STUDY OF THE SPECTRAL GRADIENT OF FROZEN SOIL

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1. INTRODUCTION

Permafrost and seasonally frozen soil are considered as key component of the cryosphere. The thermal and physical properties of frozen soil are quite different from unfrozen soil. So, the regional energy and water exchange between land and atmosphere are quite different under frozen/unfrozen conditions. In the context of global warming, the degradation of frozen ground has attracted much attention because of its positive feed to global warming by releasing latent heat and carbon. The study of frozen soil requires knowledge of the extent and distribution of frozen ground area. Passive microwave remote sensing has been used to provide this information in previous studies [1-4]. One of the classification criteria of frozen/unfrozen ground is the spectral gradient (SG) of 18.7GHz and 36.5GHz. It's reported that SG of frozen soil have positive spectral gradient referring to [5]. A nearly linear relationship between the brightness temperatures of 37GHz and SG was also found. These results from satellite data were explained by volume scattering of frozen soil [4, 6], and the dielectric constant was treated as a constant value without changing with temperature or water contents. However, ground based experiments has not found positive SG when the ground is frozen [7].

In this study, we simulated the brightness temperature of frozen soil using AIEM and dielectric constant model of frozen soil. In this simulation scheme, no volume scattering is considered. The simulation results show that the SG of soil has a relationship with the soil temperature. The linear relationship between the brightness temperatures of 37GHz and SG may be caused by the change of dielectric constant with soil temperature. This conjecture is also supported by experimental data from the measurement of frozen ground using a truck mounted microwave radiometer.

2. MODEL SIMULATION

In order to simulate the microwave brightness temperature of frozen soil, a dielectric constant model for frozen soil [8] was used. In this model, the unfrozen water in frozen soil is calculated as a function of soil physical temperature. Then, the calculated dielectric constants were input to the AIEM[9] to calculate the emissivity of soil surface. The brightness temperature is then calculated by multiplying the emissivity and the physical temperature of soil. We simulated soil with different water content and surface roughness. The parameters used as input of models are shown in Table. 1.

In Figure 1, the SG is the calculated using the simulated H polarization brightness temperature of 18.7GHz and 36.5GHz. The results show that when the soil is frozen, the SG decreases as the temperature goes down. This behavior is in consistent with the measured results in section 3.

Table. 1 Input of the dielectric constant model and AIEM

Temperature (℃)	-20 ~ 20
Volumetric Water Content (%)	5 ~ 30, step: 5
Surface correlation length (cm)	5 ~ 30, step: 5
Surface rms height (cm)	1 ~ 3, step: 1
Viewing angle (°)	55
Soil clay content (%)	8.53
Soil sand content (%)	41.96
Soil bulk density (g/cm^3)	1.2

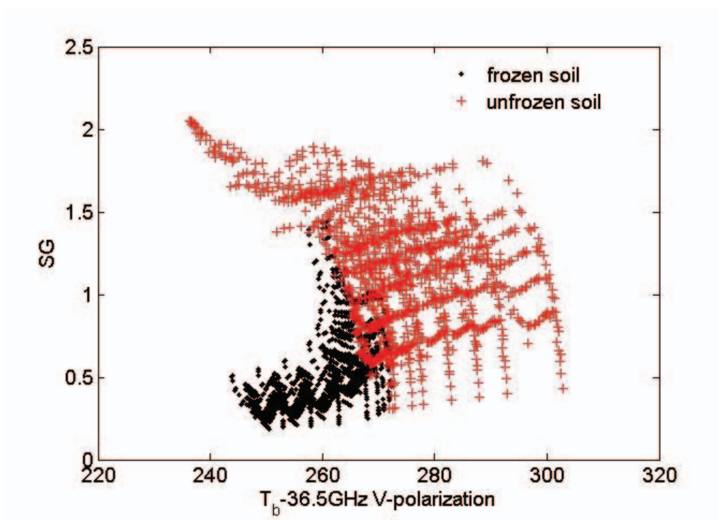

Figure 1 The simulated relationship between SG and the brightness temperature of 36.5GHz V-polarization.

3. EXPERIMENTS

Radiometric data of frozen soil were obtained through a truck-mounted microwave radiometer in two experiments. This radiometer [10] has 4 frequency and both with dual-polarization. The first experiment was conducted on farmland in the North China Plain. In this experiment, the radiometer measured the brightness temperature at a constant viewing angle (55°) several days. The other experiment was conducted in Heihe watershed in Qinghai, China. The viewing angle was set to 50°.

The SG of the 18.7GHz and 36.5GHz was calculated. The relationship of SG with the brightness temperature of 36.5GHz V-polarization is shown in Figure 2. It's clear that the SG change with temperature when the soil is frozen. We also noticed that the SG of H polarization was not positive indicating that the volume scattering in frozen soil is not as strong as that described in former studies.

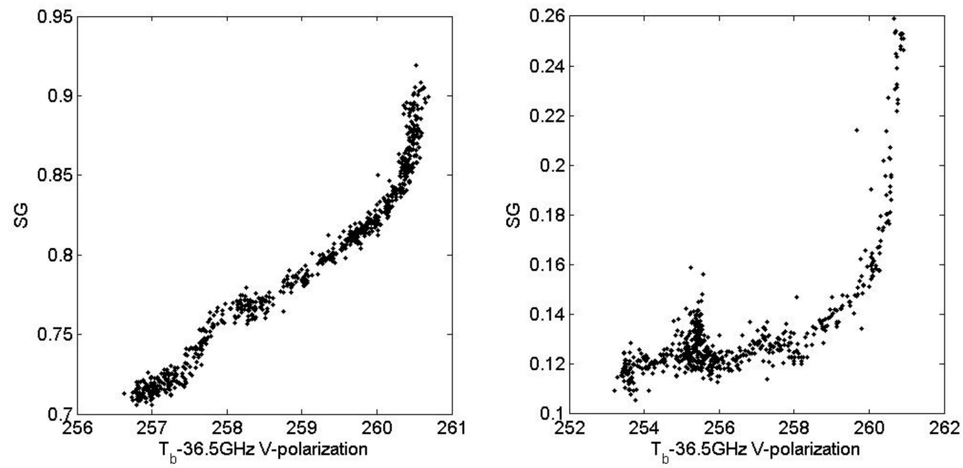

Figure 2 The measured relationship between SG and the brightness temperature of 36.5GHz V-polarization. Data from the North China Plain (left); data from Heihe watershed (right).

4. CONCLUTIONS

The simulation and experiment result clearly show the relationship between the SG and the brightness temperature of 36.5GHz V-polarization. This relationship is similar to that found through satellite data. We conclude that the low value of SG and its relationship with temperature are mainly because of the unfrozen water content in frozen soil. This conclusion is helpful in analyzing satellite data and developing better decision criteria for frozen/unfrozen soil. It's also possible to retrieve the unfrozen water content using SG, which need more in-depth study.

5. REFERENCES

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