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Observations and Cloud-Resolving Simulations of Arctic Stratus

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Introduction

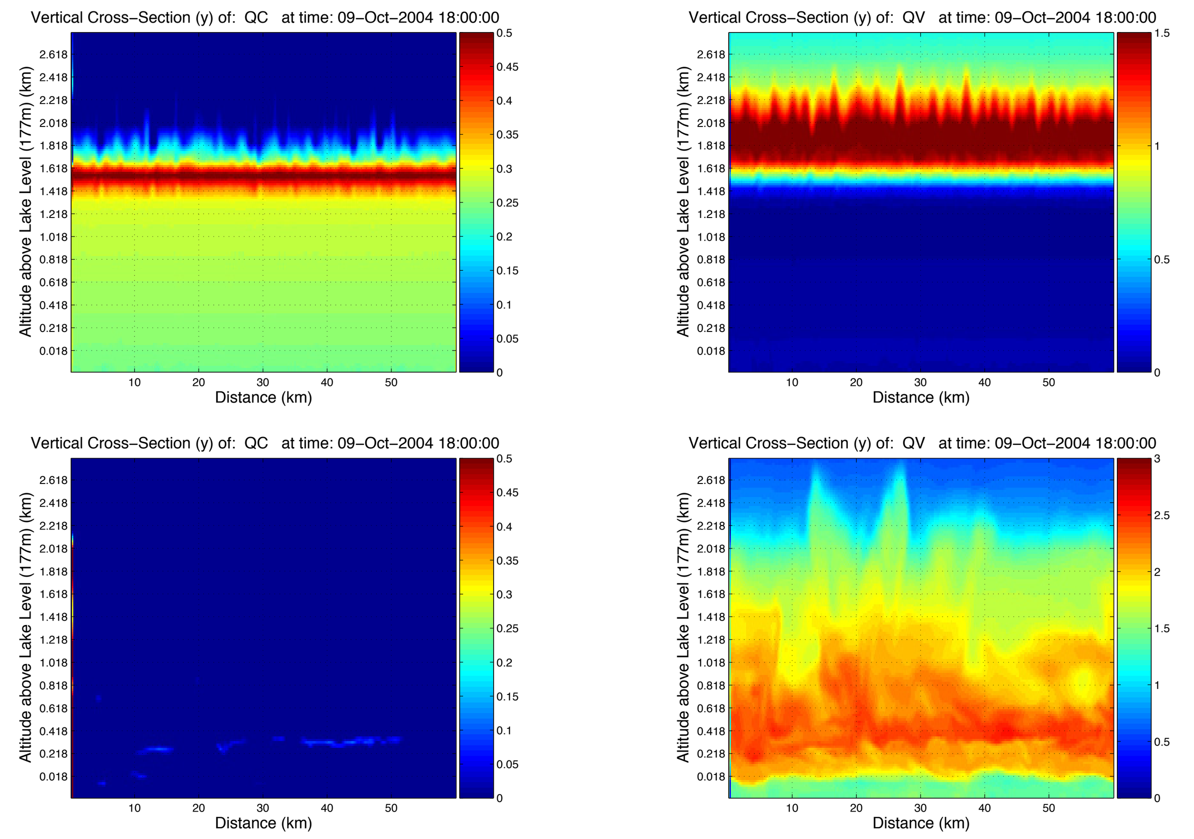
Clouds have always presented a challenge in the development and improvement of numerical simulation of atmospheric processes. Particularly challenging is the simulation of mixed-phase cloud structures, primarily because of their complex evolution and lifecycle. In order to better understand the lifecycles of mixed-phase arctic clouds, particularly how these lifecycles are handled by models, our group is providing high-resolution simulations and observations of these cloud structures. These efforts represent a portion of the work being completed by the ARM Cloud Parameterization and Modeling workgroup to improve parameterizations of mixed phase cloud layers at high latitudes in climate scale models.

