A Case Study of Horizontal Variability in Arctic Cloud Microphysical Properties

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Overview

The importance of arctic cloud properties to the surface radiative flux budget is well known, and accurate representation of these clouds is essential to proper modeling of the arctic environment. One of the interesting characteristics of arctic clouds is the prevalence of mixed phase cloud layers. In these mixed-phase clouds, the water content tends to dominate the radiative effects, causing them to act as all liquid clouds. Measurements have shown these clouds to be highly inhomogeneous in terms of ice and liquid water content. The horizontal dimension is important to proper interpretation of remotely sensed data where properties are averaged over space and/or time. It is also of interest to the modeling community for the parameterization of sub-grid scale features. The objective of this research is to characterize the horizontal variability of the cloud microphysical properties sampled during the Mixed-Phase Arctic Cloud Experiment (M-PACE).

Case Study

The cloud on October 9, 2004, was a single-layer mixed-phase stratus forced by cold air flowing off the arctic ice pack over open ocean water (Figure 1). The cloud layer formed in a well-mixed boundary layer. The low-level wind had a slight on-shore component and the clouds developed in rolls parallel to the flow. The cloud depth increased with distance from the ice pack, as in Harrington and Olsson (2001). The University of North Dakota (UND) Citation aircraft sampled from Oliktok Point to Barrow, a distance of ~250 km (Figure 1), with ramp climbs/descents and level legs (Figure 2).

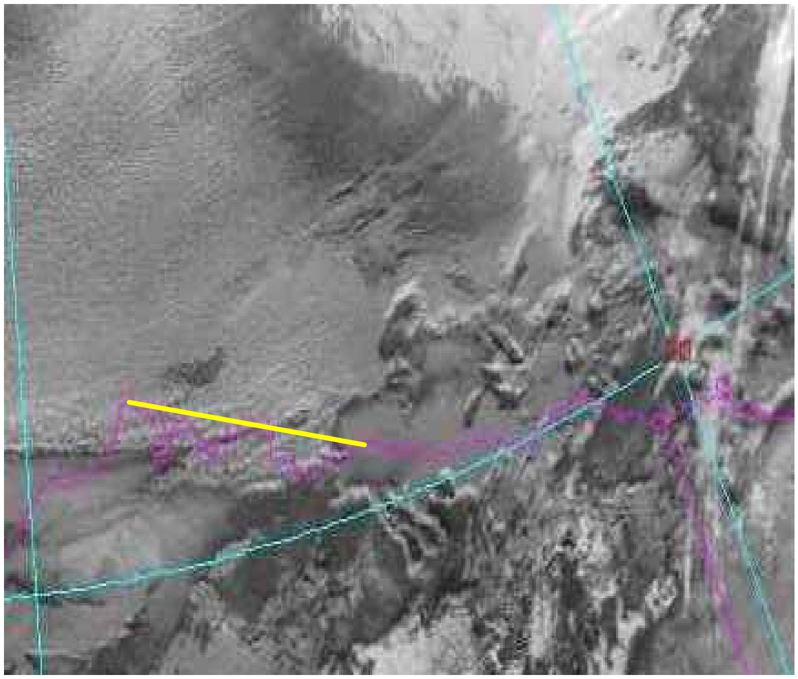

Figure 1. An advanced very-high-resolution radiometer image from 2352 Universal Time Coordinates (UTC). The yellow line is the Citation tract.

