Geophysical Research Abstracts,
Vol. 10, EGU2008-A-09619, 2008
SRef-ID: 1607-7962/gra/EGU2008-A-09619
EGU General Assembly 2008

Flagging profiles burdened by multiple-scattering in the CloudSat rain product over ocean

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Multiple scattering strongly affects the CloudSat Profiling Radar reflectivity when the satellite is overpassing moderate and heavy precipitation systems. Therefore, as a preliminary step to the generation of the CloudSat rain product (Level 2B-E), an identification of the profiles burdened by multiple-scattering contamination is needed. A flagging criterion dictated by other 2B-Geoprof products is here proposed, grounded on multiple scattering reflectivity MonteCarlo numerical simulations of Cloud Resolving Model-generated microphysical profiles encompassing a large variety of precipitating systems. Four regimes are identified:

1) the single scattering approximation is applicable to the entire Z-profile;

2) the single scattering approximation is unreliable but the second order of scattering approximation is valid;

3) the second order of scattering approximation is not valid with higher order of multiple scattering affecting the reflectivity profile but not affecting the surface reference technique-based path integrated attenuation estimates;

4) the multiple scattering is affecting the surface return as well, thus spoiling the path integrated attenuation estimates as well.

The operational thresholds are defined according to the freezing level height and to the surface reference technique-based hydrometeor path integrated attenuation and

are then applied to the CloudSat dataset over sea, where path integrated attenuation estimations are more accurate. A threshold value of 20 dB for the one-way path integrated attenuation is suggested for the applicability of the surface reference technique to the CloudSat Profiling Radar system.

Case studies and global statistics of the occurrence of multiple scattering are presented: for ocean pixels, around 80% (90%) of the profiles identified as rainy can be treated in the single scattering (second order of scattering) approximation. However, due to the completely different precipitation regimes, results are strongly regional and seasonal dependent. For instance in the InterTropical Convergence Zone order of scattering higher than the second are typically necessary for 30-40% of the rainy profiles while the surface reference technique becomes inapplicable in 20-30% of the cases.