3.9 A Comparison of WVSS-II and NWS Radiosonde Temperature and Moisture Data

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1. INTRODUCTION

Measurement of atmospheric water vapor by commercial aircraft began in the late 1990s, in a cooperative venture by United Parcel Service (UPS) Airlines and the National Weather Service (NWS). A sensor employing a thin film capacitor became known as the Water Vapor Sensing System (WVSS). It was installed on six UPS aircraft between 1997 and 1999. A two week study was conducted by the NWS in Louisville, Kentucky in the fall of 1999 that compared WVSS data from UPS aircraft with radiosondes launched from a nearby mobile sounding unit. A comparison was also made in the second half of 1999 of these six aircraft when they were near NWS radiosondes around the 00 and 12UTC sounding times. These studies showed that WVSS data to be comparable to NWS radiosondes.

The availability of sixteen WVSS aircraft in the spring of 2001 prompted a comparison of this new data source with NWS radiosondes over a several month period. Data was accessed from the Forecast Systems Laboratory's (FSL) Aircraft Data web page and was compared to NWS radiosonde data that is also available at that site. Nearly 1100 data comparisons were made at various mandatory sounding levels from 925 to 250 mb in the three month period from May through July 2001 This experiment is described in detail in Mamrosh, et. al. (2001). While the WVSS supplied data of reasonable quality, they required maintenance at intervals unacceptable to the airline. In response to this problem, and in an attempt to get water vapor data of superior quality, a new sensor called the Water Vapor Sensing System II (WVSS-II) was developed.

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Instead of a thin film capacitor to measure atmospheric moisture, it employs a more accurate technology using a laser diode. It had been installed on 25 UPS aircraft by the summer of 2005. In order to determine how the WVSS-II compared to the WVSS (hereafter called WVSS-I), a study was conducted during the summer of 2005 that was nearly identical to the WVSS-I to radiosonde comparison. Preliminary data suggest that the WVSS-II compares more favorably to NWS radiosondes than its predecessor.

2. THE WATER VAPOR SENSING SYSTEM - VERSION II

The laser diode used in the WVSS-II is produced by SpectraSensors, and is quite small (Fig. 1). It receives environmental air from an air sampler designed by the University Center for Atmospheric research. The air sampler is mounted on the outside of the fuselage of the aircraft, and directs air to the WVSS-II sensor (Fleming, 2006).

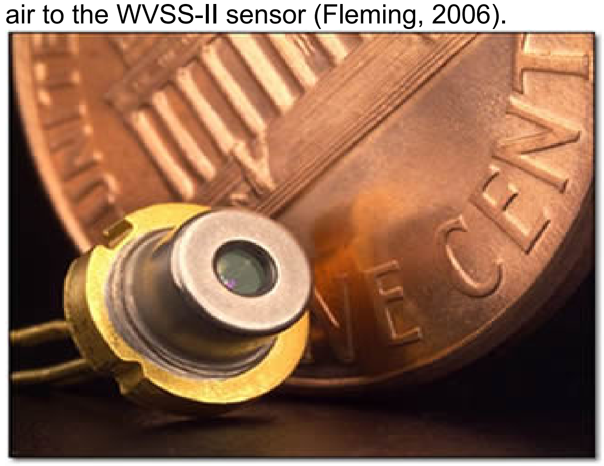

Fig. 1 WVSS-II laser diode shown next to a penny, for size comparison purposes.

The WVSS-II has been installed on Boeing 757 aircraft used by United Parcel Service Airlines (UPS) as package carriers.

The WVSS-II measures mixing ratio of environmental air, while radiosondes measure relative humidity. For this study, the WVSS-II mixing ratios and radiosonde relative humidities were converted to dewpoint. While these conversions were necessary to compare the two platforms, it should be noted that some errors can be introduced in converting mixing ratio from the WVSS-II to dewpoints (due to inaccuracies in temperature measurements).

3. EXPERIMENT DESIGN

This experiment was designed so that the results could be easily comparable to those from the VWSS-I and radiosonde study. For the period May through mid September 2005, the authors compared WVSS-II soundings to NWS radiosondes when they were available within 50 km of a radiosonde site, and within one hour either side of the morning and evening launch times. Data were retrieved from the ESRL Aircraft Data Web at http://amdar.noaa.gov/java.

