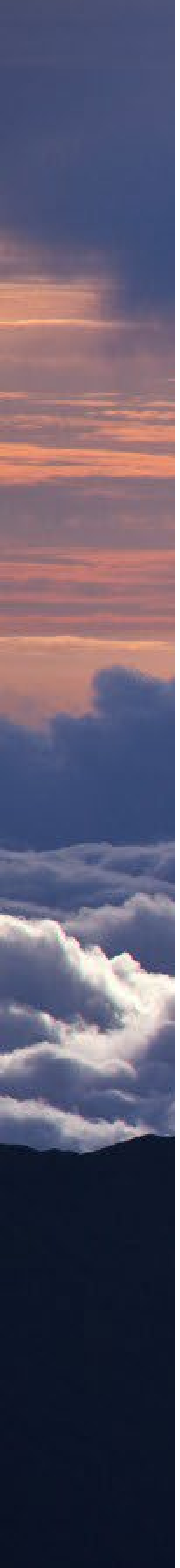
Catching soil INPs on the fly: early results from the AGINSGP campaign

Susannah M. Burrows

ARM/ASR PI Meeting, 2022

October 26, 2022

Microscopy image of dust particles: Courtesy of Pacific Northwest National Laboratory.



Acknowledgements

Project team:

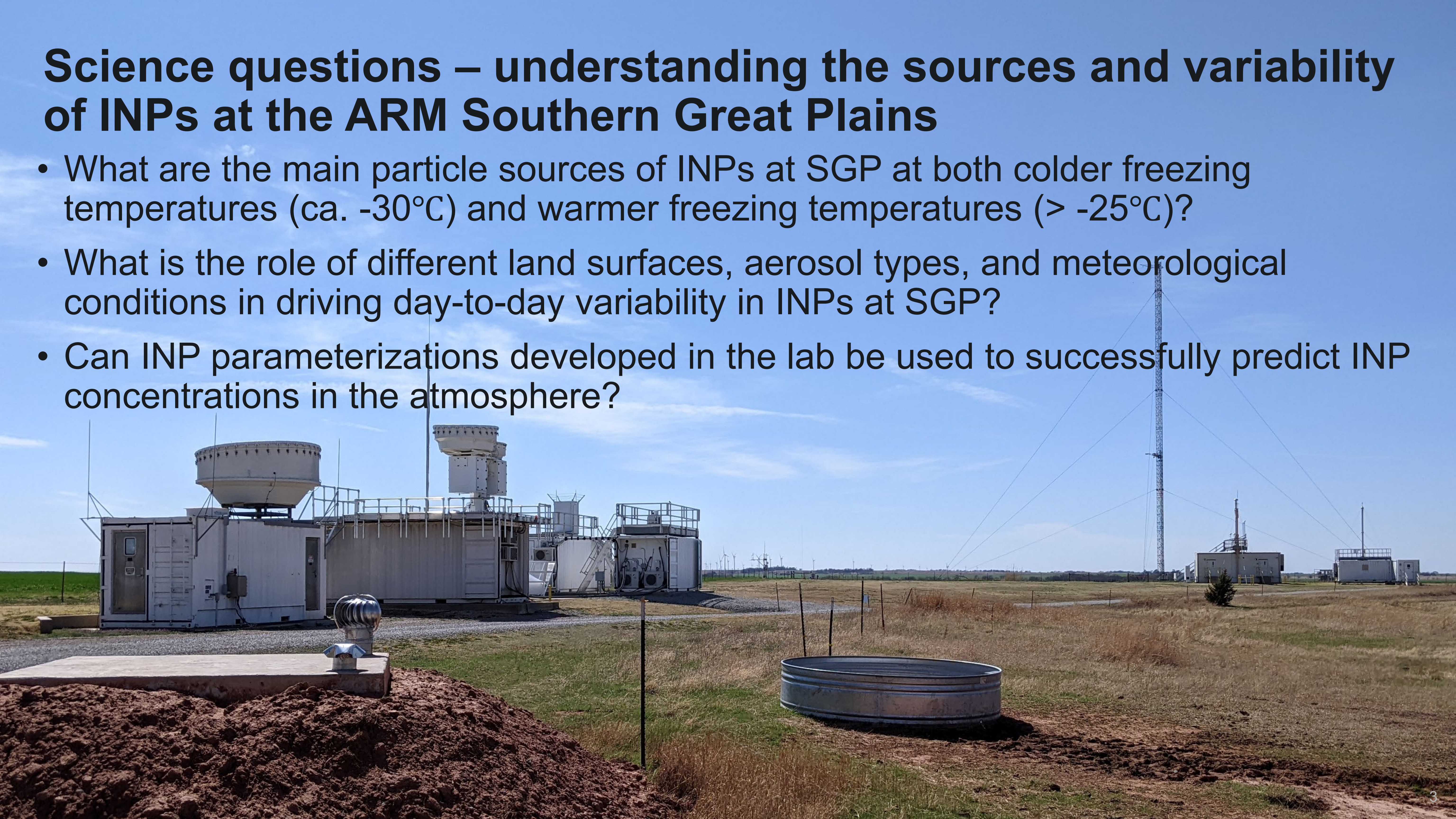
- Gavin Cornwell, Isabelle Steinke (now at Uni Leipzig), Aishwarya Raman

Collaborators:

- **Pacific Northwest National Laboratory:** Alla Zelenyuk, Gourihar Kulkarni, Mikhail Pekour, Swarup China, Nurun Nahar Lata, Gregory Vandergrift
- **Colorado State University:** Paul DeMott, Tom Hill, Russell Perkins, Jessie Creamean, Carson Hume
- **National Center for Atmospheric Research:** Christina McCluskey
- **Karlsruhe Institute of Technology:** Ottmar Möhler, Larissa Lacher
- **University of Denver:** Alex Huffman, Alex Volkova, Dorian Schwartz
- **Sandia National Laboratory:** Dari Dexheimer
- **Purdue University:** Alex Laskin
- And many others…

Science questions – understanding the sources and variability of INPs at the ARM Southern Great Plains

- What are the main particle sources of INPs at SGP at both colder freezing temperatures (ca. -30℃) and warmer freezing temperatures (> -25℃)?
- What is the role of different land surfaces, aerosol types, and meteorological conditions in driving day-to-day variability in INPs at SGP?
- Can INP parameterizations developed in the lab be used to successfully predict INP concentrations in the atmosphere?

