

Sensitivity of Convective Indices to Humidity Adjustments

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Introduction

Modification of Atmospheric Radiation Measurement (ARM) Program Balloon-borne Sounding System (BBSS) data streams has been conducted as part of instantaneous radiative Flux (IRF) Working Group efforts to improve the comparison between Atmospheric Emitted Radiance Interferometer (AERI) spectral infrared radiation measurements and line-by-line radiative transfer model estimates (Turner et al. 1998). The focus for the modification of BBSS data has been on its humidity measurements. The Vaisala relative humidity (RH) sensors on the radiosondes that have been used by ARM Program have been demonstrated (e.g., Clough et al. 1996) to have a dry bias. Others (e.g., Miller et al. 1999; Lesht 1999) have shown that these radiosondes lose their humidity calibration over time due to contamination from the packaging material used. Scaling the BBSS humidity measurements with Microwave Radiometer (MWR) precipitable water vapor (PWV) estimates has been shown to reduce the residuals between the AERI measurements and model estimates.

The approach of this study will be to evaluate the impacts of the four moisture adjustment techniques on convective indices that are generated from atmospheric soundings for determining the thermodynamic structure in severe weather forecasting and for computing parameterizations in atmospheric models.

Scaling Methods

Scaling of the ARM BBSS humidity data has been accomplished by determining the ratio (b) of the BBSS PWV to the MWR PWV and modifying the mixing ratios at each sonde level by this ratio. The actual mixing ratio, w , can be represented as follows:

$$w = w_s \times RH$$

where w_s is the saturated mixing ratio (a function of temperature and pressure) and RH is the relative humidity.

By multiplying the above equation by the ratio b , this adjustment is accomplished:

$$w \times b = w_s \times (RH \times b) = w \text{ slope}$$

Note that multiplying the mixing ratio by b is equivalent to multiplying the RH by b . This method of adjusting the sonde data will be referred to as the “slope adjustment.”

An alternative method to adjusting the mixing ratios would be to determine a single value or offset to adjust all sonde RH values by so that the sonde PWV value matches the MWR value. So, for each level of BBSS data:

$$w_s \times (RH + a) = w \text{ offset}$$

where a is the necessary RH offset required for the BBSS PWV to match the MWR value. It (a) is determined in an iterative approach by modifying the offset values until the best agreement in PWV is obtained. This method of adjusting sonde data will be referred to as the “offset adjustment.”

The two methods of sonde adjustment described above are each accomplished by comparison of BBSS data to MWR data. Two other methods are also examined here for adjusting the BBSS moisture: (1) an algorithm developed by Vaisala to adjust RH values based on sonde age, and (2) use of Raman Lidar mixing ratio data as a replacement for BBSS humidity values.

While greater confidence has been gained within ARM by using the MWR PWV adjustments, the slope and offset adjustment methods noted above are still unproven ways of adjusting the BBSS data vertically. This is because even though the adjusted sonde values provide the same integrated values of water vapor as the MWR, the level-by-level values do not necessarily represent a better truth to the vertical distribution of the moisture. Use of the Vaisala algorithm is also unproven as of this writing, and the Raman Lidar data have not been well tested as an avenue for sonde adjustment within the ARM Program.

Spring 1998 and Summer 1999 Comparisons

The first set of evaluations of adjustment methods was conducted on Southern Great Plains (SGP) Central Facility (CF) BBSS data collected during portions of spring 1998 and summer 1999. A total of 105 sondes from this period were analyzed. The CF MWR PWV values averaged over a 15-min period following the sonde launch time were used for the slope and offset methods. Figure 1 shows an example of the adjustment of the RH based on these two adjustment methods.

Numerous convective indices were computed from the original and adjusted BBSS data. These included convective available potential energy (CAPE) and convective inhibition (CIN), see Blanchard (1998); and lifted index (LI), total totals index (TT), K-index, severe weather threat index (SWEAT), Showalter

