# Using ARM Data to Verify the Modification of Clouds by Aerosols

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## Introduction

The goal of our project is to use the Atmospheric Radiation Measurement (ARM) data to examine how aerosols alter the reflection of sunlight by clouds. In order to carry through with this goal, we have selected data from the Southern Great Plains (SGP) ARM site. The data include total liquid water path (from the Microwave Radiometer), temperature, pressure, and relative humidity profiles (from the atmospheric sonde data), surface aerosol concentration (from the optical particle counter [OPC] measurements and condensation nucleus [CN] measurements), and total sky narrowband and broadband albedo (from analysis of satellite measurements [Minnis et al. 1995]). Because we only have aerosol concentrations at the surface, we have limited our study to cases where the cloud forms at the top of a well-mixed boundary layer. Also, in this initial study, we have limited the number of cases examined to only those in which the cloud has not undergone a significant amount of entrainment and mixing of dry air with cloudy air (Penner and Chuang 1999). We also limited our examination to clouds that are entirely liquid. Thus, we developed the following criteria in selecting the time periods and data for examination:

1. The cloud thickness estimated from the sonde data is within 200 m of that estimated from the satellite analysis.

2. The mixing ratio of water vapor is approximately constant below cloud base.

3. The cloud base is less than 3 km.

4. The mixing ratio of water below cloud is approximately equal to the sum of the mixing ratio of cloud water and water vapor within cloud.

5. The cloud cover determined from the satellite data is larger than 95%.

To examine the accuracy and consistency of the data from different sensors, we first explored the errors associated with using the liquid water path from the Microwave Radiometer (MWR) in predicting fluxes at the top of the atmosphere (TOA). Differences between the model predicted broadband shortwave fluxes and satellite-derived fluxes ranged from -250 $Wm^{-2}$ to +250 $Wm^{-2}$ with an average bias of 29 $Wm^{-2}$ (about 14%). We also compared model-predicted narrowband fluxes with those inferred from satellite measurements and demonstrated that no bias is present in the broadband product. Figure 1 presents our comparison of the model predicted shortwave fluxes at TOA under cloudy skies to that measured from the satellite during time periods of April 1996; June 18, 1997, to July 18, 1998; September 15, 1997, to October 5, 1997; and January 1, 1998, to January 31, 1998.

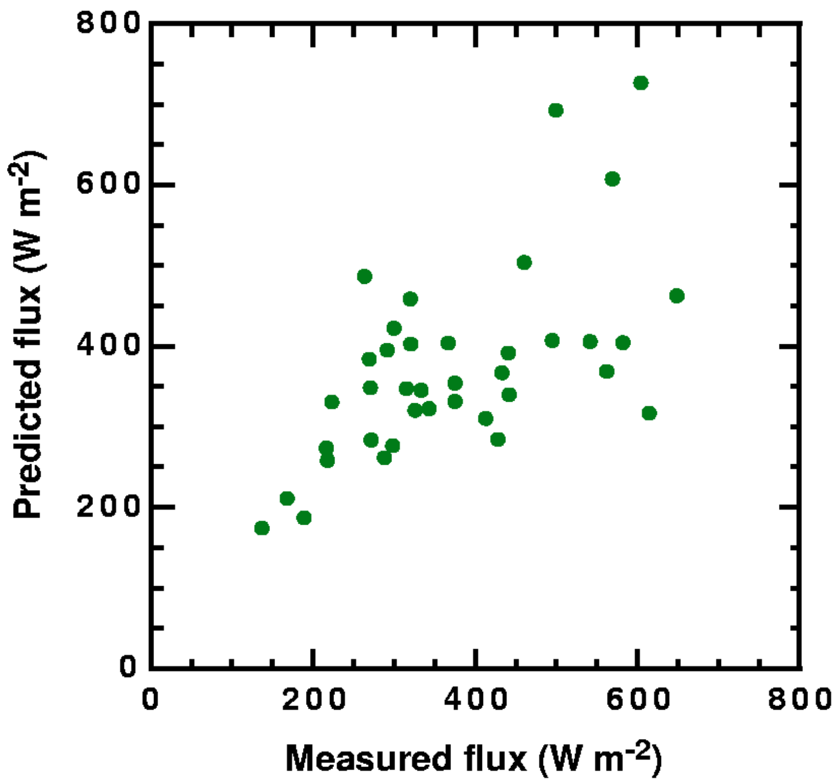


**Figure 1**. Comparison of measured and model predicted flux of solar radiation from time periods with >95% cloud cover and which satisfy our other criteria. The average bias between predicted and measured flux is 29 $Wm^{-2}$ (about 14%).

