Characterization of Radar Boundary Layer Data Collected During the 2001 Multi-Frequency Radar IOP

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Introduction

Ground-based radar measurements of insect clutter at Ka-band (35 GHz) and W-band (95 GHz) were collected over an extended period during the 2001 multi-frequency radar (MFR) intensive operational period (IOP). Previous research has indicated that Ka-band radar measurements of liquid clouds are often contaminated by insect clutter but that W-band measurements are less affected by insect clutter. The contrast between cloud and insect echos is two orders of magnitude (20 dB) higher at 95 GHz than at 35 GHz, which is the frequency of the Southern Great Plains (SGP) Cloud and Radiation Testbed (CART) site millimeter wave cloud radar (MMCR) (Khandwalla 2001). These initial findings based on previous IOP data indicate that it is significantly easier to distinguish between cloud and insect echoes at 95 GHz.

The abstract presents results derived from measurements collected during the 9-month MFR IOP, which began in late April 2001. Insect clutter data collected during cloud-free days is presented to illustrate diurnal variations and characterized verses temperature and wavelength to show seasonal variations.

Radar Observations

Measured Quantities. We characterize insects by looking at two quantities in particular: mean reflectivity and the maximum height of the insect boundary layer (Figure 1). The boundary layer mean reflectivity, dBZ_e is simply the average reflectivity in the boundary layer verses height over a given time interval. Here the time interval used is 30 seconds, which corresponds to the radar averaging time. In our analysis, periods of precipitation are identified and discarded from our analysis. The remaining measurements represent mostly insect echos, although low clouds might be present.

$$\overline{dBZ_e}(t) = 10\log\left[\frac{1}{R_{top}}\int_0^{R_{top}} Z(r,t)dr\right] \tag{1}$$

R_{top} represents the maximum height of the boundary layer, which is determined by the maximum height at which the radars detect an echo. We filter for clouds above 4.5 km and for precipitation which is identified as radar echoes extending from the surface to a height greater than 4.5km. Thus, R_{top} effectively provides a measure of the top of the layer of airborne insects. Insects are present under clear-sky conditions when the temperature is above 10°C.

