A COMPOSED MICROWAVE EMISSION MODEL FOR COLD LAND*

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1. INTRODUCTION

The passive microwave remote sensing is widely used in the monitoring of ground surfaces environments on cold land. Many of key parameters, such as snow water equivalent, snow depth, freeze-thaw status, and phase changed water, can be obtained by this technology, which plays an important role in the meteorological, hydrological and global changes studies. However, the accuracy and applicability are strongly limited by two questions: one is the mixed pixel problem caused by the coarse resolution of passive microwave data, and the other is complex and variable ground surfaces environments that are usually ignored when parameter retrieving. In this paper, the available models for cold regions have been analyzed, and especially, the parameters of ω-τ model are calibrated against typical vegetations during winter through observations using a multi-channel truck-mounted radiometer. Then a composed model including the dielectric constant model of frozen soil, AIEM surface scattering model, HUT snow emission model and ω-τ vegetation emission model is established. Its applicability in simulating microwave radiation from mixed surfaces is verified by some exact field experiments. And in the last section an application example is showed. These results will provide useful reference for mixed pixel and parameter retrieval researches.

2. METHODS

2.1. Model Developing

Not all liquid water freezes below the freezing point. Based on the semiempirical dielectric mixing model for soil water mixture, Zhang, etc. (2003) uses an empirical function to estimate the fractions of liquid water and ice in frozen soil, and adds a new term to consider the contribution of ice fraction, the expression for calculating the dielectric constant of soil-water-ice mixture can be written as:

$$\varepsilon_{mf}^{\alpha} = 1 + \left(\rho_b / \rho_s\right)\left(\varepsilon_s^{\alpha} - 1\right) + m_{vu}^{\beta}\varepsilon_{fw}^{\alpha} - m_{vu} + m_{vi}\varepsilon_i^{\alpha} \quad (1)$$

Chen, etc. (2003) improved the IEM model, kept the absolute phase term in Greens function, which made this Advanced IEM have more accuracy than before. The application of AIEM has been verified by Monte Carlo simulation and ground experimental data. It can be applied to a wider range of roughness, dielectric constant and frequency.

In the Helsinki University of Technology (HUT) snow microwave emission model (Pulliainen, J.T., etc., 1999), the radiative transfer based semi-empirical model describes the emission behavior of a homogeneous snowpack as a function of water equivalent (SWE), effective grain size, and density of snow. For a homogeneous snow layer with a total thickness of d, the following formula for the emitted brightness temperature just below the snow–air boundary:

$$T_{B,snow}(\theta) = T_{B,g} + T_{B,s} = T_B(\theta)e^{-(k_e - qk_s)\sec\theta d} + (k_\alpha T_s / k_e - qk_s)(1 - e^{-(k_e - qk_s)\sec\theta d}) \quad (2)$$

In the low-frequency band, the ω-τ model (Eni G. Njoku, etc., 1999) as the first order approximate solution of the transmission equation is a widely used semi-empirical microwave emission model for ground with vegetation covered. Based on the optical thickness of the vegetation and single-scattering albedo, it can be expressed as:

$$T_{B,veg} = (1 + r_s t)(1 - t)(1 - w)T_c + (1 - r_s)tT_s \quad (3)$$

* Supported by National Basic Research Program of China, No. 2007CB714403.

Grass and winter wheat are two frequent typical vegetation types in the North China Plain. Two groups of ω, τ parameters under 6.925, 10.65, 18.7, and 36.5GHz are obtained by observations using a multi-channel radiometer and simulations with physics model.

Based on the above models related to cold land, the dielectric constant model is firstly used to estimate the permittivity of freeze-thaw soil, in succession, which is as the inputs of AIEM to calculate the emissivity of exposed soil. Then, the results from AIEM replace the description of ground of HUT, and the emissivity of snow covered ground can be calculated by the function (2). Similarly, the emissivity of vegetation covered ground would be accounted by the function (3). And lastly, the model would do the calculation of brightness temperature of ground with both snow and vegetation covered.

When it comes to the mixed pixel, the brightness temperature of the whole pixel is assumed to be calculated as:

$$T_B = f_{soil}T_{B,soil} + f_{snow}T_{B,snow} + f_{veg}T_{B,veg} + (1 - f_{soil} - f_{snow} - f_{veg})T_{B,snow,veg} \quad (4)$$

where f_{soil}, f_{snow}, f_{veg}, mean the fraction of soil, snow and vegetation in the mixed pixel respectively.

2.2. Validation

The multi-channel dual-polarization truck-mounted radiometer has 8 channels at 6.925, 10.65, 18.7 and 36.5GHz with V, H polarization respectively. Using this instrument, some exact observation experiments of complex ground are carried out over farmland in Beijing during winter in 2008. With the supporting ground measurements, the model simulation results have a good agreement with varying measurements.

3. APPLICATION

The microwave radiation from ground is determined by many various factors, such as temperature, soil moisture, surface roughness, soil texture. With that in mind, the composed model for cold land above is used for simulating the emission from six typical ground environments: frozen bare soil, thawed bare soil, frozen soil with grass, thawed soil with grass, frozen soil with snow, and frozen soil with snow and grass. 100 groups of brightness temperature with dual polarization at 6.925, 10.65, 18.7 and 36.5GHz are simulated randomly for each typical ground. The incident angle is 55deg. in correspondence with AMSR-E. Through analysis, it is found that the ratio between Tb in the horizontal polarization at low frequency (6.925H, 10.65H, and 18.7H) and 36.5V can indicate the variation of ground emissivity. Combined Tb36.5V to describe the surface temperature, the freeze-thaw status of soil can easily be judged.

4. CONCLUSIONS

A composed model is established for cold land, in which, using the outputs of dielectric constant model of frozen soil, AIEM model is introduced to simulate the microwave radiation from freeze-thaw soil. HUT model considers the impacts of snow, and ω-τ model calculates vegetation's. With relative ground measurements, the composed model succeeds to predict the measured microwave radiation characteristics of mixed ground surfaces. The application example showed that it is very useful in discrimination of freeze-thaw soil. And other further studies are under going.

5. REFERENCES

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