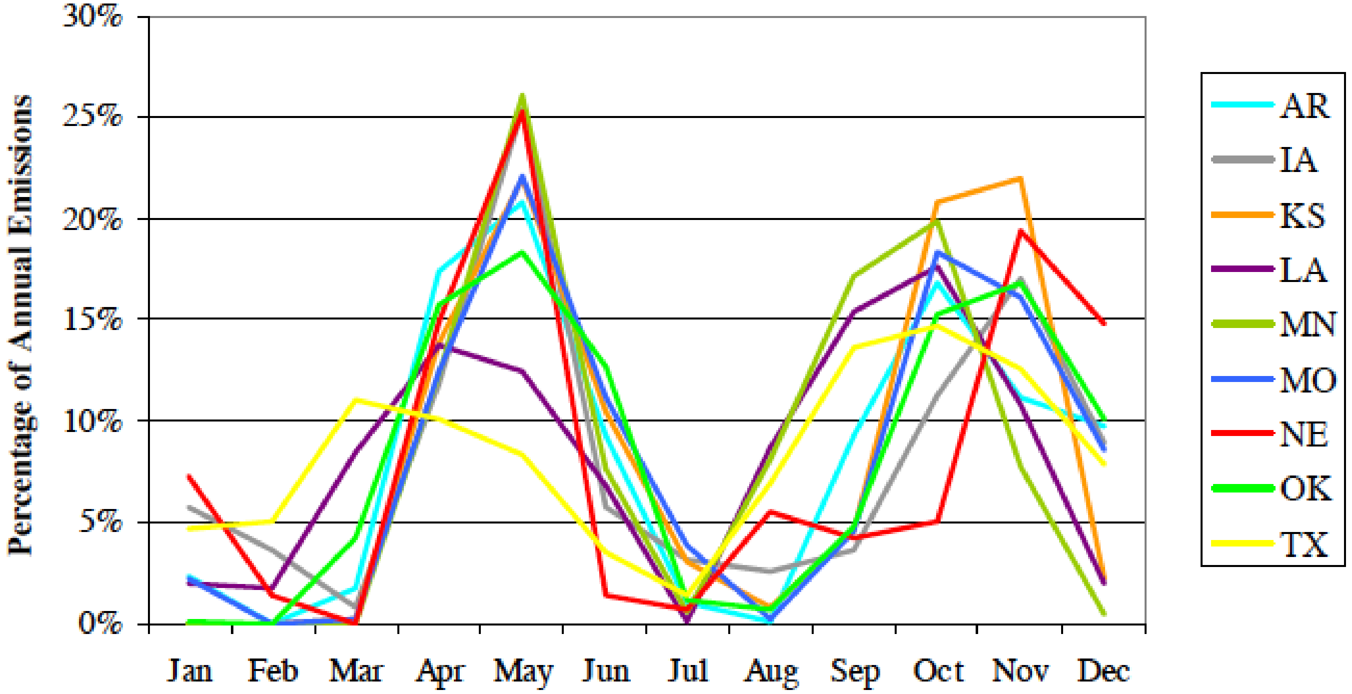


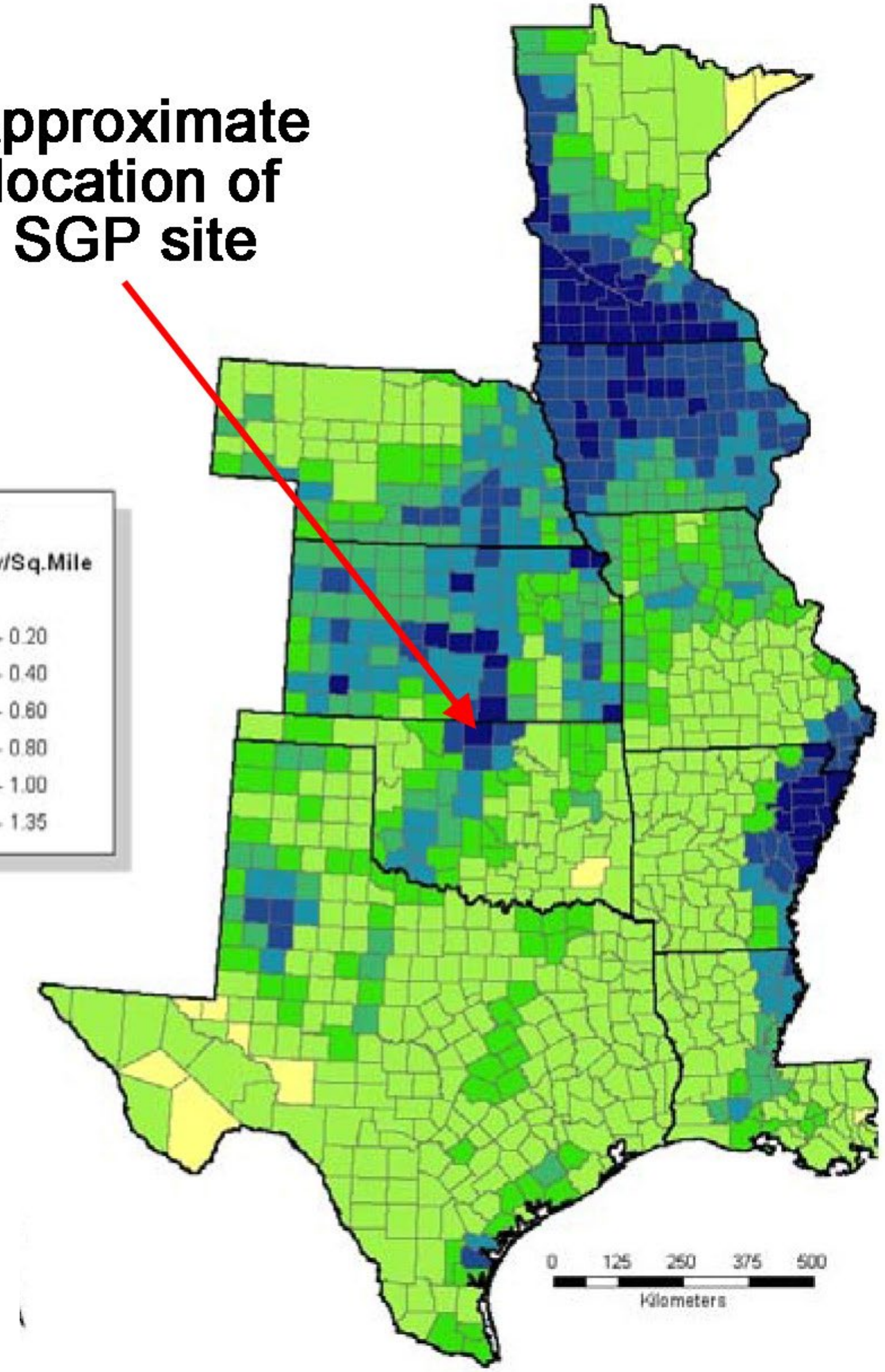
Field campaign design: target agricultural dust INPs

Emissions of soil dusts in the Southern Great Plains are mainly associated with agricultural activities (tilling, harvesting)

Strategy: target spring tilling season & contrast with a prior campaign conducted during the fall tilling season

Seasonal cycle of tilling emissions

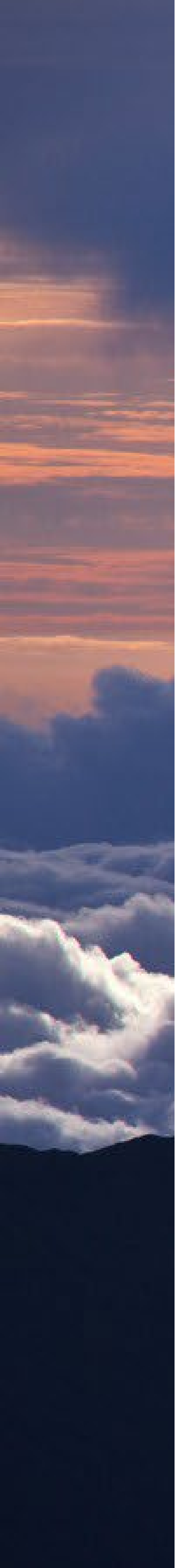




Approximate location of SGP site

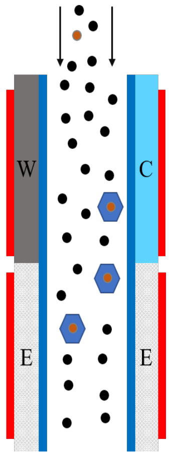
Ground-based observations: INPs and aerosol properties

- Five complementary measurements of INPs
  - PNNL ice nucleation chamber (CFDC)
  - CSU CFDC
  - Ice spectrometer
  - Portable Ice Nucleation Chamber PINE
  - Offline measurements in the IN-ESEM (EMSL)
- Aerosol properties
  - Single particle information from the **miniSPLAT single particle mass spectrometer** (EMSL)
  - Size distribution from the **Aerodynamic Particle Sizer (APS)**
  - Offline aerosol measurements: SEM-EDX, TEM-SAED
  - Aerosol concentrator
  - Aerosol inlets, impactors, and pumped counterflow virtual impactor (PCVI)

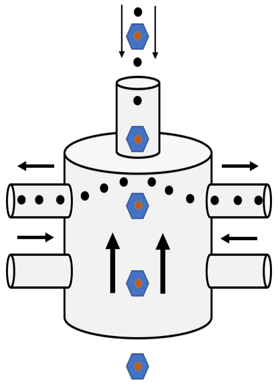


We performed a “residual characterization experiment” to characterize the composition of individual INPs

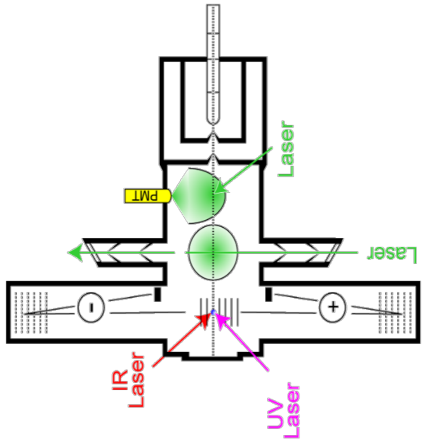
This technically challenging experiment can give us a “smoking” gun for the identity of INPs.



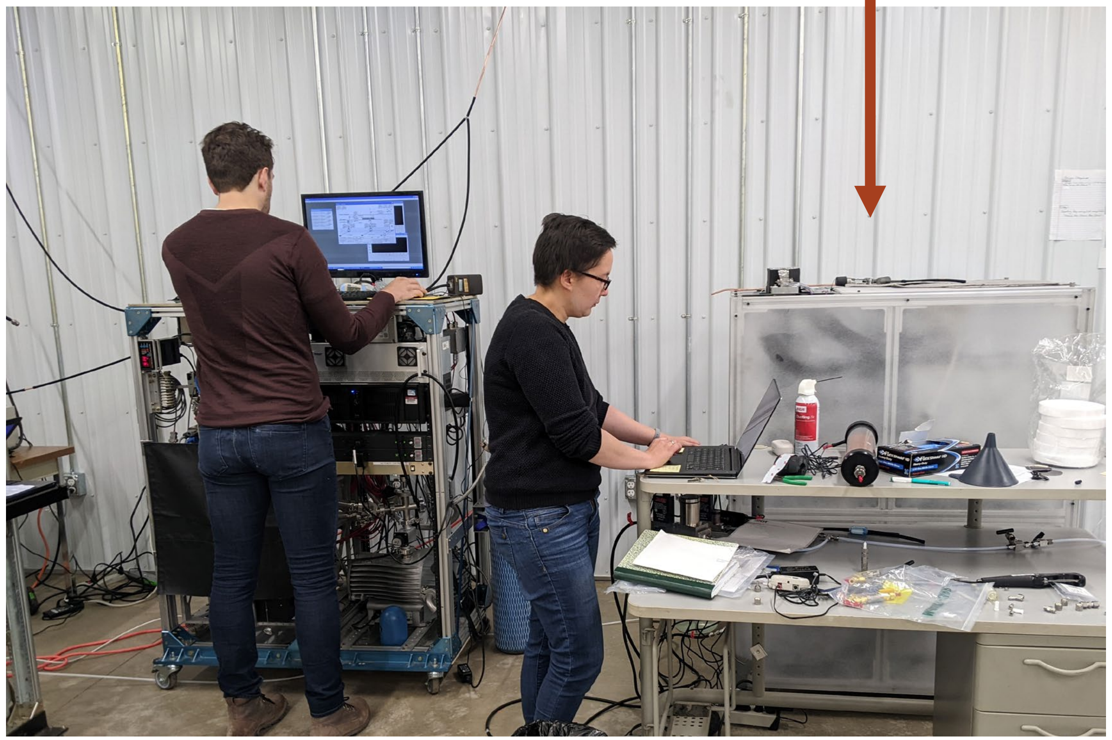
PNNL ice nucleation chamber:
Activate INPs into ice crystals



