

Snow particle orientation observed by ground-based microwave radiometry

Falling snow plays an essential role in the hydrological cycle; however, its microphysical characteristics still pose large uncertainties in numerical weather prediction. An important source of uncertainties for snowfall retrievals is whether snow particle falling with a certain orientation or not. Especially for larger aggregates, their falling attitudes are still not clear.

Oriented snow particles can induce polarized difference (PD) between vertical and horizontal polarizations due to their dichroic effects. In order to investigate potential PDs of snow particles, a Dual-Polarized microwave Radiometer (DPR) has been deployed at "Umweltforschungsstation Schneefernerhaus"(UFS, 2650m MSL) at Mt. Zugspitze (German Alps). The DPR provides Brightness Temperature (TB) measurements at three channels, one at 90 GHz and the other two channels (vertical and horizontal polarizations) at 150 GHz. A second microwave radiometer-a Humidity And Temperature PROfiler (HATPRO), which measures at the wing of water vapor absorption line (20-30 GHz) and at the oxygen absorption band (50-60 GHz), was installed next to DPR and it is used for integrated liquid water and water vapor observations. To make sure that the data observed by microwave radiometers are qualitatively controlled, web cameras have been installed to observe whether the radomes of the two microwave radiometers are covered with snow or melted ice. A Micro Rain Radar (MRR) operating at 24.1 GHz at UFS provides ancillary information on snow water path during snowfall up to 3 km height.

The observed PD at 150 GHz ranged up to -10 K at 34.8 degree elevation angle during snowfall, according to the statistical analysis using a 458-hour dataset of falling snow during the year 2010. By means of the synergy of the three active/passive instruments, the analysis shows that (1) an increase in snow water content corresponds to the increasing TBs and PDs, the latter resulting from oriented snow particles; (2) the occurrence of cloud liquid water also enhances TBs but damps PDs. Both the snow scattering and liquid water emission effects dominate DPR received TBs at 150 GHz, while at 90 GHz the snow scattering effects are much weaker, a factor of three, compared to 150 GHz.

Radiative Transfer (RT) simulations with horizontally-oriented snow oblates confirm the effects of liquid water and snow water on TBs and PDs. The observed PDs and TBs by the DPR are captured well with the RT simulations by realistic assumptions on snow particle Aspect Ratio and mass size distribution. The study reveals further that the observed PDs as a function of the DPR observing elevation angles can constrain the snow water content and snow particle AR estimation. Thus, the PD information offers a high potential for an improved retrieval of ice and liquid water phase in precipitation clouds.