REVISITING ESTIMATES OF LONGWAVE AEROSOL INDIRECT EFFECTS IN THIN, LIQUID-CONTAINING ARCTIC CLOUDS

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Introduction

Of the uncertainties surrounding our understanding of global climate, one of the largest involves the relationships between aerosols and clouds along with the resulting impacts on atmospheric radiation and precipitation. Due to very limited profiling of aerosol properties, traditionally aerosol-cloud interactions are evaluated using surface aerosol measurements as a proxy for aerosol at cloud height. At low- and mid-latitudes, clouds often form atop a well-mixed atmospheric boundary layer, meaning that the use of surface-based aerosol measurements is not necessarily unreasonable. At high latitudes, however, the atmosphere is often very stable. This stability limits vertical mixing of aerosols, meaning aerosol properties (e.g., number, hygroscopicity, scattering, size) observed at the Earth’s surface may be very different from those at cloud height. This limitation makes it challenging to interpret previous efforts to understand the impacts of aerosols on liquid-containing Arctic clouds (e.g., Lubin and Vogelmann, 2006).

In this work, we first use a variety of measurements from high-latitude measurement campaigns that included some form of aerosol profiling to demonstrate the relationship between surface and elevated aerosol properties under different stability regimes. Then, using surface-based remote sensors we derive and validate estimates for atmospheric mixing state. This mixing state product is subsequently used to provide revised estimates on the influence of aerosol effects in thin, liquid-containing Arctic stratiform clouds using only cases in which the lower atmosphere is well mixed.

Datasets Used

A variety of long-term (here 2000-2003) datasets from the DOE Atmospheric Radiation Measurement (ARM) North Slope of Alaska site (in Barrow, AK) are used to derive revised AIE estimates for single-layer Arctic clouds. Datasets used are outlined in the lists below. The availability of long-term datasets, as collected through the ARM program, is critical for evaluations of AIE. This is because a relatively large number of cases must be available to result in statistically significant results. We are currently working to expand this evaluation beyond the 2000-2003 time period, using measurements from 2004-2014.

To derive lower atmospheric mixing:
- Millimeter Cloud Radar (MMCR) reflectivity and Doppler velocity
- Wind Profiler derived horizontal wind speed. If the wind profiler is not available, interpolated radiosonde measurements are used
- Ceilometer/MPL backscatter to derive cloud boundary (base)

For more information, please see: Shupe et al. [2012, AMT]

Well-Mixed

For more information, please see: Garrett and Zhao [2013, AMT]

To derive cloud microphysics and emissivity:
- Rawinsonde Temperature and water vapor profiles
- AERI surface radiation
- Ceilometer/MPL derived cloud boundaries
- MMCR reflectivity, Doppler velocity
- Microwave Radiometer derived LWP
- Spectrometer derived O\textsubscript{3} profile
- ECMWF Analysis for T, RH profiles

For more information, please see: Garrett and Zhao [2013, AMT]

Next Steps

- Extend study beyond 2000-2003 to improve statistical significance of results
- Thoroughly evaluate radar-derived determination of atmospheric mixing using radiosondes from the last decade of measurements from NSA
- Evaluate the true influence of atmospheric mixing on the use of surface-based aerosol measurements for deriving aerosol indirect effects in thin liquid-containing Arctic clouds
- Use HSRL data to demonstrate the relationship between aerosol loading near the surface and aerosol loading at cloud height under clear conditions

References


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