1.1 DENSITY OF SNOWFLAKES BASED ON SURFACE OBSERVATIONS

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Irregular structure and different sizes of snowflakes present in Nature are challenging for microphysical parametrization and thereby also introduce uncertainty in remote sensing retrievals. Nowadays surface-based data are gathered mostly by automatic optical imagers. A typical limitation of automatic observations, however, is that only a subset of needed parameters is directly measured and the observations are limited by the viewing projection. Although, microphysical properties of snow particles are not independent, for example fall velocity can be computed from particle mass and shape equalizing gravitational attraction and aerodynamic drag, the remaining degrees of freedom are rather numerous. Typically mass or density of snow particles are either retrieved from combined observations of disdrometer and other instrument or utilizing the general hydrodynamic theory.

We have implemented two methods to retrieve the density of snowflakes with combined measurements of optical disdrometer (Particle Imaging Package, PIP) and precipitation gauge. The first method retrieves the ensemble mean density, i.e. the volume-flux weighted snow density, as function of median volume diameter. One of the biggest uncertainties with this method is the estimated volume-equivalent diameter. We have assumed that snowflakes are spheroids with axis ratios of 0.6 and given this assumption, a conversion factor relating volume equivalent and disc equivalent diameters observed from a single projection was defined.

The second method utilizes the hydrodynamic theory, where mass of single particle is computed from the observed dimension, fall velocity and area ratio of a snow particle. PIP observes falling particles from the side, whereas the particle dimensions projected to the flow are needed for the hydrodynamic calculations. The errors associated with the observation geometry and the measured particle size distribution were addressed by devising a simple correction procedure; the value of the correction was chosen for each snow event by comparing the estimated accumulated precipitation to gauge measurements. With the retrieved masses of snowflakes the ensemble densities with various definitions can be determined and compared.

Various definitions may yield significantly different results. We have processed snowfall cases over winters 2014-2017 and studied the changes of the microphysical properties corresponding to environmental conditions. Preliminary results indicate that the ensemble mean snow density and the volume-flux weighted snow density calculated from the retrieved masses of the second method are corresponding well, although comparison is sensitive to the assumption of the conversion factor relating volume equivalent and disc equivalent diameters.

In our study, we present a comparison of density definitions based on observations relative to the microphysical properties of snow particles and link the differences to uncertainties in parametrization. For example, the volume flux weighted snow density is expected to be lower in values than the velocity-weighted snow density, although the difference is not generally prominent especially with low-density aggregates, whose velocity is weekly dependent on snowflake size. The magnitude of differences are assumed to be determined by the exponential term of power-law expression of snow particle mass-dimensional relation.