4.3 The Consensus Reference Methodology as it Applies to a Radiosonde under Test

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1. INTRODUCTION

This extended abstract will describe examples of the methodology the NOAA, National Weather Service will be utilizing for implementing the Consensus Reference Concept into actuality. The reader should refer to the references for additional information on this concept and an overview of some of the technologies. To illustrate the concept, this paper will define areas where the techniques will evolve into a series of consensus procedures for evaluating upper air radiosonde measurements from a candidate system against more than one reference type. The techniques will center on data collected from a variety of reference instruments during this past summer's **Water Vapor Validation Experiment Satellite/Sondes (WAVES 2007)** project sponsored by NASA, NOAA, and the Howard University Atmospheric Observatory (HUAO) along with a number of other government and academic institutions. The NWS through its NOAA-Howard University Center for Atmospheric Science (NCAS) agreement is leveraging their equipment, e.g., RAMAN LIDAR situated at Beltsville, Maryland in partnership with NASA. Preliminary results from some of these procedures will be provided as they pertain to this concept.

2. REFERENCE TECHNOLOGIES

In support of the test mission, NWS also has access to the HUAO for use of their technologies and facilities. HUAO has a 30-meter tower instrumented for planetary boundary layer (PBL) measurements useful for many applications and a whole sky camera for capturing the state of the sky cover from horizon-to-horizon in addition to radiometers and LIDARs.

2.1 Surface Observational Equipment

Detailed surface observations are used to compare surface conditions with the upper air measurements. Either the Automated Surface Observing System (ASOS) or the Radiosonde Surface Observing Instrumentation System (RSOIS) can be used to perform this function, since basic surface parameters such as the following are available:

Sky Condition
Visibility
Present Weather (type and intensity)
Freezing Rain (If Installed)
Thunderstorm (If Available)
Obscurations
Ambient Temperature, Relative Humidity, and Dew point Temperature
Wind (speed, direction, gusts, and direction variability)
Pressure (altimeter, station, density altitude, pressure altitude, and sea level)
Precipitation Amount
*Long wave/Shortwave/Net Radiation
*GPSMET-Integrated Precipitable Water
* Adjunct systems to the ASOS/RSOIS

2.2 Surface Comparisons

Figure 1 illustrates how information from various types of surface-based sensors can be combined with upper air measurements for referencing purposes and for characterizing the test environment. These can then be further combined statistically to ascertain trends and detect anomalies, temporally.

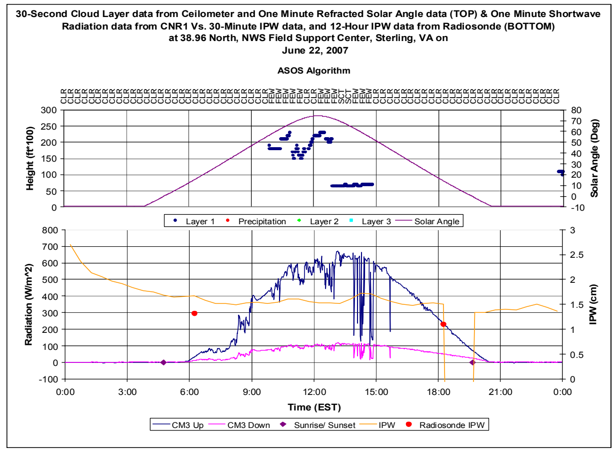


Figure 1. Example of combining various instruments.

In this example, NWS has integrated data from the Kipp and Zonen© CNR 1 sensor with the output from a ground-based ceilometer measuring cloud bases to 25k-ft. In this way the correlation between the amount of radiation and the sky condition can provide some excellent background reference with the instrument under test. Likewise, correlations can be made between the IPW produced from the GPSMET system and the ceilometer.

Furthermore, NWS will be developing a new technique whereby the output from the long-wave and shortwave measurements (Figure 2) can be converted into a "raw" temperature using the Stefan-Boltzmann Law. This is the temperature of the atmosphere factoring the emissivity into the calculation. Using a shielded temperature sensor, which minimizes solar effects, one can now bound the lower temperature end, while the unshielded one bounds the upper end. At night both measurements should read very close, i.e., be in consensus, and diverge throughout the day as a function of the amount of solar energy down-welling to the surface. A test instrument left outside and properly aspirated during the night should also be in consensus with these measurements. If there are radiation effects on the test instrument, or if the sensor coating has not been applied correctly, the temperatures will tend towards the radiometer values. If it has been applied correctly, then the temperatures should closely match the shielded temperature sensor.

