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Ice–Ice Collisions: An Ice Multiplication Process in Atmospheric Clouds

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Ice in atmospheric clouds undergoes complex physical processes interacting especially with radiation, leading to serious impacts on global climate. After their primary production, atmospheric ice crystals multiply extensively by secondary processes. Here, it is shown that a mostly overlooked process of mechanical break-up of ice particles by ice-ice collisions contributes to such observed multiplication. A regime for explosive multiplication is identified in its phase space of ice-multiplication efficiency and number concentration of ice particles. Many natural mixed-phase clouds, if they have copious millimetre-sized graupel, fall into this explosive regime. The usual Hallett-Mossop (H-M) process of ice multiplication is shown to dominate the overall ice multiplication when active, as it starts sooner, compared to the break-up ice multiplication process. However, for deep clouds with a cold base temperature where the usual H-M process is inactive, the ice break-up mechanism should play a critical role. Supercooled rain, which may freeze to form graupel directly in only a few minutes, is shown to hasten such ice multiplication by mechanical break-up, with an ice enhancement ratio exceeding 1×10^4 about 20 minutes after small graupel first appear. The ascent-dependent onset of sub-saturation with respect to liquid water during explosive ice multiplication is predicted to determine the eventual ice concentrations.

Reference:

J.-I. Yano, and V. T. J. Phillips, 2010: Ice–Ice Collisions: An Ice Multiplication Process in Atmospheric Clouds, *J. Atmos. Sci.*, in press.