Lessons from long-term measurements of ice nucleating particles at ARM sites

Tom Hill*, Carson Hume and Jessie Creamean* | *Co-mentors, Colorado State University

ARM

"All that is solid melts into air"[1]

Introduction

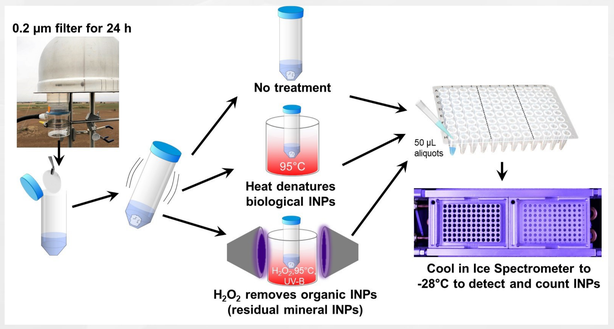
Interactions between aerosols and clouds are some of the least understood atmospheric processes, especially those involving the particles that facilitate cloud ice formation, the ice nucleating particles (INPs). INPs trigger primary ice above ~-38°C, modifying precipitation (rate, amount, type, distribution), latent heat release, cloud electrification, cloud albedo, and cloud lifetime.[2-7]

ARM added INP measurements in 2020, to establish baselines in diverse locations and to facilitate the understanding of the factors that control INP emissions from sources.

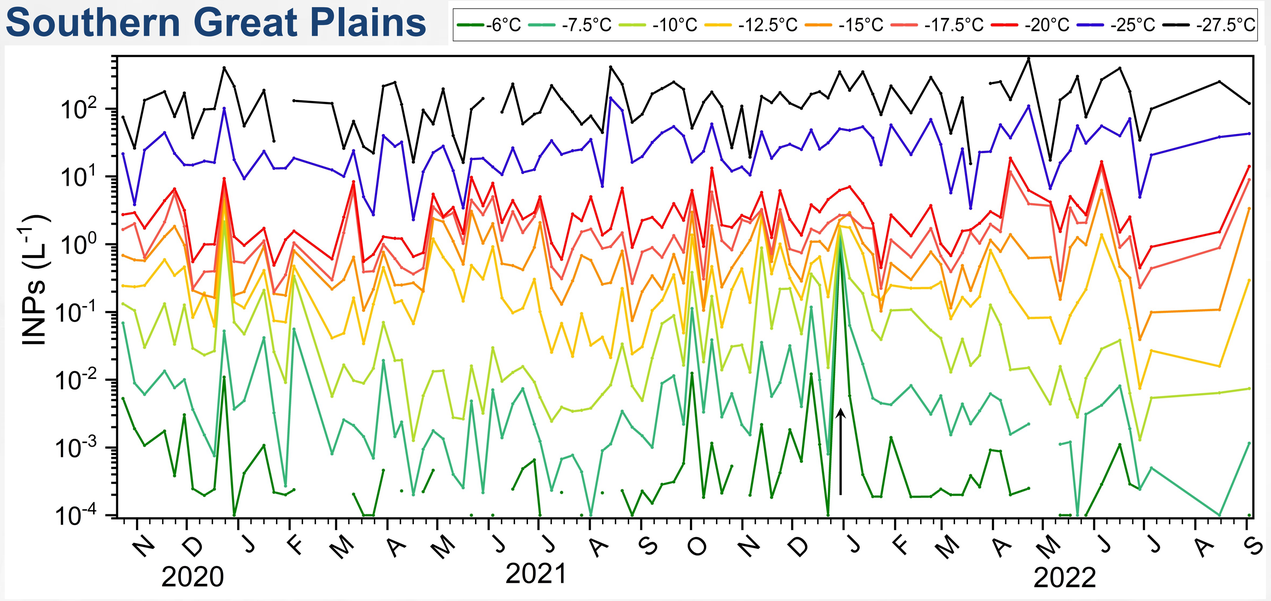
Campaigns in which we have collected samples include: 1) AMF3 at Oliktok Point, 2) SGP, 3) SAIL, 4) TRACER, and 5) EPCAPE. Future campaigns include BNF, CAPE-K in Tasmania and at the NSA site at Utqiaġvik, AK

Protocols

- 24 h filter samples every 3 or 6 days in duplicate (2nd filter available to researchers).
- Measure immersion freezing INPs with an ice nucleation spectrometer to ~-28°C.
- Test ⅓ of samples after heating (95°C) and H_2O_2 digestion to estimate relative abundances of heat-labile/biological organic and heat stable organic INPs. Remainder are inorganic/mineral INPs.

