A 4-Year Study of the RASS Temperature Bias

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Introduction

Measurements of vertical profiles of virtual temperature have been made with radio acoustic sounding systems (RASSs) at the central facility (CF) of the Southern Great Plains (SGP) Cloud and Radiation Testbed (CART) site since 1994 and at the three intermediate facilities since 1997. Several investigators (e. g., Peters and Angevine 1996; Angevine et al. 1998) noted that RASS measurements of virtual temperature appear to be larger than measurements made at towers or with radiosondes. The reasons include vertical motion of the atmosphere, turbulent inhomogeneities, and inaccuracies in the temperature retrieval. The coincidence of the continuous RASS measurements (the first ten minutes of every hour) and Balloon-Born Sounding System (BBSS) measurements up to eight times daily (during some Intensive Operational Periods [IOPs]) provides an unprecedented opportunity for making extensive comparisons of measurements of virtual temperature under many different operating conditions.

Data Retrieval and Processing

Data from all BBSS flights at the CF are analyzed to compute virtual temperature, temperature and wind speed averaged over 100-m vertical slices, centered at 100-m increments above the surface. Radar wind profiler RASS virtual temperature profiles from the hour coinciding with each BBSS launch (inherently averaged over 100 m) are interpolated to 100-m height increments. Beginning January 1997, the RASS files contain virtual temperatures that are corrected and uncorrected for vertical air motion. Values from the two data streams are combined to form the data for subsequent comparisons.

Results

The mean and standard deviation of the virtual temperature difference between BBSS and RASS data (uncorrected for vertical motion) from the four-year period (Figure 1) are -0.42 K and 1.05 K, respectively, calculated from 14,068 points. When RASS values are corrected for vertical motion, mean and standard deviations are -0.64 K and 0.95 K. Perusal of Figure 1 shows considerable scatter in the results, but a warm bias of the RASS values is quite evident, in agreement with prior results.
Figures 2-4 show the height dependence of the data. Above 200 m the bias is approximately constant near 0.7 K; below that the bias is substantially less. Indeed, probability distributions indicate that most of the instances of negative bias (difference greater than zero) occur near the surface.

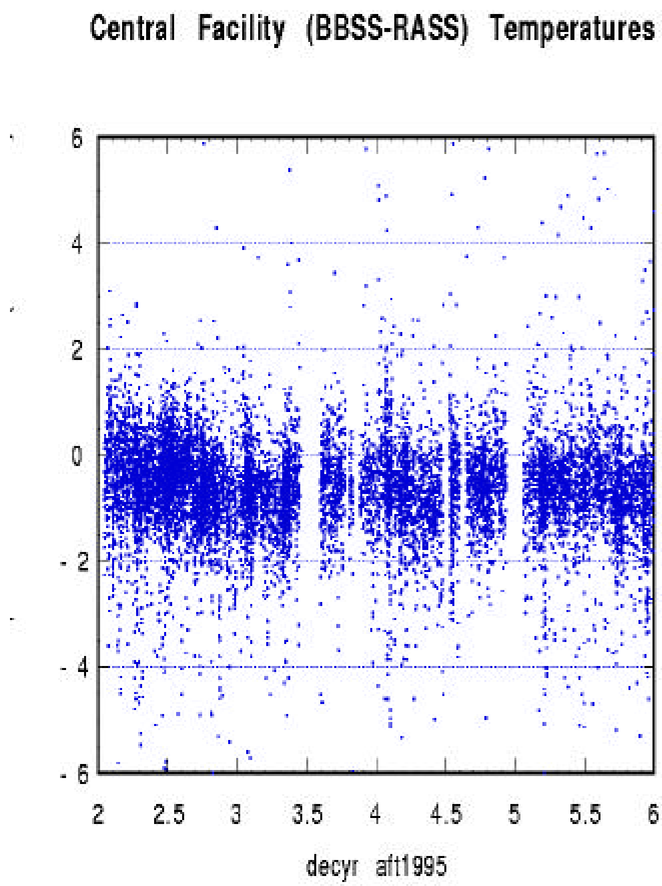

Figure 1. Values of virtual temperature difference between BBSS and RASS wind profiler data calculated between 1997 and 2000. Radiosonde values are averaged over 100 m to a 100-m grid; RASS values are interpolated to the same grid.

