Remote Cloud Sensing Intensive Observation Period (RCS-IOP) Millimeter-Wave Radar Calibration and Data Intercomparison

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Introduction

During April 1994, the University of Massachusetts (UMass) and the Pennsylvania State University (Penn State) fielded two millimeter-wave atmospheric radars in the Atmospheric Radiation Measurement Remote Cloud Sensing Intensive Operation Period (RCS-IOP) experiment. The UMass Cloud Profiling Radar System (CPRS) operates simultaneously at 33.12 GHz and 94.92 GHz through a single antenna (Sekelsky and McIntosh 1995). The Penn State radar operates at 93.95 GHz and has separate transmitting and receiving antennas (Clothiaux et al. 1995). The two systems were separated by approximately 75 meters and simultaneously observed a variety of cloud types at vertical incidence over the course of the experiment.

This abstract presents some initial results from our calibration efforts. An absolute calibration of the UMass radar was made from radar measurements of a trihedral corner reflector, which has a known radar cross-section. A relative calibration of between the Penn State and UMass radars is made from the statistical comparison of zenith pointing measurements of low altitude liquid clouds. Attenuation is removed with the aid of radiosonde data, and the difference in the calibration between the UMass and Penn State radars is determined by comparing the ratio of 94-GHz and 95-GHz reflectivity values to a model that accounts for parallax effects of the two antennas used in the Penn State system.

Analysis of Cloud Data

Figure 1 shows images of reflectivity values collected on April 11, 1994. Averaging time is 8 seconds, and range gates are spaced 75 meters apart. These data are unique in that the cloud was composed of small water droplets and because temperature and radar depolarization measurements suggest that no insects were present in the cloud volume sampled. Scattering from insects can generate significant biases in measurements at different frequencies and, possibly, in measurements at the same frequency in different locations if the effect cannot be statistically removed by averaging. Uncorrected reflectivity values averaged from 1900 GMT to 1946 GMT are plotted in Figure 2. Although the 33-GHz and 95-GHz data are very similar, difference in extinction rates though the cloud cause the 33-GHz and 95-GHz dBZe curves to diverge. CART radiosonde data and 33-GHz reflectivity measurements are used to correct for extinction by water vapor, oxygen, and liquid cloud droplets.

A substantial difference between UMass and Penn State estimates of reflectivity is seen at the lowest range gate and decreases with height. The large differences in reflectivity values can be accounted for by modeling a well-known parallax effect in bistatic radars (Ulaby et al. 1982) for various offsets in pointing angle between the two antennas. A numerical simulation was performed to determine sample volume overlap for the transmitting and receiving antennas of the 94-GHz radar as a

