# ESTIMATION OF SOIL MOISTURE WITH AIRBORNE L-BAND MICROWAVE RADIOMETER

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ABSTRACT ... Soil moisture plays an important role in the land-atmosphere energy balance because it governs the partitioning of energy through latent heat fluxes or evapotranspiration. From the numerous studies, it is evident that the L-band radiometer is a useful and effective tool to measure soil moisture. The objective of the study is to develop and to verify the soil moisture retrieval algorithms for the L-band radiometer system. Through the radiometer-observed brightness temperature, surface emissivity and reflectivity can be derived, and, hence, soil moisture. We collect field and L-band airborne radiometer data from washita92, SGP97 and SGP99 experiments to assist the development of the retrieval algorithms. Upon launching the satellite L-band radiometer such as ESA-sponsored SMOS (Soil Moisture and Ocean Salinity) mission, the developed algorithms may be used to study and monitor globe soil moisture change.

**KEY WORDS:** Soil moisture, Microwave remote sensing, L-band

## 1. INTRODUCTION

Soil moisture plays a crucial role in the land-atmosphere energy balance because it governs the partitioning of energy and water through latent heat fluxes and evapotranspiration at the lower boundary of the atmosphere. To identify the crucial role, it is a common agreement that knowledge of land surface processes and development of remote sensing techniques are introduced in the scientific issues. In the recent years, using microwave region to detect in particular the soil moisture content had the considerable advancement (Wang and Schmugge, 1980; Schmugge et al. 1986; Liou and England, 1996, 1998a, 1998b; Liou et al. 2001; Liu et al., 2002). Therefore, we considered to estimate soil moisture content on the Tibetan Plateau by using the microwave remote sensing data. Moreover, the Tibetan Plateau was chosen as a study region because this very high plateau is considered as a heat source of atmosphere in summer and to have an important impact on the Asian monsoon system. The information of spatial soil moisture change over the Tibetan Plateau in summer is important for the atmosphere, hydrological and engineering applications.

Many scholars have proposed that L band is the most appropriate microwave region to detect surface soil moisture content (Jackson et al., 1982; Shutko, 1982; Schmugge et al., 1986; Pampaloni et al., 1990; Jackson, 1993; E. Njoku et al., 1996). However, we consider that there is not L wave band satellite and obtain the data conveniently, therefore, we collect field and L-band airborne radiometer data from washita92, SGP97 and SGP99 experiments to assist the development of the retrieval algorithms. Upon launching the satellite L-band radiometer such as ESA-sponsored SMOS (Soil Moisture and Ocean Salinity) mission, the developed algorithms may be used to study and monitor globe soil moisture change.

## 2. METHODOLOGY

We modified the R model from the LSP/R model of Liou et al. (1999) and changed the R model a backward model. A backward model means that we used the brightness temperature that combines the contributions from the surface soil, the canopy and the atmosphere observed from radiometer in the satellite to retrieve the soil moisture we are interested in.

In the R model, it used the concept of layers that contribution from a layer of soil and a layer of canopy, each layer is homogeneous. The total model brightness, $T_b$ observed from the satellite is comprised of four components,

$$T_b = T_{bs} + T_{bc,d} + T_{bc,u} + T_{bsky} \qquad (1)$$

Where $T_{bs} = T_{s,e}(1-r)e^{-\tau_0/\mu}$ is the soil brightness attenuated by one trip through the canopy, $T_{bc,d} = T_{c,e}((1-e^{-\tau_0/\mu})r)e^{-\tau_0/\mu}$ is the down-welling canopy brightness reflected by the soil and attenuated by one trip through the canopy; $T_{bc,u} = T_{c,e}(1-e^{-\tau_0/\mu})$ is the upwelling canopy brightness, and $T_{sky} = T_{sky}re^{-2\tau_0/\mu}$ is the sky brightness reflected by the soil and attenuated by two trips through the canopy, $T_{s,e}$ is the soil temperature, $T_{c,e}$ is the emitting temperature of canopy, $e$ is the surface emissivity, μ is the cosine of the incidence angle, $\tau_0$ is the optical depth, and $r$ is the Fresnel reflectivity of soil and it is relation to soil dielectric constant and can be written as:

