A Proposed Study of the Interaction Between Aerosols and Arctic Stratocumulus

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Introduction

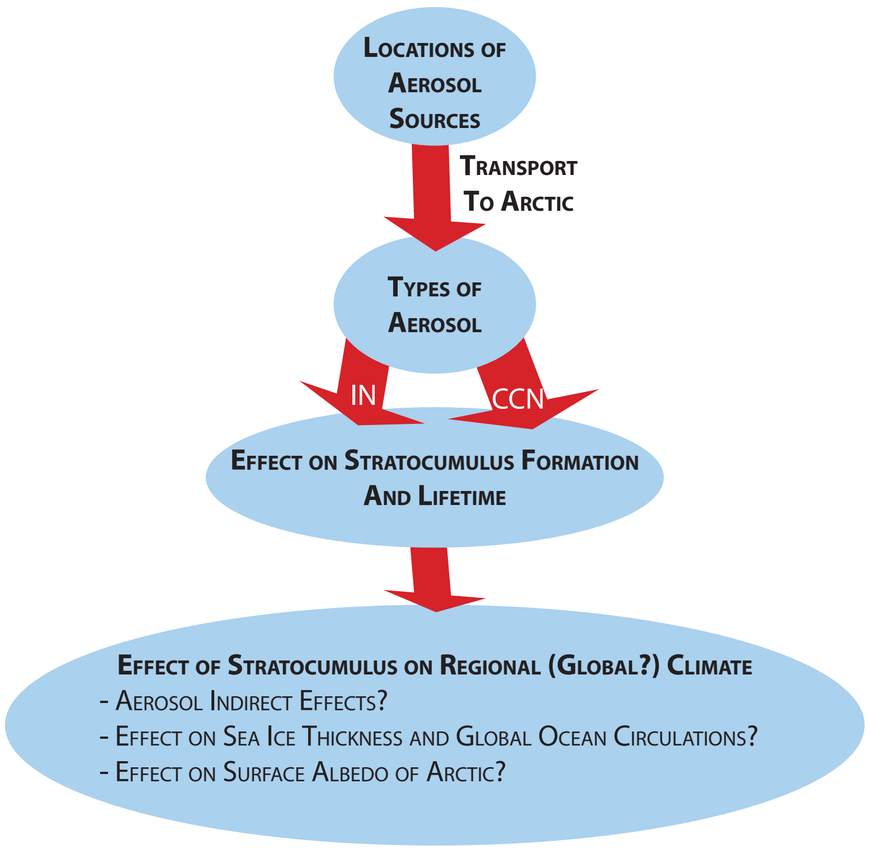
The arctic region is one of particular interest in climate studies because of possible implications of large-scale climate changes in that region, and because of the lack of understanding of processes occurring there. One of several important potential climate forcings in this region is the dependence of sea-ice thickness to the radiative properties of clouds (Curry and Ebert, 1990). Past climate studies have indicated that changes in sea-ice cover have the potential to affect general ocean circulation patterns, leading to global climatic changes (Broecker et al., 2001). Therefore, accurate and thorough understanding of arctic cloud properties and coverage, as well as accurate simulation of these characteristics in Global Climate Models (GCMs) are vital to furthering our ability to understand global climate change.

One of the most intriguing and challenging issues to be addressed is the proper replication and handling of mixed-phase arctic stratocumulus clouds. Some of these lower tropospheric cloud decks persist for many days, and the mechanisms behind their longevity are yet to be well understood. A recent study by Harrington and Olsson (2001) pointed to the presence but relatively small abundance of ice-forming nuclei (IN) as a major influence on the maintenance of these types of clouds. Although this is likely a part of the solution, the theory presented appears to result in an unstable situation in which the cloud structure is highly sensitive to the IN population. Since these clouds are known to persist for long periods of time, it would seem additional mechanisms must be involved. In addition to a lack of understanding of the microphysics involved, there is also a lack of understanding of the sources, types, and transport mechanisms of the ice nuclei in question.

As part of the Study of Environmental Arctic Change (SEARCH, 2001) the University of Wisconsin Arctic High Spectral Resolution Lidar (AHSRL, Eloranta, 2005) will be deployed to Eureka, Canada during the summer of 2005 along with a suite of measuring devices to capture important cloud microphysical properties and relative CCN and IN concentrations.

This study proposes the incorporation of an aerosol scheme into the University of Wisconsin Non-Hydrostatic Modeling System (UW-NMS, Tripoli, 1992) so that it can be used as an investigative tool to study the potential mechanisms and transport processes supporting the longevity of these stratocumulus, as well as their general microphysical characteristics. The data collected at the SEARCH site in Eureka will provide an excellent means of model validation, while simultaneously serving as a source of independent insight into the structure and maintenance of these long lasting cloud formations.