The emphasis of our work has thus far been on the observational side. The University of Wisconsin Arctic High-Spectral Resolution Lidar (AHSRL) has been deployed in Barrow, AK as part of the Mixed-Phase Arctic Clouds Experiment (M-PACE), and in Eureka, Canada as a part of the long-term Study of Environmental Arctic Change (SEARCH). These deployments have been as a part of large instrument clusters, and we are still working on gaining additional information out of combined instrument measurements. One combination that has proven to be very beneficial is that of the AHSRL and a NOAA-ETL Millimeter Cloud Radar (MMCR). Together, measurements from these instruments lead to effective retrieval of important microphysical properties. These retrievals mirror those implemented by Donovan and Van Lammeren (2001) and have been modified and updated by our group. Some examples and a brief overview are shown below.

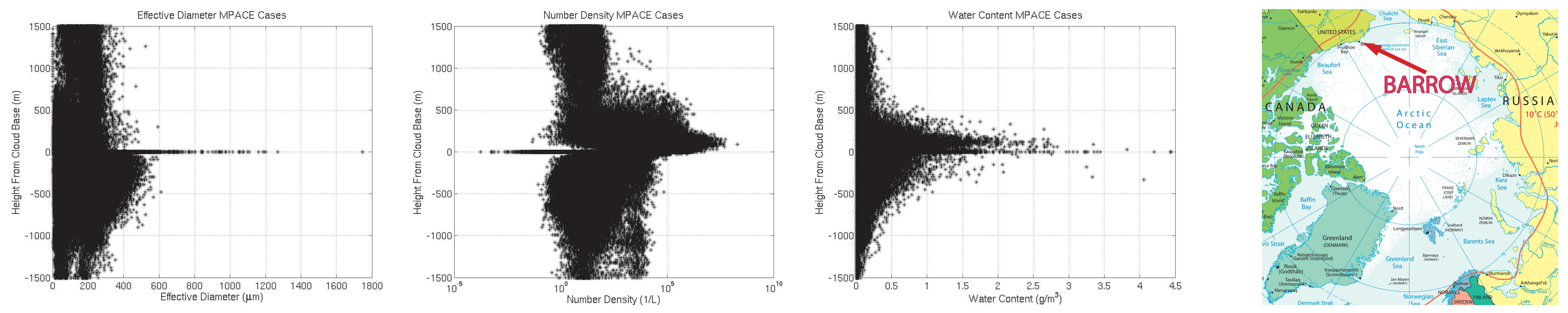
The next step is proper simulation of these situations. Preliminary simulations have done an excellent job of outlining the challenge, with ice microphysics wreaking havoc on the structure of these clouds. Main points of interest will be understanding the general cloud dynamics, as well as understanding and documenting the role that ice nuclei (IN) and cloud nuclei (CCN) in the correct maintenance and simulation of these clouds. To do this, we are using the University of Wisconsin Non-Hydrostatic Modeling System (Tripoli, 1992), which has been updated to include the Spectral Habitat Ice Prediction System (SHIPS, Hashino and Tripoli, Talk 2.4).

The Challenge

Improving simulation capabilities in the area of mixed phase stratus clouds. Below are shown cloud and vapor mixing ratio from simulations without ice (top) and with ice (bottom). When ice is added, the cloud strucutre is depleted by the presence of ice. Observations show these mixedphase scenarios to be long-lived, however (see lidar and radar observations, right).