We explored this observation further by investigating the dependence of the temperature difference on temperature gradient and/or stability. The temperature and wind speed values (averaged to the same 100 m vertical grid, by using BBSS data) were used to compute wind and atmospheric temperature gradients over the region of the atmosphere where comparisons were made (Figures 3-4). In these figures, the data was divided into regions of temperature gradient and the stability that provided roughly equal numbers of data points, except for conditions with medium to large negative temperature gradients, which do not occur frequently at these heights but are a significant regime for investigating the RASS bias. These data clearly show a maximum relative warmth in RASS temperature values near neutral to slightly stable conditions and near zero temperature gradient. The smallest mean differences occur in unstable conditions and at negative temperature gradient. When the temperature gradient is more negative that -0.03 K/m, RASS virtual temperatures are less than BBSS values. These conditions occur most often at small heights because of strong surface heating.

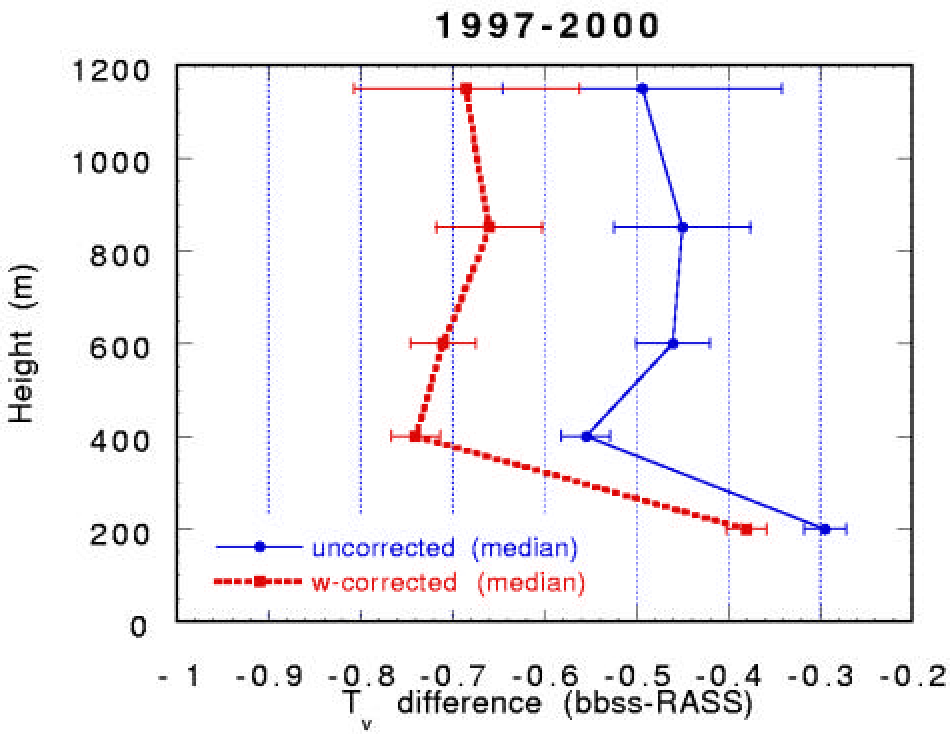

Figure 2. Height dependence of virtual temperature difference. Two height intervals are averaged together in the lowest 600 m; three intervals are used above this height to increase the statistical significance (Fewer "good" vakyes iccyr with increasing height.)

