Snow Precipitation Measurement and Analysis
During MASCRAD Winter Observations

Branislav M. Notaros, V. N. Bringi, Cameron Kleinkort, Gwo-Jong Huang, Merhala Thurai, Patrick C. Kennedy, Sanja B. Manic
Electrical & Computer Engineering Dept., Colorado State University, Ft. Collins, CO, USA, notaros@colostate.edu
Andrew J. Newman
Research Applications Laboratory/Hydrometeorology Applications Program
National Center for Atmospheric Research (NCAR)
Boulder, CO, USA

Abstract—We present our continued studies of winter precipitation within the MASCRAD (MASC + Radar) project, using multi-angle snowflake camera (MASC), 2D-video disdrometer, computational electromagnetic scattering methods, and state-of-the-art polarimetric radar. We also introduce some recent advancements to the observation and analysis process, and discuss new illustrative results.

Keywords—snow observations; polarimetric radar; scattering; remote sensing.

I. INTRODUCTION

This summary presents our continued studies of winter precipitation within the MASCRAD (MASC + Radar) project [1], introduces some recent advancements, and discusses new illustrative results. This project is developing a novel approach to characterization of winter precipitation and modeling of radar observables through a synergistic use of advanced optical imaging disdrometers for microphysical and geometrical measurements of ice and snow particles, image processing methodology to reconstruct complex particle 3D shapes, fullwave computational electromagnetics (CEM) to analyze realistic winter precipitation scattering, and state-of-the-art polarimetric radar to validate the modeling approach. The principal enabling methodologies and technologies are specifically (i) multi-angle snowflake camera (MASC) and two-dimensional video disdrometer (2DVD), shown in Fig. 1, (ii) visual hull method for reconstruction of 3D hydrometeor shapes [2], (iii) CEM scattering models and solutions based on a higher order method of moments (MoM) in the surface integral equation (SIE) formulation and the frequency domain [3], and (iv) fully polarimetric data from the CSU-CHILL radar. We develop physical and scattering models of natural snowflakes using the MASC, 2DVD, visual hull, and MoM-SIE, with the modeling and scattering calculations being analyzed against CSU-CHILL and SPOL radar observations.

II. MASCRAD OPERATIONS AND ADVANCEMENTS TO OBSERVATION AND ANALYSIS PROCESS

We have observed and analyzed all significant snow events during the 2014/2015 MASCRAD winter campaign. Shown in Fig. 2 are examples of MASC snowflake images.

We added several other advanced instruments to the MASCRAD Field Site, including a precipitation occurrence sensor system (POSS), shown in Fig. 3, thanks to Dr. David Hudak, Environment Canada. The POSS measures the bistatic Doppler spectrum from which the mean Doppler velocity and reflectivity are obtained. Reflectivity comparisons between POSS and CHILL X-band data ensured accurate POSS calibration. Fig. 3(c) shows one such set of comparisons for a snow event. Excellent agreement can be seen.

Fig. 1. MASCRA...
from the visual hull method, two additional cameras are added to the MASC, “externally,” to provide additional views, as shown in Fig. 4(b). All five cameras trigger simultaneously and collect images at a 2-Hz rate. We perform 5-camera software self-calibration of the MASC, to obtain a correction matrix that is then used as an input to the visual hull code to correct for a non-perfect mechanical calibration. Without this, the visual hull fails to create 3D reconstructions for many snowflakes.

III. ADDITIONAL ILLUSTRATIVE RESULTS FROM 2014/2015 MASCRAD WINTER CAMPAIGN

Fig. 5 shows an example of snowflake shape reconstruction using the upgraded MASC, in Fig. 4(b), and new processing methodology. We observe very good results, which are much better than any snowflake 3D realistic-shape reconstruction data in the literature. Fig. 6 shows illustrative results of higher order MoM-SIE scattering calculations based on both (a) MASC and (b) 2DVD images captured at the same time at the MASCRAD site (Fig. 1) during the unusual winter graupel shower event on Feb. 16, 2015 and the resulting 3D shape reconstructions, in comparison with the corresponding CSU-CHILL radar RHI plots of (c) $Z_{\text{dr}}$ and (d) LDR. Results: 2DVD: $\epsilon_r = 1.407 - j0.0002$, $Z_{\text{dr}} \approx 0.138$ dB, LDR $\approx -35.43$ dB; MASC: $\epsilon_r = 1.3638 - j0.0005$, $Z_{\text{dr}} \approx 0.186$ dB, LDR $\approx -37.34$ dB; CHILL Radar: $Z_{\text{dr}}$ from -1 to 0.5 dB, LDR from -38 to -28 dB – at the 12.92-km range).

REFERENCES