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Examining the Ice Nucleating Particles from Southern Great Plains Part II (ExINP-SGP) Field Campaign Report

N Hiranuma DA Knopf

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N Hiranuma, West Texas A&M University
DA Knopf, Stony Brook University

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Acronyms and Abbreviations

AEROICESTUDY	Aerosol-Ice Formation Closure Pilot Study
AIC02	Aerosol-Ice Formation Closure Study
AIDA	Aerosol Interactions and Dynamics in the Atmosphere
AOS	Aerosol Observing System
APS	aerosol particle sizer
ARM	Atmospheric Radiation Measurement
CPC	condensation particle counter
DOE	U.S. Department of Energy
ExINP	Examining the Ice-Nucleating Particles
HPLC	high-performance liquid chromatography
INP	ice nucleating particle
PI	principal investigator
PM	particulate matter
RH	relative humidity
SGP	Southern Great Plains
USDA	U.S. Department of Agriculture
UTC	Coordinated Universal Time

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1.0 Summary

Knowledge of airborne particulate matter (PM), especially the particles that have supermicron diameters, is key for understanding ice-nucleating particles (INPs). Supported by the Atmospheric Radiation Measurement (ARM) user facility, recent INP measurements at the Southern Great Plains observatory (SGP; 36° 36′ 18″ N, 97° 29′ 6″ W) during multiple campaigns, such as SINCE-2014 (DeMott et al. 2015), Examining the Ice-Nucleating Particles from SGP (ExINP-2019; Hiranuma and Vepuri 2020), and Aerosol-Ice Formation Closure Pilot Study (AEROICESTUDY; Knopf et al. 2021a), strongly suggested the contribution of supermicron aerosol particles to observed INP abundance at SGP. However, verification of this hypothesis was hampered since additional offline laboratory analyses require sufficient amounts of collected airborne PM, which was lacking. Therefore, the principal investigators (PIs) conducted a field campaign, named ExINP-SGP II, to collect airborne PM at SGP for complementary laboratory characterization of the particles' physicochemical properties (including ice nucleation properties). We used a passive particle sampler, which is a 4' x 4' x 2" (L x W x D) aluminum pan inside the 12"-high wooden windshield wall at the rooftop deck of the ARM Aerosol Observing System (AOS) trailer to collect dry PM deposits from January to April 2021. Figure 1 shows images of our experimental setup at the site. Additionally, we also collected surface soil near the ARM AOS trailer on 20 November 2020 (Figure 1b) to examine the ground soil dust particles (< 63 µm sieved) for their propensities to initiate immersion freezing compared to collected ambient PM. Surface soil and airborne samples were stored in the chemically inert container separately and kept in a dry, cool place until analyzed.

