A Study of Forward Models for Predicting Cross-Polarized Backscatter From Soil Surfaces

Shanka N. Wijesundara and Joel T. Johnson
The Ohio State University, Columbus, OH, USA

The study of cross-polarized backscatter normalized radar cross section (NRCS) predictions from rough surfaces is of increasing interest in a wide array of remote sensing applications. Physical models such as the second-order small-slope approximation (SSA-2) or the two-scale (composite) model (TSM) have typically been used in forward modeling studies. However, the computational complexity associated with SSA-2 limits its practical use, while TSM is challenged by is failure to include higher order scattering effects. This study examines the cross-pol backscatter NRCS from soil surfaces for soil moisture retrieval using SSA-2, a high-frequency (HF) approximation of the SSA-2, and a simplified second-order Taylor-expanded form of the TSM.

The reliable prediction of cross-polarized backscatter from rough surfaces has been shown by SSA-2. However, it requires the evaluation of a four-dimensional integral, which limits its practical implementation. In order to simplify the numerical complexity associated with SSA-2, a cross-polarized off-nadir HF approximation method was recently proposed by Guérin and Johnson. While no results were reported on land surfaces, the performance of the HF method was characterized using several simulations of ocean-like surfaces. The off-nadir HF method performed favorably for moderate incidence angles while drastically reducing the computational time. The final form of the off-nadir HF approximation also appears similar to a simplified form of a second-order Taylor expansion of the standard TSM. The NRCS predictions of the expression obtained by replacing the kernel of the HF expression with that of the simplified TSM expression have also been shown to improve cross-pol NRCS predictions over grazing incidence angles ($60^\circ \leq \theta_i \leq 80^\circ$) for ocean-like surfaces at L-band frequencies.

We investigate the applicability of the models described above to bare soil surfaces and their sensitivity to soil moisture. A bare soil surface is typically described as a stationary Gaussian random process with an exponential autocorrelation function (ACF). We use the isotropic band-limited exponential rough surface spectrum proposed by Darawankul and Johnson, which uses a Gaussian truncation function with a "short-scale" correlation length to limit high-frequency components of the exponential ACF. The widely accepted Peplinski model is then used to describe the soil permittivity and its dependence on soil moisture content. The model results will also be compared with documented soil surface measurements and related empirical models such as those outlined in Oh et, al. (1992).

The results of the study provide further physical insight into the dependence of soil surface cross polarized backscatter on radar and medium parameters, as well as the utility of cross polarized backscatter for soil moisture remote sensing. Practical implications of the results will also be discussed with regard to future attempts to remotely sense soil moisture using radar backscatter measurements.