EVALUATION OF VEGETATION INDICES BASED ON MICROWAVE DATA BY SIMULATION AND MEASUREMENTS

Yunqing Li[1, 2], *Lixin Zhang*[1, 2], *Lingmei Jiang*[1, 2], *Tianjie Zhao*[1, 2], *Zhongjun Zhang*[3]

(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;
3. College of Information Science and Technology, Beijing Normal University, Beijing 100875, China.)

1. INTRODUCTION

One of significant purposes of microwave remote sensing is to obtain soil moisture and vegetation water content (VWC). As an important vegetation indicator, vegetation index has become a commonly used tool in surface parameters retrieving mentioned above. Currently, many indices based on microwave has been widely used for soil moisture estimation and VWC monitoring, such as Microwave Polarization Difference Temperatures (MPDT) [1], Microwave Polarization Difference Index (MPDI) [2] and Microwave Vegetation Indices (MVIs) [3], and so on. However, they are quite different in the sensitivities to some key parameters of surface, even in the applications. In this paper, a comparison and evaluation of the three vegetation indices' sensitivities to soil moisture and VWC were proposed by utilizing model simulation and field measurements. Meanwhile, our work could have some contribution to the applications of estimating soil moisture and vegetation water content.

2. METHODOLOGIES

2.1. Vegetation Indices Based on Microwave Data

With decades of development, many indices based on microwave have been raised for corresponding applications. Some of the earliest investigations [1] showed that MPDT at 37GHz were highly correlated to NDVI in arid and semi-arid regions. The expression can be written as:

$$MPDT = T_b(V) - T_b(H) \quad (1)$$

Here, Tb(V) and Tb(H) denote the brightness temperature at V and H polarization.

MPDI for a given frequency has been used in the research of LAI retrieval, the relationship with NDVI and the effect of vegetation on soil moisture conversion [2, 4, 5, 6].

$$MPDI = \frac{c(T_b(V) - T_b(H))}{T_b(V) + T_b(H)} \quad (2)$$

The parameter c is a scale factor.

Another index is defined as the microwave emissivity difference vegetation index (EDVI) with the formulas of

$$EDVI = \frac{2(T_{bp}(f_1) - T_{bp}(f_2))}{T_{bp}(f_1) + T_{bp}(f_2)} \quad (3)$$

Here, p denotes V polarization or H polarization. It was intended for application to dense forest conditions using 19 GHz and 37 GHz observations [7].

Based on radiative transfer model and a set of appropriate assumptions, Shi et al. (2008) has developed Microwave Vegetation Indices (MVIs) which are independent of soil surface emission signals.

$$A(f_1, f_2) = \frac{1}{2}\left[T_{bv}(f_2) + T_{bh}(f_2) - B(f_1, f_2)(T_{bv}(f_1) + T_{bh}(f_1))\right] \quad (4)$$

$$B(f_1, f_2) = \frac{T_{bv}(f_2) - T_{bh}(f_2)}{T_{bv}(f_1) - T_{bh}(f_1)} \quad (5)$$

Here, f_1 and f_2 denote the lower and higher frequency respectively.

In this paper, we have taken 3 of these indices for analysis and evaluation. They are MPDT, MPDI (when c=1) and MVIs.

2.2. Model Simulation

Considering that some indices were developed based on certain assumptions, a complex radiative transfer model [8] by Ferrazzoli was utilized in this paper to provide more objective evaluation.

The radiative transfer model is based on a Matrix-Doubling algorithm including multiple scattering. In this model, the vegetation layer is described by randomly distributed discs and cylinders, while the soil is described by Integral Equation Model (IEM). Here IEM was replaced by AIEM. It can obtain the total emissivity e_{tot}, vegetation emissivity e_v, bare soil emissivity e_s, and bare soil emissivity attenuated by vegetation e_{as} at different frequencies, polarizations and incidence angles.

A set of simulation data can be established from this model, which the three vegetation indices can be calculated from. There are 3 methods for simulation. To match with our microwave radiometer, the simulation was raised at C-Band (6.925GHz), X-Band (10.65GHz) and K-Band (18.7GHz).

(1). Keep vegetation parameters as constants, and change soil parameters at a suitable range and interval;

(2). Keep soil parameters as constants, and change vegetation parameters at a suitable range and interval.

