# DENSE MEDIA RADIATIVE TRANSFER THEORY FOR ACTIVE REMOTE SENSING AND APPLICATIONS TO SWE RETRIEVAL

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## 1. ABSTRACT

Snow is an essential element in the global water cycle and important source of fresh water for many places in the world. The global mapping of snow water storage will advance our knowledge of the climate systems. Currently the global mapping of the snow water equivalence (SWE) and snow depth are based on the satellite microwave radiometers, such as SSM/I and AMSR-E [1]. The coarse resolution of satellite radiometers limited the applications of the retrieval algorithm for snow depth and SWE to the relatively homogeneous snow cover over large spatial areas. It is hard to retrieve the snow water storage over mountainous terrains with complex vegetation cover and highly variable terrain elevation and slopes. In order to image the snow cover at adequate spatial resolution, the dual frequency satellite mission Cold Regions Hydrology High-resolution Observatory, (CoReH2O), was proposed [2]. The two frequencies at X-band and Ku-band (9.6 and 17.2GHz), for both co-polarization and cross-polarization will be recorded simultaneously. A working algorithm has been proposed to CoReH2O which uses four channels (co-polarization and cross-polarization at X- and Ku- band).

To further the development of the active retrieval algorithm, it is essential for to have a single forward physical model with one set of snow parameters, which are consistently used for 4 channels. The dense media radiative transfer (DMRT) theory offers such solution. In the previous work, full multiple-scattering solutions has been solved for the DMRT equations by decomposing the diffused scattering intensities into Fourier series in the azimuthal direction. The simulation has been applied

to active remote sensing of dry snow at Ku-band (13.5GHz) [3], [4]. The phase matrix and extinction coefficient used in the DMRT equations can be calculated based on hard sphere snow model, either analytically by applying Quasi-crystalline approximation or numerically by solving the Maxwell's equations with Monte Carlo simulations. Recently, we proposed a new bi-continuous model [5]. Compared to the hard sphere model, the bi-continuous model also shows low frequency dependence and larger cross-polarization. The comparison with the models will be demonstrated in this paper. To investigate the relationship between the X-band and Ku-band backscattering coefficient, the DMRT model is applied to both frequencies for self consistency.

The semi-empirical scattering model is used in the retrieval algorithm [6] which states as

$$\sigma_i^{\text{model}} = \frac{\omega_i}{2}\cos\theta_i\left(1-t_i^2\right)+\sigma_i^G t_i^2$$

where

$$t_i = \exp\left(-\frac{2\left(\omega_i + k_{ai}^{'}\right)SWE}{\cos\theta}\right)$$

There are four measurements with i=1, 2, 3 and 4 that correspond to co-pol and cross-pol at X band and Ku band. The ground scattering terms $\sigma_i^G$ are determined from measurements at the beginning of snow season. For baseline retrieval algorithm, the objective function is defined

$$F(x) = \sum_{i=1}^{4} w_i \left|\sigma_i^{data} - \sigma_i^{\mathrm{mod}\,el}(x)\right|^2$$

The parameters in x include the $\omega_i$ of each channel and SWE. Based on the DMRT model, the polarization and frequency dependences are established among the 4 scattering albedos, $\omega_i$, with i=1,2,3,4, and allow us to reduce the number of free parameters for optimization of the objective function. Using the DMRT theory to reduce the number of free parameters enables the retrieval of SWE from X- and Ku-band dual-polarized radar measurements.

## 2. BIBLIOGRAPHY


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