Pumped counterflow virtual impactor:
Separate
large ice crystals



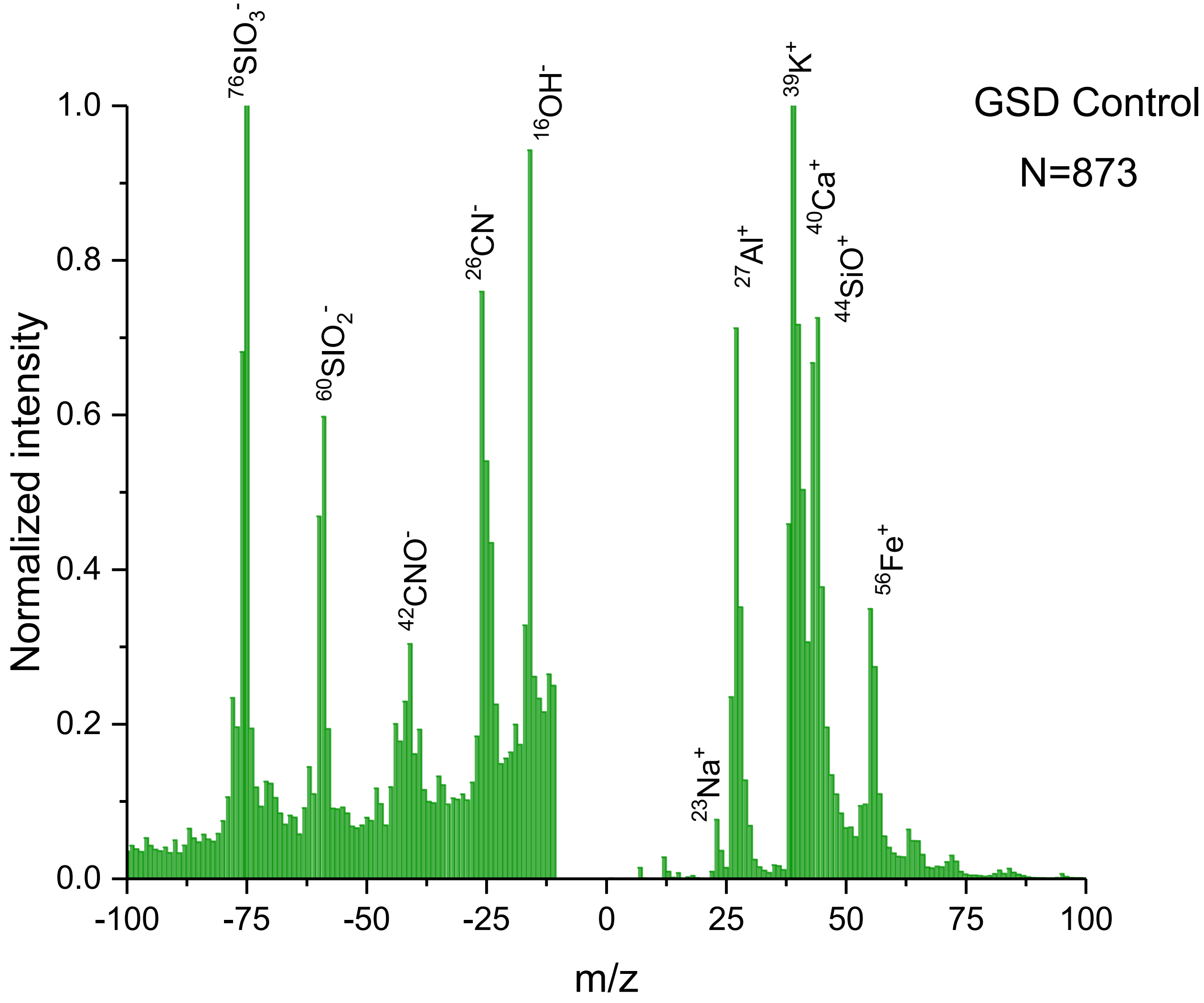
miniSPLAT:
Measure particle composition



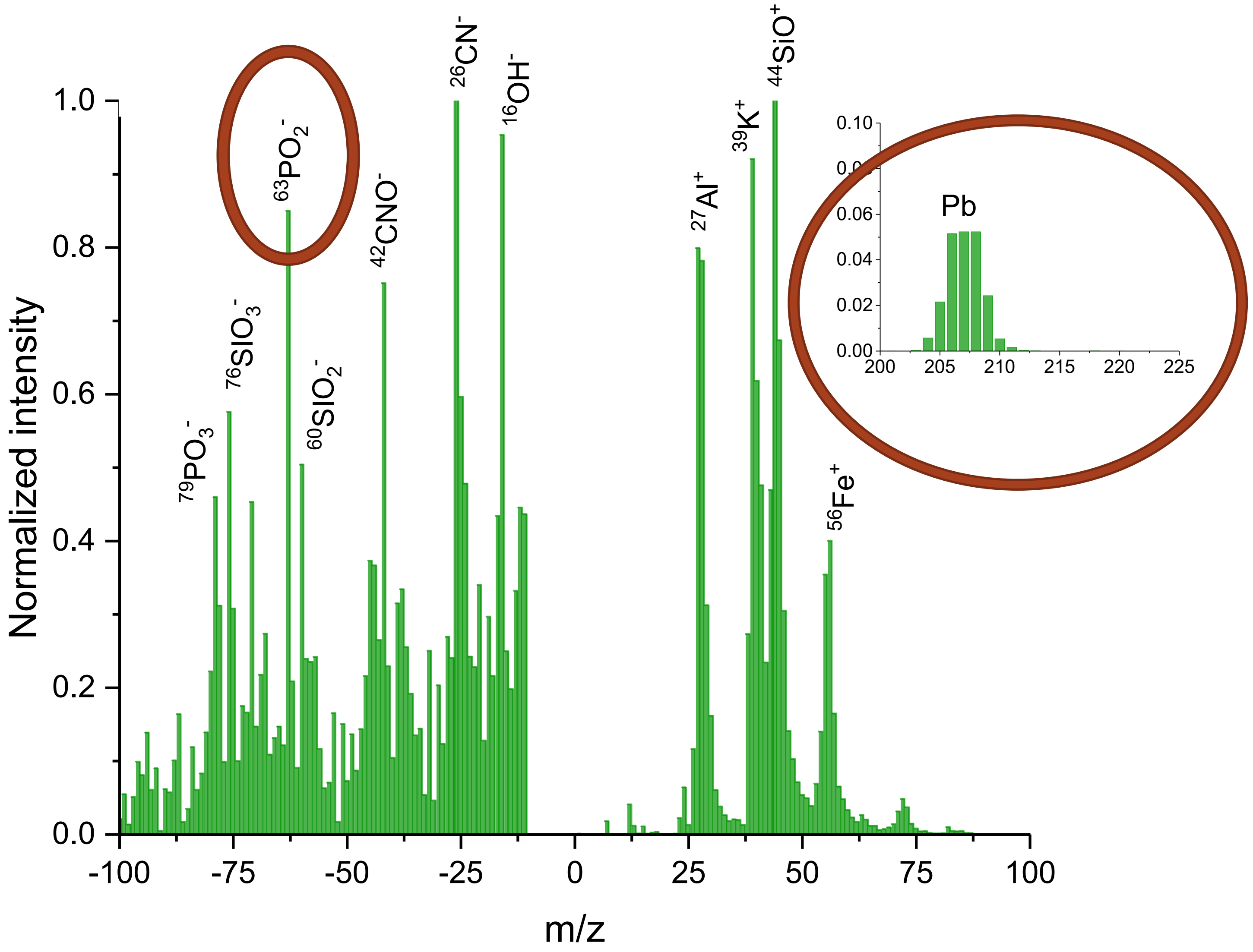
Schematic figure:
Gavin Cornwell

In lab measurements of soil dust INPs at EMSL, we observed enhancements in phosphate (marker for bioaerosol) and lead

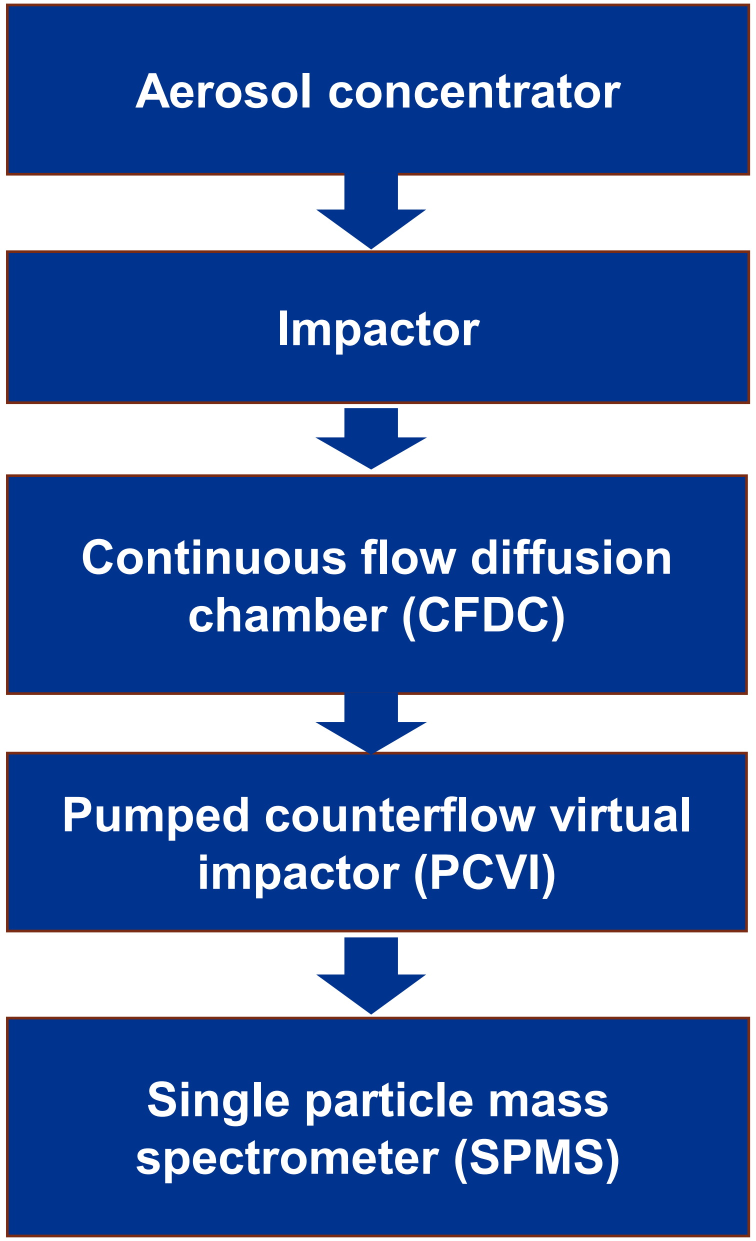
Total particles – average mass spectrum (miniSPLAT)