Then the effects of different vegetation water content and soil moisture on the three vegetation indices were analyzed and evaluated. A comparison was also necessary. Considering that MVIs is suitable for the occasion at 55°, we will take 55°for example.

(1). Analyze the influence on MPDT, MPDI and MVIs when soil moisture changes at given soil roughness and vegetation occasions, and compare the features at three frequencies. Here soil RMS height and correlation length will be discussed separately.

(2). Analyze the influence on MPDT, MPDI and MVIs when VWC changes at given soil condition, and then compare the features at three frequencies.

Considering the different magnitude, normalization is necessary before comparison.

2.3. Experimental Measurements

To validate the results from simulation, a field experiment has been developed by a truck-mounted radiometer, in Baoding, Hebei Province, China. The microwave radiometer is a multi-angle, four-frequency (6.925GHz, 10.65GHz, 18.7GHz and 36.5GHz) and dual-polarization (V-polarization and H-polarization) radiometer with channels that match with AMSR-E.

For a single experiment, the radiometer is placed in the same position to ensure every observation has the same field-of-view. Only 3 frequencies (6.925GHz, 10.65GHz and 18.7GHz) are used in the experiment.

(1). Take cotton as view object, and derived a dataset by cutting the leaves and branches uniformly and gradually, aiming at changing vegetation water content step by step. The structure parameters and soil parameters that match with the Ferrazzoli's Model were measured simultaneously. Those should be repeated for 8 times and the stuffs cut off will be weighed separately.

(2). Take corn as view object, and water the soil uniformly and gradually, aiming at changing soil moisture step by step. The vegetation parameters and soil parameters that match with the Ferrazzoli's model were measured simultaneously. Those should be repeated for 8times and the weight every time watered will be written down separately.

3. CONCLUSIONS

From the model simulation, an analysis and evaluation of these indices can be carried out so that it can be used for subsequent applications on surface key parameters retrieval.

(1). For soil moisture influence, MPDT and MPDI are more sensitive to lower soil moisture. And the sensitivity descends at higher frequency.

(2). In term of VWC influence, it is obvious that MPDT and MPDI correlate very well and both have higher sensitivity to lower WVC vegetation. However, MVIs, especially MVIs_B, can predict better than MPDT and MPDI do.

(3). Combining the two points above, MVIs are more suitable for retrieving soil moisture and VWC. However, MVIs are established under some assumptions, and are only effective for short vegetation. So it is necessary to do further research on the applicability for tall vegetation.

This is a preliminary study on the relationship between soil moisture and vegetation water content and the related parameters, a lot of work need to be done in the future.

4. REFERENCES

[1]B. J. Choudhury, and C. J. Tucker, "Monitoring global vegetation using Nimbus-7 37GHz data: some empirical relations," *International Journal of Remote Sensing*, Vol.8, No.7, pp.1085-1090, 1987.

[2]K. P. Kirdiashev, A. A. Chukhantsev, and A. M. Shutko, "Microwave radiation of the Earth's surface in the presence of vegetation cover," *Radio Eng. Elect.*,Vol.24, pp.256-264,1979.

[3]J.C. Shi et al., "Microwave vegetation indices for short vegetation covers from satellite passive microwave sensor AMSR-E," *Remote Sens. Environ.*, Vol.112, pp.4285-4300, 2008.

[4]P. Pampaloni, S. Paloscia, G. Zipoli, "Microwave emission of soil and vegetation at X and Ka bands," *IGARSS*, 1983.

[5]J. R.Wang, "Effect of vegetation on soil moisture sensing observed from orbiting microwave radiometers," *Remote Sensing of Environment*, Vol.17, pp.141-151, 1985.

[6]F. Becker, B. J. Choudhury, "Relative sensitivity of Normalized Difference Vegetation Index (NDVI) and Microwave Polarization Difference Index (MPDI) for vegetation and desertification monitoring," *Remote Sensing of Environment*, Vol.24, pp.287-311,1988.

[7]Q. Min and B. Lin, "Remote sensing of evapotranspiration and carbon uptake at Harvard forest," *Remote Sensing of Environment*, Vol.100, pp.379-387, 2006.

[8] P. Ferrazzoli and L. Guerriero, "Passive microwave remote sensing of forests: a model investigation," *IEEE Trans. Geosci. Remote Sensing*, vol.34, pp.433–443, 1996.