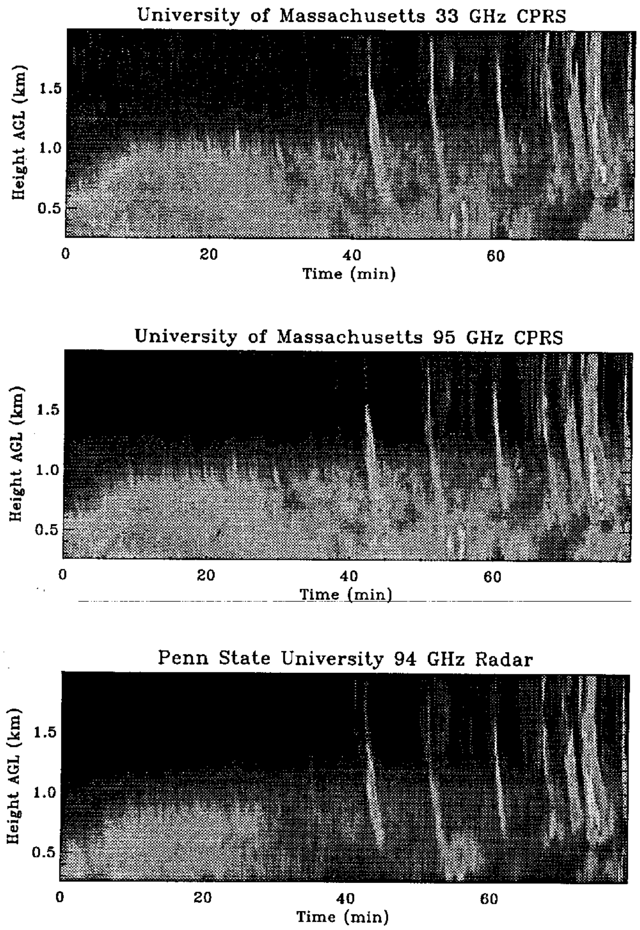

Figure 1. Liquid water cloud measurements collected with (a) CPRS 33-GHz radar, (b) CPRS 95-GHz radar, and (c) Penn State 94-GHz radar.

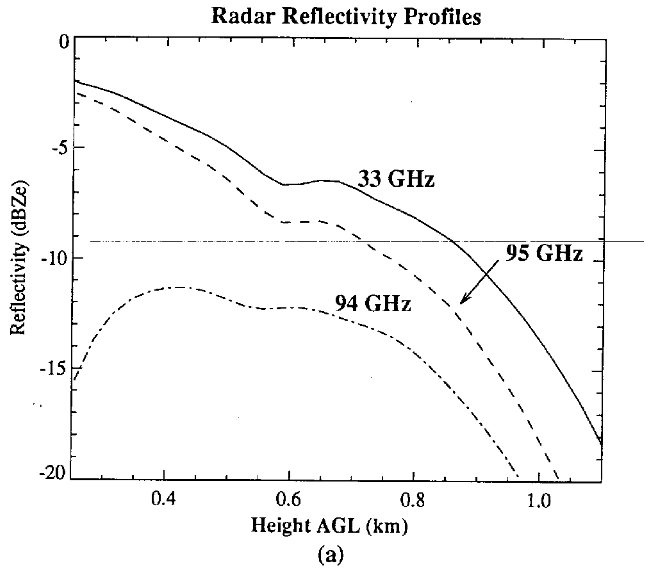

Figure 2. Vertical profiles of reflectivity averaged between 1900 and 1946 GMT without attenuation correction.

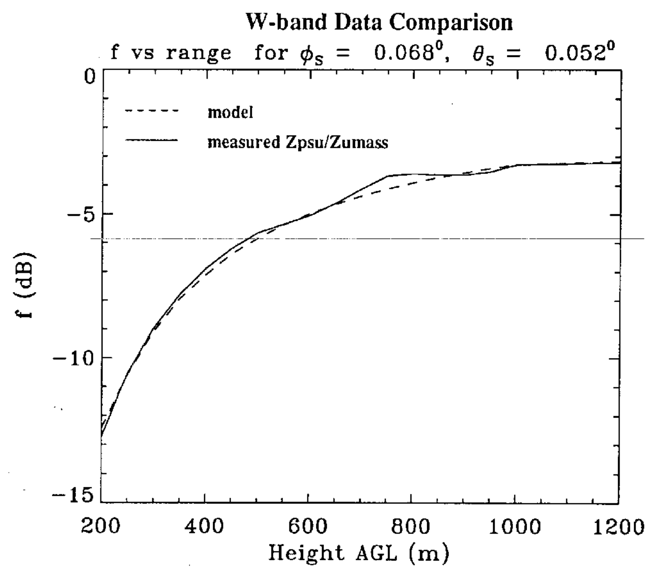

Figure 3. Ratio of non-parallel-pointing dual-antenna reflectivity values versus range to that for single antenna.

function of range and offset of one antenna from the boresight direction of the other. Figure 3 compares model data with measured ratios of $Z_{94.92}/Z_{93.95}$ (averaged over 46 minutes). A least mean square fit of the measured data to simulations was performed for 0.001° angular increments. Results indicate angular offsets of 0.052° and 0.068° in the pointing directions of the two antennas. A mean difference between the UMass and Penn State calibrations of 0.98 dB was determined from the mean offset of the $Z_{94.92}/Z_{93.95}$ curve from the simulated curve. Thus, the actual difference in calibration between the Penn State and UMass radars is -0.98 dB for this dataset after attenuation and parallax errors are removed.