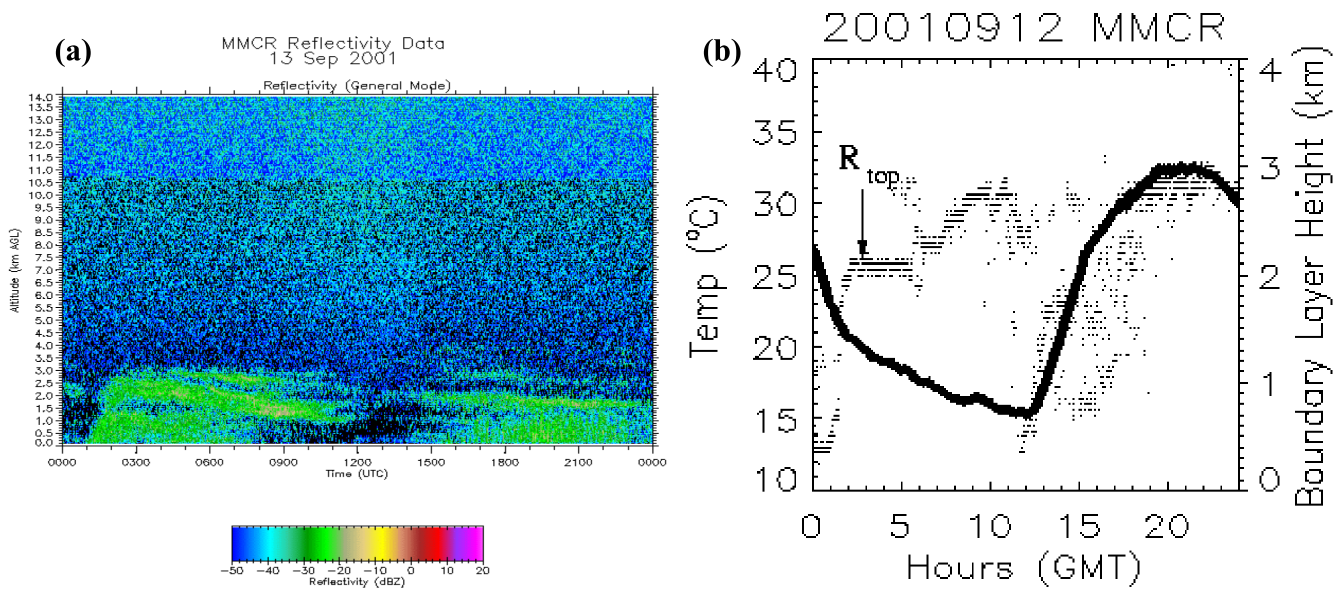

Figure 1. The mean reflectivity (a) and the maximum height (b) of the insect boundary layer.

September 12, 2001, Case Study

We present a case study for September 12, 2001, a clear day with no clouds but with a thick insect boundary layer. Figures 2a and 2b illustrate the relationship between temperature and boundary layer mean reflectivity for 95 GHz and 35 GHz, respectively.

The solid line corresponds to surface temperature while the dotted line refers to mean reflectivity per time bin. Figure 2a shows that at 95 GHz, the almost flat line indicates that the radar is observing mostly noise and few insects. Figure 2b illustrates a strong correlation between mean reflectivity and temperature for 35 GHz. As temperature dips after sunset and reaches a minimum before sunrise, the mean reflectivity values of the insects decreases when the temperature reaches a minimum and increases with increasing temperature during daylight. So nighttime insects seem to recede as daylight approaches and different daytime insects slowly appear.

Figures 3a and 3b show insect boundary layer heights (R_{top}) and temperature for 95 GHz and 35 GHz, respectively. R_{top} at 95 GHz is less than 1 km, while R_{top} at 35 GHz can be as large as 3km.

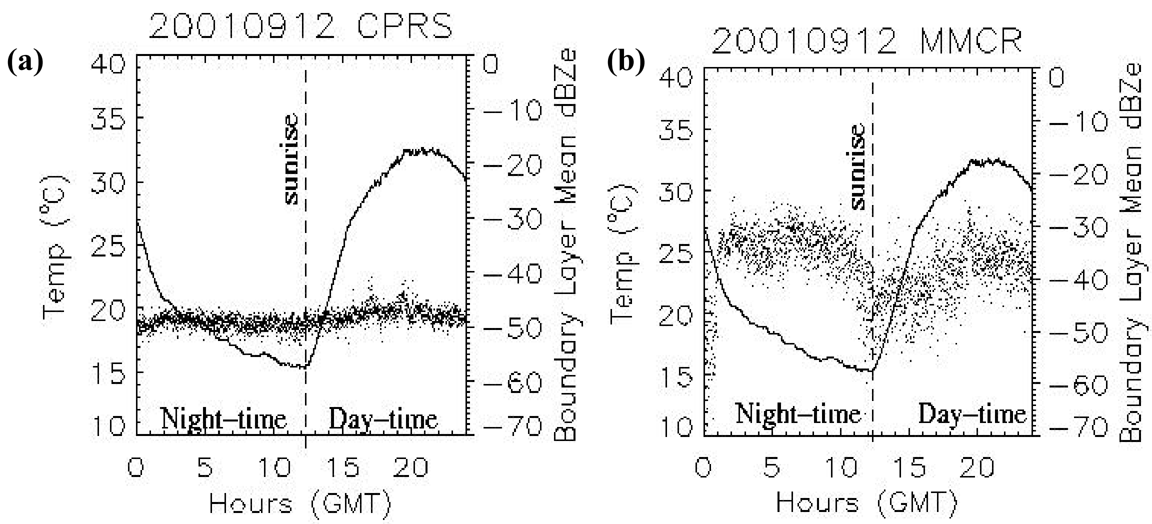

Figure 2. Showing the relationship between temperature and boundary layer mean reflectivity for 95 GHz (a) and 35 GHz (b).

