Sample Observations from the 2001 Multi-Frequency Radar IOP

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Introduction

The 2001 Multi-Frequency Radar Intensive Operational Period (IOP) was designed to collect a long dataset of W-band (95 GHz), Ka-band (35 GHz), and S-band (2.8 GHz) vertical profiling observations to investigate insect scattering and precipitating particle scattering above the Southern Great Plains (SGP) Cloud and Radiation Testbed (CART) site. The 95 and 2.8 GHz vertically pointing radars were placed next to the permanently installed 35 GHz Millimeter Wave Cloud Radar (MMCR) at the SGP Central Facility from mid-May 2001 through mid-January 2002. The University of Massachusetts at Amherst Microwave Remote Sensing Laboratory deployed the guest 95 GHz system and the National Oceanic and Atmospheric Administration (NOAA) Aeronomy Laboratory deployed the guest 2.8 GHz system.

During this 8-month campaign, several different cloud types were observed simultaneously by all three radars as well as several insect events. The contribution by A. Khandwalla, N. Majurec, and S. M. Sekelsky, "Characterization of radar boundary layer data collected during the Multi-Frequency Radar IOP," and presented at this Atmospheric Radiation Measurement [ARM] meeting, discusses insect/cloud particle discrimination using the reflectivity ratios between the 95 and 35 GHz observations. This contribution illustrates the sensitivity of each radar to the different sized particles present during the lifecycle of one convective cloud event passing over the observation site.

Attenuation is an Asset

One reason to operate profiling radars at these three different wavelengths is to exploit the attenuation effects of transmitting small wavelength signals through distributed media. The 10-cm wavelength S-band system is long relative to the size of the rain and ice particles resulting in Rayleigh scattering without any attenuation of the signal. The 8.6-mm wavelength Ka-band system is short relative to the rain and ice particles resulting in attenuation of the signal dependent on the particle size, density, and concentration. The very short wavelength 3-mm W-band system is very sensitive to the properties of the transmission media, both the particles in the resolution volume and the water vapor between the instrument and the cloud. Typically, attenuation of the signal through the media is considered a liability because the true reflectivity cannot be estimated from a single attenuated signal. But, since the attenuation through the cloud is dependent on the particle density and particle size distribution, the difference in total attenuation between 35 and 95 GHz observations provides an estimate of the particle size distribution. Also, the total concentration of the particle size distribution is estimated from the unattenuated 2.8 GHz observations. Thus, the attenuation at the 35 and 95 GHz operating frequencies converts from a liability to an asset.

Anvil Cloud Produced by Convective Uplift

On September 7 and 8, 2001, a convective rain event passed over the SGP CART site and is shown in Figure 1 as time-altitude cross sections of reflectivity from the three radar systems. While there was over an hour of precipitation detected at the surface, this convective event produced an anvil cloud that was detected directly overhead for over 8 hours. This ratio of 1 hour of surface rain to 8 hours of anvil cloud was typical of the convective uplift events observed during this 8-month IOP at the SGP CART site. While this 1:8 time ratio of convective uplift to anvil shield represents the ratio of cloud types over a single point, the area ratio will be different as the anvil cloud spreads over a larger area than the area producing the moisture uplift. The convective uplift to anvil cloud area ratio can only be determined from scanning radar or satellite observations, which is beyond the scope of this work.

The 2.8 GHz reflectivity is shown in the top panel of Figure 1. The convective uplifting core is indicated by the large reflectivities extending from the surface to 14 km near 22:30 Universal Time Coordinates (UTC). The pseudo-color scale has been set to focus on the reflectivities in the anvil cloud and do not represent the reflectivities exceeding 25 dBZ. The 35 GHz and 95 GHz reflectivities are shown in the middle and bottom panels of Figure 1. The 35 GHz reflectivities were extracted from the Active Remote Sensing Cloud Layer product. These two radar systems corroborate the convective rain core by the *lack* of any reflectivity estimated above 3 to 4 km due to the attenuation at these operating frequencies. The attenuation of these signals is an attribute that will be used to estimate the raindrop size distribution during rain events.

After about 23:30 UTC on September 7, all three profiling radars observe the anvil cloud produced by the convective uplift. The thickness of the anvil starts at about 8 km thick and decreases to about 4 km before dissipating or advecting away from the profiler site. The reflectivity patterns resolved by all three profilers are similar for this anvil cloud.

