Cloud Properties in the ARM SGP Site and Their Relations to the Meteorological Conditions

G. J. Zhang
Center for Atmospheric Sciences
Scripps Institution of Oceanography
La Jolla, California

Introduction

The conventional approach to studying clouds examines cloud properties, such as fractional cloud cover, at fixed locations. While this approach is useful in documenting cloud climatologies (Lin and Rossow 1997), it provides no information on the individual cloud systems that constitute the climatology. Cloud systems of different types play different roles in the global energy and hydrological budget. Even for the same type of clouds, their contribution to the cloud radiative effects varies greatly with the size of the cloud systems (Roca and Ramanathan 2000). Recently, Boer and Ramanathan (1997) developed a Lagrangian cloud classification algorithm that follows individual cloud systems. The technique can determine the spatial and temporal characteristics of the cloud systems and the scale dependence of cloud physical and radiative properties. The statistic of the cloud properties for different cloud types and under different climate regimes can be used to evaluate the model cloud parameterization in regional and global climate models (Zhang et al. 1999).

This study examines the spatial characteristics and the scale dependence of the cloud physical and radiative properties in the ARM South Great Plains (SGP) site using satellite observations. We apply the Lagrangian cloud classification scheme of Boer and Ramanathan (1997) to the Minnis satellite cloud product. In addition, we will relate the cloud properties to the prevailing meteorological conditions, so as to provide an observational basis for developing and evaluating cloud parameterization.

Data

The cloud data are from the Minnis cloud products based on Geostationary Operational Environmental Satellite (GOES)-8 satellite observations from June 18 to July 18, 1997. The analysis domain covers an area of 9.5° in latitude and 13.5° in longitude for (32.25°N, 41.75°N) and (91.25°W, 104.7 °W) with 0.5° spatial resolution and hourly temporal resolution. The observed clouds are classified as being high, middle, and low clouds. The high clouds have their tops above 6 km, the middle clouds have their tops between 2 km and 6 km, and the low clouds have their tops below 2 km. For each cloud type, the basic cloud physical and radiative properties, such as cloud top temperature and height, outgoing longwave radiation, broadband albedo, visible optical depth, etc. are retrieved. The meteorological data are the analysis products from the NCEP Rapid Update Cycle (RUC) procedure, provided by the ARM Data Center. The analysis data have a horizontal resolution of roughly 0.5° and a vertical resolution of 25 hPa from 1000 hPa to 100 hPa. The basic meteorological fields, i. e., winds, temperature, relative humidity, geopotential heights, are available every three hours. The vertical velocity is computed using the wind fields, and adjusted to zero at the 100 mb level. The atmospheric stability, measured by both the dry and moist static energy difference between the top and the bottom of the three cloud layers, is calculated.

Results

We use the Lagrangian cloud classification algorithm to determine the cloud area and relate the size distribution to the large-scale meteorological conditions. Figure 1 shows that cloud area has a strong relationship with the layer averaged relative humidity for all three-cloud types. In general, larger clouds are associated with higher relative humidity. In addition to relative humidity, cloud size is also related to other meteorological fields. For low clouds, cloud area is large when the lower troposphere is moist statically unstable. On the other hand, the area of middle clouds strongly depends on the dry static stability of the layer. Only the area of high clouds is found to depend on the layer averaged vertical velocity: clouds are larger in stronger upward motion regions.

The cloud amount also shows clear dependence on these meteorological fields. Figure 2 plots the cloud amount as functions of the same fields as in Figure 1. The cloud amount is higher when the atmosphere is moister. This suggests that the traditional approach to diagnosing cloud amount using relative humidity is not unreasonable when no other better technique is available. However, other fields, such as static stability and vertical velocity, may as well be incorporated. Note that one needs to use different large-scale fields to parameterize the cloud amount for different cloud types. Examination of cloud radiative properties, such as cloud albedo and optical thickness, also show clear dependence of these properties on the large-scale meteorological conditions (figures not shown). These observational relationships can be used to guide and evaluate cloud parameterization.

References

Boer, E. R., and V. Ramanathan, 1997: Lagrangian approach for deriving cloud characteristics from satellite observations and its implications to cloud parameterization. *J. Geophys. Res.*, **102**, 21383-21399.

