Characterizing the Channel Dependence of Vegetation Effects on Microwave Emissions from Soils

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Introduction

- The two vegetation transfer parameters of τ (Vegetation Optical Depth, VOD) and ω (Single Scattering albedo) could vary significantly across microwave channels in terms of frequencies, polarizations, and incidence angles, and their characteristics of channel dependence have not yet been fully investigated. The accurate accounting of multiple scattering effects in vegetation on passive microwave radiation signals is a critical challenge. Developing more precise models that consider the scattering process inside the vegetation canopy is essential for better estimating the brightness temperature of plants at different frequencies. To improve the accuracy of soil moisture retrieval in vegetated areas, the parameters of the zero-order τ-ω model need to be optimized. In this study, we investigate the channel dependence of vegetation effects on microwave emissions from soils using a higher-order vegetation radiative transfer model.

Method

- Corn was chosen as the research object, and a corn growth model was developed using the multifrequency and multiangle ground-based microwave radiation experiment (Zhao et al,.2021) from the Soil Moisture Experiment in the Luan River (SMELR).

Data Set Sorce:
https://doi.org/10.11888/Soil.tpdc.271622

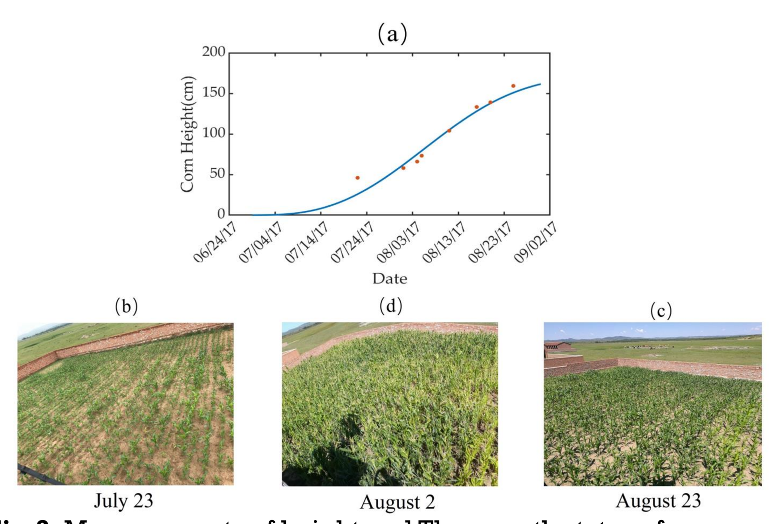

Fig.2. Measurements of height and The growth status of corn

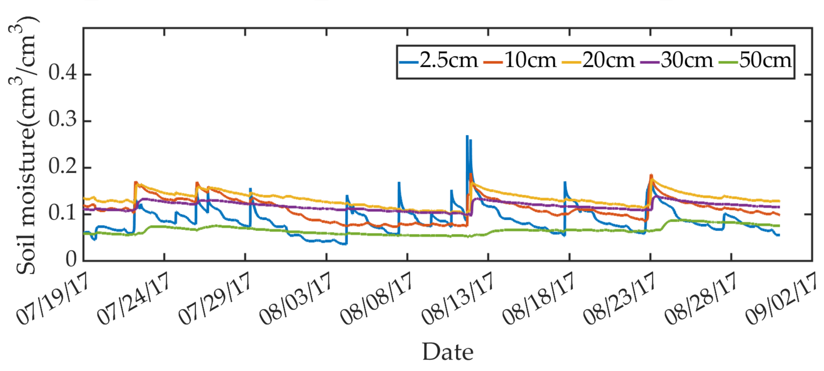

Fig.1. Soil moisture data measured by Decagon EM50.

