EFFECTS OF SPATIAL HETEROGENTITY OF SOIL AND VEGETATION PARAMETERS ON SOIL MOISTURE RETRIEVAL FROM PASSIVE MICROWAVE REMOTE SENSING

Tao Zhang[1, 2], *Lixin Zhang*[1, 2], *Lingmei, Jiang*[1, 2], *Tianjie Zhao*[1, 2]

(1. State Key Laboratory of Remote Sensing Science, Jointly Sponsored by Beijing Normal University and the Institute of Remote Sensing Applications of Chinese Academy of Sciences, Beijing 100875, China;
2. School of Geography and Remote Sensing Science, Beijing Normal University, Beijing 100875, China)

1. INTRODUCTION

Soil moisture is an important variable in the process of water and energy exchange at the land surface. Measuring this variable has potential application in hydrology and meteorology. Passive microwave remote sensing techniques have great potential for its frequent coverage, low data rates, and simpler data processing, but with poor resolution, which resulted in sub-pixel heterogeneity. The heterogeneity within an image pixel might have considerable impact on the accuracy of soil moisture retrievals from passive microwave data. It has shown that the passive microwave mixed pixel containing vegetation, water or forest resulted in different content of error on the retrieval of soil moisture [1]. The spatial heterogeneity of soil and vegetation parameters but not the different types of land cover fraction were less mentioned. In this paper, the soil and vegetation end-member were taken into account to study the effect of the spatial heterogeneity on soil moisture with simulating data. The conclusion was validated by some exact field experiments based on a multi-channel truck-mounted passive microwave radiometer.

2. METHODS

To study the effect of spatial heterogeneity of soil and vegetation parameters on the retrieval of soil moisture, this paper firstly simulated different sub-pixel heterogeneities of every parameter, which were used as the input of the forward modeling, and then compared the soil moisture results retrieved by taking heterogeneity into account with that neglected the heterogeneity, using a proper soil moisture retrieval algorithm, seeking the relationship between those parameters' heterogeneity and the error of soil moisture retrieval. Finally, the conclusion was validated by some exact field experiments.

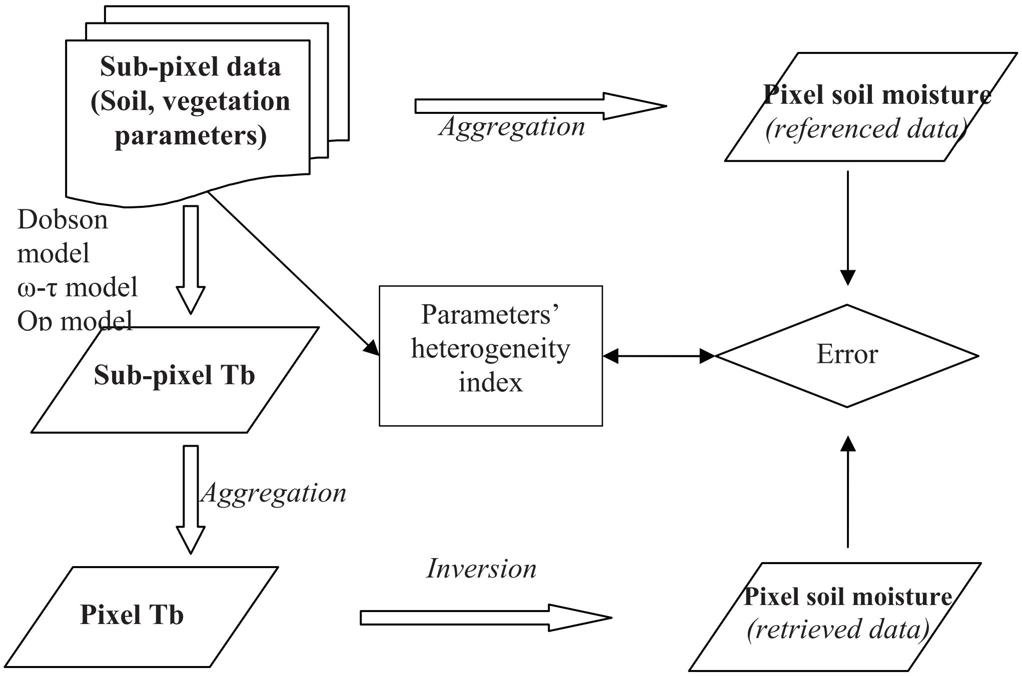

Fig.1 The analysis flow chart

2.1. Simulation models

Within the present study, we used the model of Dobson [2] to relate the dielectric properties ε^{α} of the soil to the volumetric water content m_v. It can be expressed as

$$\varepsilon^{\alpha} = 1 + (\rho_b / \rho_s)(\varepsilon_s^{\alpha} - 1) + m_v^{\beta}\varepsilon_{fw}^{\alpha} - m_v \quad (1)$$

