Poster 209

Validation Studies of WVSS-II Moisture Observations – Final Test Results

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BACKGROUND

The Water Vapor Sensing System (WVSS) project was established to develop moisture sensors appropriate for use on commercial aircraft to fill the space and time gaps in high-resolution tropospheric moisture profiles left between other observations.

The overall objectives of this study being carried out at the University of Wisconsin Cooperative Institute for Meteorological Satellite Studies (UW-CIMSS) regarding WVSS-II are:

- *To assess the accuracy of the aircraft humidity data by comparing it with rawinsonde and ground based remote sensing systems, and*
- *To provide a basis for determining the optimal spacing and timing of the observations for a variety of weather events (to be accomplished later).*

Three ground-truth assessments of the WVSS-II systems were conducted during periods in November 2009, May - June 2010, and August 2010. The WVSS-II humidity data were compared with rawinsonde and ground based remote sensing systems.

Between 15 and 32 UPS B757 aircraft provided WVSS-II data via MDCRS.

Rawinsonde observations were made at the UPS hub in Rockford, IL – where about 20-25% of the WVSS-II equipped planes land / take off daily.

VALIDATION OBSERVING SYSTEMS

Observations taken from CIMSS' portable "AERIbago" vehicle 24 hours/day included:
- surface temperature, dewpoint temperature and wind,
- an NWS standard Ceilometer,
- a GPS receiver for Total Precipitable Water (GPS-TPW),
- an upward looking Atmospheric Emitted Radiance Infrared Interferometer (AERI) to measure boundary layer temperature / moisture every 6-7 minutes, and
- a Vaisala RS-92 GPS rawinsonde system.

Data are available at: ftp://ftp.ssec.wisc.edu/validation/exper/wvssii/ A full set of aircraft data were also collected from the NOAA/GSD MADIS data system for use in the assessment.

Rawinsonde observations were taken three times each night, one immediately before the majority of the UPS arrivals (~0240 UTC), another between the descents/ascents rush (~0645 UTC) and a third after the majority of departures (~0915 UTC).

- On Mondays and Fridays, scheduling of WVSS-II equipped aircraft by UPS sometimes supported only 2 launches
- Typically, about 5-10 aircraft co-locations were available daily.
- Night observations eliminate the need to make 'radiation corrections' to raob data

ASSESSMENT PROCEDURES

1) WVSS-II data problems described previously have been addressed:
   - Data processing hardware replaced with digital systems that are unaffected by temperature
   - Issues regarding water accumulating in intake tubes corrected.
   - All moisture was removed from laser chambers.
   - Every laser was tested for long-term stability before use.
   - *Test systems were independently assessed:*
     - *In Chambers at the NOAA's Upper-Air Facility*
     - *In Chambers at Deutscher Wetterdienst*
     - *Versus chilled mirror on Research aircraft*
     - *In long-term laser stability tests*
   - *Reporting Precision issues resolved on all UPS aircraft*

