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3.6 THE TAMDAR SENSOR'S RELATIVE HUMIDITY PERFORMANCE ON ERJ-145 COMMERCIAL AIRCRAFT

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1 INTRODUCTION

The TAMDAR (Tropospheric Airborne Meteorological Data Reporting) Sensor is an airborne atmospheric instrument developed by AirDat in cooperation with NASA (Figure 1). TAMDAR is a novel approach for an aircraft mounted, in-situ, atmospheric measurement system that combines the measurement capabilities of temperature, turbulence, icing, relative humidity (RH), pressure altitude, GPS altitude, and winds into one sensor. Each observation includes the associated time, latitude, longitude. It has proven effective for measuring atmospheric parameters not only in the lower troposphere, which contains significant water vapor, but also at the higher altitudes above 30,000 feet flown by jet aircraft. Accurate water vapor data from all altitudes is lacking and is important for better weather modeling. TAMDAR is now helping to fill this void at both low and high altitudes.

Figure 1 The TAMDAR Sensor

TAMDAR has been addressing the critical need for water vapor data in the lower troposphere since spring of 2005 when the Mesaba SAAB340 turbo prop fleet of 64 airplanes was equipped. This fleet provides data from the greater Great Lakes region. The PenAir SAAB340 fleet was subsequently equipped in June of 2007 and provides valuable data and improved forecasts for the Alaska region. Improvements in forecasting and model accuracy for both the PenAir fleet and the Mesaba fleet have been documented in several papers [6,1]; for example, RH forecast errors in the 3-hr rapid update cycle (RUC) in the region in which Mesaba flies have been estimated to improve by about 15-25% when the TAMDAR data is used [6]. Further advances have been the equipage of Horizon Q-400s (West Coast) and Chautauqua ERJ-145s (Eastern US).

AirDat currently has 137 planes equipped with TAMDAR. A typical 3 days of flights is shown in Figure 2. AirDat has equipage agreements, or is in discussion with airlines that will provide for CONUS TAMDAR coverage, as well as all of Alaska and parts of Canada and Mexico.

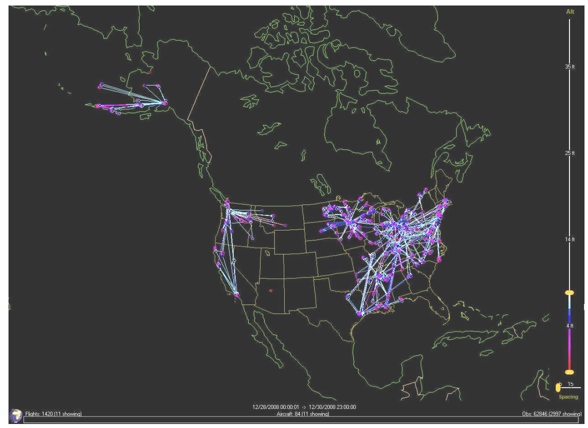

Figure 2 TAMDAR data; 28-30 Dec 2008

The equipage of 52 ERJ-145 (also known as EMB-145) Chautauqua aircraft, beginning in November 2007, has provided an opportunity to evaluate TAMDAR RH at higher speeds and altitudes than are presently covered by the SAABs. The ERJ fleet provides coverage mainly in the eastern and central CONUS. Data points for 13 April for the Chautauqua fleet are shown in the NOAA Global Systems Division (GSD) map in Figure 3.

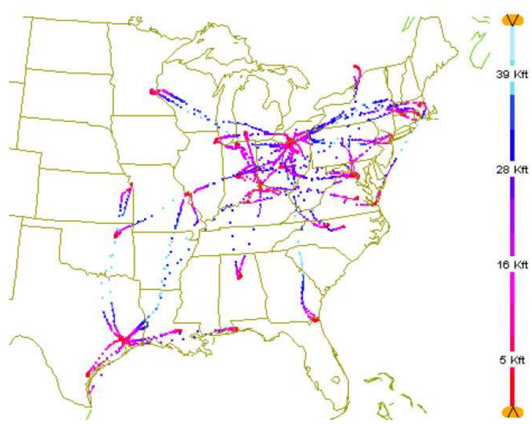

Figure 3 TAMDAR Chautauqua fleet, Sunday, 13 Apr 2008. NOAA GSD map [7].

The terms "TAMDAR Sensor" or "TAMDAR" in this paper refer to the complete TAMDAR unit (combined probe and processing unit as in Figure 1); whereas the

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term “RH sensor” refers only to the capacitive sensor device housed in the TAMDAR probe assembly.

2 RELATIVE HUMIDITY THEORY

2.1 MEASUREMENT METHODS

Airplanes in many ways are ideal platforms for water vapor probes since they can be used to obtain profiles during ascent and descent. The TAMDAR sensor is especially versatile in that it is remotely configurable to provide pressure-based or time-based measurements at adjustable intervals. Turbo props in some ways are better than jets because they service more locations and fly in the lower troposphere even during cruise; however, the recent availability of data from Chautauqua ERJs has also demonstrated them to be useful platforms for the gathering of RH data, especially at higher altitudes not covered by turbo props.

