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DEVELOPING A TECHNIQUE FOR VERIFYING RADIOSONDE SOLAR RADIATION CORRECTION ALGORITHMS

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1. INTRODUCTION

Beginning in 2004, the National Weather Service (NWS) will be replacing its obsolete upper air network with state-of-the-art tracking systems and Global Positioning System (GPS) radiosondes. As part of the implementation of the Radiosonde Replacement System (RRS), the NWS has been evaluating and characterizing the performance of the new GPS radiosondes. This paper outlines the processes used to verify the radiation correction algorithms implemented with the Sippican Mark IIA RRS radiosonde.

Historically, radiation correction algorithms have applied corrections for both solar and infrared radiation. For the Sippican RRS radiosonde, Sippican Inc., believes that improvements in temperature sensor design have made the infrared induced errors so small that the impact is negligible, and therefore, no corrections need be applied for infrared effects. However, for the solar radiation correction, the NWS will not only be correcting for the traditional solar elevation angle, but will also correct for the effects of absorption and reflection of solar radiation due to cloud cover.

2. BACKGROUND

At the time this paper was written, the correction algorithms for cloud coverage were still in the development stage. The information used to correct for cloud coverage is based on a surface observation taken at the time of release. Then, using an NWS developed cloud and weather code group, the observation is entered in the RRS workstation. The cloud and weather code group is of the form: $N_hC_LhC_MC_H$WWWW. The break down for this code group is as follows:

- N_h is the amount (in oktas) of the sky covered low or mid clouds.
- C_L is the type of low clouds.
- h is the height of base of lowest cloud seen.
- C_M is the type of middle clouds.
- C_H is the type of high clouds.
- WWWW is the present weather in two groups of WW.

For information pertaining to this code group refer to the WMO Code Manual 306 (1995) and the Micro-ART Training Guide for VIZ Radiosondes (1990).

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In addition to the above-mentioned code group, the algorithm also uses statistical data based on climatological cloud cover information from a paper by Poore (1995).

3. METHODOLOGY

The procedures discussed in this paper have evolved from a process developed using the NWS operational radiosondes and MicroART PC. This process used a Digital Audio Tape (DAT) as the input to the PC. To evaluate the RRS software and radiation correction schemes, a flight simulator was developed to send uncorrected radiosonde data over a serial link to the RRS workstation for processing. This simulator was designed to simulate the output from the vendor-supplied radiosonde Signal Processing System (SPS). The SPS converts the uncorrected telemetered radiosonde data into meteorological and GPS data.

The simulator has the capability to use actual flight data or flight scenarios generated, manually by test personnel. When the NWS began evaluating the radiation correction scheme, the RRS software was still not mature enough to be used. For this reason, a program used to evaluate radiosondes was used to collect and format the radiosonde data for this test. This program is called Protocol Interface Test Suite (PITS). With the flight simulator connected to the RRS workstation and using PITS, the data files were created for the different scenarios to be evaluated.

The verification of the radiation correction algorithms consisted of a three-step process: the first step consisted of using a clear sky time series to evaluate the impact that time of day or solar elevation angle has on the data. The second step was to evaluate the portion of the algorithm that corrected the data for the effects of the cloud cover. The final step was to evaluate the corrected radiosonde data against a reference system for comparison purposes.

4. TIME SERIES EVALUATION

To demonstrate proper implementation of the solar radiation correction scheme with regard to solar elevation angle, a time series comparison was made. To create the baseline data set for this test, a live flight was made in total darkness on a night having clear skies. Using PITS to collect the data for this flight, a “raw” uncorrected data set was created from a balloon released on March 3, 2003 at 22:10 local. Using this baseline data set and simulator, the data were replayed into PITS to create a data set with a 01:55 local release on July 25, 2003. Solar corrections were applied to this data set. The temperature data from the original live flight was then compared against the corrected 01:55 data set. Figure 1 is a plot of the temperature difference between the two data sets.

