INTERCOMPARISON OF SURFACE ROUGHNESS PARAMETERIZATIONS FOR SOIL MOISTURE RETRIEVAL

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1. INTRODUCTION

Soil moisture plays a key role in many hydrological and agricultural processes because it controls the water and heat energy exchange between the earth and the atmosphere. Addressing the need for routine global surface soil moisture maps, the European Space Agency (ESA) launched the Soil Moisture and Ocean Salinity (SMOS) mission in 2009. It provides L-band microwave brightness temperature observations in dual polarization with multi-incidence angles [1]. Scheduled for launch in 2014, the National Aeronautics and Space Administration (NASA) is developing the Soil Moisture Active Passive (SMAP) mission which will deploy a combined radar and radiometer instrument to improve soil moisture retrieval capabilities and spatial resolution [2]. Both the SMOS and the SMAP missions use the *tau-omega* model as the key algorithm for passive microwave soil moisture retrieval. This model has been used in numerous L-band studies for soil moisture retrieval at different scales throughout Europe, America and Australia (eg. [3, 4]). However, the surface roughness parameterization of this model remains an unresolved issue and is often considered a tuning variable. Consequently, this paper tests the current roughness parameterizations with independent field data.

2. ROUGHNESS PARAMETERIZATIONS

In the *tau-omega* model, the calculation of soil emission from a rough bare surface is based on a semi-empirical equation proposed by [5]. Accordingly, the emissivity of a rough surface is computed as a function of the emissivity of a smooth surface and three other parameters that account for the roughness: polarization mixing factor (Q_R), roughness parameter (H_R) and the exponent (N_R). Based on this equation, the classic Choudhury *et al*. (1979) [6] parameterization for H_R has typically been used:

$$H_R = (2k\, S_D)^2 \,, \qquad \text{Eq. 1}$$

where $k = 2\pi/\lambda$ (λ is the wave length) and S_D is the standard deviation for surface roughness. Recently, Wigneron *et al*. (2011) [7] developed an alternate H_R parameterization based on data collected by the PORTOS radiometer at the INRA Avignon Remote Sensing test site:

$$H_R = (0.9437\, S_D/(0.8865\, S_D + 2.2913))^6 \,. \qquad \text{Eq. 2}$$

It was demonstrated that the classical parameterization largely overestimated H_R for S_D greater than 10 mm. While these relationships are independent of moisture content, [8] found that for clay soils H_R is higher in intermediate wetness conditions (~0.25 m^3/m^3) and lower in both dry and wet conditions. However, on sandy soils a monotonic decrease from dry to wet conditions was found. This study examines the above parameterizations using data acquired from the third Soil Moisture Active Passive Experiment (SMAPEx-3).

3. DATA AND METHODOLOGY

The third Soil Moisture Active Passive Experiment (SMAPEx-3) airborne campaign was undertaken in the Yanco study area in south-eastern Australia in September, 2011 [9]. It was part of the SMAPEx campaigns which were designed specifically to support the development of soil moisture retrieval algorithms for the SMAP mission. SMAPEx-3 included a 3-week intensive monitoring period when data was collected from airborne radar and radiometer instruments concurrently with ground sampling of soil moisture, vegetation information, and surface roughness. Brightness temperature (T_B) data were acquired at 1 km resolution over a 40 km × 40 km regional area, while ground soil moisture sampling was undertaken on a regular grid of 250 m in six intensive monitoring areas of approximately 3 km × 3 km in size. Surface roughness was sampled at three locations within each major land cover type at each of the six focus areas.

In this study, three 1 km pixels with relatively homogeneous bare surface (> 90% of the pixel is either bare soil or fallow) were selected from two of the SMAPE-3 focus areas, YA4 and YA7 [Fig. 1(a)]. These pixels