BBSS Water Vapor Adjustment

June 28 1999 2330 UTC

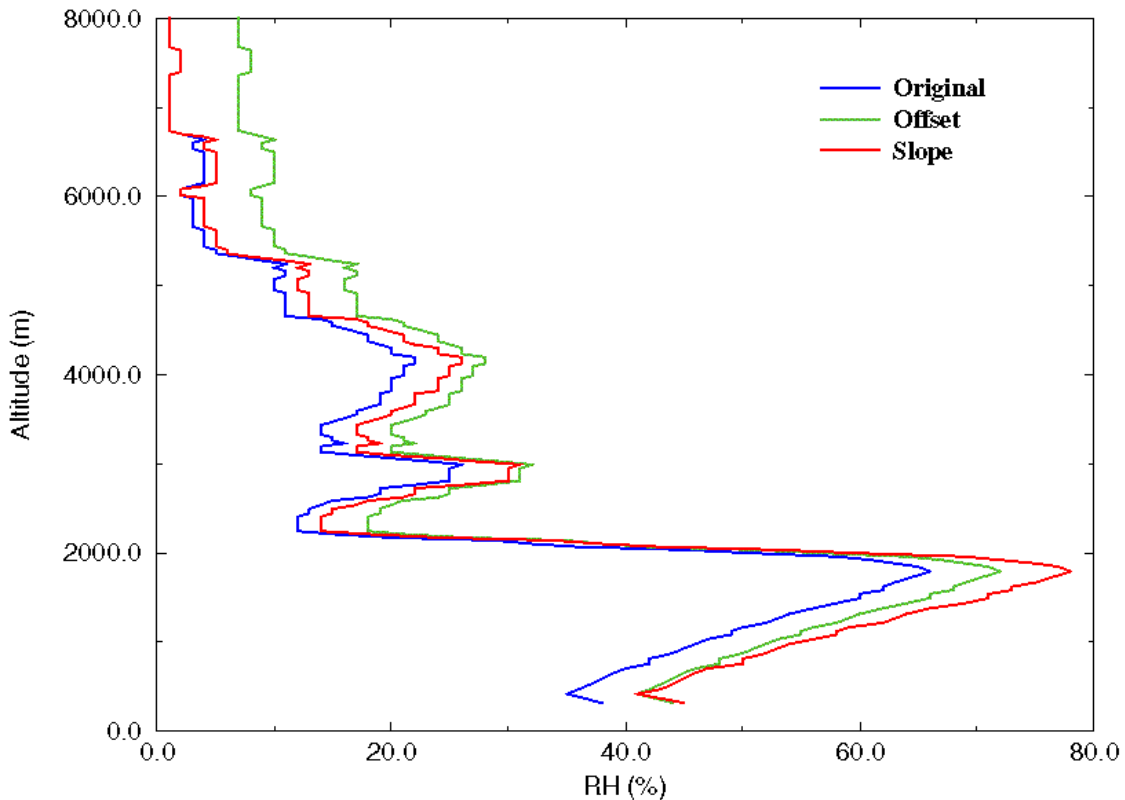


Figure 1. RH adjustments computed from the slope and offset scaling methods.

index (SI), and Bulk Richardson number (BRN), see Pepler (1988). The GEMPAK computer program was used to generate the index values, using default specifications. Table 1 shows the average index values for the 105 soundings using unaltered BBSS data, offset adjusted data, and slope adjusted data. Both the offset and slope adjustments to the BBSS data destabilized the atmosphere based on the values of the various convective indices computed.

Table 1. Averages of convective indices for 105 soundings for the original sondes and the offset and slope adjustments.								
	CAPE	CIN	LI	TT	KI	SWEAT	SI	BRN
Original Sonde	727.38	295.82	0.498	45.27	16.77	142.66	2.158	109.09
Offset Method	846.23	273.02	-0.0275	45.98	18.37	151.12	1.687	119.14
Slope Method	905.67	264.24	-0.0343	45.97	17.92	154.47	1.623	124.55
CAPE and CIN are in J/kg; LI, TT, KI, SWEAT, SI, and BRN are dimensionless.								

August-September 1998 Comparisons

A second period of data was analyzed to compare all four the adjustment methods, but only for CAPE. The Raman Lidar/BBSS method uses Raman Lidar mixing ratio data and BBSS temperature data. The computer program NSHARP was used to compute CAPE in this analysis. Three methods of calculating CAPE were utilized: (1) surface observation-based CAPE, (2) mixed layer-based CAPE, and (3) the most-unstable parcel CAPE. Surface-based CAPE values respond to moisture adjustments at the surface only. The mixed layer-based CAPE uses an average mixing ratio for the mixed layer, while the most-unstable parcel CAPE provides additional information on how the vertical adjustment of the BBSS data affects CAPE.

Figures 2 - 6 depict NSHARP soundings for the original and adjusted data for a single case (August 25, 1998, 1127 UTC [Universal Time Coordinates]). Note that the adjustment (green line) is visible only in the dewpoint data as only the RH values are adjusted in any of these methods. On this particular day and time, the slope adjustment provided the most destabilization to CAPE (2122 J/kg) compared to the value from the original sounding (1313 J/kg). The Raman Lidar adjustment provided a value of 1973 J/kg, and the offset adjustment gave a value of 1903 J/kg. The value produced by the Vaisala algorithm was more stable than the other adjustments, 1700 J/kg.

