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Project Title: Use of DOE SGP Radars in Support of ASR Modeling Activities
Principal Investigator: Steven A. Rutledge, Colorado State University, Ft. Collins, CO
Period Covered by the Report: 09/15/2011 – 09/14/2015
Date of Report: 12/13/15

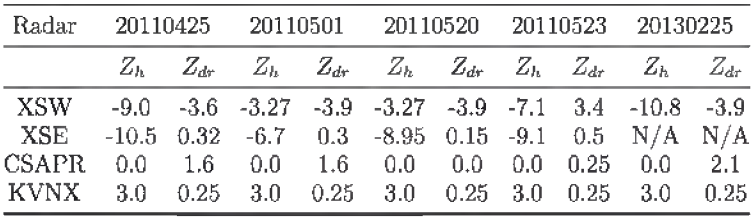
Executive summary:

The objective of this work was to use the DOE Southern Great Plains (SGP) precipitation radars to investigate physical characteristics of clouds and precipitation, and use this knowledge in support of DOE ASR modeling efforts. The goal was to develop an integrated data set based on the SGP instrumentation to yield statistically robust fields to aid in the task of verifying simulated cloud dynamical and microphysical fields. For this effort we relied heavily on the ARM scanning precipitation radars, X-SAPR's and C-SAPR, and also incorporating data from wind profilers, surface disdrometers and the nearby WSR-88D radar, KVNX. Initially we lent our expertise to quality controlling the data from the newly installed ARM radars, particularly the X-band polarimetric data, and additionally assessed automatic radial velocity unfolding algorithms developed by other ASR researchers. We focused our efforts on four cases from the MC3E field campaign in 2011 and developed a dataset including microphysical information derived from hydrometeor identification and kinematic analysis using multiple-Doppler retrieval techniques. This dataset became a PI product and was released to the community in 2014. This analysis was used to investigate the source of big drops (> 5 mm) observed with disdrometers at the surface. It was found that the big drops were coincident with the strongest updrafts, suggesting they resulted from the melting of large precipitation ice, likely hail. We teamed up with W-K Tao and T. Matsui to statistically compare radar-derived observational kinematics and microphysics to WRF model output for the 25 April 2011. Comparisons highlighted some areas where the model may need improvement, such as generating too much hail and big drops, as well as overly-strong updrafts and overly-weak of downdrafts.

Technical Report

Data Quality Control:

Given the rather recent deployment of ARM radars at the SGP site, we devoted considerable time to ensuring that the quality of data was sufficient for quantitative studies. Our efforts focused on the polarimetric data from the X-band SAPRs, specifically the southeast (SE) and southwest (SW) radars. We calculated differential reflectivity (Zdr) biases using vertically pointing data and over-the-top RHIs to estimate the biases and found that the SW X-SAPR had a significant bias of larger than -3 dB, while the SE was less than 1 dB (Figure 1). We worked hard to find a reliable method to calculate specific differential phase, which is essential for attenuation correction and both rain rate estimation and hydrometeor classification. In the end we settled on using the Wang and Chandrasekar (2009) methodology, which still did not completely account for some remarkable Mie effects. We also documented periods of radome attenuation which cannot be corrected for with current techniques. In addition to the extensive work with the polarimetric data quality control (QC), we also tested automated methods for unfolding radial velocity by comparing with brute-force, “hand” unfolded data. Through collaboration with Kirk North and Prof. Pavlos Kollias at McGill University, we improved the automatic unfolding algorithm to the point where it now routinely produces reliable velocity fields. .



Radar	20110425		20110501		20110520		20110523		20130225	
	Z_h	Z_{dr}	Z_h	Z_{dr}	Z_h	Z_{dr}	Z_h	Z_{dr}	Z_h	Z_{dr}
XSW	-9.0	-3.6	-3.27	-3.9	-3.27	-3.9	-7.1	3.4	-10.8	-3.9
XSE	-10.5	0.32	-6.7	0.3	-8.95	0.15	-9.1	0.5	N/A	N/A
CSAPR	0.0	1.6	0.0	1.6	0.0	0.0	0.0	0.25	0.0	2.1
KVNX	3.0	0.25	3.0	0.25	3.0	0.25	3.0	0.25	3.0	0.25

Figure 1: Reflectivity and Zdr bias estimates for the SGP radars.