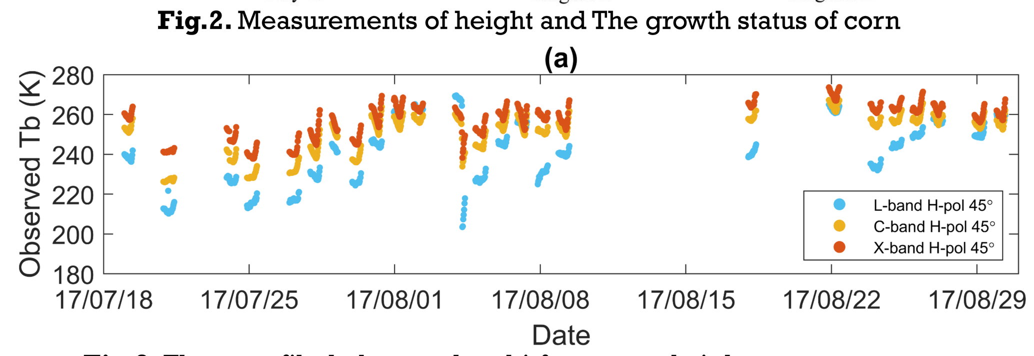

Fig.3. The corn filed observed multi-frequency brightness temperatures at the incidence angle of 45° for H-pol

- After establishing the corresponding database of corn radiation characteristics, the effective scattering albedo under various channels was calculated using the Tor Vergata model (Ferrazzoli et al. 1996).

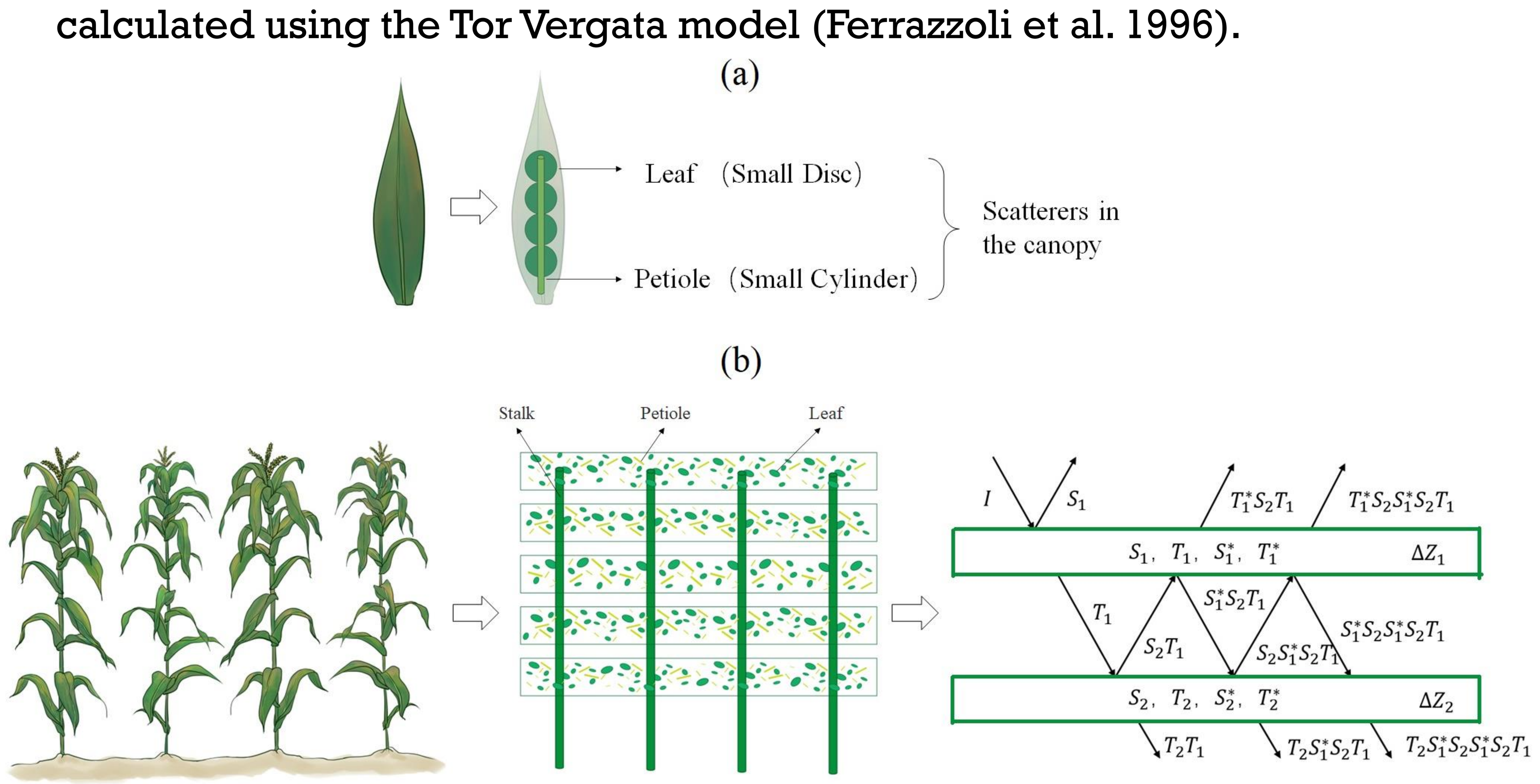

Fig.4. Scatterer representation of corn leaves in the model. (b) Tor Vergata Model structure and matrix doubling algorithm diagram.