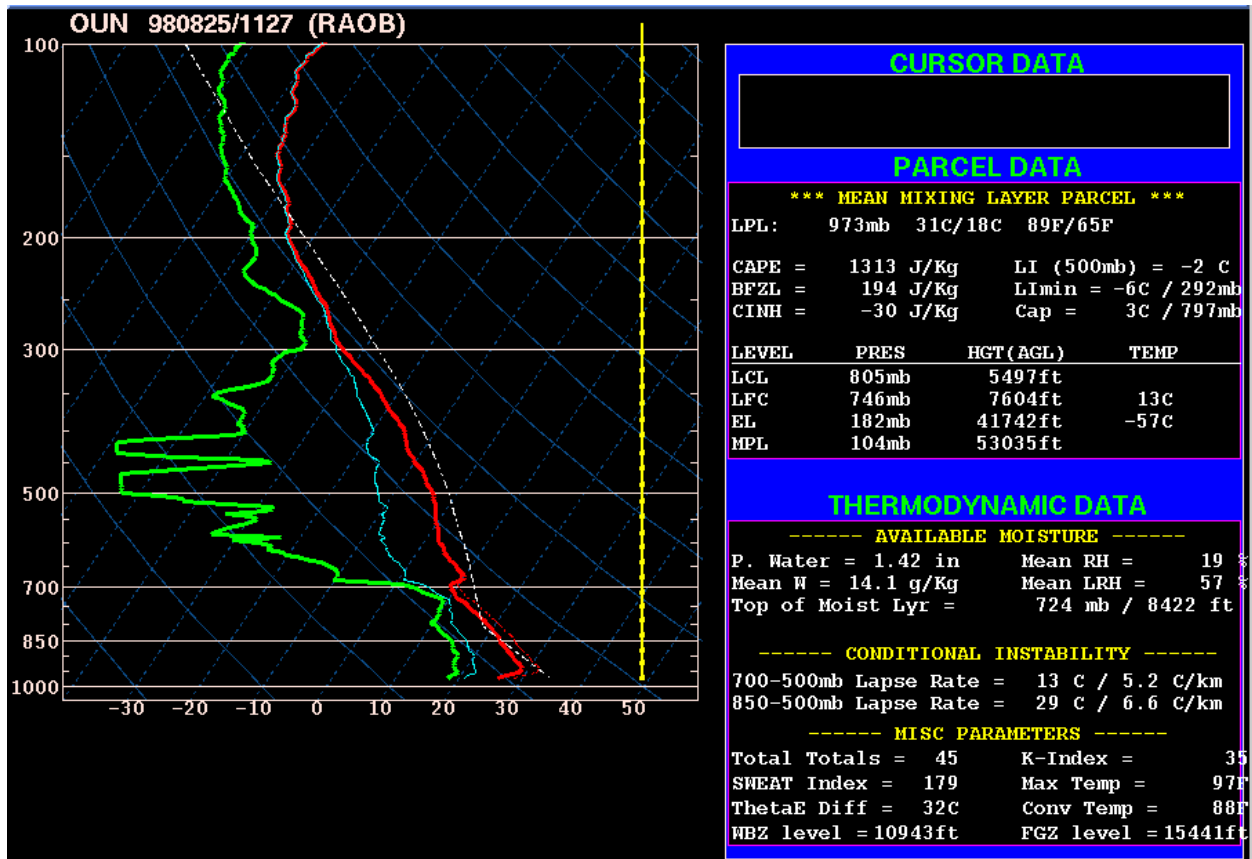


Figure 2. Original sounding and its statistics.

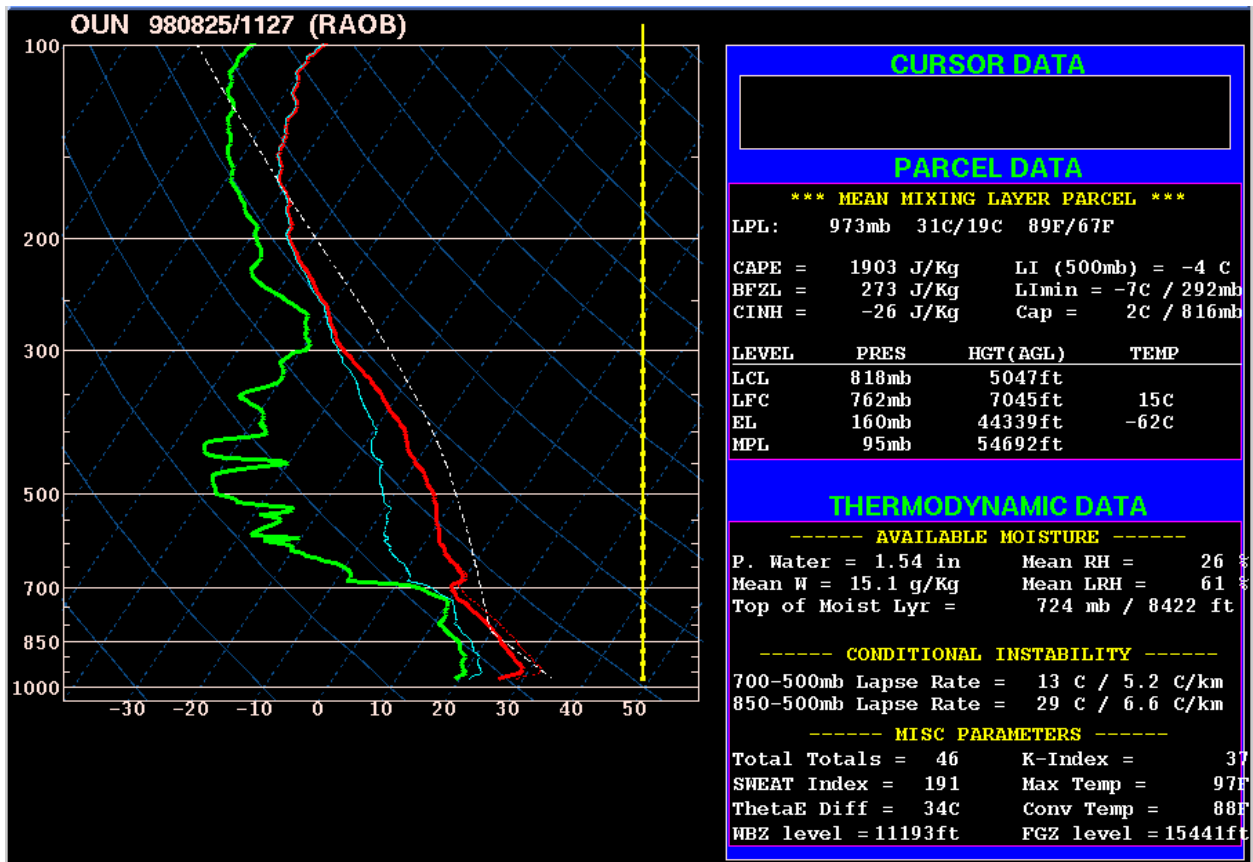


Figure 3. Offset-adjusted sounding and its statistics.

