Modeling and measurements of cloud radar dual-wavelength ratio of ice hydrometeors

*Sergey Y Matrosov[1], Maximilian Maahn[1], Gijs de Boer[1]

1. CIRES, Universty of Colorado and NOAA ESRL

Ice hydrometeor shape influence on the dual-wavelength ratio (DWR) of radar reflectivities at millimeter-wavelength frequencies is studied theoretically and based on observations. Measurements from dual-frequency (K_a-W-bands) cloud radar at the Oliktok Point Alaska Atmospheric Radiation Measurement (ARM) program’s Mobile Facility 3 (AMF3) show that, for vertically pointing measurements, DWR increasing trends with reflectivity, Z_e, are very pronounced when K_a-band Z_e is greater than about 0 dBZ. The DWR and Z_e, values are also well correlated. This correlation is explained, in part, by the fact that both DWR and Z_e are related to particle characteristic size. The observed DWR variability for a given level of reflectivity is as large as 8 dB, which is in part due to changes in mean hydrometeor shape as expressed in terms of mean particle aspect ratio. Hydrometeors with a higher degree of nonsphericity exhibit lower DWR values compared to quasi-spherical particles due to near-zenith reflectivity enhancements when non-Rayleigh scatterers are present. When particle mass - size relations do not change significantly (e.g., for low rime conditions), DWR values can be used to differentiate between quasi-spherical and highly nonspherical hydrometeors if a reflectivity level is constrained. Another approach for differentiating among different degrees of nonsphericty of non-Rayleigh scatterers is based on analyzing DWR changes as a function of radar elevation angle. These changes are more pronounced for highly nonspherical particles and can exceed 10 dB. Spatiotemporally collocated measurements of snowfall from the satellite W-band radar and S-band operational weather radars also indicate that DWR values are generally smaller for ice hydrometeors with higher degrees of nonspherictity, which, for the same level of absolute reflectivity, exhibit greater differential reflectivity values.

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