.

Fig. 11 shows the TAMDAR impact on RH bias for November 2008. Although both models show a moist bias with respect to RAOBs, near the surface, and between 200 and 700 hPa, **the dev2 shows substantially lower RH bias than the dev at nearly all levels up to 200 hPa**.

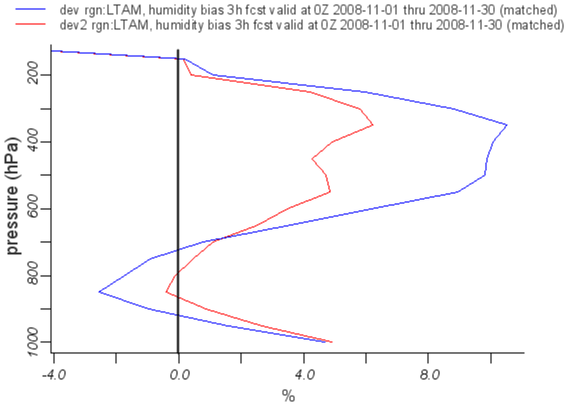

Fig. 11. RH "bias" (model minus RAOB) for dev (blue) and dev2 (red) 3-h RH forecasts, for Nov. 2008.

4. TAMDAR FLEET ERROR CHARACTERISTICS

4.1 *TAMDAR-Chautauqua comparisons with RAOBs*

As an initial inspection of TAMDAR-Chautauqua errors, we check the data against RAOBs. Here are some comparisons from the past month.

Fig 12 shows several Chautauqua soundings at La Guardia, NY, near 12 UTC 6 Jan 2009, along with the Brookhaven, NY RAOB. Only one Chautauqua sounding reports winds (the descent landing at 1134 UTC, shown in green), and this agrees well with the RAOB (in black).

All of the Chautauqua soundings capture the dry layer near the surface; the variations in the depth of this layer may be a result of the different air sampled. The flight tracks are shown in the upper left, and show that the aircraft soundings go to the west and southwest, whereas the RAOB drifts to the east. Moreover, the Brookhaven sounding release point is 47 nm to the east of La Guardia.

Perhaps of greatest import is the ascent sounding starting at 1350 UTC (violet) that extends up to 30,000 ft (300 mb). Even in this cold (-44 °C) region, the Chautauqua sensor evidently is able to report RH with good accuracy, as shown by the agreement between the RAOB and aircraft dewpoint.

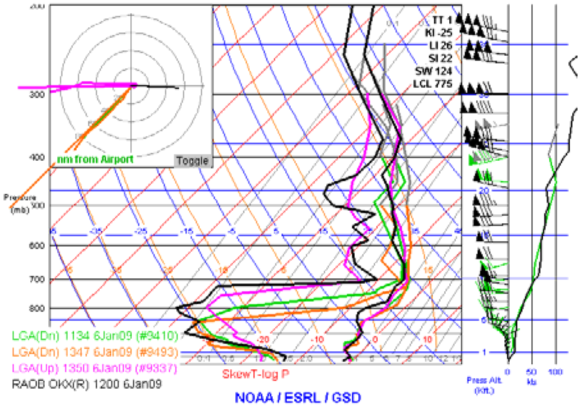

Figure 12. TAMDAR-Chautauqua soundings from La Guardia, NY, compared with the Brookhaven, NY RAOB, around 12 UTC 6 Jan 2009. Flight tracks are shown in the upper left.

Figure 13 shows a TAMDAR-Chautauqua sounding at Dulles, VA and the RAOB from Dulles. Agreement in wind, temperature, and dewpoint is generally good from the surface to the top of the aircraft sounding at 28,000 ft (330 hPa).

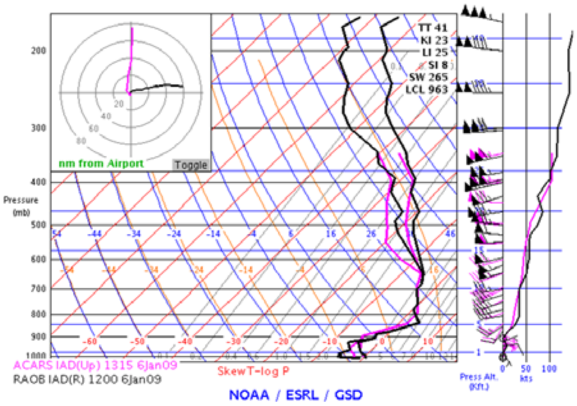

Figure 13. TAMDAR-Chautauqua sounding from Dulles, VA, compared with the collocated RAOB, around 12 UTC 6 Jan 2009. Flight tracks are shown in the upper left.