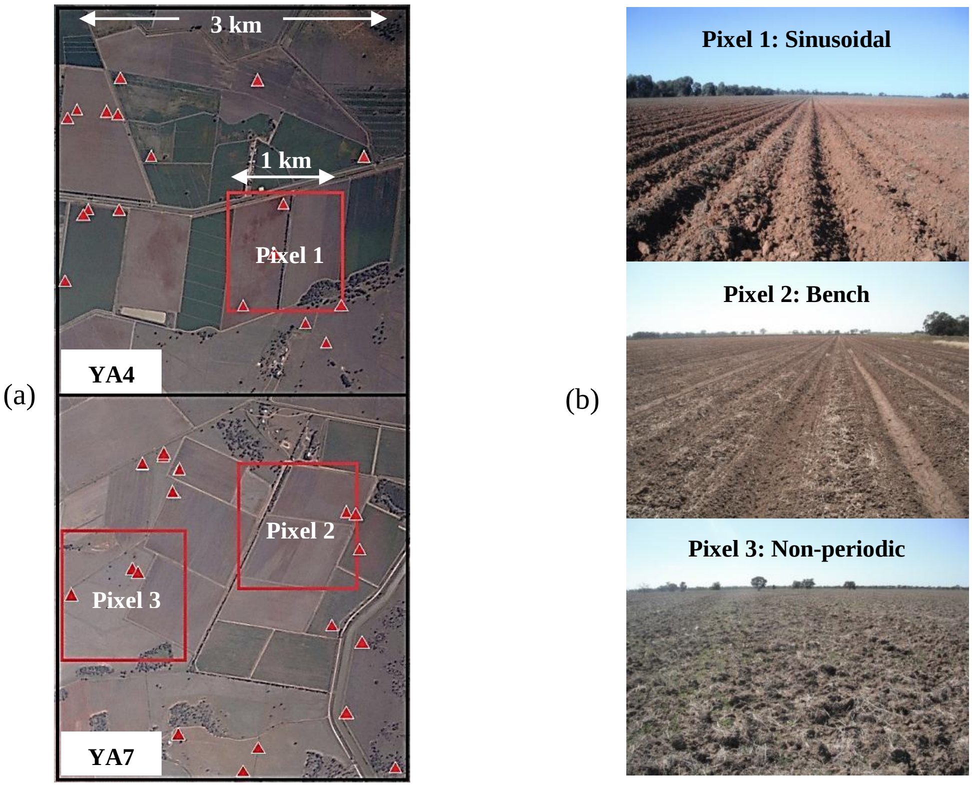

Fig. 1. (a) Focus area YA4 and YA7 (black box) and location of the three bare pixels (red box); red triangular symbols indicate roughness sampling locations. (b) Dominant surface pattern of the three bare pixels.

also represent three types of roughness: sinusoidal, bench and non-periodic structure [Fig. 1(b)]. The soil was classified as silty clay loam according to the soil texture analysis. With the observed soil moisture and 1 km resolution T_B data at both horizontal and vertical polarizations, H_R for each pixel was retrieved from the L-MEB implementation of the tau-omega model. The measured S_D for each pixel was averaged from all available roughness samples in that pixel and then compared with its corresponding H_R. It should be noted that S_D at each sample location was averaged from two 3-m-long profiles, made in the across-row and along-row directions for periodic surfaces, and in the north-south and east-west directions for non-periodic surfaces. Only the one-scale roughness data was used in this study (i.e. low-frequency roughness contributed by periodic structures was not removed). The observed soil moisture from ground sampling data were averaged for each pixel and also compared with H_R.

4. RESULTS

A comparison between the retrieved H_R values and the different parameterizations is shown in Fig. 2. It was found that for these three bare pixels (S_D >10 mm), Choudhury's equation [6] overestimated the roughness parameter H_R, thus confirming the results by [7]. Moreover, the observations match very well with the new formulation proposed in [7], especially for S_D greater than 40 mm. Furthermore, the "bench" pixel with intermediate wetness (the orange square in Fig. 2) has the highest H_R, decreasing for both the drier and wetter condition, thus confirming the results from [8]. However, this dependency on soil moisture is not seen in the other two pixels, possibly due to the small sample size and range of soil moisture value observed.

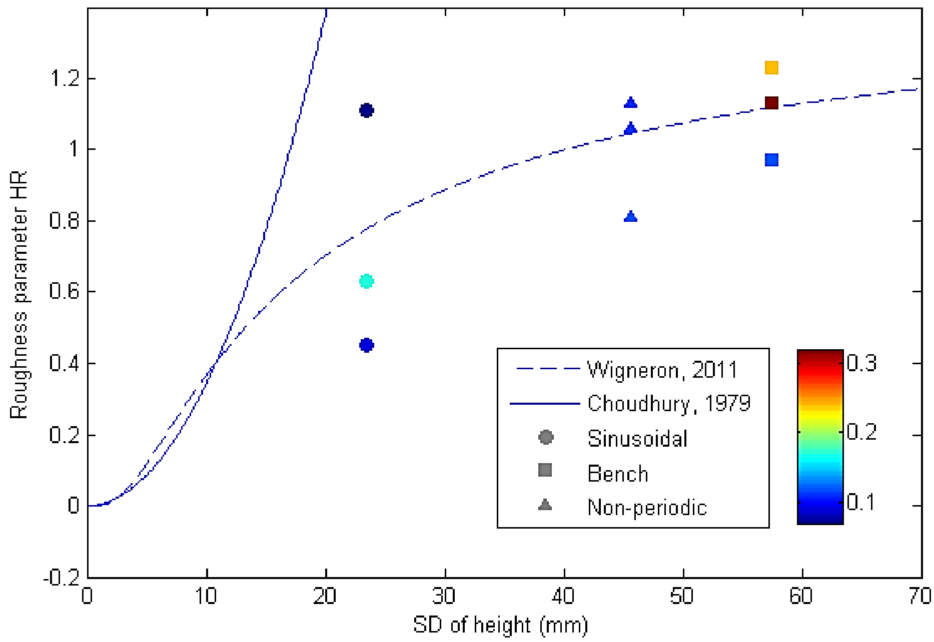

Fig. 2. Scatterplot of retrieved H_R against measured SD of surface height with periodic patterns retained. Also shown are the predicted H_R values using the formulations of Choudhury *et al.* (1979) and Wigneron *et al.* (2011); the colour bar indicates soil moisture values in m^3/m^3.

5. CONCLUSIONS

Optimal parameterization of surface roughness is a very important issue for soil moisture retrieval and its effect on observations at L-band frequency has been difficult to quantify. It is suggested by this study that the H_R parameterization by [7] most accurately estimates this roughness parameter, especially for surfaces with large S_D. However, the dependency of H_R on soil moisture content still remains to be confirmed.

6. ACKNOWLEDGMENTS

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