- The core of the Tor Vergata model is the Matrix Doubling algorithm, which assigns these scatterers to each sublayer and then uses the lower hemisphere scatter matrix T and the upper hemisphere scatter matrix S to merge the two adjacent thin sublayers.

$$S = S_1 + T_1^* S_2 T_1 + T_1^* S_2 S_1^* S_2 T_1 \ldots = S_1 + T_1^* S_2 (1 - S_1^* S_2)^{-1} T_1$$

$$T = T_2 [1 + S_1^* s_2 + (S_1^* S_2)^2 + \cdots] T_1 = T_2\ (1 - S_1^* S_2)^{-1} T_1$$

The subscripts 1 and 2 respectively represent the upper hemisphere scatter matrix of Incident Sublayer 1 and Incident Sublayer 2 from above. After reversing the incidence angle, the scattering matrix is represented by the superscript *.

$$S_T = S_{veg} + T_{veg}^* S_{soil} (1 - S_{veg}^* S_{soil})^{-1} T_{veg}$$

Where S_T is the total scattering matrix. The subscripts veg and soil represent the vegetation layer and soil layer.

- The zero-order radiative transfer model can be optimized by fitting it to the computed emissivity from the Tor Vergata model using a least squares approach:

$$\sigma = \sqrt{\sum_{i=1}^{N} (e_{1i} - e_{2i})^2}$$

where N is the number of simulated experiments, e_{1i} is the total vegetation emissivity calculated by the Tor Vergata model, and e_{2i} is the total vegetation emissivity calculated by the τ-ω model.

- The channel dependence analysis of the vegetation optical depth and effective scattering albedo in the database was performed. Specific frequency, angle, and polarization dependences apply to the optical depth of vegetation. We use the following formula to represent the vegetation optical depth for any two different channels (Zhao et al,2021):

$$\frac{\tau_1}{\tau_2} = \left(\frac{f_1}{f_2}\right)^{C_f} \frac{\sin^2\theta_1 C_{P_1} + \cos^2\theta_1}{\sin^2\theta_2 C_{P_2} + \cos^2\theta_2}$$

where C_f is the frequency-dependent parameter of vegetation optical depth, and C_P is the polarization-dependent parameter.

Results and Conclusion

- The results show that the channel dependence of vegetation optical depth can be described as the polarization dependence parameter (C_P) and the frequency dependence parameter (C_f).
- According to these two parameters, the vegetation optical depth can be calculated at any channel under three adjacent frequencies (L band, C band and X band).
- The effective scattering albedo has no obvious dependence on the angle, so the effective scattering albedo based on the higher-order radiation transfer model under three adjacent frequencies with different polarizations is obtained.

