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Agricultural Ice Nuclei at Southern Great Plains Supplemental Sampling (AGINSGP-SUPP) Field Campaign Report

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Acronyms and Abbreviations

AGINSGP	Agricultural Ice Nuclei at Southern Great Plains
ARM	Atmospheric Radiation Measurement
CPC	condensation particle counter
FICUS	Facilities Integrating Collaborations for User Science
INP	ice-nucleating particle
INS	ice-nucleation spectrometer
SGP	Southern Great Plains
TBS	tethered balloon system

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1.0 Summary

The Agricultural Ice Nuclei at Southern Great Plains Supplemental Sampling (AGINSGP-SUPP) field campaign took place from April 8 to April 28, 2022. It included sample collection and analysis of filter samples for ice-nucleating particle (INP) concentrations. By enabling quantification of INPs at warmer temperatures (i.e., T > 258 K), these samples complemented the real-time observations of INPs that were performed as part of the AGINSGP campaign during the same period. In addition to collecting ground-based samples, the campaign collected vertical samples of INPs aboard the Atmospheric Radiation Measurement (ARM) tethered balloon system (TBS) as shown in Figure 1. These vertical samples complemented the vertical profiling of aerosol properties that was supported under a related Facilities Integrating Collaborations for User Science (FICUS) proposal.

Figure 1. The ARM tethered balloon system in action on April 11, 2022. Photo: Darielle Dexheimer, Sandia National Laboratories.

The overall aim of these three campaigns was to improve understanding of the sources and variability in observed INP concentrations at ARM's SGP observatory. For example, warm-temperature INPs in this agricultural region are thought to originate in part from regional emissions of fertile, agricultural soils containing high organic content. Laboratory experiments have shown that soil particles with high organic content are more efficient INPs than inorganic soils (e.g., Tobo et al. 2014). Quantification of warm-temperature INPs under ambient conditions currently can only be achieved via offline methods such as the ARM ice-nucleation spectrometer (INS). Therefore, offline sampling for the INS was required to complement the real-time INP measurements conducted during the AGINSGP campaign.

INS samples are collected operationally at the SGP site on a 6-day frequency. However, this temporal resolution is not sufficient to distinguish between INP concentrations in different air masses impacted by different particle sources and meteorological conditions. To better distinguish between INPs impacted by different air masses, 12-hourly ground-based samples (see Figure 2) were collected (day/night). A total of 27 ground-based filters were collected.

Figure 2. Ground-based sampling of INPs at the ARM SGP site. Photo: Darielle Dexheimer, Sandia National Laboratories.

Vertical profiles of INPs are also of interest since INPs need to be transported vertically in order to impact clouds. While INPs sampled in near-surface air are frequently assumed to be representative for INPs impacting clouds that are coupled with the boundary layer, few measurements of INP vertical profiles exist to test the validity of this assumption. Larger (supermicron) particles can contribute a substantial fraction of the atmospheric INP budget (e.g., Si et al. 2018) and are potentially less well mixed in the boundary layer than smaller particles (Cornwell et al. 2021).

Vertical profiles of INPs were measured by collecting samples aboard the TBS using a miniature, time-resolved filter sampler, called the IcePuck (Handix Scientific). TBS samples were successfully collected on 10 days during the campaign; windy conditions prevented flights on most other days. The IcePuck collected 2-4 samples per flight at different altitude ranges.

Dusty conditions dominated during the early period of the campaign, while the later period included frequent observations of biomass burning aerosol, likely originating from regional controlled burns and wildfires.

2.0 Results

Table 1 provides an overview of the sample collection and processing status. Ice spectra analyses have been completed for all TBS samples and for selected ground samples. Real-time observations were used to identify days with high INP events as potential case study days. Ice spectra analyses have also been completed for the ground-based samples on the identified case study days.

Table 1. Overview of INS samples collected and processed during the campaign, in both ground-based and TBS-based sampling.

Date	Ground INS Samples Collected	Ground INS Samples Processed	TBS INS Samples Collected	TBS INS Samples Processed
4/7/2022	day/night	night	–	–
4/8/2022	day/night	day	–	–
4/9/2022	day/night	unprocessed	–	–
4/10/2022	day/night	night	✓	✓
4/11/2022	day/night	day	✓	✓
4/12/2022	day/night	unprocessed	–	–
4/13/2022	day/night	unprocessed	–	–
4/14/2022	day/night	unprocessed	✓	✓
4/15/2022	day/night	unprocessed	–	–
4/16/2022	day/night	unprocessed	–	–
4/17/2022	day/night	night	✓	✓
4/18/2022	day/night	day/night	✓	✓
4/19/2022	day/night	day	✓	✓
4/20/2022	day/night	unprocessed	–	–
4/21/2022	day/night	unprocessed	✓	✓
4/22/2022	day/night	unprocessed	–	–
4/23/2022	day/night	unprocessed	–	–
4/24/2022	day/night	unprocessed	✓	✓
4/25/2022	day/night	unprocessed	✓	✓
4/26/2022	day/night	unprocessed	✓	✓
4/27/2022	day/night	unprocessed	–	–
4/28/2022	day/night	unprocessed	–	–

Initial analysis of the INS data from the campaign shows that two samples exhibited elevated concentrations of INPs in the temperature range from -12 to -20°C (Figure 3). Elevated INP concentrations in this temperature range have frequently been associated with the presence of biological INPs in past studies (e.g., Hill et al. 2016).

