A One-Year Cloud Climatology for the Southern Great Plains Site

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Introduction

The addition of the millimeter wave cloud radar (MMCR) to the suite of instruments at the Southern Great Plains (SGP) site has provided the necessary observations to produce a cloud climatology. Data from the MMCR are currently being combined with data from the Belfort laser ceilometer (BLC) and micropulse lidar (MPL) to determine cloud occurrence and location using algorithms developed by our research group. These basic cloud statistics should prove useful for comparing with both single-column model (SCM) and general circulation model (GCM) predictions of cloud cover, as well as in assessing satellite measurements of cloud cover and cloud properties.

These data are also being input into a database that can be used to correlate cloud properties with data from other instruments such as liquid water path (LWP) from the microwave radiometer (MWR) or downward solar irradiance from the Atmospheric Radiation Measurement (ARM) pyranometers.

At the March science team meeting, data were presented for the period October 1 through December 31, 1997. Since then, our processing has been extended back to June 1997 and eventually we intend to incorporate all MMCR data gathered since November 1996. We are also actively processing all new incoming radar data, with about a 1-month lag time.

Statistics and Data Analysis for October 1997 – December 1997

In this section, we present a sample of cloud statistics for the period from October 1, 1997, through December 31, 1997. In Tables 1 and 2 are the basic cloud fractions, that is, the fraction of time that the upward looking narrow field of view radar and lidar instruments detected clouds. Reported is 1) the fraction of time any cloud is detected; 2) the fraction of time more than one cloud layer is detected; 3) the fraction of time low (cloud base < 2000 meters), mid, and high (cloud base > 7000 meters) clouds are detected; and 4) the fraction of time that the lidar detected clouds but the radar did not. Note that it is possible to have both low and high cloud layers present at the same instant so the low, mid, and high cloud fraction will not equal the "any cloud" fraction. Also, the multilayer cloud fraction (18% during this period) that was detected is with respect to the total elapsed time. So, for this time period, when it was cloudy the clouds were multilayered (multilayered fraction/any cloud fraction = 0.18/0.57 = 31.5% of the time). (For the purpose of these statistics, a cloud layer is defined as separation between cloud-filled radar bins of more than 100 meters).

Table 1. Cloud fractions for the full 3-month period.

Relative Frequency	October 1997 - December 1997
Any Cloud	0.57
Multilayer Clouds	0.18
Low Cloud Present	0.39
Mid-Level Cloud Present	0.18
High Cloud Present	0.16
Lidar Detection Only	0.03

Table 2. Cloud fractions for each month.

Relative Frequency	Dec 97	Nov 97	Oct 97
Any Cloud	0.65	0.58	0.48
Multilayer Clouds	0.19	0.19	0.15
Low Cloud Present	0.49	0.33	0.35
Mid-Level Cloud Present	0.16	0.24	0.15
High Cloud Present	0.16	0.18	0.13
Lidar Detection Only	0.03	0.03	0.03

Other useful statistics are shown on the following figures. Figure 1 plots the cloud occurrence versus height (i.e., the fraction of the time clouds are present for each radar resolution volume) for the 3-month period October 1 through December 31, 1997. One can also examine the distribution of cloud boundaries. Figure 2 displays the distribution of cloud base and cloud top. The cloud base or top value is chosen as the center of the bottom most or top