Figures 7 - 9 show the effects of the adjustment methods on the three methods for computing CAPE. For the surface-based CAPE (Figure 7), all adjusted values showed a marked increase in CAPE. The offset and slope adjustments, both constrained by the MWR PWV, showed the largest adjustments, while the Raman Lidar-based and Vaisala-scaled adjustments showed less modification. Mixed layer-based CAPE values (Figure 8) showed better agreement between the offset, slope and Raman Lidar adjustments as compared to the surface based results. This is in part due to the fact that the lower levels of the Raman Lidar estimates are derived from other surface observations systems at the CF. Use of the mixed layer CAPE allows for the Raman Lidar-based estimate to be mainly calculated from Raman Lidar data. The most-unstable parcel CAPE estimates (Figure 9) showed results similar to the other findings. Generally, the CAPE values are significantly larger (or less stable) after adjustment regardless of the CAPE method used.

Conclusions

While the adjustments used in this study tended to produce more unstable convective indices, there was still a good bit of variance between the adjustments methods. The best comparisons were found between the offset, slope and Raman Lidar adjustments for the mixed layer CAPE. The most-unstable CAPE showed the largest variance between methods. Choice of adjustment method may depend on the intended data application. Algorithms dependent on mixed layer averaged moisture estimates are

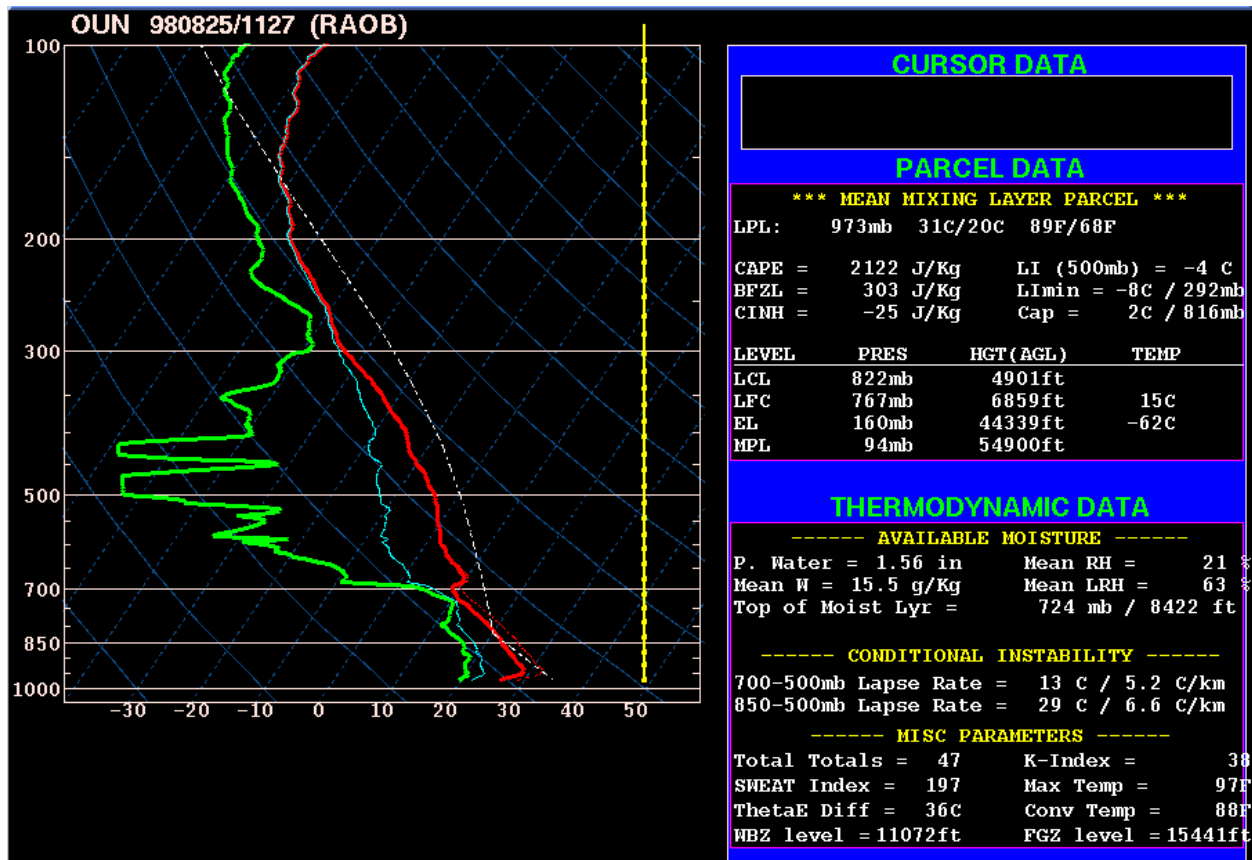


Figure 4. Slope-adjusted sounding and its statistics.

