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Ground based remote sensing of snowfall through active and passive sensor synergy

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Although snow is the predominant type of precipitation in the sub-polar and polar latitudes, not many reliable remote-sensing methods of determining the vertical distributions of micro-physical snowfall parameters (i.e. snow mass density, snow crystal size and type) today exist. These parameters - together with temperature, humidity and turbulence - govern processes such as riming and aggregation, which in turn determine the ground-based snowfall rate. However, these parameters are highly variable in space and time and thus their measurement - and subsequent modeling - is a difficult task. The "Towards an Optimal estimation based Snow Characterization Algorithm" (DFG-TOSCA) project addresses these points in combining the unique information contained from a suite of ground-based sensors: microwave radiometers (22 – 150 GHz), 24 and 35 GHz radar, lidar, and in-situ measurement methods. During the winter of 2008/2009, such instruments were deployed at the Environmental Research Station Schneefernerhaus (UFS at 2650 m MSL) at the Zugspitze Mountain in Germany for deriving microphysical properties of falling snow. In the high altitude region of the UFS station snow events occur much more frequently than in lower regions and the low water vapor amounts account for clearer scattering signals from ice hydrometeors.

We will present results of an extended case study where measured TBs at 90 and 150 GHz were found to be significantly enhanced during snowfall due to scattering of surface radiation at snow crystals and that this enhancement is clearly correlated with the radar derived snow water path. Radiative transfer (RT) simulations highlight the strong influence of the vertical distribution of cloud liquid water (liquid water path LWP$<$0.1 kgm-2) on the TB which in extreme cases can fully obscure the snow scattering signal. Simulation experiments for this specific case, using typical variations in snow amount, particle shape and snow particle size distribution revealed the equal importance of these contributors to the TB variations. Further, we show a statistical analysis of the whole TOSCA period which highlights the very frequent presence of super-cooled water within snow clouds and their importance to radiative transfer in the microwave spectral region. Finally we present results of RT studies that illustrate the benefit of combining passive and active microwave systems to disentangle the influences of different snow shape, SSD and SWP. The identification of potentially valuable ground-based instrument synergies for the retrieval of snowfall parameters from the surface will also be of importance for the development of new space-borne observational techniques.