Theory and Observations Between Ka-Band and W-Band to Explain Scattering Differences from Insects

A. Khandwalla
Harvard University
Cambridge, Massachusetts

S. M. Sekelsky, L. Li, and M. Bergada
Microwave Remote Sensing Laboratory
University of Massachusetts
Amherst, Massachusetts

Introduction

Ground based Ka-band (33 GHz) cloud radar measurements collected at the Southern Great Plains (SGP) Cloud and Radiation Testbed (CART) site show that liquid cloud measurements are often contaminated by insect echoes during warm weather. Depolarization is one method of identifying and filtering insects from radar data. However, this technique often fails because the high number density of insects in the lower atmosphere overwhelm and mask the weaker cloud echos. It is impossible to tell whether clouds are present or not in such circumstances. Comparisons of measurements from Ka-band and W-band (95 GHz) radars with approximately equal sensitivity to clouds show that W-band is significantly less sensitive to insects.

Until now, only qualitative comparisons have been made between Ka-band and W-band insect scattering data. This abstract presents a simplified model of insect scattering differences based on Mie theory that explains the observed differences in sensitivity to insects. These results are corroborated with observations made during the 2000 Cloud Intensive Operational Period (IOP), where simultaneous Ka-band and W-band observations of clouds and insects were collected with the University of Massachusetts, Cloud Profiling Radar System (CPRS). CPRS operates simultaneously at 33.12 GHz and 94.92 GHz through a single antenna.

Theory

Figures 1 and 2 plot a theoretical model showing 33 GHz and 95 GHz back-scattering, and radar reflectivity differences for insects. Figure 2 plots the dual wavelength ratio (DWR), which is a measure of reflectivity differences at 33 GHz and 95 GHz. DWR is defined as:

$$\mathrm{DWR} = 10\log\,(Z_{Ka}/Z_{W})$$

The insect DWR model is derived from a Mie model, shown in the following section, of backscatter from water spheres There is excellent agreement between theory and measurements despite the fact that

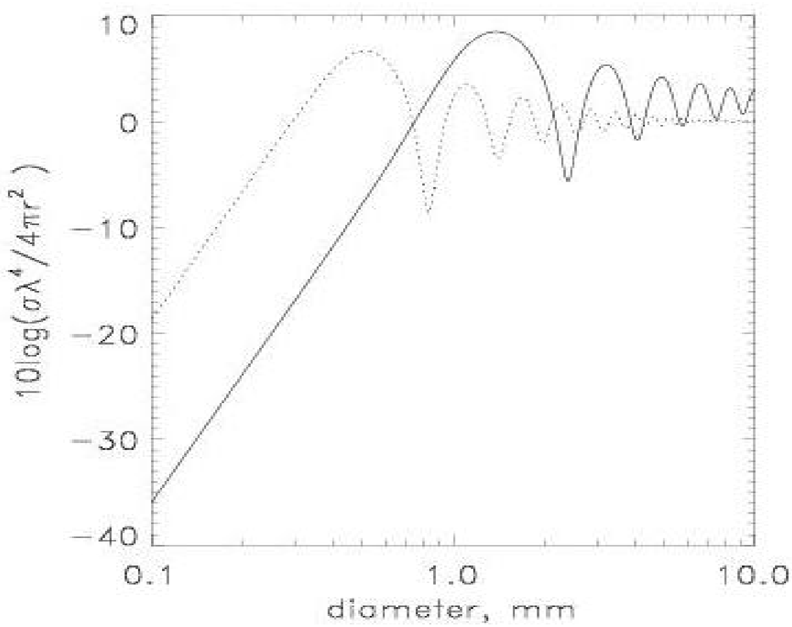

Figure 1. Mie scattering from spheres.