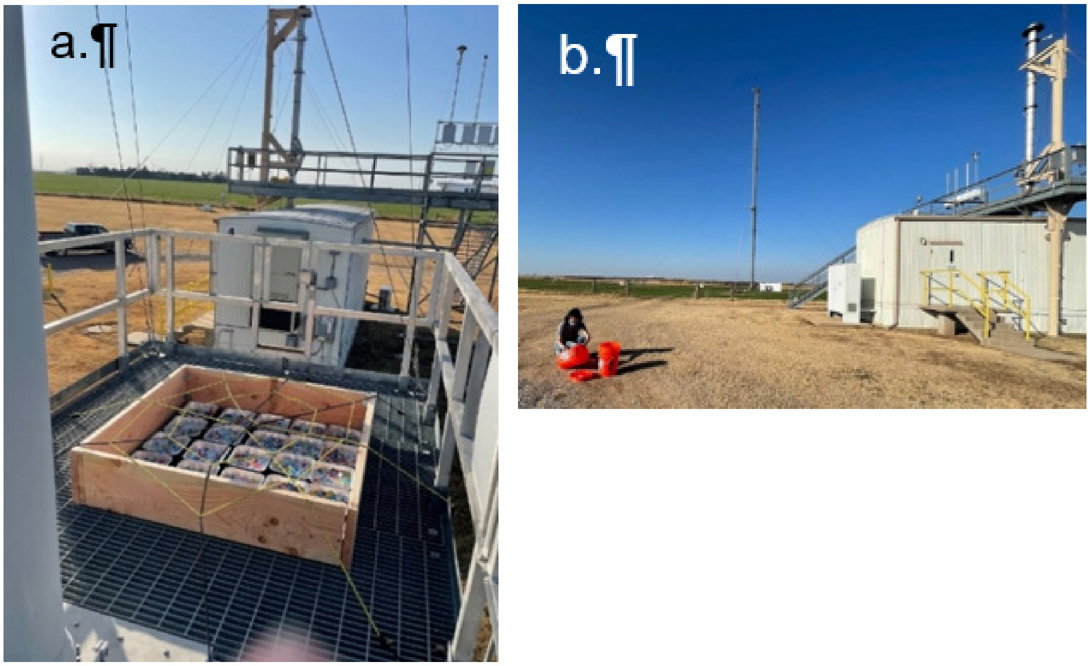

Figure 1. The passive ambient PM sampler deployed on the SGP AOS trailer (a) and surface soil sampling activity taking place at the southwestern boundary of the SGP facility.

This report focuses on describing the outcomes of (1) field sampling activities and (2) preliminary offline characterizations for our field samples. Actual airborne PM samples were successfully collected from 20 January to 20 April 2021. During the three months, we collected a total of 11 samples. Table 1 summarizes the sampling time in Coordinated Universal Time (UTC) as well as ambient conditions, including temperature, relative humidity (RH), wind speed, and wind direction, for individual sampling periods. Furthermore, Figure 2 shows temporal plots of the measured ambient conditions along with averages during the entire ExINP-SGP-II campaign. In general, we chose warm and dry conditions to carry out our ambient sampling activities**.** As seen in Table 1, with a few exceptions, the ambient temperatures during most of our sampling periods were higher than the ExINP-SGP II campaign average temperature (6.6 °C). Likewise, the observed RHs during sampling were mostly lower than the same campaign average RH (70.6 %).

The wind properties frequently changed during the campaign as seen in Figures 2c and 2d. Due to the observed variabilities, we decided to analyze the wind speed and direction over each sampling period instead of analyzing back-trajectories, which cannot be integrated over our sampling intervals (i.e., typically several days). While the average wind speed ranged from 3.7 to 10.2 m s^{-1}, the average wind direction was predominantly from the south (90° ≤ wind direction ≤ 270°; Table 1). We covered our passive sampler with a weather protection tarp during raining and snowing days. For instance, as we observed intermittent precipitation events between 24 January and 3 February, we did not conduct any PM sampling during this time. The corresponding ambient conditions for this nominal wet period (temperature, RH, wind speed, and wind direction) were on average 3.7 ± 0.3 °C, 81.5 ± 0.9 %, 5.4 ± 0.1 m s^{-1}, and 196.5 ± 6.3 degree, respectively. Without any exceptions, our sampling was conducted with a higher average temperature and lower RH conditions than this predominantly wet period.

Table 1. Summary of the sampling time and associated ambient conditions based on hourly time-averaged meteorological data (sgpmetE13). The presented data are averaged over each sampling period, and the average ± standard error values are shown.

