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# Estimating radar reflectivity - snowfall rate relationships and their uncertainties over Antarctica by combining disdrometer and radar observations

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The Antarctic Ice Sheet (AIS) is the largest ice body on earth, having a volume equivalent to 58.3 m global mean sea level rise. Precipitation is the dominant source term in the surface mass balance of the AIS. However, this quantity is not well constrained in both models and observations. Direct observations over the AIS are also not coherent, as they are sparse in space and time and acquisition techniques differ. As a result, precipitation observations stay mostly limited to continent-wide averages based on satellite radar observations.

Snowfall rate (SR) at high temporal resolution can be derived from the ground-based radar effective reflectivity factor (Z) using information about snow particle size and shape. Here we present reflectivity snowfall rate relations ($Z = aSR^b$) for the East Antarctic escarpment region using the measurements at the Princess Elisabeth (PE) station and an overview of their uncertainties. A novel technique is developed by combining an optical disdrometer (NASA's Precipitation Imaging Package; PIP) and a vertically pointing 24 GHz FMCW micro rain radar (Metek's MRR) in order to reduce the uncertainty in SR estimates. PIP is used to obtain information about snow particle characteristics and to get an estimate of Z, SR and the Z-SR relation. For PE, located 173 km inland, the relation equals $Z = 18SR^{1.1}$. The prefactor (a) of the relation is sensitive to the median diameter of the particles. Larger particles, found closer to the coast, lead to an increase of the value of the prefactor. More inland locations, where smaller snow particles are found, obtain lower values for the prefactor. The exponent of the Z-SR relation (b) is insensitive to the median diameter of the snow particles. This dependence of the prefactor of the Z-SR relation to the particle size needs to be taken into account when converting radar reflectivities to snowfall rates over Antarctica.

The uncertainty on the Z-SR relations is quantified using a bootstrapping approach and subdivided in three terms: measurement uncertainty by the PIP, uncertainties in snow particle characteristics within each particle shape (parameter uncertainty) and uncertainties in the shape of the snow particles (shape uncertainty). The uncertainty range of resulting snowfall rates is close to 40%, which is relatively small and found to be also dependent on the snow particle diameter. In contrast with previous studies for various locations, shape uncertainty is not the main source of uncertainty in the Z-SR relation at PE. Parameter uncertainty was found to be the most dominant term, mainly driven by the uncertainty in mass-size relation of different snow particles. Future research aiming at reducing the uncertainty of Z-SR relations should therefore focus on obtaining reliable estimates of the mass of snow particles.

The relatively low uncertainties on the Z-SR relation opens perspectives for research with disdrometers over Antarctica. These relations can be applied on radar observations in order to obtain long-term accurate estimates of snowfall rates and to improve surface mass balance estimates.