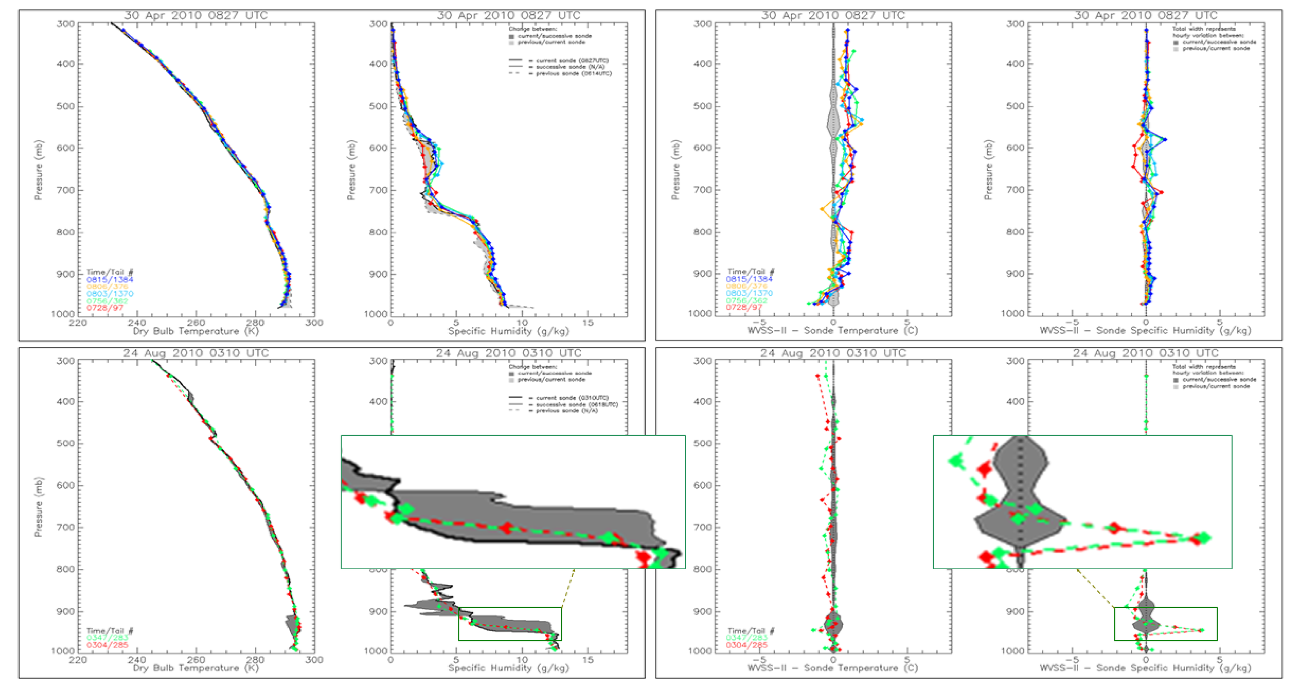
2) Because the objective of the experiment was to assess the difference in good quality reports made by both the aircraft and rawinsonde systems:
   - *The assessments of moisture profiles were made primarily in terms of Mixing Ratio/Specific Humidity* – the water vapor parameter that WVSS-II observes.
   - Assessment were restricted to time and space windows of +/- 60 minutes and 50 kilometers.

CO-LOCATION DATA

Almost 20 days of ascending rawinsonde/WVSS-II matches were available for comparison in three seasons. Reports from all but one aircraft with known engineering defects were used.

Nov 2009-2010 Validation Results

Direct Sounding Intercomparisons



Direct Data Comparison:

Aircraft data generally fell between bounding Rawinsonde reports

Large vertical/temporal variability within moister regimes led to a few large Specific Humidity differences

Because a strong, slowly descending inversion produced substantial differences due to time-mismatching near 800 hPa. Additional constraints and computational limits were included to eliminate layers when the verifying rawinsonde reports showed large time and vertical changes

2009-2010 VALIDATION RESULTS

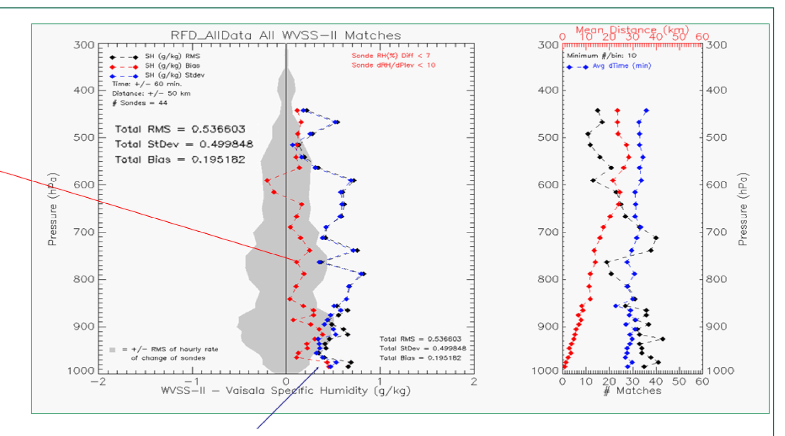
Specific Humidity

(Excludes cases with large time and vertical rawinsonde differences)

Systematic Differences:

WVSS-II Biases at low levels of 0.1 to +0.4 g/kg from surface to 850 hPa.

