Snowflake Mixtures in Coastal Northeast United States Winter Storms

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Introduction

Heavy accumulations of snow and ice from cold-season extratropical cyclones in the northeastern United States can shut down cities for extended periods. Snow and mixed-phase precipitation accumulation are influenced by many characteristics including the number and size of particles, particle crystal shape, degree of riming, and density. Prior research has shown that denser, more rimed snow is expected close to the cyclone low-pressure center while less dense, less rimed snow occurs along the northwest edge of the storms. Riming occurs when a snowflake falls through a cloud with supercooled water droplets, which adhere to the snowflake and freeze. Improved understanding of snowfall characteristics can yield better estimates of snow from radar since reflectivity alone is too unconstrained.

Figure 1. Set of examples illustrates increasing degrees of riming from no riming through light, moderate, to heavy riming and graupel – from left to right.

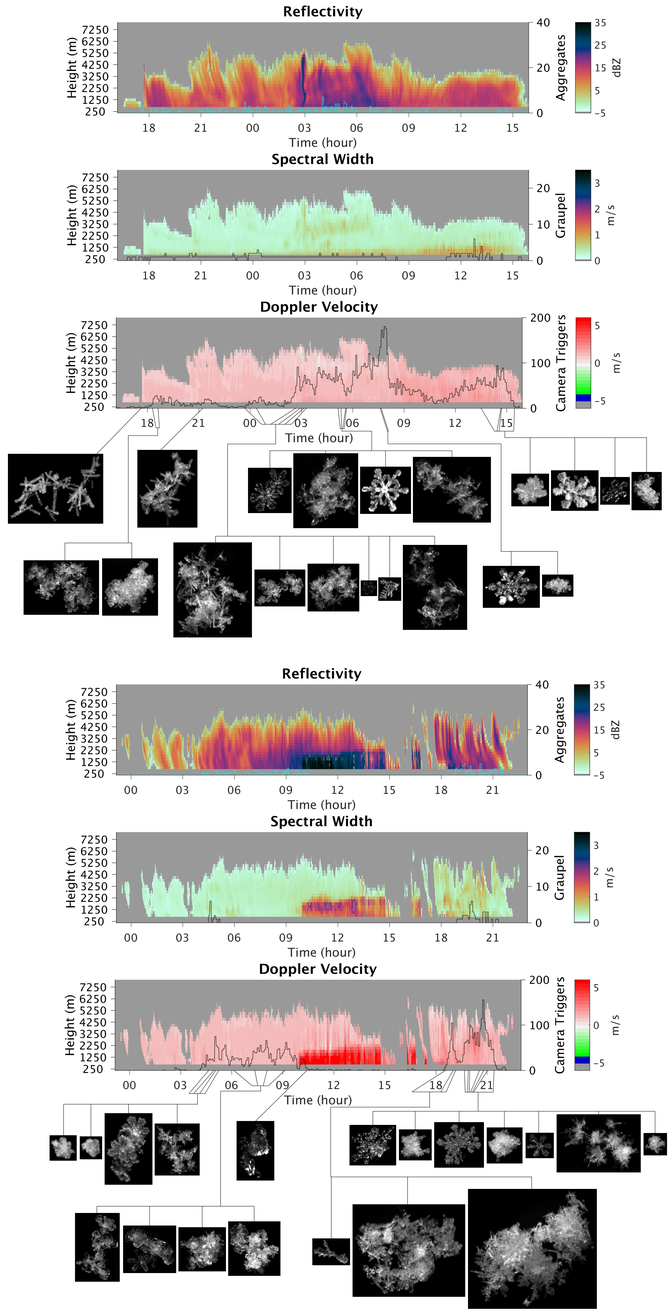
Methods

Our dataset is comprised of vertically-pointing radar data from a Micro Rain Radar (MRR) and snowflake data from a Multi-Angle Snowflake Camera (MASC). The data have been collected together at Stony Brook University (SBU) on Long Island, New York since December 2014. Time-height plots show MRR reflectivity, spectral width (a proxy for turbulence), and Doppler velocity (w_{air}+$w_{hydrometeors}$). Overlaid on the MRR plots are MASC 5-minute totals for in-focus large aggregates, graupel, and the number of camera triggers (≤ # of particles).

Figure 2. Map of NE US showing location of SBU.

Figure 3. MASC (foreground) and MRR (background). Image courtesy Dr. Brian Colle.

Data Analysis and Results



<u>26-27 January 2015</u>: Storm onset featured aggregates of mixed habits including needles. An unusual vertically-oriented reflectivity band evident at 03:00 UTC had a high number concentration of particles with predominately aggregates and individual snowflakes observed at the surface. Around 07:00 UTC another reflectivity band neared the observation site and aggregates were common. The peak number of camera triggers occurred after the peak in near surface reflectivity. Increasing near-surface spectral width at the end of the storm corresponded to an increase in degree of riming.

<u>02 February 2015</u>: Rimed and unrimed, sectored plates and hexagonal plates occurred near the beginning of the storm coincident with low spectral width. A transition to rain from around 10:10 UTC to 18:00 UTC was followed by a snow period from 18:30 UTC to 22:00 UTC. During this later snow period, spectral width increased while a mixture of aggregates, graupel, and individual snowflakes including dendrites fell at the surface.

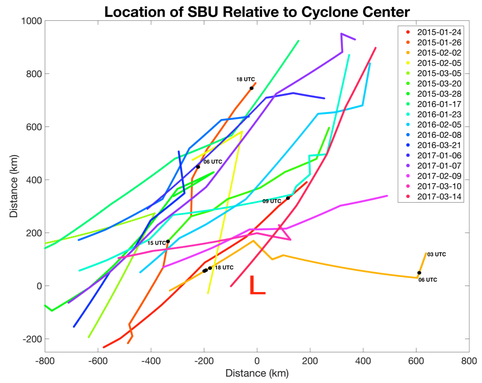


Figure 4. Locations of measurements at SBU relative to the low pressure center for 17 storms when MASC data were collected and there was a distinct low pressure center. Shaded circles represent approximate location of image pairs and the large aggregate example from 1/24/15 relative to the low pressure center. UTC hour represents nearest 3-hourly time.

