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A THREE-MONTH COMPARISON OF HOURLY WINDS AND TEMPERATURES FROM CO-LOCATED 50-MHZ AND 915-MHZ RASS PROFILERS

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1.0 INTRODUCTION

The Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) Program has operated a 915-MHz and a 50-MHz radar wind profiler [boundary layer profiler (BLP) and tropospheric profiler (TP), respectively], each coupled with a Radio Acoustic Sounding System (RASS) since April 1994 at its Southern Great Plains (SGP) Cloud and Radiation Testbed (CART) central facility in north central Oklahoma. The dual system is designed to provide continuous wind profiles from near the surface (100 m) to 12 km or more and virtual temperature profiles from near the surface to 6 km. Because the BLP has a larger antenna than many other 915-MHz systems (see Table 1), the wind profiles sampled by the two systems overlap between 1.5 km and 5.5 km. The two systems are adjacent (with antenna centers separated by approximately 120 m), so the wind profilers sample almost identical air masses in their overlap region during the averaging period. Unfortunately, there is no true overlap region in the temperature profiles from the two systems, because the maximum reliable range of the BLP RASS is generally less than the lowest usable height available with the TP. Nevertheless, the two RASS systems can be compared, and methods can be devised to estimate the temperature profile in the inaccessible region. Data used in all comparisons and calculations discussed below are consensus-averaged values supplied by the profiler software. Although the spectra and moments from the data are available, they were not accessed for this analysis.

2.0 SYSTEM DESCRIPTIONS

Table 1 compares the physical and operational parameters of the two profiler systems. Both systems alternate between low-power and high-power modes of wind profiling to provide near-surface and large-altitude coverage. The BLP has been in operation since November 1992. while the TP began operation in April 1994. The BLP senses rain and (to some degree) cloud drops, but the TP should be insensitive to them because of its much larger wavelength. Similarly, the BLP should be more sensitive to a variety of birds and insects, as will be discussed below.

The sound source for RASS operation is provided by high-power transducers positioned at the edges of the antenna field for each system (four for the BLP at the north, east, south and east edges and three for the TP, located at the southwest, southeast and north ends of the antenna field).

TABLE 1.
Operating parameters for the profiler systems (High power mode for the BLP, and low power mode for the TP).

Parameter	915 MHz (BLP)	50 MHz (TP)
Wavelength (m)	0.29	6
No. of beams	5	3
Peak power (W)	500	3.9
Antenna size (m)	3 X 3	70 X 70
Tilted beams (deg)	14	15
Min Height (km)	0.3	1.5
Max Height (km)	5.5	12
Range gate (m)	105	150
Spect ave. Time (s)	34	48
No. of spectral pts	64	128

The two systems normally operate on identical schedules consisting of 10 min of RASS operation followed by 50 min of wind profile operation.

3.0 WINDS

Wind components were compared between the high power mode of the BLP and the low power mode of the TP to maximize the range of data overlap (1.5 km to 5 km). To allow direct comparisons, the BLP data from the BLP range gates immediately below and above each

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range gate for the TP were interpolated to match the range gates of the TP as follows :

$$c_i = \frac{c_-(z_+ - z) + c_+(z - z_-)}{(z_+ - z_-)}. \quad (1)$$

Here c_i is the interpolated wind component (u or v), and (z_-, z_+) and (c_-, c_+) are, respectively, the heights and wind components of the BLP range gates below and above the height of the TP range gate, z. If no data were available from the height immediately above or below, the next available range gate was used.

Figure 1 compares the u and v components of the two systems over the three-month period in terms of the mean difference between the system estimates as a function of height. We believe that the TP data below 2 km are contaminated with ground reflections that account for the apparent positive offset of BLP values; this belief is corroborated by the fact that far fewer data points from the TP lie at these lower altitudes. Above 2 km, mean differences for the east-west component (u) are less than 0.5 m s^{-1} (with a RMS difference of approximately 2.5 m s^{-1}). The north-south component of the BLP has a negative mean offset greater than 1 m s^{-1}, with a maximum near 1.6 m s^{-1} between 3 and 4 km (where RMS differences exceed 3.2 m s^{-1}).