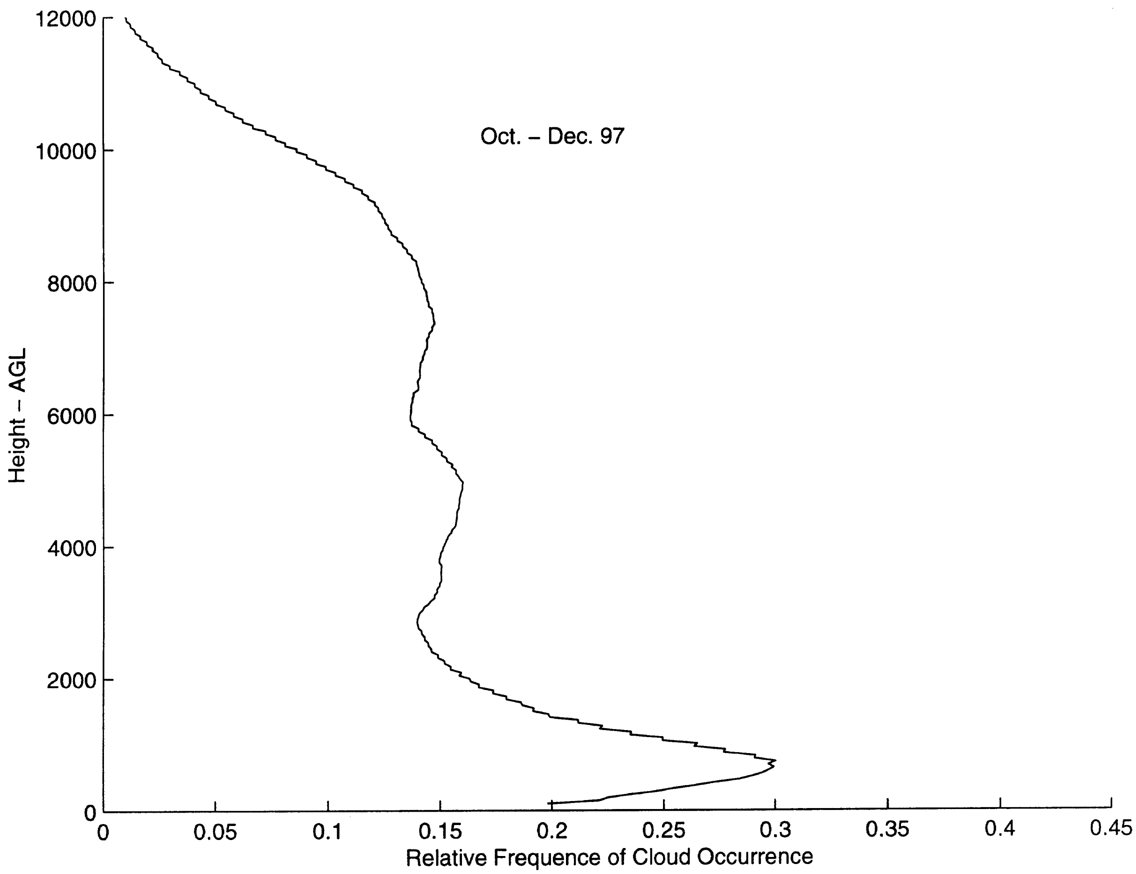

Figure 1. MMCR measurement of cloud occurrence versus height (i.e., the fraction of the time clouds are present for each radar resolution volume) for the 3-month period October 1 through December 31, 1997.

most radar resolution volume (or radar bin) for every cloud in the vertical column. Clouds detected by lidar, but not by radar, are included in the base height distribution but not in the cloud top distribution. Altitude bins are centered every 250 meters starting at 0 meters above ground level (AGL). Figure 3 plots the distribution of cloud thickness. Clouds detected only by lidar or that fill only one radar range bin are considered to have zero thickness for the purpose of computing this frequency distribution.

Cloud fractions over hourly and daily time scales can also be examined. Figure 4, for example, shows the distribution of hourly cloud fraction for the full 3-month period. The figure shows that most of the time the radar sees either complete cloud cover or no clouds over the course of 1 hour. Similar findings have been reported by other research based on analysis of lidar data.

In addition to these basic statistics, we have also begun correlating cloud boundaries and fractions with data from other instruments. Two quantities that we routinely examine are LWP and downwelling solar irradiance. Figure 5, for example, shows a scatter plot of MWR-derived LWP versus downwelling solar cloud forcing (or cloud effect) relative to the estimated clear-sky value. (The cloud effect is the measured value minus the estimated clear-sky value.) Each point in Figure 5 represents a 5-minute average in both LWP and cloud forcing. Included are only those times when the cosine of the solar zenith angle is greater than 0.2 and where the variation in the LWP and cloud forcing are reasonably small. Interestingly, the figure shows no apparent change for single-layer versus multilayer clouds.