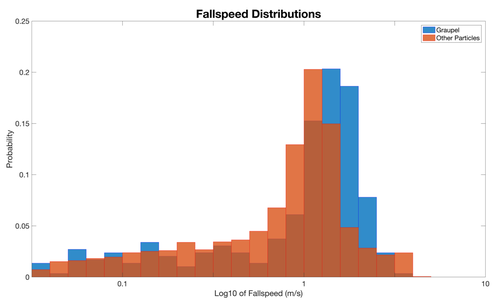


Figure 5. Distributions of fallspeeds for MASC particles obtained at SBU since December 2014 (8424 particles). Graupel (295 particles) is identified when Max Diameter < 5(mm), Frac > 1.6, Solidity > 0.75, and Radial Variance < 6. Remaining snow particles with fall speeds (8129 particles) are classified as Other. Some of the particles included may be partially melted. Particle fallspeed is used when there is only one particle in the MASC image, not typical for the SBU location. Fallspeed upper limit in histogram set to 4 m/s to remove rain (Yuter et al. 2006).

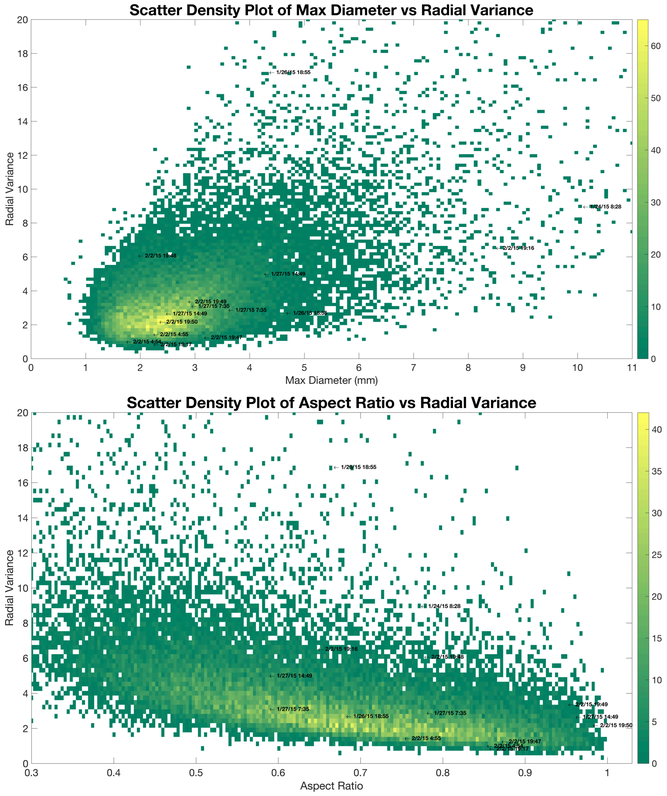


*Figure 6. Scatter density plots of size and shape characteristics of all in-focus snow particles (27408 particles) captured by the MASC at SBU since December 2014. Points corresponding to snow particles shown at right are highlighted. **(Top)** Max Diameter (0-11 mm) and Radial Variance (0-20), and **(Bottom)** Aspect Ratio (0.3-1) and Radial Variance (0-20).*

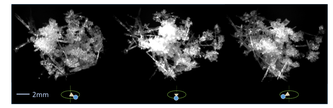


Figure 7. Large aggregate from 1/24/15 at 08:28 UTC includes needles, sector plates, and differential riming. Images are 3 views of the same particle obtained at different angles by the MASC cameras.

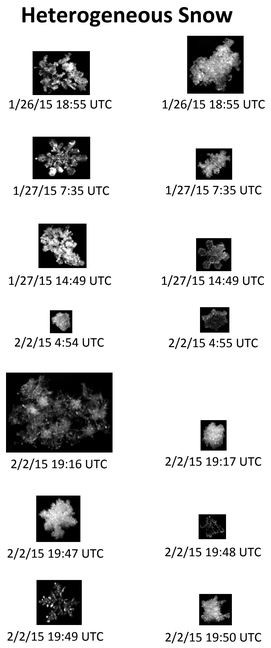


Figure 8. Pairs of particles that fell within a minute of each other. Scale bar shown in center panel.

Conclusions

Snowfall within winter storms in the coastal northeastern United States frequently contains mixtures of different degrees of riming and different habits falling at the same time. Individual aggregates can contain components that are more heavily and more lightly rimed. Graupel (heavily rimed) constitutes < 5% of particles at SBU. In this location, pristine snow crystals are rare. The majority of the particles reaching the surface exhibit light to moderate riming. There is a lack of a consistent relation between locally higher radar reflectivity and the occurrence of graupel at the surface. The distributions of fallspeeds of graupel versus all other snow particles have modes that differ by less than 0.33 m/s. These graupel fallspeed results from a coastal area near sea level are similar to fallspeed distributions from an inland, mountain location (Alta, Utah; Garrett and Yuter 2014).

Definitions

<u>Radial Variance:</u> From the calculated center of the snow particle, a set of 360 lines are drawn at each angle from 0 to 359. Value is the variance of the lengths of these lines.
<u>Max Diameter:</u> Max particle length in camera view (±15%) is usually ≤ real max diameter.
<u>Aspect Ratio:</u> Ratio of minor and major axes of best fit ellipse.

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