±0.2 g/kg above



Random Differences (Including Dry/Moist Environments):

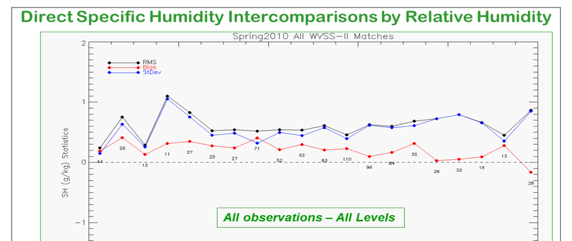
Differences between aircraft data and rawinsonde reports generally showed variability of 0.3 to 0.7 g/kg from the surface to 600 hPa – decreases aloft.

StdDev slightly larger than 1-hour variability between bounding rawinsonde reports (gray shading).

Ascent and Descent data showed similar results.

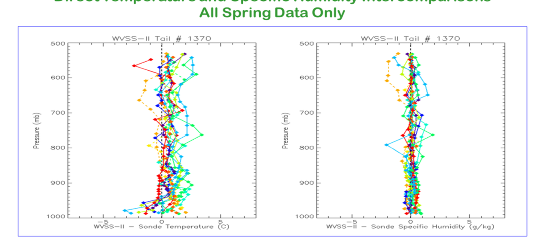
Note: Fewer intercomparisons near 800 hPa and above 700 hPa. Greater time and space separation above 650 hPa.

Direct Specific Humidity Intercomparisons by Relative Humidity



Differences showed:
Small positive Bias and Small SdtDev across all RH ranges
Random Errors average ~0.5-0.7 g/kg *(low bias improbable)*
Higher Random Errors between 20-25% RH and Near Saturation

Spring 2010 Validation Results
Direct Temperature and Specific Humidity Intercomparisons
All Spring Data Only



Differences from Rawinsondes showed:
Warm Temperature Bias at all levels
Large Temperature variability
Random SH Differences average ~ ± 0.5 g/kg

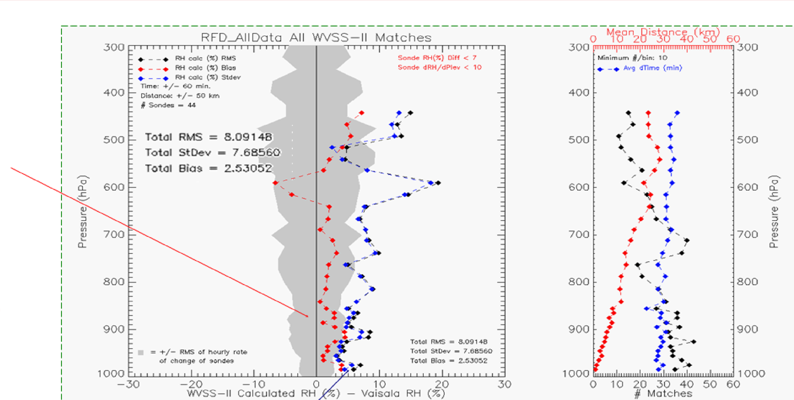
Relative Humidity

(From WVSS-II Humidity & Rawinsonde Temperature)

Systematic Differences:

RH Biases due to WVSS-II were small positive (1 – ±4%) from surface to 650 hPa.

Negative maximum at observation minimum.



Random Differences (Including Dry/Moist Environments):

Differences between aircraft data and rawinsonde reports generally showed variability of 6 to 9% from the surface to 750 hPa.

Above 750 hPa, RH StdDev increases as number of matches decreases and space/time distance increases.

Random Differences slightly larger than 1-hour variability between bounding rawinsonde reports (gray shading).