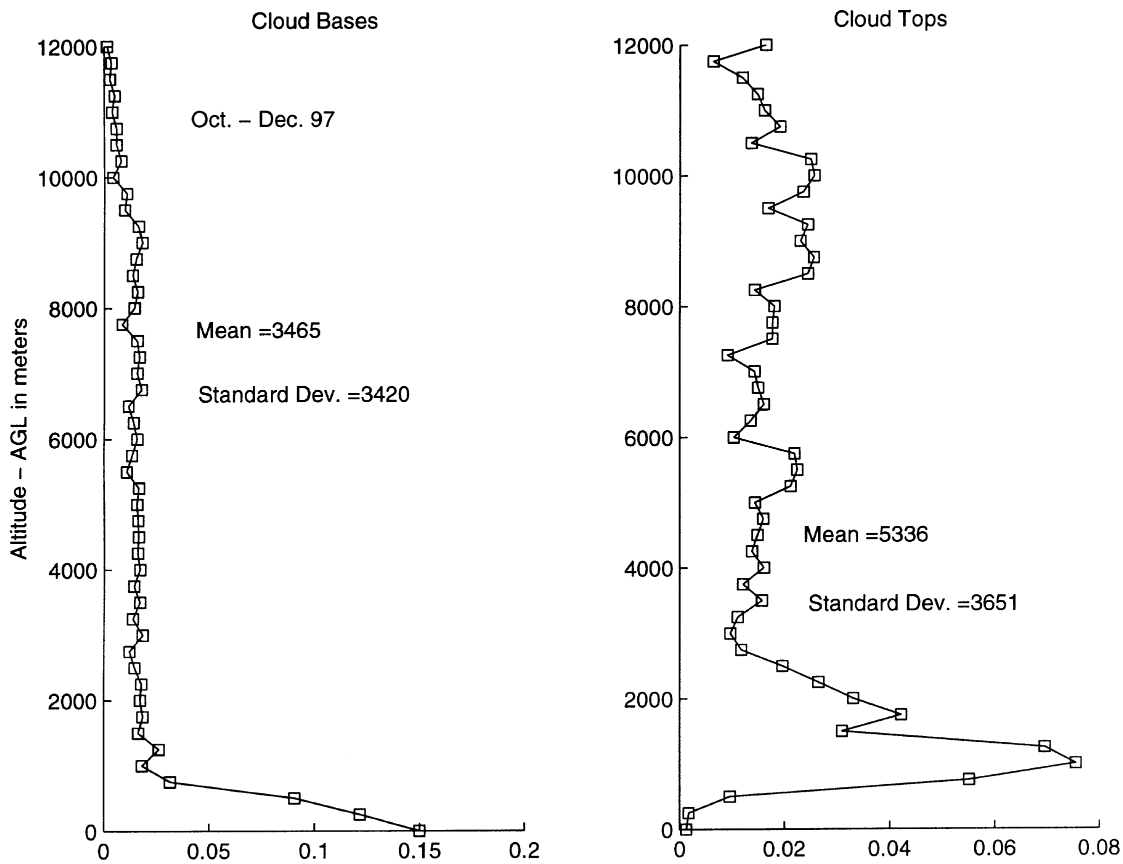

Figure 2. Distribution of cloud base and cloud top. The cloud base or top value is chosen as the center of the bottom most or top most radar resolution volume (or radar bin) for every cloud in the vertical column. Clouds detected by lidar, but not by radar, are included in the base height distribution but not in the cloud top distribution. Altitude bins are centered every 250 meters starting at 0 meters AGL.