Sample ID	Start DAT (UTC)	Stop DAT (UTC)	Temperature (°C)	RH (%)	Wind Spd (m s^{-1})	Wind Dir (degree)
1	1/20/2021 19:00	1/22/2021 21:00	4.3 ± 0.5	79.5 ± 2.9	3.7 ± 0.3	114.2 ± 9.0
2	2/3/2021 15:00	2/5/2021 20:00	7.5 ± 0.7	64.1 ± 2.1	6.2 ± 0.4	215.2 ± 11.5
3	2/22/2021 18:00	3/1/2021 17:00	7.3 ± 0.4	70.8 ± 1.6	5.1 ± 0.2	178.7 ± 7.4
4	3/1/2021 18:00	3/4/2021 18:00	9.8 ± 0.7	49.1 ± 2.3	4.2 ± 0.2	191.5 ± 4.4
5	3/8/2021 21:06	3/11/2021 0:27	18.4 ± 0.6	60.3 ± 1.9	10.2 ± 0.3	178.8 ± 2.1
6	3/25/2021 20:50	3/29/2021 20:05	12.9 ± 0.6	64.4 ± 2.1	5.4 ± 0.3	208.0 ± 7.2
7	3/29/2021 22:00	4/1/2021 20:00	11.5 ± 0.8	43.7 ± 2.3	5.7 ± 0.6	126.5 ± 14.3
8	4/1/2021 21:05	4/5/2021 22:23	15.4 ± 0.6	59.9 ± 2.1	6.4 ± 0.2	176.9 ± 1.9
9	4/5/2021 23:00	4/8/2021 22:00	15.8 ± 0.7	65.9 ± 1.7	8.4 ± 0.2	229.0 ± 7.4
10	4/8/2021 22:38	4/12/2021 20:40	14.4 ± 0.6	56.0 ± 1.8	5.3 ± 0.3	188.2 ± 11.4
11	4/19/2021 21:40	4/20/2021 1:20	19.9 ± 1.4	41.2 ± 5.4	5.8 ± 1.4	84.0 ± 39.9

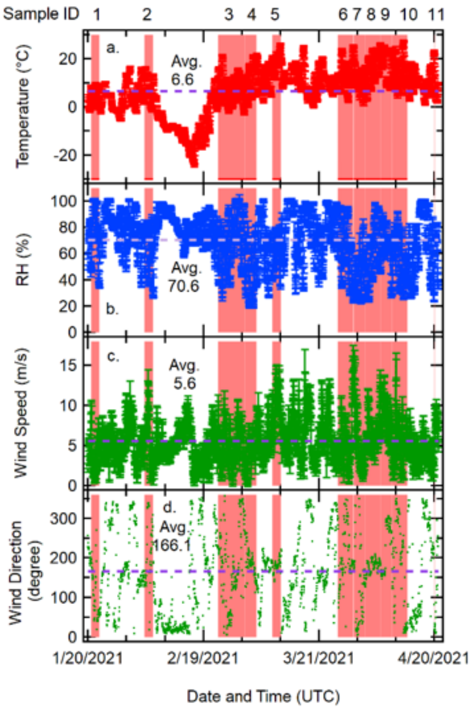

Figure 2. Time series of the hourly time-averaged ambient temperature, RH, wind speed, and wind direction during ExINP-SGP-II. The horizontal dashed lines represent the overall average conditions.

Figure 3 shows the time series of aerosol particle concentrations measured by two different ARM baseline instruments, a fine condensation particle counter (sgpaoscpcfE13; CPC hereafter) and an aerosol particle sizer (sgpaosapsE13; APS henceforth). The fine CPC used at SGP counts particles with sizes that range from 10 nm to 3 µm. The APS is a particle size spectrometer, measuring the particle aerodynamic diameter and associated concentration. The APS provides the number, surface, and volume size distributions for particles with aerodynamic diameters from 0.5 to 20 µm and with optical diameters from approx. 0.3 to 20 µm. The cumulative concentrations of CPC and APS were used for proxies of fine and coarse PM at SGP, respectively. To complement Figure 3, we also computed the time-averaged concentrations for individual sampling periods from a CPC and an APS. The summary is provided in Table 2 (next page). As can be seen in Figure 3 and Table 2, our sampling typically coincided with the conditions where we observed CPC concentrations close to or exceeding the overall campaign average (~ 2000 cm^{-3}). Thus, we conducted our sampling in a particle-laden environment. With many episodic spikes, presumably due to the wind-driven coarse particles and/or suspension of surface soil materials, the APS results also suggest that coarse particles were present during sampling. Afterward, we combined all collected samples to generate a composite (neglecting seasonality). This amount was sufficient for a set of organized offline measurement activities and re-suspension for ice nucleation experiments, which were completed in summer 2021 in part supported by an external transnational laboratory campaign, named Aerosol-Ice Formation Closure Laboratory Study (AIC02 hereafter), supported by EUROCHAMP (Aerosol Interactions and Dynamics in the Atmosphere [AIDA]-010-2021; https://www.eurochamp.org/tna-documents) (Knopf et al. 2021b). Altogether, we collected approximately 5 mL volume of airborne particle deposits during the ExINP-SGP-II campaign.