Kinematic and Microphysical Analysis:

Once the radial velocities for selected case studies were dealiased, we performed sensitivity tests to determine the most appropriate gridding parameters (spatial resolution, temporal matching) for multiple-Doppler 3D wind retrievals. We determined it was necessary to include KVNX data to broaden the coverage and fill in gaps outside of the limited 40 km coverage of the X-SAPR radars. We developed a new methodology to account for contamination of precipitation fall speeds by using hydrometeor identification to determine the appropriate reflectivity-fall speed relationships at each grid point in the analysis domain. The algorithm uses HID to determine if the volume is snow, graupel/hail, or rain, and a category-specific fallspeed relationship from Giangrande et al. (2013) is then applied. This is an important improvement to the multi-Doppler processing given the high elevation angle volume scans performed by the SAPR radars in general. The retrieved multi-Doppler winds were compared with a wind profiler located within the multi-Doppler domain, and the multi-Doppler winds were found to be generally within 1 ms^{-1} of the profiler retrievals (Fig. 2). However, downdrafts were not as strong in the multi-Doppler retrievals compared to the wind profiler. This is a known limitation of the retrieval technique due to undersampling of the low-level divergence by the radars.

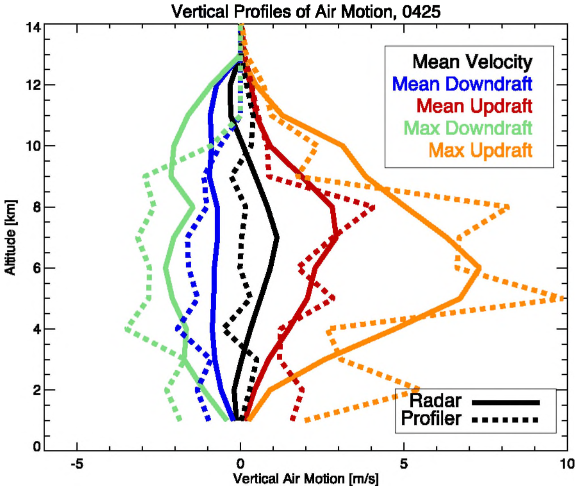


Figure 2: Comparison of vertical wind statistics between profiler and radar derived vertical wind for 25 April 2011 case for the 08-1130 UTC time frame.

Through the course of the project, we refined and improved our hydrometeor identification algorithm for X- and C-band. We also developed a multi-wavelength hydrometeor identification algorithm (MWHID) to integrate data from the numerous polarimetric scanning radars at the SGP and exploit the strengths of different wavelengths, including the local polarimetric NEXRAD KVNX radar. The hydrometeor identification algorithm showed evidence of prolific large drops or melting hail signatures during the 25 April 2011 case which were compared to ground observations from 2D video disdrometers. It was found that the big drop /melting hail category was associated with size distributions containing drops larger than 5 mm (Fig. 3). The May 23 and April 25 cases both showed that the swaths of melting hail / large drops were coincident with the strong updraft cores, indicating the large drops were most likely associated with melting (large) ice grown in strong updrafts (Fig. 4).

