# A PHYSICAL MODEL FOR MICROWAVE RADIOMETRY OF FOREST CANOPIES

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Retrieving soil moisture from microwave brightness temperatures in the presence of vegetation has been the subject of much research in the past. Most microwave soil moisture retrieval algorithms for sensing soil moisture through a vegetation canopy have been developed at L, S and C band microwave frequencies. They have been based on a zero-order solution to the radiative transfer equation called the tau-omega model. The model ignores scattering except for the effect of the scatterers in the attenuation of the emission through the vegetation. The attenuation includes both the absorption and scattering losses. Application of the tau-omega model to data acquired during airborne and ground-based campaigns over the years has solidified scientific understanding of microwave interactions with different landscapes. In particularly, shrubland, grasslands, agricultural crops, and light to moderate vegetation have been investigated. Further investigation is, however, required for assessing the suitability of this approach when applied to a forest canopy; here, scattering from branches and trunks is very important. Since the zeroth order solution does not account for the scattered radiation which can be important for forested areas, the first order solution needs to be considered.

In this paper, a physical microwave radiometry model based on an iterative solution of the radiative transfer equation up to the first order is developed for a forest canopy. The first order solution is obtained by substituting the zeroth-order solution into the scattering source term and then solving the resulting radiative transfer equation. This formulation adds a new scattering term to the tau-omega model. This term represents emission by particles in the layer and emission by the ground that is scattered once by particles in the layer. The resulting model represents an improvement over the standard zero-order solution (the tau-omega model) since it accounts for the scattered vegetation and ground radiation that can have a pronounced effect on the observed brightness temperature. Numerical simulations will be performed to validate the model and to investigate the influence of the scattered radiations on the accuracy of microwave soil moisture retrieval under trees.

The model is being tested by using microwave brightness temperature data acquired over deciduous trees canopies in Maryland during 2006 and 2007. The experiment has been conducted with a goal of optimizing microwave soil moisture retrieval algorithms for small to medium trees. Microwave measurements at several incident angles and supporting ground truth data (including size/angle distributions of tree constituents) have been collected over stands of deciduous Paulownia trees of different densities under full canopy and leaf-drop conditions. Detailed ground truth data obtained during this experiment is being used to compute the additional radiation due to scattering and emission by the vegetation components. The preliminary model predictions are in good agreement with the data and they give quantitative understanding for the influence of the first order scattering within the canopy on the radiometer brightness temperature. The model results using tree ground truth show that the scattering term is significant for trees and that the tau-omega model needs modification to account for additional scattering contribution. Numerical simulations also indicate that the single scattered radiation increases the canopy brightness temperature considerably. These simulations show that the scattering term has a negligible dependence on soil moisture and is only function of angle and polarization.

In this paper, the zeroth and first order solutions to radiative transfer equation will be compared for the deciduous Paulownia trees. Contributions of the individual scattering terms to the tree scattering will be demonstrated. Significant terms contributing to forest scattering will be identified and their dependence on angle and soil moisture will be demonstrated. Finally, the accuracy of microwave soil moisture retrieval under trees will be discussed, as well as the importance of the scattered radiation for the microwave remote sensing of soil emission through a forest canopy.