Figures 6 and 7 related these quantities to the cloud boundaries. Figure 6 is a scatter plot of cloud thickness versus relative cloud effect for single-layer clouds. The figure shows that clouds with bases less than 2000 meters tend to have a fractional cloud forcing of 50% or larger, even when they are relatively thin. Clouds with bases greater than 2000 meters tend to have fractional cloud forcing less than 50%. Each point in this plot corresponds to a 5-minute time interval and only those times when the local 1 hour cloud fraction was 100% are included. Even with this restriction, there are several positive cloud forcing events. Figure 7 shows a scatter plot of cloud thickness versus LWP. This figure shows that (from October 1 to December 31) clouds with base altitudes greater than 2000 meters have little liquid water, and generally range in thickness from nearly 0 meters to 4000 meters. For clouds with bases less than 2000 meters, there appears to be a minimum thickness which increases with LWP. However, thicker clouds do not necessarily show the largest LWP.

Summary

We are currently constructing a cloud data base for the Southern Great Plains based on millimeter cloud radar and lidar measurements. When complete, a continuous time series of data from November 1996 to the present will be available. Statistics such as monthly and seasonal values of cloud occurrence, cloud fraction, and multilayer statistics will be generated.

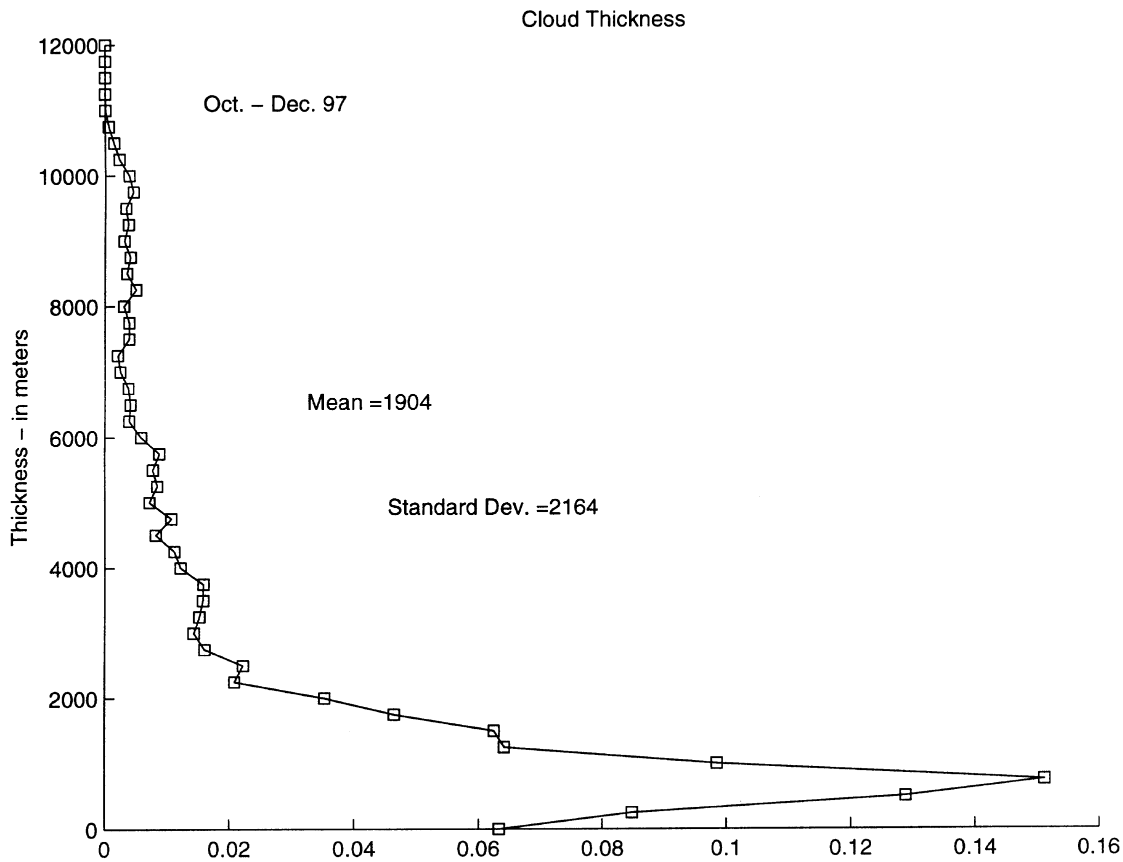

Figure 3. Distribution of cloud thickness. Clouds detected only by lidar or that fill only one radar range bin are considered to have zero thickness for the purpose of computing the frequency distribution.

We are also analyzing the surface solar radiation record and derived values of the surface solar cloud forcing for this same time period. These values will be correlated with the cloud climatology results to provide an assessment of the relationship between clouds and the surface solar flux. Other data, such as LWP (obtained primarily from microwave radiometer measurements) and cloud temperature profiles (estimated from a combination of sources including radiosondes and atmospheric emitted radiance interferometer [AERI] measurements) will also be examined.

Acknowledgments

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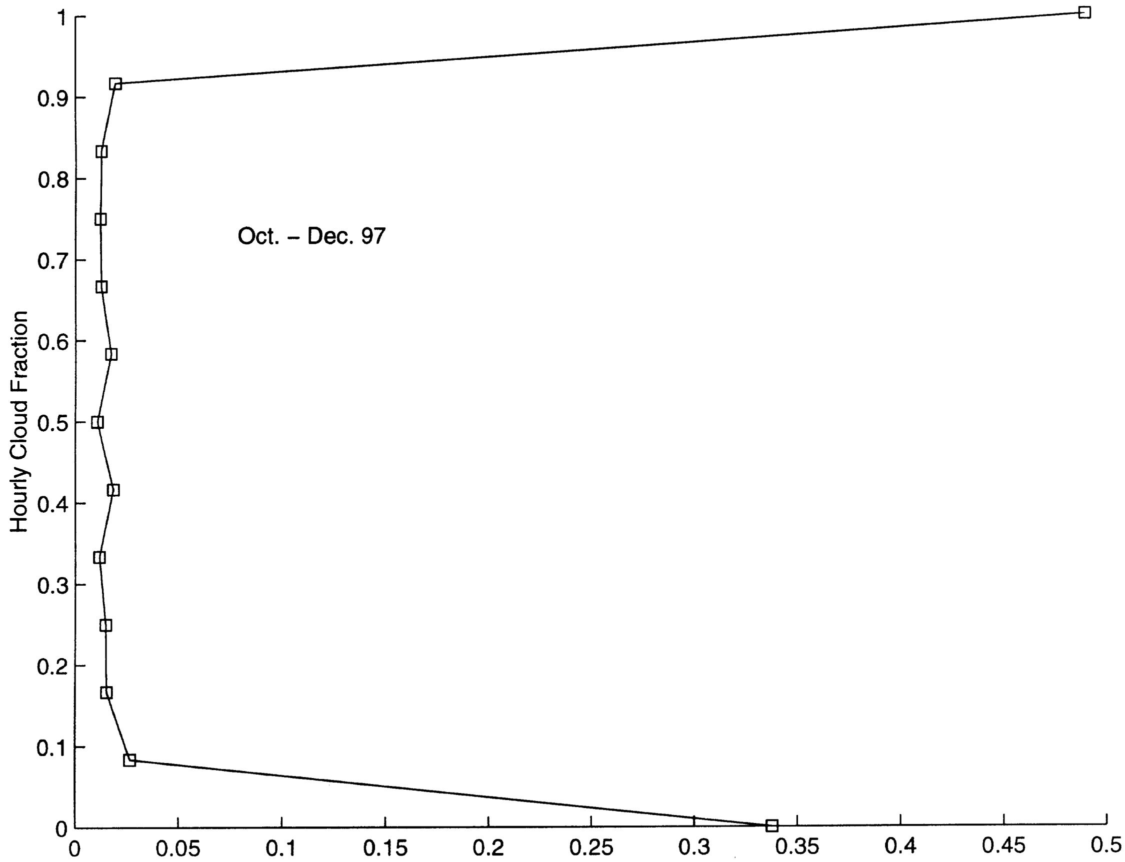

Figure 4. Distribution of hourly cloud fraction. The figure shows that most of the time the radar sees either complete cloud cover or no clouds over the course of 1 hour.

