Use of ARM Measurements to Evaluate Droplet Number Prediction in Single-Column Models

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Introduction

Droplet number prediction is a crucial step in any estimate of indirect radiative forcing by anthropogenic aerosol. Although several global climate models now predict droplet number concentration, evaluation of the treatment of droplet number in these models has been hindered by the scarcity of suitable measurements. Here we explore the use of remote sensing measurements for the evaluation of the prediction of droplet number by single-column versions of global climate models.

Experiment Design

The experiment focuses on the Fall 1997 Cloud Intensive Operational Period (IOP) at the Atmospheric Radiation Measurement site in the Southern Great Plains. During this IOP, aircraft were flown to provide in situ measurements of aerosol and droplet number concentration for comparison with remote sensing estimates. The in situ measurements of aerosol also provide the necessary information about the aerosol characteristics that are most important for predicting droplet number; namely, the spectrum of cloud condensation nuclei (CCN) concentration as a function of supersaturation. However, the CCN measurements must first be converted into the aerosol characteristics used by the droplet prediction models; namely, number concentration, number mode radius, and geometric standard deviation. This was accomplished by applying Kohler theory to an assumed lognormal size distribution, and using least squares to determine the aerosol parameters from the CCN spectrum. These aerosol parameters were then plotted as a function of time for the selected period, and typical values were selected as input to the models.

Results

The experiment was performed on the only day during the entire IOP in which remote sensing of droplet number concentration was feasible (September 25). The single-column models (SCMs) were driven by lateral boundary conditions analyzed objectively using the scheme of Zhang and Lin (1997). Figure 1 compares the mm cloud radar reflectivity for the experiment with the droplet number concentration simulated by the Pacific Northwest National Laboratory SCM. Although radar reflectivity and droplet number are not directly comparable, the figure does show that the simulation reproduces the observed vertical distribution of the cloud and the timing of the cloud dissipation quite well.

A quantitative evaluation of the droplet number prediction is shown in Figure 2, which compares the vertical in-cloud mean droplet number concentration as simulated and as estimated from remote sensing. Although it would be highly desirable to compare both estimates with in situ measurements, the aircraft measurements on this day did not begin until after the cloud dissipated. The predicted droplet number agrees quite well with the remote sensing estimate at the times that remote sensing estimates were available. However, the predicted droplet number is rather sensitive to the value of the aerosol number, so that reliable estimates of aerosol number are necessary for the evaluation. It is not clear whether such estimates can be obtained from remote sensing.

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References

Zhang, M. H., and J. L. Lin, 1997: Constrained variational analysis of sounding data based on column-integrated budgets of mass, heat, moisture and momentum: Approach and application to ARM measurements. *J. Atmos. Sci*., **54**, 1503-1524.