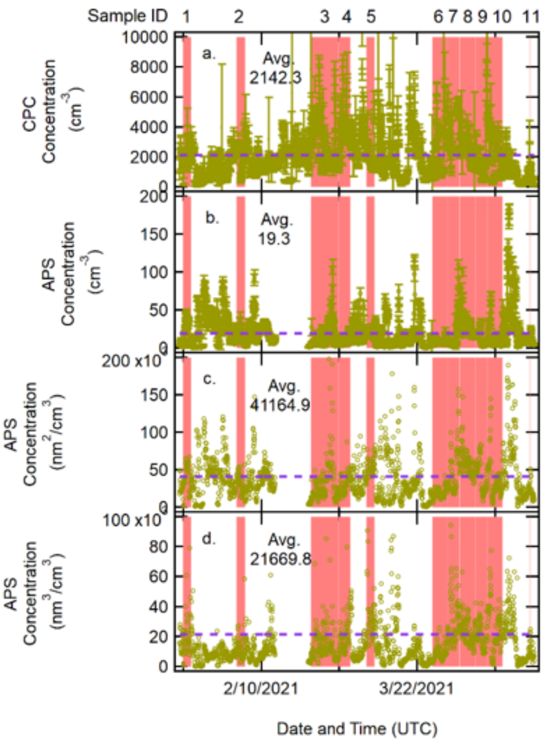

Figure 3. Time series of the measured CPC and APS particle concentrations during ExINP-SGP-II (1-hr time-averaged). The horizontal dashed lines represent the overall average conditions.

Lastly, the time-integrated APS volume concentrations showed a reasonable correlation with the estimated sample volumes, which is visually assessed after gently compacting samples (Table 2), with a Pearson correlation coefficient of ~ 0.57.

Table 2. Summary of the average aerosol particle concentrations measured during each sampling period. The presented data are averaged over each sampling period, and the average ± standard error values are shown.

Sample ID	Start DAT (UTC)	Stop DAT (UTC)	CPC Number Conc. (cm^{-3})	APS Number Conc. (cm^{-3})	APS Surface Conc. ($nm^2\ cm^{-3}$)	APS Volume Conc. ($nm^3\ cm^{-3}$)	Visually estimated Vol. collected (mL)
1	1/20/2021 19:00	1/22/2021 21:00	1832.7 ± 107.7	20.4 ± 2.1	95129.2 ± 31296.7	154450.4 ± 74511.6	0.2_5
2	2/3/2021 15:00	2/5/2021 20:00	1982.4 ± 120.4	16.5 ± 1.2	30985.9 ± 1733.4	12501.9 ± 1205.4	0.2_5
3	2/22/2021 18:00	3/1/2021 17:00	2932.3 ± 133.0	14.6 ± 1.2	45629.1 ± 6347.2	46476.7 ± 13272.5	1.5_0
4	3/1/2021 18:00	3/4/2021 18:00	4171.9 ± 171.3	8.4 ± 0.7	29261.2 ± 1595.5	18412.6 ± 1268.0	0.5_0
5	3/8/2021 21:06	3/11/2021 0:27	2332.9 ± 162.7	17.5 ± 0.6	51783.2 ± 1392.7	33698.5 ± 2830.6	0.2_5

Sample ID	**Start DAT (UTC)**	**Stop DAT (UTC)**	**CPC Number Conc. (cm^{-3})**	**APS Number Conc. (cm^{-3})**	**APS Surface Conc. (nm^{2} cm^{-3})**	**APS Volume Conc. (nm^{3} cm^{-3})**	**Visually estimated Vol. collected (mL)**
6	3/25/2021 20:50	3/29/2021 20:05	3614.4 ± 459.5	7.8 ± 0.4	19338.4 ± 737.3	9468.3 ± 551.5	$<0.1_{0}$
7	3/29/2021 22:00	4/1/2021 20:00	3767.4 ± 205.7	17.0 ± 3.4	50979.2 ± 4825.7	33925.7 ± 3007.3	0.2_{5}
8	4/1/2021 21:05	4/5/2021 22:23	2479.6 ± 98.1	28.0 ± 1.6	59832.6 ± 1784.7	24082.8 ± 866.2	1.0_{0}
9	4/5/2021 23:00	4/8/2021 22:00	1869.3 ± 239.3	13.3 ± 1.1	40704.7 ± 2499.1	20140.0 ± 999.9	0.5_{0}
10	4/8/2021 22:38	4/12/2021 20:40	2364.5 ± 168.3	10.0 ± 1.3	37604.6 ± 2825.2	24696.8 ± 1582.4	0.5_{0}
11	4/19/2021 21:40	4/20/2021 1:20	1240.37 ± 124.8	17.5 ± 3.7	39685.6 ± 5382.2	21020.6 ± 2313.4	$<0.1_{0}$