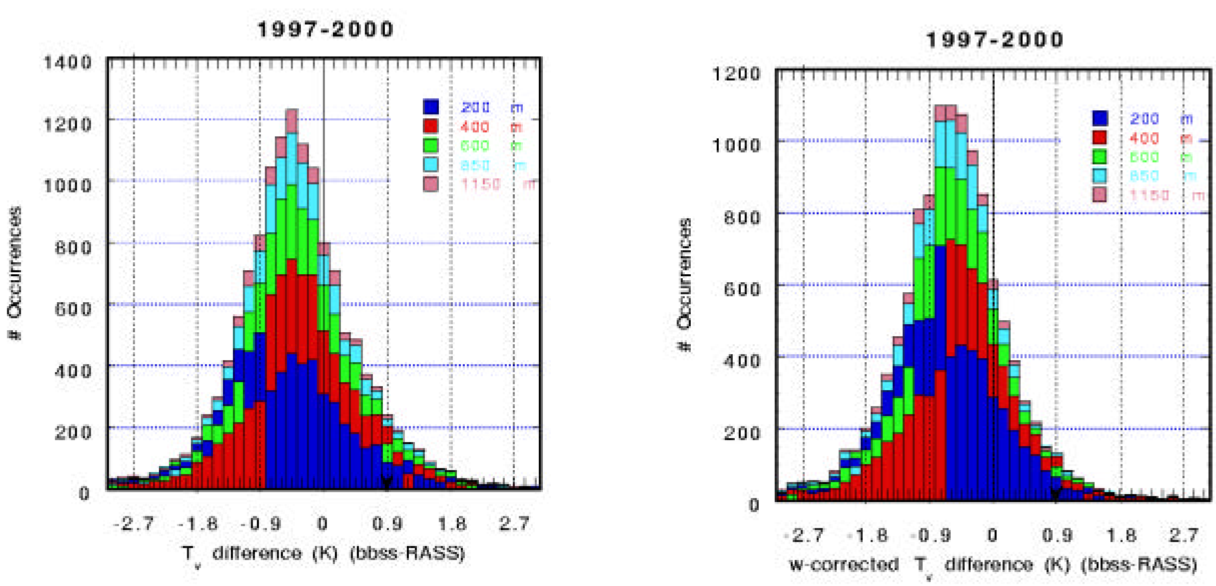

Figure 3. Probability distributions of corrected and uncorrected virtual temperature difference. Note the shift toward larger bias at heights above 200 m.

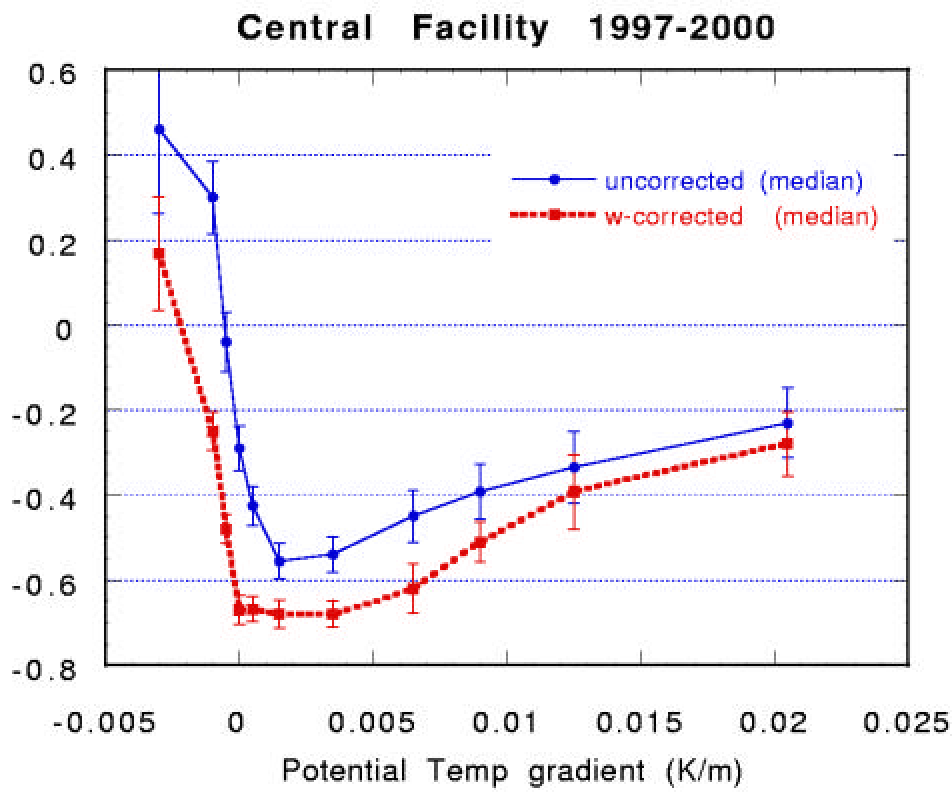

Figure 4. Dependence of virtual temperature difference on potential temperature gradient (calculated from BBSS data). Divisions of potential temperature gradient were chosen to enhance statistical significance, except for large negative values where fewer samples were available. Error bars are standard error for each interval.

