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Fragmentation in graupel-snow collisions

Aircraft observations of cold precipitating clouds with tops warmer than -38°C have always revealed that Secondary Ice Production (SIP) produces most of the ice particles. One such SIP mechanism is fragmentation via collisions among ice particles. The central theme of this study is to understand the dependencies of this SIP mechanism and improve its existing numerical and theoretical predictions, through field-based observations.

This study is motivated by the only field experiment to observe this type of mechanism, by Vardiman in 1978, who built a probe to sample falling ice precipitation outdoors. We modify aspects of that study by building our own portable chamber with knowledge from more recent publications and advances in technology. Fragmentation of individual snowflakes falling into it was recorded with high-speed video cameras. An array of 126 ice spheres were fixed to the base of the chamber and each was assumed to be representative of graupel. With this chamber, fragments from each collision between a falling snowflake and an ice sphere could be counted and sized from inspection of video recordings, after sampling outdoors.

There was a field trip to sample naturally falling snow particles in the Svartberget forest in Vindeln, in the north of Sweden, about 650 km south of the Arctic Circle on 24 February 2022, around midnight UTC. It was a snowfall lasting about 4 hours from orographic stratiform cloud (with precipitation rate of about 7 mm/hr) with a mixed-phase cloud top of about -20°C and a cloud base of -2.6°C about 100m above the ground (elevation 270 metres MSL). Simultaneously the mass-size relationship parameters for the falling snow particles were measured, which enabled the mass of each snow particle in the chamber to be estimated from its size before collision.

The results for the average size distribution of fragments, the coincident mass-size parameters, fall speed–size relation, and dependencies on Collision Kinetic Energy (CKE) correspond well with previously reported studies for dendritic snow. From the observed number of fragments, we refitted the theoretical formulation for this type of fragmentation in graupel snow collisions. For this formulation, a new form of the dependence of rime fraction on size is inferred from the coincident measurements of axial ratio. This refitting yielded an improved value of the asperity-fragility coefficient, C, of about 3.86×10^4 J^{-1} for dendritic snow colliding with graupel. Our field observations suggests that fragmentation in graupel-snow collisions is even more profound (about 3 times higher) than the previous estimations from the original version of the formulation. And a new revised version of the formulation is proposed for use in atmospheric cloud models.

Keywords: Physical Geography and Ecosystem Analysis, Clouds, Snow, Graupel, SIP, Fragmentation, CKE, Rime Fraction

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