When suitable comparisons were available, temperature and dewpoint data were collected from each platform at 925, 850, 700 and 500mb. Water vapor mixing ratios were retrieved from the WVSS-II and calculated for the radisondes. The bearing and range of the aircraft from the airport was used to determine the aircraft distance from the radiosonde launch site. For ease of calculations, and to make the experiment as much like the 2001 study, it was assumed that radiosonde data at all levels were located over the launch site. Approximately 1300 individual comparisons were made during the period.

The lowest levels were naturally not available for comparison at higher elevation stations in the west (such as Salt Lake City and Reno), and the highest levels were often not available when aircraft made short flights between cities in the east.

4. DATA

For the period of May 3 to September 14, 2005, there were 372 soundings of WVSS-II equipped aircraft that were compared with nearby radiosondes. These soundings allowed 1385 individual comparisons at different levels.

a.) Geographical distribution

Comparisons were available at 15 radiosonde locations (see Figure 2) in the continental United States. With the exception of the northern Plains states and the Ohio Valley, there is reasonable coverage of various geographic and climatological regions. Data were distributed fairly uniformly amongst the cities, with one very notable exception. Miami is one of UPS's main domestic and international hubs, and accounted for almost one-quarter of all the comparisons.

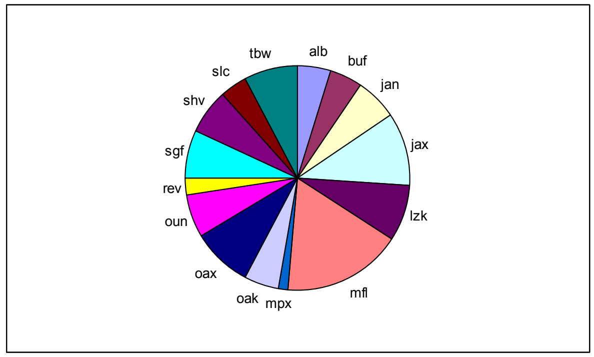

Fig. 2 Geographic distribution of comparisons

b.) Vertical Distribution

Vertical distribution of the observations was fairly uniform. There are slightly fewer data at 925 mb as a few of the sites (SLC,REV) are located above 925 mb. There are also slightly fewer data at 500 mb. This is because some short hop flights in the eastern United States cruise below 500mb. The distribution of the data by pressure level is shown In figure 3.

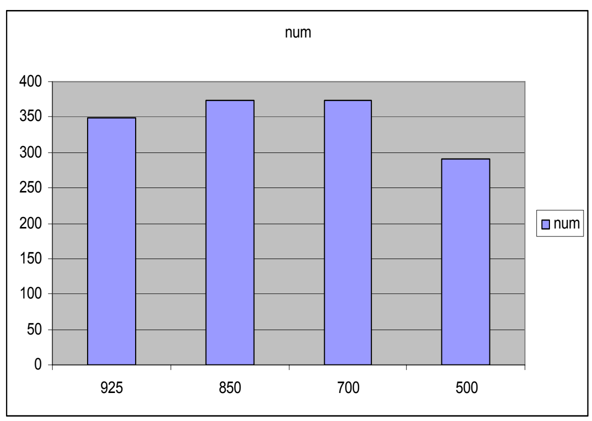

Fig 3. Numbers of observations by pressure level

5. RESULTS

LEVEL	ΔT (C)	T (std)	ΔTd (C)	Td (std)	ΔMixR (g/kg)	MixR (std)	# of Obs
925 MB	0.37	1.05	-0.35	2.87	-0.26	1.89	349
850 MB	0.30	1.06	-0.61	3.19	-0.25	1.51	373
700 MB	0.42	1.00	1.16	5.54	0.26	1.29	373
500 MB	0.61	2.15	2.92	7.48	0.28	0.82	290

Table 1. Differences and Standard Deviations in Temperature (T), Dewpoint (Td), and Mixing Ration (Mix R) between WVSS-II aircraft and NWS radiosondes.