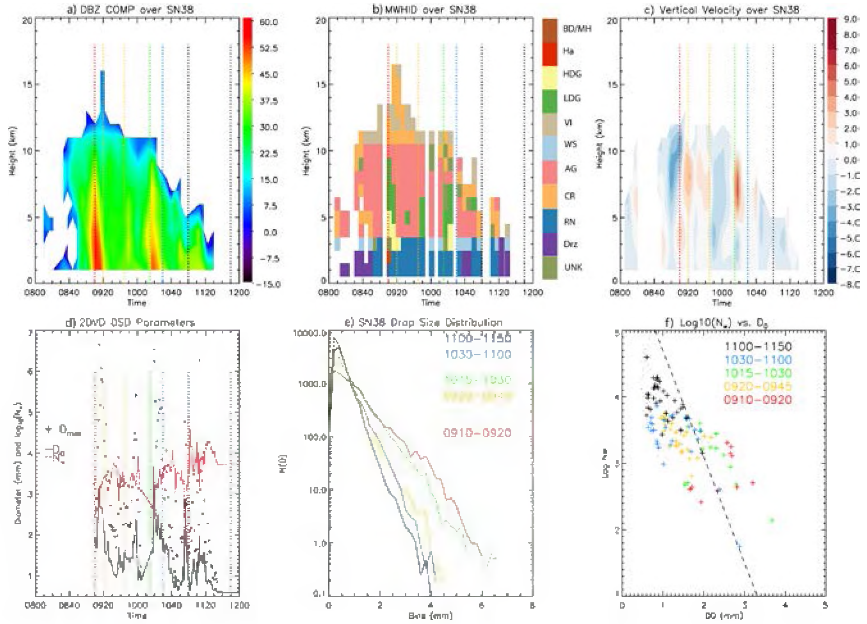


Figure 3: Timeseries of a) Reflectivity, b) MWHID, c) Vertical Velocity over the 2DVD site named SN38. Lorwer panels are data from SN38 showing d) timeseries of $\log_{10}(N_w)$ (red), D_0 (black) and D_{max} (+ symbol), e) the mean 5-minute drop size distribution for five times, and f) $\log_{10}(N_w)$ as a function of D_0 grouped by the five analysis times. The five analysis times are 0910-0920 UTC (red), 0920-0945 UTC (yellow), 1015-1030 UTC (green), 1030-1100 UTC (blue), and 1100-1150 UTC (black), and are indicated in a-d with colored vertical dotted lines. The black dashed line in f) represents the Bringi et al. 2009 convective-stratiform separator line.

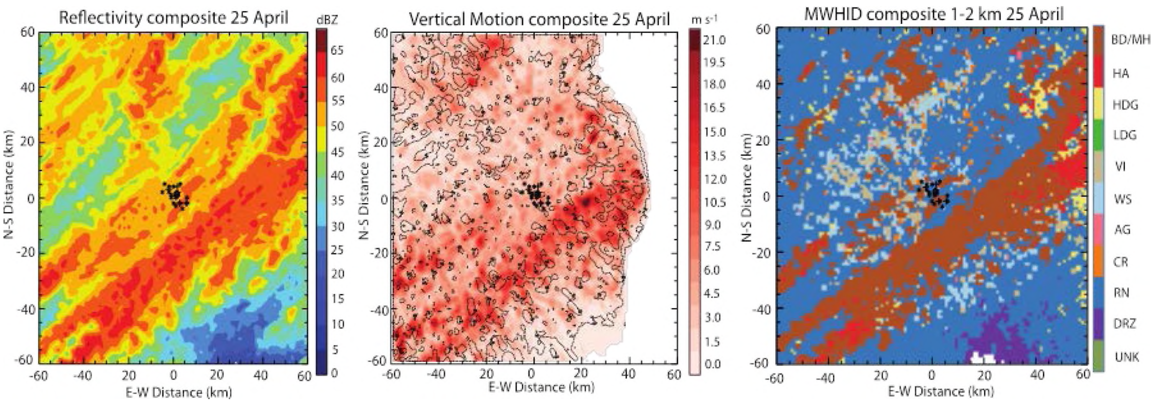


Figure 4: Overview of the 25 April 2011 case, from 08-11 UTC. Left panel is reflectivity swath (highest value at each grid point over the time period), middle panel is vertical motion swath (dashed lines are downward motion, shaded contours are upward motion), and low-level (1-2 km) MWHID swaths. (*) Indicate the location of APUs, (+) the 2DVDs, and (0) the ARM SGP.