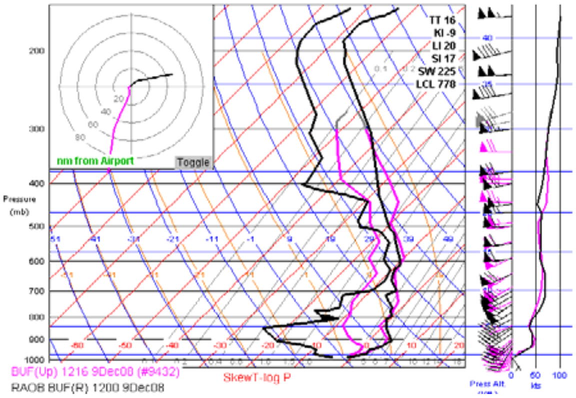

Fig. 14. TAMDAR-Chautauqua ascent sounding from Buffalo, NY (violet) and Buffalo RAOB for near 12 UTC, 9 Dec. 2009.

Figure 14 shows a TAMDAR-Chautauqua ascent sounding from Buffalo, NY, compared with the RAOB there. Agreement between TAMDAR and the RAOB is generally good for both temperature and wind. However, the RAOB reports drier conditions below 700 hPa. The flight tracks for the aircraft (violet) and RAOB (black) in the upper left of the plot show that the two sensors sampled different locations. Mesoscale variability could certainly account for the moisture difference seen.

Figure 15 shows a TAMDAR-Chautauqua ascent sounding from Dallas, compared with the nearby Fort Worth RAOB near 0 UTC 19 December 2008. In this case the TAMDAR sensor was not reporting winds. Agreement between TAMDAR and RAOB is generally good for both temperature and dewpoint, and remains reasonably good for dewpoint up to the 220 hPa maximum height of the aircraft sounding. (Portions of aircraft soundings taken when the aircraft is more than 100 nm from the airport are colored gray.) Below 830 hPa, however, the RAOB reports saturated conditions while TAMDAR reports drier conditions. At the surface, TAMDAR reports a dewpoint of 43 °F, while the RAOB reports 62 °F. The Fort Worth METAR station reports a dewpoint of 61 °F at that time. In this case, the TAMDAR sensor is apparently reporting an inaccurate dewpoint at the surface.

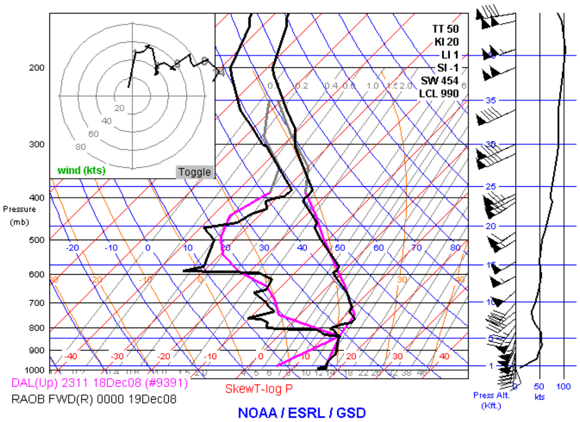

Fig. 15. TAMDAR ascent sounding from Dallas, TX, compared with the nearby Ft. Worth, TX RAOB for near 0 UTC 19 Dec 2008.

4.2 *TAMDAR comparisons with RUC forecasts*

In the discussions below, we compare AMDAR (including TAMDAR) and RAOB observations with 1-h forecasts from the dev2 model. Dev2 forecasts are interpolated in space to the location of each aircraft observation, and the forecast with a valid time nearest the observation time is used. For RAOBs, we match the observation with the forecast from the grid column nearest to the launch point. In every case, the observations we are comparing are *not* assimilated into the analysis that produced the forecast, so observations do not indirectly verify themselves.

For instance, a TAMDAR observation taken at 1131 UTC will be compared with the dev2 forecast valid at 12 UTC, which was produced by the dev2 11 UTC analysis. And the 11 UTC analysis does not ingest any AMDAR data taken after 11 UTC.