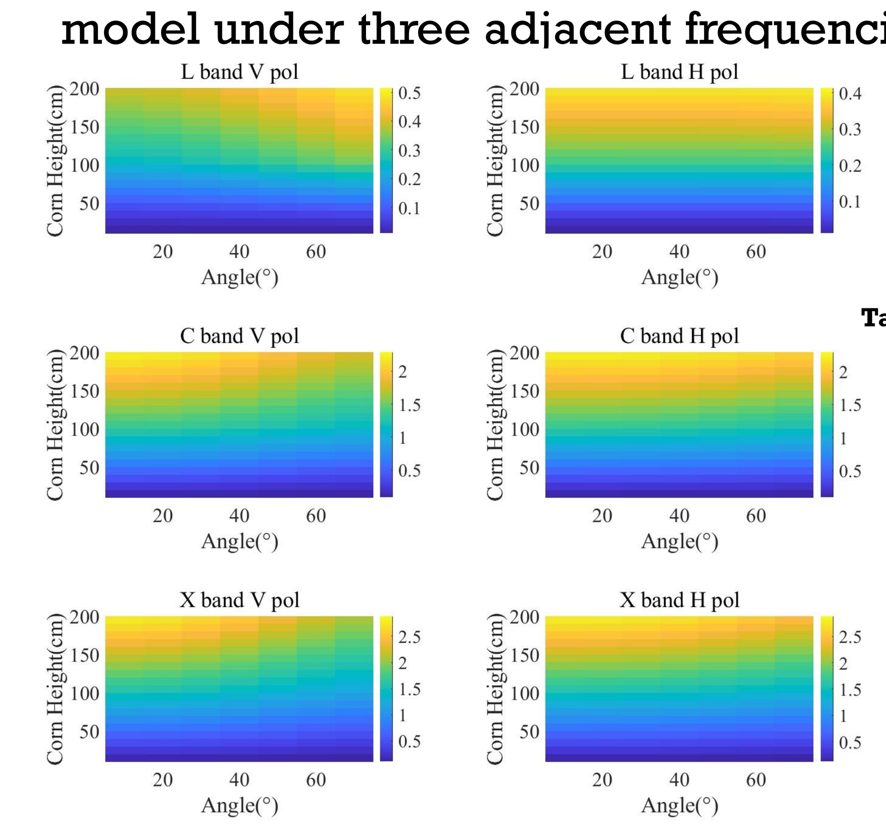

Fig.5. Vegetation Optical Depth with Observation Angle for Different Cha

Table Ⅰ. The Polarization dependence parameter (C_P) at different channels

Frequency	V Polarization	H Polarization
L Band (1.4Ghz)	1.5404	1.0067
C Band (6.92Ghz)	0.8801	0.9519
X Band(10.65Ghz)	0.7750	0.9070

Table Ⅱ. The frequency dependence parameter (C_f) between two different bands

f_1	f_2	C_f
1.4Ghz	6.925Ghz	0.9154
1.4Ghz	10.65Ghz	0.7978
6.925Ghz	10.65Ghz	0.3682
6.925Ghz	1.4Ghz	0.9172
10.65Ghz	1.4Ghz	0.8058
10.65Ghz	6.925Ghz	0.3845

