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The effect of roughness in simultaneously retrieval of land surface parameters

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Using remotely-sensed data, various soil moisture estimation models have been developed for bare soil areas. Previous studies have shown that the brightness temperature (BT) measured by passive microwave sensors were affected by characteristics of the land surface parameters including soil moisture, vegetation cover and soil roughness. Therefore knowledge of vegetation cover and soil roughness is important for obtaining frequent and global estimations of land surface parameters especially soil moisture.

In this study, a model called Simultaneous Land Parameters Retrieval Model (SLPRM) that is an iterative least-squares minimization method is proposed. The algorithm estimates surface soil moisture, land surface temperature and canopy temperature simultaneously in vegetated areas using AMSR-E (Advance Microwave Scanning Radiometer-EOS) brightness temperature data. The simultaneous estimations of the three parameters are based on a multi-parameter inversion algorithm which includes model construction, calibration and validation using observations carried out for the SMEX03 (Soil Moisture Experiment, 2003) region in the South and North of Oklahoma.

Roughness parameter has also been included in the algorithm to increase the soil parameters retrieval accuracy. Unlike other methods, the SLPRM method works efficiently in all land covers types.

The study focuses on soil parameters estimation by comparing three different scenarios with the inclusion of roughness data and selects the most appropriate one. The difference between the resulted accuracies of scenarios is due to the roughness calculation approach.

The analysis on the retrieval model shows a meaningful and acceptable accuracy on soil moisture estimation according to the three scenarios.

The SLPRM method has shown better performance when the SAR (Synthetic Aperture RADAR) data are used for roughness calculation.

1. Introduction

Surface soil moisture has direct influence on the exchange of heat and moisture between the land surface and the atmosphere. It is therefore a key parameter in the fields of global circulation process, weather prediction, climate monitoring, flood forecasting (Owe et al., 2001; Doubkova et al., 2012; Seneviratneet al. 2006; Schar et al., 1999) agricultural activities and drought monitoring. Due to the intense variability of precipitation and heterogeneity of the land surface (e.g., vegetation, soil physical properties, topography, etc.) which result in high temporal and spatial variation of soil moisture, relying only on in situ measurements would not be sufficient to monitor soil moisture in large areas. Therefore, studies on soil moisture monitoring through remote sensing in wide areas have made great progress. The studies are mainly according to the soil physical properties and radiative transfer theory (Srivastava et al., 2009; Saradjian and Hosseini, 2011; Gao et al., 2011; Owe et al., 2001 and Doubkova et al., 2012).

Linear empirical models were used for soil moisture estimation in vegetated areas using visible and NIR (Near Infra-Red) bands in most of early studies (Ahmed, 1995; Choudhury et al., 1987 and Gao et al., 2011). These approaches did not account for some of the properties that normally affect the microwave emission processes. They were not based on physical approaches. Other problem with such approaches was the lack of sufficient spatially representative ground data (Owe et al., 1992).

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Radiative transfer mechanisms which are based on physical-theoretical models to simulate the relationship between the microwave observation signature and land surface parameters do not serve as basis of the direct inversion models for land surface parameter because of their inverse problem and significant computing efforts (Owe et al., 2001).

Subsequent studies have used more physical-based models. Some researchers used both dual polarization and multi frequency based approaches to retrieve land surface parameters (e.g. soil moisture, vegetation biomass, and land surface temperature) (Wigneron et al., 1995). In order to perform regional calibrations, some of these methods relied heavily on the knowledge of certain surface properties (e.g. bulk density, roughness, soil texture, etc.).

It is evident that there are a large number of factors such as soil moisture, soil temperature, vegetation characters and surface roughness along with soil texture affecting the emission process and brightness temperature of the surface as observed from space. They are typically required to model radiative transfer in all regions except for regions of water and snow cover (Njokuand chan 2006; Colliander et al., 2012; Tsang and Newton, 1982; Pampaloni and Paloscia, 1986). On the other hand, each remote sensing sensor is distinctly sensitive to different land surface parameters and because radiometer is likely to be more sensitive to the near surface soil moisture, microwave remote sensing provides a unique capability for direct observation of soil moisture and land surface temperature (Njoku and Entekhabi, 1996).

Therefore, in order to obtain a higher accuracy soil moisture measurement by means of remote sensing technology, retrieving multiple land surface parameters using passive microwave remote sensing observations has become a research focus.

Among these efforts, some operational algorithms have been developed by NASA and JAXA (Japan Aerospace Exploration Agency) and other research groups (Koike et al., 2004; Njoku et al., 2003; Owe et al., 2008; Paloscia et al., 2006; Pellarin et al., 2008) to retrieve soil parameters especially soil moisture from measured brightness temperature by AMSR-E (Advance Microwave Scanning Radiometer-EOS). The AMSR-E soil moisture retrievals are expected to be accurate due to the relatively low microwave frequency and high temporal and spatial resolution of the sensor.