Central Uncertainties



SEARCH

SEARCH stands for the **S**tudy of **E**nvironmental **A**rctic **Ch**ange. It is a collaborative effort headed by the University Of Washington, and includes contributions by the Departments of Agriculture, Defense, Energy, and the Interior, as well as NOAA, NASA, NSF, and the Smithsonian Institute. Additional information is available at: http://psc.apl.washington.edu/search .

Eureka is situated on Ellesmere Island at near 80 N latitude.

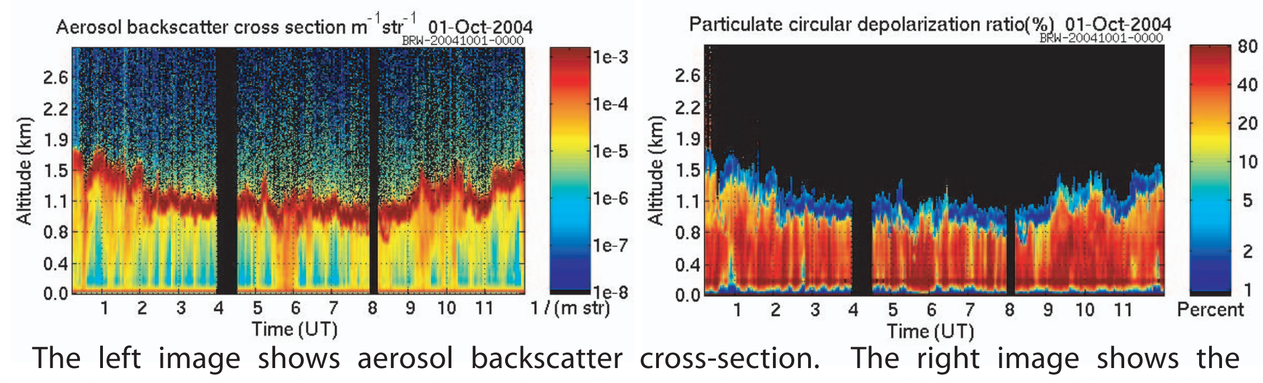
List of Instruments

- Univ. of Wisconsin Arctic High Spectral Resolution Lidar
- ETL Millimeter Cloud Radar
- Ground-Based Scanning Radiometer (GSR)
- Integrating Nephelometer
- Condensation Particle Counter
- Particle/Soot Absorption Photometer
- 8 channel sun photometer
- Licor LI-7500 fast H_2O/CO_2
- Daily Rawinsondes
- Thermistors, Hygrometers, Anemometers, Snow Gauges
- Total Sky Imager
- Pryheliometer
- Pyranometers
- Sonic Anemometers
- Vaisala T/RH Probe

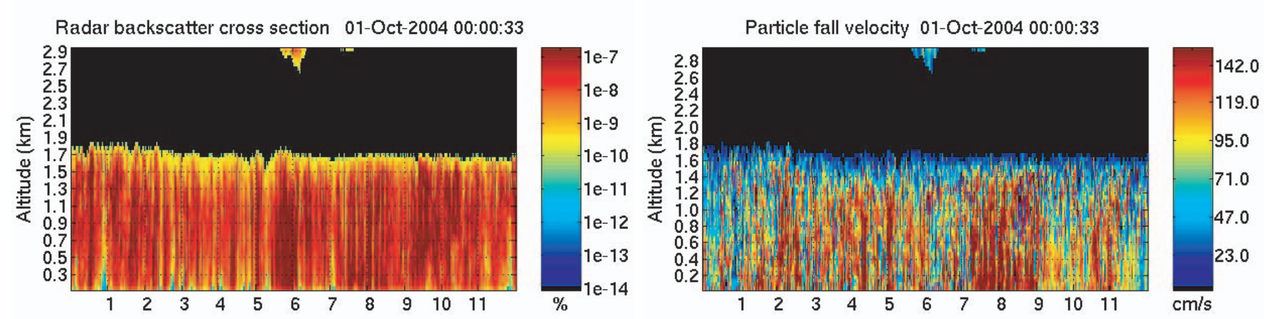
UW-AHSRL

The **U**niversity of **W**isconsin **A**rctic **H**igh-**S**pectral **R**esolution **L**idar was developed for routine, untended measurement of arctic clouds and aerosols. Unlike traditional lidars, the AHSRL is capable of attaining calibrated measurements of aerosol backscatter cross-section, polarization and optical depth by using the molecular return as a reference channel. Additional information that can be obtained with the help of a cloud radar (to be installed at the SEARCH site) includes effective particle size, and potentially liquid and ice water content. Additional information is available at http://lidar.ssec.wisc.edu .