There are several ways of measuring water vapor content from an aircraft. One common method is the direct measurement of dewpoint or frostpoint. This is usually done with a chilled mirror system having a control system that maintains the mirror’s temperature at a point where water vapor or frost just forms on its surface. The temperature of the mirror at this equilibrium point is the dewpoint (or possibly frost point for temperatures below 0°C). Although good results can be obtained, the method has disadvantages in that the equipment must be kept in calibration and the mirror must be kept free of contamination. It is also relatively large and complex.

Another measurement is mixing ratio which is the ratio of mass of water to mass of dry air. This can be done with a tunable diode laser system which can be accurate, but is complicated, expensive and has reliability issues.

The method chosen for TAMDAR uses two capacitive sensing devices to directly measure RH. The actual device used has a proven track record in industrial applications and, with the addition of a custom hydrophobic filter, has been shown to be very reliable on TAMDAR equipped aircraft. The filter dramatically increases reliability and prevents direct wetting of the sensor element resulting in increased accuracy. The sensor board containing the RH sensors is also easily field replaceable in less than 10 minutes, without requiring removal of the TAMDAR Sensor itself. This operation requires no aircraft power or operational tests making the maintenance load on the airlines minimal.

The RH measurement technology chosen for TAMDAR has the advantages of low cost and high reliability. The limitations to using this technology on high speed aircraft have been carefully addressed and as a result, TAMDAR RH has been proven to be useful not only in the lower troposphere (as on the Mesaba turboprop fleet), but also on faster, higher altitude planes such as the Republic Embraer ERJ-145 (Figure 4). This paper primarily documents RH performance results on the ERJ-145.

Figure 4 TAMDAR on Chautauqua ERJ-145

The TAMDAR Sensor uses two identical RH sensors for redundancy. The RH reported value is a “consensus” value that is determined by an algorithm in AirDat’s ground processing system. The system considers the value and quality of each sensor output. Usually, both sensors are reporting very close to the same value and the consensus value is simply the average of the two after the proper compensation is done. If the sensors disagree significantly, and one is determined to be good, then only the good one’s output will be used. Unless otherwise indicated, the RH consensus value is the one used in this paper. Also reported is an estimate of the RH uncertainty. This is described further in the next section.

2.2 RELATIVE HUMIDITY CORRECTIONS

Certain corrections need to be made to the actual RH that the RH sensor is reporting. The primary corrections are because of the Mach heating occurring to the air the RH sensor is measuring, and the difference in air pressure between the ambient conditions and the conditions the sensor is seeing.

The RH for a parcel of air with a given water vapor concentration is a function of both temperature and pressure. There are 4 major factors that contribute to the errors in the direct measurement of true RH as is done in TAMDAR:

1. The accuracy of the RH sensor itself (ΔRH).
2. The accuracy of the TAMDAR probe temperature (T_{probe}) measurement--done with a platinum resistive temperature device (RTD) in TAMDAR.
3. The accuracy of the calculated static air temperature (T_{static}).
4. The accuracy of the ratio of the static pressure (P_{static}) to the RH sensor pressure (P_{probe}) ratio calculation.

Eq. 1 describes the basic calculation necessary for static RH.

$$RH_{static} = RH_{probe}(P_{static}/P_{probe}) \cdot e_{s,probe}(T_{probe})/e_{s,static}(T_{static}), \qquad (1)$$

Where RH_{static} is the atmospheric RH, RH_{probe} is the actual RH measurement from the RH sensor in the TAMDAR probe, P_{static} is the static air pressure, P_{probe} is the air pressure at the RH sensor in the probe, T_{probe} is the temperature in the probe sensing cavity, T_{static} is the static air temperature, $e_{s,probe}$ is the probe saturation vapor pressure relative to water, and $e_{s,static}$ is the static saturation vapor pressure relative to water. The saturation pressure ratio is strictly a function of T_{probe} and T_{static} as shown above. The calculation for the pressure ratio (P_{static}/P_{probe}) has been derived from data from wind tunnel testing and is believed to be accurate.

The relationship between T_{probe} (essentially the recovered temperature) and T_{static} is,

$$T_{probe} = T_{static}(1 + \lambda \cdot m^2), \tag{2}$$

where m is the Mach number and λ is a constant approximately equal to 0.17 in TAMDAR.

The actual RH sensor measurement is the true value plus a sensor error ΔRH, thus

$$RH_{probe} = RH_{true} + \Delta RH \,. \tag{3}$$

Substituting Eq. 3 into Eq. 1 illustrates an issue that needs consideration when using the RH method. As the Mach number increases, and the temperature decreases, the saturation pressure ratio ($e_{s,probe}/e_{s,static}$) in Eq. 1 increases rapidly, and as a result, the effect of the sensor error, ΔRH, is amplified. The AirDat ground processing system estimates the error in the RH based on temperature and Mach. This is used along with the known accuracy of the RH sensor and the temperature accuracies to calculate an overall RH uncertainty which is reported along with the RH.

The range of RH that will be experienced by the RH sensor is also reduced due to the Mach heating; in fact, at high speeds the RH internal to the probe will generally be less than 10% due to the Mach heating of the air. This effect is addressed in TAMDAR by the AirDat custom calibration process. Each RH sensor is characterized over several RH and temperature conditions. Values are specifically chosen at conditions which are error prone; in particular, cold, dry conditions. This calibration process results in a TAMDAR RH measurement capability that is useful even at high altitudes.