M-PACE Observations from Barrow, AK



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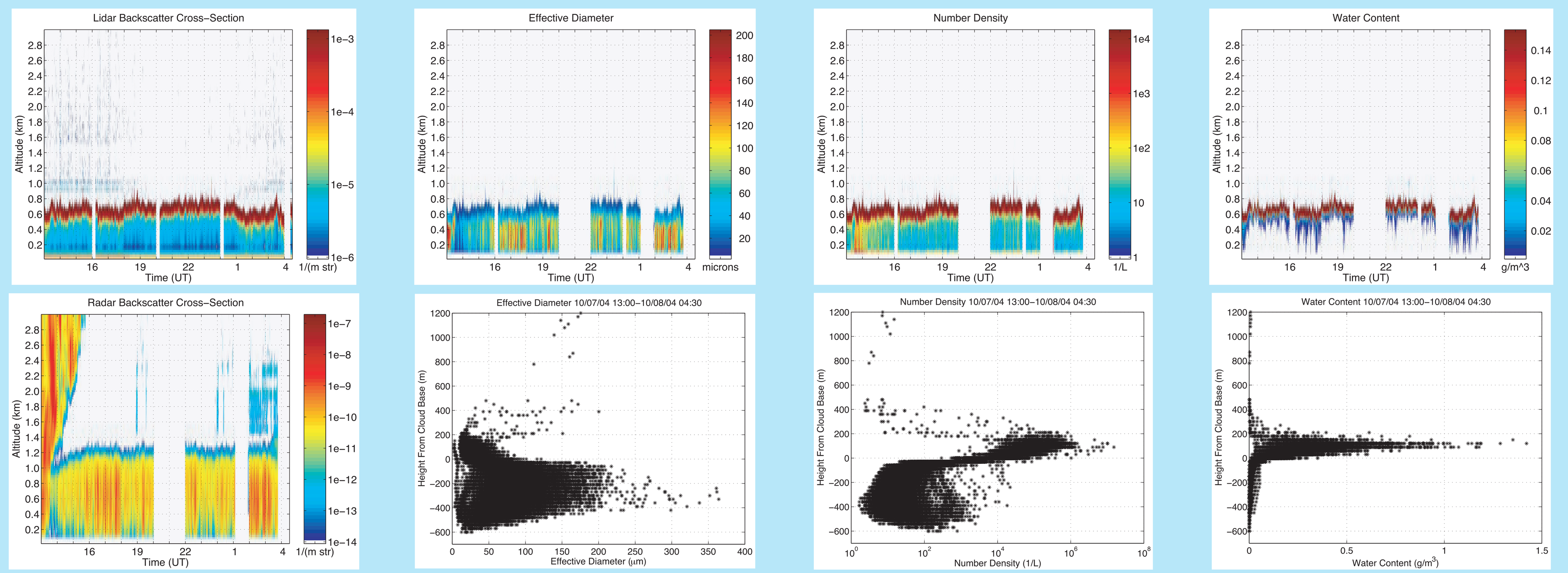

