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Fragmentation in graupel-snow collisions

Cloud systems form an essential part of ecosystems sustaining life on Earth . They provide life at the Earth's surface with water in the form of precipitation and protect us from incoming solar radiation. Precipitation in the form of rain occurs when water vapour condenses onto droplets, which further grows until the raindrops are heavy enough to descend from the clouds. At temperatures lowers than 0°C, supercooled rain drops undergoes freezing, which later precipitates as snow, graupel (small hail particles), hail etc. This is the primary ice formation process in clouds. Riming is a process where ice crystals grow by collecting supercooled water droplets on its surface. However, radar-based aircraft observations of cold precipitating clouds have found higher concentration of ice crystals than what was expected from primary ice formation process only. This led to the acceptance of the presence of different *Secondary Ice Production* (*SIP*) mechanisms. Study of one such *SIP* mechanism, namely fragmentation due to collision between ice particles, is the central theme of this report. Previously only one field experiment was done in 1978, by Larry Vardiman to study the fragmentation due to collision of ice particles.

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. An experimental setup, motivated from Vardiman's 1978 field experiment, was designed to record the fragmentation process due to collisions between snow and graupel particles. The recordings were done during a snowfall lasting about 4 hours, on 24 February 2022, around midnight UTC. From the recordings, the number of fragments produced in each collision, size of the fragments and fall speed of snow particles were measured. The mass of the snowflakes was also measured separately by collecting naturally falling snowflakes inside a small plastic container and weighing the container afterwards. Further, the *Collision Kinetic Energy* (*CKE*) of the snowflakes was also estimated from the mass and fall speed information.

The results for the average size distribution of fragments, mass-size relation, fall speed–size relation and dependencies on *CKE* correspond well with previously reported studies for dendritic snow particles. The information on size, mass and fall speed obtained from the video recordings, were used as an input to an established theoretical formulation for predicting the number of fragments produced due to graupel-snow collisions. This gave a new form of dependence of riming of the colliding snowflakes on the number of fragments predicted, by the formulation. Refitting of the formulation was done, and a correction parameter inside the formulation was updated. This updated formulation, obtained through field-based observations, can be applied to cloud models for a better representation of the *SIP* mechanism, studied in this report.

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

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Master degree project 30 credits in Atmospheric Sciences and Biochemical Cycles, 2022
Department of Physical Geography and Ecosystem Science, Lund University. Student thesis series INES nr 571