Phosphate and lead are enhanced in INPs (T=-25℃)



The INP residual characterization experiment is much more challenging under ambient conditions



Aerosol concentrator

Impactor

Continuous flow diffusion chamber (CFDC)

Pumped counterflow virtual impactor (PCVI)

Single particle mass spectrometer (SPMS)

The challenge:

- INP concentrations are very low (e.g., 1 L^{-1})
- We must distinguish them from non-INP particles concentrations that are far higher (e.g., 10,000 L^{-1})

Technical implications:

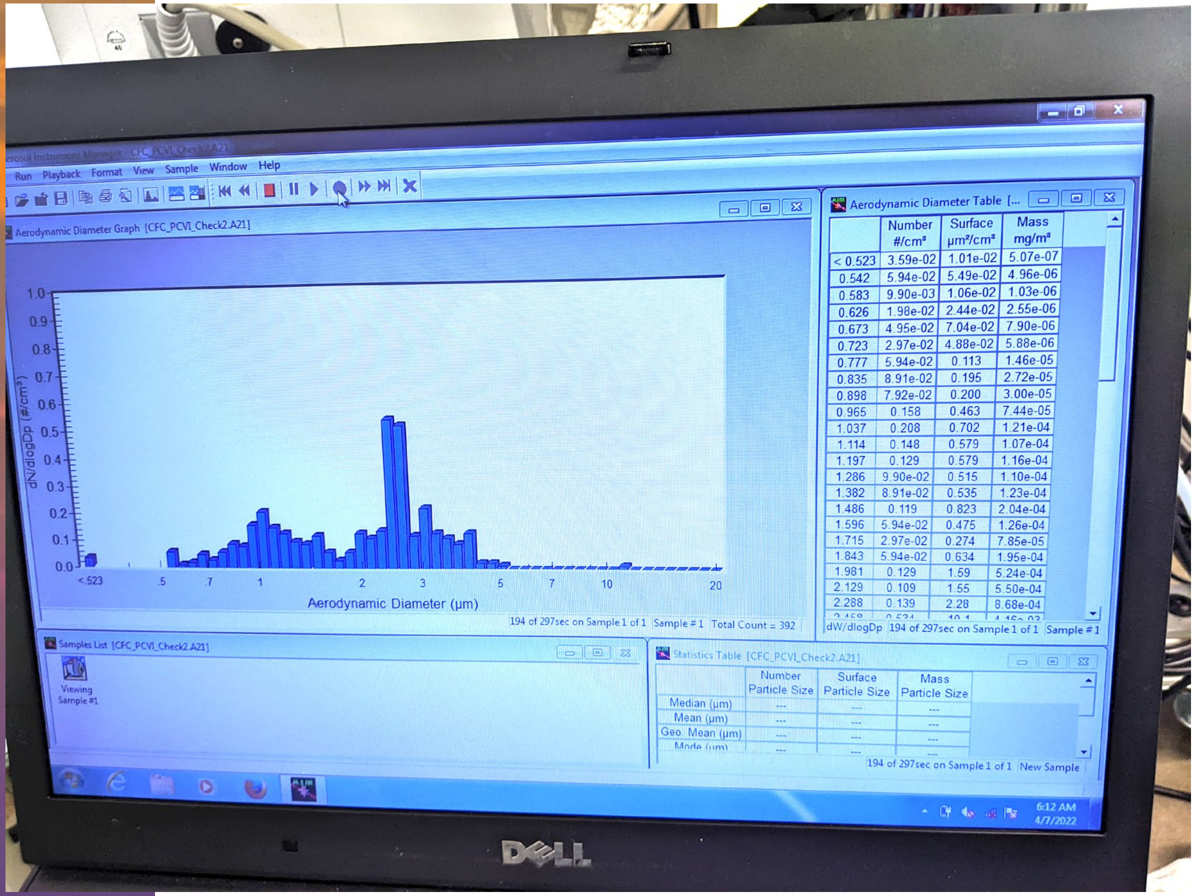
1. A single particle mass spectrometer is the only instrument with sufficient sensitivity to perform this experiment
2. Even under the best conditions, sample sizes are small

Estimate prior to the campaign:

ca. 50 hours of sampling required to characterize 100 INPs under background conditions of 1 L^{-1} with a 10x enhancement (Burrows et al., 2022)

Are dust INPs larger?
Maybe, but data is too noisy to be sure

Aerodynamic Particle Sizer (APS)
Real-time computer display



194 of 297sec on Sample 1 of 1 | Sample # 1 | Total Count = 392

Aerodynamic Diameter Table [...

	Number #/cm³	Surface µm²/cm³	Mass mg/m³
< 0.523	3.59e-02	1.01e-02	5.07e-07
0.542	5.94e-02	5.49e-02	4.96e-06
0.583	9.90e-03	1.06e-02	1.03e-06
0.626	1.98e-02	2.44e-02	2.55e-06
0.673	4.95e-02	7.04e-02	7.90e-06
0.723	2.97e-02	4.88e-02	5.88e-06
0.777	5.94e-02	0.113	1.46e-05
0.835	8.91e-02	0.195	2.72e-05
0.898	7.92e-02	0.200	3.00e-05
0.965	0.158	0.463	7.44e-05
1.037	0.208	0.702	1.21e-04
1.114	0.148	0.579	1.07e-04
1.197	0.129	0.579	1.16e-04
1.286	9.90e-02	0.515	1.10e-04
1.382	8.91e-02	0.535	1.23e-04
1.486	0.119	0.823	2.04e-04
1.596	5.94e-02	0.475	1.26e-04
1.715	2.97e-02	0.274	7.85e-05
1.843	5.94e-02	0.634	1.95e-04
1.981	0.129	1.59	5.24e-04
2.129	0.109	1.55	5.50e-04
2.288	0.139	2.28	8.68e-04

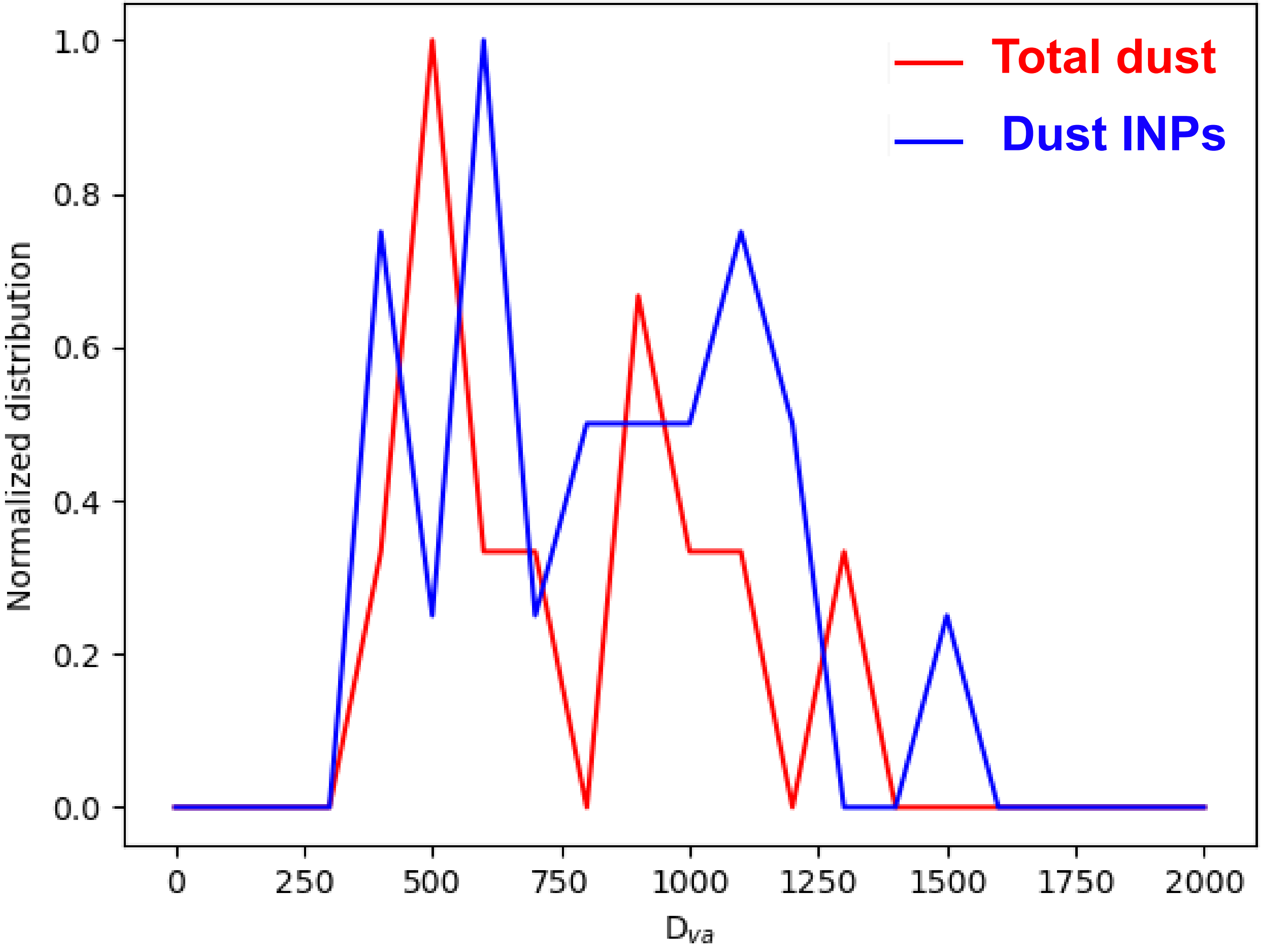
dW/dlogDp | 194 of 297sec on Sample 1 of 1 | Sample # 1