Further investigation of the offset between BLP and TP values above 2 km (Fig. 2) showed that the mean offset varies with time, approaching -3 m s^{-1} in the month of August. This behavior is symptomatic of artifacts in the BLP signal from migrating birds. Recent reports have described biases in 915 MHz profiler data attibuted to signal reflection from migrating birds in the profiler beam (Rogers et al., 1994,Wilzcak et al., 1994). With this data set, however, the evidence is augmented by the fact that the 50-MHz profiler should be relatively immune to reflections from all but extremely large birds, such as cranes (or pterodactyls?) because of its 6-m wavelength. Further evidence

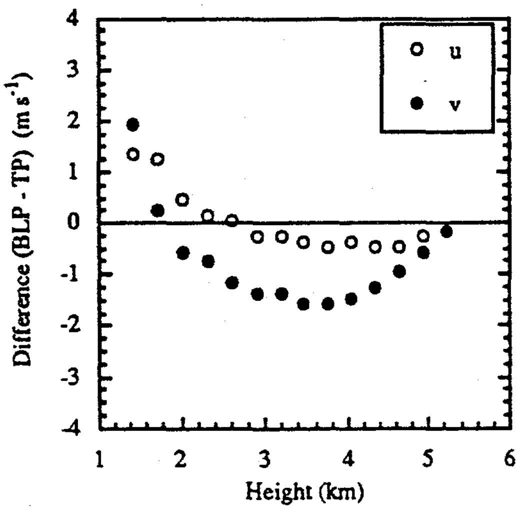

Figure 1. Mean difference between BLP and TP wind components as a function of height. Data covers the period from 28 May 1994 through 6 Sep 1994.

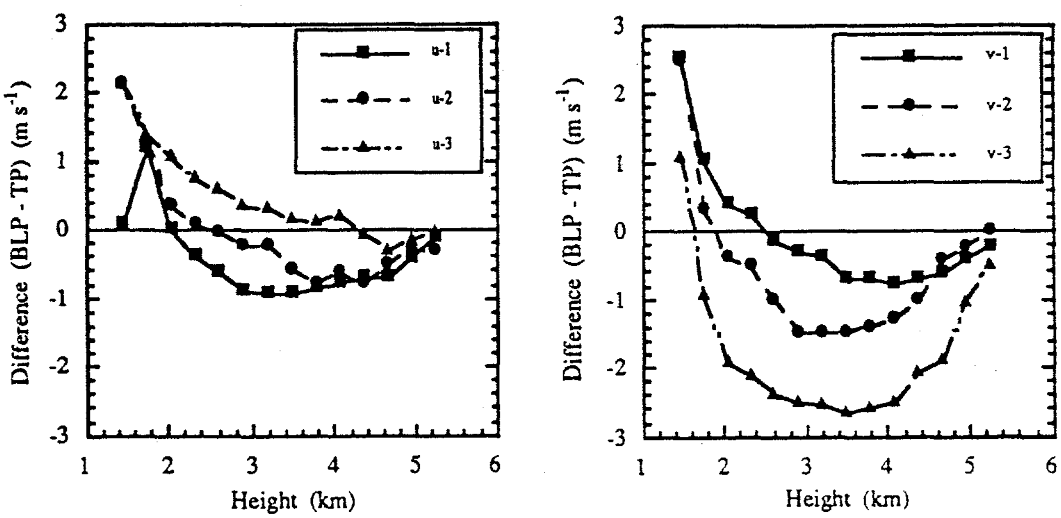

Figure 2. Height dependence of difference between the BLP and TP components (u, v) of the wind. Curves (1, 2, and 3) represent June, July, and August, respectively.

