The problem of retrieving snowfall: Are multi-frequency radars a way forward?

Stefan Kneifel[1], Maximilian Maahn[1], Susanne Crewell[1]

[1]University of Cologne, Germany

Although snowfall is undoubtable of major importance for the water cycle at high latitudes and for our understanding of cold rain formation, snowfall microphysics is still a big challenge for atmospheric modelers and observationalists. One reason is the enormous variability of snowfall properties including for example various habits ranging from single ice crystals, snow aggregates, and rimed particles. These variations in sizes, densities and habits not only affect the actual snowfall rate but also influence the snow's interaction with electromagnetic radiation. Although single-frequency radars like the W-band radar onboard CloudSat opened new avenues to observe global distribution of snowfall, the large variability of snowfall properties always limits the accuracy of derived snowfall products. Another source of uncertainty particularly for spaceborne systems is the radar blind zone, usually the first km above ground, where surface reflection inhibits detection of hydrometeors.

In recent years, the increasing number of available snow and ice particle scattering models suggested that a combination of three radar frequencies which cover the Rayleigh scattering regime up to the Mie scattering regime could help to untangle at least certain classes of snowfall like aggregates or graupel-like particles. Recent observations from airborne and ground-based campaigns confirmed the general existence of different regimes in the triple-frequency space similar to those predicted by the scattering models.

In this contribution we will show first results from a campaign in Hyytiälä (Finland) in 2014 where ground-based triple-frequency (X-, Ka-, and W-band) radar observations can for the first time be analyzed in combination with a comprehensive set of collocated in-situ observations. The three analyzed case studies cover a wide range of snowflake habits and densities (degrees of riming). The observed triple-frequency signatures are in general agreement with former studies but also reveal new features and additional snowfall categories: Besides open low-density aggregates, rimed particles populate in a distinctly different regions and show high sensitivity on the change in bulk particle density. Therefore, we can conclude that triple-frequency radar observations bear the potential to constrain some key parameters of snowfall microphysics like median mass diameter or bulk snowfall density. In combination with collocated in-situ observations they can also be used to test the consistency of snowfall scattering models. Future satellite missions should thus combine a dual frequency radar like the Ku/Ka-band combination onboard GPM and a W-band radar similar to those onboard CloudSat to exploit the triple-frequency information for improved snowfall retrievals.