11.5 Testing Radiosonde Replacement System (RRS) Radiosondes – Part 1

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1. INTRODUCTION

The National Weather Service (NWS) has developed the Radiosonde Replacement System (RRS) to replace its antiquated Micro-ART system, which has been in operation since the late 1980s. Although the NWS tested and qualified two1680-MHz GPS radiosondes for use with the RRS, NWS is currently only procuring the Sippican Mark IIA radiosonde.

Over the course of the last two years the NWS has conducted a series of tests to understand the measurement characteristics of the radiosondes qualified for use with the RRS. This paper will discuss some recent updates to techniques developed for these tests. Test procedures discussed are the use of the Global Positioning Satellite-derived Integrated Precipitable Water (GPS-IPW) to evaluate the total moisture, evaluation of atmospheric profiles and derived parameters using the RAOB[1] program, inter-comparison testing with the NASA developed reference radiosonde for evaluating the temperature's radiation correction, and the use of benchmarks to test software. Examples of the types of data acquired during each of these tests will also be presented.

2. GPS-IPW

The Forecast Systems Laboratory (FSL) within NOAA has developed and evaluated the GPS-IPW over the past decade with excellent agreement with IPW derived from upper air data. As a result, NWS in coordination with FSL's Seth Gutman (see Section 6) are working to develop techniques for evaluating new relative humidity sensors being developed by radiosonde vendors.

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[1] RAOB, *the complete rawinsonde observation program*, is produced by Environmental Research Services, ©, 1994-2004.

2.1 Methodology

Because of the good agreement between the two technologies, the test methodology is based on simple comparative readings from the nearly real time continuous GPS-IPW sensor with the less frequent values from the radiosonde overlaid on the same graph. If the radiosonde sensors are performing to NWS requirements, it is anticipated there should be good agreement between the data sets in just about any kind of weather conditions.

2.2 Data Analysis

Although the NWS is just beginning to use this technique to evaluate radiosonde data, the initial results have looked very promising. Figure 1 is a sample of the type of data analysis being developed by the NWS to understand and characterize radiosonde performance. As Figure 1 depicts, during this four-day period there was good agreement between the GPS-IPW and the IPW determined from both the RRS radiosonde and the radiosonde flown with the legacy Micro-ART system.

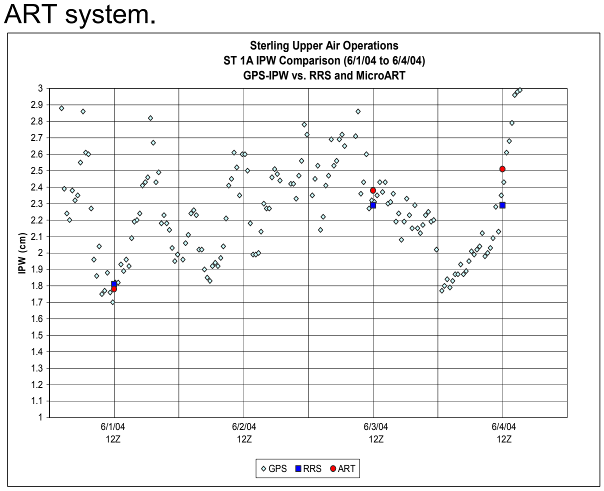

Figure 1. Example of GPS vs Radiosonde IPW.

3. USE OF RAOB

NWS has been using RAOB to compare radiosonde profiles for some time; however, its use has become more prevalent this past year, as the RRS program has evolved. The following sections describe its use in evaluating radiosonde performance and software algorithms.

3.1 Methodology

For this test, there were actually two different flight configurations used. The first consisted of releasing two separate balloons at nearly the same time. In this case both balloons were configured in accordance with standard NWS procedures and had a flight train typically between 25 and 35 meters long. For these launches the legacy MicroART system used the manual release button to begin the flight and the RRS used an auto-release detection routine to start the flight. These releases were conducted at the synoptic times and were conducted in this fashion to avoid any impact on normal operations.