of an avian artifact is shown in Fig. 3, where the data are stratified according to wind direction and stability. Birds begin to migrate toward warmer climes during late summer and fall (note Fig. 2); however, they usually fly with the wind rather than against it and migrate in stable, nighttime conditions to maximize efficiency. Figure 3 shows a large offset in nighttime, stable conditions when the winds are northerly during August that is not present in June when migration would not be expected. In both

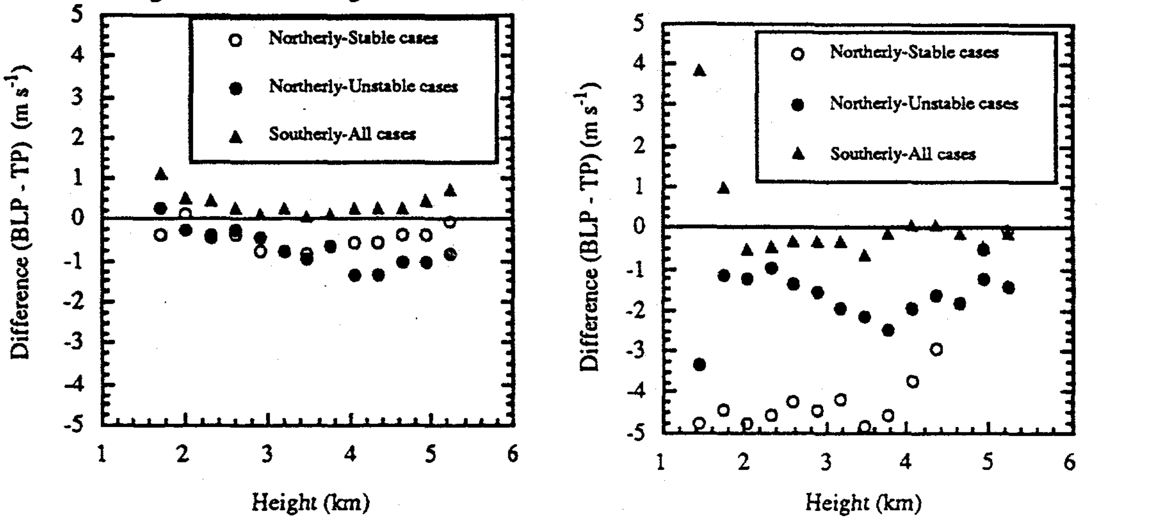

Figure 3. Difference between the BLP and TP v component of the wind during June (left) and August (right), stratified by stability and wind direction.

months, the offset is very nearly zero when the winds are southerly, because the birds prefer tailwinds. We note that the offset decreases for heights above 4 km, nearly disappearing at 5 km. All these results are commensurate with the efffects of migrating birds.

Operation of the 50-MHz system next to the 915-MHz system enables ARM researchers to determine when bird contamination of the signals is likely to be a problem. Since the spectra from the data are saved, it should be possible to reprocess the data with specific reference to the 50-MHz data as a control over processing options.

4.0 VIRTUAL TEMPERATURE

No direct comparison between virtual temperatures determined with the BLP and the TP is possible because of the difference in height coverage with the two systems. The maximum range of a RASS is limited by the atmospheric absorption of the transmitted sound wave, which increases exponentially with frequency. Thus the expected maximum height for the BLP (acoustic frequency ~ 2 kHz) is considerably less than that for the TP (acoustic frequency ~ 110 Hz). On the other hand, although the TP RASS can achieve heights to 6 km, its minimum usable range is near 2 km (minimum data height is presently 1.5 km), because of the ground reflections noted above. The amount of coverage within the maximum range of both systems is also much more variable than with wind profiles. This is due primarily to advection of the sound wave out of the profiler beam at high ambient wind speeds. Because the minimum height for the TP is large, considerable horizontal movement of the sound wave may occur before it reaches the lowest range gate. (The sound wave will traverse the 50 MHz array by the time it reaches the first range gate with mean winds of 17 m s^{-1}.) We can, however, investigate the nature of virtual temperature profiles composed of BLP values in the lowest 1.5 km and TP values above 2 km and extend them into the zone between.