2.0 Results

Besides airborne samples (SGP Ambient hereafter; Figure 1a), we collected surface soil samples from SGP near the ARM AOS trailer (SGP Soil; Figure 1b) and obtained attic/filter-collected dust at the U. S. Department of Agriculture (USDA) facility in Big Spring, Texas (USDA). Table 3 (on the next page) summarizes the properties of SGP Soil and USDA. We note that no offline characterizations were conducted for airborne particles collected by a passive particle sampler at SGP (SGP Ambient) due to their limited amount.

We also characterized the immersion-freeing efficiencies of SGP Ambient, SGP Soil, and USDA samples. The freezing assay method for this preliminary assessment is described in Vepuri et al. (2021) and Hiranuma et al. (2021). Briefly, a known amount of sample was suspended in high-performance liquid chromatography (HPLC)-grade water (3 mL). The amount of HPLC water volume was determined to have a suspension weight percentage (wt%) of 0.1, which limits the detection capability to ~5000 INP per gram of sample. At this concentration, no substantial particle settling in a stock suspension was observed. Before starting an immersion freezing measurement, a suspension was vortex-shaken for 10 min. Idle time of 1 min without further stirring was applied for large particles to settle out. A series of diluted suspensions (×10 to ×1000) was analyzed as needed to acquire INP spectra covering the temperature down to -25 ºC. The measurements from the undiluted and diluted runs were merged by taking lower n_{m} values, which typically possess lower uncertainties (i.e., 95% confidence interval), for the overlapped temperature region. The total systematic temperature and immersion freezing efficiency uncertainties are ± 0.5 °C and ± 23.5 %. For this plot, the experimental uncertainty in the estimated n_{m} was evaluated and reported using the 95 % confidence interval method described in Schiebel (2017).

For our heating test, the suspension sample tube was immersed in boiling water (~100 °C) for 20 minutes. This temperature was chosen to denature proteinaceous INPs. Thus, the subtraction of heated n_{m} from non-heated n_{m} might represent their contribution of biological particles to immersion freezing. This procedure is adapted from Schiebel (2017). Briefly, the aerosol particle suspension (1 mL) from a non-treated stock was first transferred to a sterile Falcon tube. The screw-cap was closed, such that no water was lost. Then the tube was placed together with a precisely fitting Styrofoam ring in a water-filled glass beaker. The Styrofoam ring ensured that the tube was floating, and all of the aerosol suspension was submerged below the water surface for best heat transfer. The beaker was placed on a stirring hot plate for boiling.

Table 3. Properties of surface soil materials.

System	SGP Soil	*USDA
Sample Form	Powder (<63 µm sieved)	Powder (<53 µm sieved)
[1]Density, g m^{-3}	2.66	2.44
[2]N_2 BET-based specific surface area, m^2 g^{-1}	7.73	3.43
[3]Pore Volume, cm^3 g^{-1}	0.01	0.01
[4]XRD	Measurements done. Elemental composition analysis pending.	

[*] Van Pelt and Zobeck (2007).

[1] Bulk density values were measured using an N_2 gas displacement pycnometer (Quantachrome, 1200e Ultrapyc); ±3% uncertainty.

[2] Based on 3Flex (Micromeritics) N_2 physisorption (±<10% uncertainty).

[3] Based on 3Flex (Micromeritics) He physisorption for <202 Å pore sizes (± <10% uncertainty).

[4] Measured by Rigaku SmartLab.

