MULTILAYERED MULTIPLE-SPECIES FOREST SCATTERING MODEL BASED ON A WAVE THEORY APPROACH

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1. INTRODUCTION

A realistic radar scattering model to predict backscattering cross section for different frequencies and polarizations is an important tool for understanding the relationship between radar measurement and forest properties, and for enabling the estimation of forest parameters from radar data. Popular, conventional models typically specify a two-layer discrete random medium placed on a continuous random rough surface representing the ground. These can effectively model a single-species forest, but cannot readily incorporate variety in forest compositional complexity, from sparsely forested steppe to multi-story tropical forest (understory, shrubs, and overstory), whether single- (with variation in growth stages) or multi-species. A more realistic representation of complex forest with multiple species has to take multiple layers and their interactions into account. Here, we present an *N*-layered vegetated medium model using a discrete-component scattering model. This model is based on wave theory, in contrast with an existing multilayer model based on radiative transfer theory (RT) developed in our group previously [1].

2. APPROACH

We present a forward scattering model, which yields the polarimetric backscattering coefficients of an arbitrary forest with multiple species, based on the geometry of the forest. Single-species scattering models generally neglect the diversity and variation of complex forests. Modeling several separate species of trees simultaneously can be considered as being equivalent to a single-species representation, but with several uniform layers. Each layer is modeled as a collection of randomly distributed finite cylinders; trunk layers are modeled as a distribution of nearly vertical tall cylinders, whilst crown (branch) layers are modeled as a distribution of randomly oriented cylinders. Additionally, allometric relations are used to account for relationships between trunk and crown layer properties, matching the real forests more closely. The combination of the multi-layered and allometrically specified geometry results in a realistic rendering of forested regions, and therefore enables a more accurate prediction of radar measurements.

3. IMPLEMENTATION

We have developed the multispecies forest scattering model using an approach based on the distorted Born approximation, the single-species version of which was developed by Durden et al. [2]. To our knowledge, such a multispecies model has not been developed elsewhere. First, the geometry of the forest is generated, based on the knowledge of species and their geometric and dielectric properties. The model only treats the vertical variability, assuming lateral homogeneity within each radar pixel, and derives the full wave scattering matrix. The scattering matrix of one single cylinder with arbitrary orientation and finite length is simulated based on vector scattering theory. The layer is then simulated by integrating over a probability density function for the possible range of sizes and orientations of the cylinders, which could vary for each of these layers. Backscattering and attenuation are taken into account by a top-to-bottom approach. The interaction of the layers is calculated by cascading their specific scattering matrices and attenuation of each layer is taken into account for the layers below. Two major types of layers are considered: the *trunk layer,* containing wooden trunks modeled as nearly vertical dielectric cylinders of finite length and the *crown layer,* containing randomly oriented small and large cylinders of finite length representing branches with disks or needles for leaves. The ground is modeled as a rough dielectric surface. The type of scatterers of a specific species inside a layer is considered homogenous, with stationary statistics.

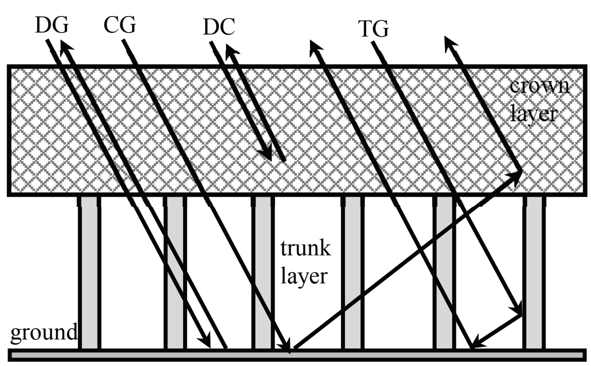

Figure 1: Four main backscattering mechanisms for a single-species forest.

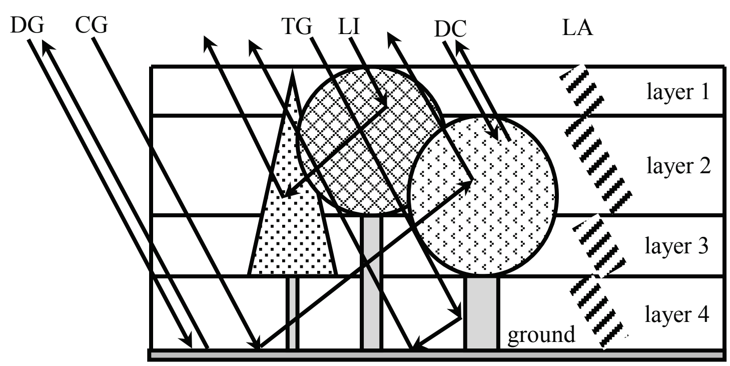

Figure 2: Five main backscattering mechanisms in multi-layer, multi-species approach based on wave theory with symbolic layer attenuation (LA).

Five main scattering mechanisms are incorporated. These are: direct backscattering from each of the crown layers (DC), direct backscattering from ground (DG), specular crown scattering followed by ground reflection for each of the crown layers (CG), and specular trunk scattering followed by ground reflection by each of the crown layers (TG); we also incorporate backscattering from interspecies layer interaction (LI), as seen in Figures 1 and 2. Multiple scattering within the crown layer, trunk layer, or between trunk and crown layer is neglected, as are higher-order scattering mechanisms (e.g., crown-ground-crown and trunk-ground-trunk interaction); these were generally found negligible [3]. The total backscattering coefficient is then found by summing those of the five main mechanisms.

The model flexibly integrates specific combinations of species, and simulates its SAR backscattering coefficient at P-, L- and C-band, based on geometric and dielectric input variables of forest canopies. The model is realized in a modular manner to simplify replacement and expansion of individual scattering mechanisms.

4. RESULTS AND CONCLUSIONS

The model is parameterized using allometric relations and geometries of several mixed-species forest stands near Injune in Queensland, Australia, for which a rather extensive ground reference data set exists. The model is thoroughly validated against SAR data from the JPL airborne SAR (AIRSAR) of the same forested sites. The range of applicability and sensitivity to various parameters are investigated. The model is flexible and modular, and can be easily adapted for application to any other forested region with arbitrary species distribution.

5. REFERENCES

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