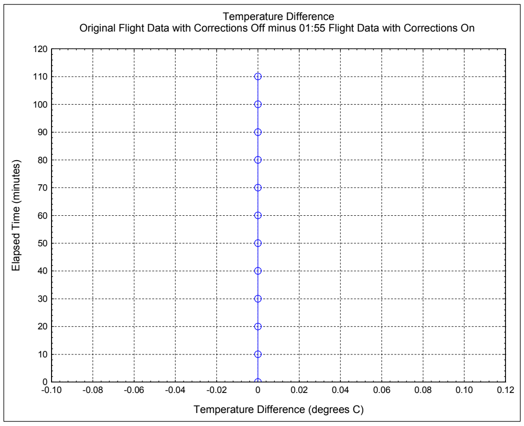

Figure 1. Temperature difference plot for the live flight minus the 01:55L data.

As indicated in Figure 1, there were no differences between the original data set which was created with the radiation correction turned off and the 01:55L data set which was created with the corrections turned on. This indicates that the 01:55L data set was processed as a night flight and occurred in total darkness. Therefore, no corrections were applied, as one would expect.

Using the simulator and the 01:55L data set, four more data sets were created with release times approximately two hours apart starting at 06:00L. These data sets were only corrected for solar elevation angle. Table 1 summarizes the time used for these test scenarios.

Table 1. Summary of release times.

Test #	Time (local)	Time (UTC)
1	01:55	05:55
2	06:00	10:00
3	08:00	12:00
4	10:00	14:00
5	12:00	16:00

For the time series comparison the corrected temperature data set was subtracted from the uncorrected data set for each release time. Figure 2 is a plot of the temperature differences for those release times. As indicated in Figure 2, the differences between the raw data sets and the corrected data increases near the surface as time increases. These are the expected results. As the solar angle increases with time, so does the correction being applied. At high altitudes, the solar corrections converge indicating a maximum correction of about 0.94°C at about 32 km.

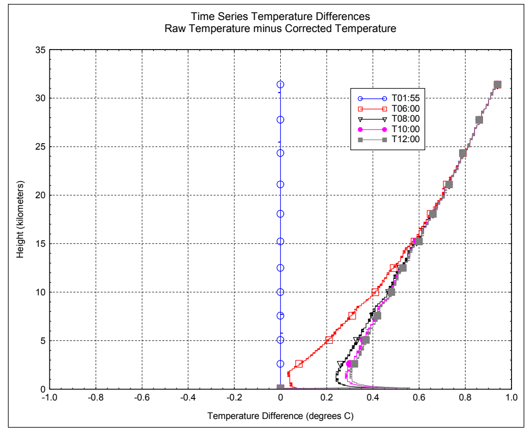

Figure 2. Time series temperature differences.

5. CORRECTING FOR CLOUD COVER

Due to the reflection and absorption of solar radiation, cloud cover can have a significant impact on radiation corrections. For this reason, the NWS has been validating the cloud cover radiation correction algorithms used with the Sippican Mark IIA. At the time this paper was written, these algorithms may not have been in their final state.

To validate the cloud cover correction scheme, the 10:00L raw data set from the time series was used. Using this raw data set, two more files were created for the same 10:00L launch time. The first was corrected solely for solar angle; the second was corrected for solar angle and some nominal sky condition to be investigated. In this case, the cloud/weather code group used was 108410202. This cloud code group is interpreted as follows:

- 1 - is the amount of middle clouds in oktas.
- 0 - there are no low clouds present.
- 8 - is a cloud height of 7000 to 8000 ft.
- 4 - mid cloud type altocumulus.
- 1 - high cloud type cirrus.
- 02 - weather element indicating sky unchanged during past hour.
- 02 - weather element indicating sky unchanged during past hour.

Using the information from the cloud code group and climatological cloud data, assumptions are made about cloud thickness of all cloud etages and the height and coverage amounts of the high cloud. Figure 3 is a plot of three temperature profiles created for the 10:00L data set. The data sets are raw, corrected for solar angle only and corrected for solar angle and cloud cover. As indicated in Figure 3, the corrected temperatures are cooler than the raw. This is the expected impact of the radiation correction algorithm. To examine in more detail the effects of the cloud correction scheme, a difference plot was created for both corrected data sets. Subtracting the corrected data from the raw data created the differences. Figure 4 is a plot of those differences.