Lin, B., and W. B. Rossow, 1997: Precipitation water path and rainfall rate estimates over oceans using special sensor microwave imager and International Satellite Cloud Climatology Project data. *J. Geophys. Res.*, **102**, 9359-9374.

Roca, R., and V. Ramanathan, 2000: Scale dependence of monsoonal convective systems over the Indian Ocean. *J. Climate*, **13**, 1286-1298

Zhang, G. J., D. Zurovac-Jevtic, and E. R. Boer, 1999: Spatial characteristics of the tropical cloud systems: Comparison between model simulation and satellite observations. *Tellus*, **51A**, 922-936.

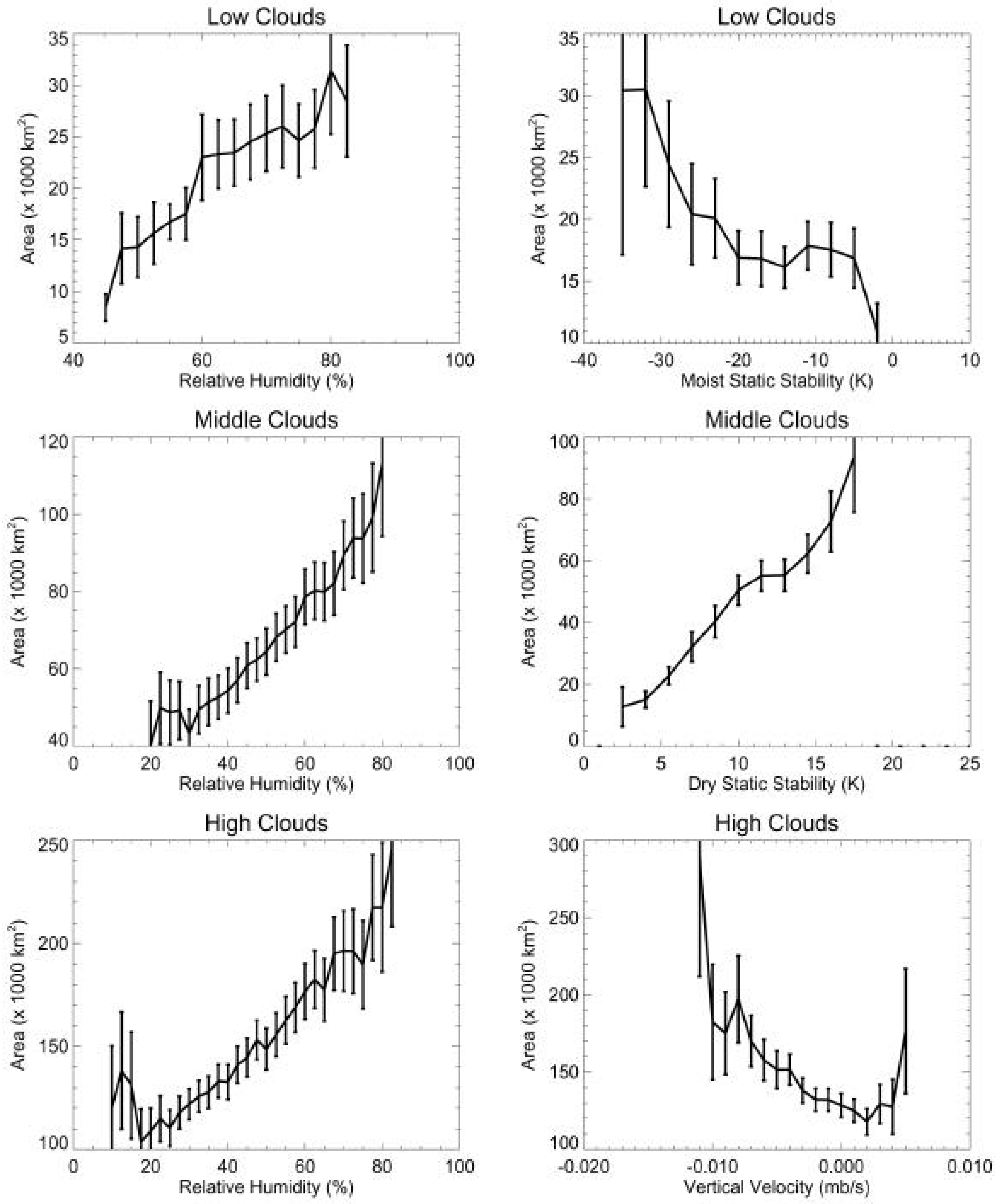

Figure 1. Relationships between cloud area and layer averaged meteorological parameters for low clouds (upper panel), middle clouds (middle panel), and high clouds (lower panel). Error bars represent standard error for cloud areas within each bin.