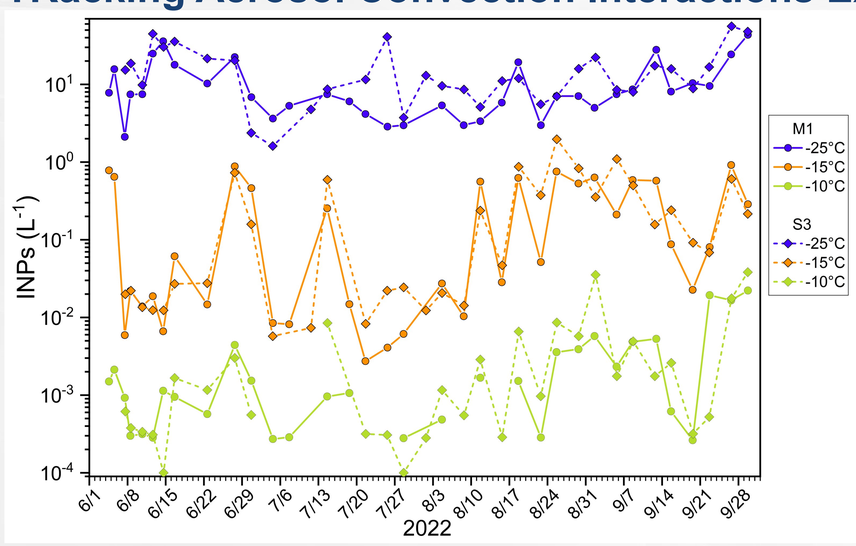


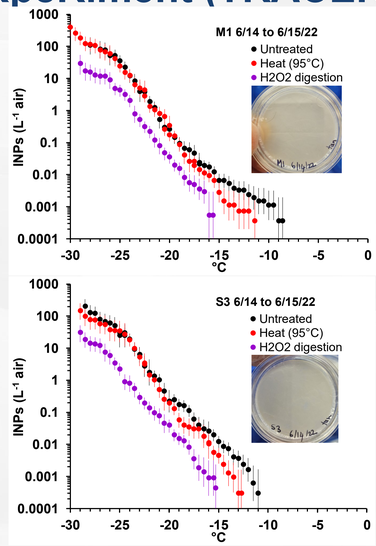
Southern Great Plains



INP concentrations at SGP. INPs active at ≥-12.5°C increase in the fall, sometimes with dramatic spikes in activity (arrow). INPs at -25°C and -27.5°C don't show clear seasonal trends. INPs are predominantly biological (heat labile) to -17.5°C, and a combination of biological and heat-stable organics to -27.5°C.

TRacking Aerosol Convection Interactions ExpeRiment (TRACER)





INP concentrations ≥-20°C often comparable at both sites (main site M1 and ancillary site S3) even though 75 km apart (left). Heating (95°C) and H_2O_2 digestion to reveal contribution of biological and heat-stable organic INPs also often similar in matched samples at M1 and S3 (right).

QA/QC: Prosaic but essential

FIELD

- **Setup**
  - In-person tech training ► Whole line vacuum ► Flows ► Freezer
- **Sampling/PM Reports**
  - Data download ► Reports complete ► Reports accurate ► Indicators of function (flow, vacuum)
- **Maintenance**
  - Pump ► Flow meter ► HEPA ► Tubing integrity ► Whole line vacuum ► Exterior parts clean ► Clean filter removal area ► Replace consumables
- **Return shipping/storage**
  - Ample dry ice/cool blocks ► Monitor CSU freezers ► Periodic organization

LABORATORY

- **Filter unit prep**
  - Leak testing ► Count consumables (extra gloves)
- **Ice Spectrometer runs**
  - New site: run several filters ► Backing filter removed ► DI service ea. 3 mo
- **Data sheets/IS spectra**
  - Check counts vs images ► Remove dynamic links ► Best transitions ► Truncate cold end of spectra ► H_2O_2 dilutions correct?
- **Final spectra processing**
  - Background subtraction ► Dates and volumes ► Final IS spectra curation
- **Upload**
  - Check 2 base runs ► Check averaging ► Check one with treatments

Acknowledgments

Thanks to Rolanda Jundt for our ARM website, and Yan Shi for DOD. Sincere thanks also to Chris Martin, James Martin and Jim Stow (SGP); Mark Spychala, David Oaks, Ana Gabriela Pessoa and Daniel Bahrt (TRACER); Travis Guy, Tom Day and Frank Zurek (SAIL); and David Oaks, Ana Gabriela Pessoa and Daniel Bahrt (EPCAPE).

Contact information

Data from Oliktok (AK), SGP, SAIL, and TRACER are available on the DOE Data Archive

Jessie.Creamean@colostate.edu

Thomas.Hill@colostate.edu

1 Marx, K. and Engels, F. 1848. The Communist Manifesto.
2 DeMott et al. 2010. PNAS, 107, 11217-11222.
3 Cantrell and Heymsfield. 2005. BAMS, 86, 795–807.
4 DeMott and Prenni. 2010. Atmos. Env., 44, 1944-1945.
5 Murray et al. 2012. Chemical Soc. Rev., 41, 6519-6554.
6 Rogers. 1994. BAMS, 75, 2312-2314.
7 Vergara-Temprado et al. 2018. PNAS, 115, 2687-92.

Colorado State University

U.S. DEPARTMENT OF ENERGY | Office of Science