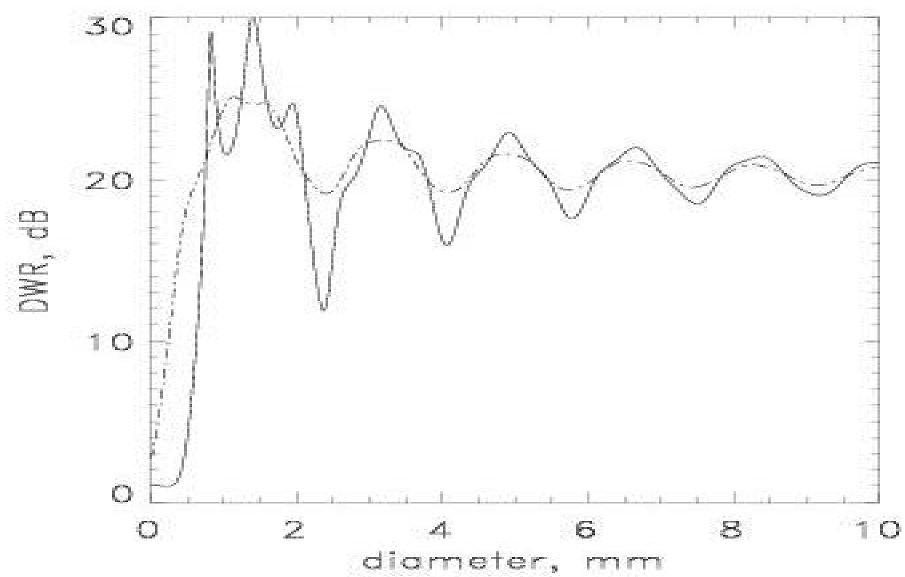

Figure 2. DWR model of insects.

insects are not spherical and despite the fact that the insect dielectric constant is variable. Although insect orientation and shape vary with time (wings beating, etc.), it is assumed that the average shape projected is that of a sphere. Furthermore, while reflectivity is a function of dielectric constant, previous studies have shown that the ratio of 33 GHz and 95 GHz reflectivity is insensitive to dielectric constants. Thus, the model in Figure 2 predicts that frequency normalized backscatter from a distribution of insects will be 20 - 25 dB higher at Ka-band than at W-band.

Observations

The case study presented here quantifies the reflectivity distribution of insect echos at both radar bands. Figures 3 and 4 plot 33 GHz and 95 GHz reflectivity data at the SGP CART site March 12, 2000. Comparison of these figures show that the W-band response to insects is consistently lower than that at Ka-band. The lower portion of the images show the insect signal while a cloud is present at higher altitudes. Here there is a clear separation between cloud and insect targets.

Comparison of cloud data shows that the sensitivity of each radar band to clouds is nearly identical. In contrast, comparison of the insect data shows that

- fewer insects are detected at W-band.
- the magnitude of the W-band reflectivity for insects is approximately 2 orders of magnitude (20 dB) lower than that at Ka-band.

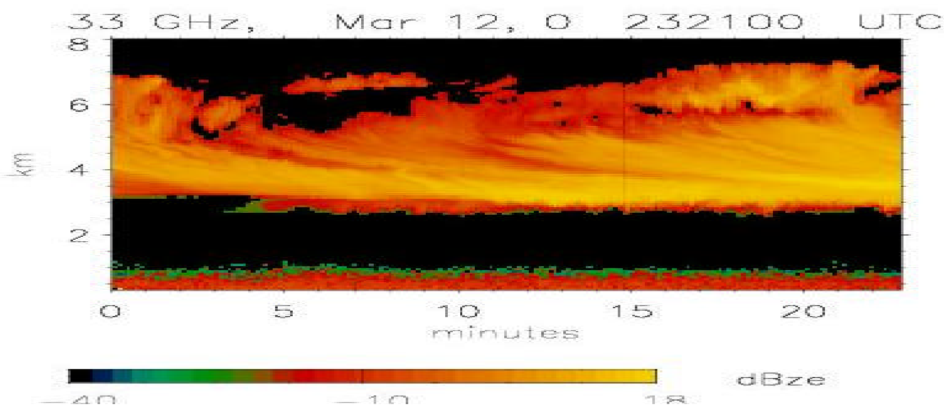

Figure 3. Ka-band reflectivity measurement.

