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Multiscale Modelization of Multilayered Bi-Dimensional Soils

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Abstract : Soil moisture content is a key variable in many environmental sciences. Even though it represents a small proportion of the liquid freshwater on Earth, it modulates interactions between the land surface and the atmosphere, thereby influencing climate and weather. Accurate modeling of the above processes depends on the ability to provide a proper spatial characterization of soil moisture. The measurement of soil moisture content allows assessment of soil water resources in the field of hydrology and agronomy. The second parameter in interaction with the radar signal is the geometric structure of the soil. Most traditional electromagnetic models consider natural surfaces as single scale zero mean stationary Gaussian random processes. Roughness behavior is characterized by statistical parameters like the Root Mean Square (RMS) height and the correlation length. Then, the main problem is that the agreement between experimental measurements and theoretical values is usually poor due to the large variability of the correlation function, and as a consequence, backscattering models have often failed to predict correctly backscattering. In this study, surfaces are considered as band-limited fractal random processes corresponding to a superposition of a finite number of one-dimensional Gaussian process each one having a spatial scale. Multiscale roughness is characterized by two parameters, the first one is proportional to the RMS height, and the other one is related to the fractal dimension. Soil moisture is related to the complex dielectric constant. This multiscale description has been adapted to two-dimensional profiles using the bi-dimensional wavelet transform and the Mallat algorithm to describe more correctly natural surfaces. We characterize the soil surfaces and sub-surfaces by a three layers geo-electrical model. The upper layer is described by its dielectric constant, thickness, a multiscale bi-dimensional surface roughness model by using the wavelet transform and the Mallat algorithm, and volume scattering parameters. The lower layer is divided into three fictive layers separated by an assumed plane interface. These three layers were modeled by an effective medium characterized by an apparent effective dielectric constant taking into account the presence of air pockets in the soil. We have adopted the 2D multiscale three layers small perturbations model including, firstly air pockets in the soil sub-structure, and then a vegetable canopy in the soil surface structure, that is to simulate the radar backscattering. A sensitivity analysis of backscattering coefficient dependence on multiscale roughness and new soil moisture has been performed. Later, we proposed to change the dielectric constant of the multilayer medium because it takes into account the different moisture values of each layer in the soil. A sensitivity analysis of the backscattering coefficient, including the air pockets in the volume structure with respect to the multiscale roughness parameters and the apparent dielectric constant, was carried out. Finally, we proposed to study the behavior of the backscattering coefficient of the radar on a soil having a vegetable layer in its surface structure.

Keywords : multiscale, bidimensional, wavelets, backscattering, multilayer, SPM, air pockets
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