The RAOB-model differences are shown with respect to the 1-h forecast valid at 0 UTC, generated from the analysis at 23 UTC, so the RAOBs also do not self-verify.

We don't consider the RUC model to be the "truth", but it does provide a common benchmark against which we can compare multiple data sources.

a. Temperature

Figure 16 shows temperature "bias" (defined here as observation minus model 1-h forecasts) for TAMDAR-Chautauqua, traditional jets, and the 38 RAOBs in the eastern U.S. region (approximately the violet rectangle shown in Fig. 1).

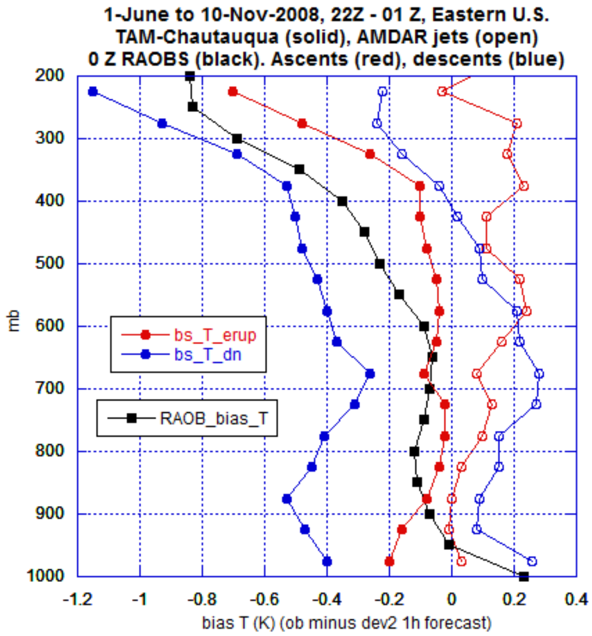

Fig. 16. Temperature "bias" (observations minus dev2 1-h forecasts) for TAMDAR-Chautauqua (solid circles), traditional AMDAR jets (open circles) and 0 UTC RAOBs (black squares). Ascents are shown in red; descents in blue.

Generally, Chautauqua ascents and descents have bias within ±0.4°C of the RAOB bias. Near the surface, however, Chautauqua ascents and descents are both cooler than the RAOB. Traditional AMDAR jets are generally warmer than the RAOB and Chautauqua data, and agree more closely with the dev2 1-h forecasts. (The closer agreement between traditional AMDAR jets and dev2 is unsurprising because AMDAR jets provide far more data to the dev2 than do TAMDAR or RAOBs.) The Chautauqua ascents, however, are closer at some levels to the dev2 1-h forecasts than the AMDAR observations.

For comparison with our previous studies, Fig. 17 shows the same RAOB and TAMDAR-Chautauqua data as Fig 16 (although the scale is slightly different), but the open circles are TAMDAR-Mesaba data. The Mesaba data are warmer than the Chautauqua data and the RAOB data at most levels. They are more in line with traditional AMDAR jets. For both TAMDAR fleets, ascents are warmer than descents by 0°C to 0.4°C, unlike traditional jets for which descents are warmer than ascents below 600 mb.

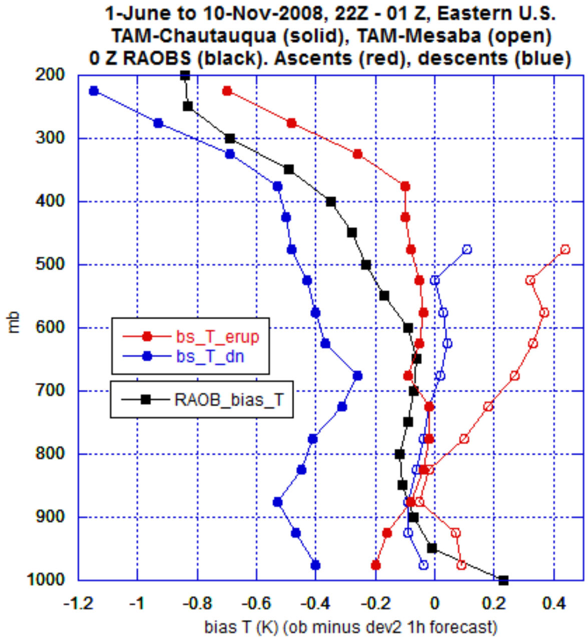

Fig. 17. As for Fig. 16 except open circles are for TAMDAR-Mesaba data.