Summary of Liquid Cloud Measurements

Figures 4 and 5 summarize liquid cloud reflectivity measurements from the UMass and Penn State radars in the form of histograms. Figure 4 shows obvious differences in the positions of the peak and in the range of values spanned in the raw reflectivity measurements. Figure 5 plots the same data with much better agreement after corrections for attenuation are applied to each measurement set and after correcting the Penn State measurements for parallax. The analysis illustrates some important issues involved in comparing measurements collected with different sensors.

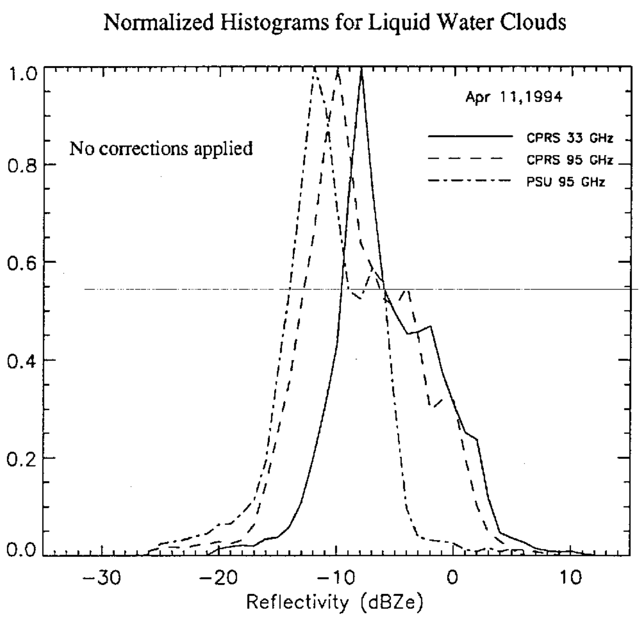

Figure 4. Uncorrected histograms of liquid water cloud measurements. Bin size is 1 dB.

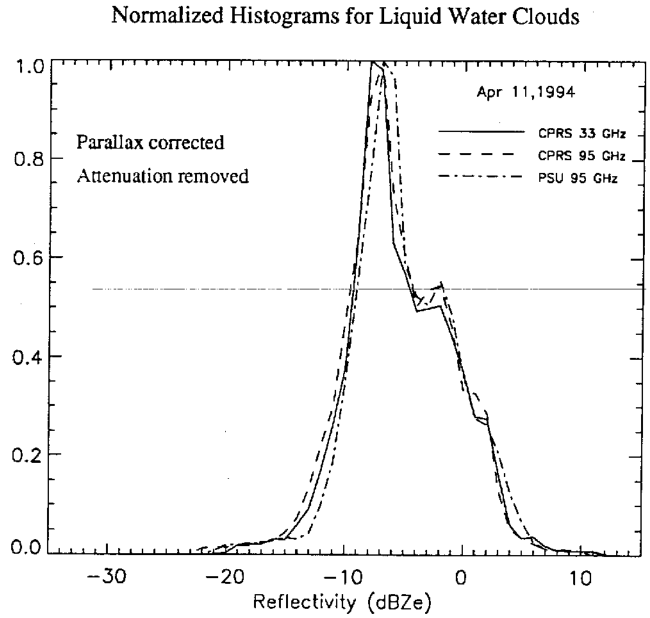

Figure 5. Histograms of liquid water cloud measurements after correction for attenuation and parallax. Bin size is 1 dB.

References

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