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Accounting for roughness effects in L-MEB: Suggested Modifications to the H-Q semi-empirical model

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The Soil Moisture and Ocean Salinity (SMOS) mission [1] was successfully launched in November 2009 and is the first mission dedicated to providing global surface soil moisture fields at a high temporal resolution of three days. The satellite carries a 1.4 GHz (L-band) interferometric radiometer which measures the brightness temperature at angles from 0° to $50-55°$ and at polarizations X and Y, which are in the antenna frame. From these measurements we can derive brightness temperatures at H and V polarization, for all measured angles. A forward inversion algorithm, using the so-called L-band Microwave Emission of the Biosphere (L-MEB) model [2], is used to retrieve land soil moisture from brightness temperature measurements with a target accuracy of 0.04 m^3/m^3.

The L-band emissivity of bare soil is dependent on soil moisture, but is also significantly affected by surface roughness. Surface roughness effects are accounted for in L-MEB by a semi-empirical model known as the $H-Q$ model. This model was chosen for use in the SMOS forward algorithm due to its simplicity and ease of computation: other modeling approaches such as the Integral Equation Model (IEM), the Method of Moments (MoM), the Finite Element Method or the Finite Time Domain Method, are more exact but too computationally costly to be included in the SMOS retrieval algorithm. In the $H-Q$ model the emissivity is calculated from the Fresnel equations, modified by an exponential factor. The model includes the parameters H_R, Q_R and N_{Rp}, for polarization p, which account for surface roughness effects, and must be calibrated using measurements.

In this paper we present a study which aimed to evaluate potential relationships between the parameters H_R, Q_R, and N_{Rp} and physical roughness parameters (standard deviation of surface heights σ and autocorrelation length L_c), using a numerical modeling approach. The motivation for this study was that there have been very few such modeling studies and none performed on the most recent version of the $H-Q$ model, where N_R is replaced by N_{RH} and N_{RV}. Also, a relationship

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between H_R and σ was recently found by an experimental study [3] and it is of interest to test this relationship. The modeling approach used in this paper was presented in [4]. It comprises the use of Ansoft's High Frequency Structure Simulator (HFSS) software which solves Maxwell's equations using the numerical Finite Element Method (FEM). In this paper it is referred to as the FEM modeling approach. In [4] it was compared to the Method of Moments (MoM), which is considered the most accurate modeling approach for rough surface scattering and emissivity, and found to agree to within approximately $3K$ with the MoM.

In the first part of this study a synthetic dataset of the rough soil emissivity was generated by the FEM modeling approach for different values of σ and L_c, different angles, both H and V polarisation and different soil moisture values. Values were then retrieved for the $H-Q$ model parameters from these emissivities, allowing a comparison of retrieved values with σ, L_c, and soil moisture, and an investigation into whether relationships may be obtained between them. The retrieved values of H_R were found to be linearly correlated to σ^2/L_c ($R^2 = 0.989$), as shown in Fig. 1. A slight dependence on soil moisture content was observed but it could be considered to be negligible. Retrieved values of Q_R and N_{Rp} were found to be related to H_R, with $R^2 > 0.6$, as shown in Fig. 2.

The relationships found led us to propose a new retrieval scheme. In this retrieval, H_R may be either calculated from the physical parameter Zs, where $Zs = \sigma^2/L_c$, calibrated experimentally or retrieved simultaneously to soil moisture, and Q_R and N_{Rp} are replaced by functions of H_R. Therefore four calibrated variables (H_R, Q_R, N_{RH} and N_{RV}) have been replaced with one physical one ($Zs = \sigma^2/L_c$). In the second part of this study, the new proposed roughness retrieval model was evaluated against three different data sets in soil moisture retrieval studies: the PORTOS 93 dataset [3], the SMOSREX 2006 dataset [5] and a new dataset from an experimental study carried out on the Valencia Anchor Station (VAS) site, near Valencia, Spain in 2012 (see [6] for details of the site). Both the PORTOS '93 and SMOSREX datasets include multi-angular, multi-polar brightness temperatures measurements which were taken over a rough bare soil for a variety of roughness and soil moisture conditions. The VAS 2012 dataset included brightness temperatures measured over a mediteranean vineyard during several months in 2012. Roughness measurements were taken at regular intervals on the site and additional measurements were taken after plowing. The new retrieval model, used on these datasets, provided very interesting results even though only one variable was used to calibrate the roughness effects ($Zs = \sigma^2/L_c$), instead of the four classical parameters of L-MEB (H_r, Q_r, N_{RV}, N_{RH}).