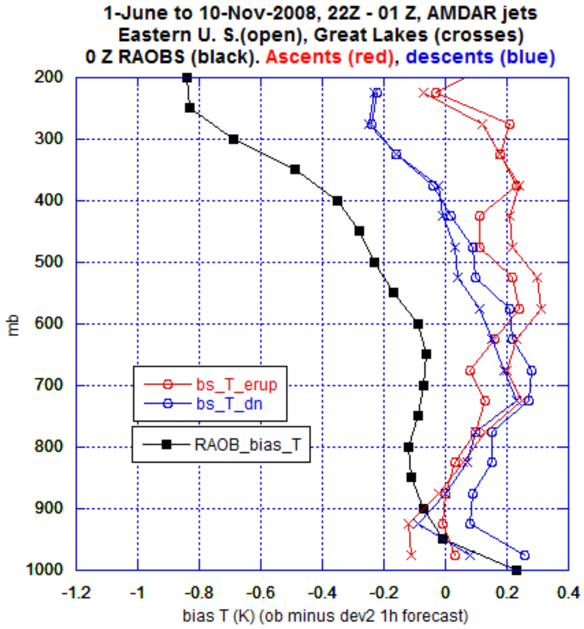

Fig. 18. Temperature "bias" (observations minus dev2 1-h forecasts) for traditional AMDAR jets in the eastern U.S. (open circles), and Great Lakes (crosses) regions, along with eastern U.S. RAOBs (black squares) for the times indicated.

In comparing the Chautauqua and Mesaba fleets, it is worth considering whether geographic differences in the routes of the two airlines may cause statistical differences due to climatological differences in this five-month-plus time period. Figure 18 sheds some light on this.

Because AMDAR jet observations cover both regions fairly uniformly, the differences in the two red curves and the two blue curves indicate the impact of climatological differences between the Great Lakes region and the eastern U. S. region. The differences are seen to be slight, generally less than 0.1°C. Thus, we feel we can safely compare Chautauqua and Mesaba data over this relatively long time period, even though the two fleets fly in different regions.

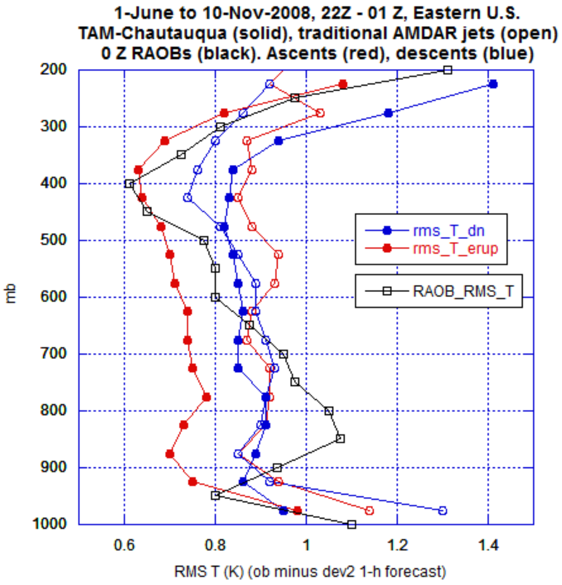

Fig. 19. Temperature RMS difference (observations minus dev2 1-h forecasts) for TAMDAR-Chautauqua (solid circles), traditional AMDAR jets (open circles) and 0 UTC RAOBs (black squares). Ascents are shown in red; descents in blue.

Figure 19 shows that **Chautauqua ascent temperature RMS differences with the dev2 are generally lower than those of traditional AMDAR jets, and are lower than those of RAOBs at most altitudes.** Above 350 hPa, TAMDAR descents show higher RMS differences than do RAOBs or traditional jets, but there are relatively few TAMDAR descent observations at these altitudes. In general, the RMS differences for temperature observations taken during Chautauqua ascents and descents differ from each other more than the AMDAR jet ascents and descents do, suggesting a possible hysteresis problem with Chautauqua temperatures.