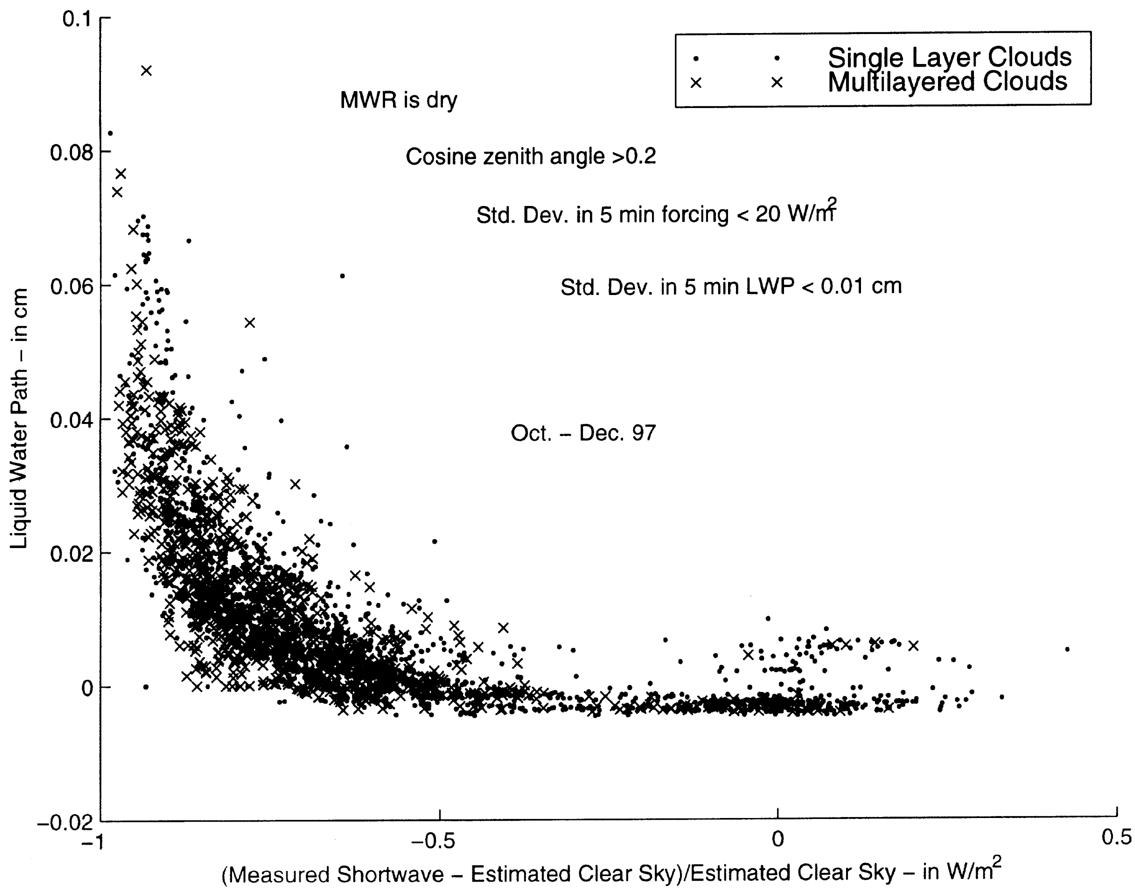

Figure 5. Scatter plot of MWR-derived LWP versus downwelling solar cloud forcing (or cloud effect) relative to the estimated clear sky value. Each point represents a 5-minute average in both LWP and cloud forcing. Included are only those times when the solar zenith angle is greater than 0.2 and where the variation in the LWP and cloud forcing are reasonably small. The figure shows no apparent change for single-layer versus multilayer clouds.

