SNOW DENSITY ESTIMATION USING POLARIMETRIC ASAR DATA

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ABSTRACT

Remote sensing of Radar Polarimety has great potential to determine the extent and properties of snow cover. Availability of spaceborne sensor dual polarimetric C-band data of ENVISAT-ASAR can enhance the accuracy in measurement of snow physical parameters as compared to single fixed polarization data measurement. This study shows that the capability of C-band SAR data for estimating dry snow density over snow coverer rugged terrain in Himalayan region. The study area lies in Beas, Chandra and Bhaga catchments of Himachal state (India). For this investigation, the main assumptions are that the snow is dry and at C-band, total backscattering coefficient comes from snowpack and snow ground interface. An algorithm for estimating snow density has been developed based on snow volume scattering and snow-ground scattering components. Snow density estimation algorithm requires HH and VV polarization combination data. The radar backscattering coefficients of both HH and VV polarization and incidence angle are given as input to the developed algorithm. Finally, the algorithm gives the snow dielectric constant which can further be related to snow density using Looyenga's semi empirical formula. Comparison was done between algorithm estimated snow density and field value of snow density in the study region. The mean absolute error between estimated and measured snow density was 21.3 kg/m$_3$.

I. INTRODUTION

The measurement of snow parameters or snow pack characteristics is important for hydrological modeling and snow avalanche risk assessment, climatology, meteorology and hydropower industry. Backscatter coefficient image of radar is extremely useful for the quantitative estimation of snow pack characteristics. Satellite-borne synthetic aperture radars (SAR) are promising for determination of snow pack characteristics like wetness, snow water equivalent, grain size, snow density, snow dielectric constant [1-3]. Advanced synthetic aperture radar (ASAR) is one of the instruments onboard ENVISAT, launched on 1$_{st}$ March 2002 by European Space Agency (ESA). It is a C-band SAR which can operate in different modes, seven swaths (IS1-IS7) located over a range of incidence angles from 15^0 - 45^0 with HH or VV polarization and 35 day revisit. In this study, ENVISAT-ASAR data of 24 Dec., 2007 with HH and VV dual polarization with incidence angle range $31.0\,^o$– $36.3\,^o$ has been used. Data processing of ENVISAT-ASAR dual polarization is explained in detail by [4].

The study area comprising snow covered rugged terrain forming a part of Beas and Chandra Bhaga catchment lies in the kullu district of Himchal state. It is located between latitude 32^o 15' N to 32^o 45' N and longitude 77^0 E to 77^0 30'E. Snow and Avalanche Study Establishment (DRDO) under Ministry of Defence is maintaining four manual observatories at Bhang, Solang, Dhundi and Patsio. Bhang, Palchan, Solang, Kothi and Gulaba, are important villages in the area. Dhundi region is endowed with great natural beauty and have rich assemblage of fauna and flora. The area is characterized by subtropical pine forest, subalpine and alpine forest.

II. ALGORITHM DEVELOPMENT

Microwave interaction with snow depends on dielectric and geometric properties of the snow. Sensor properties also influence the target response to incident wave. In the case of snow covered terrain, different processes contribute to the total backscattered signal. 1) Scattering at the air-snow interface. 2) Scattering inside the snow layer due to ice particles and at density boundaries. 3) Scattering at the snow-ground interface. Total backscattering from the snow is sum of scattering from air-snow, volume scattering in the snow layer and scattering from the snow-ground attenuated by snow layer [5]. Due to large penetration (approximately 10m at 200 kg/m^3 snow density) at C-band, in dry snow layer and small contribution of air/snow interface scattering in total backscattering from dry snow, we can neglect the air/snow interface scattering contribution from the total backscattering coefficient [6]. Therefore total backscattering coefficient for dry snow is the sum of two main components i.e. snow volume backscattering and snow ground backscattering.

For developing an algorithm for snow density estimation, we used the first order volume scattering model and the integral equation method with an exponential correlation function for the surface backscattering contribution from the snow–ground interface. The incident angle at air-snow interface and the angle of refraction in the snow layer and snow-ground interface can be related by the Snell's law. Both models depend on the four unknown functions viz. dielectric constant, incident angle, volume scattering albedo and root mean square height and surface correlation length. In case of snow-ground, using best pair of polarization, the unknown can be reduced to only dielectric constant and incident angle. In the case of volume backscattering, using volume backscattering ratios, the unknown can be reduced to only dielectric constant and incident angle. In the final term combining both volume backscatter and snow-ground scattering only two functions viz. incident angle and dielectric constant remain. The algorithm gives the snow dielectric constant which can further be related to snow density using Looyenga's semi empirical formula [7].

III. RESULTS AND DISCUSSIONS

In this study we have developed integral equation method based algorithm which has been developed for retrieval of snow density from polarimetric data at C-band. An algorithm is also applied on radar backscattering coefficient for the estimation of snow permittivity and snow density in Himalayan region. An algorithm can not be solved algebraically, therefore we have developed a software in C-Language and it helps to construct a separate lookup table for the algorithm for each incidence angle. The lookup table is restricted to between 1 and 81 for the value of snow dielectric constant value. Average filter with window size 3×3 has been applied for smoothing the density image. ASAR estimated values for snow density have been validated by insitu measurements recorded concurrently with ENVISAT ASAR pass in the study region. The comparison of snow density between field measured and ASAR estimated at 7 snow pits has been done. The absolute error was observed to be 21.2 kg/m^3. It indicates that the algorithm works well for the seasonal fresh snow cover.

IV. CONCLUSIONS

An algorithm for estimating snow density for C-Band SAR in VV and HH polarization measurements has been developed by considering the scattering mechanism. The model does not require roughness properties. This investigation shows that this algorithm can be used for estimating dry snow density. The model can be applied to the seasonal snow cover when the snow is dry where the subsurface is soil or rock. The mean absolute error between measured and estimated snow density was found to be 21.2 kg/m3 where subsurface is soil without vegetation cover but it may not be useful where the subsurface is dominated by volume scattering e.g. in snow-covered firn area.

Furthermore, effect of vegetation cover on snow density mapping may be included for accurate mapping of snow cover in vegetated area. Best range of incidence angle will be found out for this model because this model is dependent on incidence angle.

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