The Latitudinal Variability of Raindrop Size Distribution Properties And the Implication for GPM Rainfall Algorithms

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In this study, we analyse a new in-situ shipboard global ocean Drop Size Distribution (DSD) database to better understand the underpinning microphysical reasons for discrepancies between satellite rainfall products at high latitudes which are reported in the literature. The natural, latitudinal, and convective-stratiform variability of the DSD is found to be large, with a substantially lower concentration of drops with diameter smaller than 3 mm in the Southern hemisphere high latitude (S-highlat) and Northern Hemisphere polar latitude (N-polar) bands, which is where satellite rainfall products most disagree. The S-highlat and N-polar latitude bands stand out as regions with different rainfall properties in comparison to other latitudes in our dataset, highlighting fundamental differences in rainfall processes at different latitudes and associated specific challenges for satellite rainfall retrieval techniques. The most salient differences in DSD properties between these two regions and the other latitude bands are: (1) a systematically higher (lower) frequency of occurrence of rainfall rates below (above) 1 mm h^{-1}, (2) much lower drop concentrations, (3) very different values of the DSD shape parameter (μ) from what is currently assumed in satellite radar rainfall algorithms, and (4) very different DSD properties in both the convective and stratiform rainfall regimes.

We then review how those statistical differences in DSD properties translate into differences between radar observables and DSD properties within different latitude bands. A crucial underlying assumption in satellite radar rainfall retrievals is the relationship between attenuation and reflectivity. Our attenuation –reflectivity relationships systematically produce smaller attenuation than the satellite relationships within all latitude bands (close for the tropical bands). Relationships between radar reflectivity and mass-weighted diameter D_m, and between dual frequency ratio (ratio of Ka to Ku band reflectivities) and D_m are found to be quite scattered, and disappointingly, equally scattered. This important result suggests that the added value of two radar frequencies to improve the D_m retrieval from space is limited. In contrast the relationship between D_m and the ratio (attenuation/reflectivity) is found to be very robust and not dependent on latitude. Direct relationships between rainfall and either reflectivity or attenuation are also found to be very robust. Attenuation –reflectivity, D_m –reflectivity, and rainfall rate –reflectivity relationships in the Southern Hemisphere high latitude and Northern Hemisphere polar latitude bands are fundamentally different from those at other latitude bands, producing smaller attenuation, much larger D_m, and lower rainfall rates for any given reflectivity. This implies that specific relationships need to be used for these latitude bands in radar rainfall retrieval techniques using such relationships.

Figure caption: (top) Global map of all OceanRAIN precipitation observations included in this analysis. Colours indicate during which season each observation has been collected. Dashed lines of constant latitude delimit the latitude bins used in this study. (bottom) The latitudinal variability of the R - D_m, relationship. Coloured solid and dotted lines are for each latitude band (see colour bar on the right). Solid (dotted) lines are Northern Hemisphere (Southern Hemisphere) results from each latitude band. Also shown in color (in dB scale) is the overall joint R - D_m distribution when all samples are included. The dashed black, red, and blue lines are the W14 fit, GPM V04 convective, and GPM V04 stratiform *relationships, respectively.*

Keywords: Statistical properties of DSDs, GPM radar rainfall algorithms