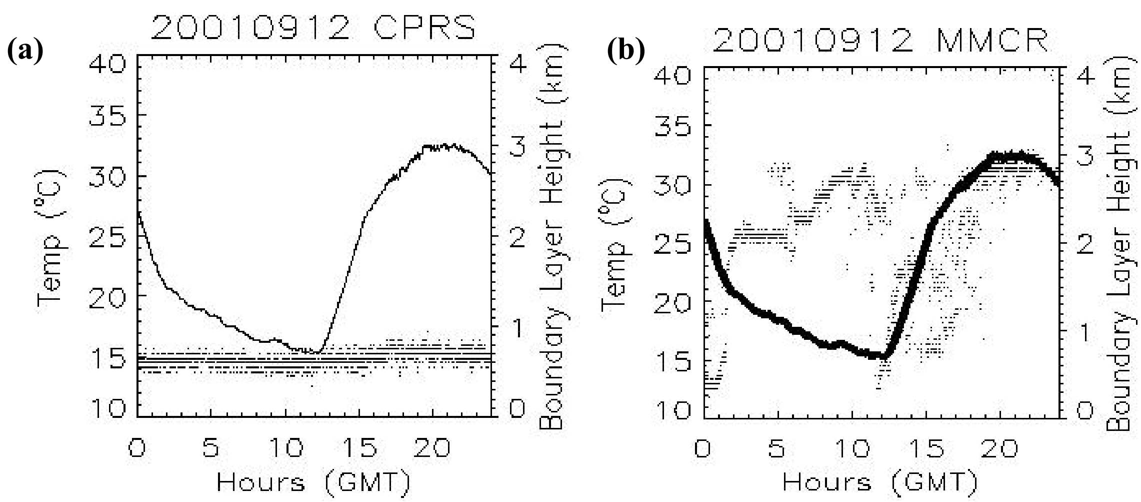

Figure 3. Insect boundary layer heights and temperature for 95 GHz (a) and 35 GHz (b).

Measurement Averages Over Extended Periods

Analysis of measurements collected during the 2001 insect season show that 35-GHz radar measures boundary layer heights and reflectivities are consistently higher than those collected at 95 GHz. Seasonal statistics are calculated versus time and versus temperature using MMCR 35-GHz and UMass 95-GHz radar measurements. Our analysis shows several interesting relationships. Comparisons between Figures 4a, 4b and 5a, 5b reveal that mean boundary layer height and reflectivity measured at 95 GHz are consistently lower than those measured by the 35-GHz radar by a significant amount. Figure 6a illustrates that significant insect echoes exist only when the daily mean surface temperature is above a threshold of approximately 10°C. Further, Figures 6a and 6b show that for the 35-GHz MMCR

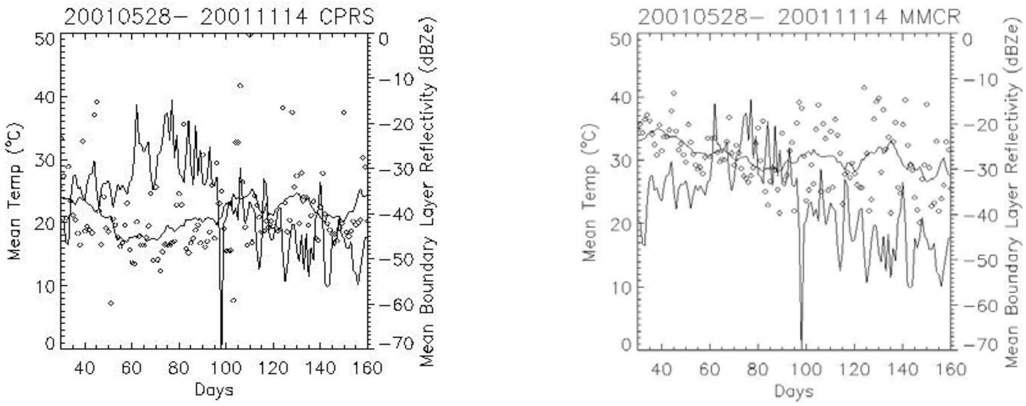

Figure 4.