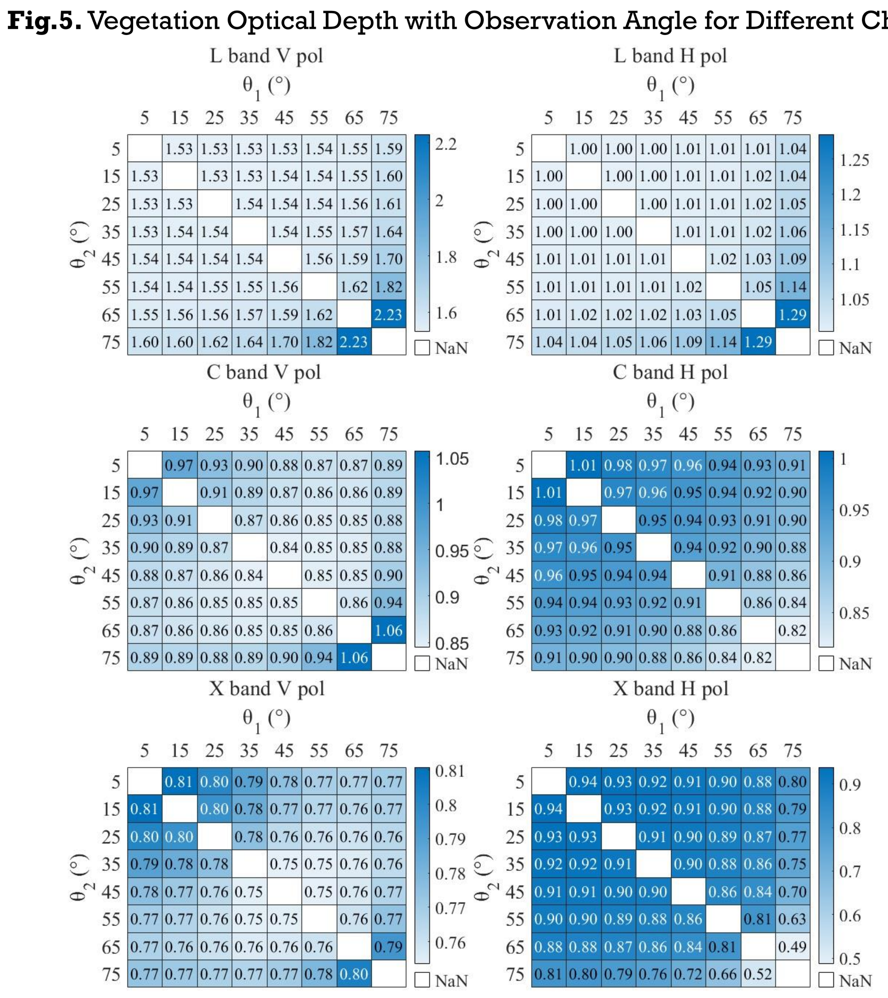

Fig.6. Polarization dependence parameter C_P at two different angle channels

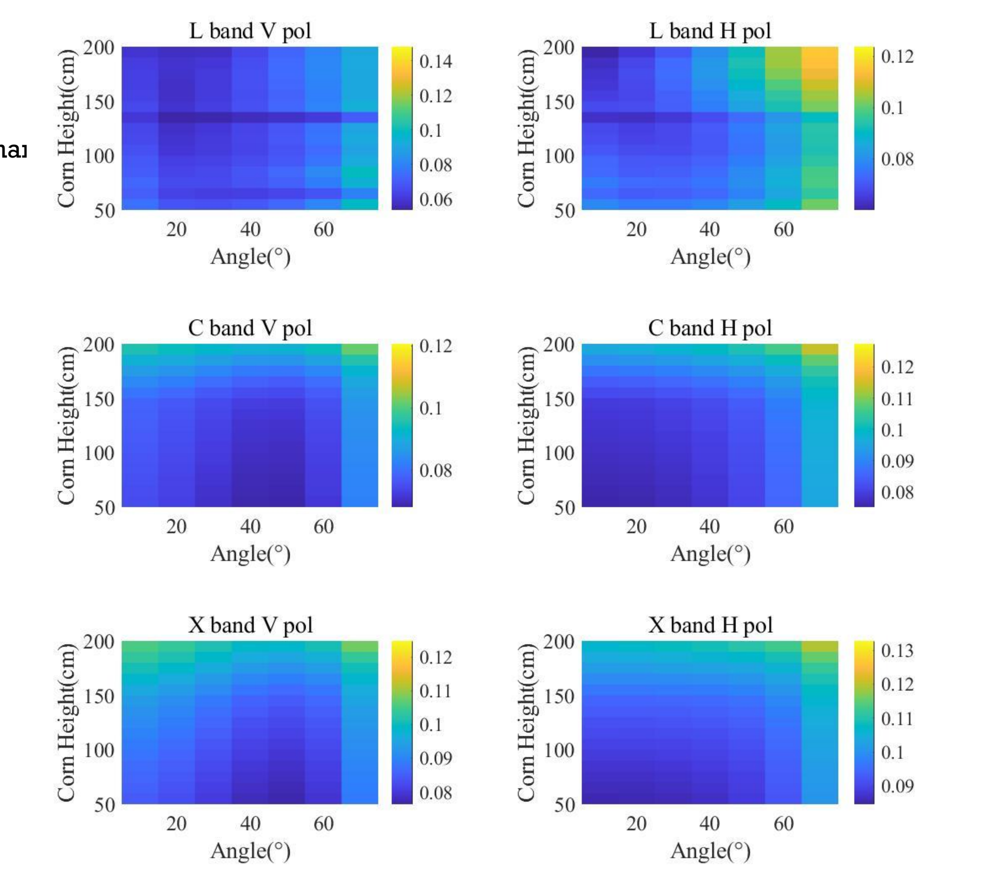

Fig.7. Effective scattering albedo at different angles and different heights

Table Ⅲ. The effective scattering albedo at six channels

Frequency	V Polarization	H Polarization
L Band (1.4Ghz)	0.0619	0.0536
C Band (6.92Ghz)	0.0814	0.1025
X Band(10.65Ghz)	0.0888	0.1052

Outlook

- Future research will be expanded to more commonly encountered vegetation-covered areas such as forests, shrubs, and grasslands to better serve large-scale satellite observations and soil moisture retrievals.

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