ARM Summer Training and Science Applications

Cloud Properties Report

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1.0 Cloud Properties

The liquid water path (LWP) is a major parameter used for estimating the impact of clouds on climate. However, the LWP alone does not give any insight into the geometric properties of clouds or the mass of liquid water contained in a single cloud. Here we will describe an algorithm for the identification of individual clouds and the calculation of contained liquid water. We make use of data products of Microwave Radiometers (MWRs), Millimeter Wave Cloud Radars, Micropulse Lidars, and Radiosondes. The algorithm will be employed on data obtained from the Atmospheric Radiation Measurement (ARM) Southern Great Plains (SGP) site on June 25, 2007. This day featured shallow cumulus clouds early in the day with high-level ice clouds developing toward the end of the day.

To derive the volume and liquid water mass of individual one-layer liquid clouds, the height of the cloud's base and top are determined from the retrieval described by Clothiaux et al. (2000). Individual clouds are identified with the following restrictions. First, the individual clouds are assumed to be represented by a continuous measurement of cloud base heights, separated by missing values of cloud base heights from other clouds. Second, those clouds with multi-layers are removed from our analysis. Third, the melting level through the analysis period is determined from interpolated Radiosonde data. All clouds above the melting level are removed. The last restriction on the selection of analyzed clouds was made due to unphysical, negative values from the LWP retrieval (Turner et al. 2007). To avoid an artificial reduction of the liquid water cloud mass, clouds with negative LWP have been omitted as well.

The first step in the analysis is to calculate the horizontal extent of the cloud. This is calculated from the cloud base horizontal velocity, determined from linearly interpolated Radiosonde data of horizontal velocity. The equation used is $\Delta x = v \cdot \Delta t$, where Δx is the streamwise horizontal extent, v the horizontal velocity at cloud base, and Δt the time between two measurements. Since the cloud's cross-wind extent is unknown, two different attempts are made: (i) the same extent as for the streamwise component (called "column cloud"), and (ii) a circular shape (called "circle cloud"). Second, the cloud volume/mass is calculated by multiplying the horizontal area of the cloud by its depth/LWP. The latent heat contained in the cloud can is then found by simply multiplying the cloud's mass by the latent heat of vaporization.

Figure 1 shows cloud mass, latent heat (cloud mass multiplied by the latent heat of vaporization J = 2.26 x 10^6 J kg^{-1}), and cloud volume for the examined clouds assuming either column (Figure 1a) or circle clouds (Figure 1b). Due to the larger horizontal extent, the circle clouds exhibit larger values of cloud mass, latent heat, and cloud volume. This study gives an overview on the relationship between the typical mass, volume, and latent heat of shallow cumulus clouds. Our analysis shows that for the investigated day at SGP, the liquid water mass of shallow cumulus clouds is 67 tons, which corresponds to 1.56 x 10^{11} J of latent heat.

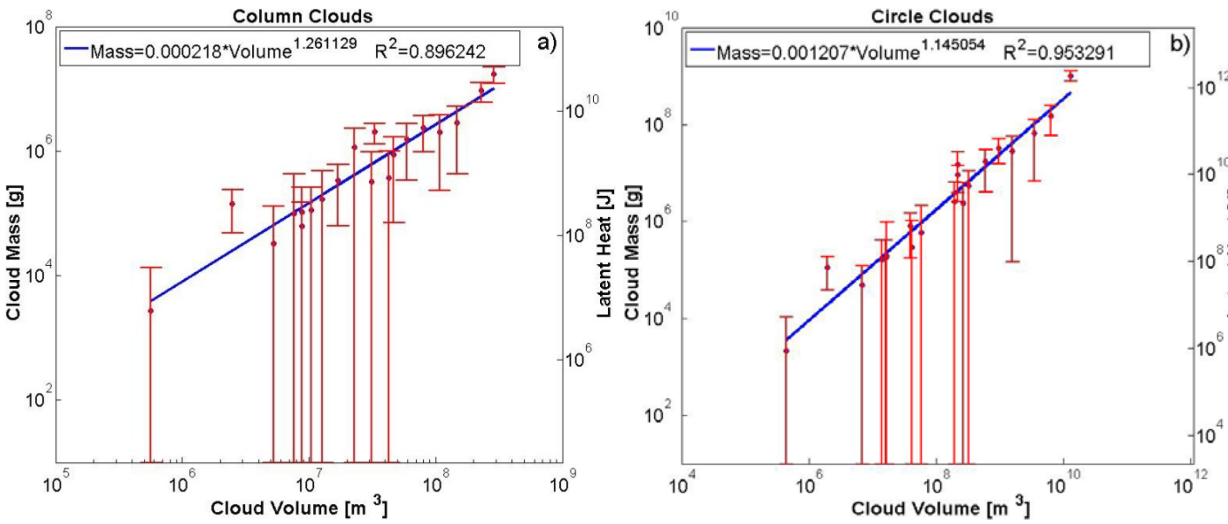

Figure 1. Cloud mass and latent heat as a function of cloud volume for (a) column clouds and (b) circle clouds.

2.0 References

Clothiaux, EE, TP Ackerman, GG Mace, KP Moran, RT Marchand, MA Miller, and BE Martner. 2000. "Objective determination of cloud heights and radar reflectivities using a combination of active remote sensors at the ARM CART sites." *Journal of Applied Meteorology*, 39: 645-665, doi: 10.1175/1520-0450(2000)039-0645:ODOCHA>2.0CO:2.

Turner, DD, SA Clough, JC Liljegren, EE Clothiaux, K Cady-Pereira, and KL Gaustad. 2007. "Retrieving liquid water path and precipitable water vapor from the Atmospheric Radiation Measurement (ARM) microwave radiometers." *IEEE Transactions on Geoscience and Remote Sensing* 45: 3680-3689.