The forward emission modeling approach is based on the ω-τ concept [3] which is a zero order radiative transfer approach and a widely used semi-empirical microwave emission model for ground with vegetation covered. It is given by

$$T_b = e_s t T_s + (1-t)(1-\omega)(1-e_s)T_c t + (1-t)(1-\omega)T_c \quad (2)$$

Where, T_b is the recorded brightness temperature; t is the transmissivity of the canopy; ω is the single scattering albedo of the canopy; T_c and T_s are the temperature of the soil skin layer and canopy respectively.

The emissivity of the soil e_s is related to the soil effective reflectivity R_p^e which depends on a roughness parameter Q_p and specular reflectivity r_p by Qp model developed by shi etc. [4]. It can be expressed as

$$R_p^e = Q_p \cdot r_p + (1-Q_p) \cdot r_p \quad (3)$$

2.2. Analysis methods

This paper simulated parameter data with different levels of its heterogeneity. Those parameters included temperature, moisture, texture of soil and water content, type, temperature of vegetation. As one parameter was taken into account, others can be a constant in proper value, and then analyzed the effect of spatial heterogeneity of this parameter according to the flow displayed in fig.1, seeking the relationship between the parameters' heterogeneity index and the error of soil moisture retrieval.

2.3. Performance benchmarks

To score the effect of spatial heterogeneity of soil and vegetation parameters on soil moisture retrieval, HI (Heterogeneity Index) was defined as the standard deviation of study parameter to describe the content of parameters' heterogeneity, which was used to seek relationship with the error between the soil moisture retrieved and referenced. It can be expressed as

$$HI = \delta_p = \sqrt{\frac{\sum_i \left(p_i - \bar{p} \right)}{N-1}} \quad (4)$$

Where, p_i is the value of the parameter of one sub-pixel, $\bar{p}$ and N are the mean value and the number of the parameter in one pixel.

The retrieval RMS error is calculated to quantify the absolute error of the soil moisture results as

$$rmse = \sqrt{\frac{\sum_i (v_i - \tilde{v}_i)^2}{N-1}} \quad (5)$$

Where, v_i and $\tilde{v}_i$ are the reference data and retrieved values respectively.

2.4. Validation

Some exact experiments were designed and carried out to validate the conclusion derived from simulated analysis based on a truck-mounted passive microwave radiometer in Baoding, China. It was shown that the simulation results coincided with measurements.

3. CONCLUSIONS

It was concluded that, the effect of spatial heterogeneity of soil and vegetation parameters on the retrieval of soil moisture is definite. Also, there is a good relationship between some parameters' HI and the error of soil moisture retrieval result. The error of soil moisture is a function of HI. When the HI is low, it has minor impact on the accuracy of soil moisture retrieval. Thus the accuracy decreased with HI becoming higher. The future work is trying to cancel out the effect of some parameters' heterogeneity to improve the accuracy of soil moisture retrieval.

4. REFERENCES

[1] Alexander Loew, "Impact of surface heterogeneity on surface soil moisture retrievals from passive microwave data at the regional scale: The Upper Danube case," *Remote Sensing of Environment*, vol.112, pp. 231-248, 2008.

[2] Dobson, M. C., Ulaby, F. J., Hallikainen, M. T., &El-Rayes, M. A.., "Microwave dielectric behavior of wet soil—Part Ⅱ: Dielectric mixing models," *IEEE Transaction on Geoscience and Remote Sensing*, vol.23, pp. 35-46, 1985.

[3] Eni G. Njoku, Lili, "Retrieval of Land Surface Parameter Using Passive Microwave Measurements at 6-18 GHz," *IEEE Transaction on Geoscience and Remote Sensing*, vol.37, pp. 79-93, 1999.

[4] Jiancheng Shi, Lingmei Jiang, Lixin Zhang, K. S. Chen, Jean-Pierre Wigneron, Andre Chanzy, "A Parameterized Multifrequency-Polarization Surface Emission Model," *IEEE Transaction on Geoscience and Remote Sensing,* vol. 43, pp. 2831-2841, 2005.