Advances in PolSAR remote sensing of seasonal snow at C-band. Application in alpine environment by means of Radarsat-2 data

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\textbf{ABSTRACT}

Two PolSAR methods are presented to analyse the main characteristics of snow in alpine region: depth, wetness. At C-band, the potential of SAR data for wet snow mapping has been clearly demonstrated by literature for single or alternating polarization data. Contrariwise, at such frequency, dry snow is a too low attenuation medium and only slightly affects the amplitude of the backscattered signal versus snow-free conditions. Therefore, X-band is more attractive at single or dual mode (TerraSAR-X). However the full polarization configuration of Radarsat-2 (C-band) offers new algorithms capabilities, leaving out the soil scattering component. Here are developed the methodology and results obtained from a set of Radarsat-2 images registered from 2009 to 2015 time period over an instrumented region located in the French Alps (N 45° 05'/ E 6° 10'). During each Radarsat-2 data acquisition, intensive field measurements of the snow pack properties (snow stratigraphy) and weather conditions were gathered on 10 representative measurement sites. For each SAR image, a topographic processing was done by means of a fine DEM (5m, IGN-France) in order to correct the slope effects and determine the local incidence angles for each measurement point. Then, two PolSAR decompositions methods were conducted on the Radarsat-2 dataset: (i) the Cloude-Pottier algebraic one, able to define the nature of the scattering mechanism and relative importance of the backscattered signal; (ii) the Yamaguchi model which make possible to separate dry from wet snow versus snow-free areas and to retrieve the wetness content of the snow surface.

For dry snow conditions, three statistical multivariate methods are considered in order to retrieve the snow physical characteristics: principal component analysis (PCA) which maximizes the second-order moment (variance), independent component analysis (ICA) which maximizes the fourth-order moment (kurtosis), and the canonical correlation analysis (CCA) exploring the relationship of dependence between two sets of random variables. In our study, the set of snow variables are depth, density and snow water equivalent (SWE). The set of polarimetric descriptors are based on the Cloude-Pottier decomposition parameters: entropy (H), alpha angle (α), simple reflection (SERD) and multiple reflection (DERD). The calibration and the application steps to retrieve snow cover characteristics are based on 23 samples (acquisition angle from 38.3° to 40.7°) and 16 samples (acquisition angle from 33.4° to 35.1°) served as the training set to calibrate the models, one model applied for each acquisition angle group. Then, the performance of the model is evaluated using a cross-validation technique applied on the same input database. The CCA model shows the best performance in retrieving dry snow cover depth and SWE, compared to PCA and ICA models results. Moreover, the lower incidence angle group of images ranging from 33.4° to 35.1° offer better correlation with the simultaneous ground measurements, in regard of the dates registered under higher beam values (38.3° to 40.7°) due to topography effects.

For wet snow conditions, the Yamaguchi decomposition model offer the more satisfactory results in order to separate dry snow from wet snow mapping by means of the Volume and Helix decomposition components. Concerning the liquid water content (LWC) values measured at the snow surface (% vol), a consistent correlation is observed for 40 samples with the double bounce (DBL) parameter for low LWC (1 to 3%), and the surface parameter (ODD) for higher LWC values (3% and more).

All these results are promising as a monitoring tool for the the RADARSAT Constellation Mission (RCM) following the current RADARSAT-2 program: 3 satellites, compact polarimetry.