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CLOUD BOUNDARIES DURING FIRE II

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1. BACKGROUND

Cirrus and stratus clouds are currently the subject of active research because of their importance in correctly modeling global climatic trends. Many cloud properties are of interest, including particle concentrations, size distributions, integrated ice mass path, ice mass fluxes, supercooled liquid water distributions and cloud location. Of these, cloud location would seem to be one of the simpler parameters to measure. However, Uttal and Intrieri (1993) have recently demonstrated that different range-gated remote sensors operating at different wavelengths often detect significantly different cloud boundaries. They concluded that care must be taken in choosing an appropriate combination of sensors to accurately record cloud boundary heights for a wide range of meteorological situations.

To our knowledge, previous observations of cloud boundaries have been limited to studies of cloud bases with ceilometers, cloud tops with satellites, and intermittent reports by aircraft pilots. Comprehensive studies that simultaneously record information of cloud top and cloud base, especially in multiple layer cases, have been difficult, and require the use of active remote sensors with range-gated information.

In this study, we examined a 4-week period during which the NOAA Wave Propagation Laboratory (WPL) 8-mm radar (Kropfli et al., 1990) and the Pennsylvania State University (PSU) 3-mm radar (Albrecht et al., 1992) operated quasi-continuously, side by side. By quasi-continuously, we mean that both radars operated during all periods when cloud was present, during both daytime and nighttime hours. Using this data, we develop a summary of cloud boundaries for the month of November for a single location in the mid-continental United States.

2. EXPERIMENT

The First International Satellite Cloud Climatology Project (ISCCP) Regional Experiment (FIRE) II Experiment conducted in Coffeyville, Kansas during the winter of 1991, was a large, multi-agency experiment designed to study the effects of cirrus clouds on the planetary radiation budget. During the experiment the NOAA/WPL 8-mm scanning Doppler radar and the PSU 3-mm radar pointed vertically, and collected high-resolution, range-gated data on clouds as they passed over the observation site. The WPL radar collected a beam (profile) of data every 0.25 sec, which were subsequently averaged to 3-s samples, with range-gate spacing of 37.5 m. The PSU radar collected a beam of data every 4-6 sec, which were averaged to 60-s samples, with range-gate spacing of 30 m.

To determine cloud boundaries, WPL uses a program which searches for user-defined threshold values in individual beams of data to determine in-cloud versus out-of-cloud conditions. PSU has developed an alternative cloud boundary detection algorithm that applies a box filter scheme. For each box, several pixels wide by several pixels high, the pixel in the center of the box is set to "on" for cloud or "off" for no-cloud depending on whether the total number of pixels in the box exceeds, or does not exceed a user-specified threshold. The different schemes for cloud boundary detection do not appear to produce significantly different results.

Both WPL and PSU divided information on cloud boundaries into 6-h periods for the entire experimental month. The data sets were time matched for this study to include only the 6-h periods when both sensors were operating. In this preliminary study, we have not yet corrected for short periods within a given 6-h period when the two sensors might not have been running at exactly coincident times. Also, the WPL radar always collected data from the surface up to 12 km, while the PSU radar was adjusted to bracket the clouds of interest. Occasionally, when the lowest range gate was too high, PSU lost some information on lower cloud boundaries. These factors contribute to some of the differences between radars in the following results.

3. RESULTS

Figures 1 and 2 show histograms of the frequency of occurrence of cloud base height for the WPL and PSU radars, respectively. The figures show a distinct bimodal distribution, suggesting that cloud bases tend to occur predominantly near 2.5 km and 7.5 km. Both distributions indicate that cloud base frequency is relatively low near 5 km. Clouds occurred with approximately equal frequency at stratus and cirrus levels, which is interesting because the generating mechanisms for the clouds at these two altitudes are quite different.

The WPL radar shows a third peak near the surface that is not seen is the PSU data. This peak is a result of the WPL radar operating in some heavy precipitation periods when the PSU radar shut down.

Figures 3 and 4 show histograms of the frequency occurrence of cloud top. Cloud top distributions are less centralized for lower level clouds which are more convective, but still show a well defined peak at near 8.5 km for the cirrus clouds which are less convective and often capped by the tropopause. The cloud top peak is slightly higher for the WPL radar (9 km) when compared to the PSU radar (8.3 km), and skewed towards higher altitudes, This is indicative of the fact that the 3-mm radar occasionally is attenuated before

reaching cloud top. Figures 5 and 6 show histograms of cloud thickness from the WPL and PSU radars, respectively. Cloud thickness appears to be about 1.0 to 1.3 km on average.

Makhover and Nudelman (1989) report average cirrus bases and tops over the European Soviet Union at 7 and 9 km, respectively, with very little annual variation. These are in good agreement with our results.

4. DISCUSSION

This study is unique in that it was not limited by cloud thickness and/or multiple layer cases, and achieved information on both cloud bases and cloud tops simultaneously. Future work with this data set will include examining diurnal effects, differences between precipitating and non-precipitating cases, and the generation of separate statistics for the stratus and cirrus clouds.

