Measurement and Characterization of Winter Precipitation at Wallops Island Snow Field Site

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***Abstract*—We present our ongoing studies of physical and scattering properties of ice particles in winter precipitation combining delicate optical, electronic, and mechanical surface instrumentation and state-of-the-art radars. We outline integrated field measurements, followed by analysis, at the NASA Precipitation Research Facility Wallops Island, Virginia. Accurate measurements and characterization of snowflakes and snowfall are crucial for advancement of numerical weather prediction models and in the correct interpretation of data from the national network of weather radars.**

I. Introduction

This summary presents our ongoing studies of winter precipitation aimed at developing, implementing, and testing novel approaches to measurement, characterization, and analysis of the physical and scattering properties of ice particles in winter precipitation combining delicate optical, electronic, and mechanical instrumentation and state-of-the-art radars. We present integrated field measurements at the Precipitation Research Facility operated by NASA Goddard Space Flight Center at Wallops Island, Virginia. This is a densely instrumented facility with a variety of instruments and radars, needed for the measurement of the physical properties of snow. Another feature of the Wallops Precipitation Research Facility essential for our studies is its coastal mid-latitude location, which experiences snowfall from so-called East Coast Winter Storms (or Nor'easters) that develop off the eastern coast of the United States from North Carolina northwards, and can be very devastating producing large amounts of snowfall, freezing rain, sleet and resultant flooding.

The US National Weather Service's recently modernized network of dual-polarized (polarimetric) Doppler radars along with sophisticated numerical models are used to forecast the hazardous areas but they depend crucially on the physical properties of the various classes of precipitation such as size, shape, concentration, density, fall speed and composition which are highly variable in both space and time. This is why accurate measurements, analyses, and estimates of the physical and scattering properties of winter precipitation are crucial for advancement of numerical weather prediction models and in the correct interpretation of data from the national network of weather radars.

II. Surface Instruments and Radars for Measurments of Snowflakes and Precipitation

We use a combination of instrumentation and radars for in-situ surface measurements and remote sensing observations of winter precipitation within our Wallops project. The Snowflake Measurement and Analysis System (SMAS), Fig. 1, is brand new, in-house designed and built instrument, containing seven high-resolution cameras placed in a 3D fashion for 3D reconstruction of particle shapes and measurements of particle fall speeds, along with six flashes, five sensor boards, two lasers, a printed circuit board, a peripheral interface controller, and a built-in workstation (computer). The shape of the cover for the SMAS was a streamlined design and built to reduce air motion fluctuations near the sensor area due to uniform horizontal wind. The Multi-Angle Snowflake Camera (MASC), Fig. 1, captures high resolution photographs of snowflakes using five cameras, while simultaneously measuring their fall speed [1]. The 2D-video disdrometer (2DVD), Fig. 1, gives two mutually orthogonal images of the particle using high-speed line-scan cameras [1]. The Precipitation Imaging Package (PIP) is a video camera system that gives projected views in one plane.

Figure 1. Colorado State University's SMAS and MASC installed within a double-fence windshield at the NASA Precipitation Research Facility, Wallops Island, VA (where PIP and 2DVD are already operational), December 2021.

The particle fall speed measured by the SMAS and MASC can be used to estimate the "effective" density and dielectric constant of the snow particles [1]. The multiple camera images of a particle captured by the SMAS and MASC can be processed by means of a visual hull method to obtain 3D shape reconstructions (meshes) of hydrometeors [2]. Such meshes, with the estimated dielectric constants, enable computation of polarimetric radar measurables for winter precipitation [3].

They can also be used for studies of snow habits, for advanced analyses of microphysical characteristics of particles, and for hydrometeor classification [4]. We can as well compute the particle size distribution (PSD) during snowfall events [5].

The radars used in this project include the Precipitation Occurrence Sensor System (POSS), a bistatic Doppler radar that measures the reflectivity at X-band just a few meters above the surface; the scanning S-band NPOL radar, with the lowest height with good data being 400 m above surface; and the Micro Rain Radar (MRR), operating at 24 GHz.