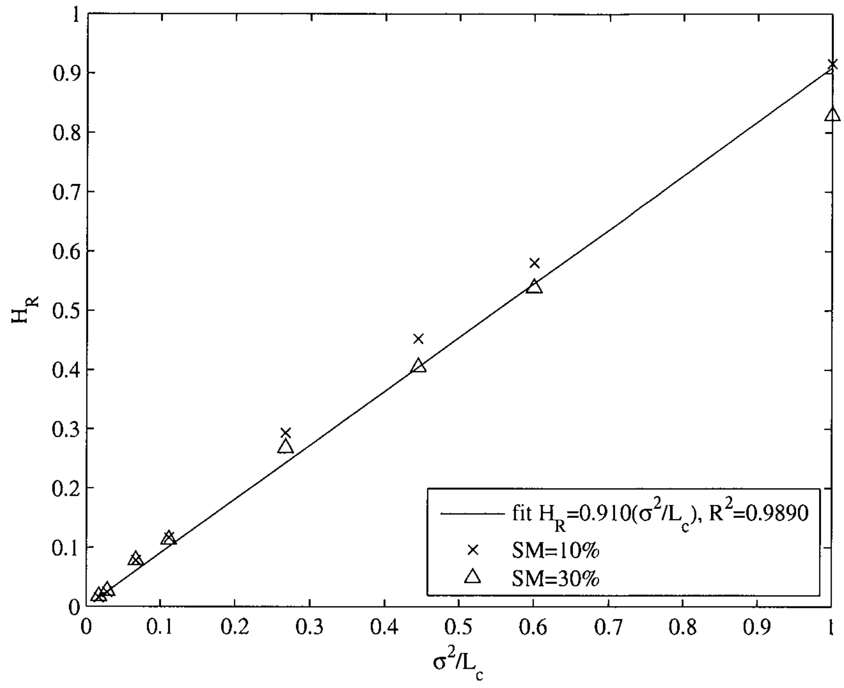

Fig. 1. retrieved values of H_R as a function of σ^2/L_c. Crosses represent values for a soil moisture of 10% and triangles represent values retrieved for a soil moisture of 30%.

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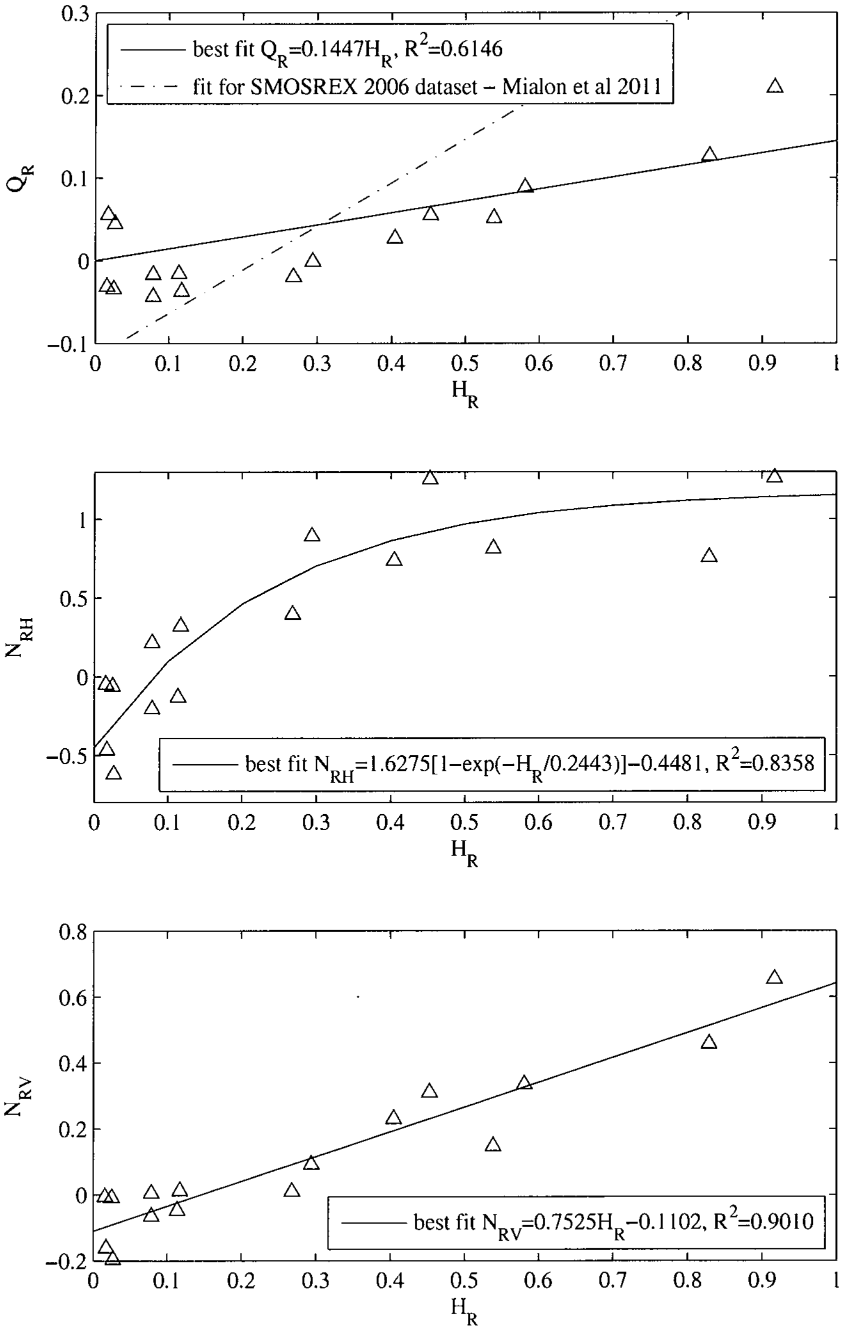

Fig. 2. Retrieved values of H_R, Q_R, N_{RH}, and N_{RV} as a function of retrieved H_R