For an adiabatic cloud, the indirect effect of aerosols on cloud droplet number concentration can be inferred by plotting cloud optical depth divided by cloud depth to the 5/3 power versus cloud condensation nuclei (CCN) concentration to the 1/3 power (Brenguier et al. 1998). We have examined this relationship for the data used in our analysis (Figure 2). The relationship does show the expected linear correlation if the liquid water content of the cloud is above 0.3 $g/m^3$. This limitation is similar to that used by workers examining the relationship between aerosols and cloud droplet concentrations from in situ data (Vong and Covert 1998), but the linear relationship depends on only five points! Because our current methods for inferring cloud depth come from an examination of sonde and satellite analysis

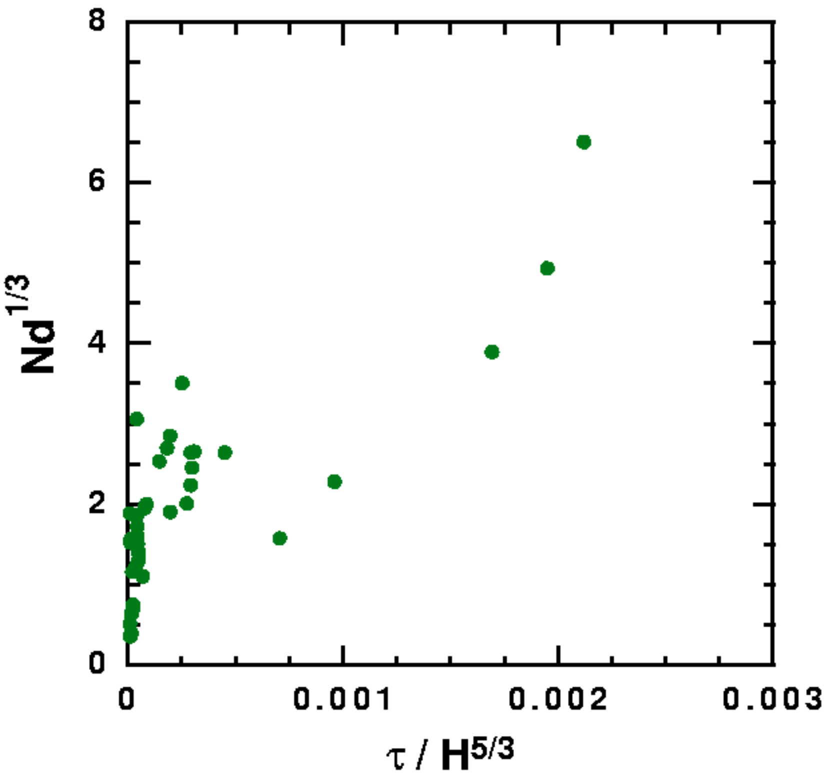


**Figure 2**. Droplet concentration to the one-third power versus cloud optical depth divide by cloud depth to the 5/3 power. $N_d$ was assumed to be linearly related to the aerosol concentration above d>1 µm as measured by the OPC.

(both of which may have significant errors in terms of determining cloud depth), the analysis of these data should be significantly improved after the cloud radar data for cloud depth become available. We also expect to re-examine this relationship after the size distribution data for aerosol become available. Then, we will test whether use of the microphysical model to predict droplet number concentration directly, given the measured size distribution, will improve the correlation between $N_d^{1/3}$ and $\tau/H^{5/3}$ (Figure 2) as well as the relationship between modeled and observed fluxes (Figure 1).

We are proceeding with an examination of sensor data, which may provide a better determination of cloud depth, such as the ceilometer data for cloud base. In addition, we are seeking data on aerosol size distribution that could provide a better indication of CCN number concentration. Finally, as more satellite data become available we should be able to examine a much larger range of cases.

## References

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