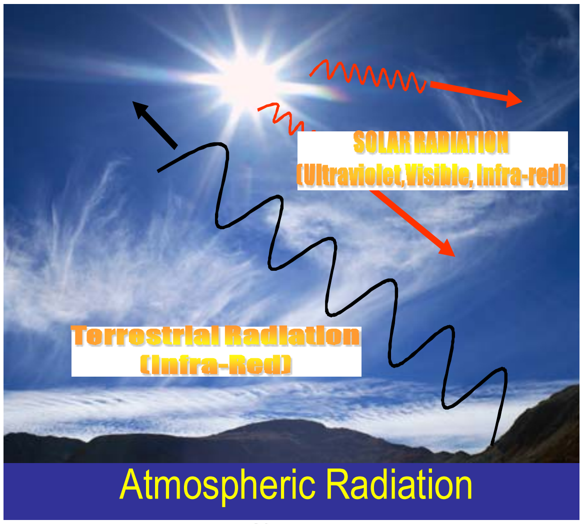
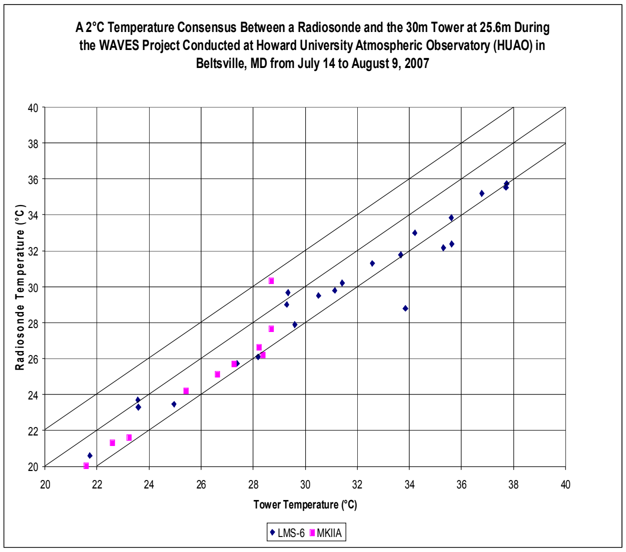


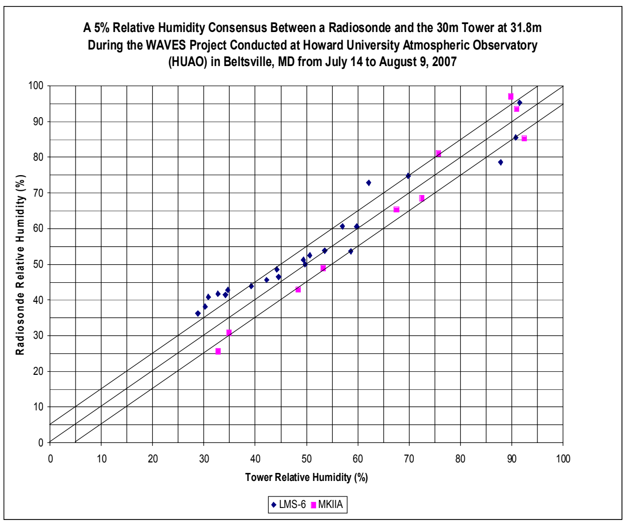
Figure 2. Terrestial/Solar Radiation.

2.3 30-Meter Tower Inter-comparisons

This test is conducted to evaluate the accuracy of radiosonde temperature and moisture measurements near the surface in the lower part of the PBL. The HUAO tower can be instrumented to whatever number and types of sensors as required.

Figure 3. HUAO 30-meter instrumented tower.





Figures 4a and b. Inter-comparison of RAOB/30-meter tower.

Figures 4a and b illustrate how these comparisons can be accomplished in a consensus referencing manner at the 25.6 and 31.8 meter levels. Profiles can be derived from the surface (1.5 meters) to the top of the tower (31.8 meters) for temperature and relative humidity. These types of measurements have great benefit for detecting potential biases immediately off of the surface.

2.4 LIDAR Inter-comparisons

Another exciting area being developed for this concept is with respect to inter-comparisons with RAMAN LIDAR measurements. A picture of the LIDAR with one of the authors of this paper in the background is shown in Figure 5. RAMAN LIDAR offers the opportunity to depict in high-resolution the water vapor expressed as mixing ratio values up to 20 km, cloud bases, and can provide rapid water vapor profile updates every 5 and 30 minutes depending on the level of quality-control being applied to the data.