Figure 4 represents the freezing efficiencies scaled to the mass, n_m, of SGP airborne particle deposit (SGP Ambient), bulk SGP soil, and USDA dust samples as a function of temperature. We also superpose several reference immersion freezing spectra (i.e., Niemand et al. 2012, Atkinson et al. 2013) for comparison. Panel (a) shows an overall comparison of the three samples. Panels (b)-(d) show comparisons of heated versus non-treated for each sample type. As seen in Figure 4a, the SGP Ambient sample showed relatively higher n_m values at temperatures above about -15 °C than two other samples. The n_m values of the SGP soil sample, however, were higher at temperatures below about -20 °C than two other samples. The USDA sample in general exhibited the lowest freezing efficiency across the examined temperatures (but within uncertainties). Further, only a slight suppression of freezing efficiency by heating was observed for the SGP Ambient sample, especially at temperatures above around -15 °C (Figure 4b). On the other hand, the heated SGP Soil sample showed a freezing efficiency suppression at temperatures above -10 °C as well as the temperature range between around -21 °C and -23 °C, perhaps due to thermal decomposition of soil organics (Figure 4c). Similar to the ambient sample, the USDA did not show a substantial impact of heating on its freezing efficiency within uncertainties (Figure 4d).

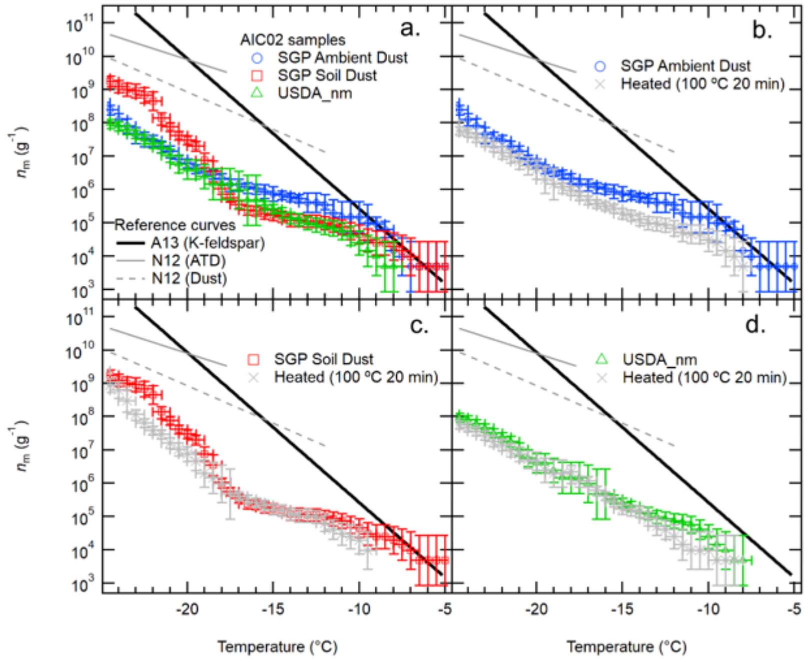

Figure 4. Preliminary immersion freezing efficiencies of SGP Ambient, SGP Soil, and USDA samples.

In conclusion, our field campaign results well demonstrated the success of sampling activities (as proposed) and subsequent complementary offline measurements. Further insights and results will be available upon the completion of the recent EUROCHAMP-AIC02 laboratory campaign data analyses. Together with the AIC02 participants, the PIs plan to organize a two-day virtual AIC02 data workshop in November 2021 and potentially a follow-up in-person meeting(s) afterward. During the laboratory analyses, we applied the AIDA chamber to elucidate immersion freezing processes of relevant regional representative samples from ExINP-SGP-II. Our evaluation of different dust samples for representativeness and relationship to SGP aerosol-ice formation closure study (Knopf et al. 2021a) and the comparison of actual ambient dust versus soil surface dust in a controlled condition will be invaluable to the U.S. Department of Energy (DOE). Recently, the Office of Biological and Environmental Research reported the vision of ARM over the next decade in 2014 (U.S. DOE 2014), and the report mentions the importance of INP measurements at other ARM observatories. We specifically target understanding the parameters that lead to "order of magnitude" effects in cloud and climate models such as size and composition of mineral dust and the role of soil organics by comparing total aerosol versus ice residuals.