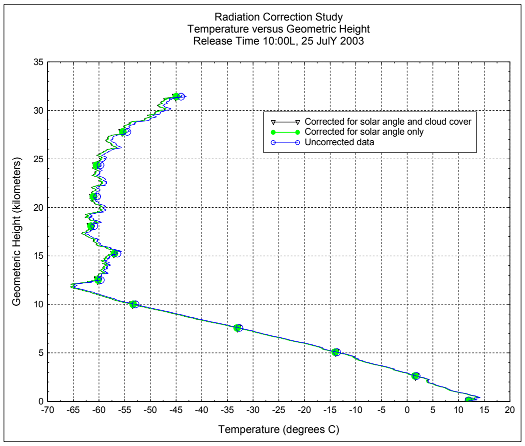

Figure 3. Temperature profiles for the raw and corrected data sets.

Figure 4 shows the difference between the two correction schemes. The data corrected for solar angle only, had a correction that was nearly linear from surface to termination altitude. The difference profile that includes the cloud correction has a smaller correction applied from the surface to eight kilometers. This reduction is the result of the algorithm compensating for the absorption and reflection of solar radiation associated with the clouds.

Above the clouds, the radiation correction increases in order to compensate for the increased solar radiation reflected from the cloud tops.

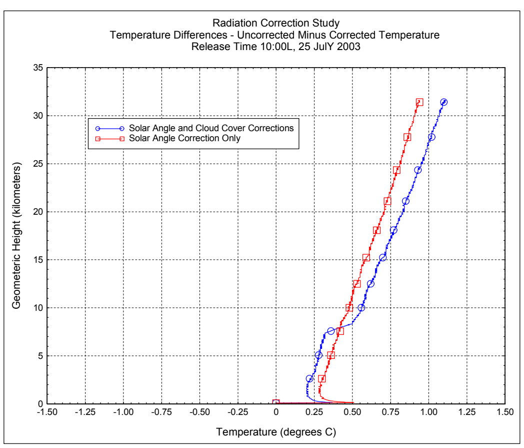

Figure 4. Temperature difference plot for raw minus corrected data sets.

6. EVALUATING AGAINST A STANDARD

For the final step in verification of the radiation correction algorithms, the NWS flew the Sippican radiosonde against the NASA multi-thermistor radiosonde. A series of flights were conducted in which the NASA multi-thermistor radiosonde approach (Schmidlin, et. al., 1986) used for test reference activities and the Sippican radiosondes were flown on the same balloon using a two-meter spreader bar. The multi-thermistor temperature solution was then compared against the Sippican temperature.

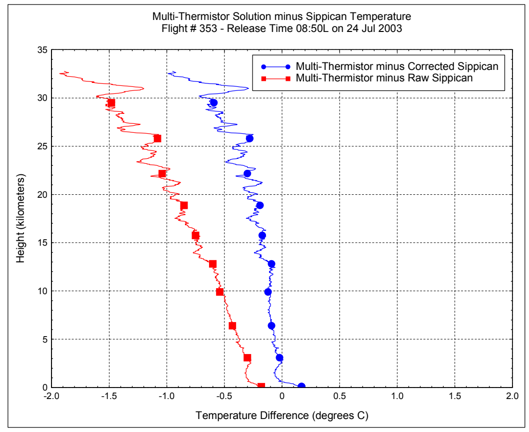

Figure 6. Temperature difference plots multi-thermistor minus Sippican.

Figure 6 shows the difference between the multi-thermistor minus the raw Sippican temperature and multi-thermistor minus the corrected Sippican temperature. As expected, due to the solar radiation, the Sippican raw data starts off about 0.2^{o}C warmer near the surface and increases to about 1.6^{o}C warmer at 30 kilometers. After correction, the temperature would be about 0.2 ^{o}C cooler than the multi-thermistor near the surface and about 0.6^{o}C warmer at 30 km.

7. CONCLUSION

The procedures described in this paper are only examples of a very involved process the NWS will be using to validate radiation correction algorithms. It is anticipated that the processes discussed will be expanded to include a larger range of solar angles and many different cloud cover scenarios. Although the initial results are positive, additional tests of this type will be used to determine if adjustments in the correction schemes are required.

8. REFERENCES

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