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Mass of individual snow particles retrieved from measured fall speed for various shapes

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Weather forecast and climate models require good knowledge of the microphysical properties of atmospheric snow particles. For example, particle cross-sectional area and shape are especially important parameters that strongly affect the scattering properties of ice particles and consequently their response to remote sensing techniques. The fall speed and mass of ice particles are other important parameters. The fall speed affects the rate of removal of ice from numerical models. The particle mass is a key quantity that connects the cloud microphysical properties to radiative properties.

Measurements of snow particles using the ground-based in-situ instrument Dual Ice Crystal Imager (D-ICI) have been carried out in Kiruna, Sweden, during several winter seasons. The D-ICI takes high-resolution side- and top-view images of falling hydrometeors, from which maximum dimension (describing particle size), cross-sectional area, and fall speed of individual particles are determined. Images from 2014 to 2018 form the dataset that is analysed for relationships between the different microphysical properties. The analysis is performed as a function of snow particle shape after sorting particles into 15 different shape groups.

While particle mass can be easily estimated geometrically from the image data for the simpler shapes such as columns and plates, mass for particles with more complex shapes cannot. Thus, particle mass of all snow particles in our dataset is derived from the direct measurements of particle size, cross-sectional area, and fall speed. For this we use an approach that connects mass to fall speed using an empirical relationship between the dimensionless Reynolds and Best numbers. Consequently, the relation between mass and the other microphysical properties can be studied as a function of shape. In addition, by evaluating these relationships and comparison to relationships from literature, we can study the usability of this Reynolds-to-Best-number-approach for the different shapes.

In general, our results show, depending on shape, varying but moderately to strongly correlated relationships among particle size, cross-sectional area, and fall speed that also compare favourably with many previous studies. There are a few discrepancies that can be linked to certain shapes, in particular column- and needle-like shapes, which show poor correlations between fall speed and particle size. We speculate that maximum dimension is not suitable to represent

particle size for these shapes. Inconsistencies between the different relationships found for the same shapes corroborate our hypothesis as they indicate that maximum dimension is not suitable to determine Reynolds number. Thus, the Reynolds-to-Best-number-approach works poorly for these shapes and mass cannot be determined accurately. However, column width, where available, is a better representative particle size. Using a selection of columns, for which the simple geometry allows the verification of the empirical Best number vs. Reynolds number relationship, we show that Reynolds number and fall speed are more closely related to the diameter of the basal facet (i.e. the column width) than the maximum dimension. The agreement with the empirical relationship is further improved using a modified Best number, a function of an area ratio based on the falling particle seen in the vertical direction.