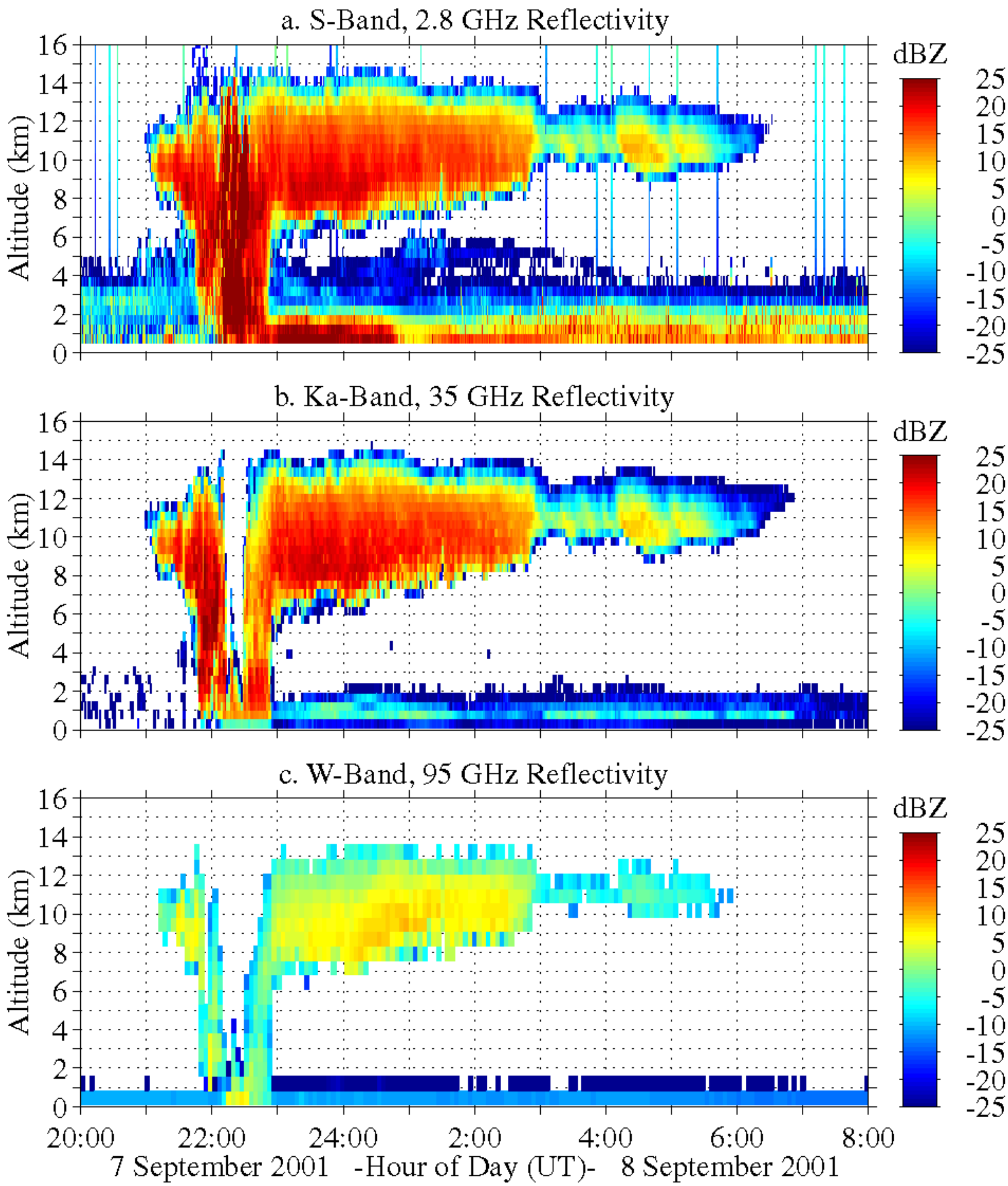

Figure 1. Time-altitude cross section of observed reflectivity beginning at 20:00 UTC on September 7, 2001, and ending at 08:00 UTC on September 8, 2001, (a) 2.8 GHz profiler, (b) 35 GHz MMCR, and (c) 95 GHz radar.

Vertical Profiles of Reflectivity

Figure 2 shows two vertical profiles of reflectivity observed by all three radars. The panel on the left is during the convective uplift and shows the attenuation of the 35 and 95 GHz radar systems. The 2.8 GHz profiler reflectivity is shown in both the 495- and 60-m pulse length modes due to the saturation of the 495-m mode close to the surface (the 60-m mode is designed for precipitation research and the 495-m mode is designed for cloud research). The panel on the right shows the vertical profiles of reflectivity during the anvil cloud. The 35 and 2.8 GHz reflectivities agree in the anvil cloud as the attenuation of the 35 GHz observations through ice is on the order of 0.1 dBZ/km. The 95 GHz reflectivity shows the same vertical pattern as the other two systems, but is decreased by about 8 dBZ due to the larger sensitivity to attenuation at this smaller operating wavelength.