It should be mentioned that one effect of Mach heating is beneficial. Since the response of the capacitive sensor slows down as temperature decreases, the Mach heating effect keeps the RH sensor significantly warmer than ambient, resulting in a response time faster than otherwise. The sensor in a radiosonde (RAOB) does not experience this Mach heating.

3 DATA AND VERIFICATION METHODS

Verification methods include flights on the University of Wyoming King Air; indirect RAOBs comparisons; and the GSD RUC and the AirDat real-time four-dimensional data assimilation (RTFDDA) model comparisons. All RH error units are %RH unless otherwise noted, and all temperatures are static air temperatures unless otherwise noted.

Histograms of Chautauqua and Mesaba flights for a 2 day period shows the distribution of observations at various pressure levels for the two fleets (Figure 5 and Figure 6).

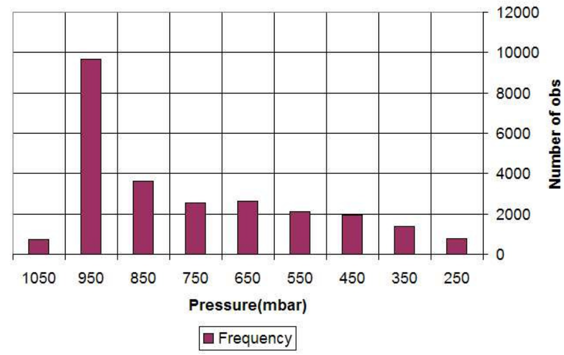

Figure 5 Histogram of Chautauqua (ERJ) observations versus pressure level for 21-22 Dec 2008.

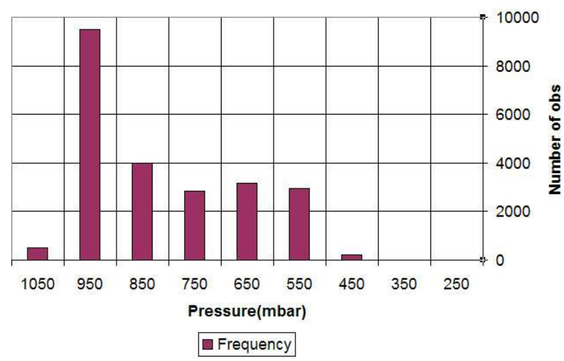

Figure 6 Histogram of Mesaba (SAAB) observations versus pressure level for 21-22 Dec 2008.

4 RESULTS

4.1 UNIVERSITY OF WYOMING KING AIR

The University of Wyoming King Air is one of several research aircraft used to verify TAMDAR performance. Figure 7 shows a typical King Air flight comparing TAMDAR RH to a chilled mirror reference. A LICOR instrument not shown here gave similar results. The air temperature is shown on the right axis. Strong agreement is evident between TAMDAR and the reference although the TAMDAR RH signal is slower.

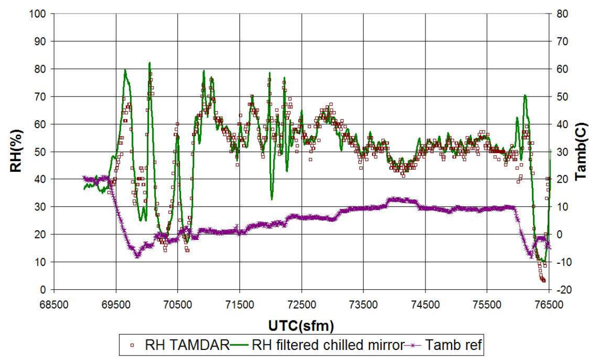

Figure 7 TAMDAR RH and temperature, and chilled mirror time series on the University of Wyoming King Air. 6 Sep 2007.

4.2 GLOBAL SYSTEMS DIVISION ANALYSIS

The data and some of the plots are from monthly reports by Bill Moninger of NOAA GSD as part of an FAA sponsored TAMDAR evaluation. The data are from two time periods: 4 Apr to 14 May 2008 and 1 Jun to 10 Nov 2008. The analysis compares TAMDAR, ACARS (for temperature only) and RAOBS observations to the RUC dev or dev2 1hr forecasts each day. Observations for TAMDAR and ACARS from 2200 to 0100 UTC, and RAOB data at 0000 UTC are compared. Each observation is compared to the 1 hour forecast for the nearest hour. The RUC dev forecast does not have TAMDAR ingested whereas the dev2 does. Observations with a calculated RH uncertainty of less than 49% were used.

4.2.1 GSD APRIL-MAY 2008

Shown below are Chautauqua data comparison statistics for 4 Apr to 14 May using the RUC dev cycle from 2200 to 0100 UTC along with RAOBs data at 0000 UTC. The Aircraft Meteorological Data Relay (AMDAR) jets (ACARS) data are from the eastern US (Lat 28^0 to 49^0 N, Long 69^0 to 101^0 W) since that is the region in which Chautauqua flies. The RAOBs data are mostly from that same region with the exception of three that are slightly to the north: INL, YMO and WPL. The dev RUC cycle is used here rather than the dev2 because the Chautauqua data had only recently been added to the dev2 and using the dev allowed longer term comparisons.

Figure 8 shows the model to be wetter than the RAOB or TAMDAR data at high altitudes; however, the fact that the TAMDAR data tracks the RAOB data well even at the higher altitudes is a very encouraging trend. RAOB data are assumed closer to truth than the RUC. Figure 9 shows TAMDAR to have a lower standard deviation with respect to the model than that of the RAOB data suggesting that Chautauqua data are as good as or better than RAOBS.

