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PERFORMANCE OF RADAR WIND PROFILERS, RADIOSONDES, AND SURFACE FLUX STATIONS AT THE SGP CART SITE

by

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The performance of several routinely operating observational systems at the Southern Great Plains (SGP) Cloud and Radiation Testbed (CART) site has been evaluated. The results of a few specific investigations are shown here for Radar Wind Profilers (RWPs) and Radio Acoustic Sounding Systems (RASSs), Balloon-Borne Sounding Systems (BBSSs), and Energy Balance Bowen Ratio (EBBR) stations (Coulter and Holdridge, 1995; Coulter and Martin, 1995; Lesht, 1995; Wesely et al., 1995).

Radar Wind Profilers and Radio Acoustic Sounding Systems

A comparison of three months of data on hourly winds and temperatures from the two RWPs collocated at the SGP CART central facility indicated that data from the 50-MHz system can be used to determine if the winds measured by the 915-MHz system are distorted by signal returns from migrating birds. Average differences in the *v* (north-south) component of the wind measured with the 915-MHz boundary layer profiler (BLP) versus the 50-MHz tropospheric profiler (TP) are shown in Figure 1 for the months of June and August. Evidence suggests that the large differences in August were caused by migrating birds passing through the beams of the BLP, particularly with northerly winds at night. Data from the 50-MHz system, which is unaffected by birds, can be compared to 915-MHz system data to detect this problem. In the absence of artifacts caused by birds, the agreement between the systems is usually better than 0.5 m s^{-1}.

Table 1 shows statistics generated by comparison of temperatures measured with the BLP and TP RASSes. Although the virtual temperature profiles from the two systems do not overlap, fitting a polynomial to measurements at the largest three heights where temperatures are reliably detected with the BLP RASS and at the smallest three heights for the TP RASS produces values that agree very well with the radiosonde values in the zone not accessible to either radar system.

Realistic evaluations of statistics on vertical velocity (w) from wind profiler data often require a sample rate larger than that available from normal profiler operations at the CART site; however, the existence of four tilted beams, rather than the minimum of two required for horizontal wind measurements, allows additional measurements of the vertical component of motion with pairs of beams tilted in opposed directions. These tilted beams can be used to provide better statistics on vertical velocity and, potentially, direct measurements of momentum flux. Spectra in convective conditions for w sampled directly at 15-s intervals with only the vertical beam and for w derived from both the vertical and the four tilted beams are shown in Figure 2. These and other tentative results indicate that problems exist with the five-beam approach at high frequencies because increased variance is introduced by spatial and temporal separations in the vertical velocities calculated from opposing tilted beams. Additional noise is apparently introduced by the irregular time spacing of the enhanced time series. On the other hand, the low-frequency resolution of the enhanced time series may be improved, which would aid in the detection and resolution of coherent structures like thermal plumes. Better selection of beam sampling order might be possible to eliminate the irregular time series. For example, arranging for the vertical low- and high-power beams to operate sequentially and averaging their signals would yield a time series with five different estimates of w that are equally spaced in time.

Balloon-Borne Sounding Systems

A quantitative measure of the quality of the BBSS data is needed because the Atmospheric Radiation Measurements (ARM) program uses data from the radiosondes in sensitive modeling applications and for purposes of real-time quality control. Finding such a measure is difficult because the basic sensing system, the radiosonde package, is discarded after each use and is not available for repeated calibration checks. Furthermore, methods of evaluating the quality of radiosonde data that depend on point-by-point comparisons with profiles obtained by ground-based remote sensors and sensors aboard aircraft are difficult because they lack simultaneity of sampling in space and time, especially at high altitudes.

From January 1993 through August 1994, the temperature and humidity sensors on radiosondes launched from the SGP CART central facility were checked with a commercially supplied ground-check set before launch. Investigations with the ground-check set showed that the radiosondes are within the manufacturer's specifications for measurement of relative humidity (±2% for one standard deviation). Because of procedural artifacts, the ground-check data could not be used to similarly verify the specification for temperature (±0.2°C for one standard deviation). Examination of the time series of temperature differences showed a clear seasonal pattern, with greater differences occurring during the cold winter months. This pattern suggests that the apparent bias in temperature is an artifact of the ground-check procedure, most likely resulting from a failure of the ground check set to be in thermal equilibrium when the instrument shelter is being heated during the winter. The variability in the differences probably reflects the variable experience of the different operators. Ground checks were suspended in August 1994 because analysis of the accumulated data indicated that the potential for introducing errors into the sounding data as a result of procedural errors outweighed potential improvements over the factory-supplied calibrations.