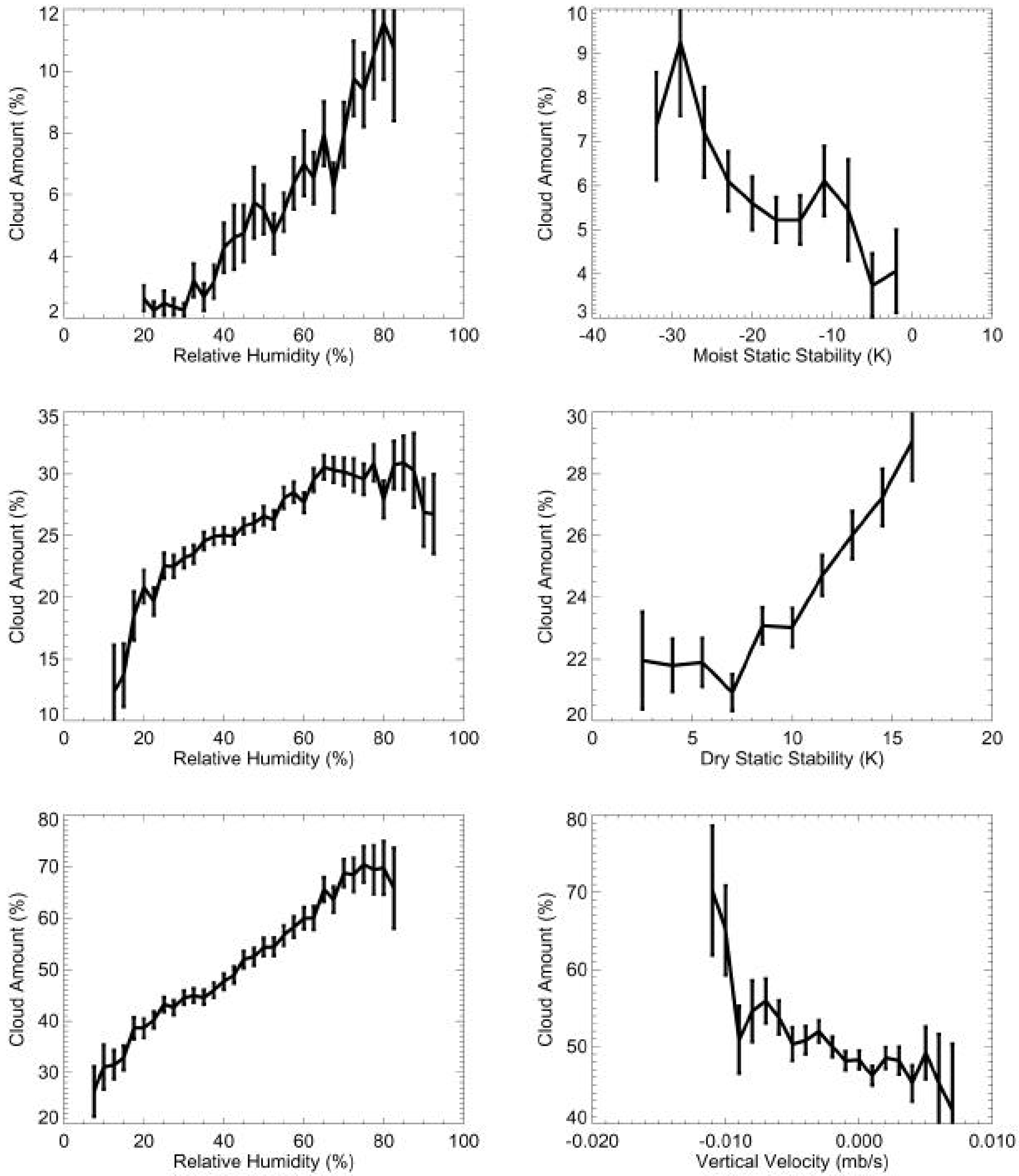

Figure 2. Same as Figure 1 except for cloud amount.