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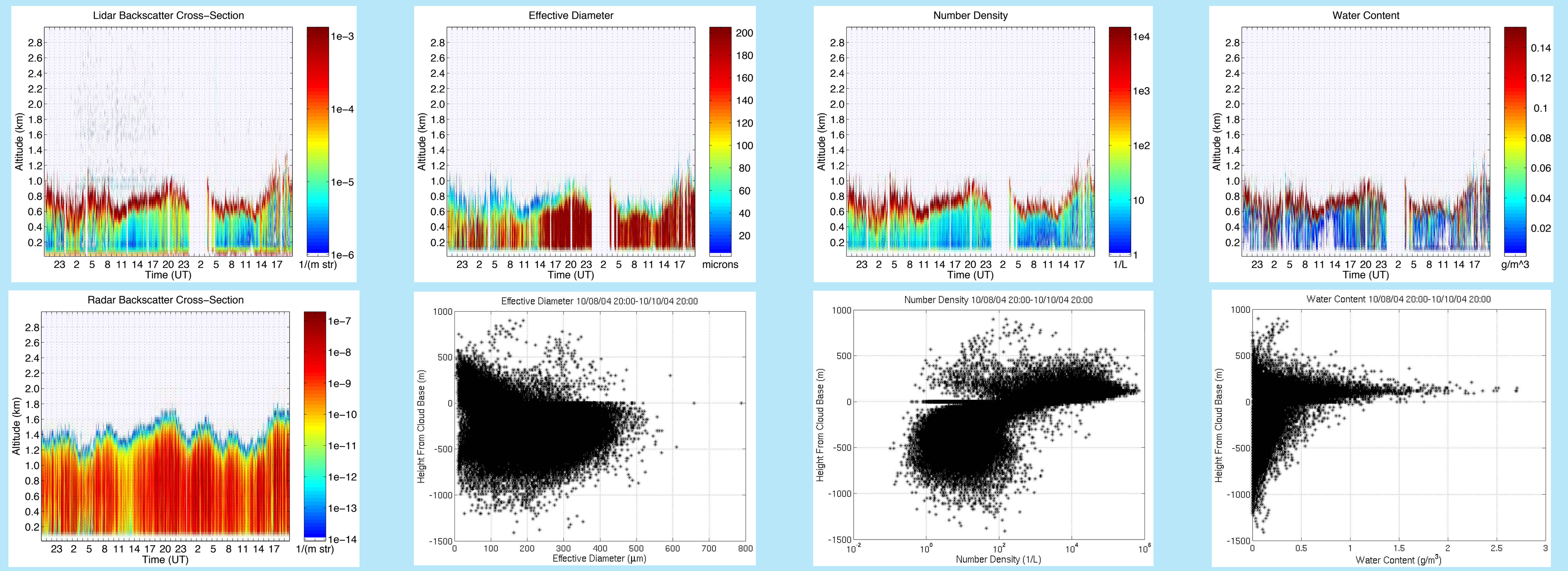
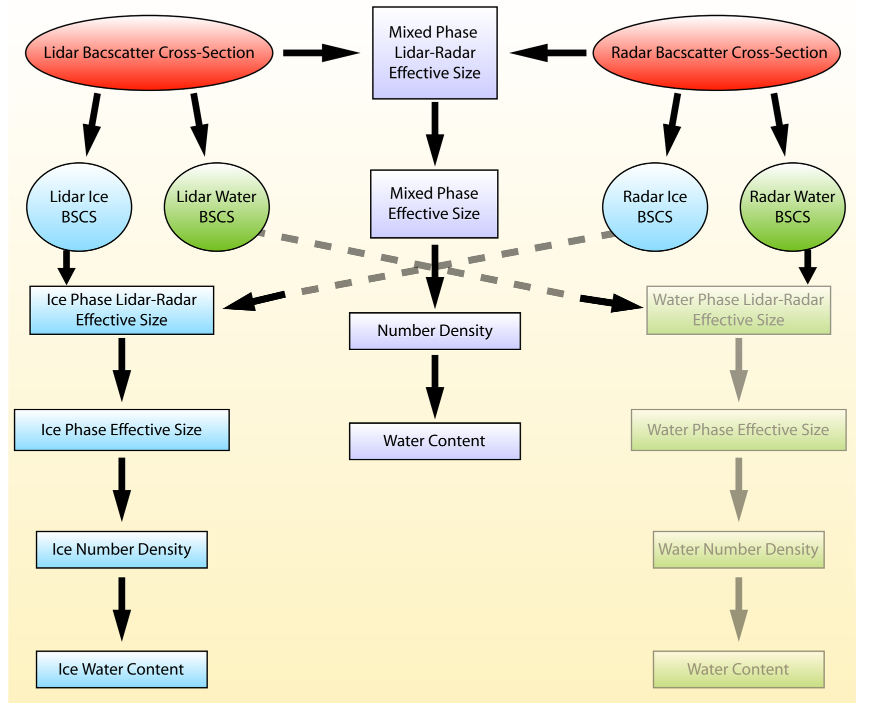


Retrieval Method

The technique used mirrors that introduced by Donovan and Van Lammeren (2001), and has been modified by Eloranta to work with the available instruments. Visually outlined below, it utilizes the backscatter cross-sections from both the AHSRL and MMCR to estimate an effective particle size. From there, number density and water contents are estimated. The figure above outlines the steps in the retrieval process. Note that the water only retreival is shown to be semi transparent. This is because there is very little contribution to the radar backscatter cross-section in mixed phase situations.



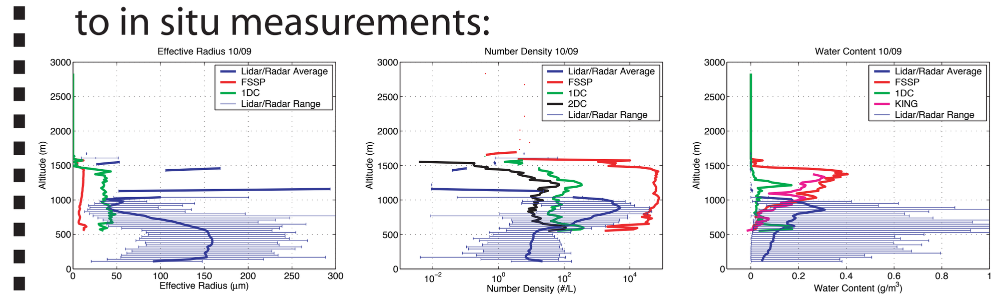
Because we are not able to measure individual particles, we must make an assumption about the distribution of particles in the scattering volume. Here, a modified Gamma distribution has been used:

$$n(D) = aD^{\alpha}e^{-bD^{\gamma}}$$

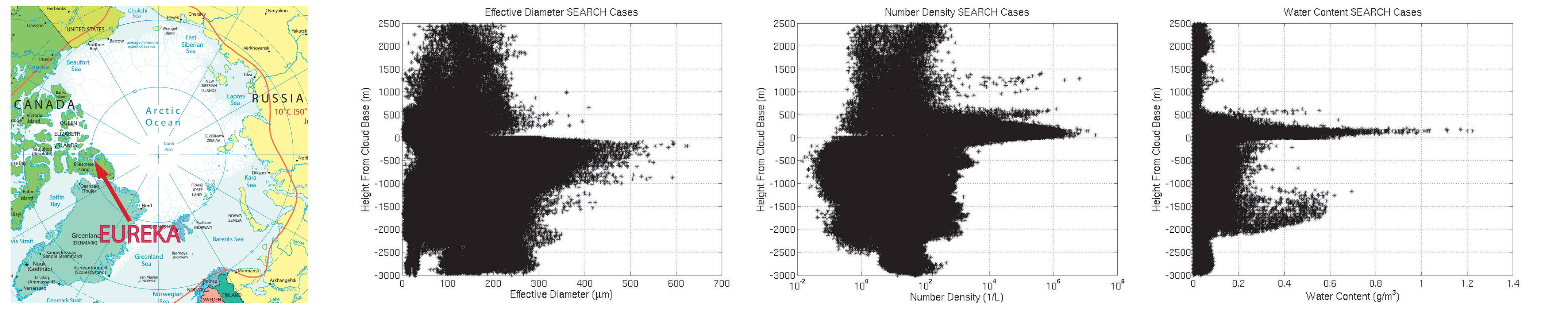
Also, we make assumptions about the relationships between particle diameter and volume and area:

$$V = \sigma_V \frac{\pi}{6} D^{3-\delta_V} D^{\delta_V} \qquad A = \sigma_A \frac{\pi}{4} D^{2-\delta_A} D^{\delta_A}$$

The plots below compare these retrieval techniques to in situ measurements:



SEARCH Observations from Eureka, Canada



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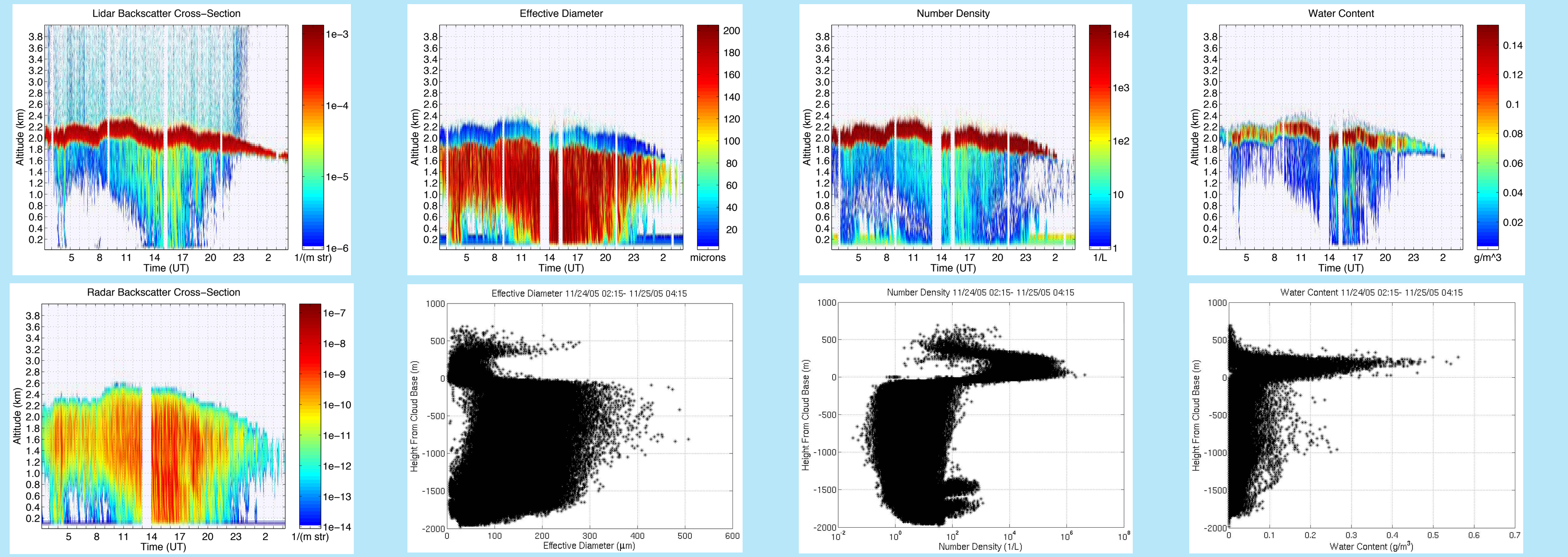