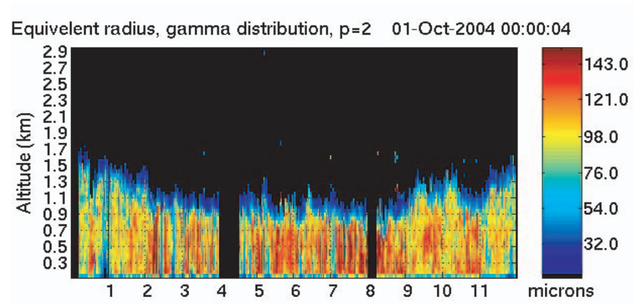
Examples from the Mixed-Phase Arctic Clouds Experiment (M-PACE)

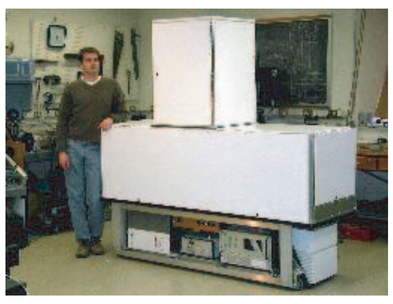


The left image shows aerosol backscatter cross-section. The right image shows the particulate circular depolarization ratio, and reveals that we are looking at a liquid cloud (low depolarization) with frozen precipitation (high depolarization).



The left image shows backscatter cross-section from the 8.6 cm wavelength ARM NSA radar. The right image shows the particle fall velocity from the same radar. The horizontal axis is time (UT).

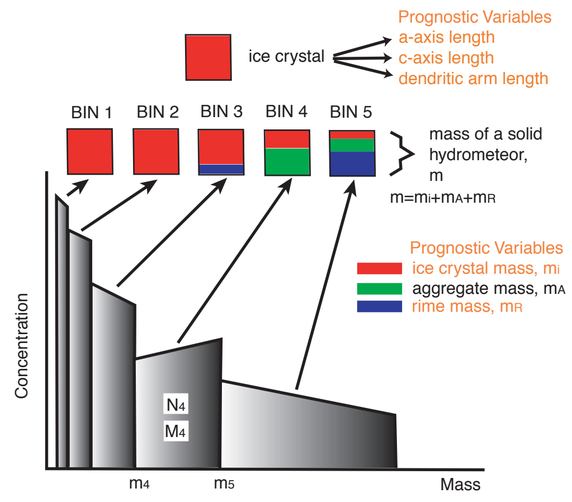


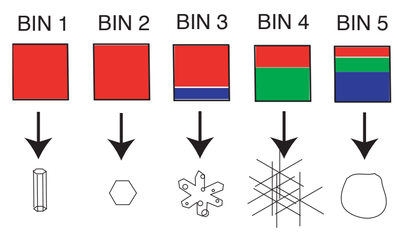


Assuming a gamma distribution of particle sizes, we can derive the equivalent radius of particles from a combination of the radar and lidar data, as shown above. The system is shown in its housing in the right image.

UW-NMS

The **U**niversity of **W**isconsin **N**on-Hydrostatic **M**odelling **S**ystem is a non-hydrostatic research model used to investigate processes at a large range of scales, from hemispheric to micro-β. The model has several important features, including scalability in all directions, terrain-following step topography, two-way interactive grid nesting, long and shortwave radiation parameterization, and a 1.5 level TKE turbulence closure. It is currently being updated to include the Spectral Habitat Ice Prediction System (SHIPS, Hashino and Tripoli, in progress). Additional information is available at: http://mocha.meteor.wisc.edu .





References

Broecker, W.S., 2001: The Big Climate Amplifier Ocean Circulation-Sea Ice-Storminess-Dustiness-Albedo The Oceans and Rapid Climate Change. Past, Present, and Future. Geophysical Monograph, 126, 53-56.

Curry, J.A. and E.E. Ebert, 1990: Sensitivity of the thickness of Arctic sea ice to the optical properties of clouds. Ann. Glac., 14, 43-46.

Eloranta, E. W., I. A. Razenkov, J. P. Garcia, J. P. Hedrick, 2005: An Automated High Spectral Resolution Lidar for Long Term Measurements in the Arctic, 2nd Symposium on Lidar Atmospheric Applications at the 85th Annual Meeting of the American Meteorological Society, January 9-13, San Diego, CA.

Harrington, J.Y., and P.Q. Olsson, 2001: On the Potential Influence of Ice Nuclei on Surface-Forced Marine Stratocumulus Cloud Dynamics. Journal of Geophysical Research, 106, 27473-27484.

SEARCH SSC, SEARCH: Study of Environmental Arctic Change, Science Plan, 2001, Polar Science Center, Applied Physics Laboratory, University of Washington, Seattle, 89 pp.

Tripoli, G.J., 1992: A Non-Hydrostatic Mesoscale Model Designed to Simulate Scale Interaction. Monthly Weather Review, 120, 1342-1359.

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