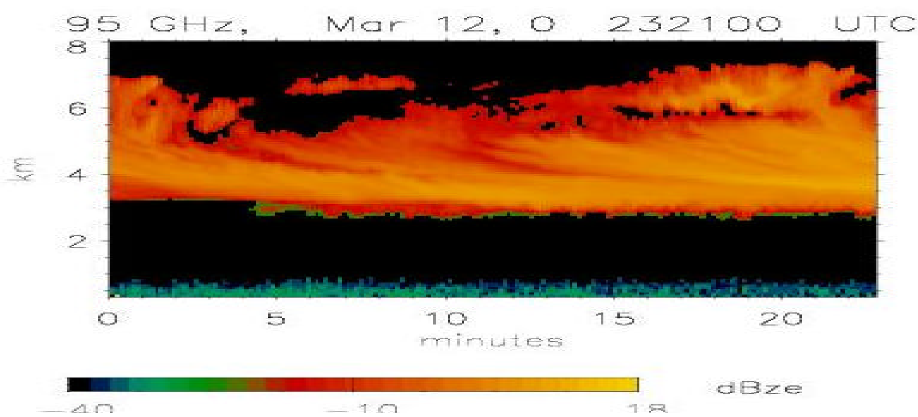

Figure 4. W-band reflectivity measurements.

Three-dimensional histograms plotted in Figures 5 and 6 show the distribution of radar reflectivity versus height. 33 GHz data plotted in Figure 5, show similar cloud reflectivity values, which decreases in intensity and occurrence with height at about the surface. However, the reflectivity values and the number of occurrences of insects are both dramatically lower at 95 GHz.

DWR has been used to estimate particle size in precipitation and in ice clouds from non-Rayleigh scattering. It has also been used to estimate liquid water content in stratus clouds. Both the model plotted in Figure 2 and data presented below show a narrow range of DWR for insects. Figure 8 shows that DWR is constrained between 18 dB and 25 dB, which agrees with Figure 2 for insects with dimensions larger than 0.5mm. Although, only one case study is presented here, the 18 dB - 25 dB range is quite consistent. A previous example of insect measurements published (Sekelsky and McIntosh 1996) shows the same range of values of DWR for insects.

Reflectivity Histograms

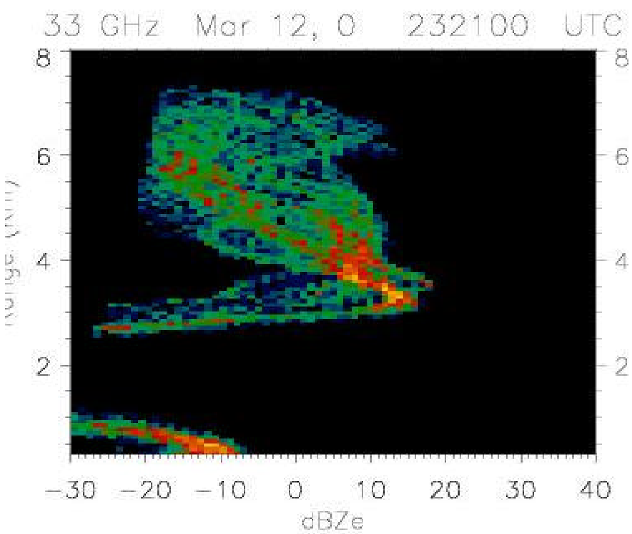

Figure 5. Ka-band (33 Ghz).

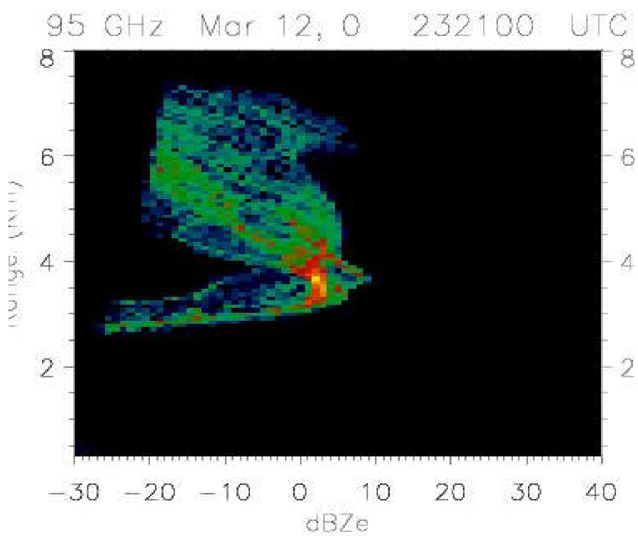

Figure 6. W-band(95 Ghz).