Concluding Comments

The purpose of this presentation was to present examples of the observations collected during the 2001 Multi-Frequency Radar IOP conducted from mid-May 2001, through mid-January 2002, at the SGP site. The two guest radars operating at 95 and 2.8 GHz and the permanently installed 35 GHz MMCR simultaneously observed several cloud events during this 8-month campaign. The difference in attenuation signatures

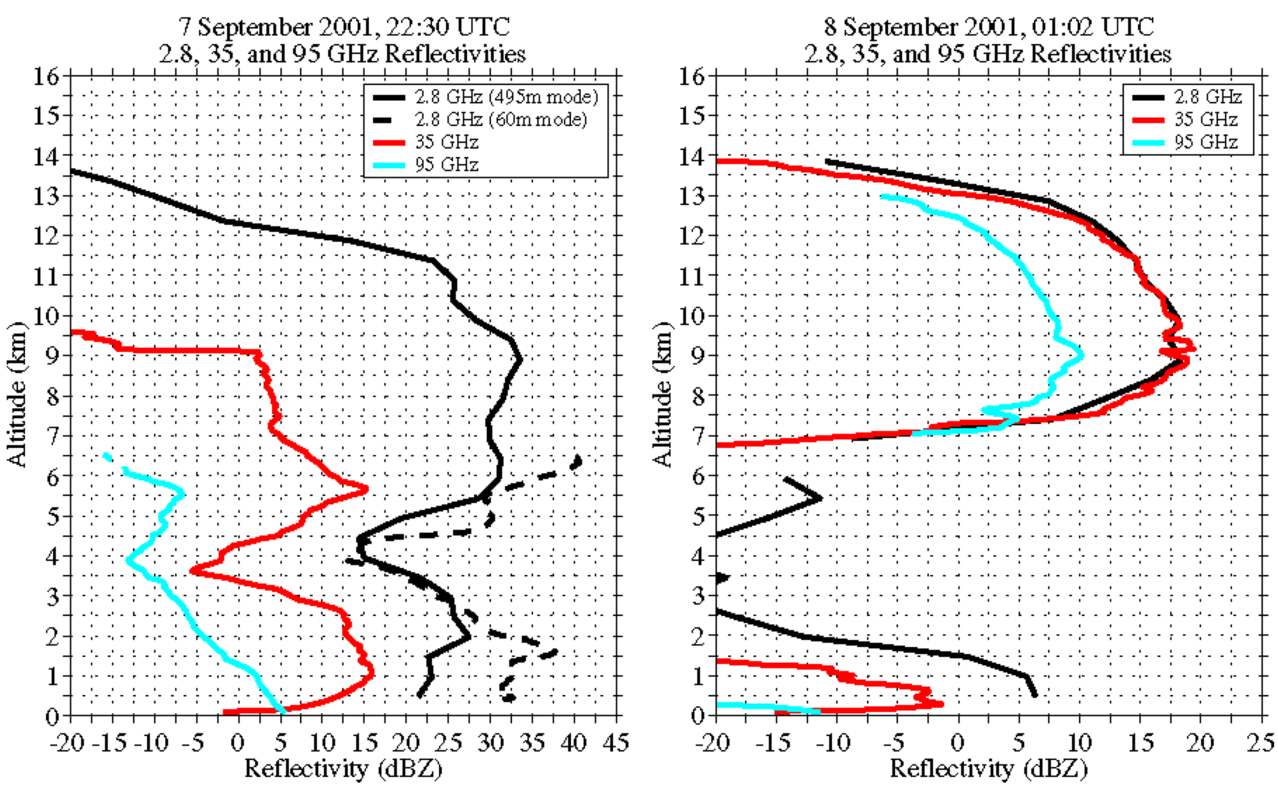

Figure 2. Vertical profile of reflectivity observed by the 2.8 GHz profiler (black), 35 GHz MMCR (red), and 95 GHz radar (blue). (Left panel) Reflectivity profile at 22:30 UTC on September 7, 2001. (Right panel) Reflectivity profile at 01:02 UTC on September 8, 2001.

through the clouds due to the different operating frequencies will enable the particle size distributions to be estimated. And the unattenuated reflectivity from the 2.8 GHz system will enable the total number concentration to be estimated as well.

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