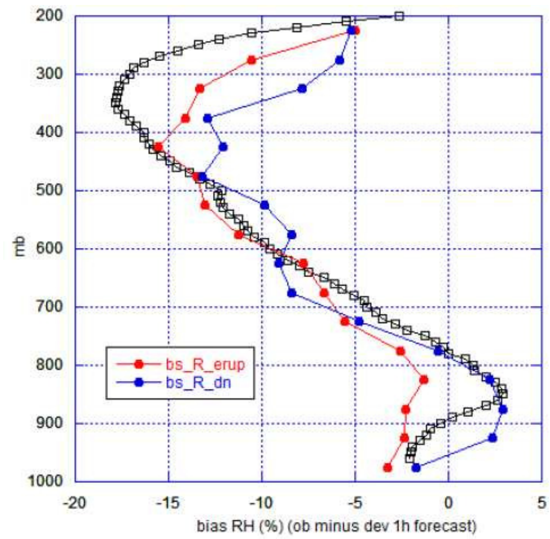

Figure 8 Chautauqua ERJ-145 (circles) and RAOB (black squares) RH Bias Compared to the RUC dev, 4 Apr to 14 May 2008. Chautauqua descents in Blue, enroute/ascents in Red [7].

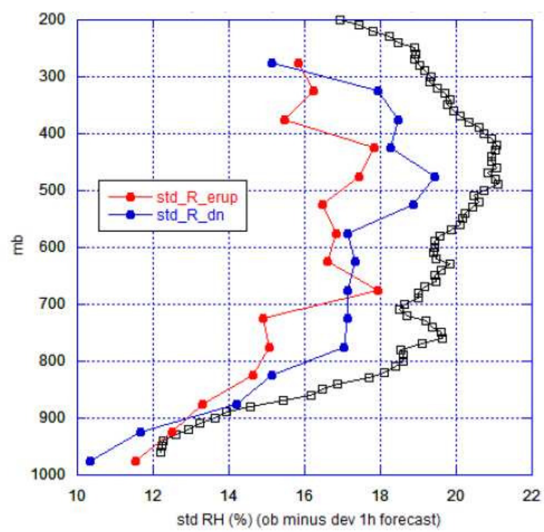

Figure 9 Chautauqua ERJ-145 (solid circles) and RAOB (black squares) RH standard deviation compared to the RUC dev, 4 Apr to 14 May 2008. Descents in blue, enroute/ascents in red [7].

Figure 10 shows the temperature bias of Chautauqua, RAOB and AMDAR. TAMDAR has the capability of using its own temperature sensor, or taking the temperature off of an aircraft data bus if such a bus is available and the data is deemed to be as good as TAMDAR. For the ERJs, the bus temperature is used (Mesaba on the other hands uses the TAMDAR temperature). The spread between the enroute/ascent and descent curves are greater than AMDAR; however, the enroute/ascent TAMDAR curve is closer to RAOBS than AMDAR. The ingestion of a relatively large amount of warm AMDAR data could be causing the model to be warm.

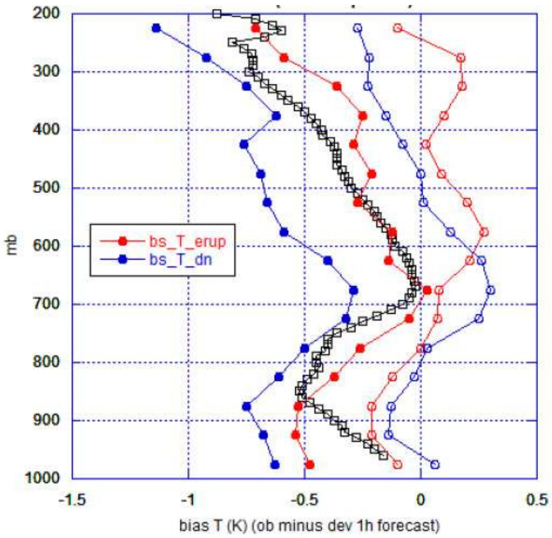

Figure 10 Chautauqua (ERJ-145) (solid circles), RAOB (black squares), and AMDAR (open circles) Temperature bias compared to the RUC dev, 4 Apr to 14 May 2008. Chautauqua and AMDAR descents in blue, ascents/en-route in red [7].

Since the calculation of the RH is a function of air temperature, errors in the temperature calculation will result in errors in the RH calculation. This might explain some of the difference between the enroute/ascent and the descent bias. Because the ascent temperature is slightly warmer than descent, the calculated ascent RH will be less than the descent. The actual difference will also be a function of the RH and temperature.

To investigate the magnitude of this effect, the ascent temperature was assumed to be correct and the descent slightly too cold. A standard temperature lapse rate of -6.5C/1000m and an RH of 40% were assumed since the actual data weren't available; only the biases. Then a new descent RH was calculated based on the ratio of the saturation pressure of the assumed ascent temperature to the saturation pressure of the assumed descent temperature, and the assumed RH. The resulting change in RH is about 0.5% at ground level and increased to about 2% at 225mb. Since the actual RH and temperature for each observation is not available, this correction is only approximate.

