Simulations and observations of multiple scattering effects in space-borne radars when observing precipitation systems (Review Lecture)

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Recent work has highlighted the importance of multiple scattering effects when dealing with high frequency space-borne radars in configurations like those planned or employed for the GPM, the CloudSat, and the EarthCare missions. The first images delivered by the 94 GHz Cloud Profiling Radar on board of CloudSat when passing precipitating systems provide distinctive signatures of multiple scattering effects (e.g. no 'discontinuity' peak in the reflectivity signal at the surface range, long tails in the reflectivity profiles at apparent ranges below the surface).

A numerical model based on the Monte Carlo solution of the vector radiative transfer equation has been developed to simulate radar signals. Except for contributions due to the backscattering enhancement, the model is particularly suited for evaluating multiple scattering effects. The model accounts for general radar configurations such as airborne/space-borne/ground-based, monostatic/bistatic, and includes the polarization, the antenna pattern and the interaction with a Kirchoff surface as particularly relevant features. Multiple scattering effects in co- and cross-polar radar returns are evaluated for realistic vertically inhomogeneous scenarios involving rainfall, snow, graupel, and ice crystals extracted from cloud resolving model simulations forspace-borne and air-borne configurations.

Results show that the multiple scattering enhancements become a real issue for space-borne Ka band radars for medium to heavy precipitation and for W band radars already in the presence of light precipitation. Multiple scattering effects can reach several tens of dB when heavy cold rain systems are considered, i.e. when the profiles include rain layers with a high density of ice particles aloft. Multiple scattering effects are, however, highly dependent on the ice layer of the cloud and on its microphysical assumptions (e.g. large ice particles strongly enhance multiple scattering). For some of the simulated profiles, reflectivities display no discontinuity at the surface range and long signal tails at ranges below the surface range in accordance with Cloudsat observations.

When the cross-polar returns are analyzed, high LDR values appear both in space-borne and air-borne configurations. The LDR signatures are indicators of multiple scattering effects since they cannot be explained by single scattering computations even including non-spherical particles.