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On the geometry and growth of aggregate snowflakes

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It is often said that no two snowflakes are alike. This usually refers to dendritic crystals, which can develop complicated and therefore unique branches. Most snowflakes in the atmosphere are not dendrites, but aggregates of primary crystals such as plates, dendrites or needles (also called monomers). Each aggregate is unique because the size, shape, collision angles, and overlap of the monomers are random. Earlier work has shown that aggregate snowflakes show a fractal scaling behaviour for large monomer numbers (also called cluster size). Nevertheless, there is a large variability of aggregate snowflake geometry. Given a certain snowflake mass and monomer number, the observable variables such as maximum dimension, aspect ratio, and terminal fall velocity can vary greatly. To understand and parameterize snowflake geometry, we have generated several million aggregate snowflakes with an aggregation model. This dataset allows us to parameterize the joint probability distributions of maximum dimension, aspect ratio, and cross-sectional area for aggregate snowflakes.
These probability distributions have been implemented in the Monte-Carlo super-particle model McSnow as a stochastic parameterization of snowflake geometry. This allows us to investigate the effect of snowflake variability on snowflake growth. The collision kernel is affected by the geometry itself and by the variability in terminal fall velocity caused by the different geometries. Hence, by taking into account the variability in snowflake geometry two snowflakes with the same mass can indeed collide, because they end up having different terminal fall velocities. Similar to considering turbulence effects in the collision kernel, this leads to a faster growth of aggregates. McSnow can already predict the habit of primary crystals using a spheroid model. This habit information can now be propagated to the aggregates. With the new stochastic snowflake model, McSnow can distinguish between aggregates of plates, aggregates of needles, and mixture aggregates.
To investigate the impact of the stochastic snowflake model on (polarimetric) radar quantities, we need to consistently forward simulate the model output. For this we have used DDA on representative aggregates from the aggregate database, generating a large scattering database. First results indicate that contrary to previous forward simulations using soft spheroid models such as the T-matrix, aggregates contribute significantly to the specific differential phase shift KDP. Also, the variability of snowflake geometry leads to a broadening of the Doppler spectra. The latter are often too narrow in numerical cloud models with simplified snowflake assumptions.

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