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Targeted Observations of Blowing Snow during SAIL (SAIL-TOBS) Field Campaign Report

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ARM

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Acronyms and Abbreviations

AGL	above ground level
AMF	ARM Mobile Facility
AMF2	second ARM Mobile Facility
ARM	Atmospheric Radiation Measurement
LED	light-emitting diode
LTE	long-term evolution
MASC	multi-angle snowflake camera
OSCRE	Open Snowflake Camera for Research and Education
PSD	particle size distribution
SAIL	Surface Atmosphere Integrated Field Laboratory
SAIL-TOBS	Targeted Observations of Blowing Snow during SAIL
SoS	Sublimation of Snow
SPLASH	Study of Precipitation, the Lower Atmosphere and Surface for Hydrometeorology
USB	universal serial bus
UTC	Coordinated Universal Tie

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1.0 Summary

Blowing snow research at high-latitude U.S. Department of Energy Atmospheric Radiation Measurement (ARM) user facility observatories and mobile campaigns demonstrated the need for ground truth during falling and blowing snow events. The purpose of the Targeted Observations of Blowing Snow during SAIL (SAIL-TOBS) field campaign was to affordably deploy additional instruments to observe mixed-phase and frozen hydrometeors, including falling and blowing snow, during the second winter of the Surface Atmosphere Integrated Field Laboratory (SAIL) campaign. Instruments included two installations of the Open Snowflake Camera for Research and Education (OSCRE), one at the Gothic, Colorado main site (second ARM Mobile Facility [AMF2]) and a second at the Kettle Ponds external field site in support of the Study of Precipitation, the Lower Atmosphere and Surface for Hydrometeorology (SPLASH) campaign. Two FlowCapt FC4 acoustic mass flux sensors were also deployed at AMF2 in proximity to OSCRE on top of the instrumented hill (Figure 1).

Figure 1. Instruments deployed during SAIL-TOBS. Left: OSCRE at Kettle Ponds. Middle: OSCRE at AMF2 in Gothic. Right: FlowCapt FC4s at AMF2.

OSCRE is an affordable (<$5K) edge-based, hydrometeor camera. The instrument works based on strobe photography; a high-speed (10µs), LED projector light illuminates a sampling volume imaged by a 3.2 megapixel machine vision camera. In principle, this is similar to the multi-angle snowflake camera (MASC), except only one camera is used, and the design is open field. Instead of hydrometeors falling through the instrument, they can freely fall vertically or advect horizontally through the imaging field.

FlowCapts are an acoustic sensor that measure impacts of particles against a hollow cylinder. The noise is associated with a kinetic energy that is then converted to a mass flux. The installation included two instruments at a height centered at ~1m and 2 m AGL. At the beginning of the winter, this is designed to measure both drifting and blowing snow. As snow accumulates, the lower sensor can be buried, which occurred during this deployment. The highest sensor is then a better estimate of drifting snow until the snowpack begins its melt.

Instruments were installed in early October and were in place to begin collecting data for the first snowfall on 23 October 2022. An overview of data is now provided along with descriptions of issues that made the deployment and data acquisition challenging.

OSCRE at Kettle Ponds: The OSCRE at Kettle Ponds was the first installation of an OSCRE with 1) a shorter focal length (85- versus 135-mm) lens and 2) a USB cellular modem. The use of a shorter lens with extension tube provided identical resolution to the Gothic OSCRE (~28µm/pixel) but with a smaller physical footprint. While laboratory testing with the USB LTE modem was successful, real-world deployment was another story.

After a week of connectivity, access to OSCRE was lost. While the instrument could be seen online, no remote connection could be established. Based on observations by AMF2 technicians, the instrument was left on until a power outage took the instrument down in early December. Because image acquisition is started manually, it was not possible to restart the camera until early January when team members from the University of Washington Sublimation of Snow (SoS) field campaign restarted the acquisition script. Unfortunately, the camera appeared to glitch shortly after the restart and stopped image acquisition. In summary, data are available at SPLASH from 10 October 2022 to 6 December 2022.

OSCRE at AMF2: Initial image acquisition was successful through the first set of snowfalls in late October. After that, scattering of sunlight off the snowpack led to poor image quality into November, and a camera glitch required a hard restart of the camera. Once remote network access was established in early December, image settings were reconfigured and the camera was restarted. The unit ran with no issues from 6 December 2022 to 25 March 2023. After this date, the LED strobe light failed and data collection was stopped. Note that due to scattered light off of the snowpack, image quality is poorer during the late morning and early afternoon hours ~17-21 UTC, especially later in the data record.

FlowCapts at AM2: FlowCapt data was acquired via serial connection to a Raspberry Pi which served as the datalogger. After successfully collecting data through October, the datalogger suffered from seemingly random serial glitches. After remote network access was established in early December, the device was configured to reboot at 00 UTC each day to minimize this issue.