Figure 4 is an example of 10-min-average temperature profiles for BLP and TP data. In general, the maximum height of the BLP profile and the minimum height of the TP profile are variable. We investigated the compatibility of the upper and lower profiles by calculating linear fits to the top three points of the BLP and the bottom three points of the TP and extending each of them to an arbitrary reference point, defined as 1.7 km. Their relative offset does not necessarily imply the existence a bias because the capping inversion is frequently located within the interval without data.

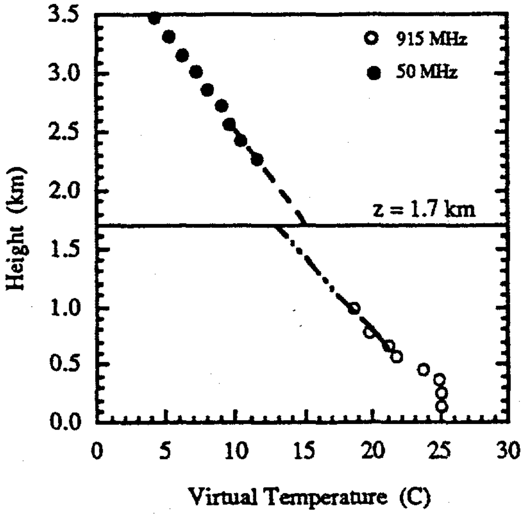

Figure 4. Sample profiles from BLP and TP RASSes. Lines are defined by the upper three and lower three points of the BLP and TP, respectively. Horizontal line at 1.7 km represents the reference point for virtual temperature comparison.

Figure 5 shows the distribution of the median absolute difference between BLP and TP values at the reference point in Fig. 4 as a function of the maximum height achieved with the BLP, z_b, for all available data from the three-month period. Not surprisingly, the differences increase as the maximum BLP height decreases.

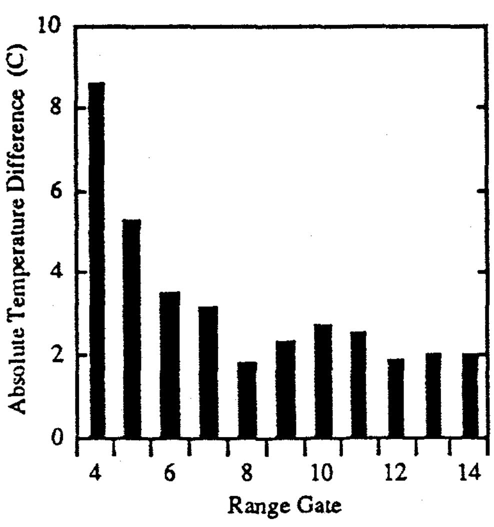

Figure 5. Distribution of median difference at 1.7 km between BLP virtual temperature extrapolated upward and TP virtual temperature extrapolated downward.

However, for $z_b > 0.8$ km, the median difference is relatively constant near 2^{o}C. Although this difference seems rather large, small differences in computed slopes on the two profiles can result in large differences at the reference point. Curvature in the profile is a particular problem for the BLP, because the capping inversion at the top of the mixed layer may include some or all of the points used in the BLP fit; a positive slope locally can lead to significant errors at the reference point.