Statistics Table [CFC_PCVI_Check2.A21]

	Number Particle Size	Surface Particle Size	Mass Particle Size
Median (µm)	---	---	---
Mean (µm)	---	---	---
Geo. Mean (µm)	---	---	---
Mode (µm)	---	---	---

194 of 297sec on Sample 1 of 1 | New Sample

Size distributions of dust particles



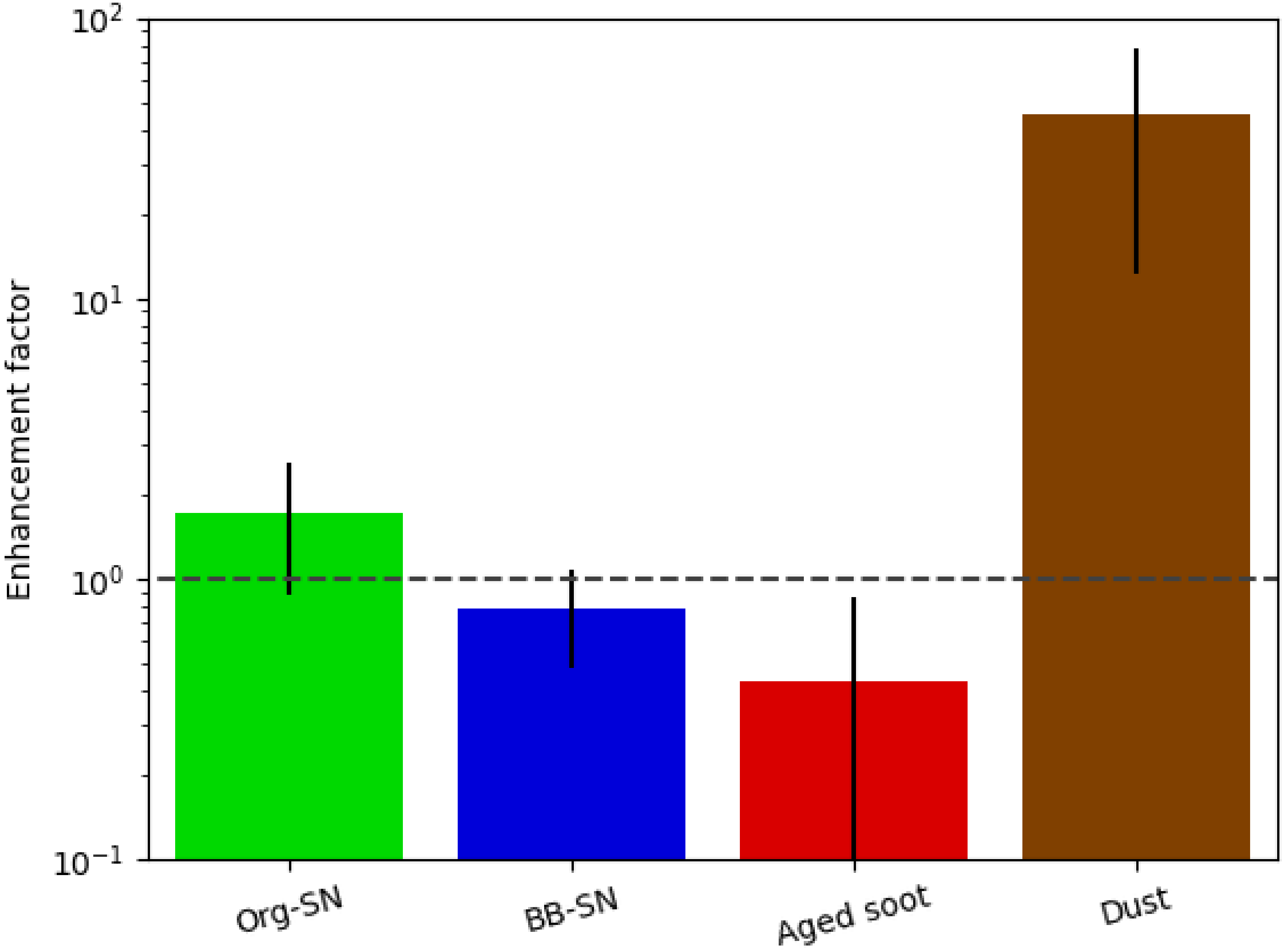
Are dust particles more likely to be INPs?

YES: dust is enhanced by more than an order of magnitude in ice residuals [T = ca. -30℃]

Enhancement factors for particle types classified from the miniSPLAT single-particle mass spectrometer.

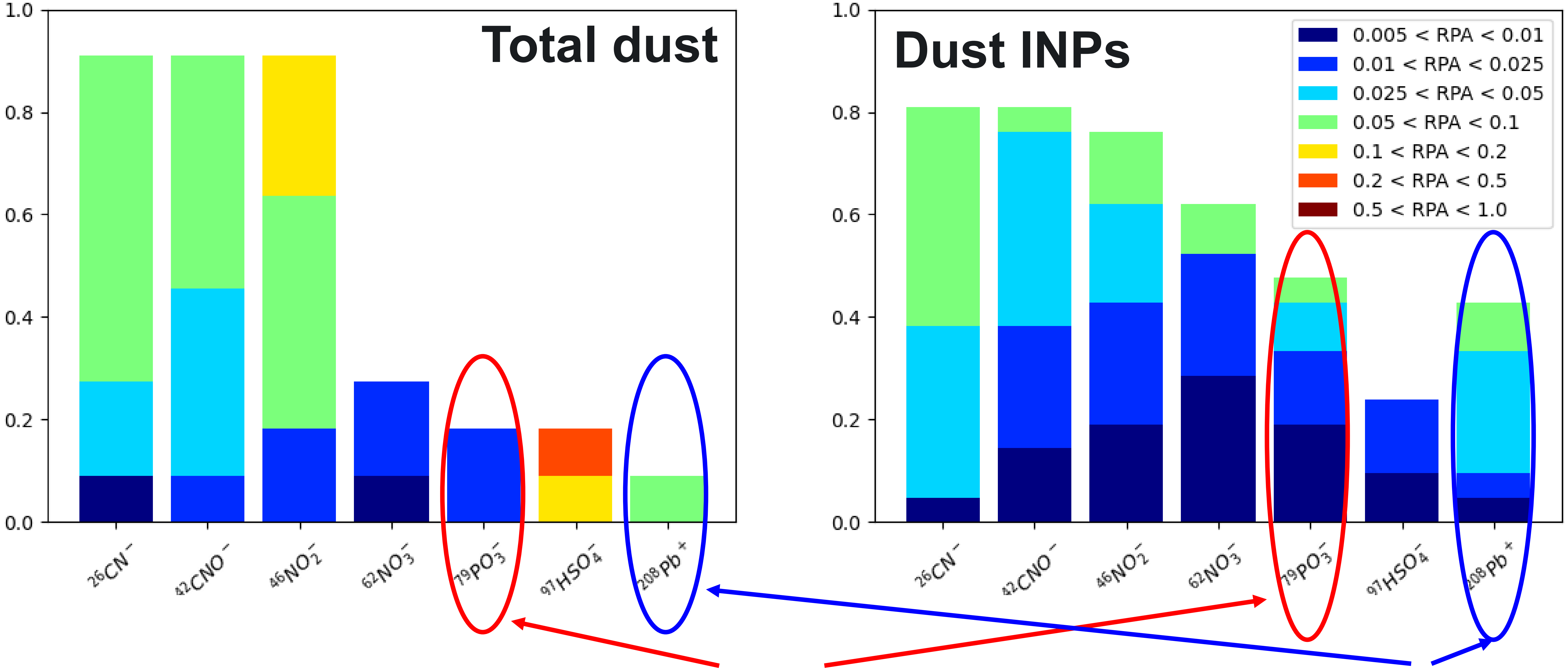
Enhancement factor = Fraction of INPs / Fraction of all particles

(per particle type)



Cornwell et al., in prep.

