Modeling the effect of Surface Roughness on the Bistatic Scattering Coefficient and Emissivity of a Soil-Litter medium using a Numerical Model

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IMS (Bordeaux 1 University) and INRA-EPHYSE laboratories are currently taking part in the study and validation of the L-MEB inversion algorithm used for the SMOS (Soil Moisture and Ocean Salinity) mission. This mission will carry a 1.4 GHz (L-Band) interferometer which will measure the brightness temperature at both H and V polarization. The LMEB inversion algorithm will then be used to retrieve land soil moisture with a target accuracy of 4%. This algorithm must take into account the many parameters which could affect the measurements made by the radiometer. In particular, over forests there are several layers above the soil surface which could both change the ground emission to be measured and add an emission of their own. These include the canopy layer and the litter layer. In addition both the soil and the litter surfaces may have a roughness which could affect the measured ground emission. Both the canopy and soil layers have been studied in some depth however less is known about the litter layer. Some attempts have been made recently to characterize the effects of this layer [1,2,3].

In the context of this research we propose a new numerical model, based on the finite element method (FEM), that is able to calculate the emissivity of a 3D multi-layered geological system. This model enables us to integrate many parameters and in particular to study the emission of the soil-litter system, including the effects of a surface roughness in both layers. The aim is to use this model to create a database of the simulated emissivity of the soil-litter system which we will then be able to use to validate and develop the L-MEB algorithm over forests.

In this model, a plane wave incident upon the system surface is simulated and Maxwell's equations are solved in order to obtain the reflected electromagnetic field in the far field region, using the finite element method. This allows us to calculate the bistatic scattering coefficient as a function of the reflected field, at all angles. The emissivity of the system is then calculated from one minus its reflectivity, which is obtained by the integration of the bistatic scattering coefficient over half space.

We have compared results from this model with other methods to validate it for a one-layer system with a known surface roughness: validating the model firstly for the bistatic scattering and backscatter coefficients and secondly for the emissivity. Surface roughness is typically calculated using root mean square height (σ), autocorrelation length (L_c), and the shape of the autocorrelation function.

Firstly, for the backscattering and bistatic scattering coefficients**,** validation was carried out against 2-D moment methods, by comparing with results presented in the literature [4]. For each value of [kσ, kL] the calculations were repeated over 20-50 different surfaces. This was done in order to counteract approximations arising from the small width of each surface (1.27m x 1.27m) compared to the large surface of the SMOS pixel. The bistatic scattering coefficient was calculated for the case of an incident plane wave of 1.4 GHz frequency with incidence angles ranging between 0° and 50°. The average bistatic scattering coefficient of all the surfaces was calculated, from which the backscattering coefficient could also be found.

The results obtained were compared with those found by the 2-D moment method for the same roughness conditions. It must be noted that a difference in the results is expected since the numerical model is 3-dimensional whereas the moment method used for comparison is 2-dimensional. However there is a good general agreement, which is encouraging at this stage.

Secondly for the validation of emissivity, simulations were carried out for a large range of σ and L_c values. These values were taken from measurements of natural rough surfaces over which microwave radiometric measurements were acquired during the SMOSREX experiment [5]. Results were also obtained for the same roughness conditions using the AIEM model [6]. Comparisons were then made between the emissivity values obtained from the numerical model, the AIEM model and the SMOSREX experimental data.

As with the bistatic case, these results show a good agreement which further validates our model. The next step will be to integrate the litter layer into the model and thus investigate the soil-litter system including a surface roughness for both layers.

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