b. Wind

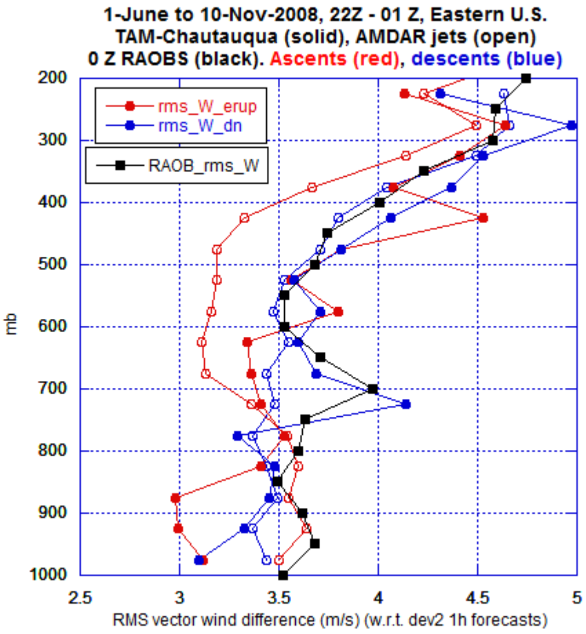

Fig. 20. RMS of vector wind difference (observations minus dev2 1-h forecasts) for TAMDAR-Chautauqua (solid circles), traditional AMDAR jets (open circles) and 0 UTC RAOBs (black squares). Ascents are shown in red; descents in blue.

Figure 20 shows RMS vector wind differences. The **Chautauqua data generally have slightly higher RMS differences with dev2 than do the traditional jets**, perhaps because the Chautauqua jets are smaller and provide a less-stable measurement platform. But the Chautauqua data are reasonably consistent with the RAOB data.

Figure 21 compares Chautauqua and RAOB data (solid) with Mesaba data (open circles). We see the typical pattern: Mesaba wind errors are larger than those from the other data sources, because of the relatively poor heading information from the Mesaba turboprops.

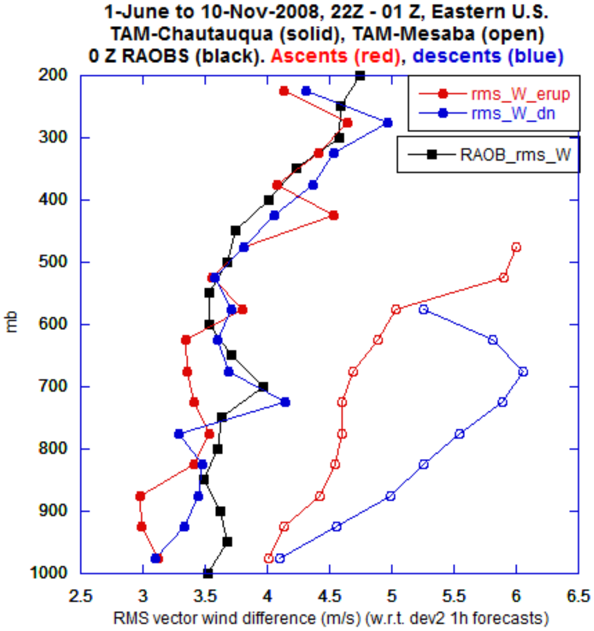

Fig. 21. RMS of vector wind difference (observations minus dev2 1-h forecasts) for TAMDAR-Chautauqua (solid circles), TAMDAR-Mesaba (open circles) and 0 UTC RAOBs (black squares). Ascents are shown in red; descents in blue

c. Relative Humidity

Since AMDAR jets generally do not measure relative humidity (RH), we cannot perform similar comparisons between TAMDAR and traditional jets for RH. However, we can compare TAMDAR RH with RAOB RH. Figure 22 shows RH "bias" (observation minus model).

Generally, the RH differences between observations and dev2 for TAMDAR and RAOBs respectively are within ±6% RH of each other. However, above 400 mb Chautauqua ascents and descents are both somewhat moister than the RAOBs. It might be expected that the Chautauqua data would be more consistent with the dev2 1-h forecasts at these levels because they are the only source of upper air RH data at these levels at non-synoptic times. But we can conclude from Fig. 22 that both the dev2 and the Chautauqua data are moister than RAOBS above 400 mb.