Table 1 shows the temperature, dewpoint and mixing ratio differences (aircraft-radiosonde) and standard deviations at the various pressure levels. Mean temperatures differences in this study are significantly smaller than a similar comparison of the WVSS-I and radiosondes (Mamrosh, 2001)

The temperature differences show that the aircraft appears to have a very small warm bias at all levels. Standard deviations increase at 500mb due to increased spatial differences at that level. Dewpoint differences indicate that the aircraft appear to have a dry bias in the lower levels of the atmosphere and a moist bias above. This has also been noted by studies conducted at NCEP (Ballish, personal communication). It is not surprising that mixing ratios reveal similar tendencies.

Dewpoint differences in this study are significantly smaller than the WVSS-I to radiosonde comparison. This was expected, as the WVSS-II is a much higher quality instrument. Standard deviations of dewpoint, however, are only slightly better in the WVSS-II. A likely explanation is that moisture is highly variable in space and time in the atmosphere, and that even small spatial and temporal differences between the aircraft and radisondes can result in large observational differences. Large gradients of moisture are frequently seen near the coasts, where a moist marine layer is frequently capped by dry air above. The comparisons at Oakland, California (OAK) resulted in the four largest dewpoint differences (> 10C) seen at 925 mb in this study. In fact 13 of the 19 largest dewpoint differences at 925 mb occurred at OAK or Miami (MFL). In nearly all cases, a sharp gradient of moisture existed near 925 mb, in the transition of moist low level air to dry air above.

An excellent example of this occurred 23 August 2005 at OAK. Very moist air existed from the surface to about 1,500' above ground level in the vicinity of OAK, with extremely dry air above. This marine layer is important to coastal California as it influences the development of low clouds and fog. The 1200 UTC NWS radisonde (launched at 1100 UTC) showed this marine well (Fig. 4). A WVSS-II equipped aircraft landed at OAK at 1040 UTC (about twenty minutes prior to radiosonde launch). That sounding (Fig. 5) showed the same shallow moisture as the radiosonde. Because the winds were nearly calm, the radiosonde ascended nearly vertically. The aircraft, however, took off to the southeast away from the ocean, and was about 10 miles southeast of the radisonde at 925 mb. Therefore, the aircraft was in a much drier environment than the radiosonde, and reported a dewpoint 15C lower than the radiosonde!