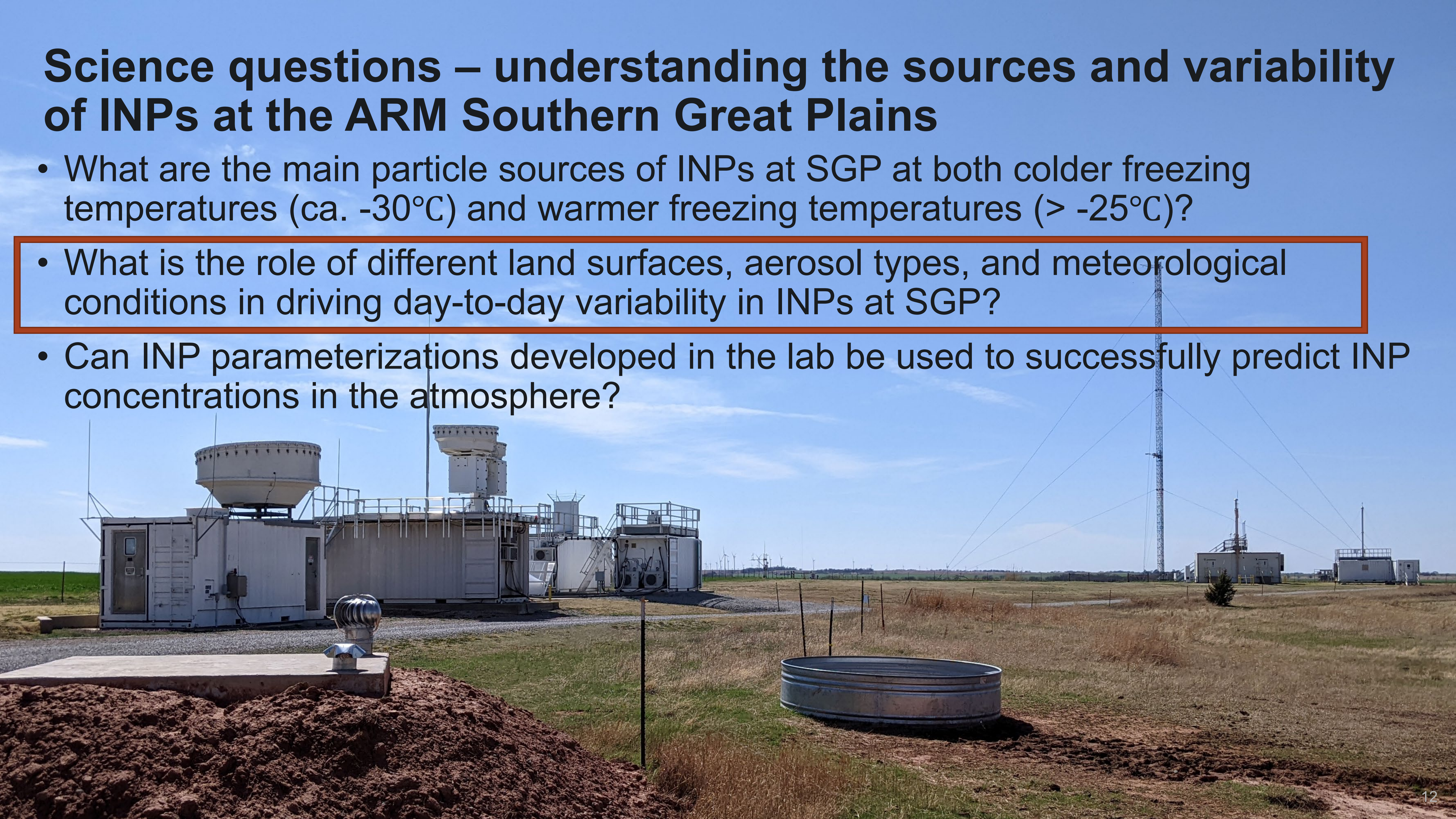
Are dust particles that contain more “biological” material more likely to be INPs? YES



Dust INPs contain more $^{79}PO_3^-$ (marker for bioaerosol) and $^{208}Pb^+$

Cornwell et al., in prep.

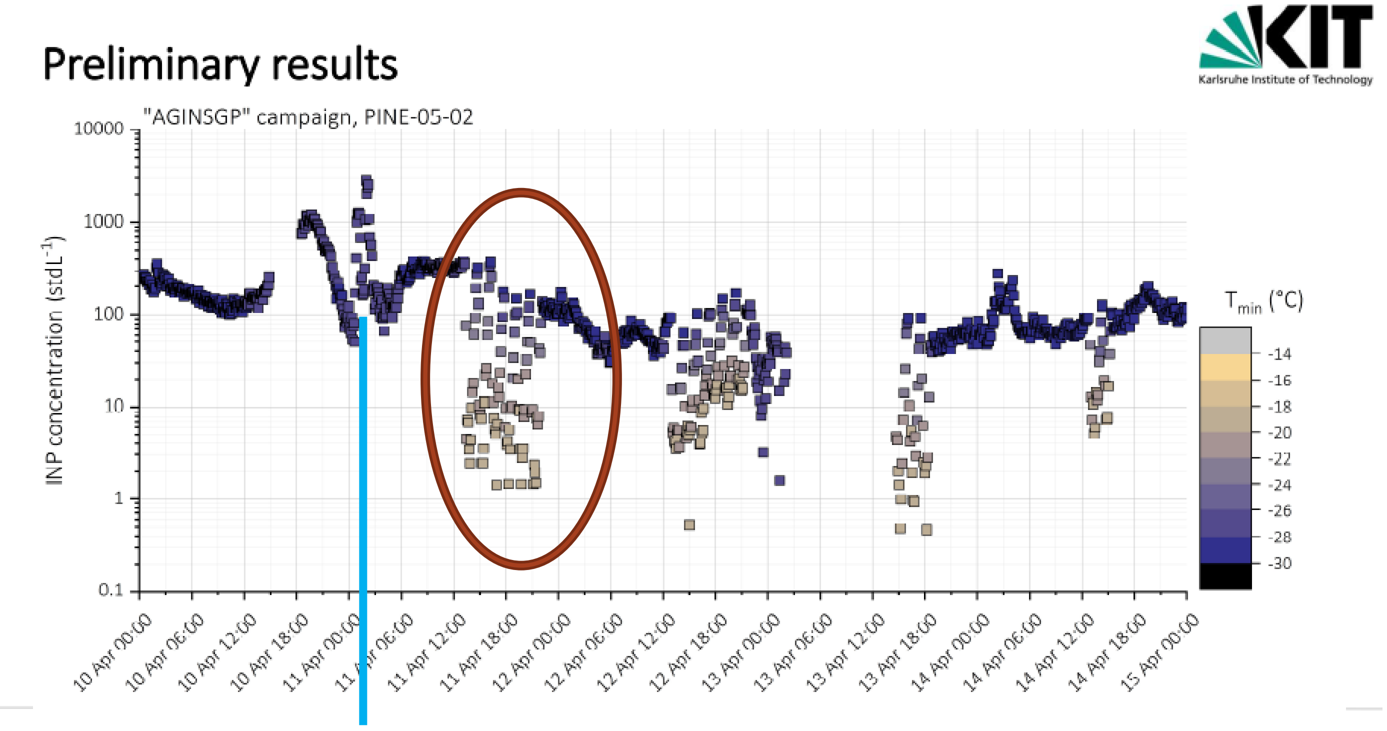
Science questions – understanding the sources and variability of INPs at the ARM Southern Great Plains



- What are the main particle sources of INPs at SGP at both colder freezing temperatures (ca. -30℃) and warmer freezing temperatures (> -25℃)?
- What is the role of different land surfaces, aerosol types, and meteorological conditions in driving day-to-day variability in INPs at SGP?
- Can INP parameterizations developed in the lab be used to successfully predict INP concentrations in the atmosphere?

Case study day – April 11
INP measurements appear uncorrelated with changes in aerosol size distribution

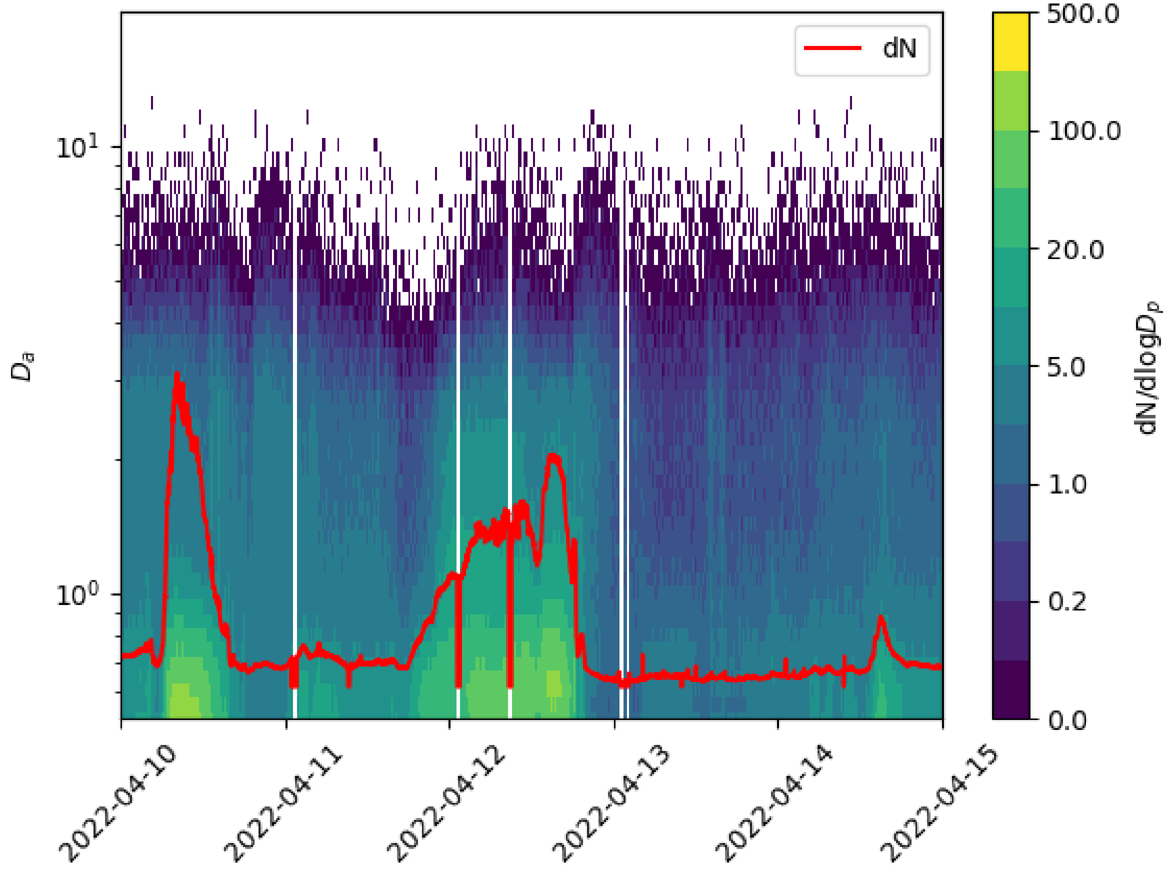
A short-term peak in INP concentrations on Sunday evening appears to be associated with a precipitation event