$$r(\theta;h)=\left|\frac{\cos\theta-\sqrt{\varepsilon-\sin^2\theta}}{\cos\theta+\sqrt{\varepsilon-\sin^2\theta}}\right|^2 \qquad (2)$$

where $\theta$ is the incidence angle of satellite, $\varepsilon$ is soil dielectric constant. Furthermore, we chose an empirical model (Dobson et al, 1985) uses a dielectric mixing approach that is dependent upon readily measured soil characteristics to retrieve the soil moisture from the soil dielectric constant.

$$\varepsilon_m^{\alpha}=1+\frac{\rho_b}{\rho_s}(\varepsilon_s^{\alpha}-1)+m_v^{\beta}\varepsilon_{fw}^{\alpha}-m_v \qquad (3)$$

$m_v$ is the soil moisture, $\rho_s$ is soil bulk density, $\rho_b$ is soil specific density, $\varepsilon_s$ is the dielectric constant of soil solids, $\varepsilon_{fw}$ is the dielectric constant of free water , $\alpha$ is shape parameter.

The relative permittivity of a wet canopy based upon the dual-dispersio model of Ulaby and El Rayes is

$$\varepsilon_{wg}=\varepsilon_r+v_{fw}[4.9+\frac{75}{1+jf/18}-j\frac{18\sigma}{f}]+v_{bw}[2.9+\frac{55}{1+(jf/0.18)^{0.05}}] \qquad (4)$$

Where $\varepsilon_r=1.7-0.74m_g+6.16m_g^2$ is the residual dielectric constant, $v_{fw}=m_g(0.55m_g-0.076)$ is the volume fraction of free water in the grass, $v_{bw}=4.46m_g^2/(1+7.36m_g^2)$ is the volume fraction of bound water in the grass, $m_g$ is the gravimetric moisture constant of the wet grass, and we should get the $m_g$ from ground truth.

## 3. DATA COLLECTION

The electronically steered thinned array radiometer (ESTAR) which is a synthetic aperture, operated at L band passive microwave radiometer was been chosen in this study. 29 ESTAR images over Southern Great Plain, Oklahoma, USA are collected to retrieve the soil moisture.

Table1. ESTAR Images in this study

| | | | |
|---|---|---|---|
| **Washita'92 (8 images)** | | | |
| 1992/06/10 | 1992/06/11 | 1992/06/12 | 1992/06/13 |
| 1992/06/14 | 1992/06/16 | 1992/06/17 | 1992/06/18 |
| 1997/06/18 | 1997/06/19 | 1997/06/20 | 1997/06/25 |
| **SGP97 (15 images)** | | | |
| 1997/06/26 | 1997/06/27 | 1997/06/29 | 1997/06/30 |
| 1997/07/01 | 1997/07/02 | 1997/07/03 | 1997/07/11 |
| 1997/07/12 | 1997/07/13 | 1997/07/14 | |
| **SGP99 (6 images)** | | | |
| 1999/07/08 | 1999/07/09 | 1999/07/14 | 1999/07/15 |
| 1999/07/19 | 1999/07/20 | | |

## 4. RESULTS

Figure 1,2,3 show the results that estimated from R model. In figure 1, there are some area which is in red colour is overestimated soil moisture, and the value is too high in some land cover. In figure 2, the correlation coefficient between the soil moisture retrieved from R model and the soil moisture product from USGS was above 0.9, and the average bias is about 0.5 $cm^3/cm^3$. In addition, the figure 3 shows the better soil moisture estimation in SGP99 data.