To make the difference between TAMDAR and RAOB easier to see, the RAOB trend was removed. Figure 12 shows the difference between the TAMDAR RH bias data and the RAOB bias data from Figure 8. TAMDAR is for the most part, somewhat drier than RAOBs below 500mb and moister above. The "corrected" descent RH based on the assumptions mentioned above is shown as the blue open squares.

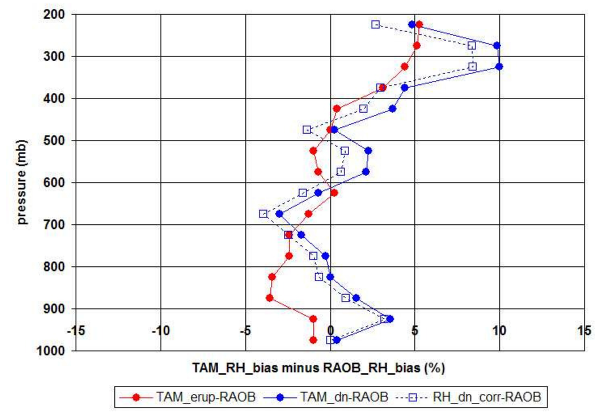

Figure 11 Chautauqua RH RUC dev2 bias minus RAOB RUC dev2 bias. 4 Apr to 14 May 2008. Descents in blue, enroute/ascents in red. Estimated corrected descent RH based on temperature bias, standard temperature lapse rate, and 40% RH (blue open squares).

4.2.2 GSD JUNE-NOVEMBER 2008

This section shows comparison statistics in the 1 Jun to 10 Nov period. The RAOBS data are mostly from the eastern US bounded by Lat 28^0 to 49^0 N and Long 70^0 to 102^0 W. There are three RAOBS in the study that are slightly north of that region: INL, YMO and WPL. The dev2 model is used for these comparisons.

Figure 12 shows the RH bias of Chautauqua, RAOB and Mesaba. Since these comparisons use the dev2 model, TAMDAR data are being ingested. Also, Chautauqua RH data is the only source for upper air RH at non-synoptic times and so that data would be expected to be consistent with the model. Chautauqua TAMDAR generally agree with the RAOB data except the trend above 400mb where TAMDAR is somewhat moister than the RAOBs. This is also the trend in Figure 8 and Figure 11. Note that the scales are different in the two examples.

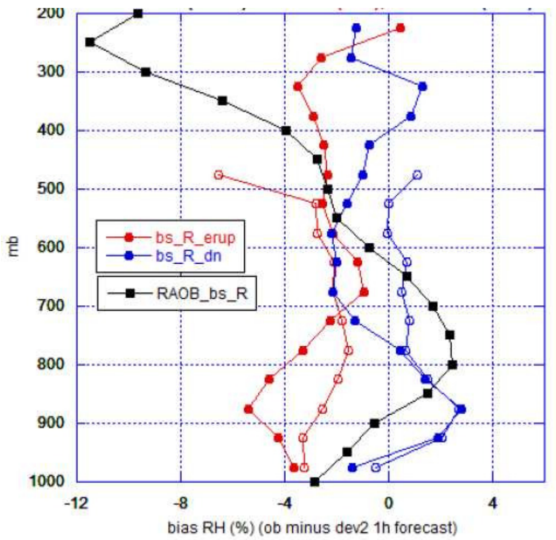

Figure 12 Chautauqua ERJ-145 (solid circles), Mesaba (open circles), and RAOB (black squares) RH bias compared to the RUC dev2, 1 Jun to 10 Nov 2008. Descents in blue, enroute/ascents in red [8].

Figure 13 shows temperature bias for Chautauqua, RAOB and AMDAR. The trend is similar to that seen in the Apr-May data. TAMDAR external temperature has a greater spread between ascent and descent than the AMDAR, but tends to agree with the RAOB data during enroute/ascent more so than does the AMDAR data as in the Apr-May case.

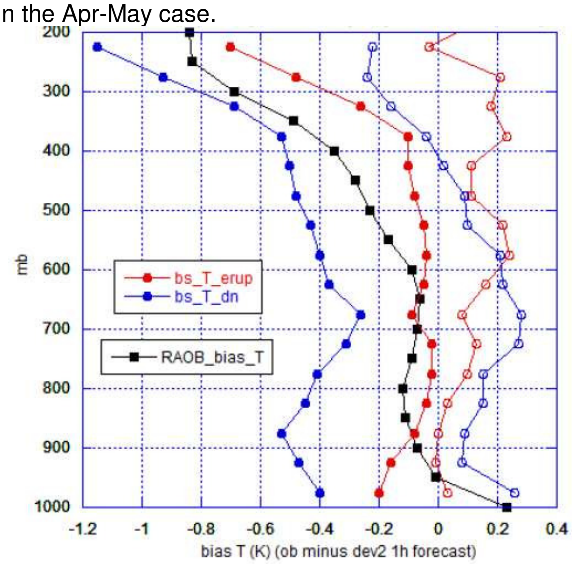

Figure 13 Chautauqua ERJ-145 (solid circles), RAOB (black squares), and AMDAR (open circles) temperature bias compared to the RUC dev2, 1 Jun to 10 Nov 2008. Descents in blue, enroute/ascents in red [8].

