DOE/SC-ARM/P-09-012

Cloud Occurrence Frequency at the Barrow, Alaska, ARM Climate Research Facility for 2008

Third Quarter 2009
ARM and Climate Change Prediction Program Metric Report

M. Jensen, Brookhaven National Laboratory
K. Johnson, Brookhaven National Laboratory
J.H. Mather, Pacific Northwest National Laboratory

June 2009

Work supported by the U.S. Department of Energy,
Office of Science, Office of Biological and Environmental Research

DISCLAIMER

Contents

Figures

1. Introduction

Clouds represent a critical component of the Earth's atmospheric energy balance as a result of their interactions with solar and terrestrial radiation and a redistribution of heat through convective processes and latent heating. Despite their importance, clouds and the processes that control their development, evolution and lifecycle remain poorly understood. Consequently, the simulation of clouds and their associated feedbacks is a primary source of inter-model differences in equilibrium climate sensitivity. An important step in improving the representation of cloud process simulations is an improved high-resolution observational data set of the cloud systems including their time evolution. The first order quantity needed to understand the important role of clouds is the height of cloud occurrence and how it changes as a function of time. To this end, the Atmospheric Radiation Measurement (ARM) Climate Research Facilities (ACRF) suite of instrumentation has been developed to make the observations required to improve the representation of cloud systems in atmospheric models.

In 2009, the ARM Program and the Climate Change Prediction Program (CCPP) have been asked to produce joint science metrics. For CCPP, the third quarter metrics are reported in *Coupled Model Comparison with Observations Using Improved Dynamics at Coarse Resolution*. For the ARM Program, the third quarter metrics are to, "Produce and make available, new continuous time series of cloud frequency, based on one year of observations from Barrow, Alaska, during the International Polar Year." To accomplish this metric, observations from the 35-GHz millimeter cloud radar (MMCR), micropulse lidar (MPL), and ceilometer have been combined using the Active Remote Sensing of Clouds (ARSCL) value-added product (Clothiaux et al. 2000) to produce cloud boundaries and time-height profiles of cloud location (among other important radar-observed quantities). From these instantaneous profiles of cloud location, hourly statistics of cloud occurrence frequency as a function of height are compiled and reported in a single annual file.

2. Cloud Occurrence Frequency Profiles

At each permanent ACRF site, data from the MMCR and MPL, as well as ceilometer and surface precipitation measurements have been synthesized to produce best-estimate time-height profiles of hydrometeor locations, radar reflectivities, mean Doppler velocities and Doppler spectral widths using the ARSCL value-added products (Clothiaux et al. 2000). None of the instruments alone can see the entire vertical cloud profile at all times. Cloud radars can miss thin clouds, particularly cirrus clouds, and cannot clearly distinguish cloud boundaries from precipitation and drizzle. Lidars cannot penetrate thick low-level clouds to see higher cloud layers that may lie above. The MMCR has several distinct operating modes, each optimized for specific types and locations of clouds and precipitation. The ARSCL software incorporates the different radar observing modes while correcting them for possible artifacts, such as velocity aliasing, or pulse-coding effects. The resulting best-estimate reflectivity observations are merged with MPL and ceilometer-determined cloud bases to separate cloud from precipitation returns and to help in the identification and removal of insect and other non-hydrometeor "clutter" radar returns. In addition, lidar observations of thin cirrus clouds, which the radar alone can miss due to incomplete radar beam filling or insufficient sensitivity, are incorporated into the product's results.

Daily data files include time sequences of cloud boundaries, specifically ceilometer cloud base, MPL/ceilometer best-estimate cloud base, radar-derived first cloud top, combined radar-MPL cloud base and top for up to 10 cloud layers for each time, the MPL derived cloud mask, original and masked MMCR reflectivity, and masked mean Doppler velocity and spectral width at a temporal resolution of 10 seconds and a vertical resolution of approximately 45 m. These daily files (arscl1cloth) are available in the ACRF Data Archive (http://www.archive.arm.gov/). From these daily files, statistics of cloud occurrence frequency are compiled based on the merged radar-MPL cloud boundaries. The hourly cloud occurrence frequency for each height bin is calculated as the ratio of the number of positive cloud detections and the number of total observations. A single annual file has been produced that reports this hourly cloud frequency over the Barrow, Alaska, site as a function of time and altitude.

