Effects of Soil Moisture Profiles and Subsurface Random Media on Differential Interferometric SAR Response

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The impact of soil moisture variations on differential interferometric SAR (DInSAR) response has recently received some attention for its potential of improving the retrievals of soil moisture and surface deformation. The observed interferometric phase is mainly due to the change of dielectric properties and the heterogeneities in the soil. In order to predict interferometric phase and coherence, it is crucial to have an accurate scattering model that accounts for depth-dependent moisture profiles and random inclusions of small scatterers (air voids/rocks) inside the soil. In this paper, the 3D full-wave scattering model of heterogeneous soil using stabilized extended boundary condition method (SEBCM) and recursive T-matrix method will be presented, demonstrating its capability of simulating different subsurface features as separate scattering matrices (modules) for computational efficiency. In particular, the sensitivity of interferometric radar response to changes in soil moisture profiles and subsurface random media will be shown.

The 3D scattering model from random rough surfaces with dielectric profiles and discrete random scatterers is constructed based on the scattering matrix approach. Scattering matrix of a single rough surface is found using the SEBCM and the dielectric profiles are modeled as finely stratified media with homogeneous layers. Recursive T-matrix method and T-matrix to S-matrix transformation are used to simulate the scattering from discrete random scatterers. For L-band radar applications, the penetration depth of radar signal is typically around 5-10 cm so a single rough surface with constant/linear soil moisture profile is considered. Since the existence of small scattering bodies in the soil has a significant effect on the relation between interferometric observables and soil moisture variations, air voids and buried rocks are included in the model as small spheres with corresponding dielectric constants. For P-band applications, the penetration depth is larger, and therefore more sophisticated functional forms, such as polynomials, are required to characterize the moisture profiles. The effects of the average soil moisture level and the shape of the profiles on interferometric response are investigated in the sensitivity analysis. Finally, preliminary results of model validation with the L-band Pol-InSAR products from the JPL UAVSAR flown over Tonzi Ranch, California, USA will be presented.

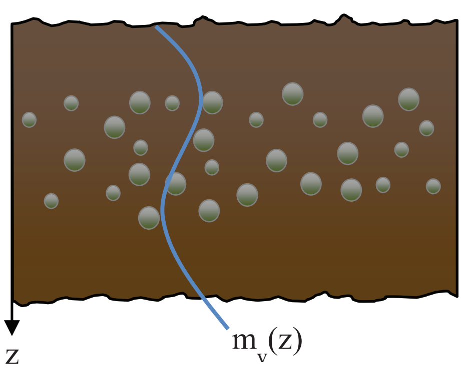

Figure 1. Rough soil surface with moisture profile and random scatterers.

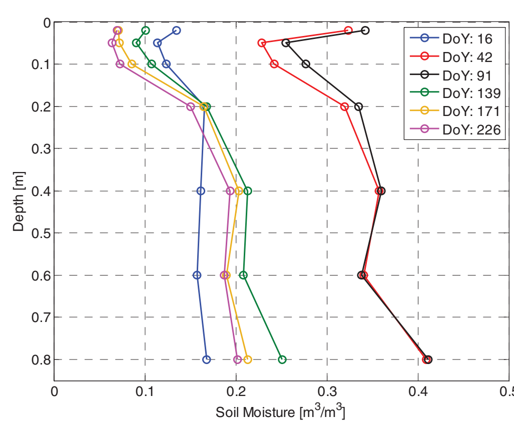

Figure 2. In-situ soil moisture profiles in Tonzi Ranch on the dates of UAVSAR flights in 2014.