Beyond Ice-Particle Images: Linking Particle Morphology and Cloud Conditions to Growth Processes

Primary A.14 Sub-Element: Sub-Element 1 – Aerosols, Clouds, and Radiative Forcing
NASA Campaign: IMPACTS

A main objective of the NASA Investigation of Microphysics and Precipitation for Atlantic Coast-Threatening Snowstorms (IMPACTS) field project is to determine how to predict high-snowfall locations. IMPACTS observations indicate that snowbands correlate with regions of high ice aggregation; hence, understanding the ice aggregation growth process is important. The high-resolution Particle Habit Imaging and Polar Scattering Probe (PHIPS) and Cloud Particle Imager (CPI) provide detailed observations of ice-particle size, shape, aggregation, and riming amount. However, ice particles with similar appearances can result from different combinations of vapor growth, aggregation, riming, and sublimation; therefore, imagery alone is insufficient to determine the physical growth process of an observed cloud population.

IMPACTS provides a unique opportunity to address growth processes because particle images were collected alongside measurements of the thermodynamic, dynamical, and cloud-microphysical conditions under which the particles were observed, along with coincident radar and lidar observations. This combination is valuable because aggregation, riming, and sublimation modify ice-particle properties in ways that affect radar and lidar measurements. The objective is to determine which growth-process information is gained by combining PHIPS and CPI imagery with quantitative particle properties and simultaneous cloud remote sensing observations. Particle properties include size, projected area, aspect ratio, circularity, solidity, porosity, symmetry, structural complexity, texture, and degree of riming and sublimation. These are combined with temperature, humidity, liquid water content, cloud droplet properties, vertical velocity, and particle size distributions. Remote sensing data from the ER-2 and satellites determine the surrounding cloud conditions. Aggregation and riming are the primary focus.

The project addresses three questions: (1) Which in-situ properties and remote-sensing observations add growth-process information beyond the image alone? (2) Can combined observations distinguish cloud populations associated with high versus low ice-particle growth, particularly when morphologies are similar? (3) Do populations with different growth rates show distinguishable remote-sensing signatures? These are addressed using three levels of information: imagery alone; imagery with quantitative particle properties; and imagery with particle properties and simultaneous cloud measurements. Reference morphologies are established from manually classified PHIPS and CPI images using consistent physical criteria. Artificial Intelligence (AI)/Machine Learning (ML) quantifies the information added by each observation type and extends the analysis across the IMPACTS archive.

The central hypothesis is that morphology alone cannot uniquely distinguish the growth process for a cloud population; combining morphology with measured thermodynamic, dynamical, and cloud-microphysical conditions provides the physical context needed to distinguish growth processes. The main advancement is moving beyond what an ice particle looks like to what its measurable properties and surrounding conditions reveal about the population's growth process. Coordinated ER-2 radar and lidar observations with coincident GOES observations to examine whether areas of large aggregation (snowband structure) exhibit identifiable growth processes in remote-sensing signatures. Expected outcomes are a combined IMPACTS dataset that identifies the measurements most useful for distinguishing growth processes, provides growth-process classifications with uncertainty estimates, and establishes relationship between these processes and NASA satellite observations. By linking PHIPS/CPI observations with simultaneous cloud and remote-sensing measurements, the project improves understanding of ice-particle growth in winter-storm snowbands and its representation in remote-sensing observations.