Figure 3 shows ascending and descending phases of a sounding initiated at 2031 hr UTC on May 10, 1994. Analysis of such pseudo-replicate data from ascending and descending phases of operational soundings suggests that the temperature measurement is within the ±0.2°C specified for the system, but more analysis is required to confirm the accuracy of the temperature sensor aloft. On average, data collected during the ascending and descending phases of the soundings are quite similar, but the detailed structure during the relatively rapid descent may be obscured by loss of sampling density. Uncertainty about the physical position of the radiosonde sensors during descent complicates the situation, but the set of ascending and descending soundings obtained at the SGP CART site represents a rich source of data for examination of both operational radiosonde sensor response and short time-scale changes in the state of the atmosphere.

Energy Balance Bowen Ratio Stations

The 350-km X 400-km domain of the SGP CART site is equipped with 10 EBBR stations at grassland sites. These stations operate continuously throughout the year and use an automatic exchange mechanism to switch the positions of the upper and lower sets of temperature and humidity sensors once every 15 min to minimize the effects of offsets and minor drifts in the all-weather sensors. The Bowen ratio (β) of the sensible heat flux (H) to the latent heat flux (λE) is computed with the energy balance equation, which tends to produce "spikes" in the heat flux data when the value of β is near -1. On some days, no spikes occur, but one to five spikes per day are common, particularly near sunrise and sunset. Incorrect estimates of sensible and latent heat fluxes occur mostly for values of β between approximately -0.75 and -1.5,. These suspect data points could be replaced with data from a bulk aerodynamic approach. After further testing, algorithms for aerodynamic approach might be implemented to provide a routine data product from the SGP CART site.

A significant source of difficulty in estimating average H and λE values across the CART site can be spatial variability, as is illustrated in Figure 4. Here, averages for 0800 to 1600 hr CST on each day are shown for two sites, one (13, central facility) near the center of the overall CART site and one (22, Cordell) in the southwest corner. Such averages of fluxes for August 1994 varied strongly among the 10 EBBR stations. Because the surfaces were all grass covered and because the momentum flux did not vary greatly from site to site, the likely cause of the variations in H and λE was differences in soil moisture. Obtaining a representative average of the fluxes for the CART site in such a situation requires a more sophisticated approach than simple averaging.

Conclusions

A comparison of three months of data on hourly winds and temperatures from the two RWPs collocated at the central facility indicated that data from the 50-MHz system can be used to determine if the winds measured by the 915-MHz system were distorted by signal returns from migrating birds. An investigation of vertical winds obtained from vertically pointing and tilted beams of the 915-MHz profiler led to suggestions on methods to enhance the time series of vertical velocities. An evaluation of the CART radiosonde system led to the conclusion that it provides data within the specified uncertainties, and its parachute-assisted descending phase provides usable temperature and humidity data below heights corresponding to atmospheric pressures above about 200 mb. An examination of the surface heat fluxes from the EBBR stations showed that the fluxes varied widely from east to west across the CART site during August 1994 and that algorithms are needed to remove data "spikes" in the computed fluxes when the Bowen ratio is near -1.

Acknowledgments

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References

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Table 1. Average and standard deviation of virtual temperature differences (^0C) between sondes and profilers and between sondes and a linear fit in the zone inaccessible to profilers.

	Sonde - BLP		Sonde - TP		Sonde - fit	
Time (UTC)	Average	St. Dev.	Average	St. Dev.	Average	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

FIGURE CAPTIONS

Figure 1. Average differences between the BLP and TP v component of the wind during June and August, according to stability and wind direction.

Figure 2. Vertical velocity spectra in convective conditions sampled directly at 15-s intervals (top) on October 13, 1994; and vertical velocities derived from vertical and tilted beams (bottom) on September 28, 1994. Solid straight lines indicate the -5/3 slope expected in atmospheric turbulence.

Figure 3. Ascending (solid heavier lines) and descending (lighter dashed lines) phases of sounding on 10 May 1994 at 20:31 UTC. Top panel shows temperature and relative humidity; bottom panel shows east and north wind components.

