Using Microwave Vegetation Indices for Soil Moisture Retrievals from Passive Microwave Radiometry

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Surface soil moisture is a key variable used to describe water and energy exchanges at the land surface/atmosphere interface. The Soil Moisture and Ocean Salinity (SMOS) satellite will provide global multi-angular microwave brightness temperature observations at L-band, in dual polarization and multi-angles. It has great potential for providing estimates of soil moisture with good temporal repetition on a daily basis and on a regional scale. However, the effects of vegetation cover play a significant role in the microwave emission from the surface. One widely discussed for allowing for the effect of vegetation on soil moisture retrievals from microwave observations is to use remotely sensed vegetation indices.

Through the analysis of the simulated database by the advanced integral equation model (AIEM) and the 0th-order radiative transfer solution, we have developed the microwave vegetation indices (MVIs) using surface emission signals on the pair of view angles.

For a satellite footprint with a fraction of vegetation cover F_v, the measured brightness temperature can be written as a four-component model:

$$\begin{aligned} T_{Bp}(\theta) = {} & F_v \cdot E_p^v(\theta) \cdot T_v + F_v \cdot E_p^v(\theta) \cdot L_p(\theta) \cdot (1 - E_p^e(\theta)) \cdot T_v \\ & + F_v \cdot E_p^s(\theta) \cdot L_p(\theta) \cdot T_s + (1 - F_v) \cdot E_p^s(\theta) \cdot T_s \end{aligned} \tag{1}$$

The superscripts v and s indicate the vegetation and soil components and the subscript p is for polarization.

Where θ and τ are incidence angle and the optical thickness of vegetation canopy, T_v and T_s are the vegetation and soil temperatures, respectively. The first term in Eq. (1) is the upward emission signal from the vegetation canopy. The second term is the downward vegetation emission signal reflected back by the soil surface after passing though the vegetation cover again. The third term is the soil emission signal after it passes though the vegetation cover. The last term is the direct soil emission signal that is not affected by the vegetation cover. Eq. (1) can be rearranged as a two component model:

$$\begin{aligned} T_{Bp}(\theta) = {} & F_v \cdot E_p^v(\theta) \cdot T_v + F_v \cdot E_p^v(\theta) \cdot L_p(\theta) \cdot T_v \\ & + ([1 - F_v + F_v \cdot L_p(\theta)] \cdot T_s - [F_v \cdot E_p^v(\theta) \cdot L_p(\theta)] \cdot T_v) \cdot E_p^s(\theta) \end{aligned} \tag{2}$$

Eq. (2) indicates that the measured brightness temperature at a given view angle and polarization p can be linearly related to the soil surface emissivity. For simplicity, we denote the intercept of Eq. (2) as the vegetation emission component

$$V_e(\theta) = F_v \cdot E_p^v(\theta) \cdot T_v + F_v \cdot E_p^v(\theta) \cdot L_p(\theta) \cdot T_v \quad (3)$$

The slope of this linear relationship in Eq. (2) is a product of temperatures and the vegetation effect. We simply denote this as the vegetation transmission component:

$$V_t(\theta) = [1 - F_v + F_v \cdot L_p(\theta)] \cdot T_s - [F_v \cdot E_p^v(\theta) \cdot L_p(\theta)] \cdot T_v \quad (4)$$

Both the slope V_t and intercept V_e are functions of the vegetation fractional cover, temperature and other physical properties.

This makes it possible to minimize the surface emission signal and maximize the vegetation signal when using multi-angular radiometer measurements. The vegetation indices derived from passive microwave measurements to be independent of background soil and atmospheric conditions, to be only dependent on the vegetation properties.

The developed MVIs is independent of soil surface emission signals and can provide new vegetation information since the L-band microwave measurements are sensitive to the properties of the overall vegetation. We compared the MVIs with the Leaf Area Index (LAI) and vegetation water content (VWC) using SMOSREX dataset in 2004-2006. The results showed that the general distribution and the change patterns of the MVIs are consistent with those of LAI and VWC derived by the field experiments.

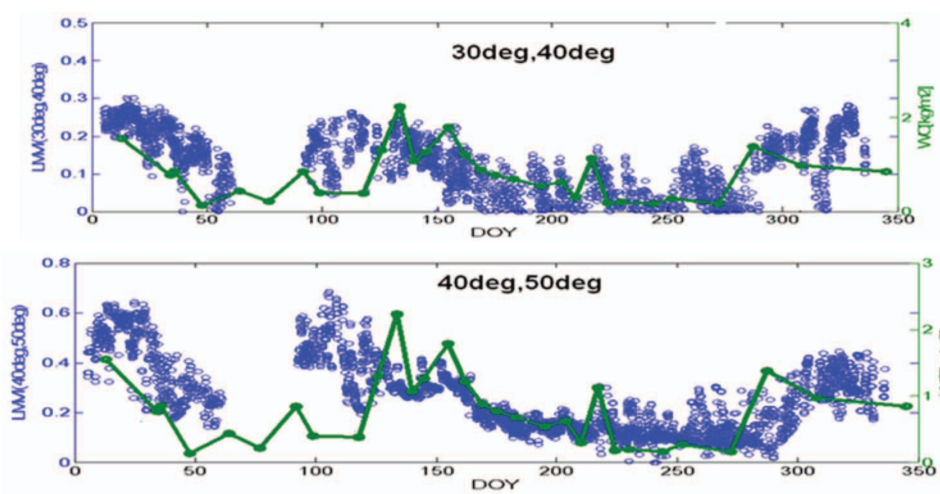

Fig.1 Comparison of VWC and developed MVIs using the SMOSREX dataset in 2004.

The L-MEB model is taken as a key element in the SMOS L2 algorithm and the main components are the vegetation module using the ω-τ approach. Estimates of optical depth are required for the retrieval of surface soil moisture from remotely sensed microwave brightness temperatures, and it has been suggested that relating optical depth to vegetation water content represents a potential mechanism to meet this need.

|Using the simulated database, we explored the potential relationship between optical depth and microwave vegetation indices and can be expressed by logarithmic equation. Iterative algorithm is used to retrieve soil moisture and reduce the unknown parameters in the inversion process. Finally, SMOSREX dataset in 2004-2006 and BARC dataset in 1979-1981 were used to validate the inversion algorithm. The results showed that the proposed method can take into account the impact of vegetation effectively and improve the stability of the soil moisture inversion.

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