probably equally suited by the offset, slope, or Raman Lidar adjustments, while the Vaisala-scaled adjustment still appears too dry. Algorithms more sensitive to a particular level (as shown by surface-based and most-unstable CAPE) may show a greater spread depending on the adjustment method chosen. Preliminary results for May 1998 (not shown here) suggest that the Vaisala-scaled CAPE values show higher variability than CAPE values computed from the other approaches.

Acknowledgements

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References

Blanchard, D. O., 1998: Assessing the vertical distribution of convective available potential energy. *Weather and Forecasting*, **13**, 870-877.

Clough S. A., P. D. Brown, J. C. Liljegren, T. R. Shippert, D. D. Turner, R. O. Knuteson, H. E. Revercomb, and W. L. Smith, 1996: Implications for atmospheric state specification from the AERI/LBLRTM quality measurement experiment and the MWR/LBLRTM quality measurement experiment. In *Proceedings of the Sixth Atmospheric Radiation Measurement (ARM) Science Team Meeting*. U.S. Department of Energy, Washington, D.C. Available URL: http://www.arm.gov/docs/documents/technical/conf_9603/clough_96.pdf

Lesht, B. M., 1999: Reanalysis of radiosonde data from the 1996 and 1997 water vapor intensive operation periods: Application of the Vaisala RS-80H contamination correction algorithm to dual-sonde soundings. . In *Proceedings of the Ninth Atmospheric Radiation Measurement (ARM) Science Team Meeting*, U.S. Department of Energy, Washington, D.C. Available URL: http://www.arm.gov/docs/documents/technical/conf_9903/lesht-99.pdf

Miller, E. R., J. Wang, and H. L. Cole, 1999: Correction for dry bias in Vaisala radiosonde RH data. . In *Proceedings of the Ninth Atmospheric Radiation Measurement (ARM) Science Team Meeting*, U.S. Department of Energy, Washington, D.C. Available URL: http://www.arm.gov/docs/documents/technical/conf_9903/miller-er-99.pdf

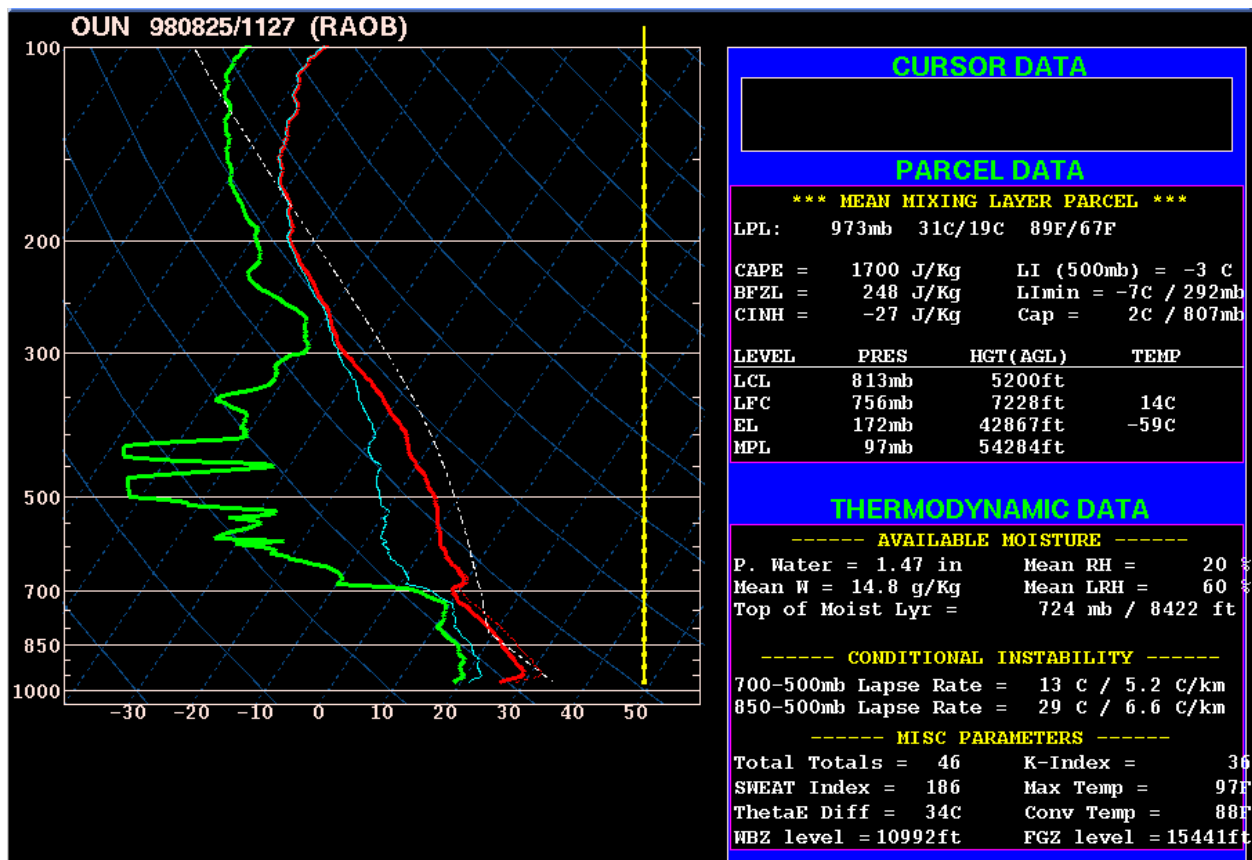


Figure 5. Vaisala-scaled sounding and its statistics.

