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

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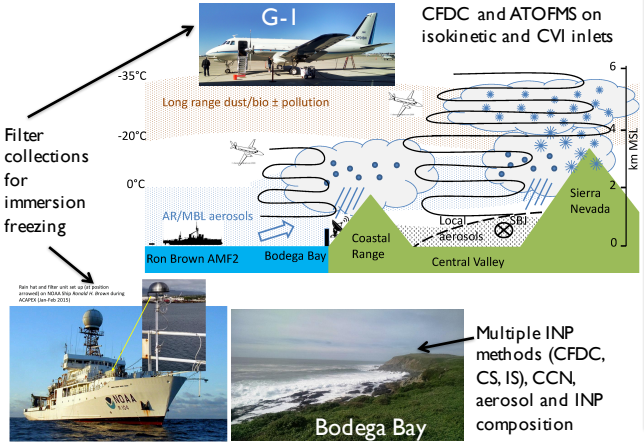
Motivation and goals

- 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 (*Creamean 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.

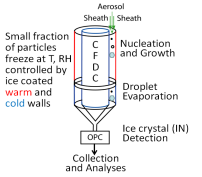
Field study design (ACAPEX)

- AAF (G-1) 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).



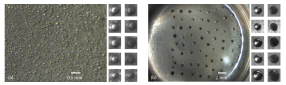
INP measurement suite

CSU continuous flow diffusion chamber (CFDC)



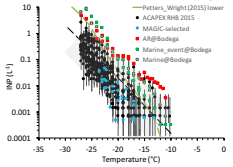
Ice Spectrometer (IS) freezing of defined volumes of collected aerosol

N.C. State University cold stage (CS)

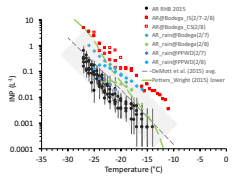


Results

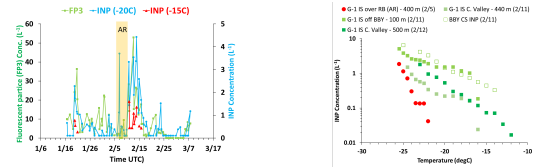
- ACAPEX ship data documented **INP number concentrations inside and outside AR's for the first time.** The large range observed generally agrees with that published for SSA-derived INPs and with MAGIC results in same ocean regions in summer. Higher INP concentrations were always present at BBY (why?).



- **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 LWC of 0.4 g m^{-3} cloud), are lower than ever reported, and span from equivalent-AR values to near-coast values.

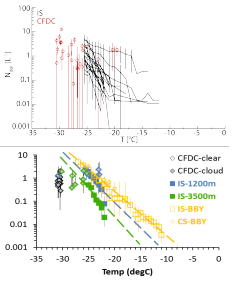


- An eight week timeline of INP data **at BBY** sampled a range of conditions from clean marine to polluted. The AR period was mostly striking for the deficiency of INPs. **Continental influences were inferred at times, especially post-AR rains, when INPs of biological origin were apparent**, similar to findings in other studies over continents. These emissions were likely detected in G-1 samples over the Central Valley.

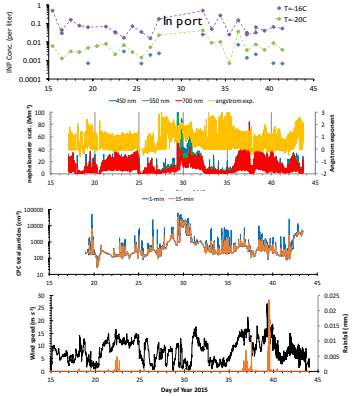


FP3: subset of fluorescent particles identified to correlate with INPs (Wright et al., 2014)

- G-1 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,



- The AMF measurement suite in concert with IS filter INP data on the RV Ron Brown and G-1 overflights should provide a rich data set to parameterize sea spray aerosol-produced INPs, Nevertheless, a range of other aerosol influences were noted during the cruise.



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.

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References. Creamean, J. M et al., 2013: Dust and Biological Aerosols from the Sahara and Asia Influence Precipitation in the Western United States, *Science*, **339**, 1572-1578; DeMott et al., 2015: Sea spray aerosol as a unique source of ice nucleating particles. Proc. Natnl. Acad. Sci., Early Edition, www.pnas.org/cgi/doi/10.1073/pnas.1514034112; Petters, M. D., and T. P. Wright (2015), Revisiting ice nucleation from precipitation samples, Geophys. Res. Lett., 42, 8758–8766; Rosenfeld, D., R. et al., 2013: The Common Occurrence of Highly Supercooled Drizzle and Rain near the Coastal Regions of the Western United States, *J. Geophys. Res. - Atmos.*, **118**, 9819–9833, doi:10.1002/jgrd.50529. Wright et al., 2014: High Relative Humidity as a Trigger for Widespread Release of Ice Nuclei, Aer. Sci. & Technol., DOI: 10.1080/02786826.2014.968244.