Finally, taking the difference between corrected and uncorrected temperature differences, causes the BBSS estimates drop out, leaving estimates of the effect of vertical velocities on the RASS virtual temperatures (Figures 5-6). An inconsistency apparent in positive differences (corrected minus uncorrected) in unstable conditions. One might expect the difference to be of opposite sign because the expected strong upward motion in unstable conditions would lead to larger uncorrected values than corrected values (increases in the measured speed of sound). However, another characteristic of wind profiler operation that uses consensus averaging is that convective conditions most often lead to negative measured vertical velocities. This in turn leads to overestimates of the corrected values. Note that these results refer to mean conditions; instantaneous comparisons can deviate significantly from these results.

Acknowledgement

Work supported by the U. S. Department of Energy, Office of Science, Office of Biological and Environmental Research, Environmental Sciences Division, under Contract W-31-109-Eng-38, as part of the Atmospheric Radiation Measurement Program.

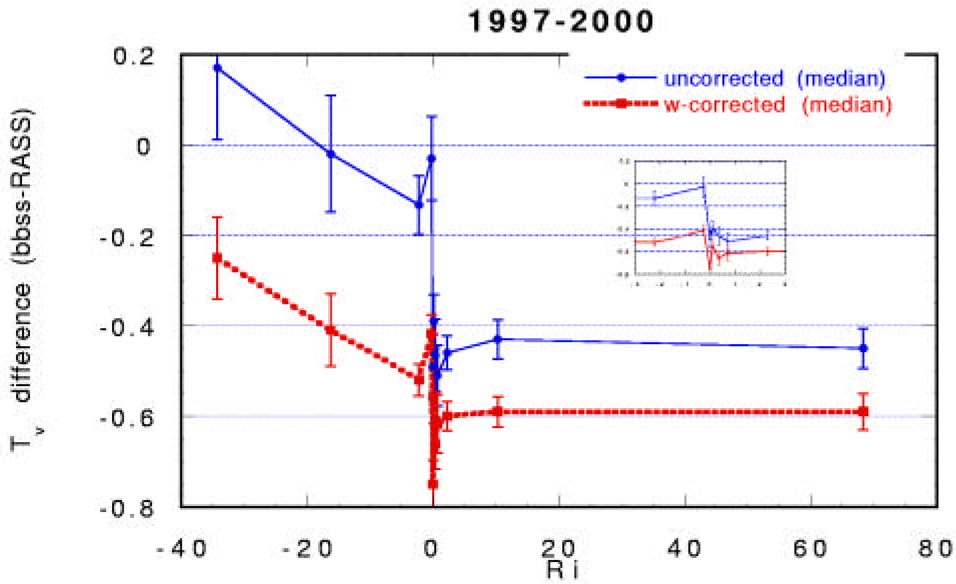

Figure 5. Dependence of virtual temperature difference on bulk Richardson number (calculated from BBSS data). Divisions of Richardson number were chosen to enhance statistical significance, except for large negative values where fewer samples were available. Error bars are standard error for each interval. Inset expands the behavior around Ri = 0.