Precipitation event

Period with successful residual characterization experiment

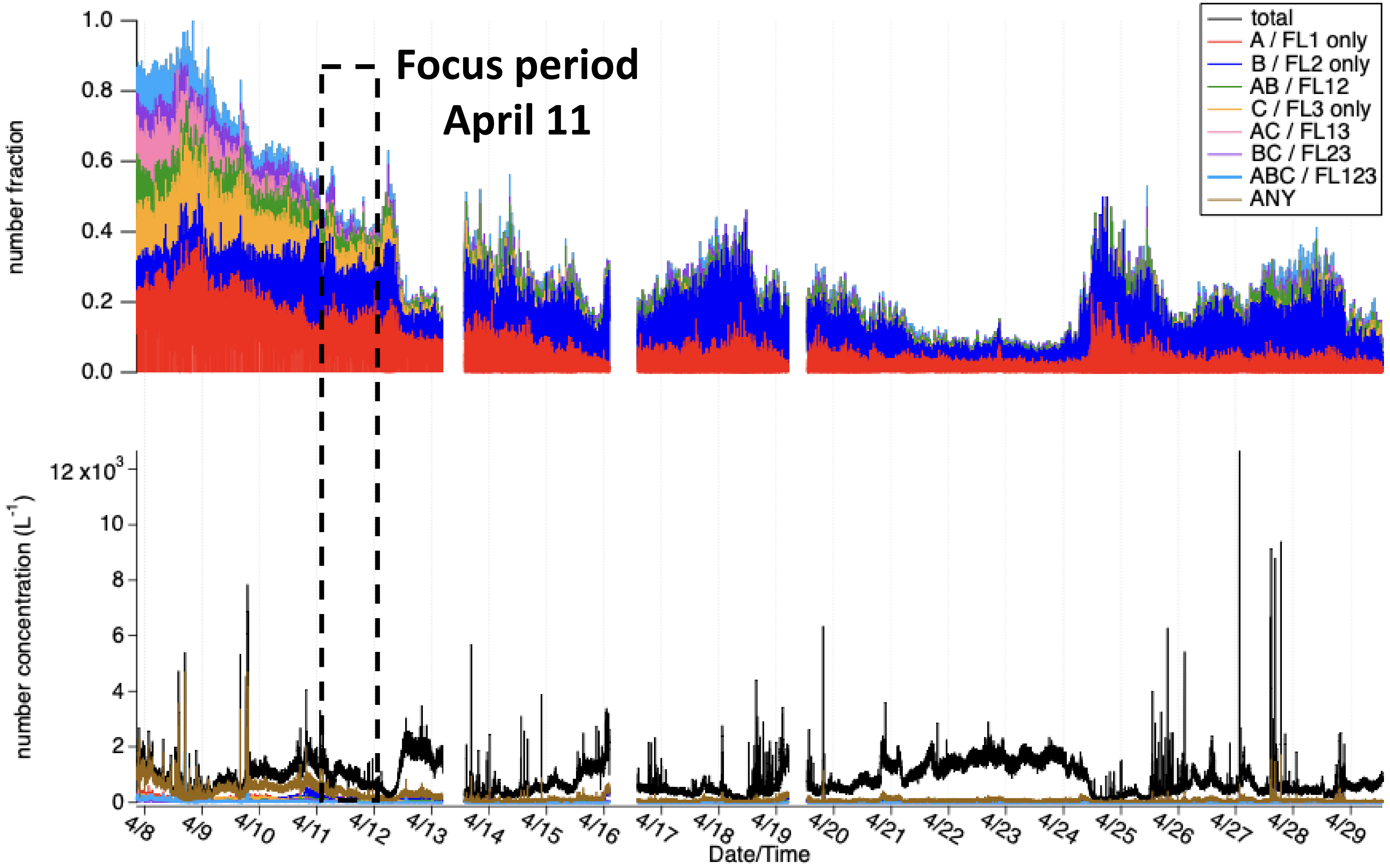
No obvious increase in total aerosol concentrations that could explain this spike (APS)



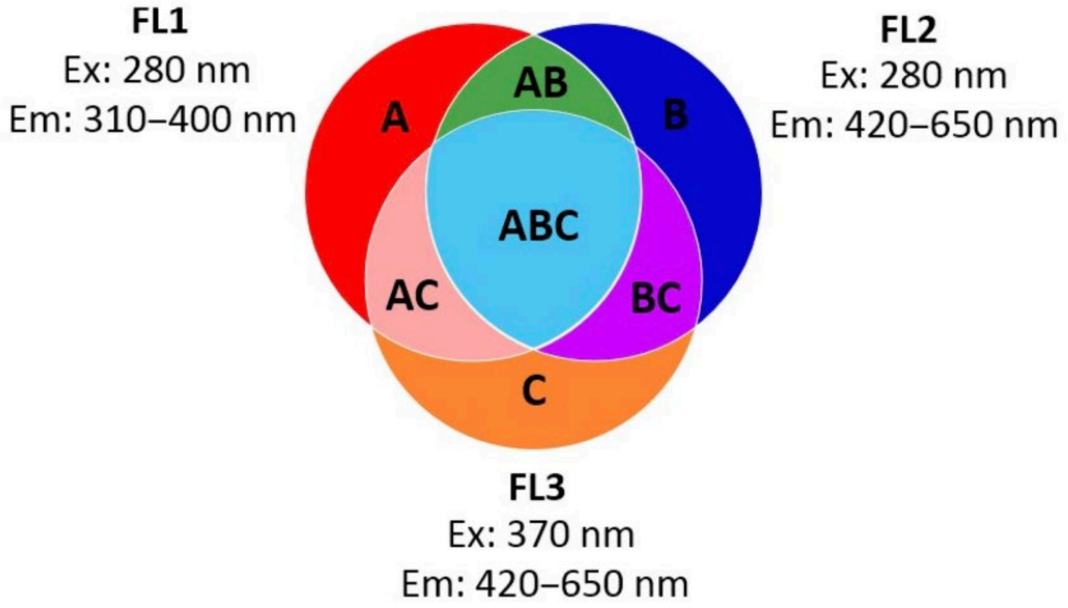
Fluorescent particles – which are often biological – are uncorrelated with total particle concentrations

Previous studies have found that subclasses of fluorescent (bio-) aerosol are predictive of warm-temperature INPs

WIBS measurements of fluorescent (bio-)aerosol



WIBS particle fluorescence categories



Figures courtesy of Alex Huffman, Alex Volkova, and Dorian Schwartz (University of Denver)

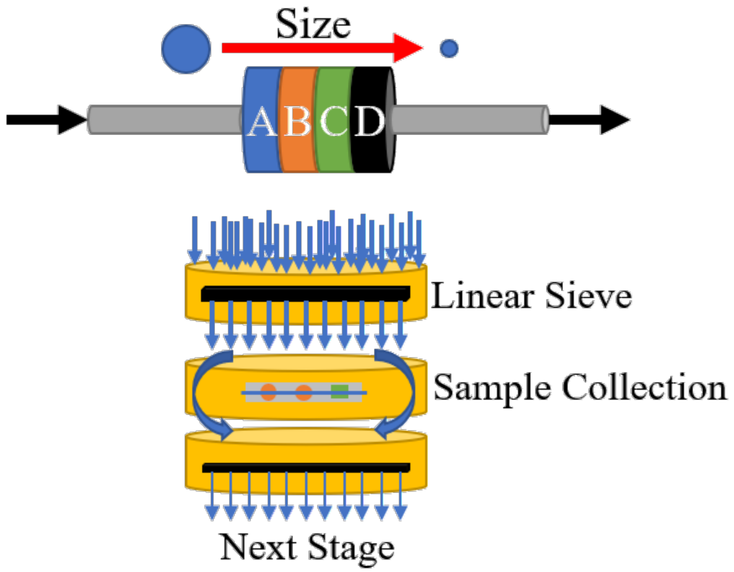
Size-resolved aerosol composition differs between samples from the surface and aloft

Ground samples: 04/11/2022; 13:39-21:39 (UTC)

Includes high-INP episode (15:00-18:00)

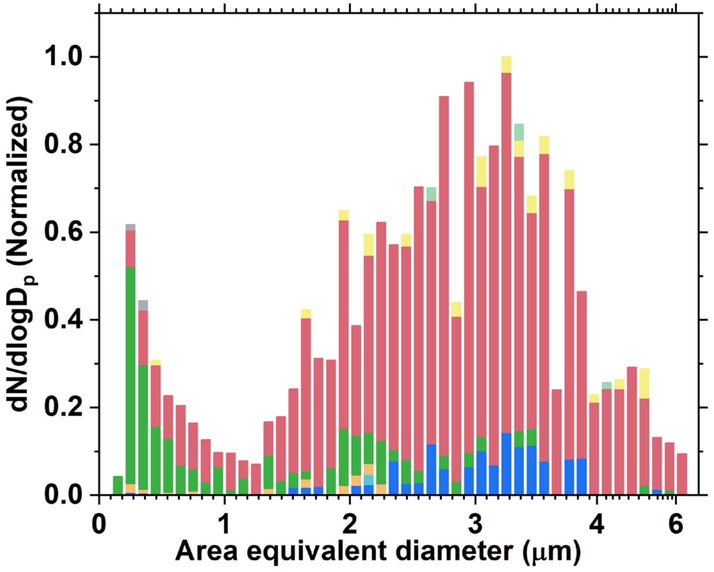
Samples aloft (250-500 m ascending): 04/11/2022 21:15-0:04

