Feasibility On The Use Of JERS-1/SAR Data For Soil Moisture Prediction Models

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ABSTRACT

This study presents an evaluation on the use of SAR/JERS-1 data for soil moisture prediction models, comparing values obtained using these data with those obtained during field campaign. We used the models presented by [1] and [2], which relate the backscatter coefficient with soil parameters, such as roughness and moisture. It was impossible to directly invert the model from Oh et al when including the complex number function. The model from Dubois et al. was inverted, but it became necessary to insert estimated values of roughness (RMS height) to permit its use with mono-polarized images. The results can be considered as adequate.

INTRODUCTION

Historically one of the natural resources that most influenced life on Earth is water. For agricultural activities, availability of water in the soil is of vital importance for the production of food. Furthermore soil moisture is a determinant factor of the quality and quantity of agricultural production [3]. Being so, the efficient and large scale monitoring of soil moisture is of great importance for crop forecast. In this frame, microwave remote sensing techniques have been a tool of growing importance in the last years (as in [4]; [5] and [6]). These techniques are based on the important thermal and dielectric changes that occur in dry soil when adding water.

MODELING OF BACKSCATTER COEFFICIENT (σ^o)

To model the backscatter coefficient based on target parameters, two approaches have been used: a theoretical and an empirical one. According to [1], the theoretical approach (such as the Small Perturbation Model and Physical Optics and Geometric Models) can be helpful to explain different phenomena, but it is difficult to implement in computers and its validity range is quite restricted.

When one uses an empirical approach, σ^o can be modeled as a function of previously defined parameters that are easily obtained and controllable.

In [2] we found semi-empirical expressions, modeling σ^o as a function of incidence angle (θ), wavelength (λ), complex soil permittivity (ε^*) and rms height.

The equations presented are:

$$\sigma^o_{vv} = \frac{g \cos^3 \theta_i}{p^{1/2}} [\Gamma_v(\theta) + \Gamma_h(\theta)] \quad (1)$$

$$\sigma^o_{hh} = p \sigma^o_{vv} \quad (2)$$

$$\sigma^o_{hv} = q \sigma^o_{vv} \quad (3)$$

$$p = \left[1 - \left(\frac{2\theta}{\pi} \right)^{[0.314/\Gamma o]} \cdot \exp(-\kappa s) \right]^2 \quad (4)$$

$$q = 0.25(\Gamma_o)^{1/2}\left(0.1 + \sin^{0.9}\theta\right) \cdot \left[1 - \exp\left[-\left(1.4 - 1.6\Gamma_o\right)\kappa s\right]\right] \quad (5)$$

$$g = 0.7\left[1 - \exp\left(-0.65(\kappa s)^{1.8}\right)\right] \quad (6)$$

where **k** is the wavenumber, **Γ** is the Fresnel reflection coefficient and **s** is the rms height.

At this model there is a good correlation between calculated and effectively measured values, but on the other side it cannot be easily inverted, in order to obtain **ε*** and **s** based on measurements of **σ°**. This inversion can be obtained when using the graphs **pXq** and **pXσ**$_{vv}$ presented by [7].

In [1] we found an algorithm for the calculus of **σ** which allows a direct algebraic inversion. The equations are:

$$\sigma^o_{hh} = 10^{-2,75} \frac{\cos^{1,5}\theta}{\sin^5\theta} 10^{0,028\varepsilon \tan\theta} (ks \sin\theta)^{1,4} \lambda^{0,7} \quad (7)$$

$$\sigma^o_{vv} = 10^{-2,35} \frac{\cos^3\theta}{\sin^3\theta} 10^{0,046\varepsilon \tan\theta} (ks \sin\theta)^{1,1} \lambda^{0,7} \quad (8)$$

Both models need polarimetric data to estimate the soil moisture. Unfortunately these datasets are not available world wide, and the launch of a polarimetric orbital SAR is not yet foreseen. Furthermore, the absolute image calibration influences strongly the precision of these calculi.

TESTING MODELS WITH MONO-POLARIZED DATA

An experiment was made with JERS-1 SAR data to evaluate the possibilities of use of these models with mono-polarized data. The test-site for this experiment is located in the municipality of Guaíra, São Paulo State, a region of extensive agricultural activities, with irrigation. Two areas were selected: one section with bare soils and another with maize, 20 days after germination.

This study was performed in 2 phases:

1st - During fieldwork, concomitantly with JERS-1 SAR imaging of this region, data of roughness, soil moisture and soil constituents were obtained. These data were used as input parameters for the models of Hallikainen et al. [8], Oh et al. [2] and Dubois et al. [1] for the calculus of ε^* and $\sigma°$. Based on the JERS-1 scene obtained, the extraction of the digital value of pixels from the selected area was done afterwards and converted to $\sigma°$, taking into account the relations described in [9] and [10]. These results were compared with those obtained, using empirical models. The model from Dubois et al. presented a higher correlation with calibrated image data, than that one from Oh et al. (Fig. 1)

2nd. The parameters calculated from the image were used to estimate the values of permittivity and volumetric moisture (U_v), inverting both models of Dubois et al. and Hallikainen et al.