A better method for comparing the profiles and assessing the reliability of composite profiles was developed by treating the two profiles as one. We calculated a second-order polynomial fit to the six points (the top three points from the BLP and the bottom three points from the TP) by using the appropriate heights to which they refer. This curve was then used to predict the virtual temperatures in the dead zone. This method has the advantage of allowing for curvature in the profile (due to the capping inversion, for example), while it constrains the profile by both sets of observed values. This method was applied to all the hourly temperature profiles that coincided (approximately) with radiosonde launches (approximately eight per day) over a three-week period in July 1994 (see Fig. 6). The virtual temperatures calculated

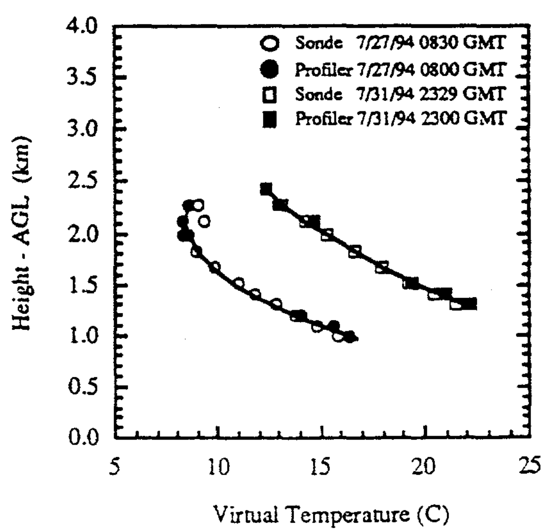

Figure 6. Examples of profiles the near region inaccessible to profilers. Lines are the curve fit for the solid points below and above the inaccessible zone.

from the radiosonde were averaged to coincide with the profiler range gate and compared with the composite profiler virtual temperature profile. Table 2 shows that the mean difference between the radiosonde values and the values in the inaccessible zone is less than 0.2 °C.

Table 2

Virtual temperature differences (°C) between sonde and profilers and linear fit in the zone inaccessible to profilers.

	Sonde - BLP		Sonde - TP		Sonde - Fit	
Time	Ave	St Dev	Ave	St Dev	Ave	St Dev
2030	-0.53	0.51	-0.03	0.78	-0.36	0.68
1130	-0.75	0.78	-0.01	0.99	-0.13	1.17
0230	-0.08	0.59	0.33	0.72	-0.03	1.06
0530	-0.41	0.92	0.30	0.75	0.16	1.16
0830	-0.12	0.87	0.56	0.89	-0.25	0.78
1130	-0.85	0.65	0.52	0.73	-0.05	0.63
1430	-0.50	1.07	0.57	0.62	-0.14	1.09
1730	-0.45	0.64	0.56	1.13	-0.10	0.99

More important, the differences between the sonde values ane the fitted values in the inaccessible zone are very comparable to the differences between the sonde values and the measured profiler values, indicating that this method or some extension thereof may work well to supply the virtual temperatures between the two profiles.

5.0 CONCLUSION

Comparisons between the 915-MHz BLP and the 50-MHz TP were carried out with data from a three-month period. The component wind comparison shows strong evidence of artifacts due to birds in the values for the 915-MHz system. However, the combination of the 50-MHz system, which is unaffected by birds, and the 915-MHz system can be used to determine if and when such conditions occur. In the absence of bird artifacts, the agreement between the systems is usually better than 0.5 m s^{-1}.

Although the virtual temperature profiles from the two systems do not overlap, fitting a polynomial to the top three heights in the BLP and the lowest three heights in the TP produced values in the zone not accessible to either system that compared very well to radiosonde values.

6.0. ACKNOWLEDGEMENT

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7.0 REFERENCES

Rogers, R. R., S. A. Cohn, W. L. Ecklund, J. S. Wilson, and D. A. Carter, 1994: *Experience from one year of operating a boundary-layer profiler in the center of a city*. Ann. Geophysicae **12**, 529-540.

Wilczak, J. M., R. G. Strauch, F. M. Ralph, and D. A. Merritt, 1994: *Contamination of wind profiler data by migrating birds*, Extended abstracts - Third International Symposium on Tropospheric Profiling: Needs and Technologies, 30 Aug-2 Sep 1994, Hamburg, Germany, pp. 212-214.