CRM Comparisons

We collaborated with Toshi Matsui and W. K. Tao to compare simulations using the WRF model with spectral bin microphysics to the radar observations for the 25 April 2011 case. The comparisons were compared en masse and subdivided into three regimes: shallow (defined as < 6 km echo tops), deep convective and deep stratiform as identified by the Steiner et al. (1995) stratiform – convective separation methodology. Comparisons of vertical velocity statistics showed that the model upward motion was too strong (30 ms^{-1} maxima compared to 20 ms^{-1}) in magnitude, but peaked in similar levels compared with the multi-Doppler statistics. Additionally, the model deep stratiform vertical motions seemed to be contaminated by convective elements, as they were biased relative to the radar observations. This is likely related to the convective – stratiform algorithm applied. Downward motion was under represented in the model compared to observations, particularly in the deep convective regime (Fig. 5). In terms of microphysics, a model to radar HID mapping algorithm was developed by T. Matsui with input from B. Dolan in order to compare hydrometeor distribution statistics between polarimetric radar and CRM microphysics. The algorithm initially mapped model bins to the radar hydrometeor types using size and density information (Fig. 6). The comparisons showed promising results (Fig. 7), and illustrated that the model was over producing hail and big drops, and indicated the presence of rain above the melting level, which the radar did not observe. This could be indicative of the presence of supercooled liquid water, which is not detectable by the radar. We are now working to develop a more sophisticated multi-wavelength HID algorithm and a more quantitative means to compare model microphysical fields to radar-derived HID fields. In this work, we are developing a developing a radar simulator to calculate polarimetric fields from model output, thereby facilitating a direct way to compare model microphysical fields to radar-derived fields.

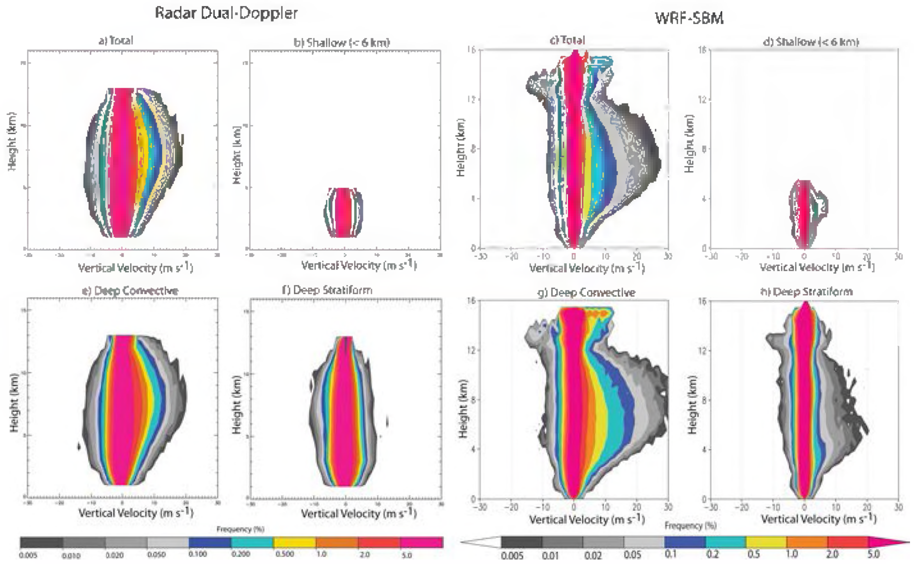


Figure 5: Radar (a,b,e,f) and WRF SBM (c,d,g,h) vertical velocity CFADs for a,c) total echoes, b,d) shallow (< 6 km echo top), e,g) deep stratiform (> 6 km echo top) and f, h) deep convection.

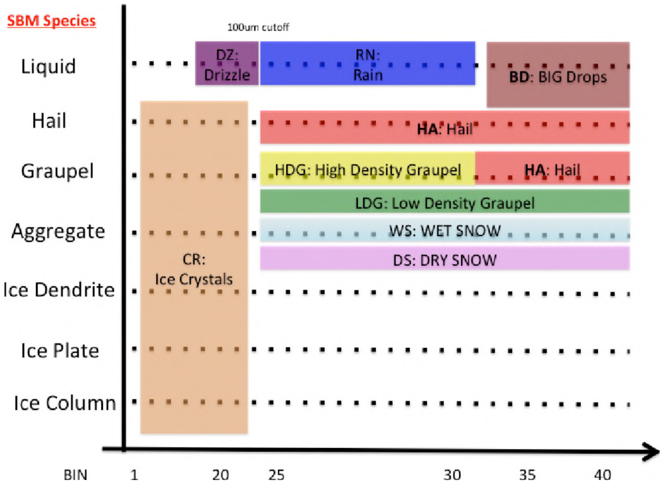


Fig. 6: Schematic for application of the CSU Hydrometeor Identification (HID) class to the WRF-SBM hydrometeor classes and bins.