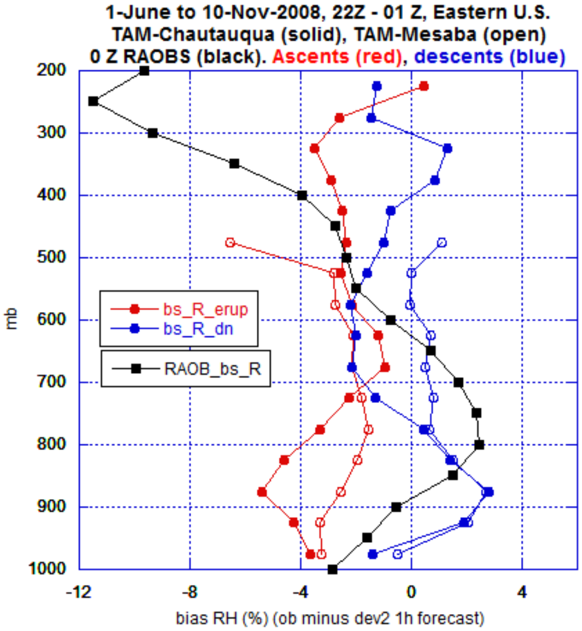

Fig. 22. Relative humidity "bias" (observations minus dev2 1-h forecasts) for TAMDAR-Chautauqua (solid circles), TAMDAR-Mesaba (open circles) and 0 UTC RAOBs (black squares). Ascents are shown in red; descents in blue.

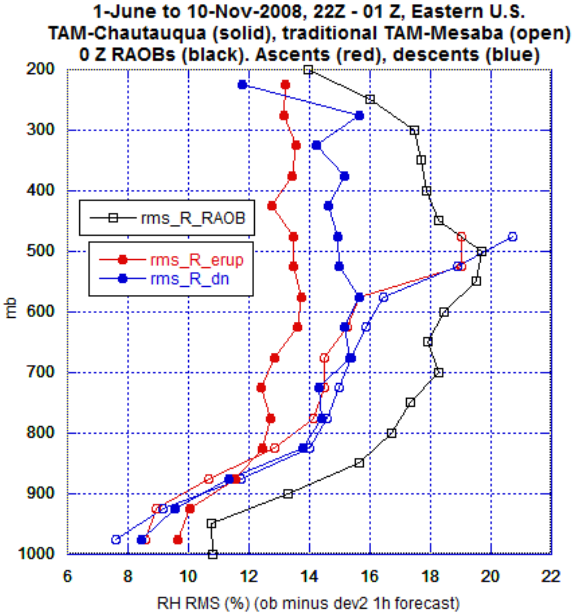

Fig. 23. RH RMS (observations minus dev2 1-h forecasts) for TAMDAR-Chautauqua (solid circles), TAMDAR-Mesaba (open circles) and 0 UTC RAOBs (black squares). Ascents are shown in red; descents in blue.

Both TAMDAR fleets generally show a lower RH RMS differences with dev2 than do RAOBs. This is not surprising since TAMDAR RH observations are ingested by the dev2 hourly, and RAOBs are only ingested when they are available—usually at synoptic times. The reader should not conclude from this that TAMDAR RH observations are necessarily more accurate than those from RAOBs. Nonetheless, Fig.

23 suggests that TAMDAR RH data are of good quality up to 200 hPa.

Above 550 hPa the Chautauqua fleet shows a smaller RMS RH than either the Mesaba fleet or the RAOB. Regarding the relatively large RMS for the Mesaba fleet above 550 hPa, it is worth noting that there are relatively few Mesaba observations in this altitude range.

5. RECENT CHANGES IN GSD INFRASTRUCTURE

Due to computer system changes and changes in FAA budget priorities, we have consolidated our efforts while continuing to maintain a capability to evaluate TAMDAR to the extent that resources allow.

5.1 Termination and replacement of the dev/dev2 cycles

Effective on 5 January 2009, the dev and dev2 parallel cycles have been terminated. This marks the end of a 4-year controlled experiment. The dev and dev2, which ran at 20 km, have been replaced by two 13-km RUC model cycles running at GSD. The backup 13-km RUC ("Bak13"), which is the official backup to the operational RUC, includes TAMDAR data, as well as a number of code and data changes that were not in the dev2—most notably assimilation of radar reflectivity data. In addition, we are running a parallel cycle to the Bak13 that does not include TAMDAR data ("NoTAM13"), and will continue to run this to the extent that resources allow. Initial comparisons between Bak13 and NoTAM13 suggest that TAMDAR impact is approximately the same as it was in the dev/dev2 pair. Forecasts from the Bak13 (along with the operational RUC and other models) are available at http://ruc.noaa.gov/.