Conclusion

W-band is significantly less sensitive to insects than Ka-band. This is consistent in the measurements and can be explained by Mie theory. The consistency of these values and the ability of W-band to discriminate between clouds and insects on an operational basis will be demonstrated in a 2001 field campaign at the SGP CART site.

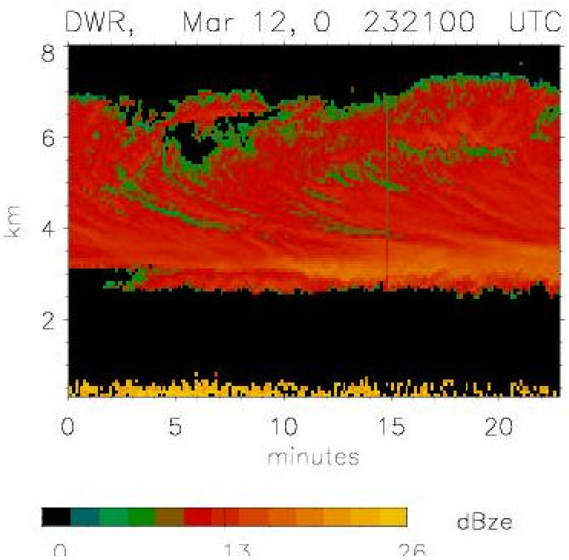

Figure 7. DWR.

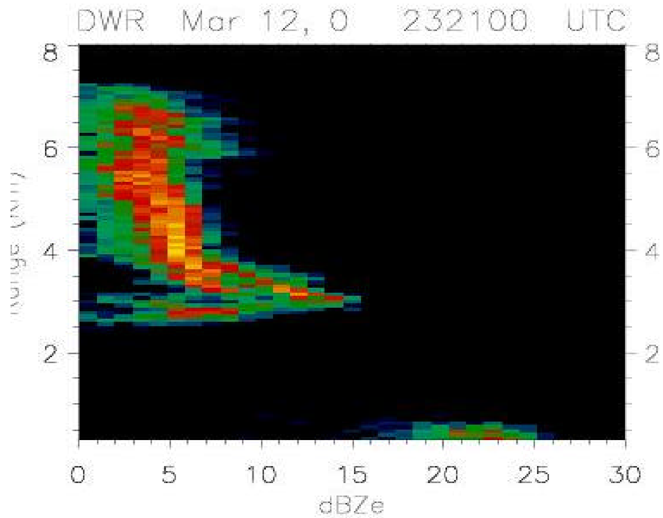

Figure 8. Histogram.

Corresponding Author

S. M. Sekelsky, sekelsky@ecs.umass.edu, (413) 545-4217

Reference

Sekelsky, S. M., and McIntosh, R. E, 1996: Cloud Observations with a Polarimetric 33 GHz and 95 GHz radar. *Meteorol. and Atmos. Phys.*, **58**, 123-140.

Bibliography

Mie, G, 1908: Betirage zur optik Truber Medien, spexiell Killoidaler Metalasungen. *Ann.Physik*, **25**.

Sekelsky, S., J. Firda, R. McIntosh, E. Clothiaux, G. Mace, and T. Ackerman, 1995: RCS-IOP millimeter-wave radar calibration and data intercomparison. In *Proceeedings of the Fifth Atmospheric Radiation Measurement (ARM) Science Team Meeting*. San Diego, California.

Ulaby, F., R. Moore, and A. Fung, 1982: *Microwave Remote Sensing; Active and Passive*, v.1, Artech House.