Figure 14 shows the difference between the TAMDAR RH bias data and the RAOB bias data from Figure 12. TAMDAR is somewhat drier than RAOBs below 500mb and moister above. The "corrected" descent RH based on the same assumptions used for Figure 11 is shown as the blue open squares. These trends for Jun-Nov are similar to those for Apr-May.

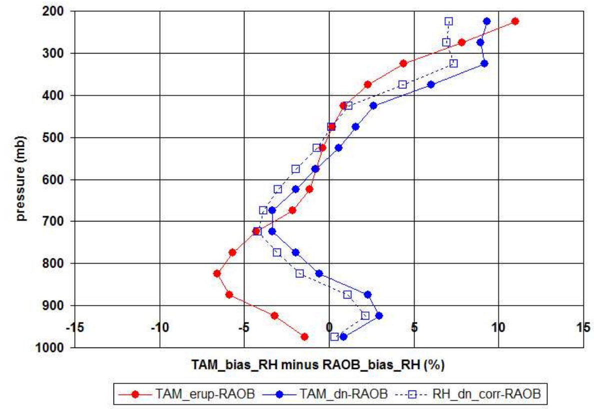

Figure 14 Chautauqua RH RUC dev2 bias minus RAOB RUC dev2 bias. 1 Jun to 10 Nov 2008. Descents in blue, enroute/ascents in red. Estimated corrected descent RH based on temperature bias, standard temperature lapse rate, and 40% RH (blue open squares).

Table 1 is based on the data in Figure 14 and shows the difference between the TAMDAR Chautauqua bias and the RAOBs bias for three pressure bands. The difference between the TAMDAR and RAOBS bias, for each pressure range, is weighted based on the number of points for each altitude, and averaged.

Table 1 Chautauqua RH RUC dev2 bias minus RAOB RUC dev2 bias for three pressure ranges. 1 Jun to 10 Nov 2008.

	TAM RH bias minus RAOBS bias		
	ascent/enroute	descent	All
sfc-701mb	-3.571	1.113	-0.848
700-301mb	-0.146	0.018	-0.057
300mb-up	8.453	9.000	8.656

4.3 ERROR AND BIAS VERSUS MACH

In order to investigate the effect of high Mach numbers on RH performance, comparisons of RH standard deviation and bias to the AirDat RTFDDA MM5 1-hr forecast were done and grouped in terms of Mach. (Generally, experience has shown that the RTFDDA tracks closely to the GSD RUC dev2.) Both ERJ (Figure 15) and Mesaba (Figure 16) plots are shown. The x-axis value represents the center value of the Mach bin. RH values with a calculated uncertainty less than 29% were used. It must be stressed that the model is not considered truth, but the limited reference data available still makes it a useful indicator of gross performance changes as the Mach increases.

The first two time periods were chosen to be the same as those used in Bill Moninger's analysis presented in section 4.2. The performance over the three time periods is surprisingly stable. This suggests TAMDAR

RH performance does not experience significant seasonal changes. The bias above Mach 0.6 does increase somewhat but the increase is less than might be expected given the Mach heating effect mentioned in section 2.

It is also apparent that the trends for bias and standard deviation for Mesaba are similar to Chautauqua over their common Mach ranges.

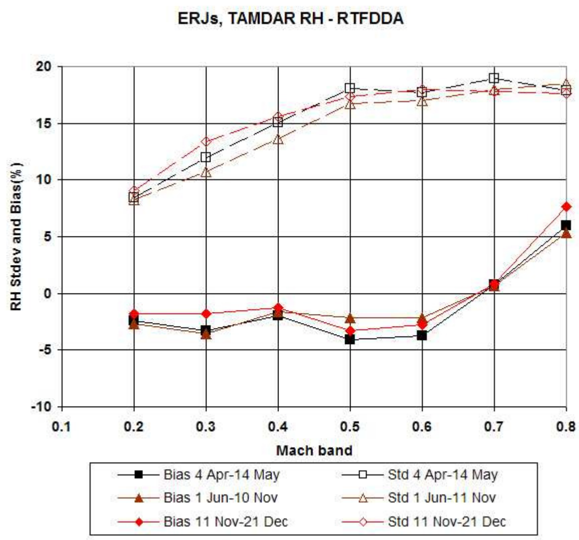

Figure 15 RH bias and standard deviation vs. Mach relative to RTFDDA for the Chautauqua (ERJ) fleet for 3 time periods.

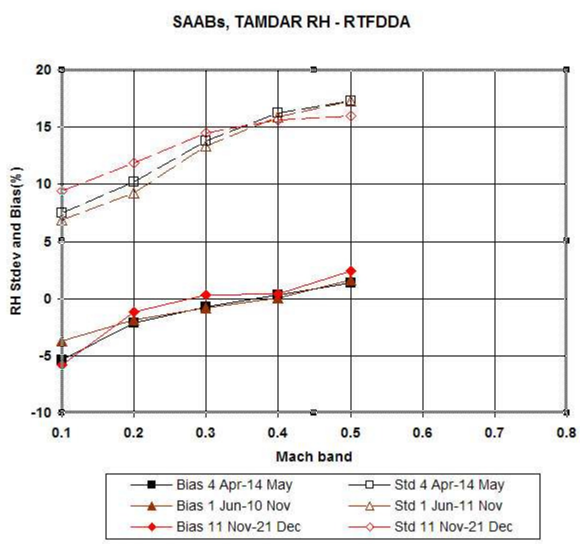

Figure 16 RH bias and standard deviation vs. Mach relative to RTFDDA for the Mesaba (SAAB) fleet for 3 time periods.