6. REFERENCES

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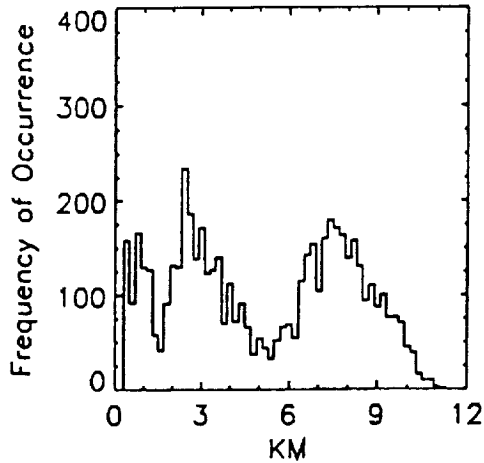
Figure 1. WPL cloud base frequency
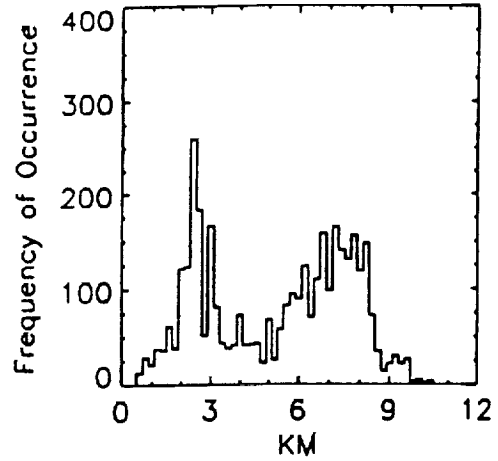distribution

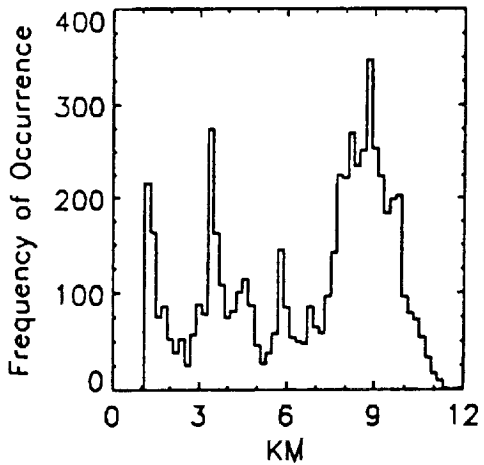Figure 2. PSU cloud base frequency
distribution

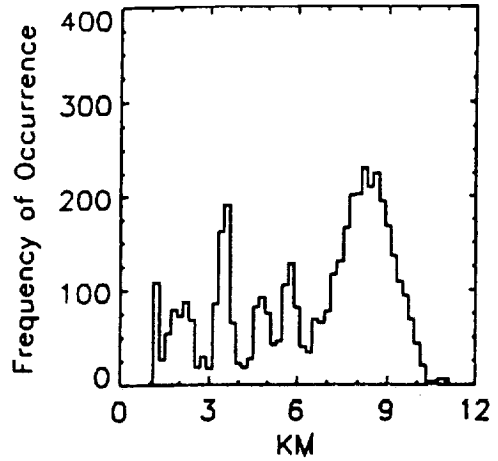Figure 3. WPL cloud top frequency
distribution

Figure 4. PSU cloud top frequency
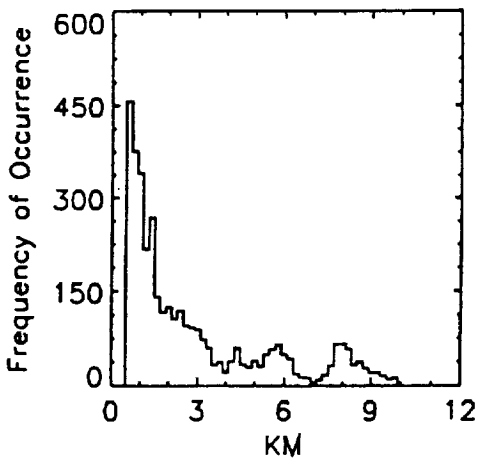distribution

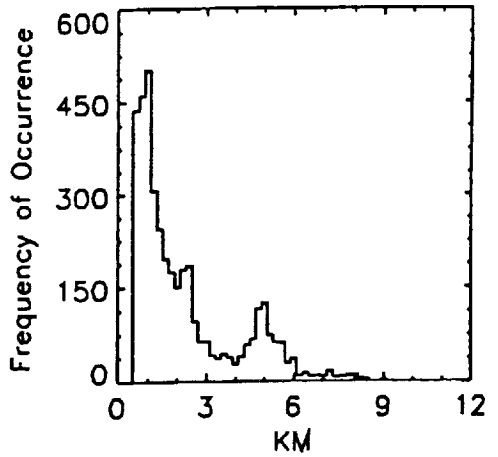

Figure 5. WPL cloud thickness
frequency distribution

Figure 6. PSU cloud thickness
frequency distribution

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