The most widely used AMSR-E based approaches for soil parameters retrieval are the Polarization Ratio Index (PRI), standard algorithm proposed by NASA (AMSR-E-NASA) (Njoku et al., 2003), and the Land Parameter Retrieval Model (AMSR-E-LPRM), developed at the “VrijeUniversiteit Amsterdam” (VUA) in collaboration with NASA (Owe et al., 2001, 2008; Pellarin et al., 2008; Wigneron et al., 2003; Brocca et al., 2011). Although, the characteristics of microwave remote sensing have long been recognized and various methodologies have been described to obtain surface soil characteristics (Wigneron et al., 1995; Owe et al., 2001; and Njoku and Li, 1999) but such algorithms do not usually consider the roughness effect and vegetation effect has not been modeled properly. They also do not provide reasonable accuracies in all vegetation cover. The shortcomings may be related to the fact that such models use separate bands to estimate different soil parameters.

There are rare models (e.g. Wigneron et al., 2007) in which both roughness and vegetation effects have been considered. In such models, soil and canopy temperature have been considered equal or have been developed for vegetation areas solely. Therefore, importance of accurate simultaneous estimations of soil parameters in all vegetation covers with roughness consideration seems reasonable.

In this study, we have proposed a model called SLPRM (Simultaneous Land Parameters Retrieval Model)to estimate surface soil moisture (SM), land surface temperature (LST) and canopy temperature (CT) simultaneously.

This model exploits iterative least-squares minimization algorithm to estimate the parameters using the horizontal and vertical polarization bands of six lower frequency channels (*i.e.* 6.9 GHz, 10.7 GHz, 18.7 GHz) in H and V polarizations of AMSR-E.

In order to obtain higher accuracies, our proposed SLPRM algorithm takes surface roughness parameter into consideration. The model is also applicable for vegetated areas because we have considered MPDI for the first time to estimate vegetation transmissivity coefficient and vegetation effect through its modeling. Furthermore, SLPRM algorithm jointly optimizes three lowest frequencies of AMSR-E instead of optimizing each band separately. The SLPRM retrieval method has been applied on AMSR_E observations which have been carried out for the SMEX03 (Soil Moisture Experiment, 2003) in North Oklahoma (ON) and South Oklahoma (OS) regions. The prime aim of this study is to assess the capability potential of the SLPRM algorithm on simultaneous retrieval of land surface parameters using appropriate data such as SMEX03. Regarding the aim, three different roughness calculation methods and comparison among their accuracies have been taken into account. In the first method, roughness retrieves as an unknown parameter. Second method estimates roughness based on active data and a constant roughness has been considered for the region in the third method.

This paper is organized as follows: The study area and the data used are described in section 2. In section3, proposed method to estimate soil parameters are presented. Section 4 describes the results and discussion of soil moisture estimates obtained using the model, and section 5 summarizes and concludes the study.

2. Datasets and study area

2.1. Study region

There were research objectives regarding soil moisture experiment with combined ground, aircraft, and spacecraft observations over sites in Oklahoma, Georgia, Alabama, and Brazil during summer 2003 (SMEX03). The goal of SMEX03 was to obtain a high resolution dataset of microwave brightness temperatures together with relevant land surface parameters (soil moisture, soil temperature, soil roughness, bulk density, etc.), in order to improve the soil moisture retrieval methodology.

SMEX03 is not necessarily the optimum dataset for microwave validation but is one of the few soil moisture data sets that provide regular observations of soil parameters over a relatively extensive area for a certain period of time.

In order to perform calibration and validation of the SLPRM method for land surface parameter retrieval over all surface types with different amount of vegetation cover, parts of the observations in SMEX03 have been used in this study.

The study area is composed of two regions, OS (N 34°27′_35°25′, E −98°20′_-97°43′) that is dominated by grassland and ON (N 36°10′_36°51′, E −98°03′_-97°25′) that is dominated by winter wheat, located in the south and north of Oklahoma, UAS, respectively. The two regions are shown in Fig. 1.

In Fig. 1, red, white and blue (in web version) pixels indicate vegetation, bare soil and dormant or senescent vegetation, respectively. The area has warm and nearly dry summers and its winters are usually moderate. Its topography is almost plain with a maximum relief less than 200 m. More details about the regions can be found in the report provided by Allen and Naney (1991).

2.2. Data sets

2.2.1. Ground-based data sets

The SMEX03 data set collected on 2, 3 and 4 July 2003 have been