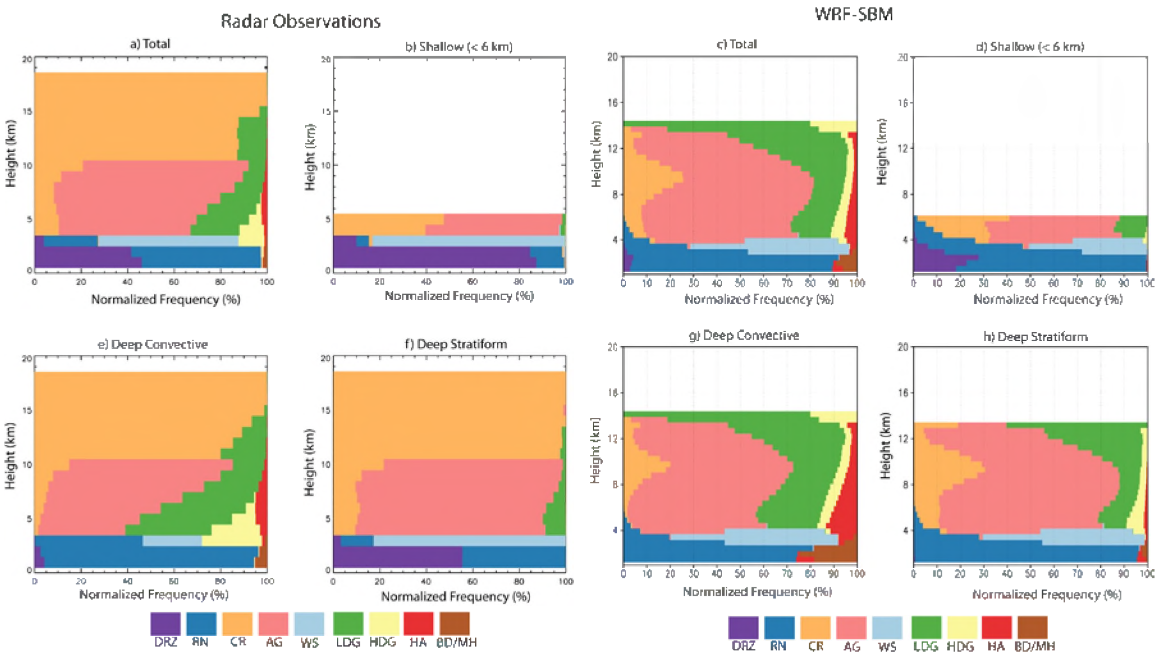


Fig. 7: Same as Fig. 5, but for normalized hydrometeor frequency profiles.

PI Products

We delivered PI products of gridded, combined X-SAPR, C-SAPR and KVNX data for four cases from MC3E: 25 April, 1 May, 20 May, 23 May. These files are gridded at 1 km resolution, and contain merged reflectivity, 3D wind data, and hydrometeor identification as well as convective-stratiform identification.

Conferences and publications

We actively presented our work at numerous conferences over the course of the funding cycle, and are working on a manuscript detailing the multi-wavelength HID. This work additionally resulted in a Masters thesis (Matthews, 2014).

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Matsui, T., T. Iguchi, W.-K. Tao, B. Dolan and S. A. Rutledge, 2014: Bulk Hydrometeor Types of Mid-latitude Convective Systems from Bin-Resolving Cloud Simulations and Dual-Polarimetric Scanning Radar Retrieval. *Amer. Geo. Union Fall General Meeting*, San Francisco, CA, 15-19 December 2014.

Matthews, A., 2014: Storm Microphysics and Kinematics at the ARM – SGP site using dual-polarized radar observations at multiple frequencies. *Dept. Atmos. Sci., Colorado State University,* Masters Thesis, 107 pp.

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Steiner, M., R. A. Houze Jr., S. E. Yuter, 1995: Climatological characterization of three-dimensional storm structure from operational radar and rain gauge data. *J. Appl. Meteor.*, **34**, 1978-2007.

Wang, Y., and V. Chandrasekar, 2009: Algorithm for estimation of the specific differential phase. *J. Atmos. Oceanic Technol.*, **26**, 2565–2578.