RETRIEVAL OF SNOW PARAMETERS FROM KU-BAND AND X-BAND RADAR BACKSCATTER MEASUREMENTS

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ABSTRACT

Radar backscatter at Ku-and X-band frequencies is very sensitive to the physical properties of the snow pack. This sensitivity is explored by the satellite mission COld REgions Hydrology High-resolution Observatory (CoReH2O) which has been selected for scientific and technical feasibility studies within the Earth Explorer Programme of the European Space Agency [1]. The focus of the mission is on spatially detailed repeat measurements of snow and ice properties in order to advance the understanding of the role of the cryosphere in the climate system and to improve the knowledge and prediction of water cycle variability and changes. The proposed sensor is a dual frequency SAR, operating at Ku-band (17.2 GHz) and X-band (9.6 GHz), VV and VH polarizations. Theoretical and experimental work has been performed to study the sensitivity of Ku- and X-band backscatter to snow properties and to develop algorithms for the retrieval of snow parameters.

A main snow parameter to be measured by the sensor is the mass of snow on ground, the snow water equivalent (SWE). The retrieval of SWE by Ku- and X-band radar measurements is based on the interaction of the backscattered radar signal with the snow volume. In order to achieve sufficient signal penetration, SWE can only be measured if the snowpack is dry. Sensitivity studies and backscatter theory show that the main parameters determining backscatter of dry snow over soil background are the mass of snow (SWE), the size of the snow grains, and the roughness and dielectric properties of the soil. In order to retrieve SWE from the backscatter measurements, it is necessary to separate the signal of the snow volume from the contribution of the background target, and to account for effects of grain size on scattering.

Various options for the retrieval of SWE from backscatter data of the proposed sensor configuration for CoReH2O were investigated and tested with experimental data, including empirical and semi-empirical approaches, the direct inversion of radiative transfer models, and statistical inversion of physical forward models. The direct inversion methods were found to be rather sensitive to noise in the backscatter measurements and in the model assumptions so that the solutions may not be unique. Empirical and semi-empirical techniques are usually quite robust, but comprehensive data sets under a wide range of target conditions are required to establish representative relations. Therefore the proposed baseline version of the SWE retrieval algorithm for CoReH2O applies a statistical inversion technique. In order to keep the number of free model parameters as small as feasible while maintaining a realistic representation of the physical interactions, a first order radiative transfer model is used to relate the backscatter data to the snowpack properties. Physical relations for the frequency dependence and polarization ratio of volume scattering, based on experimental data and theory, are applied to reduce the number of free parameters in the radiative transfer model. With this approach, the measurements are inverted iteratively in terms of SWE and the volume scattering albedo, ω, of the snowpack. The retrieval algorithm has been tested with Ku- and X-band backscatter data measured by ground-based SAR at test sites in the Austrian Alps, and with data sets of the Kuparuk River Study Site, Alaska, composed of airborne PolScat (Ku-band) data and X-band SAR data of the TerraSAR-X satellite. The investigations point out that the proposed sensor configuration and inversion algorithm are well able to meet the accuracy requirements of SWE mapping as specified for applications in climate research and hydrology.

[1] CoReH2O - Cold regions hydrology high-resolution observatory. Candidate Earth Explorer Core Mission. Report for Assessment. ESA SP1313/3. Nov. 2008.