**Dual-frequency Spaceborne Retrieval Methods and the Role of Non-Uniform Beam Filling**

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Many of the recent dual-frequency retrieval methods seek to estimate parameters of the particle size distribution (PSD) by relying on the fact that the dual-frequency ratio of the radar reflectivity factors is a function of a characteristic size parameter of the PSD, independent of particle number concentration.

An essential part of the retrieval is its account of attenuation where the PSD estimates from prior range gates are used to update the attenuation to the gate of interest. The retrieval can be framed either as a forward (from the radar outward) or backward (from the surface or final gate to the radar) recursion. The backward-going method can be further divided into a final value solution where the path attenuation is estimated from the surface reference technique (SRT) and iterative methods where the solution is iterated until the assumed path attenuations match the attenuations deduced from the PSD profiles. The primary advantage of the iterative approach is that independent estimates of the path-integrated attenuations (PIA) are not needed; the major weakness appears to be instability in the estimates especially when the attenuation is large and contributions to the attenuation from cloud liquid water and mixed phase precipitation are significant. The primary advantage of the SRT is the stability of its estimates and its independence of cloud water and mixed phase precipitation in estimating characteristics of the rain layer, assuming that these constituents appear above the rain. The major disadvantage arises from errors in the path attenuation caused by fluctuations in the surface cross section.

Using a radar simulator and MC3E (Mid-latitude Continental Convective Clouds Experiment) input model data shows the backward recursion methods generally perform well when the gradients in the reflectivities are small across the field of view. However, as the field of view increases or the reflectivity gradients increase, both the SRT and iterative approaches show significant errors. Insight into the cause of the errors can be gained by examining a simple beam geometry where the DSD parameters in one half of the beam are taken to be different than those in the other half. Comparisons are then made between this non-uniform case and the uniform case where the DSD parameters are taken to be the beam-averages of the non-uniform case. The results show that the dual-frequency ratio, DFR, defined as the difference in dB between the Ku and Ka-band attenuation-corrected reflectivity factors (in dB), is larger in the non-uniform case than in the uniform case if the median mass diameter in the two regions differ. Moreover, the path attenuations in the two cases are generally different so that retrievals based on uniform reflectivities across the beam result in errors when applied to data measured over non-uniform beam filling geometries.

To examine the situation in greater detail, a simple spaceborne geometry is constructed where a discontinuity in the DSD parameters along the horizontal axis can be shifted relative to the radar field of view. For this case, the calculation of the path attenuations and measured reflectivity factors can be reduced to one-dimensional integrals. The geometry also provides a way to compute path-attenuation measurements at sub-resolution scales that are generated for off-nadir beam geometries. In particular, off-nadir geometries yield multiple measurements of surface return power at the far radar range gates that correspond to sub-resolution path attenuations within the beam. We explore algorithms that use these data to try to remove some of the errors caused by non-uniform beamfilling. Preliminary results show that improvements in rain rate estimation may be possible if accurate sub-resolution path attenuations can be measured.