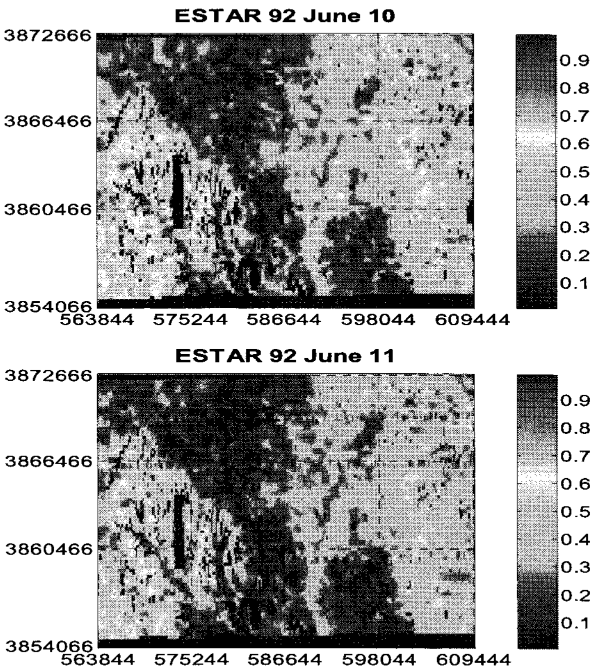


Figure 1 Regional soil moisture from Washita'92

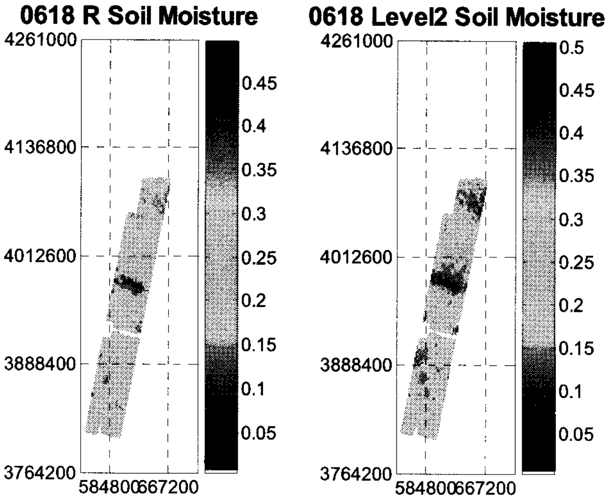


Figure 2 Regional soil moisture from SGP97

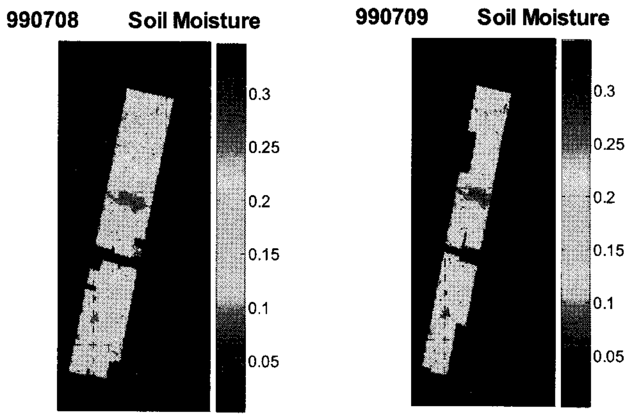


Figure 3 Regional soil moisture from SGP99

## 5. CONCLUSION

. This research used ESTAR airborne L band radiometer (1.41 GHz) images to retrieve soil moisture on the Southern Great Plain, USA. The R model was developed based on a land surface process and radiobrightness (R) model for bare soil and vegetated terrain. Compared with the Level 2 images from USGS and the soil moisture retrieved from the R model, the correlation is above 90%, and bias is about 0.8 $cm^3/cm^3$. In the future, we will apply the R model with the L-bend satellite brightness temperature such as ESA-sponsored SMOS (Soil Moisture and Ocean Salinity) mission to study and monitor globe soil moisture change.

## 6. ACKNOWLEDGMENT

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