Figure 5. Example of Howard University LIDAR used for comparison.

Initial consensus reference testing using this technology was conducted this past summer during the WAVES_2007 project. Two radiosonde types – one from NWS and another from Lockheed-Martin Sippican – were used to test some of the techniques.

A consensus reference technique under development is centered on the concept of *Partial Precipitable Water (PPW)*. Whereas some new techniques already exist for comparing the total PW from different systems, the use of comparing PPWs may have substantial benefit for determining whether diverse instruments are measuring similar moisture profiles or layers. The advantage of PPW over comparing relative humidity or mixing ratio profiles is that large differences in dry layers aloft will result in relatively small differences in PPW between instruments, while in high water vapor regions, e.g., near the surface, relatively large differences will result in large PPW differences consistent with meteorological/ climatological expectations.

The basic technique is as follows:

1. Figure 6 illustrates two instruments flown within the same frame-of reference, in this case, heights. Note, sensors and technologies have to be calibrated before commencing.
2. The two profiles are segmented into identical layers (designated by α_{ij}),

where i is the ith sensor and j is the jth layer.

3. Compute the PPW using the equation in Figure 6.[1]

By selecting the right layer thickness, the mean mixing ratio denoted by r_{layer} will closely match the actual mixing ratio and thus represent the actual amount of precipitable water in that layer. The two can then be compared as illustrated in Figure 7 by determining the differences for each α_{ij} or layer throughout the profiles. One can also assess any residual moisture by using the GPS-IPW as an independent measurement against the two profiles to see if either is over- or under reporting the total liquid content.

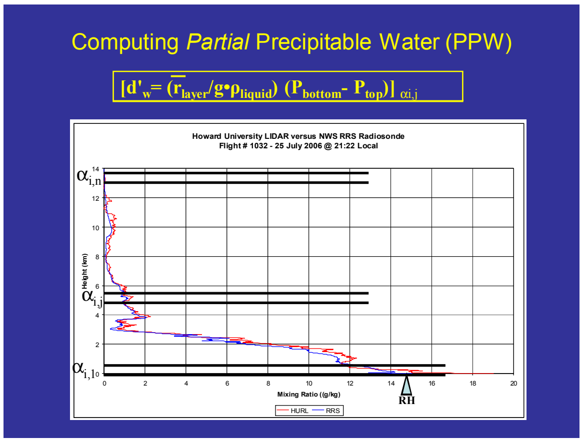


Figure 6. PPW layer calculations.

Values exceeding the consensus thresholds – refer to the companion AMS paper on consensus referencing defining these – illustrated here as linear bars, would depict whether the two are indeed in consensus.

3. Conclusions

The purpose of this paper is to inform the meteorological and climate communities about the potential for a consensus reference test concept, whereby an ensemble of tests are conducted and the results standardized to formulate a consistent pattern for evaluating upper air instrumentation and systems. Once the tests discussed in this paper are developed and proven, the plan is to document them into a catalogue for use by the wider community and conjoin them within a standard test process.

[1] Reference: *Meteorology for Scientists and Engineers*, second edition, Roland B. Stull, © 2000, page 171

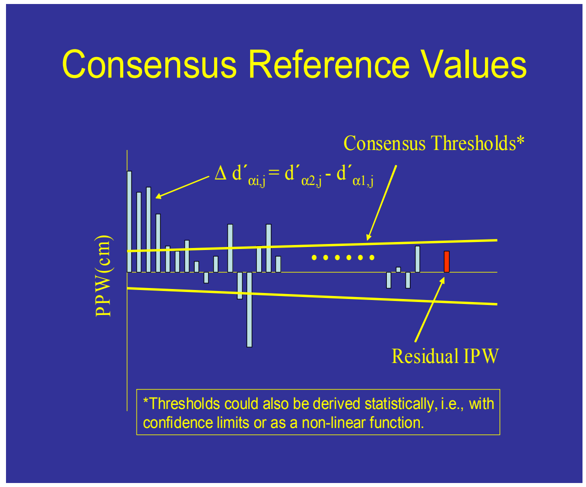


Figure 7. Example of RAMAN LIDAR/ Radiosonde water vapor comparison.

4. Acknowledements

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