5.2 Replacement of RUC-AMDAR statistics with RR-AMDAR statistics

Most of our comparisons between AMDAR (including TAMDAR) data and model forecasts have been with the dev/dev2, although we have used the GFS model to evaluate TAMDAR-PenAir errors in AK (Moninger et al. 2008). With the demise of the dev/dev2, we have developed new model-AMDAR statistics using the GSD Rapid Refresh (RR) model (Benjamin et al 2008). The RR runs hourly and covers all of North America, and thus can be used to evaluate all the TAMDAR fleets including PenAir. Initial results suggest that AMDAR observations agree somewhat better with the RR than they did with the dev2. For AMDAR data older than 48 hours, RR-AMDAR summary and time-series differences are available at http://amdar.noaa.gov/RR_amdar/.

6. SUMMARY AND A LOOK AHEAD

TAMDAR sensors provide meteorological data on a regional scale over the US. We have evaluated the impact of the TAMDAR Chautauqua jet and Mesaba turboprop fleets on wind, temperature, and relative humidity forecasts from the RUC model with real-time matched TAMDAR and no-TAMDAR runs.

We have shown that assimilation of TAMDAR observations improves 3-h RUC forecasts in the region and altitude range in which TAMDAR flies. In previous studies we have shown notable positive impact of TAMDAR data in the U.S. Great Lakes region. With the increase in coverage provided by the Chautauqua fleet, we are now able to show a positive impact over the entire eastern U.S. region. After accounting for instrument and representativeness errors in the verifying observations (i.e., the quality of the analysis fit to RAOBs), we estimate the TAMDAR impact in the eastern U.S. as follows:

- **Temperature 3-h forecast errors are reduced by up to 28%.**
- **Wind forecast 3-h errors are reduced by up to 10%.**
- **Relative humidity 3-h forecast errors are reduced by up to 45%.**

TAMDAR coverage continues to expand. The TAMDAR-PenAir fleet in Alaska has been reporting since October 2007. Moninger et al. 2008 evaluated this fleet, and the NWS AK region is also evaluating it. Recent results (not shown here) indicate that the quality of these data remain good. And recently (29 December 2008) we have started receiving TAMDAR data from Horizon Dash-8 turboprops in the western U.S.

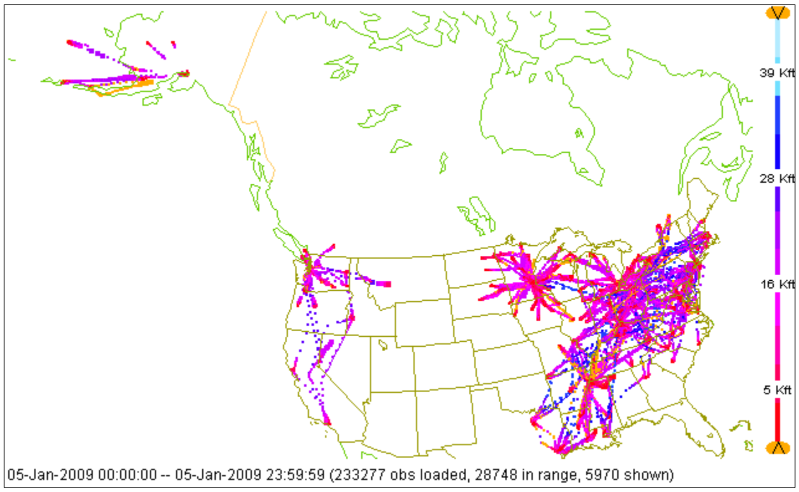

Fig. 24. TAMDAR coverage for 5 Jan 2009. PenAir data are in Alaska, Horizon data are in the western U.S., Mesaba and Chautauqua data are in the eastern U.S.

Figure 24 shows current TAMDAR data over North America. PenAir data are visible in Alaska and Horizon data are visible in the western U.S. Mesaba and Chautauqua data are in the eastern U.S. Currently, only Mesaba data are considered operational. Negotiations between NWS and AirDat are in progress regarding the status of the newer fleets.

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