Figure 4. Daily averages of Net Radiation (Rn), H, and λE between 0800 and 1600 hr CST during August 1994 at two EBBR stations selected for their large differences in H and λE values.

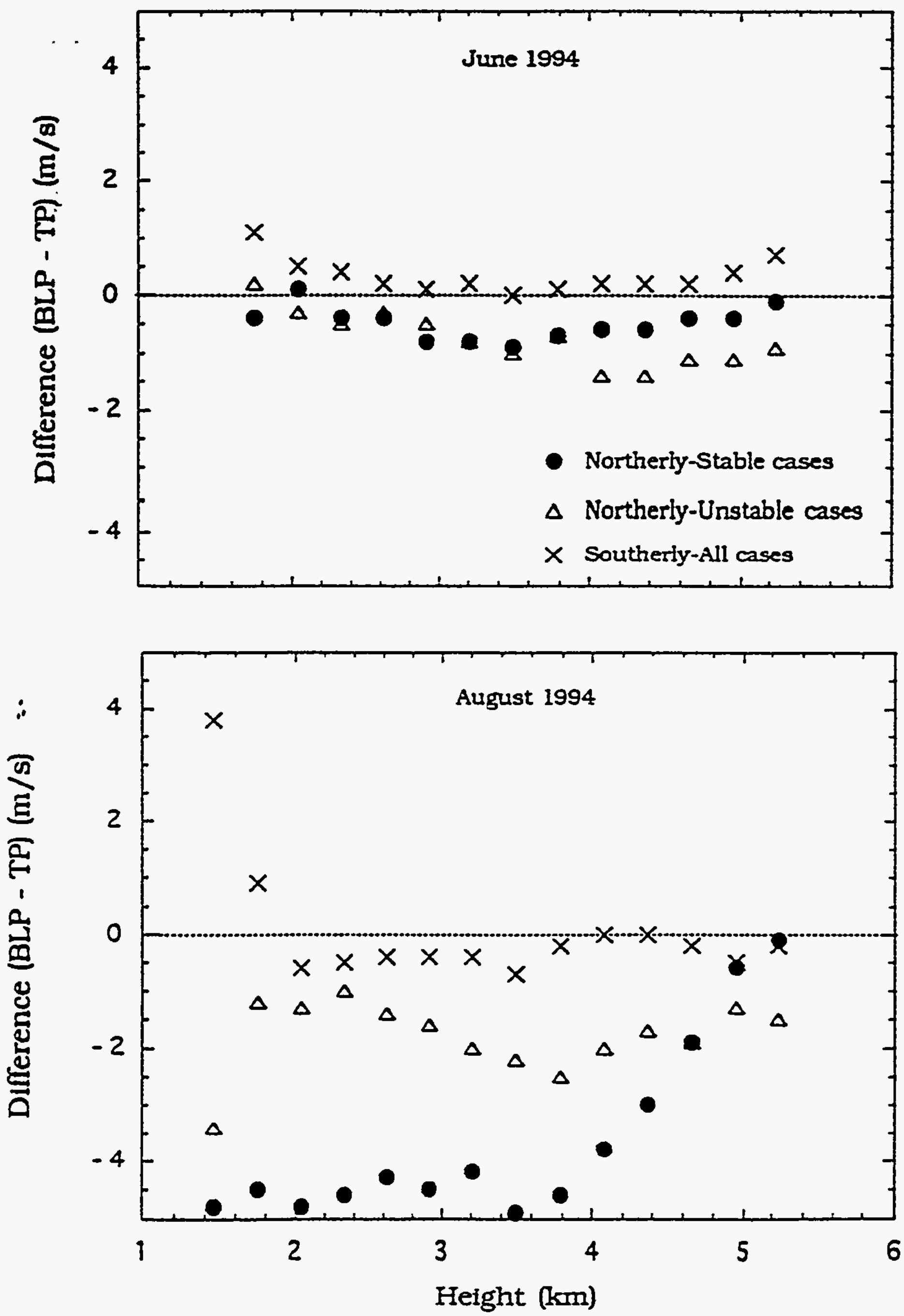

June 1994
Difference (BLP - TP) (m/s)
4
2
0
-2
-4
Northerly-Stable cases
Northerly-Unstable cases
Southerly-All cases
August 1994
Difference (BLP - TP) (m/s)
4
2
0
-2
-4
1
2
3
4
5
6
Height (km)