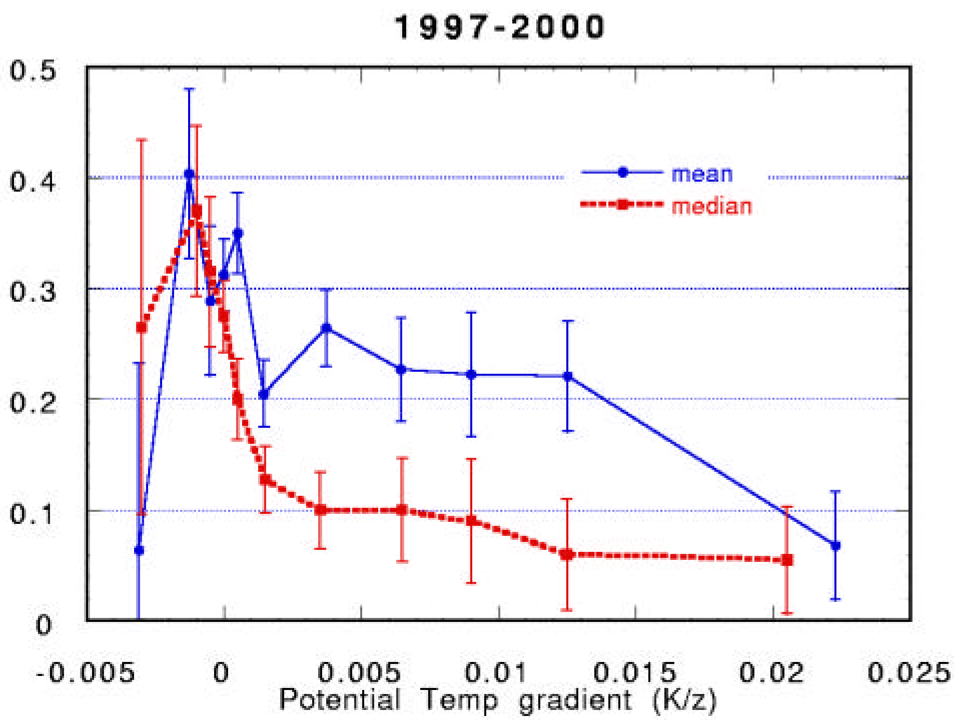

Figure 6. Dependence of difference between corrected and uncorrected (for vertical air motion) virtual temperature calculated with RASS data on temperature gradient.

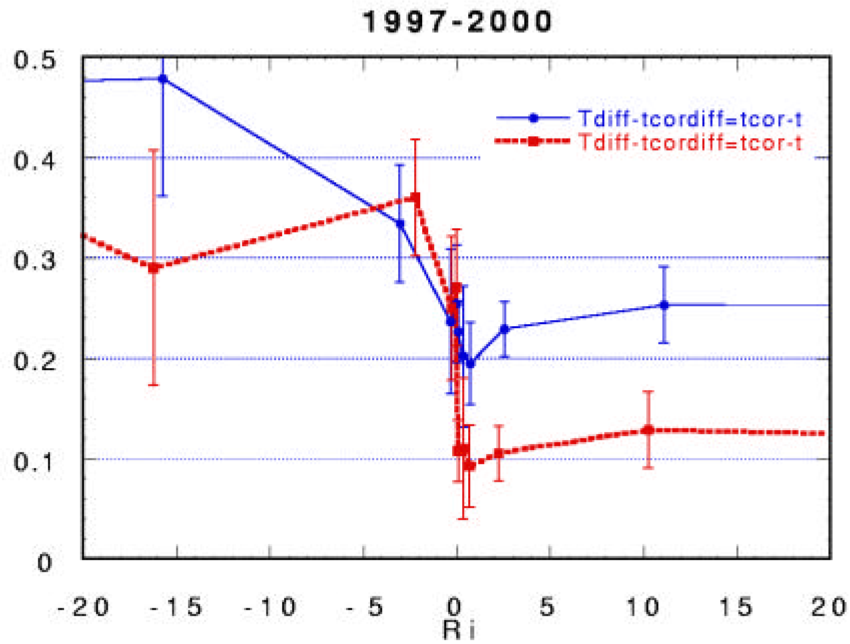

Figure 7. Dependence of difference between corrected and uncorrected (for vertical air motion) virtual temperature, calculated with RASS data on stability (bulk Richardson number).

References

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Peters, G., and W. M. Angevine, 1996: *Beitr. Phys. Atmos*. 69, 81-96.