Freshly Falling Snow: Identifying New Snowflake Geometries From Photographs

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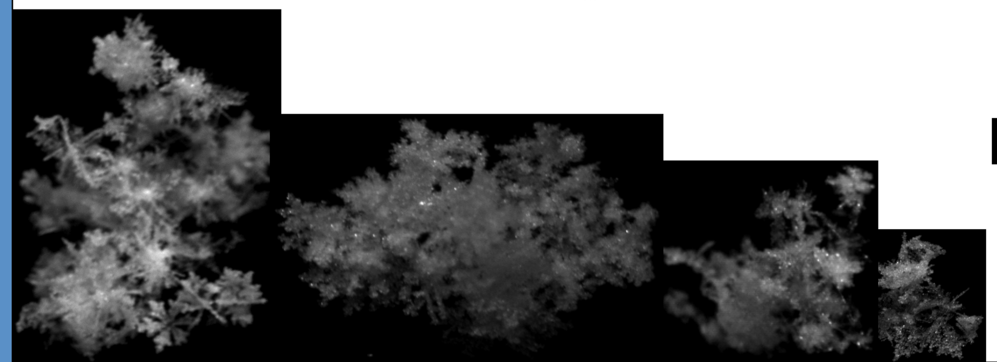

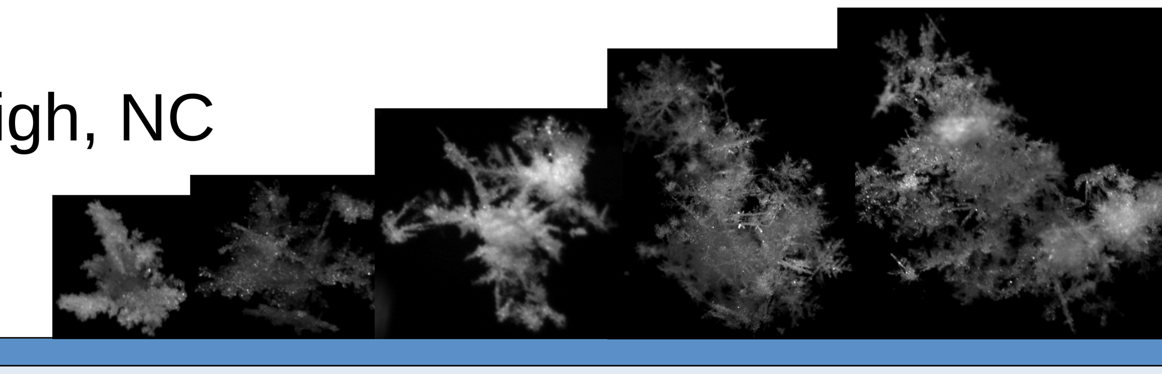

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Introduction

Snow occurs in a multitude of shapes depending on the temperature and humidity along the path it forms and falls. Current retrieval methods for snowfall rate and accumulation estimation use simplified geometries for flakes. This project examines thousands of snowflake images to more fully document the range of geometries of natural snow. Previous methods catch snowflakes on a flat surface, which can break delicate structures. We have documented three snowflake aggregate geometries not mentioned in previous classifications.