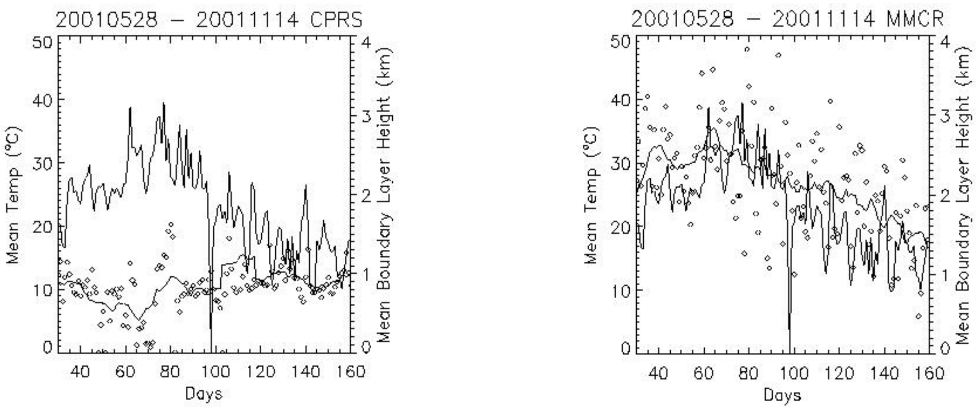

Figure 5.

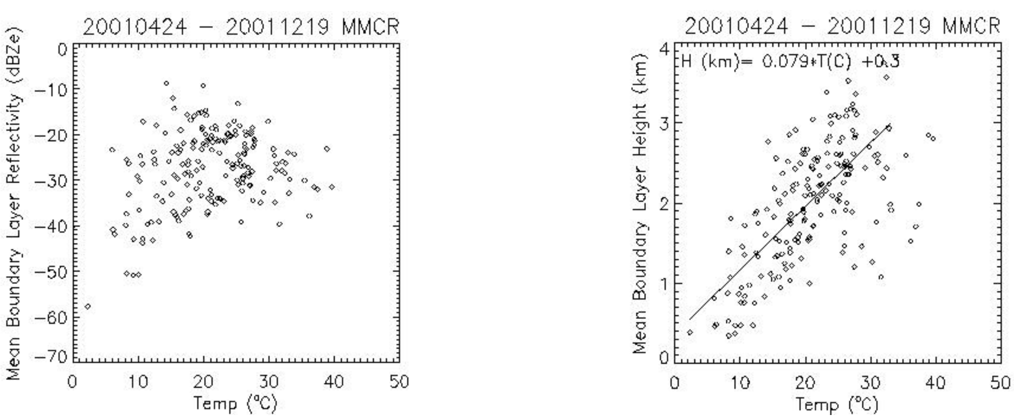

Figure 6.

radar, the mean boundary layer height and reflectivity are functions of surface temperature. However, the measurements from the 95-GHz radar show only a weak correlation between these quantities and temperature (not shown).

Conclusions

- Our observations and analysis show that the 35-GHz radar is more sensitive to insects than the 95 GHz radar.

- Few insects are present below a threshold of 10°C.

- R_{top} and insect layer reflectivity vary diurnally with temperature.

- A linear correlation is observed between mean boundary layer height and temperature for measurements over extended periods. Here H = 0.079T + 0.3.

- A non-linear relationship exists between mean daily reflectivity and temperature for measurements over extended periods.

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Reference

Khandwalla A, S. Sekelsky, L. Li, M. Bergada, 2001: Theory and observations between Ka-band and W-band to explain scattering differences between insects. In *Proceedings of the Eleventh Atmospheric Radiation Measurement (ARM) Science Team Meeting.*