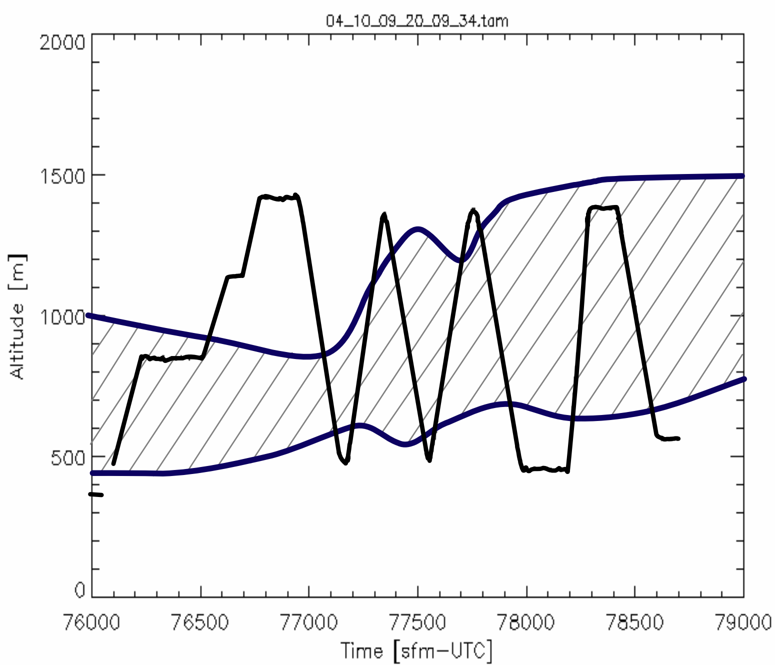

Figure 2. Citation time-height with estimated cloud boundary.

Horizontal Variability

The climb/descent profiles present a challenge to deriving horizontal variations. The liquid water content vertical profile was nearly adiabatic but the number concentration was typically constant. Precipitation ice columns extended throughout the cloud depth (Verlinde et al. 2006). The approach shown is to use relatively short-level legs for small-scale variability, continuous in cloud flight segments for mid-scale variability and averaged values to look at larger scale variations.

Small to Mid-Scale

Time series of liquid water content and vertical wind are shown with probability distributions in Figure 3. The fluctuations suggest spatial scales of 6-8 km. Images from the CPI (Figure 4) show liquid water and ice crystals (some unrimed) in close proximity.

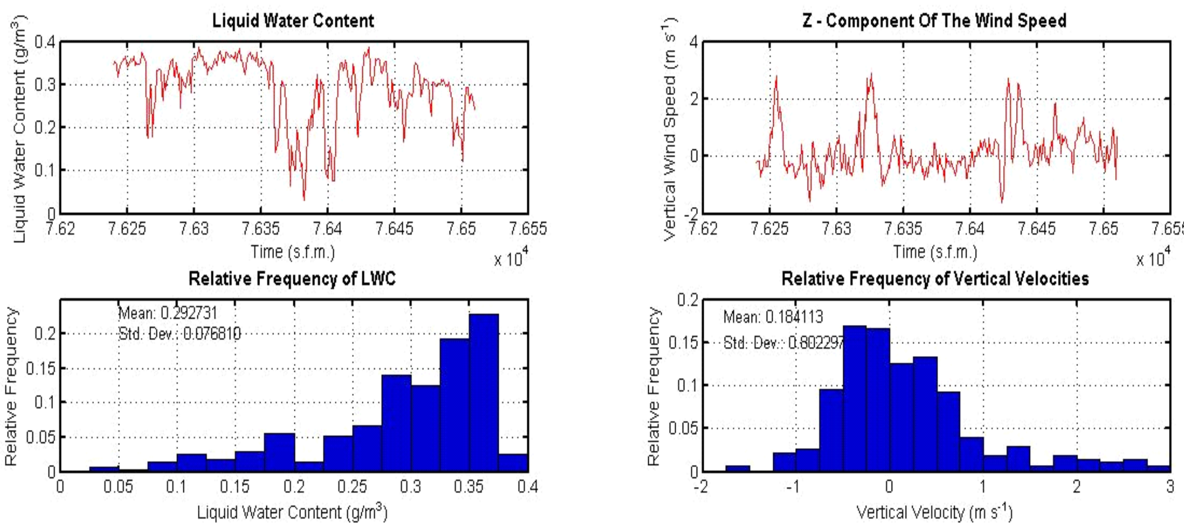

Figure 3. Liquid water (left) and vertical wind (right) from level leg.