The other flight configuration consisted of flying two radiosondes on the same balloon using a six foot spreader bar. Figure 2 is a picture illustrating this flight train assembly. Again, these flight trains were typically between 25 and 35 meters long. To initiate the start of these flights, a manual release was used to simultaneously start both systems at the same time.

Figure 2. Simultaneous Radiosonde Launch.

In either mode, the RAOB program can display the soundings in ways the meteorologist can understand the data. Rawinsonde coded messages are decoded by the RAOB software and the soundings displayed in one of several forms. The temperature and dew point plots are color-coded for distinguishing the different soundings and wind barbs are displayed for each on the right side. To the left are derived parameters such as the thickness values, LCL, CAPE TOTALs, etc. for both soundings. Figure 3 illustrates an example of the type of RAOB output used during various NWS tests.

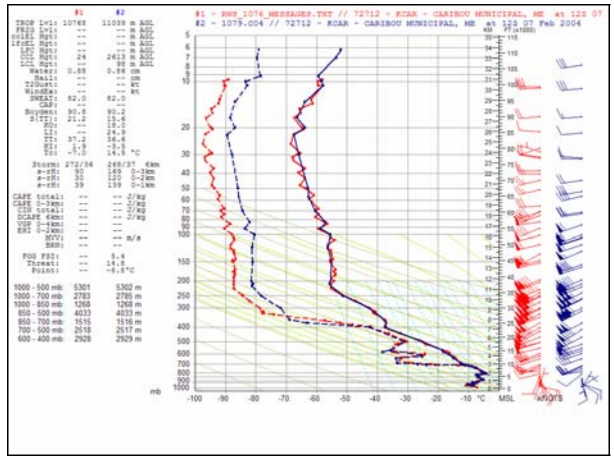

Figure 3. Example of RAOB Comparison Plots.

3.2 Data Analysis

When comparing the plots, one looks to see if there are anomalies in the plotted profiles themselves, the wind profiles, or the derived parameters. For example, if one profile has significant moisture, i.e., higher dew points, while the other radiosonde is exhibiting fairly dry ones, then there may be need for further investigation in understanding the differences.

The same type of analysis also applies to the wind profiles. In the example above, there is good agreement in depicting the Ekman spiral in the boundary layer, followed by a strong jet aloft, and then tapering off to lighter winds at the end of the flight. If one of the radiosondes had been showing light winds throughout the entire flight, then something could be suspected and further analysis required.

In a similar manner, comparing the derived parameters may hint at problems of one type or another. For instance if the total precipitable water is significantly different it may be indicative of too little or too much humidity being represented in the profiles. NWS also uses information collected from its Automated Surface Observing System (ASOS) and the GPS-IPW (see Section 2) as independent systems to evaluate radiosonde performance. For example, ASOS provides the cloud base, surface temperature and dew point information, which can be compared with the data from the radiosonde. Cloud bases reported from the ASOS ceilometer can be used as a reference for the radiosonde temperature/dew point near saturation points, i.e., inferred cloud bases. The accompanying paper shows RAOB examples of problems found when performing these types of comparisons.

4. INTERCOMPARISON WITH ACCURATE TEMPERATURE MEASURING RADIOSONDE

The NWS conducted a series of radiosonde inter-comparison flights with The NASA Accurate Temperature Measuring (ATM) radiosonde and RRS radiosonde. This type test is conducted to evaluate radiosonde temperature sensor performance and vendor supplied temperature radiation correction schemes.

4.1 Methodology

For this test, the ATM radiosonde and the RRS radiosonde were flown on the same balloon using the spreader bar assembly shown in Figure 2. The ATM radiosonde used in this test is the Sippican Mark II radiosonde equipped with two white, two aluminum and one black thermistor. For the solution, only one of each color sensor was used. For each of the three different colored sensors the emissivity and absorptivity of the coatings have been determined. This information was then used to solve simultaneous equations to determine the true temperature. Therefore, the effects of the solar radiation were eliminated. This true temperature was then compared against the RRS radiosonde.

