Breakout Session Report
ARM/ASR User and PI Meeting
March 16-20, 2015

Session Title: Ice Nucleation/Aerosol Mixing State (CAPI/ALWG**)**
Session Date: Thursday, March 19, 2015
Session Time: 8:00–10:00 a.m.
Summary Authors: Ann Fridlind, Mary Gilles, Daniel Knopf, Claudio Mazzoleni, Xiaohong Liu, Nicole Riemer, Raymond Shaw, Matthew West

Description

Characterizing aerosol mixing state in observations and models alike presents challenges because of the complexity of aerosol chemical composition and morphology. This session focused on opportunities to advance capabilities to link aerosol mixing state to ice nucleation processes in field and laboratory measurements and models. To frame the discussion, the session began with short presentations summarizing the perspectives of the Mixing State Focus Group and the Ice Nucleation Focus Group on this topic. The goal was to explore avenues for the two focus groups to join forces.

Main Discussion

The goal of this session was to explore avenues for the Ice Nucleation Focus Group and the Mixing State Focus Group to join forces. In particular, we set out to discuss how to link information on aerosol mixing state to ice nucleation processes in field and laboratory measurements, as well as in models.

To frame the discussion, we began with short presentations summarizing the perspectives of the mixing state focus group and the ice nucleation focus group on this topic. We then focused the discussion on the connections of lab measurements and models and field measurements and models.

Key Findings

While the ice nucleation community applies different parameterizations to quantify the ice nucleation efficiency of different substrates, a common denominator of these parameterizations is that they all depend on the specific surface area in contact with water vapor. Hence, it is plausible that it matters which chemical species are at the surface of the particles. This is confirmed from laboratory studies (Gourihar Kulkarni at Pacific Northwest National Laboratory and Paul DeMott at Colorado State University) of coating mineral dust by sulfate and nitrate, which significantly reduces the efficiency of dust ice nucleation in the deposition mode.

However, we are limited in our process-level understanding of the physics and chemistry of ice nucleation. Unlike cloud droplet activation, which is well-described by the Köhler theory, there is currently no generally accepted theory that accurately describes the ice nucleation process. This hampers us in representing this process in physics-based models.

Particle morphology appears to be important for ice nucleation, but at this point it is not clear which aspects of morphology are important and how these should be tracked in models. This question is complicated by the fact that different mechanisms for freezing exist.

The group felt that it would be very helpful to conduct ice nucleation laboratory studies of multi-component aerosol, tightly coupled to modeling.

Ann Fridlind gave a presentation about an aerosol and ice nucleation closure study, which has been one of the action items in the Ice Nucleation Focus Group for a few years. In analogy to a cloud condensation nuclei closure study, this field campaign would perform an "ice nucleation closure study without a cloud," with the focus to incorporate aerosol mixing state information. The study would involve a detailed characterization of the aerosol population at the ground (for example at the Southern Great Plains site), including measurements of aerosol number size distributions, surface area size distributions, particle-resolved composition, and particle morphology. In addition, the ice nuclei concentrations would be determined using several different measurement approaches. We would then attempt to calculate the ice nuclei concentration based on the measured aerosol population, and temperature and relative humidity inside the instruments, using different ice nucleation theories and parameterizations. Lastly, we will determine if we are able to obtain closure between the calculated and the observed ice nuclei concentration, and which theory or parameterization will give us the best closure.

The laboratory measurements mentioned above will feed into this because this is how we would determine the ice nucleation efficiencies of different aerosol species. Importantly, these measurements will be made at a ground site, thereby eliminating the difficulties of sampling particles from aircraft. Also, there is no in-cloud sampling involved, which simplifies the situation further and focuses our efforts on the ice nucleation process itself. This is "step 1" in a series of complicated interactions, which we currently only poorly understand. Planning a study like this would be very timely now, as results from the ice nucleation instrument intercomparison at the Aerosol Interaction and Dynamics in the Atmosphere (AIDA) chamber at the Karlsruhe Institute of Technology are expected to be available soon.

Another opportunity that may present itself is the planned SuperCAPE campaign at Lake Superior, led by Mark Kulie, Claudio Mazzoleni, and Raymond Shaw. While the scientific focus for this campaign is on ice formation and growth in shallow, mixed-phase, surface-forced clouds, it also could provide the opportunity for an ice nucleation closure study, as an upwind and a downwind site is going to be involved. Raymond Shaw will solicit feedback from the Ice Nucleation Focus Group regarding this idea (see action item below).

The group discussed the importance of comparing different methods of ice nucleation measurements: CFDC-type and offline substrate based. The current and ongoing ice nucleation instrument intercomparisons in the Karlsruhe AIDA cloud chamber in March 2015 and at the Storm Peak Laboratory in November 2015 are important steps forward to quantify the uncertainties associated with the ice nucleation instruments.

Future Plans

We plan to continue the conversation between the two focus groups and meet again in the fall (see action item below). In the meantime, we plan to flesh out the idea of the "ice nucleation closure study without a cloud" and circulate this amongst the two focus groups.

Action Items

- Raymond Shaw: Collect feedback from the about the proposed "Superior Cloud, Aerosol, and Precipitation Experiment (SuperCAPE)," if the setup would be suitable for an ice nucleation closure study, and if so, what instrumentation would be needed.
- Xiaohong Liu and Gourihar Kulkarni: Report on the progress of ice nucleation instrument intercomparisons.
- Ice nucleation and mixing state group leads: Arrange another meeting of the two focus groups in the fall.