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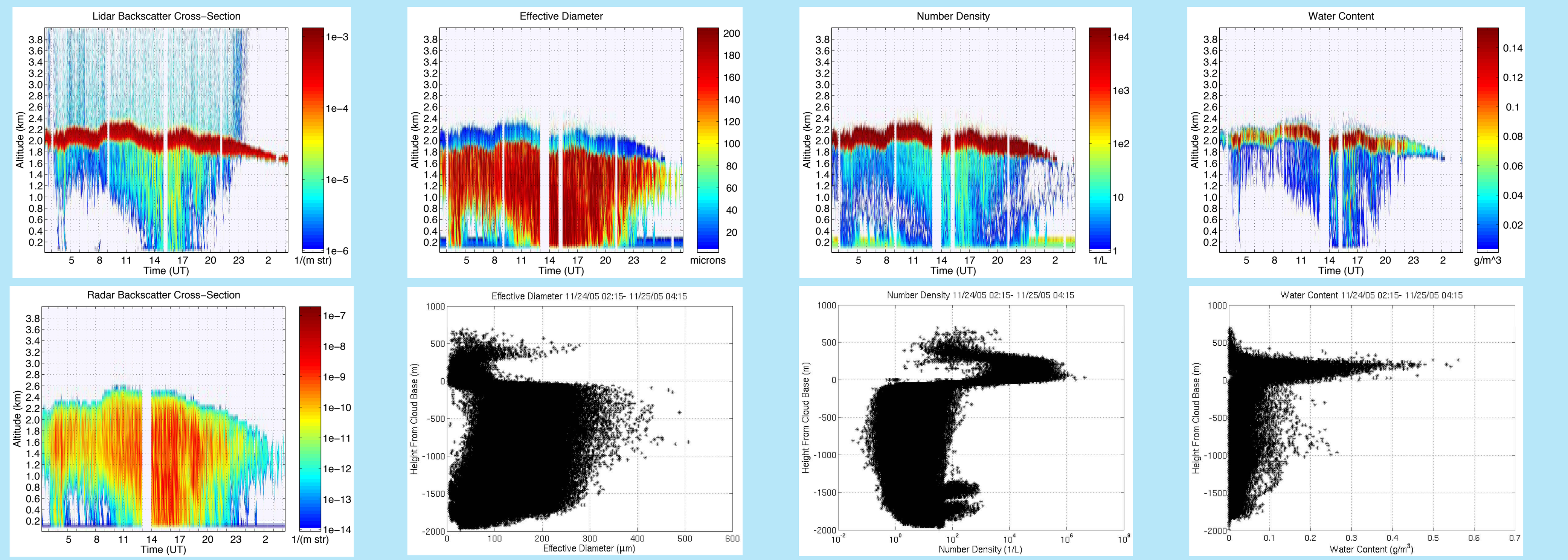

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