DEVELOPMENT OF A SIMPLE SCATTERING MODEL FOR VEGETATION CANOPIES AND EXAMINATION OF ITS VALIDITY WITH SCATTEROMETER MEASUREMENTS OF GREEN-ONION FIELDS

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Abstracts: A simple scattering model for radar backscattering from vegetated surfaces is developed based on the radiative transfer technique. The number of input parameters of the model is minimized to simplify the scattering model. The validity of the model is examined by comparison between the computation outputs and scatterometer measurements for the backscattering coefficients of green-onion (scallion) fields.

1. INTRODUCTION

The radar scattering from natural earth surfaces involves complicated electromagnetic wave interactions, because of the randomly oriented complex geometries of the various scattering particles. The vector radiative transfer theory is a common technique to compute polarimetric microwave scattering from randomly distributed scatterers [1]. However, the existing approximate scattering models are still complicated because of too many input parameters [2].

In this study, we develop a relatively simple model for microwave scattering from a vegetation canopy, which has only ten input parameters and shows a reasonably good accuracy. This model employs the iterative vector radiative transfer theory to compute the backscattering coefficients including the first-order multiple scattering effects [3]. We model the vegetation canopy with two layers; a soil surface layer and a vegetation layer. The vegetation layer contains randomly oriented and positioned leaves, branches and trunks. The polarimetric backscattering coefficients of scallion fields are measured with a well-calibrated C-band ground-based scatterometer and the measurements are compared with those estimated using the simple model.

2. MODEL DERIVATION

In this scattering model, the radar backscattering from two-layered vegetation canopy comprises five main scattering mechanisms such as (1) ground-vegetation-ground scattering, (2) vegetation-ground scattering, (3) ground-vegetation scattering, (4) direct vegetation scattering, (5) direct ground scattering. The backscattering coefficients of a vegetated surface are obtained from the 4×4 transformation matrix which can be computed using the extinction matrices of the vegetation canopy, the reflectivity matrix of the ground surface, and scattering-mechanism matrices corresponding to five scattering mechanisms. The scattering-mechanism matrices can be computed using the phase matrices for vegetation particles. The phase matrix can be computed by integration of the Mueller matrix multiplied with the distribution function of the scattering particles. The Mueller matrix functions are calculated using the scattering matrices of scatterers. In the formulation, we also assumed that the scatterers are randomly and sparsely distributed and there is no correlation between them.

The radar scattering characteristics of the scattering particles are obtained using the existing scattering models. Natural leaves and branches usually have complicated shapes and sizes. Coniferous leaves are modeled by spheroids for the computation purpose, while the deciduous leaves modeled by thin disks. The physical optics (PO) technique with the impedance sheet theory is used for computing the radar cross section (RCS) of the leaves [4]. Branches and trunks usually have cylindrical shapes. The PO model is also used for scattered field of a finite cylinder with arbitrary cross section and orientation. Oh et al.'s model [5] is used for backscattering from a bare soil surface.

After examining the sensitivities of the backscattering coefficients on each input parameters are examined, we select only ten most important input parameters, which are (1) the volumetric moisture content mv (cm^3/cm^3), (2) the rms surface height s (cm) of the ground surface, (3) the height h (m) of the vegetation layer, (4) leaf density n_l (m^{-3}), (5) leaf length l_l (cm), (6) leaf width W_l (cm), (7) branch density n_b (m^{-3}), (8) branch length l_b (cm), (9) trunk density n_t (m^{-3}), and (10) trunk length l_t (m).

3. MEASUREMENTS

The backscattering coefficients of green-onion farming fields are measured at 5.3 GHz at various incidence angles by a ground-based polarimetric C-band scatterometer which consists of an automatic vector network analyzer, an orthogonal mode transducer (OMT), a horn antenna, an 8-m boom structure, an antenna support, and two step motors for controlling azimuth and elevation angles. The polarimetric scatterometer is calibrated with the differential-Mueller-matrix calibration technique [6] by measuring the polarimetric responses of a conducting sphere at the main beam of the antenna system.

The ground truth data of the fields are measured to get ten input parameters of the simple model. For example, the ground truth data of the green-onion fields include number of clusters per unit area, number of stalks per cluster, number of leaves per stalk, stalk heights, stalk diameters, leaf lengths, leaf diameters, stalk angles, leaf angles, moisture contents of vegetation, height profiles of the soil surface, soil moisture contents. The measurements are used to examine the validity of the simple model for vv-, hh-, hv-polarized backscattering coefficients.

4. CONCLUDING REMARKS

A simple microwave backscattering model is developed for estimating the backscattering coefficients of vegetation canopies. The simple model has only ten input parameters for a vegetation canopy. The validity of this model is examined against the scatterometer measurements of green-onion (scallion) fields.

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