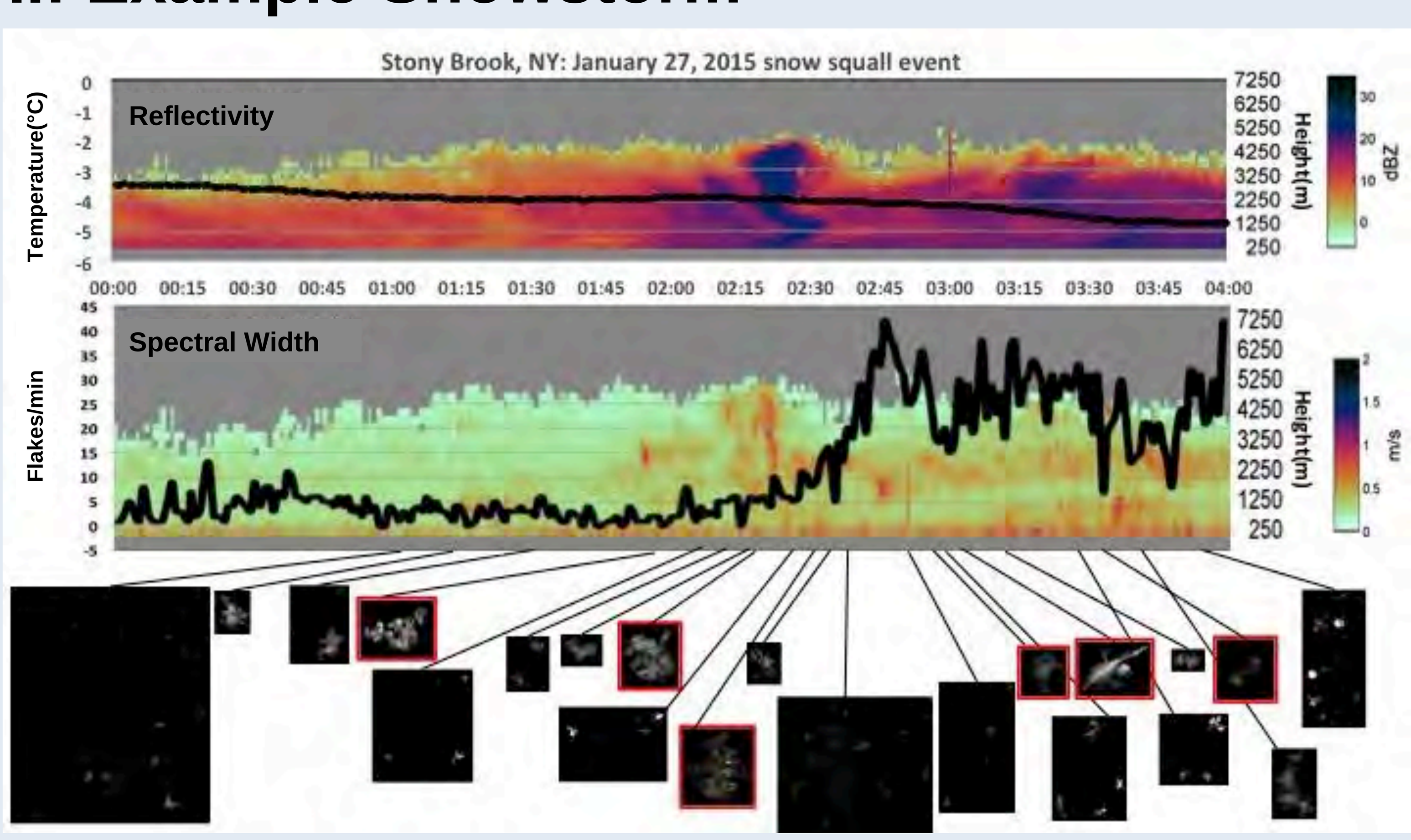
Methods

I: Data Collection

Images of snowflakes were obtained from a Multi-Angle Snowflake Camera (MASC) at Alta, UT and Stony Brook, NY from 2013 through 2015. The MASC takes pictures of flakes in free fall, preserving the natural orientations and 3D structures. Typically 10,000 or more flake images are obtained in a single snowstorm.

Multi-Angle Snowflake Camera in Alta, UT

II: Example Snowstorm



Time height plots of reflectivity with surface temperature overlaid and spectral width (a measure of turbulence) with number of camera triggers per minute overlaid. Example flakes from the MASC are shown below the plots. Images outlined in red show rimed aggregates.

Data on the turbulence present in the environment during snow formation and fallout can be used to predict the types of snowflakes that will reach the surface. The snowflake images were matched with radar reflectivity and a measure of turbulence from a nearby vertically-pointing radar based on the time of the observation. Turbulence in the air column above the camera was compared among selected flakes and to an average turbulence based on the corresponding reflectivity. Reflectivity is related to the number and diameter of the particles in a volume of precipitating cloud.

