Title: Observation of snowfall by ground-based active and passive remote sensing

Authors: S. Kneifel, U. Löhnert, S. Redl, S. Crewell

Snow is the predominant type of precipitation in the sub-polar and polar latitudes and plays an important role in the hydrological cycle. Thus, the development of reliable remote-sensing methods to determine the vertical distributions of micro-physical snowfall parameters (i.e. snow mass density, snow crystal size and type) is extremely important. These parameters - together with temperature, humidity and turbulence - govern processes such as riming and aggregation, which in turn determine the ground-based snowfall rate. Unfortunately, these parameters are highly variable in space and time and thus their measurement - and subsequent modelling - is a difficult task. The “Towards an Optimal estimation based Snow Characterization Algorithm” (DFG-TOSCA) project addresses these points by 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 2008/2009, such instruments were deployed at the Environmental Research Station Schneefernerhaus (UFS at 2650 m MSL) in Germany for deriving microphysical properties of falling snow. Snow events occur much more frequently at this high altitude than in lower regions and 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 on falling snow crystals. Furthermore, 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), e.g. its emission temperature, on 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. In addition, 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. The correct modelling of radiative transfer is very sensitive to the dielectric properties of super-cooled liquid water. Different models of refractive index are compared and their consistency with the measurements is analyzed. 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.