Collected after high-INP episode (15:00-18:00)

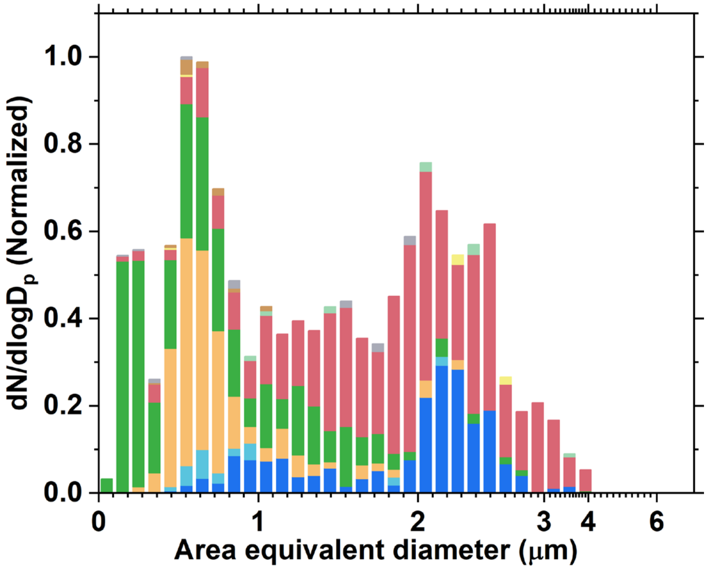


Sioutas Impactor

11/04/2022, N.P.= 1130 (Day Sample, Stage A+B)

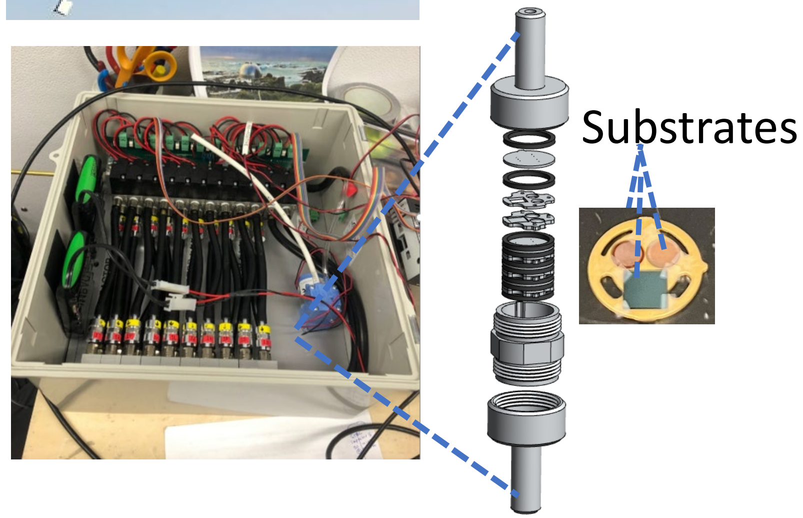


11/04/2022, N.P.= 1756 (Day Sample, Stage C+D)

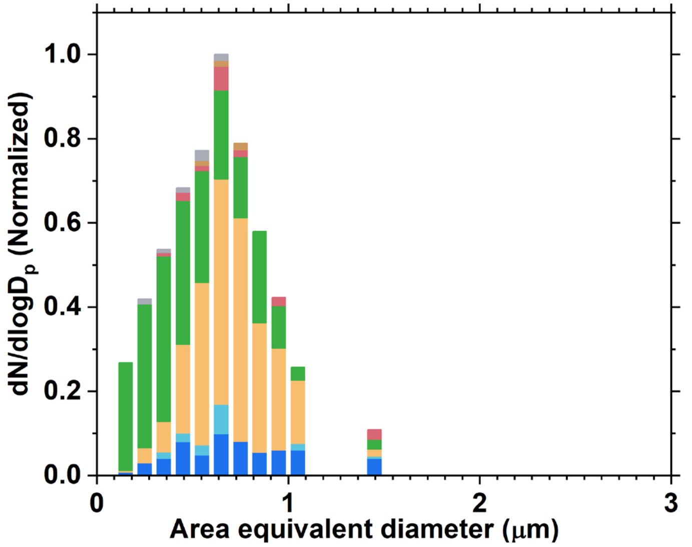


STAC deployed with TBS

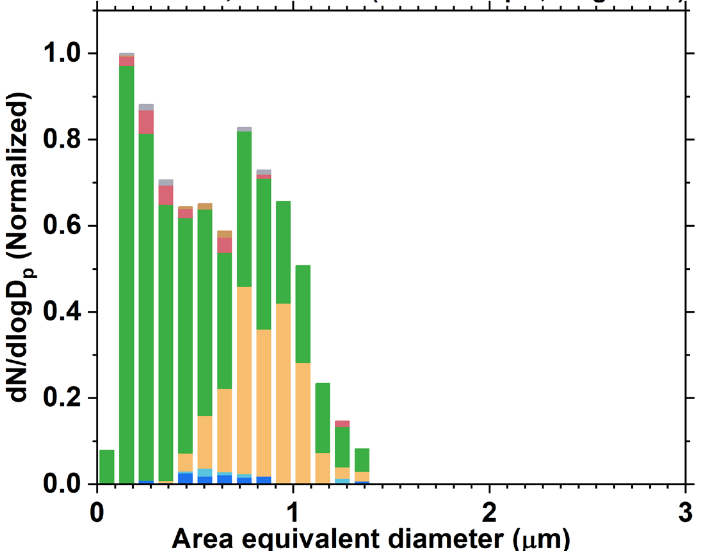
Image Courtesy: Dari Dexheimer (SNL)



11/04/2022, N.P.= 559 (STAC Sample, Stage A+B)



11/04/2022, N.P.= 1697 (STAC Sample, Stage C+D)



🟦 **Na-rich**	🟦 **Na-rich Sulfate**	🟧 **Sulfate**	🟩 **Carbonaceous**	🟥 **Dust**
🟨 **Biological**	🟩 **Si-rich Sulfate**	🟫 **K-rich Sulfate**	⬜ **Other**	

Adapted from slides by Nurun Nahar, EMSL

Ground and Tethered Balloon System sampling of size-resolved composition and INPs

Science questions:

- Are INPs and aerosols well-mixed in the boundary layer?
- Are near-surface measurements of aerosols/INPs representative of aerosols/INPs aloft?
- Are aerosols/INPs influenced by the same sources in near-surface air and aloft?

Talk by **Gavin Cornwell**, 4:15 pm breakout session in Regency room

ARM INP samplers at SGP

Ice-nucleating particle (INP) concentrations from the ARM Ice Nucleation Spectrometer

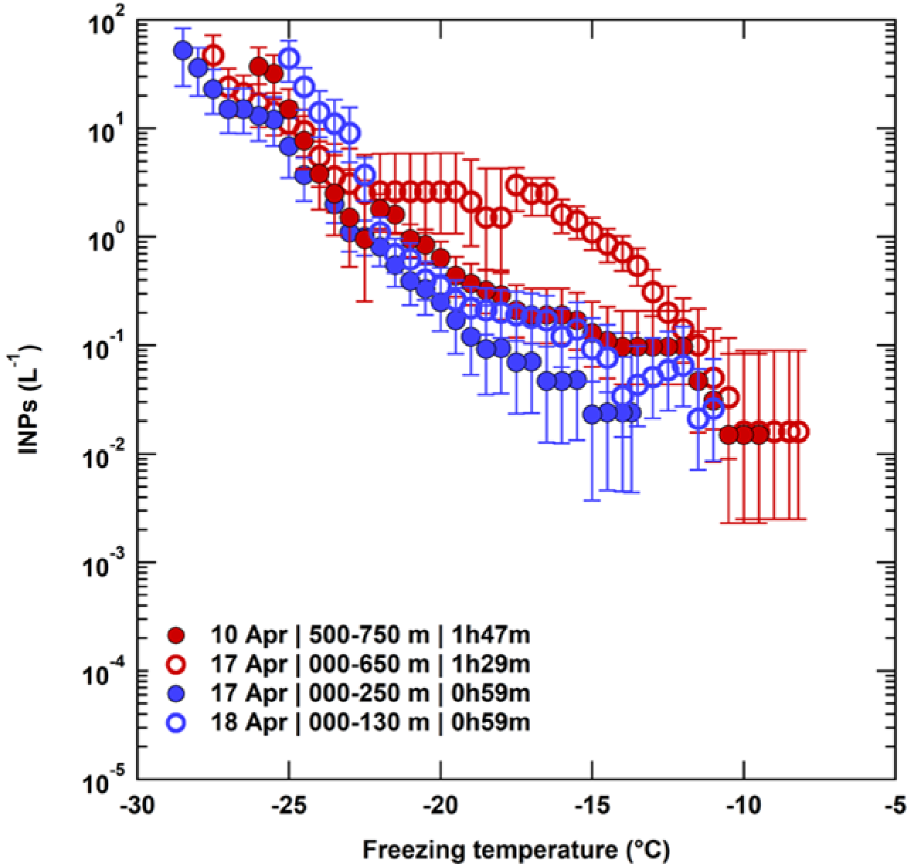


Image courtesy of Jessie Creamean, ARM instrument mentor

Open questions and ongoing/future work

- What is the role of different land surfaces or meteorological conditions in driving day-to-day variability in INPs at SGP?
    - Continuing analysis of observed features correlated with INP concentrations
    - Connect observations with source regions and meteorological conditions via back-trajectory analysis

- Can INP parameterizations developed in the lab be used to successfully predict INP concentrations in the atmosphere?
    - From ground-based observations of aerosol properties?
    - From TBS-based observations of aerosol properties
    - Using simulated aerosol properties?

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Thank you