Peppler, R. A., 1988: A Review of Static Stability Indices and Related Thermodynamic Parameters. Illinois State Water Survey Misc. Publ. 104, 87 pp.

Turner, D. D., T. R. Shippert, P. D. Brown, S. A. Clough, R. O. Knuteson, H. E. Revercomb, and W. L. Smith, 1998: Long-term analyses of observed and line-by-line calculations of longwave surface spectral radiance and the effect of scaling the water vapor profile. In *Proceedings of the Eighth Atmospheric Radiation Measurement (ARM) Science Team Meeting*, DOE/ER-0738, pp. 773-776. U.S. Department of Energy, Washington, D.C. Available URL: http://www.arm.gov/docs/documents/technical/conf_9803/turner-98.pdf

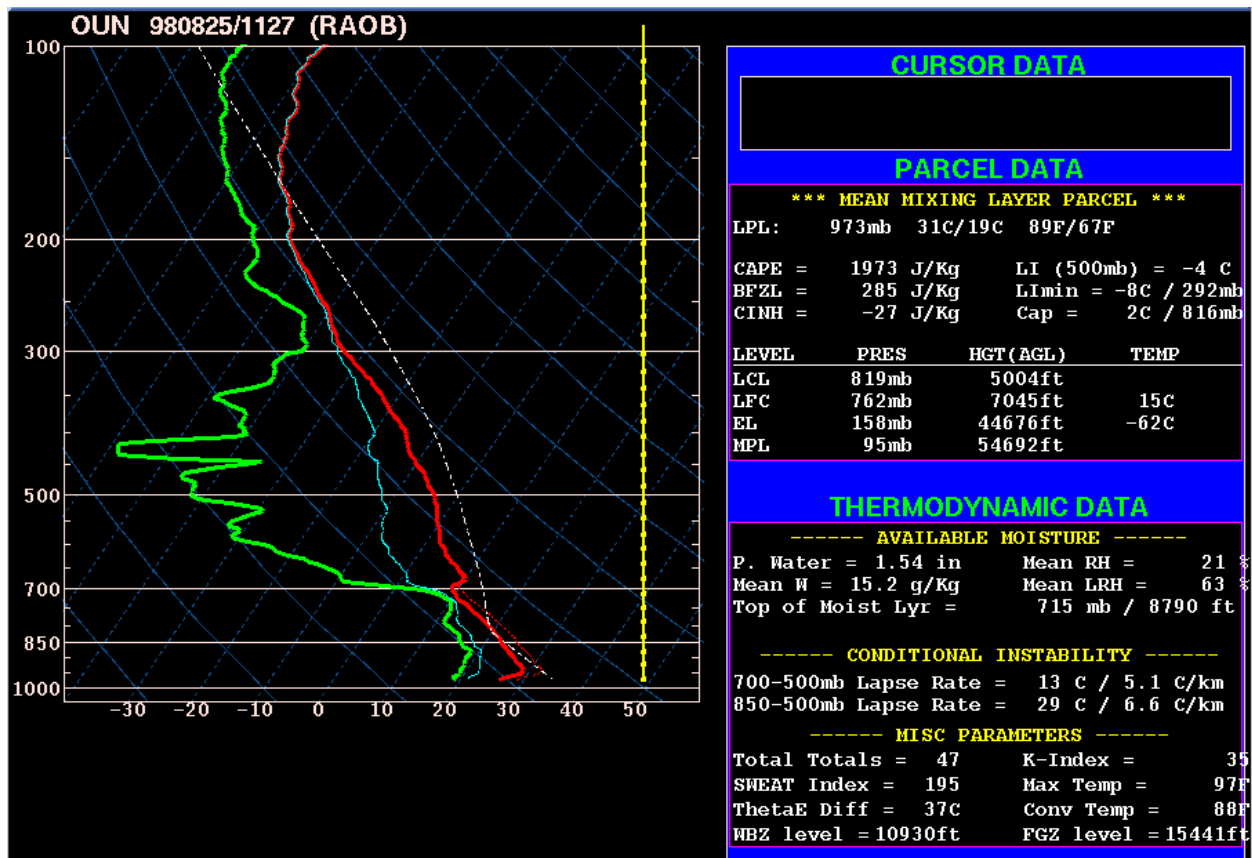


Figure 6. Raman Lidar/BBSS adjusted sounding and its statistics.