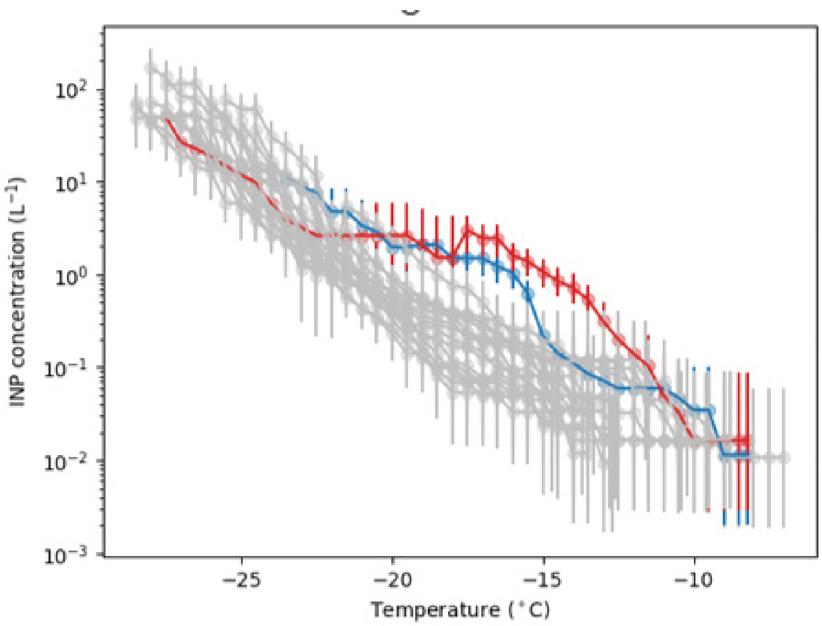

Figure 3. Initial analysis of INS data from TBS flights shows two flight days with notably elevated INP concentrations at warmer temperatures. Blue: 11 April, 2022; Red: 17 April, 2022.

Analysis is ongoing to investigate the potential causes of these variations in warm-temperature INPs. We will analyze variations in INP concentrations in combination with the aerosol composition data obtained under the related ARM and FICUS campaigns described previously, and back trajectory data. This analysis will enable us to better understand the sources of INPs impacting these measurements.

Additionally, we are exploring whether vertical concentrations of INPs can be linked to other vertical information from ground-based remote-sensing and in situ instruments aboard the TBS. For example, Figure 4 shows that on April 17, an aerosol layer was observed at about 400 m altitude by both in situ measurements and ground-based remote sensing. The flight with elevated warm-temperature INP concentrations on this day (red line in Figure 3) reached an altitude of over 600 m, penetrating this aerosol layer. Analysis of aerosol composition data has been performed for these April 17 flights. In future efforts, these composition measurements will be examined to understand whether the observed variations in INP concentrations on April 17 can be linked to observed aerosol properties.