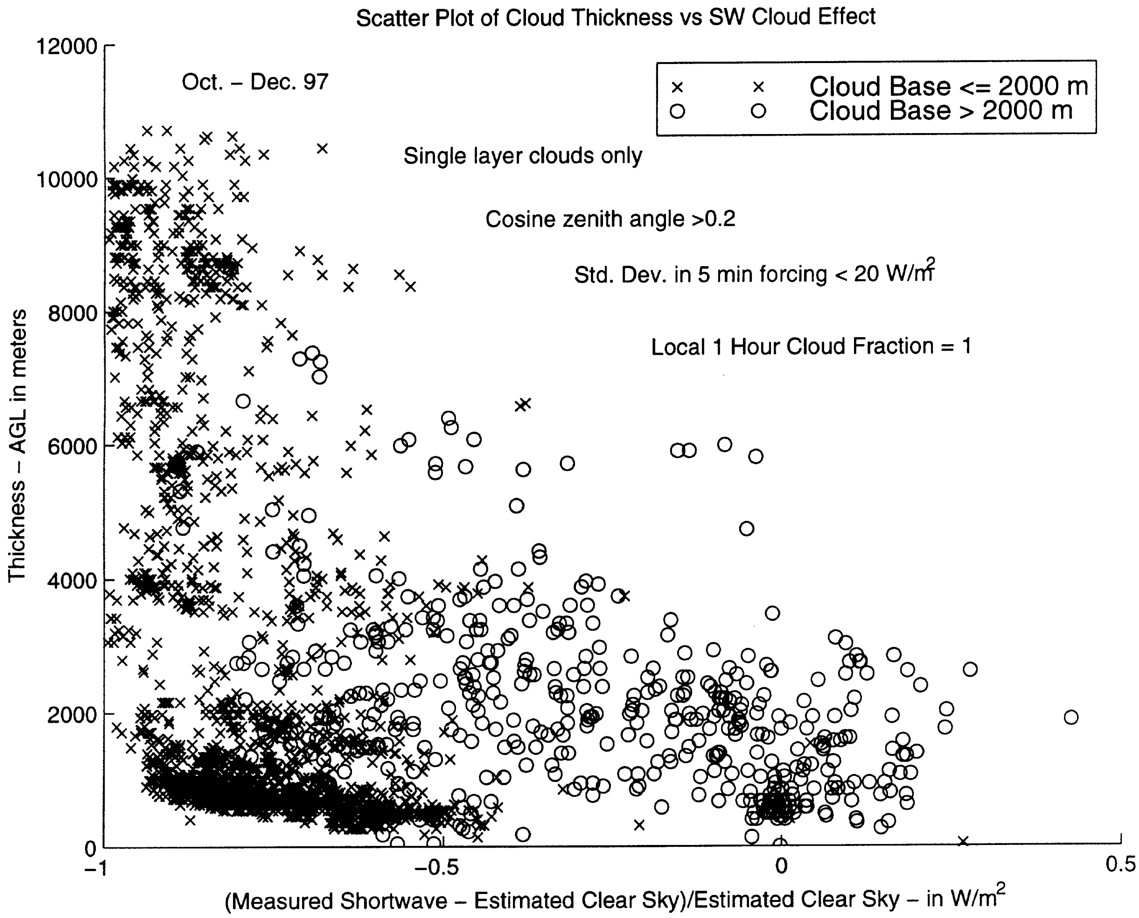

Figure 6. Scatter Plot of cloud thickness versus relative cloud effect for single-layer clouds. The figure shows that clouds with bases less than 2000 meters tend to have a fractional cloud forcing of 50% or larger, even when they are relatively thin. Clouds with bases greater than 2000 meters tend to have fractional cloud forcing less than 50%. Each point in this plot corresponds to a 5-minute time interval and only those times are included when the local 1-hour cloud fraction was 100%. Even with this restriction, there are several positive cloud forcing events.