ACKNOWLEDGMENTS

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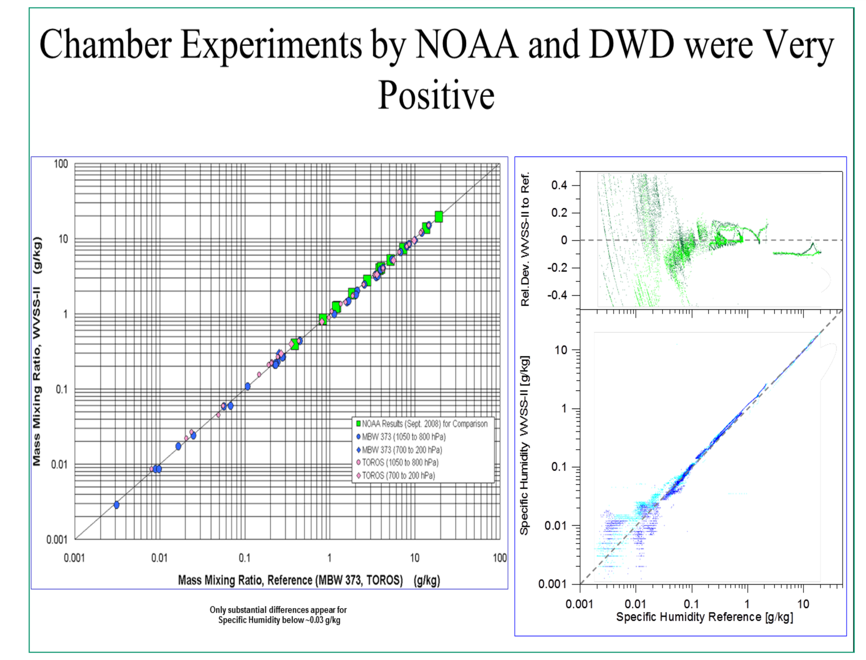
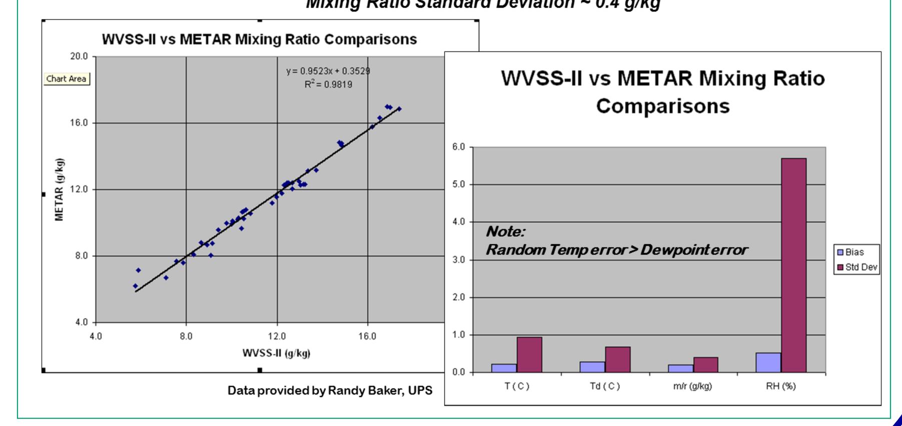
Independent Chamber Test Results



Initial Comparisons of re-engineered WVSS-II data with co-located surface (METAR) reports

New WVSS-II unit on UPS aircraft agrees very closely with time/space co-located night-time surface observations from September 2009:

Mixing Ratio Bias ~ 0.2 g/kg
Mixing Ratio Standard Deviation ~ 0.4 g/kg



TEMPORAL MOISTURE VARIABILITY EVALUATION

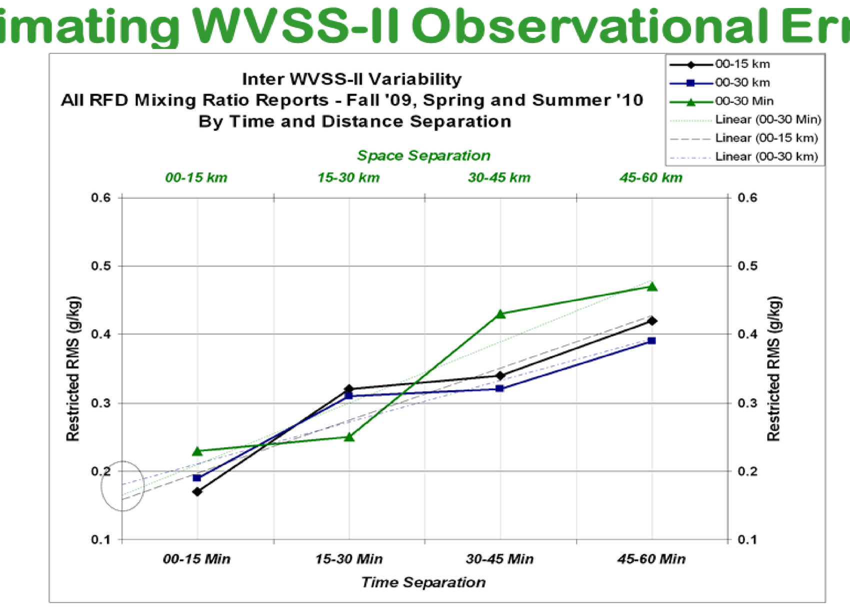
Important for mesoscale QC and Assimilation

Approximating WVSS-II Observational Error

Restricted RMS calculated for:

Time ranges of 0-15, 15-30, 30-45 and 45-60 minutes

Distance ranges of 0-15, 15-30, 3-45 and 45-60 km



Restricted (within±4σ) RMSs show (ALL reports, Including Dry/Moist Environments):

Atmospheric Temporal Variability more than doubles from 0-15 to 30-45 minute intervals
Atmospheric Spatial Variability increase consistent, but not as regular as temporal
Total Atmospheric Variability made up of 1) Instrument Error and 2) Atmospheric Variability
When projecting to exact co-locations (*ΔT and Δx ~0*), *Total Moisture Variability < 0.2 g/kg*
Expect Operational WVSS-II Instrument Errors should be ~0.1 g/kg

- SUMMARY -

Engineering/mechanical issues with WVSS-II sensors have been resolved !!!

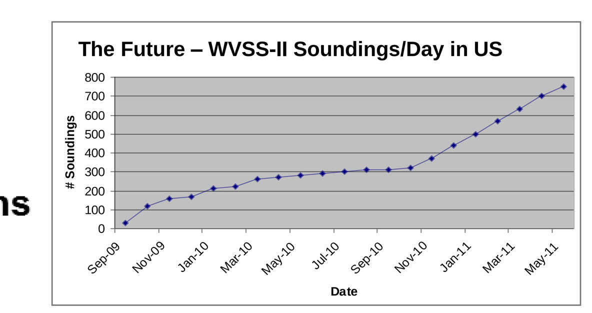
Tests made over wide range of moisture conditions show:

☑ Sensors agreed extremely closely with each other
- *Overall Specific Humidity (SH) RMS < 0.2 g/kg*

☑ Sensors agreed well with co-located Rawinsonde observations
- *Overall SH Bias ~ 0.2 g/kg, SH StDev ~ 0.5 g/kg*

☑ Relative Humidity differences were small
- *Overall RH Bias ~ 2.5 %, RH StDev ~ 7.5%*

☑ Ascent and Descent Data show similar results
- Some super-saturations remains, especially at RH>95%
  - Possibly due to evaporation of rain droplets/snow in heated intake tube?



The data are good,
The data will be plentiful,
We need to use them , and to best advantage!

☑ *WVSS-II data Meet WMO requirements for mesoscale observations*

Additional analysis underway to:
- Provide atmospheric variability and observation error to support assimilation
- Expand data base in moist environments - using NWS Rawinsonde data
- Evaluate enroute, low-moisture environments using satellite data

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