4.4 GSD RUC, Rapid Refresh RUC and RTFDDA

In order to study the differences between the various models; RH and temperature statistics, for each plane, for a one week period were plotted for the Rapid Refresh (RR) RUC, and the RUC dev2 (Figure 17, Figure 18, Figure 19, and Figure 20). Data for 300mb and above are shown. For this period there is a significant difference in the overall RH bias between the RUC dev2 and the RR RUC. Since the temperature bias difference between the models is similar, the RH bias difference seems to indicate a significant water vapor content difference between the models.

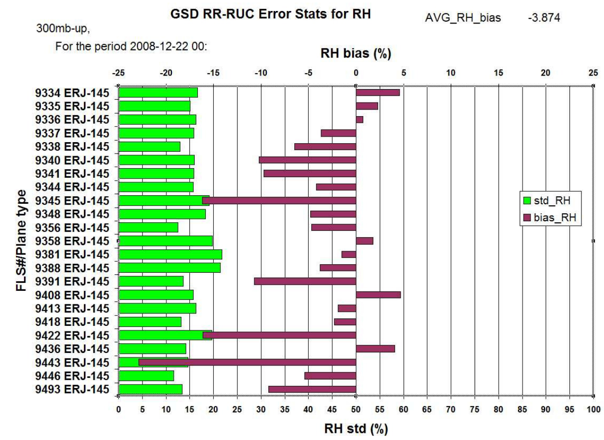

Figure 17 RH Bias (top axis) and standard deviation (bottom axis) for Chautauqua minus RR RUC for 300 mb and above. 1571 total obs. The y-axis is the GSD (FSL) aircraft ID. 23 Dec to 29 Dec 2008.

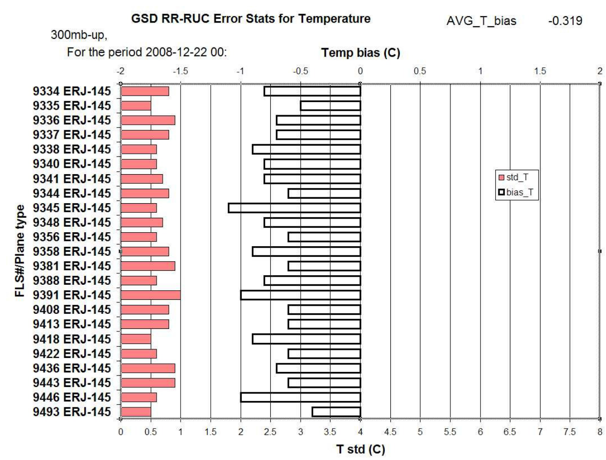

Figure 18 Temperature Bias (top axis) and standard deviation (bottom axis) for Chautauqua minus Rapid RR RUC for 300 mb and above. The y-axis is the GSD (FSL) aircraft ID. 23 Dec to 29 Dec 2008.

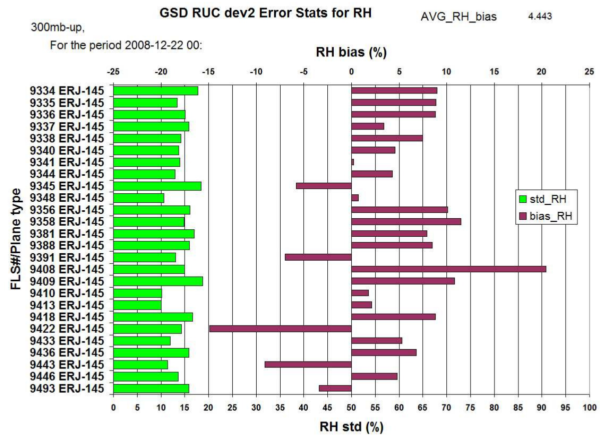

Figure 19 RH Bias (top axis) and standard deviation (bottom axis) for Chautauqua minus RUC dev2 for 300 mb and above. 1977 total obs. The y-axis is the GSD (FSL) aircraft ID. 23 Dec to 29 Dec 2008.

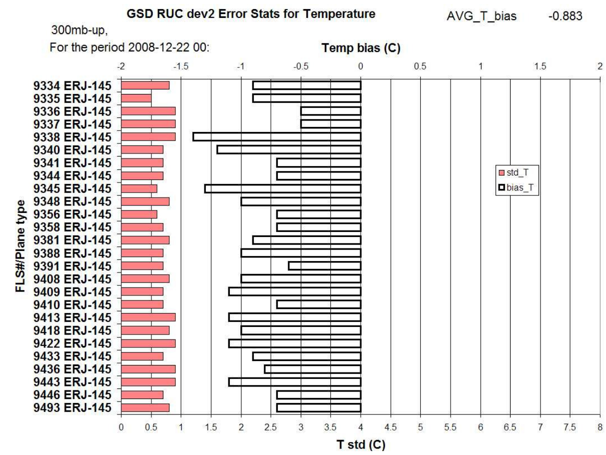

Figure 20 Temperature Bias (top axis) and standard deviation (bottom axis) for Chautauqua minus RUC dev2 for 300 mb and above. The y-axis is the GSD (FSL) aircraft ID. 23 Dec to 29 Dec 2008.

