Arctic Aerosol–Cloud Interaction Focus Group

Background

Marine stratocumulus physical and radiative properties are known to be strongly related to ambient aerosol conditions. As aerosol number concentrations increase, all else being equal, droplet number concentrations will increase and cloud droplet sedimentation and drizzle rates will decrease (because droplets are smaller), associated with potentially increased cloud layer albedo and emissivity. Owing to closely coupled dynamics and microphysics, mean liquid water path may also increase, decrease or remain unchanged, depending upon factors such as the cloud-top entrainment rate and potential temperature profile. Understanding and establishing successful parameterizations of the processes that regulate interaction of aerosol and warm stratocumulus cloud properties currently constitutes an area of very active research.

In the Arctic, analogous cloud layers are subject to a number of additional complications, such as the common occurrence of multiple stable layers, humidity inversions, and clouds with low liquid water path. Perhaps most importantly, low-level stratiform clouds are commonly cold (cloud-top temperatures of ~0 to -35°C), and therefore usually contain ice in addition to supercooled liquid. Aerosols therefore impact both droplet and ice formation by serving as cloud condensation nuclei (CCN) and ice nuclei (IN). While IN only represent a small fraction of the total aerosol population, their net impact on clouds remains highly uncertain owing in part to poor understanding of their properties and the physical processes by which they cause ice formation. In a mixed-phase cloud, nucleated ice has the ability to drastically alter the sedimentation of condensate from the cloud, introducing a cloud-level total water sink. Since ice crystal number concentrations are small relative to droplet number concentrations, generally speaking, liquid water path ultimately controls the radiative properties of mixed-phase stratiform clouds. It is therefore crucial to understand how CCN and IN together impact cloud microphysical properties, phase partitioning, and evolution.

Objective and Scientific Focus

The objective of the Arctic Aerosol–Cloud Interaction Focus Group (AACI) is to develop a more detailed, quantitative understanding of aerosol-cloud interactions and accelerate advances in modeling these interactions in the Arctic. The AACI focus group will provide a means of improving coordination among existing and future ASR observational and modeling activities, identifying critical knowledge gaps and developing and advocating innovative solutions to address them, and streamlining knowledge transfer from process-level understanding to parameterization development and implementation.

To achieve this objective and ultimately to advance treatment of the aerosol—Arctic cloud interactions in global climate models (GCMs), the group's activity will focus on two general areas:

1. an improved representation of spatiotemporal distribution of CCN and IN, and

2. an improved representation of processes controlling cloud properties in a given CCN/IN environment.

Within area 1, researchers must address a range of questions, including:

- What separates IN from the rest of aerosol population in terms of particle's morphology and physiochemical properties?
- Can IN activity spectra be derived as a function of temperature and/or supersaturation in the Arctic environment?
- What are the relative roles of different ice nucleation modes?
- What is the spatiotemporal co-variability of CCN and IN and how much overlap is there between these two aerosol populations?
- What are the removal rates for CCN and IN in the Arctic and what are the primary sources of IN regionally?

To address problem area 2, the following questions need to be answered

- What microphysical processes are most important climatologically (e.g., IN activation mode, drizzle, riming, aggregation, ice mutiplication)?
- How are microphysical and dynamical processes coupled?
- How do IN concentrations relate to cloud ice concentrations?
- How do cloud liquid properties impact ice nucleation and overall lifetime of the cloud?

Approach

ASR is exceptionally well-positioned to answer the questions introduced above because of the program's unique observational and modeling capabilities. ARM operates long-term measurement sites at the North Slope of Alaska (NSA) that include ground-based remote-sensors uniquely suited to study shallow cloud dynamics. New Recovery Act instruments deployed at NSA will provide valuable new insight into the dynamics and microphysics of these clouds. Previous Intensive Operation Periods (IOPs) at NSA have provided a foundation of in situ measurements and modeling efforts. ASR/ARM-funded scientists have led or participated in several intercomparison studies involving cloud-scale, regional and single-column models, including two recent projects dedicated to Arctic mixed-phase clouds (M-PACE and SHEBA cases).

A successful completion of an individual project or an IOP, however, by itself does not guarantee an improvement in GCMs. For that, modelers need to establish that:

- There is an adequate understanding of a phenomenon at the process level;
- Detailed models can reproduce observed case studies;
- Climate models can reproduce observed cloud properties and radiative impacts.

Scopes of individual ASR projects rarely cover all of the above aspects of parameterization development. The AACI will facilitate integration of related studies and influence future research direction. Specifically, it is proposed that the formulated focus group generate creative and innovative paths forward. Example tasks include:

- continue ARM's highly successful model intercomparison studies using observations from the ISDAC campaign
- generate consensus position document identifying specific outstanding problems

- identify programmatic approaches that will be pursued by this group in order to obtain specific measurable progress on target problems within a five-year time frame
- identify high-priority retrieval products and Value-Added Products (VAPs) from existing and new instruments and their combinations
- identify high-priority instrument development efforts (e.g., with respect to specific cloud physical and IN properties most relevant under Arctic mixed-phase cloud conditions)
- advocate for specific IOP field program targets based on modeling, observational, and climatological factors

Participation and relation to other focus groups

To achieve its goals, the proposed focus group will reach out to researchers affiliated with each of the three ASR working groups. Given the nature of the main objectives, the primary connection will be with the Cloud-Aerosol-Precipitation Interactions (CAPI) working group (WG). However, AACI will also rely on the Aerosol Lifecycle WG projects aimed to advance laboratory, field, and modeling studies of aerosol properties, especially those related to ice nucleation. AAIC will also draw heavily on expertise of Cloud Lifecycle WG members in observing and modeling cloud properties.

While AACI has unique objectives and challenges, coordinating its activity with other focus groups is mutually beneficial and will be pursued. In particular, the following proposed focus groups cover areas of common interest: aerosol effects on ice nucleation and ice clouds, physical and radiative properties of ice, vertical velocity, precipitation susceptibility, and cloud effects on aerosol properties.

Leadership

Investigators who are willing to participate in the leadership of this group include Andy Ackerman (NASA/GISS), Gijs de Boer (CIRES/NOAA/LBNL), Ann Fridlind (NASA/GISS), Mikhail Ovchinnikov (DOE/PNNL), and Matt Shupe (CU/NOAA/CIRES). We propose to establish co-chairs, one from a primarily observational background and another from a primarily modeling background, and to open the group to leadership changes each year. Ovchinnikov and Shupe have volunteered to assume leadership in Year 1.

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