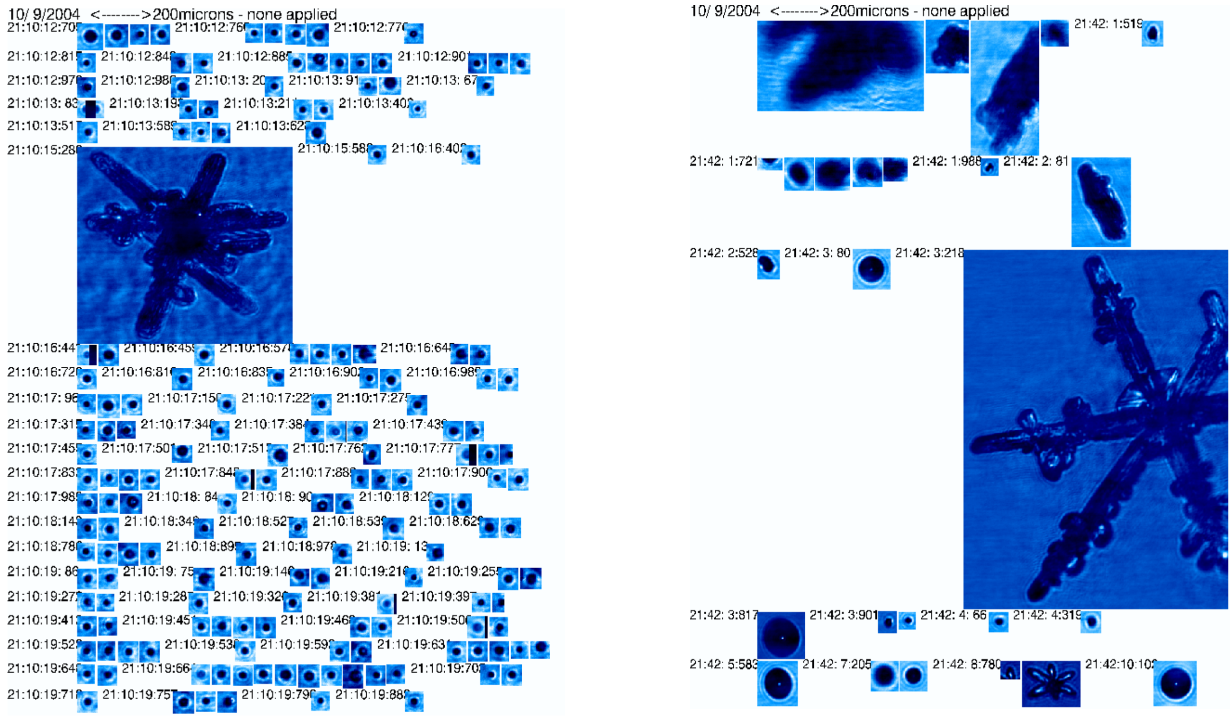

Figure 4. CPI images in cloud (left) and below cloud (right).

Larger Scale

Average liquid water content, droplet concentration and droplet diameter are shown in Figures 5-7. These values are derived from the ramp climbs and descents, with the cloud partitioned into three layers. The horizontal scale represents about 200 km. Liquid water content and drop diameter generally increased with distance from the ice pack while the concentrations varied on a scale of ~100 km. A time series of two-dimensional cloud (2-DC) concentrations (Figure 8) shows an increase with time due to higher numbers of ice crystals.

