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Ice particle mass-dimensional parameter retrieval and uncertainty analysis using an Optimal Estimation framework applied to in situ data

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The extreme variability of ice particle habits in precipitating clouds affects our understanding of these cloud systems in every aspect (i.e. radiation transfer, dynamics, precipitation rate, etc) and largely contributes to the uncertainties in the model representation of related processes. Ice particle mass-dimensional power law relationships, M=a*(Dˆb), are commonly assumed in models and retrieval algorithms, while very little knowledge exists regarding the uncertainties of these M-D parameters in real-world situations. In this study, we apply Optimal Estimation (OE) methodology to infer ice particle mass-dimensional relationship from ice particle size distributions and bulk water contents independently measured on board the University of Wyoming King Air during the Colorado Airborne Multi-Phase Cloud Study (CAMPS). We also utilize W-band radar reflectivity obtained on the same platform (King Air) offering a further constraint to this ill-posed problem (Heymsfield et al. 2010). In addition to the values of retrieved M-D parameters, the associated uncertainties are conveniently acquired in the OE framework, within the limitations of assumed Gaussian statistics. We find, given the constraints provided by the bulk water measurement and in situ radar reflectivity, that the relative uncertainty of mass-dimensional power law prefactor (a) is approximately 80% and the relative uncertainty of exponent (b) is 10-15%. With this level of uncertainty, the forward model uncertainty in radar reflectivity would be on the order of 4 dB or a factor of approximately 2.5 in ice water content. The implications of this finding are that inferences of bulk water from either remote or in situ measurements of particle spectra cannot be more certain than this when the mass-dimensional relationships are not known a priori which is almost never the case.