4.2 Data Analysis

For this test, the data were analyzed on a flight-by-flight basis. However, once a sufficient number of flights have been completed it becomes possible to draw some conclusions about the performance of the temperature sensor on the RRS radiosonde and how well the radiation correction scheme is working. Figures 4 and 5 are examples of this analysis. Figure 4 is a plot of the temperature profiles for the ATM, and the corrected and uncorrected temperature profiles for the RRS radiosonde. As indicated, there is fairly good agreement between all three profiles.

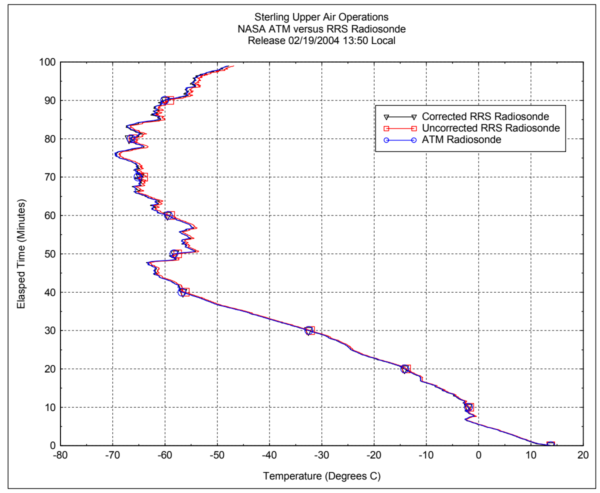

Figure 4. Example of Temperature Profiles.

Figure 5 is a temperature difference plot for the ATM minus the RRS radiosonde. In this case, the plot indicates there is very good agreement between the ATM and the RRS corrected temperature.

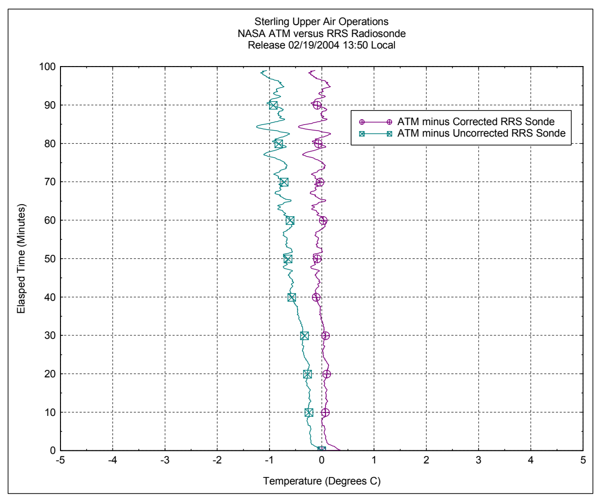

Figure 5. Example of Temperature Difference Plot.

5. Benchmarks

Another technique developed this past year by the NWS was the use of "benchmarks" to verify the correct generation of coded messages. A benchmark is a structured, controlled set of upper air data, which can test a process or determine exactly what the coded message output should be. In this way, repeatable testing of software can be conducted.

5.1 Methodology

Benchmarks were developed to test a host of coded message components including: level selection criteria, calculated parameters, and the use of correct code forms. The simplest benchmark, called the baseline, is a dataset comprised of a linear profile to 2 hPa – including one tropopause -- and constant wind direction with increasing wind speed to the maximum wind. Pressure profiles are based on a logarithmic curve. Examples of these are shown in Figures 6 through 8.

The coded messages produced for the baseline are well understood and repeatable. From this one benchmark, others can be derived by varying the meteorological parameters. For instance, by introducing changes in the linear profile, inversions, super-adiabatic lapse rates, two tropopause levels, etc., these can be introduced and the software tested to see if the coded messages produce the correct entries. The same can be done with the winds, where the shear winds can be placed within the confines of the benchmark to see if they are properly coded. Another possibility is to simply delete winds to determine if the missing data is coded correctly.