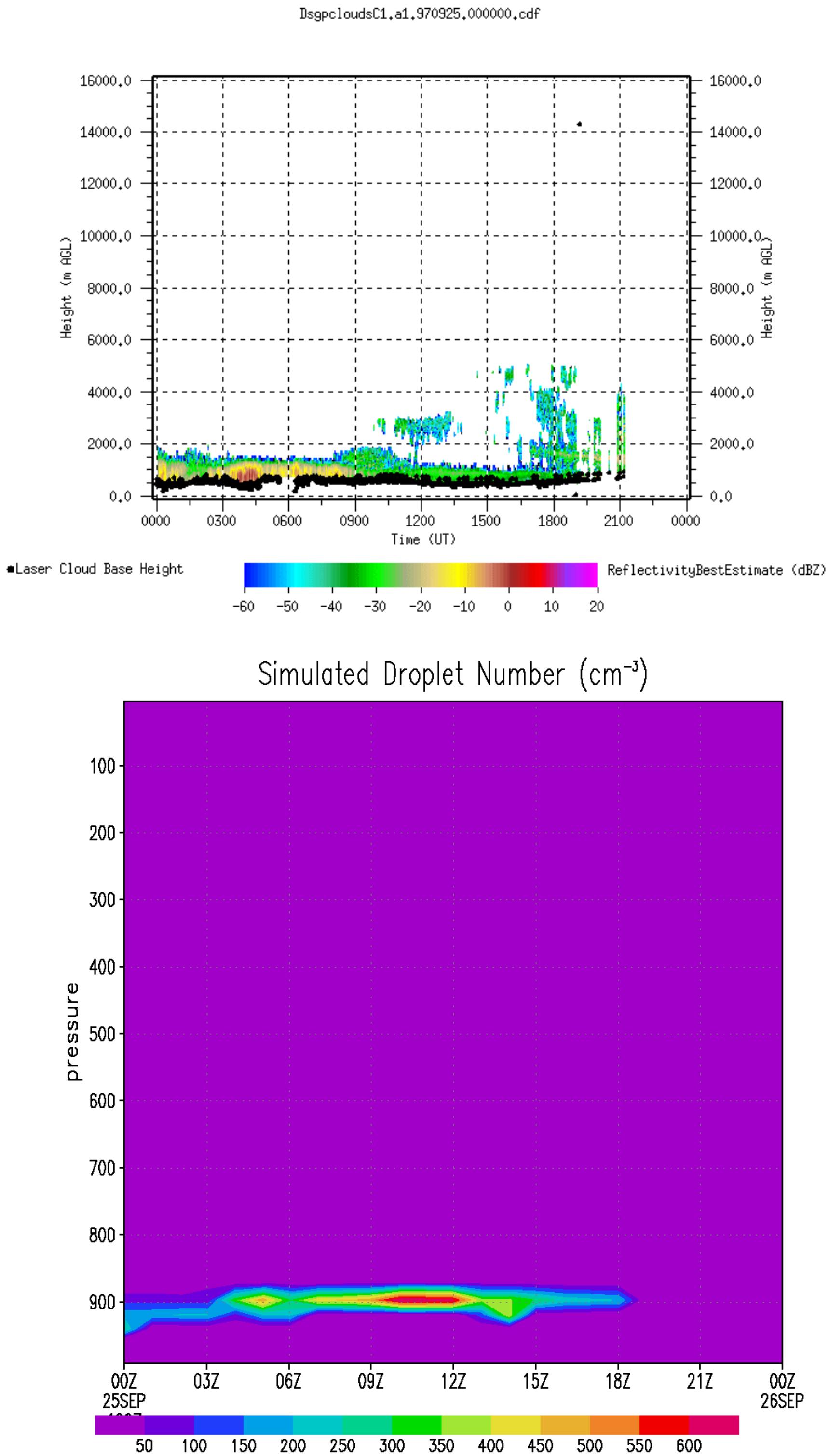

Figure 1. Reflectivity measured by ARM mm cloud radar at the SGP central facility on September 25, 1998 (above), and droplet number concentration simulated for the same period by the PNNL SCM (below).

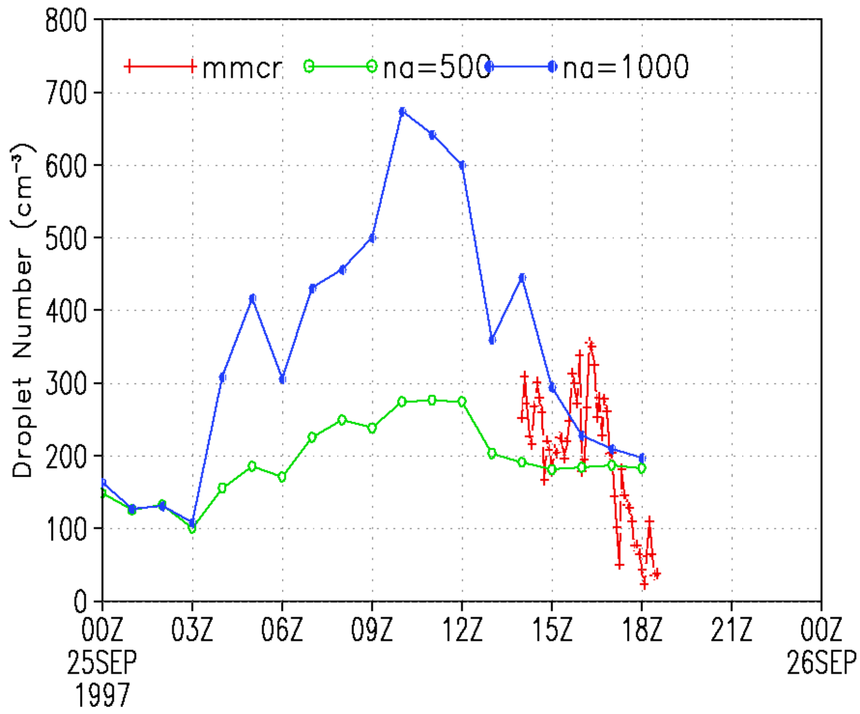

Figure 2. Vertical in-cloud mean droplet number simulated by the PNNL SCM (using aerosol number concentrations of 500 cm^{-3} and 1000 cm^{-3}) and estimated by remote sensing using a combination of mm cloud radar, microwave radiometer, and surface solar flux measurements.