3.0 Publications and References

3.1 Publications

One non-peer-reviewed project report for EUROCHAMP is publicly available at this time:

Knopf, DA, N Riemer, S China, PJ DeMott, A Fridlind, N Hiranuma, G Kulkarni, A Laskin, E Levin, X Liu, and R Perkins. 2021. Aerosol-Ice Formation Closure Laboratory Study (AEROICELAB). For EUROCHAMP-TNA Program, AIDA-010-2021 (www.eurochamp.org/tna-documents).

3.2 References

Atkinson, JD, BJ Murray, MT Woodhouse, TF Whale, KJ Baustian, KS Carslaw, S Dobbie, D O'Sullivan, and TL Malkin. 2013. "The importance of feldspar for ice nucleation by mineral dust in mixed-phase clouds." *Nature* 498: 355–358, https://doi.org/10.1038/nature12278

DeMott, PJ, TC Hill, KJ Suski, and EJ Levin. 2015. Southern Great Plains Ice Nuclei Characterization Experiment Final Campaign Summary. U.S. Department of Energy. DOE/SC-ARM-15-012, https://www.arm.gov/publications/programdocs/doe-sc-arm-15-012.pdf

Hiranuma, N, BW Auvermann, F Belosi, J Bush, KM Cory, D Georgakopoulos, K Höhler, Y Hou, H Saathoff, G Santachiara, X Shen, I Steinke, R Ullrich, NS Umo, HSK Vepuri, F Vogel, and O Möhler. 2021. "Laboratory and field studies of ice-nucleating particles from open-lot livestock facilities in Texas." *Atmospheric Chemistry and Physics* 21(18): 14215–14234, https://doi.org/10.5194/acp-21-14215-2021

Hiranuma, N, and HSK Vepuri. 2020. Examining the Ice-Nucleating Particles from the Southern Great Plains Field Campaign Report. U.S. Department of Energy. DOE/SC-ARM-20-018, https://www.arm.gov/publications/programdocs/doe-sc-arm-20-018.pdf

Knopf, DA, KR Barry, TA Brubaker, LG Jahl, KAL Jankowski, J Li, Y Lu, LW Monroe, KA Moore, FA Rivera-Adorno, KA Sauceda, Y Shi, JM Tomlin, HSK Vepuri, P Wang, NN Lata, EJT Levin, JM Creamean, TCJ Hill, S China, PA Alpert, RC Moffet, N Hiranuma, RC Sullivan, AM Fridlind, M West, N Riemer, A Laskin, PJ DeMott, and X Liu. 2021a. "Aerosol–ice formation closure: a Southern Great Plains field campaign." *Bulletin of the American Meteorological Society* 102(10): E1952−E1971, https://doi.org/10.1175/BAMS-D-20-0151.1

Knopf, DA, N Riemer, S China, PJ DeMott, A Fridlind, N Hiranuma, G Kulkarni, A Laskin, E Levin, X Liu, and R Perkins. 2021b. Aerosol-Ice Formation Closure Laboratory Study (AEROICELAB). For EUROCHAMP-TNA Program, AIDA-010-2021 (www.eurochamp.org/tna-documents)

Niemand, M, O Möhler, B Vogel, H Vogel, C Hoose, P Connolly, H Klein, H Bingemer, P DeMott, J Skrotzki, and T Leisner. 2012. "A particle-surface-area-based parameterization of immersion freezing on desert dust particles." *Journal of the Atmospheric Sciences* 69(10): 3077–3092, https://doi.org/10.1175/JAS-D-11-0249.1

Schiebel, T. 2017. Ice nucleation activity of soil dust aerosols. Ph.D. thesis, Karlsruhe Institute of Technology, https://doi.org/10.5445/IR/1000076327

U.S. Department of Energy. 2014. Atmospheric Radiation Measurement Climate Research Facility Decadal Vision. DOE/SC-ARM-14-029, https://www.arm.gov/publications/programdocs/doe-sc-arm-14-029.pdf