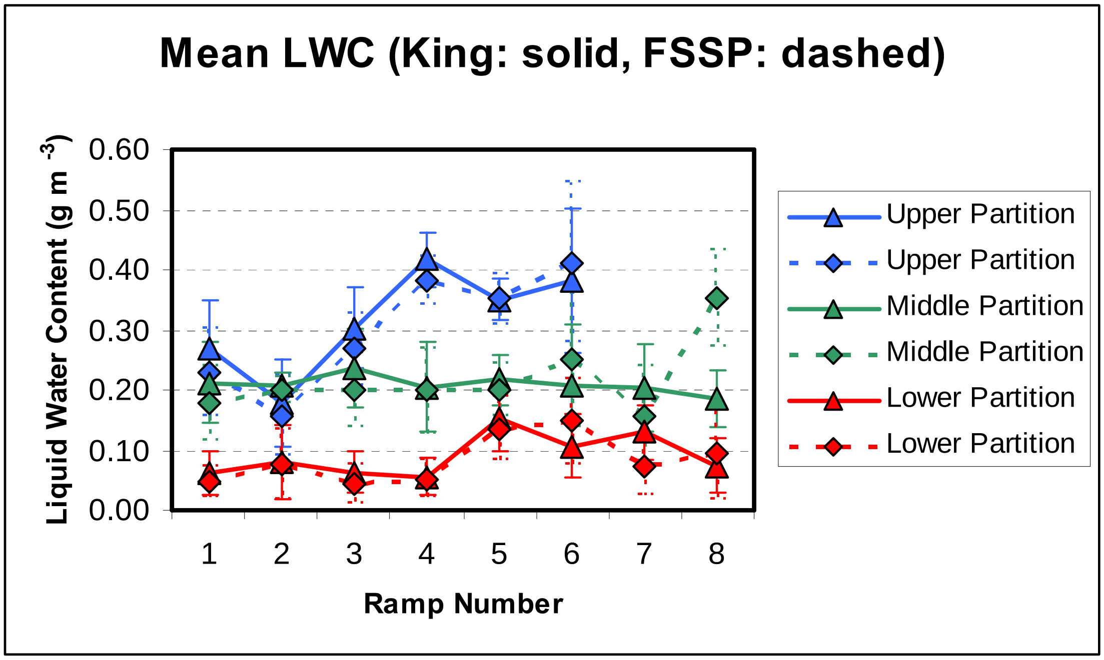

Figure 5. Mean liquid water content (King probe).

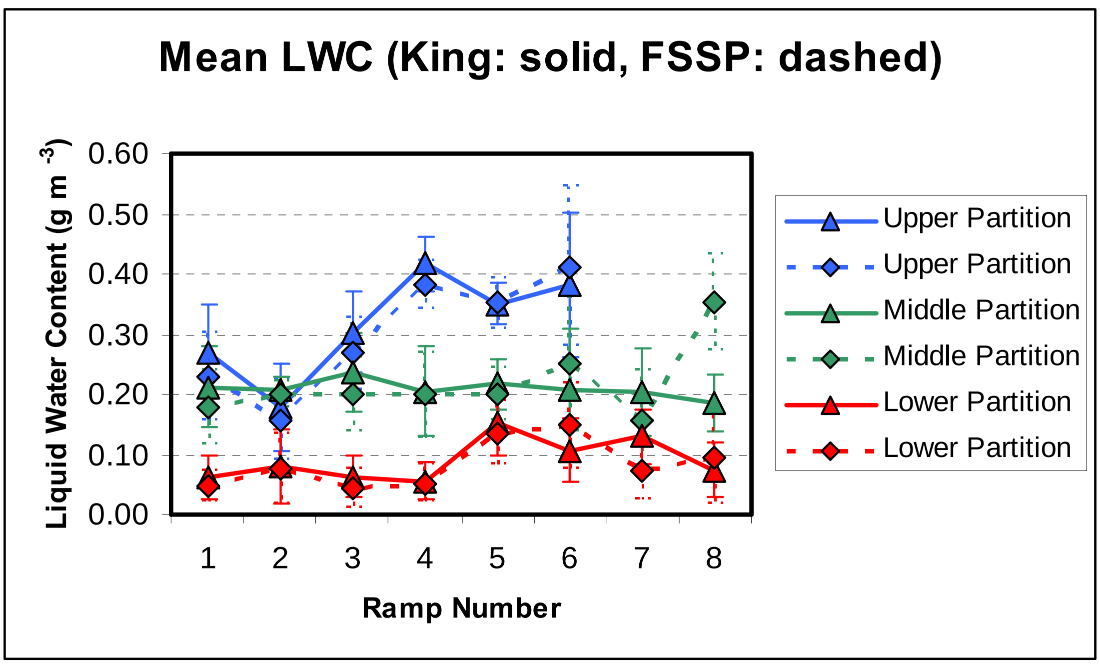

Figure 6. Mean droplet concentration forward scattering spectrometer probe (FSSP).