III. Analyses and Characterizations of Ice Particles and Snowfall at Wallops Island Field Site

Based on in-situ surface measurements by the instrumentation described in the previous section, followed by analysis, we aim to improve characterization of geometric parameters, PSD, fall speeds, and "effective" density of ice particles, by optimizing the data from projected views in one plane, obtained by the PIP, two orthogonal planes, from the 2DVD, and multiple planes, provided by the 5-camera MASC and 7-camera SMAS. An objective is also to use the combination of PIP, two 2DVD units and two 3D sonic anemometers (inside and outside the double-fence windshield) to characterize the effects of particle-turbulence in natural snowfall on the fall speed and "effective" density of particles. Our studies are tying the estimate of liquid equivalent snow rate (SR) and forward modeled polarimetric (dual-polarization) radar variables using PIP, 2DVD, MASC, and SMAS data with independent snow gauge and radar measurements, respectively. The overarching goal of this research is to reduce uncertainties in the interpretation of radar signatures and improve the accuracy of SR retrievals using an observationally-driven approach supported by advanced in-situ instrumentation and radars.

As an illustration of results, Figs. 2 and 3 show correlated measurements by the MRR and the SMAS at the Wallops Island field site during the snowstorm on January 22, 2022. We observe good agreement of the post-processed results for the particle fall speeds measured by the SMAS with the data for the lower altitude fall speeds obtained by the MRR, the SMAS hence acting as a ground validation device for the radar.

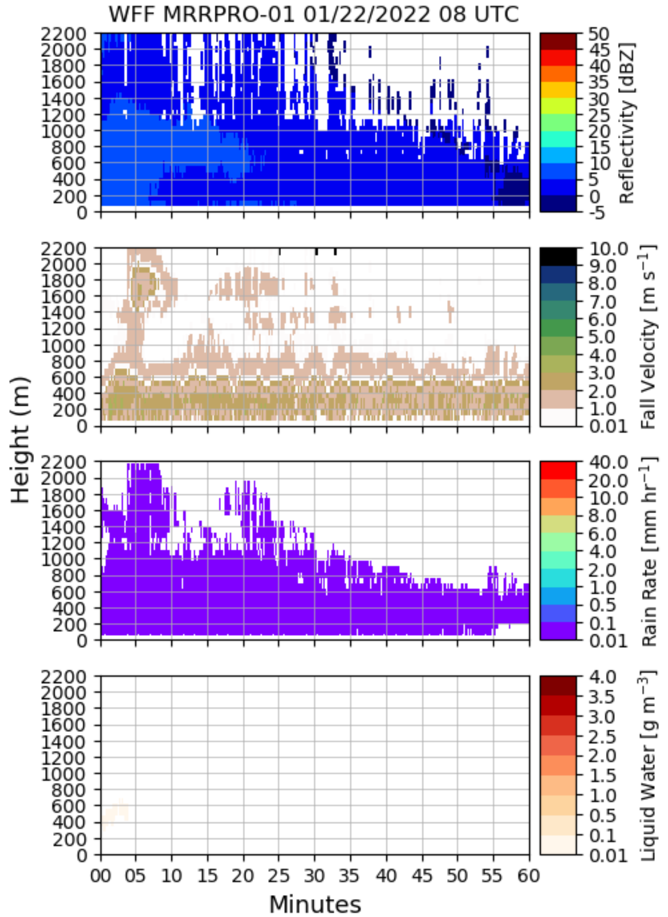

Figure 2. Micro Rain Radar (MRR) measurements from UTC 0800 to 0900 on Jan 22, 2022 at the Wallops field site.

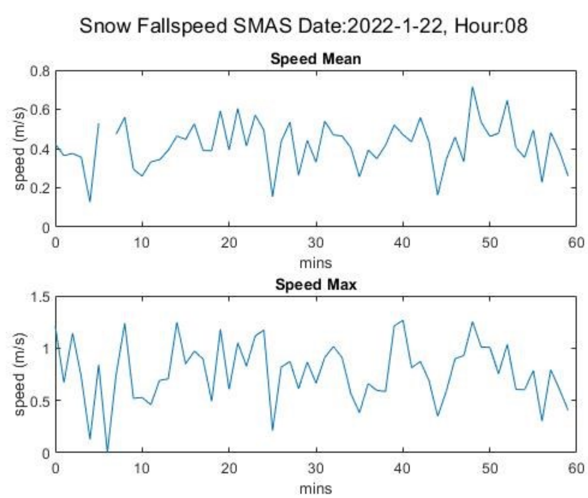

Figure 3. Snowflake Measurement and Analysis System (SMAS; Fig. 1) measurements of the fall speed of snow particles during the same time period as in Fig. 2 at the Wallops field site.

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