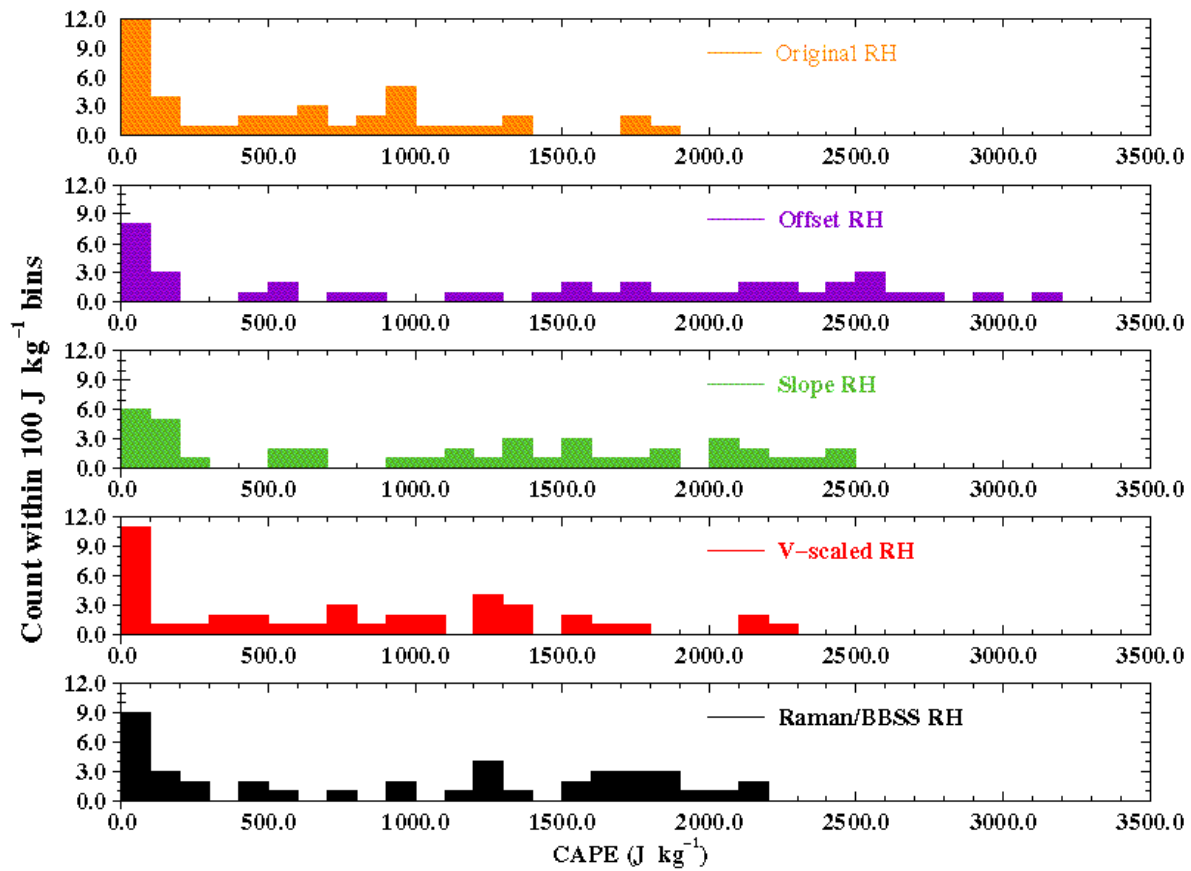


Figure 7. RH adjustment CAPE comparisons during August/September 1998 for surface-based CAPE.