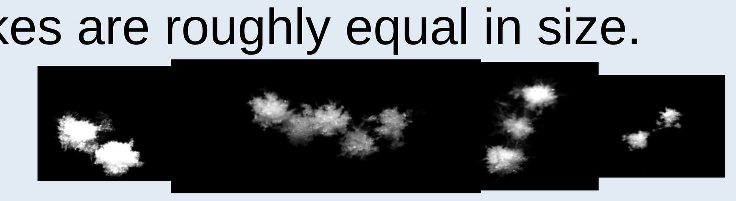
III: Snowflake Geometries

- An aggregate is a jumble of snowflakes. We do not specify that the aggregate must consist of the same crystal habits.
- Riming is a process where very tiny spheres of water stick to the surface of the aggregate and freeze.

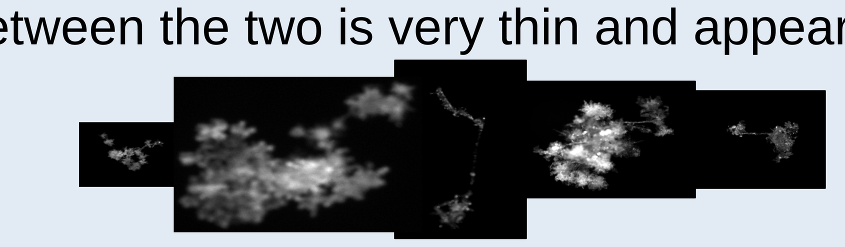
- We examine both rimed and unrimed aggregates. Rimed aggregates were documented in Locatelli and Hobbs (1974) but their emphasis was on rimed aggregates that consisted only of dendrites (6-sided branched crystals). We commonly observed aggregates containing a mixture of crystal habits (needles, columns, plates and dendrites) which demonstrates that snowflakes that formed separately can fall out at the surface together.

Three delicate aggregate geometries were observed in free falling snow.

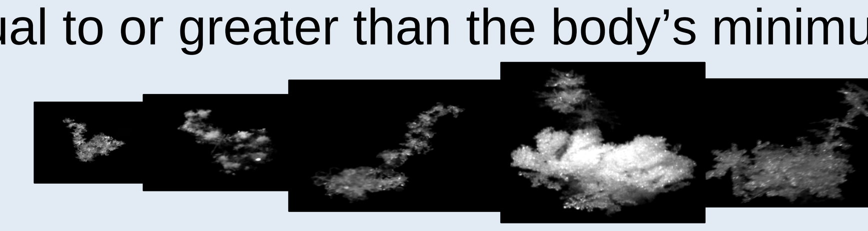
- A **train** is a chain of flakes with larger spheroids of flakes connected by much smaller ice crystals. The connectors are less than a quarter of the minimum diameter of the larger spheres in size. The connected balls of snowflakes are roughly equal in size.



- An **outrigger** snowflake contains a thin connection from the larger main body of flakes to a smaller group of particles. The smaller group of particles is less than half the size of the main body and the connection between the two is very thin and appear as a line.