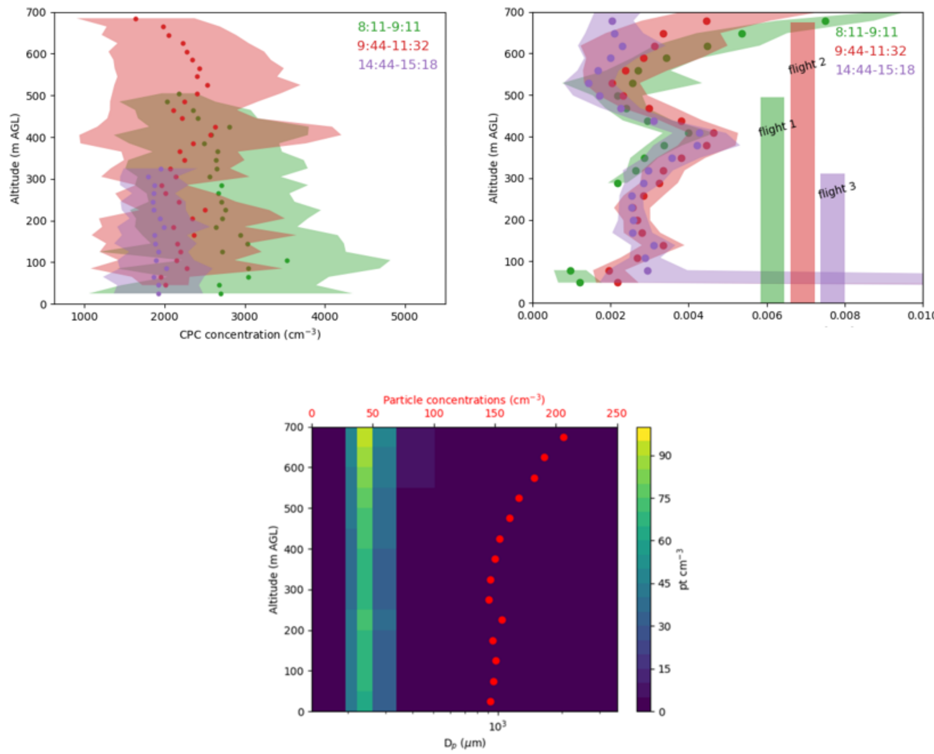

Figure 4. Vertical measurements of particle concentrations on April 17 from both in situ and remote-sensing observations indicate the presence of an elevated layer of particles near 400 m. INP concentrations were also elevated during the April 17 TBS flight that had the greatest exposure to higher altitudes within the boundary layer, suggesting a potential connection between the particle layer at 400 m and elevated INP concentrations in the TBS samples. Left: Vertical profile of particle number concentrations (mean and range) from the condensation particle counter (CPC) onboard the TBS, during three flights on April 17. Right: Raman lidar particulate backscatter during each of the three TBS flights. The altitude range sampled during each flight is indicated as a vertical bar, and the time of day for each flight is printed in the corresponding color.

3.0 Publications and References

3.1 Publications

We expect to submit at least two publications that include results from the campaign within the next year, including an invited article providing an overview of the campaign in the journal *Environmental Science: Atmospheres*. Filter processing status for the ice nucleation spectrometer is available on the ARM website (https://www.arm.gov/capabilities/instruments/ins). Data will be published to the ARM Data Center by the ARM instrument mentor team following the campaign's data management plan.

3.2 Presentations

Invited talks

1. **Burrows, SM**. Title TBD. Gordon Research Conference in Atmospheric Chemistry, Newry, Maine, July, 2023.
2. **Burrows, SM**. Catching soil INPs on the fly: early results from the AGINSGP campaign. 2022 Joint ARM User Facility and ASR PI Meeting, Rockville, Maryland, October, 2022.
3. **Cornwell, G**. Analysis of TBS INP measurements during the AGINSGP experiment. 2022 Joint ARM User Facility and ASR PI Meeting, Rockville, Maryland, October, 2022.
4. Burrows, SM, G Cornwell, I Steinke, D Dexheimer, J Creamean, NN Lata, and S China. Understanding contributions of agricultural dust to vertical profiles of ice-nucleating particles in the central Great Plains. In breakout session: "Working together – Leveraging the ESS and ASR research communities to improve understanding of coupled land-atmosphere processes." 2022 DOE-BER ESS PI meeting, Virtual conference, May 2022.
5. Creamean, J, T Hill, and C Hume. TBS ice nucleating particle (INP) measurements. 2022 Joint ARM User Facility and ASR PI Meeting, Rockville, Maryland, October, 2022.

3.3 References

Cornwell, GC, H Xiao, LK Berg, and SM Burrows. 2021. "Simulated dust transport in the convective boundary layer." *Journal of Geophysical Research − Atmospheres* 126, e2020JD033429, https://doi.org/10.1029/2020JD033429

Creamean, J, T Hill, and C Hume. 2022. Ice Nucleation Spectrometer (INS) Instrument Handbook. Ed. by Robert Stafford, ARM user facility. DOE/SC-ARM-TR-278. https://doi.org/10.2172/1846263

Hill, TC, PJ DeMott, Y Tobo, J Fröhlich-Nowoisky, BF Moffett, GD Franc, and SM Kreidenweis. 2016. "Sources of organic ice nucleating particles in soils." *Atmospheric Chemistry and Physics* 16(11): 7195−7211, https://doi.org/10.5194/acp-16-7195-2016

Si, M, VE Irish, RH Mason, J Vergara-Temprado, SJ Hanna, LA Ladino, JD Yakobi-Hancock, CL Schiller, JJ Wentzell, JP Abbatt, and KS Carslaw. 2018. "Ice-nucleating ability of aerosol particles and possible sources at three coastal marine sites." *Atmospheric Chemistry and Physics* 18(21): 15669−15685, https://doi.org/10.5194/acp-18-15669-2018

Tobo, Y, PJ DeMott, TCJ Hill, AJ Prenni, NG Swoboda-Colberg, GD Franc, and SM Kreidenweis. 2014. "Organic matter matters for ice nuclei of agricultural soil origin." *Atmospheric Chemistry and Physics* 14(16): 8521−8531, https://doi.org/10.5194/acp-14-8521-2014