

Classification of Snowflakes Using Multi-View Optical Instruments

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Classification of snowflakes has been recently invoked as an important factor in enriching our understanding of polarimetric radar signatures of snow, as well as ice cloud processes and the resulting precipitation production. We use five classes of snowflakes for categorization of snowflakes: aggregate, columnar crystal, planar crystal, small particle, and graupel. In addition, we are also evaluating the riming degree of the hydrometeor. To perform such classification, we have taken advantage of the recent developments in machine learning and have developed an automatic winter hydrometeor classification methodology utilizing Convolutional Neural Networks (CNNs). CNNs constitute a deep learning algorithm that takes an input image and learns to recognize differences between images/objects. CNNs are becoming increasingly popular in image classification, including images of winter precipitation particles, due to their high accuracy, computational efficiency, automatic feature extraction, and application versatility.

When using CNNs to classify snowflakes, we need visual inputs from optical weather instruments such as the Multi-Angle Snowflake Camera (MASC), a commercially available instrument majorly modified by Colorado State University (CSU), or Snowflake Measurement and analysis System (SMAS), a brand new, in-house designed and built instrument (by CSU students). To be able to apply CNNs to the collected images of snowflakes, we have automated an image preprocessing procedure to crop and normalize the images. We have also trained a presorting network to select bad images (blurry/out of focus) to ensure the quality of the input data for the classifier.

Our previous studies included training of a neural network from a training dataset containing images from two storm events in 2014 and 2015 captured by the MASC in Greeley, Colorado. The resulting mean accuracy was over 90% for correctly classifying a snowflake. When training with data collected over 32 snowfall events between 2014 and 2016 in Greeley, we achieved an even higher accuracy, with much greater in-class variety. However, all the previous results were obtained at a single view, i.e., using only one camera of the MASC for the snowflake image.

With the newly deployed SMAS, we have started data collection starting January 2022 at NASA Precipitation Research Facility at Wallops Island, Virginia. We have observed five snowfall events since the deployment. The SMAS is capable of capturing tens to hundreds of thousands of images during a single winter storm event, resulting in datasets prohibitively large for any sort of manual classification. This has, therefore, provided an even stronger motivation for accurate, automated snowflake classification. Unlike our previous studies, we are implementing multi-view inputs, i.e., using multiple cameras (a distinct feature of the SMAS) to build a CNN classifier. With multiple cameras and views, we gain a more dynamic and comprehensive information and further reduce classification errors caused by misleading side views of rotationally asymmetric snowflakes, etc.