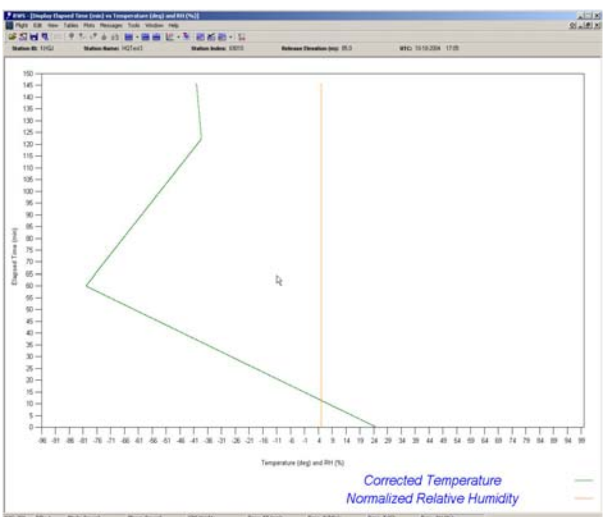

Figure 6. Baseline Temperature Profile Plot.

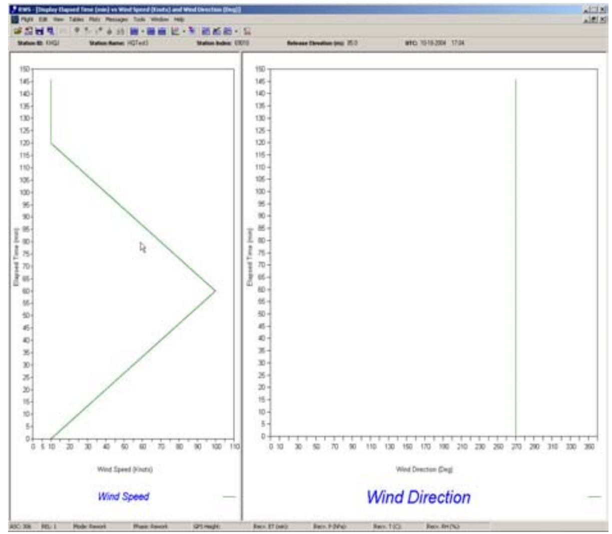

Figure 7. Baseline Wind Profile Plot.

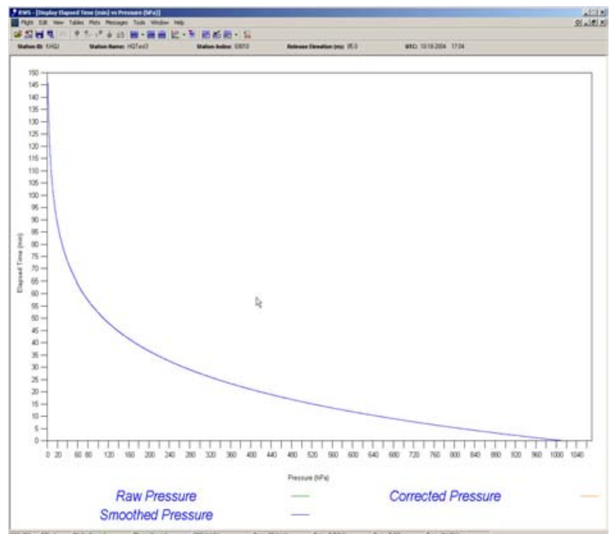

Figure 8. Baseline Pressure Profile Plot.

5.2 Data Analysis

NWS has been using benchmarks over the past year to test many facets of the RRS software to determine if it is meeting requirements. A number of deficiencies have been uncovered with their use. As testing progresses, new benchmarks can easily be generated as conditions warrant. The tool has been invaluable with regard to the software test effort.

6. Conclusions

The purpose of this paper was to inform the meteorological community about the types of tests being performed on radiosondes and software that will be introduced into the upper air network. Once the tests discussed in this paper has been completed, reports will be generated summarizing each of the tests conducted.

In addition to the test discussed in this paper, the NWS will be conducting operational comparability tests between the new and old radiosondes.

7. References

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ASTM Standard, E 177, Standard Practice for Use of the Terms Precision and Bias in Test Methods.
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AMS extended abstract, Quality Control of Radiosonde Moisture Observations, Seth I. Gutman, NOAA/FSL, Boulder, CO; J. Facundo and D. R. Helms, January 2005.