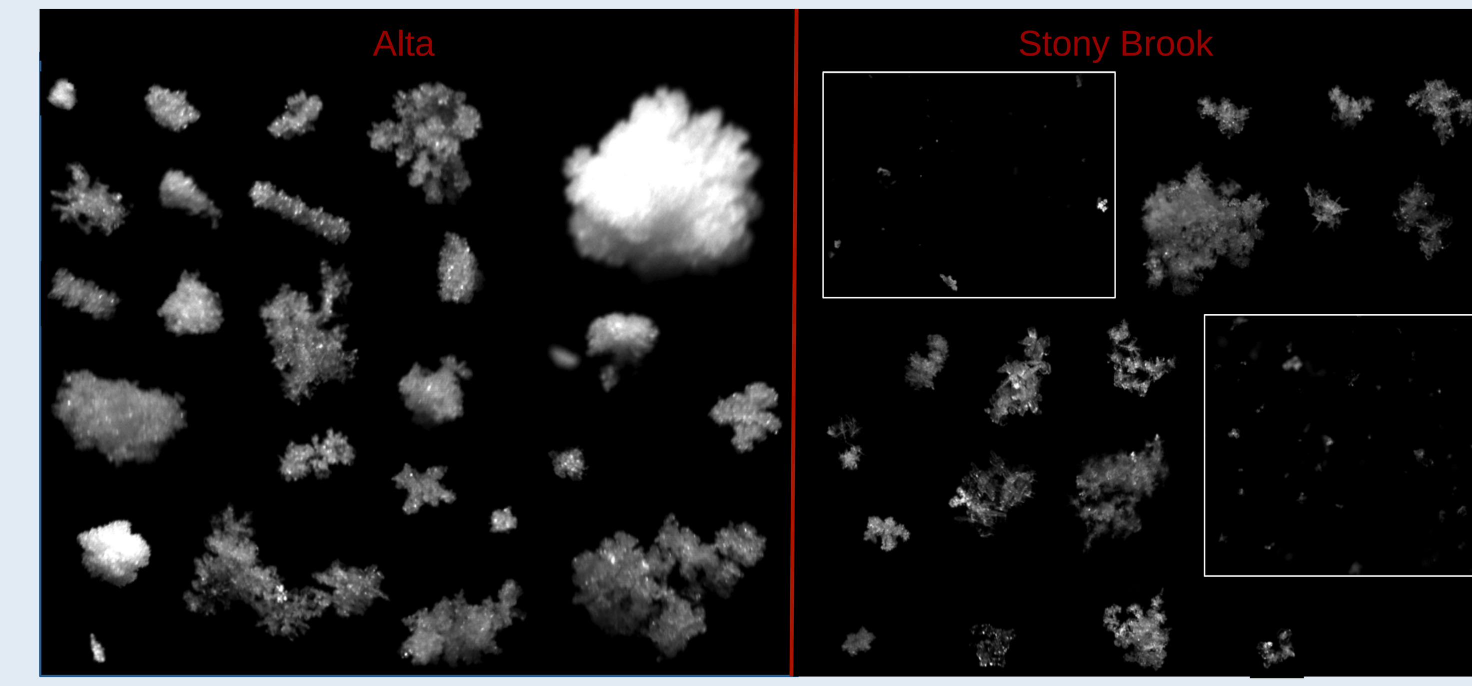
- In a **tail** snowflake, an appendage of flakes is attached to the main body of particles. The tail's width is less than half of the body's minimum diameter and should be relatively constant. The length of the tail is equal to or greater than the body's minimum diameter.