As the snowpack deepened, the AMF2 instrument technicians sent updates on snow depth at the FlowCapt tower (Figure 2). In early January, the lower FlowCapt, which was mostly buried, stopped responding. This was originally thought to be a cabling issue, but instrument takedown in June revealed the instrument cable suffered water ingress at a junction box. The upper FlowCapt functioned for the entire winter. Even though the lower FlowCapt was completely exposed by early May, the melting snowpack led to conditions not susceptible to blowing snow, so problems with the lower FlowCapt are not considered a big issue.

Figure 2. Snow depth at the FlowCapts on 16 January 2023, 12 March 2023, and 6 May 2023.

2.0 Results

Thus far, emphasis of the analysis has been on OSCRE image processing, which can handle a variety of climate regimes including the deployment at SAIL/SPLASH. Given the open-field design of OSCRE, imaged hydrometeors range from being in focus to slightly out of focus (Figure 3). Based on the texture of the images, a degree of sharpness is assigned to each hydrometeor so that users can determine the degree of sharpness and precision of sizing they require. Compared to non-mountainous environments that OSCRE has been deployed in, initial analysis reveals crystal habits and particle size distributions (PSDs) that have greater temporal variability.

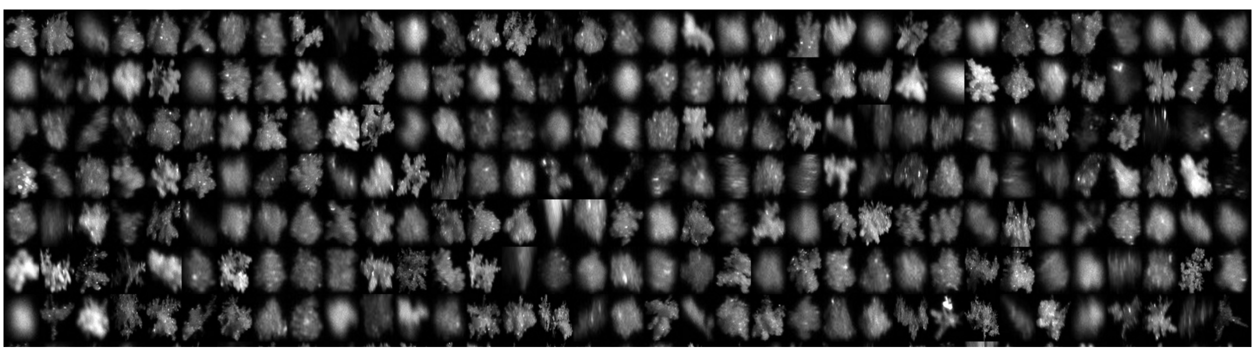

Figure 3. Example of imaged hydrometeors at SAIL between 01:30-01:40 UTC on 26 October 2022.

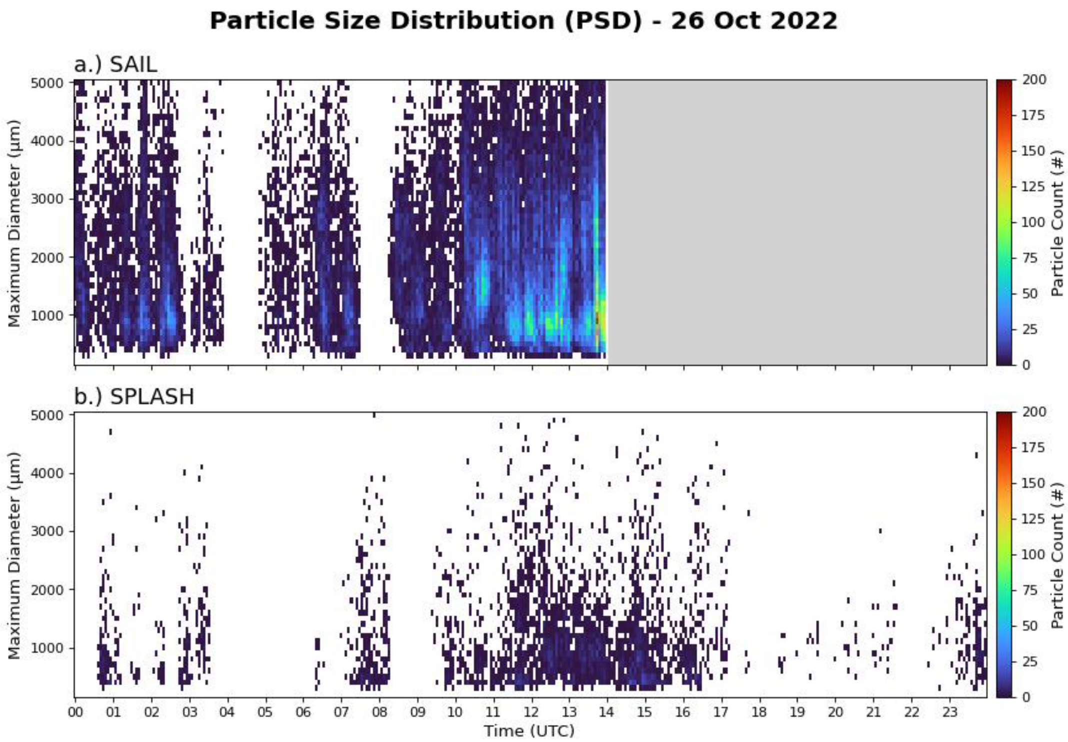

Figure 4. OSCRE PSDs on 26 October 2022 from a) SAIL and b) SPLASH. Greyed area is a period of missing data.