Since JERS-1 SAR images are mono-polarized HH it was necessary to insert estimated values of rms height (those colected in fieldwork), in order to perform the inversion of the model from Dubois et al. (results are showed in Fig. 2).

In Fig. 2, one can observe a large concentration of points close to the optimum regression line, showing that this technique is feasible. Nevertheless, some discrepant points indicate that it must be further tested to allow an accurate analysis of those parameters that influence its precision.

A first effort was made to evaluate the influence of the precision of the estimated roughness values, which were inserted during the calculus. Initially those values were calculated that guarantee a 100% precision and afterwards errors were introduced in these values, comparing the results obtained with the modified and original values. For the test-site with bare soils, errors above 5 mm rms presented unrealistic results, from both the physical and mathematical point of view (Fig. 3). For the area covered with 20 days old maize, the results obtained showed errors above 8 mm.

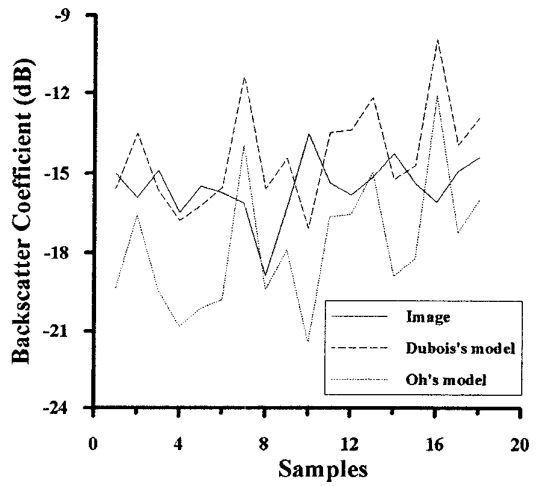

Fig. 1 - Comparison of $\sigma°$ obtained from JERS-1 SAR image and models

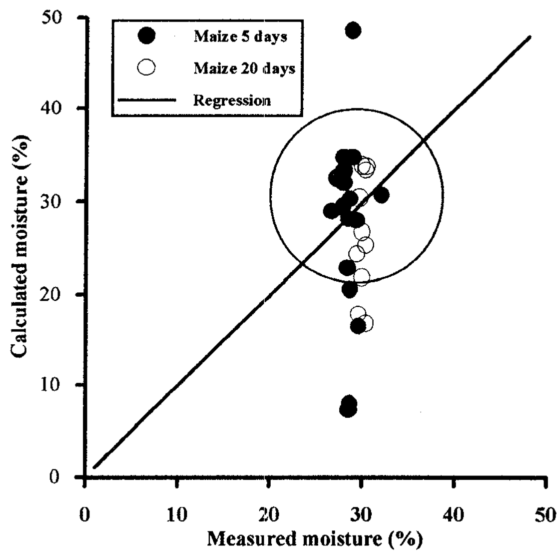

Fig. 2 - Comparison between measured and calculated moisture at 2 maize fields.

CONCLUSIONS

The technique proposed to use mono-polarized SAR images to estimate soil moisture is workable, but it needs the insertion of an additional parameter (rms height in the case of this study), since all predictive models are based on the use of multi-polarized images. Further studies must be performed to quantify the influence of errors within the values inserted, to evaluate the final precision of this technique.

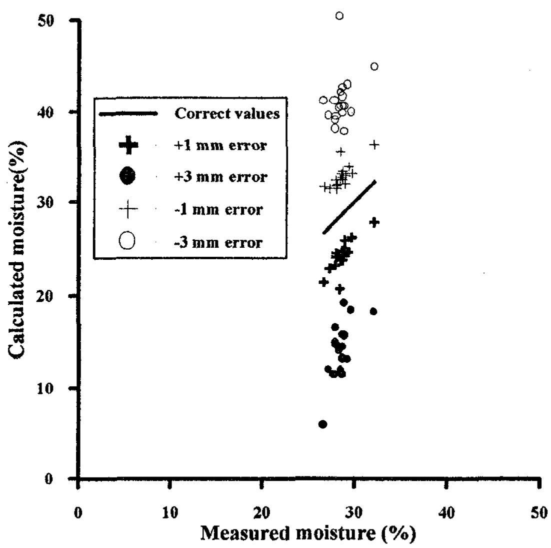

Fig. 3 – Influence of the rms estimated values precision

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