GROUND-BASED REMOTE SENSING OF SNOWFALL THROUGH ACTIVE AND PASSIVE SENSOR SYNERGY

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1. INTRODUCTION

This contribution presents first results of the DFG-funded research project TOSCA – "Towards an Optimal estimation based Snow Characterization Algorithm". A unique combination of remote sensing instruments has been 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. The UFS is a research station supported by the federal German and Bavarian state governments. It possesses an excellent infrastructure for diverse research branches such as meteorology, air quality/pollution, chemistry, biology and even medical sciences.

Numerous well-established algorithms for deriving the liquid phase of precipitation – either from satellite or from the ground – have been developed and are being routinely applied. Algorithms for deriving snowfall, in contrast, are much less sophisticated and suffer from large uncertainties. This poses a major problem in climate research, because a large part of the global precipitation falls as snow and liquid precipitation is formed via the ice phase. The global distribution of snowfall is thus very important for climate studies, especially concerning the rapid changes of the hydrological cycle in the Polar Regions. The main problem in the derivation of snowfall parameters is the high spatial and temporal variability of the snow crystals, whose interactions with atmospheric radiation is very difficult to describe. The TOSCA project addresses this point in combining the unique information contained in a combination of passive radiometers, active radar technology and in-situ measurement methods within a unified retrieval scheme. The integrated retrieval algorithm to be developed will aim at deriving the vertical distribution of the specific mass of snow. This includes not only carrying out and carefully evaluating the measurements, but also the modelling of the interaction (i.e. scattering processes) of atmospheric radiation with the snow crystals.

2. DEPLOYED INSTRUMENTS

The UFS offers a unique possibility for remote sensing of snow and ice clouds. Due to its high elevation at 2650 m snow events occur much more frequently than in lower regions. Additionally, the low water vapor amounts do not disturb the scattering signal from the ice hydrometeors as much as at sea level. During TOSCA a suite of remote sensing instruments have been installed for the remote sensing of frozen hydrometeors at UFS:

- a dual-polarisation microwave radiometer (DPR) at 90/150 GHz to evaluate the columnar microphysical properties of snow events and thick ice clouds;

- a state-of-the-art 35 GHz cloud radar for determining the vertically resolved radar reflectivity of all ice clouds with reflectivities larger than -40 dBZ, making possible the detection even of thin ice clouds;
- a 24 GHz Micro Rain Radar (MRR) for determining the vertically resolved radar reflectivity and terminal velocity of snow particles along the line of sight (elevated in the same direction as the DPR);
- an optical Disdrometer (PARSIVEL) to determine the snow size spectrum and the fall velocity at the ground;
- a microwave profiler (HATPRO) to continuously monitor the temperature and humidity profiles in the lower to middle troposphere; additionally, especially together with DPR measurements, high accuracy measurements of the liquid water column can be obtained;
- a ceilometer continuously providing information about the cloud base heights of up to three cloud layers above UFS;
- additional radiosonde data from Innsbruck and auxiliary instruments (ambient temperature, wind sensor, etc.) are available

3. SINGLE SCATTERING CALCULATIONS

In order to be able to simulate the observations and thus evaluate the potential of the synergy of different remote sensing instruments for snow fall retrieval, the single scattering properties of the ice crystals must be modeled in a sophisticated manner. Due to the high variability of crystal sizes and shapes we use the Discrete Dipole Approximation (DDSCAT code [1]) to describe the single scattering properties of snow crystals, which allows the handling of snow crystals arbitrary in shape and in size. In order to make the ice crystal shapes similar in size and shape to ground-based in-situ measurements we have modeled the geometrical shape of the ice crystal shapes according to [2], who uses the “fractal dimension” parameter to characterize snow particle aggregates. In the subsequent DDA calculation the particle is assumed to be totally randomly orientated. The resulting measurement simulations of brightness temperatures and radar reflectivities with a state-of-the-art radiative transfer model are compared and evaluated against those cases where several “typical” ice crystal shapes (i.e. columns and plates, rosettes, dendrites) are considered valid [3]. Such typical crystal shapes are often observed in ice clouds (~100 µm), whereas snowflakes of 1 mm maximum dimension and more occurring within precipitation events are frequently observed as aggregates of different constituent crystal types.

4. SENSITIVITY STUDY

The sensitivities of brightness temperature and radar reflectivity to snow water content are analyzed as a function of particle size and shape. Additionally the influence of liquid water and water vapor content is analyzed. Here we show simulated data from the German Weather Service (DWD) COSMO-DE model for snowing cases where surface temperature is below 0°C. “Real” measurements from the TOSCA measurement campaign of the winter season 2008/2009 will be shown and compared with the expected sensitivities from the COSMO-DE simulation study. These analyses will serve as a basis for the future development of an optimal estimation retrieval scheme with goal of improving profiles of snow water content from the sensor synergy of ground-based remote sensing measurements.

5. REFERENCES

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