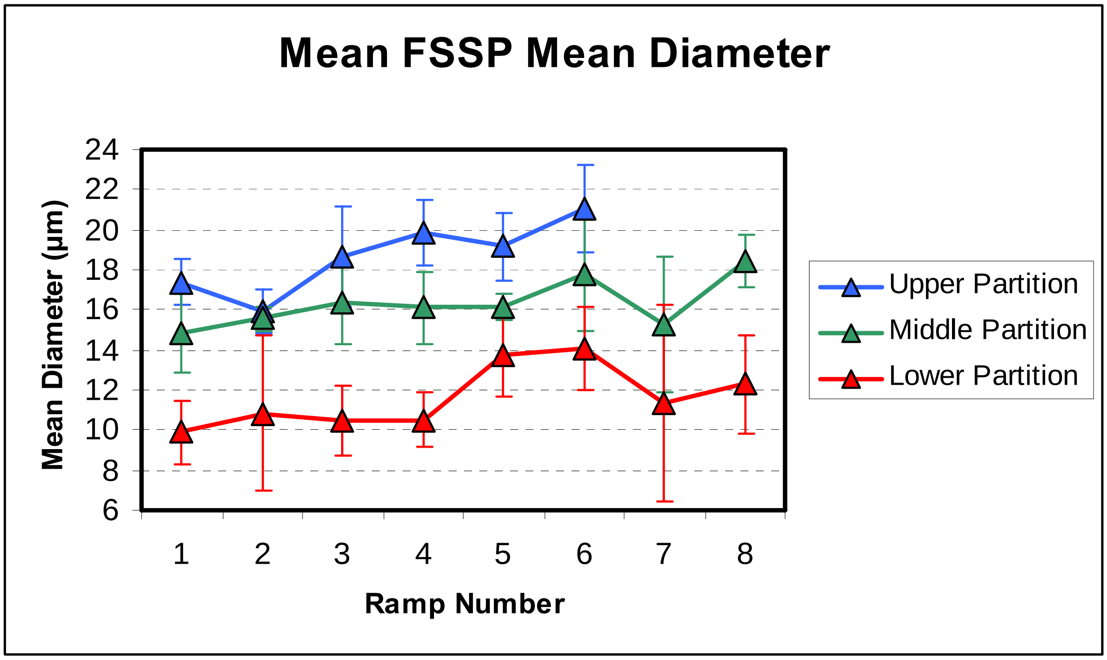

Figure 7. Mean droplet diameter from FSSP.

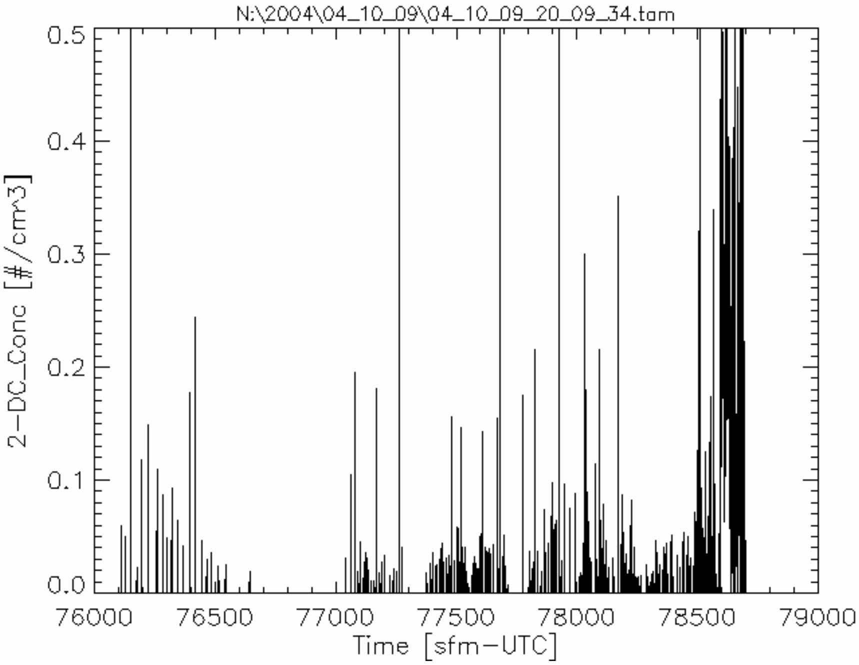

Figure 8. Two-dimensional cloud (2-DC) concentrations.

Preliminary Observations

Some observations during this period are as follows:

- Small-scale variability of microphysics and dynamic forcing is evident on scales from tens to hundreds of meters
- Larger features appear on the scale of ≥100 km
- This cloud evolved as its air mass traveled over open ocean
- Some ice crystals are able to grow to large sizes in a mixed-phase environment before significant riming occurs.

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Contact

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