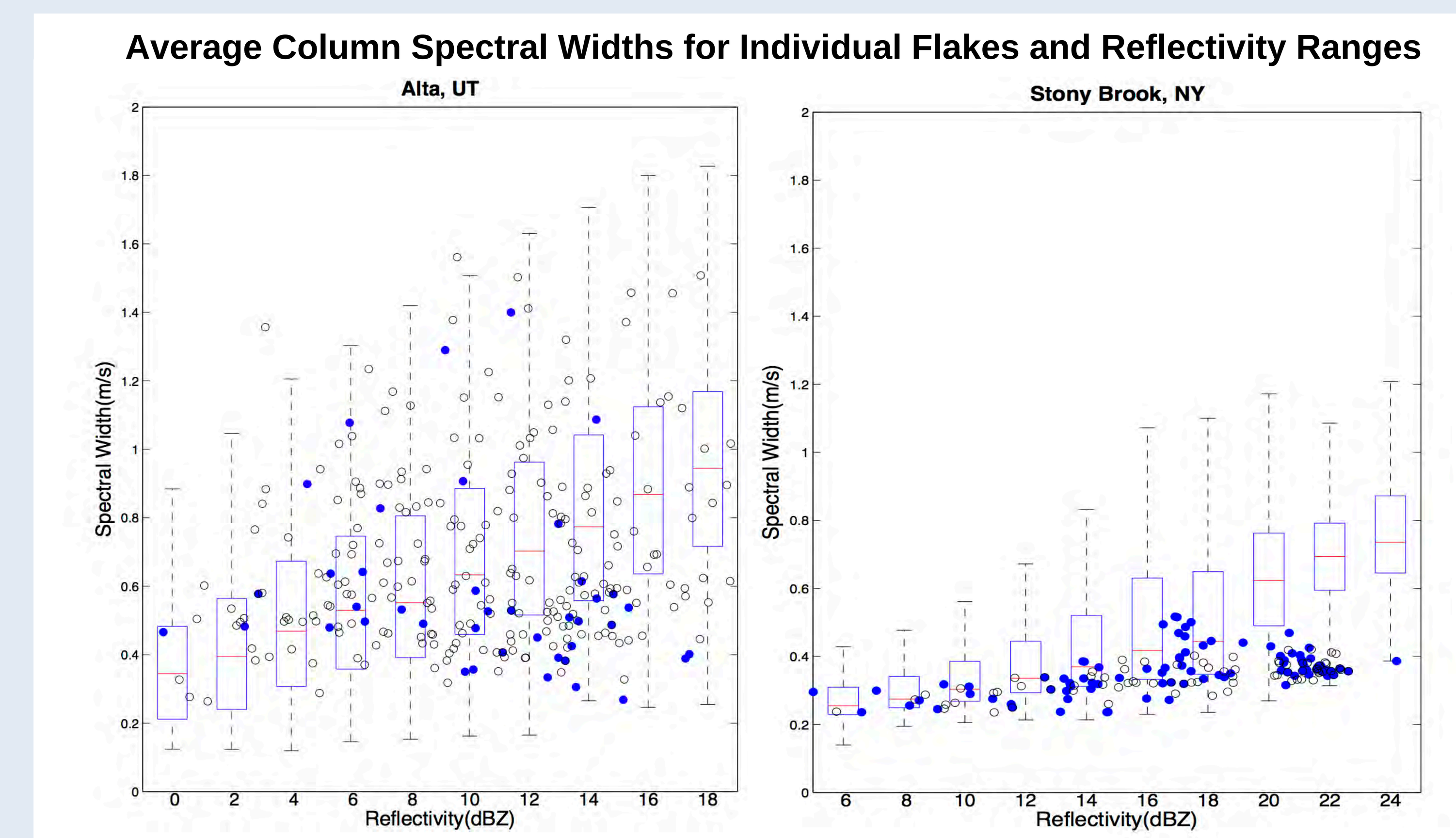
Preliminary Results

The 3 delicate geometries occurred in both locations. The snow at Alta is usually more rimed and more frequently includes heavily rimed graupel than at Stony Brook. More riming yields a higher water content than less rimed snow.

Multi-Angle Snowflake Camera (foreground) and vertical radar (background) at Stony Brook University during winter 2014-15



Comparison of typical flakes at Alta, UT and Stony Brook, NY. Occasionally, so many flakes fell at Stony Brook at the same time that the camera obtained images with dozens of flakes.



The joint variability of radar reflectivity and spectral width, a proxy for turbulence. Blue dots represent trains, outriggers, or tails. Black circles represent rimed aggregates. Box plots show 25th, 50th and 75th quartiles for all of the spectral width measurements within each respective 2 dBZ reflectivity range.

Alta is on a windward mountain slope and tends to have higher turbulence than the nearly flat coastal Stony Brook location.

Conclusions

- Three types of aggregates were distinguished that were previously not documented: tails, trains, and outriggers.
- Snowflakes that matched the new classifications were observed at both Alta, UT and Stony Brook, NY.
- The results suggest that these new delicate geometries can form and reach the surface in environments with low air turbulence.
- Future work will utilize a database of derived characteristics from the snowflake images and sounding data to examine other variables that may affect the formation of these geometries.

Reference: Locatelli, J. D., and P. V. Hobbs, 1974: Fall speeds and masses of solid precipitation particles, *J. Geophys.Res., 79,* 2185-2197, doi:10.1029/JC079i015p02185
Acknowledgements: Special thanks to Nicole Corbin, Spencer Rhodes, John Hader, and Matt Wilbanks for their assistance and advice. Research supported by National Science Foundation grants 1127759 (collaboration with T. Garrett at U. Utah) and 1347491 (collaboration with B. Colle at Stony Brook U.) .