Table 2 Shows biases for both temperature and RH for all data, surface to 300mb (sfc-300mb), 700-300mb and above 300mb (300mb-up). The main region of disagreement is that of the RR-RUC RH above 300mb; it's drier than the RUC or RTFDDA. This region is strictly ERJ data since the SAABs are limited to a maximum of 25,000 feet. RH values with an uncertainty less than 49% were used. The number of observations for the temperature bias is not shown, but is somewhat greater due to the different quality filtering for the RH.

Table 2 RH and temperature (T) bias for various pressure bands for combined Mesaba and Chautauqua TAMDAR fleets for RUC dev2, RR-RUC, and AirDat RTFDDA. 23 Dec to 29 Dec 2008.

	GSD RUC dev2			GSD RR-RUC			AirDat RTFDDA		
	RH bias(%)	# RH obs	T bias(C)	RH bias(%)	# RH obs	T bias(C)	RH bias(%)	# RH obs	T bias(C)
All	-0.262	115492	-0.065	-0.603	116662	-0.295	-0.869	63075	-0.065
sfc-701mb	-0.162	76484	-0.074	-1.311	77620	-0.334	-0.615	43453	-0.072
700-301mb	-0.752	35748	0.040	-0.596	33837	-0.242	-1.911	21015	-0.021
300mb-up	4.443	1977	-0.883	-3.874	1571	-0.319	7.083	1046	-0.397

5 RELIABILITY

Generally the components in the TAMDAR can last indefinitely with the exception of the RH sensors and the RH sensor board. AirDat has dramatically increased the reliability of the RH sensors since the first units were installed.

When both RH sensors are deemed to be in a failed state, the actual sensor board in the probe assembly can be replaced in the field without removing the TAMDAR Sensor. This is minimal maintenance requiring less than 15 minutes.

The use of two redundant RH sensors dramatically increases the MTBF because a failure of one RH sensor still allows the remaining one to be used. When a failure occurs, the sensor board containing the two RH sensors and the temperature sensor is easily field replaceable. Sensor boards returned with RH sensor still operating can be recalibrated at the factory using the standard procedure.

The TAMDAR Sensor, and the enclosed humidity/temperature sensing board, has been re-designed since the initial Mesaba Great Lakes Field Experiment (GLFE) deployment. Hence, reliability on future deployments should be substantially improved, and MTBF increased. On the Mesaba fleet of 50 aircraft, for the six month period from July 12, 2006 to Feb. 12, 2007, 11 humidity/temperature sensor boards were replaced due to failure or degraded performance. During this period there were approximately 73,000 total flight hours on 50 aircraft. Hence, one humidity sensor board replacement was required per 6,600 flight hours, for an MTBF of approximately 6,600 hours or 2.3 years. With recent improvements the MTBF is expected to be further increased.

6 SUMMARY

The TAMDAR equipped fleets have been providing meteorological data over the eastern US, the Midwest, Alaska, and now with the Horizon fleet, the West Coast. RH and temperature are two very important measurements TAMDAR provides. The accuracy of these two measurements on the Chautauqua ERJ -145 regional jet fleet was studied based on comparisons of TAMDAR and RAOBs to the RUC model; and TAMDAR to the AirDat RTFDDA model. The Chautauqua fleet is our first opportunity to effectively study TAMDAR RH on Mach 0.8 platforms

The AirDat TAMDAR Sensor uses two redundant capacitive RH sensors and a temperature source (either TAMDAR or bus temperature) to measure water vapor content. The advantages of the TAMDAR RH sensor include low cost and simplicity. The main limitations of this technology, Mach heating effects at high Mach and sensor reliability, have been effectively addressed by AirDat in the TAMDAR Sensor design. RH sensor reliability and lifespan, using the custom hydrophobic filter, has been greatly increased over that of capacitive sensors with no filter; furthermore, AirDat's custom calibration for the RH sensors has addressed those problem regions for accuracy: mainly the cold dry conditions that are experienced at high altitude along with the significant Mach heating effect.

Biases between TAMDAR and the GSD RUC; and RAOBs and the GSD RUC; were used to demonstrate TAMDAR's good performance even at high altitudes. In particular, data from the TAMDAR equipped Chautauqua ERJ-145 fleet have shown RH bias and standard deviation to be within reasonable limits compared to RAOBS. Based on GSD data from 1 Jun to 10 Nov 2008, overall TAMDAR bias relative to RAOBs above 300mb is about 8.6%, and from 700-300mb and below 700mb, the overall bias magnitude is less than 1%.

Comparisons to AirDat's RTFDDA model showed good performance at all speeds, even in the Mach 0.6-0.8 range. The fact that TAMDAR RMS error does not significantly increase after Mach 0.6 is considered an important achievement, as other attempts to directly measure RH have encountered difficulties at high Machs. It was also shown that the TAMDAR RH statistics are very stable seasonally. Stable data quality is important when that data is ingested into models.

High altitude water vapor observations from the ERJ fleet are expected to be a useful additional data set for the WRF model. Depending on the season, at mid latitudes the core of the jet stream can fall near the 300mb level. TAMDAR RH observations in this region of enhanced model vertical resolution will aid in creating an improved atmospheric analysis and forecast. The data is also expected to aid in the assimilation of various satellite derived observations. This will be especially important as AirDat begins running models over different parts of the globe as the TAMDAR fleet grows.

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