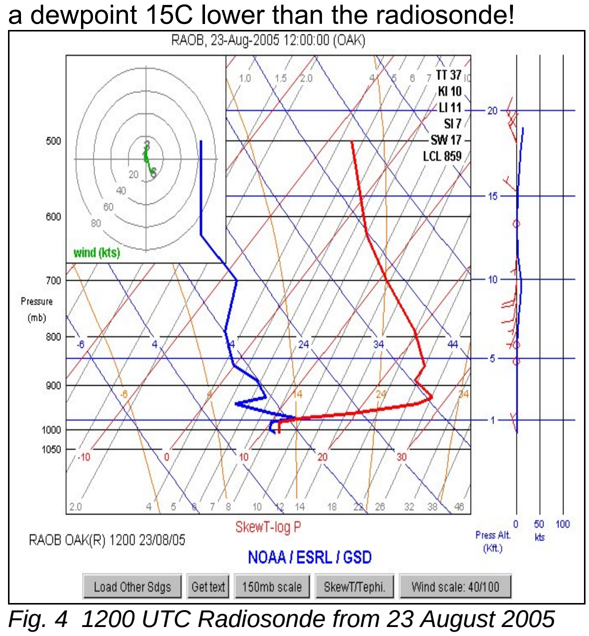

Fig. 4 1200 UTC Radiosonde from 23 August 2005

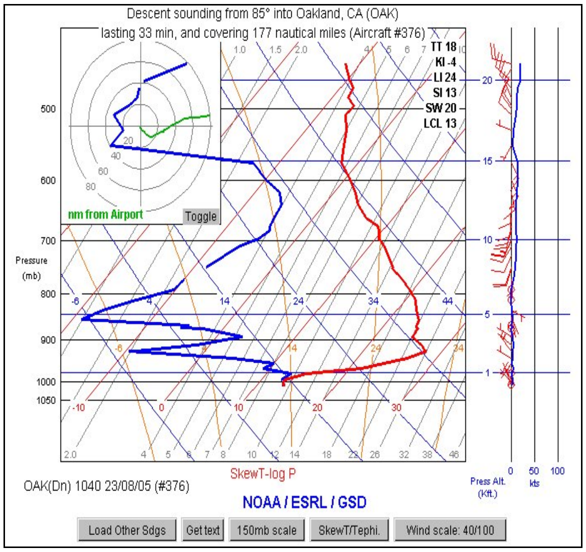

Fig. 5 WVSS-II aircraft sounding from 1040 UTC on 23 August 2005

An excerpt of text data from the radiosonde (Fig. 6) shows the 925 mb temperature to be 28C, and a dewpoint of 7C.

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OAK(R) 1200 23/08/05
RAOB, 23-Aug-2005 12:00:00 (OAK)

 TT = 37.0 KI = 10.0 LI = 11.0 SI = 7.0 SW = 17.0
 LCL = 859.0

 P_alt    mb      t/td      w_dir/w_spd
  (ft)            (°C)            (kts)

    20  1010  12.2/11.70     340°/003
   279  1000  11.8/10.70     ---°/---
   719   984  11.2/10.10     ---°/---
  1053   972  13.8/12.70     ---°/---
  1339   962  19.4/9.400     ---°/---
  1995   940  26.8/3.800     ---°/---
  2477   925  28.0/7.000     ---°/---
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Fig. 6 Text data from OAK radiosonde 23 August 2005

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OAK(Dn) 1040 23/08/05
Descent sounding from 85° into Oakland, CA (OAK)
lasting 33 min, and covering 177 nautical miles (Aircraft #376)

 TT = 18.0 KI = -4.0 LI = 24.0 SI = 13.0 SW = 20.0
 LCL = 13.0

 P_alt    mb     t/td     w_dir/w_spd   Time    Bng/Rng
  (ft)           (°C)           (kts)   (UTC)      (nm)

    90  1010  13.6/13.30      9°/002    1040   184°/002
   130  1008  13.3/13.30    337°/003    1040   179°/002
   300  1002  13.1/-----    315°/005    1040   162°/003
   480   996  13.0/12.60    329°/004    1040   164°/003
   880   981  15.2/13.30    139°/002    1039   154°/004
  1270   968  21.5/9.100    168°/007    1039   148°/005
  1640   955  23.8/10.00    218°/003    1038   145°/006
  2010   942  26.2/4.300    295°/005    1038   142°/008
  2450   927  28.0/-9.50    318°/005    1037   140°/009
  2500   925  27.9/-8.70    317°/005
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Fig. 7 Text data from WVSS-II aircraft landing at OAK on 23 August 2005

Text data from the aircraft (Fig. 7) shows a 925 mb temperature of 28C and a dewpoint of -9C. So in this case, the temperature was conserved at 925 mb, but the dewpoints were very different. This same phenomena occurs frequently at OAK, and occasionally at MFL and JAX (mainly in the spring).

The large moisture differences between the two platforms are obviously environmental, and will exist in the data in studies like this even if both platforms measure moisture perfectly. This dilemma may be somewhat alleviated by more controlled studies such as those conducted by the University of Wisconsin mobile sounding unit at the Louisville airport, where shallow marine layers are not a consideration, and soundings are launched within minutes of WVSS-II equipped aircraft.

6. CONCLUSIONS

The WVSS-II dewpoint differences are significantly smaller than the WVSS-I, and are likely the result of an improved sensor. The WVSS-II standard deviations are only slightly smaller than its predecessor. The authors believe this to be the result of sharp moisture gradients in the atmosphere, rather than deficiencies in the observing systems. Further studies should be conducted to support this contention.

7. REFERENCES

Fleming, Rex, 2006: The WVSS-II: A commercial aircraft sensor for water vapor information, *10th Symposium on IOAS-AOLS*, Atlanta, GA, Amer. Meteor. Soc., Paper 9.4.