Fig. 2

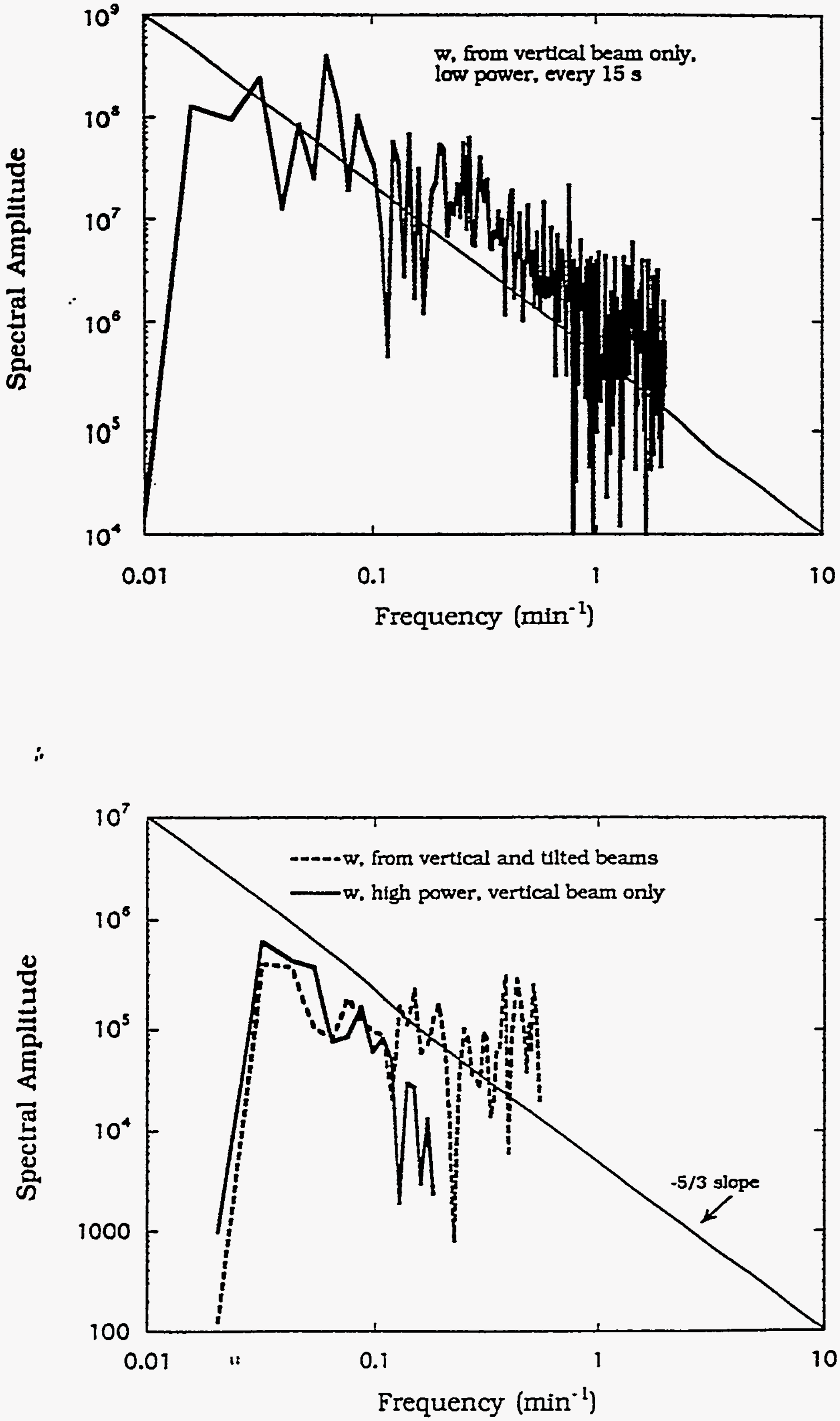
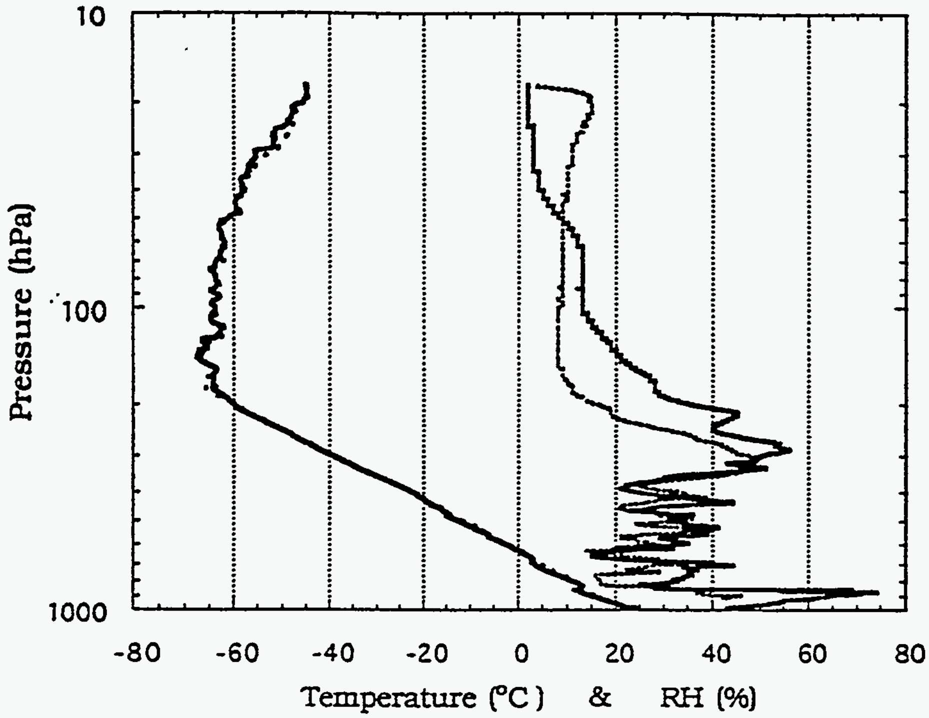