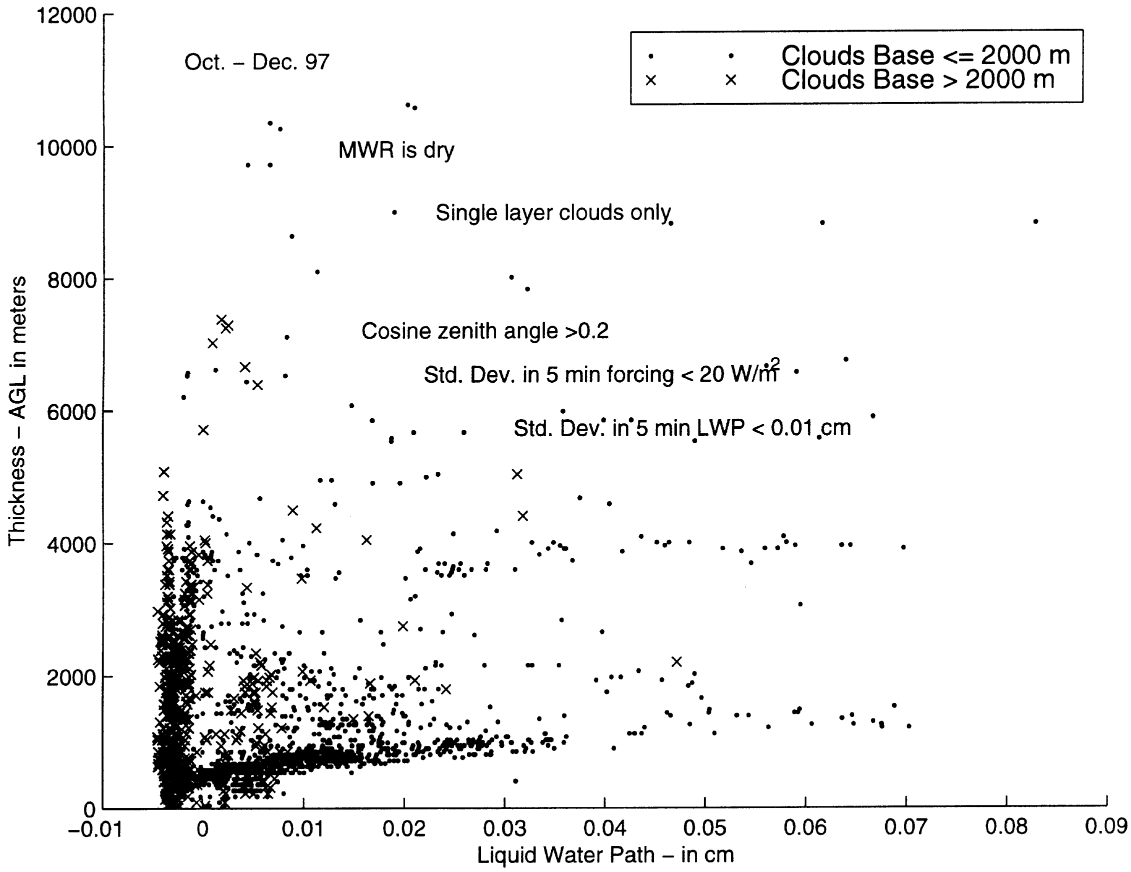

Figure 7. Scatter Plot of cloud thickness versus LWP. This figure shows that (from October 1 to December 31, 1997) clouds with base altitudes greater than 2000 meters have little liquid water, and generally range in thickness from nearly 0 meters to 4000 meters. For clouds with bases less than 2000 meters, there appears to be a minimum thickness, which increases with LWP. However, thicker clouds do not necessarily show the largest LWP.