Measurements and analysis of ice nucleating particles during ACAPEX/CalWater-2015

P. J. DeMott¹, T. C. Hill¹, M. D. Petters², C. S. McCluskey¹, K. J. Suski¹, E. J. T. Levin¹, K. A. Prather³, L. Ruby Leung⁴, and Sonia M. Kreidenweis¹

¹ Colorado State University, North Carolina State University³, University of California San Diego³, Pacific Northwest National Laboratory⁴

Motivation and goals

- Orographic clouds and rain over the Sierra Nevada are often supercooled down to -21°C, hypothesized to be due to low numbers of ice nucleating particles (INPs) and low CCN numbers in lofted layers, possibly of marine origin (Creame et al., 2013; Rosenfeld et al., 2013).
- The interagency ACAPEX (ARM Cloud Aerosol Precipitation Experiment)/CalWater-2015 campaign (January to March 2015) was designed to include comprehensive characterization of cloud-active particles that can influence winter precipitation in the California, within or outside of atmospheric river (AR) conditions.
- Provided a special focus on roles of pollution, regional and trans-Pacific transported aerosols, and biogenic particles, on impacting West Coast precipitation.

Field study design (ACAPEX)

- AAF (G-I) flights to profile marine and orographic clouds and aerosols that feed them (aerosol size and composition, CCN, online and offline INP, cloud microphysics)
- RV Ron Brown with AMF-2, offline INP
- Coastal aerosol site at Bodega Bay, CA (BBY).

INP measurement suite

- CSU continuous flow diffusion chamber (CFDC)
- Ice Spectrometer (IS) freezing of defined volumes of collected aerosol
- N.C. State University cold stage (CS)
- Filter collections for immersion freezing
- Multiple INP methods (CFDC, CS, IS), CCN, aerosol and INP composition
- G-I aircraft-collected INP data:
  1) consistency of the two INP measurement methods
  2) similar range of INP number concentrations aloft as seen on ship and at BBY
  3) vertical structure showed typical reduction in ambient concentrations of INPs entering orographic cloud layers, and few elevated dust layers in 2015.

Results

- ACAPEX ship data documented INP number concentrations inside and outside AR’s for the first time. The large range observed generally agrees with that published for SSA-derived INPs and with MAGIC results in same ocean regions in summer. Higher INP concentrations were always present at BBY (why?).
- Isolating just an AR period: Low INP number concentrations are likely purely from sea spray aerosol. INP in precipitation samples at Bodega and in the coastal range (converted to air volume for DVC of 0.4 g m⁻³ cloud), are lower than ever reported and span from equivalent AR values to near-coast values.
- An eight week timeline of INP data at BBY sampled a range of conditions from clean marine to polluted. The AR period was mostly striking for the deficiency in INPs. Continental influences were inferred at times, especially post-AR, rains, when INPs of biological origin were apparent, similar to findings in other studies over continents. These emissions were likely detected in G-I samples over the Central Valley.

Summary and future work

- Data sets were collected by air, on land, and over the Pacific Ocean that should allow integration into a 4-dimensional description of INP influences on winter storms. Analyses are ongoing.
- INPs in ARs typically reflect very clean marine influence.
- CCN and INP data will provide the basis for numerical modeling studies of aerosol impacts on clouds and precipitation.

Acknowledgments. ACAPEX measurements were supported by the Office of Biological and Environmental Research of the U.S. Department of Energy (as part of the Atmospheric Radiation Measurement Climate Research Facility). Bodega Bay measurements were supported by the National Science Foundation under AGS-1358415 and AGS-1406760. Special thanks to the PNNL AAF team, the AMF-2 team, the U.C. Davis Bodega Marine Laboratory administration and personnel, and the support of the CalWater-2 team (http://www.esrl.noaa.gov/pst/calwater/).