Van Pelt, RS, and TM Zobeck. 2007. "Chemical Constituents of Fugitive Dust." *Environmental Monitoring and Assessment* 130(1-3): 3–16, https://doi.org/10.1007/s10661-006-9446-8

Vepuri, HSK, CA Rodriguez, DG Georgakopoulos, D Hume, J Webb, GD Mayer, and N Hiranuma. 2021. "Ice-nucleating particles in precipitation samples from the Texas Panhandle." *Atmospheric Chemistry and Physics* 21(6): 4503–4520, https://doi.org/10.5194/acp-21-4503-2021

4.0 Lessons Learned

1. Pre-campaign documentation (ISRs, Site Visit Requests, Pre-IOP planning and meetings): is the process clear or confusing?

   The process was straightforward. Mike Ritsche and SGP officers have been communicative. The PIs and SGP officers had several meaningful remote meetings to plan the campaign logistics prior to the site visit of Hiranuma's team. As planned, they supported Hiranuma's team members, Elise Wilbourn and Kimberly Sauceda, who visited SGP on 11/20/20 to install samplers and collected surface soil samples.

2. Site Facilities, SGP Staffing and Assistance, Resources. (Were they adequate? How did they contribute to the outcome of the campaign?)

   Yes. All support was adequate and absolutely above average. With remote guidance of the PIs, onsite SGP staff routinely performed the onsite sampler maintenance for the PIs (i.e., cleaning up, covering the sampler with a tarp during rain and/or snow, collecting samples, and keeping them in proper conditions). Thus, they very positively contributed to the success of sample collection throughout the campaign. They shared the project updates weekly and understood the importance of this project. The PIs acknowledge (including but not limited to) Chris Martin, Ken Teske, Mark Smith, John Schatz, and Rod Soper. We could not have completed our three-month sampling campaign without their support. The collected samples have been shared with many researchers and are invaluable to the cloud microphysics research community.

3. Safety, Training, and Rollout. (Was the safety briefing adequate and beneficial? Was safety a priority? Were there any incidents or near misses? Were severe weather notices acceptable? Were there adequate storm shelters? What could be improved upon?)

   Under the current pandemic circumstance, safety was indeed prioritized professionally at SGP. The COVID safety protocol for visitors was well documented, constructive, and intuitive to follow. Rod Soper did a great job training the visitors of Hiranuma's team. Although we had no severe weather conditions while working at SGP, the notification method was appropriate.

4. Expectations and Objectives (Were the expectations and objectives achieved?)

   Yes. All objectives were met with what we achieved.

5. Project Definition, Planning, and Control throughout the campaign (Was there a project plan? Was it used? Was it realistic?)

   N/A

6. Organization –Meetings, communication, information sharing (Who managed most of the communication within the intensive operational period? Did it work?)

   All went well. The SGP onsite staff (especially Martin and Ken) and the PIs communicated frequently through virtual meetings at the campaign planning stage (see response to Q1), during the campaign, and for the shipment of samples afterward. Offsite support of Mike Ritsche and his effective communication were always helpful and appreciated, too.

7. Risk and scope change throughout the project (Did the project change significantly? How was this managed?)

   No. The project was completed as planned and proposed, even with the COVID restrictions.

8. Campaign Wrap-up (Was there adequate manpower to take down equipment, load it, and was the location that you occupied left in an acceptable manner?) If not, please give suggestions.

   The PIs appreciated Ken taking down our samplers through our remote instruction. Logistics afterward was smoothly done, too.

9. Overall intensive operational period success:

   100/100 – All missions were completed.

10. What went well, and why?

    Basically everything. The SGP staff are professional. Their attention, consideration, and ability for problem-solving made it possible to process any requests that the investigators made promptly.

11. What went badly, and why?

    Nothing.

12. What could have been done differently, with hindsight?

    See response to Q8.

13. What are the lessons for future IOPs?

    The PIs and their group members had a very meaningful outcome and positive experience from the ExINP-SGP II campaign. We believe that building relationships and trust with the ARM site managers and onsite technicians is one of the most important aspects of any ARM project. We consider that the capability to build teamwork for projects is key for success in ARM campaigns. We also believe that the voices of onsite people matter and hope to come back to SGP for future ARM projects.

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