The most striking feature in the plot of the annual cycle of the frequency of cloud occurrence (shown in Figure 1) is the increase in the depth of the layer of low-level stratiform cloud occurrence during the fall (September-November) months. This feature of the annual cloudiness cycle in the Arctic has been shown previously by Intrieri et al. 2002 and others. These changes are related to variability in the dominant cloud forcing mechanisms over the course of the seasonal cycle (Shupe et al. 2009). During the fall, surface forcing from open water sources dominates radiative cooling resulting in a well-mixed boundary layer with increased vertical motions and turbulence resulting in thicker clouds. During the spring, radiative cooling is the dominant cooling mechanism and the resultant clouds are decoupled from the surface resulting in less vertical transport and thinner clouds.

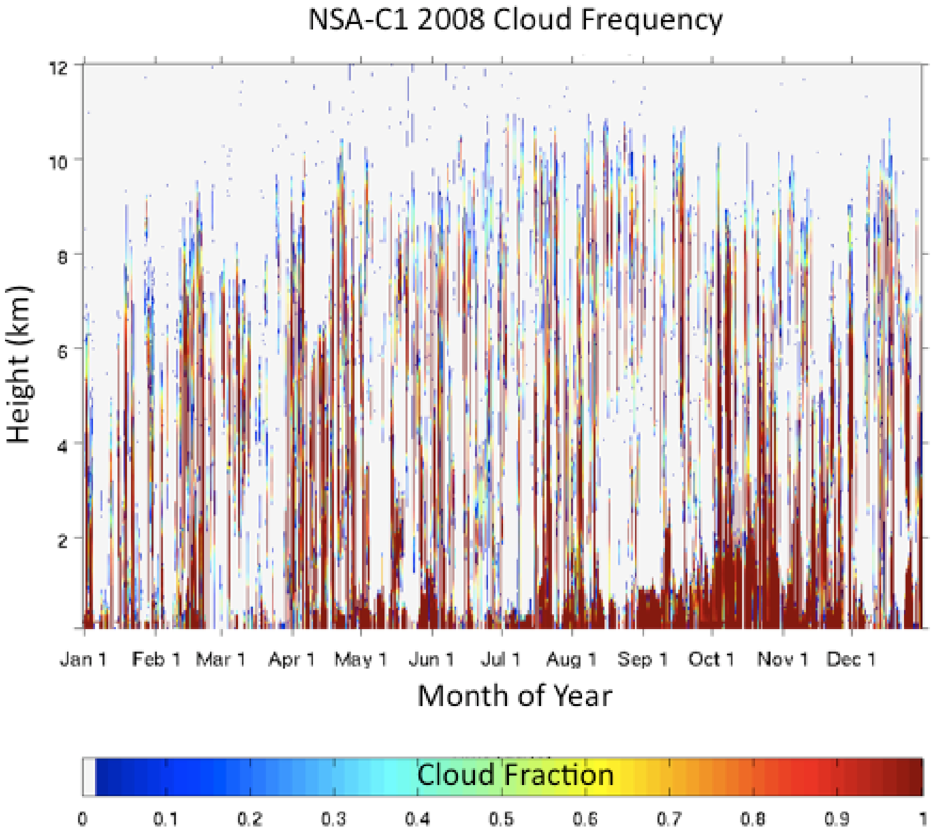

Figure 1. Hourly cloud occurrence frequency Barrow, Alaska, from the ARSCL value-added product.

3. References

Clothiaux, EE, P Ackerman, GG Mace, KP Moran, RT Marchand, MA Miller, 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.

Intrieri, JM, MD Shupe, T Uttal, and BJ McCarty. 2002. "An annual cycle of arctic cloud characteristics observed by radar and lidar at SHEBA." *Journal of Geophysical Research*, 107, 10.1029/2000JC000423.

Shupe, MD, DD Turner, E Eloranta, and P Kollias. 2009. "A comparison of spring and fall arctic mixed-phase clouds: Perspectives from the surface during ISDAC and M-PACE. Presented at the Nineteenth Atmospheric Radiation Measurement Science Team Meeting. Louisville, Kentucky