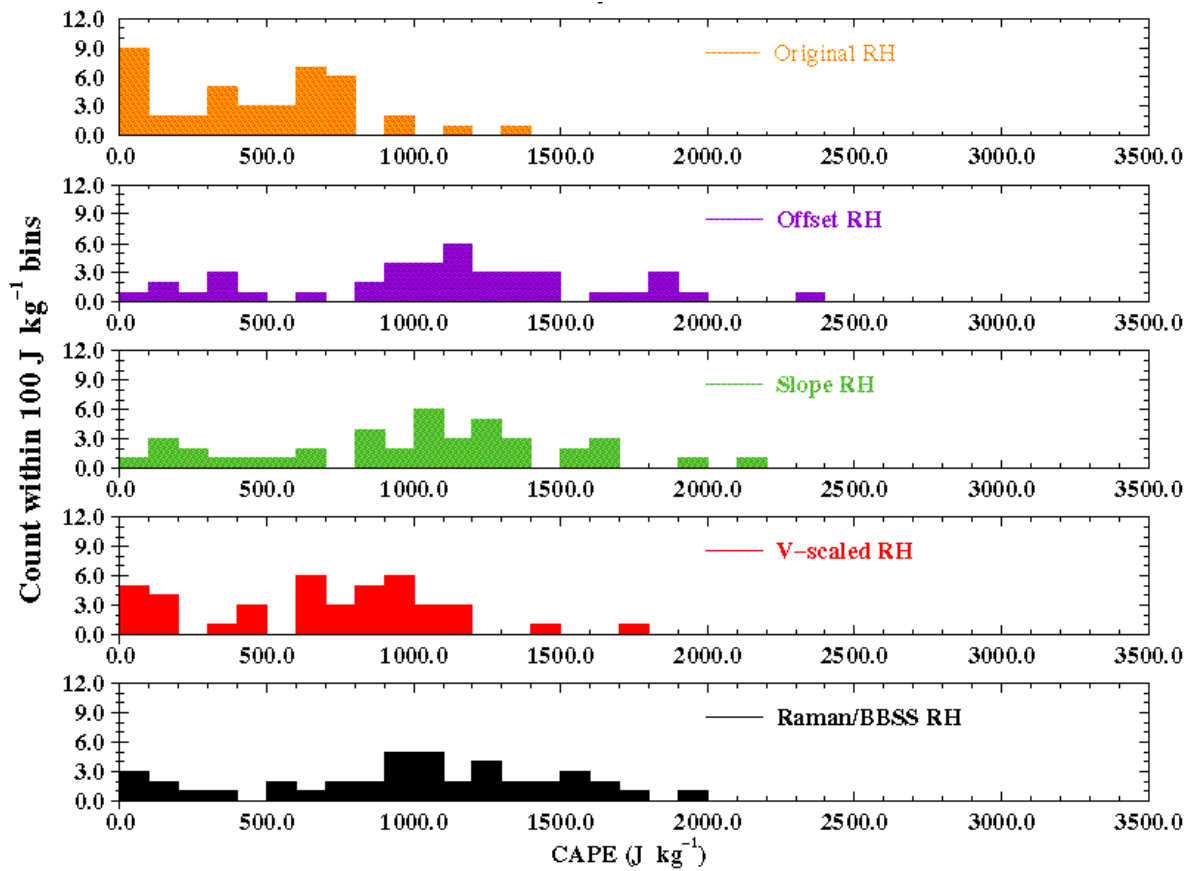


Figure 8. RH adjustment CAPE comparisons during August/September 1998 for mixed layer-based CAPE.

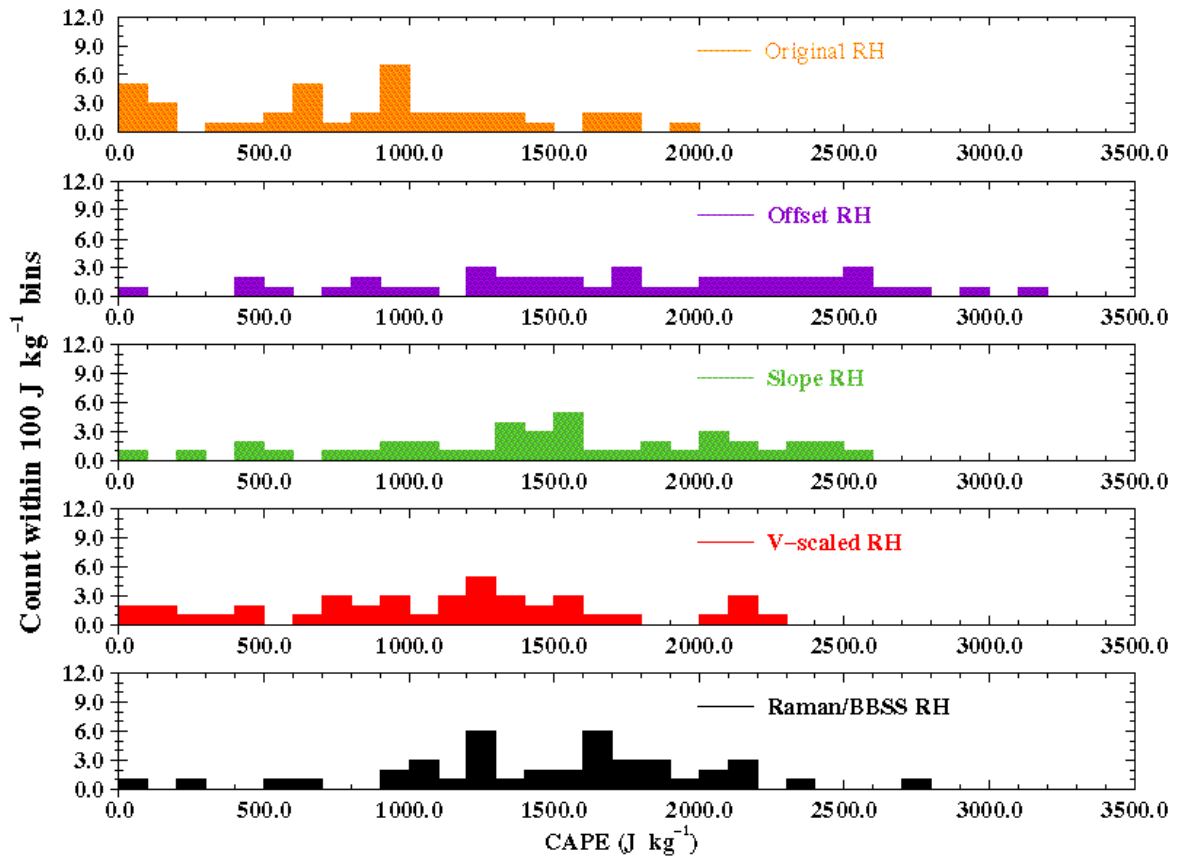


Figure 9. RH adjustment CAPE comparisons during August/September 1998 for most-unstable CAPE.