w, from vertical beam only,
low power, every 15 s
Spectral Amplitude
Frequency (min⁻¹)
w, from vertical and tilted beams
w, high power, vertical beam only
-5/3 slope
Spectral Amplitude
Frequency (min⁻¹)

Fig. 3


10
100
1000
Pressure (hPa)
-80
-60
-40
-20
0
20
40
60
80
Temperature (°C) & RH (%)

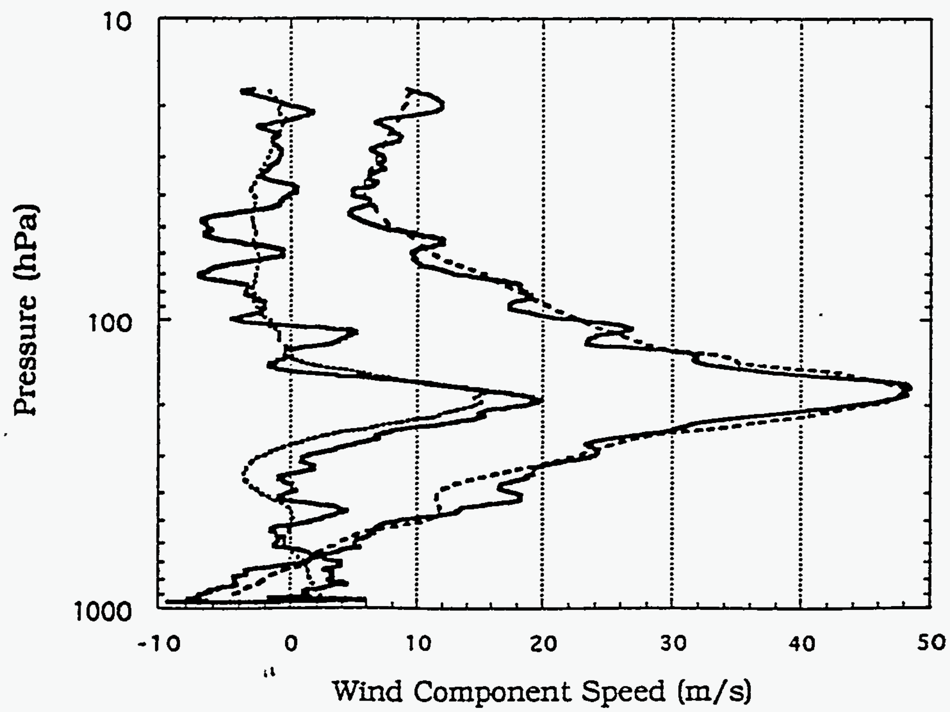
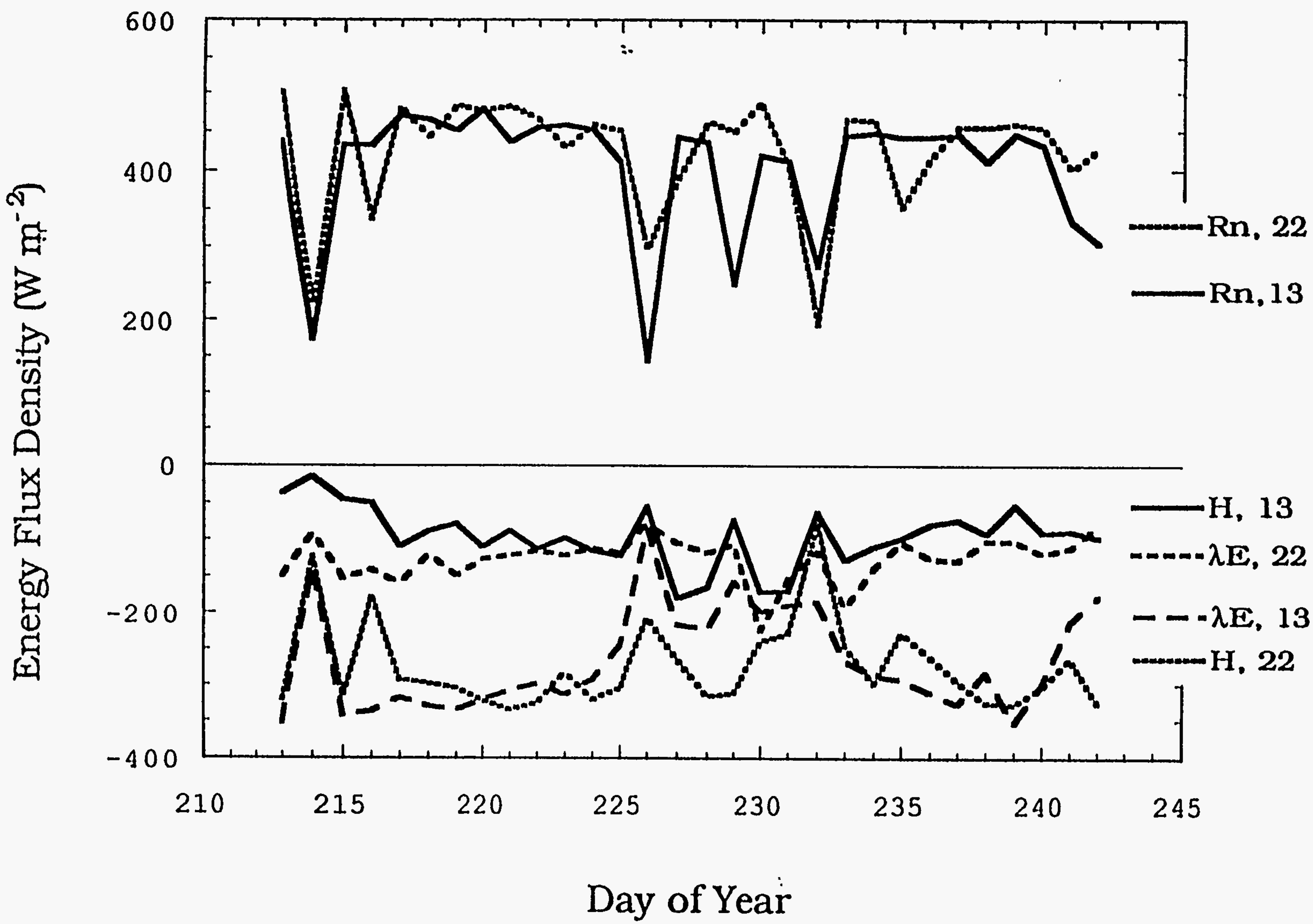

10
100
1000
Pressure (hPa)
-10
0
10
20
30
40
50
Wind Component Speed (m/s)

Fig. 4


Rn, 22
Rn, 13
H, 13
λE, 22
λE, 13
H, 22
600
400
200
0
-200
-400
210
215
220
225
230
235
240
245
Energy Flux Density (W m-2)
Day of Year