Comparisons between OSCREs during October snowfall demonstrated large variability between the SAIL and SPLASH locations (Figure 4). While some differences can be expected between the two sites, particle counts were an order of magnitude higher at SAIL versus SPLASH. Provided that resolution and image acquisition strategies were similar, this suggests something intrinsically different about the strobe lighting. Although the lighting angle may have been slightly different (e.g., 35-50° off the focal plane), experience suggests this does not have a major impact on imaging, especially for early-season snowfalls with riming that scatter a significant amount of light. Rather, it is believed either 1) the light intensity was arbitrarily lower for the SPLASH unit or 2) the lighting angle was bumped off the focal plane, limiting the number of imaged hydrometeors. Laboratory testing is needed to ensure uniformity of lighting for future OSCRE deployments.

Despite these issues, the deployment demonstrates that useful microphysical data can be acquired at an affordable price point. PSDs from the campaign suggests accurate sizing occurs for particle diameters > 100µm. Issues noted during SAIL/SPLASH have largely been resolved, and current deployments of OSCRE have benefited from the lessons learned from this campaign.

Case studies of later events show good agreement with other ARM datastreams (Figure 5). High particle counts (whether falling or blowing snow) are collocated with periods of reduced visibility and periods of lidar and radar returns (not shown). A complete analysis of field campaign data is still ongoing.

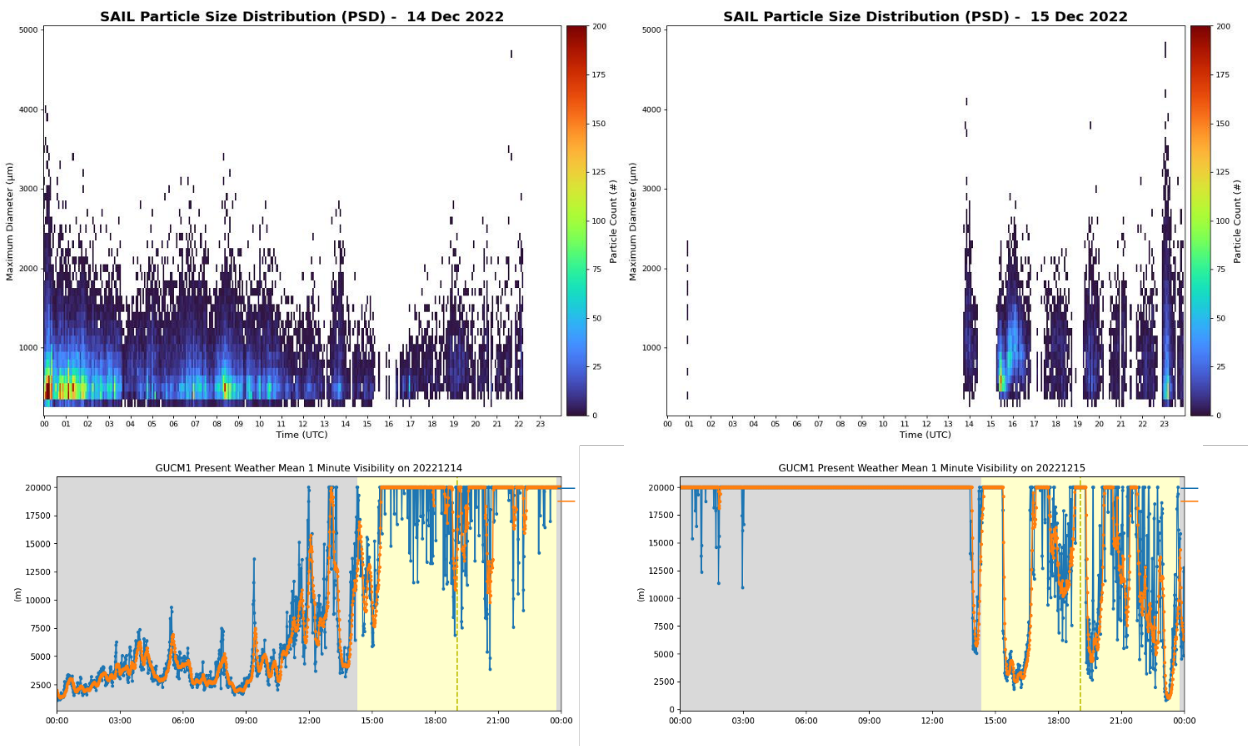

Figure 5. SAIL OSCRE PSDs (top) and ARM surface meteorological instrumentation visibility data (bottom) for 14-15 December 2022.

3.0 Publications and References

Not applicable.