CHARACTERIZATION OF FOREST OPACITY USING MULTI-ANGULAR EMISSION AND BACKSCATTER DATA

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1. INTRODUCTION

Soil moisture is recognized as an important component of the water, energy, and carbon cycles at the interface between the Earth's surface and atmosphere. Since the early studies in 1970s, a number of experiments using ground-based and airborne instruments operating in the microwave region of the electromagnetic spectrum have been undertaken to measure soil moisture remotely. In these campaigns, it has been collectively shown that L-band microwave measurements are reliable indicators of soil moisture changes across the landscape. This potential, coupled with advances in microwave sensor technology, has given rise to new satellite missions with L-band passive microwave instruments such as ESA's Soil Moisture Ocean Salinity (SMOS) which was launched in November, 2009 and NASA's Soil Moisture Active Passive (SMAP) mission which is scheduled for launch in 2014/5.

Current baseline soil moisture retrieval algorithms over vegetated regions for these missions are based on the tau-omega model, a zero-order transfer approach where scattering is largely ignored and vegetation canopies are generally treated as a bulk attenuating layer. In this approach, vegetation effects are parameterized by tau and omega, the microwave vegetation opacity and single scattering albedo, respectively. Although physically-based, it is simple enough for operational use at global scale. It has been validated over grasslands, agricultural crops, and generally light to moderate vegetation. Its applicability to areas with a significant tree fraction is unknown, especially with respect to specific tree types, anisotropic canopy structure, presence of leaves and/or understory. Although not really suitable to forests, Ferrazzoli et al. [1] proposed that a zero-order tau-omega model might be applied to such vegetation canopies with large scatterers, but that equivalent or effective parameters would have to be used. They determined these effective parameters by minimizing a cost function computed from the difference between measured multi-angular dual-polarized emissivity and modeled data (tau-omega model).

This paper will discuss the results from a series of field experiments using ground-based L-band microwave sensors to measure Virginia pine trees. The effective vegetation parameters are being computed from multi-angular pine tree emissivity data and their physical significance will be evaluated with two independent approaches which provide “theoretical” and “measured” vegetation characteristics. These two techniques are based on Foldy theory [2] and radar corner reflector measurements, respectively. The preliminary results demonstrate that “effective” values underestimate attenuation values compared to” theoretical” and “measured” ones. The discrepancies between “effective”, “measured”, and “theoretical” parameters will be explained by a first order scattering model developed recently [3]. The first order model 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.

2. ACTIVE/PASSIVE MICROWAVE EXPERIMENTS OVER PINE TREES

During 2008 and 2009, active/passive dual-polarized microwave measurements were acquired over a natural stand of Virginia pine coniferous trees at multiple incidence angles (15º, 25º, 35º, 45º, 55º). The supporting ground truth data were also collected. The soils of the pine tree site were loamy sand, with textures varying from 57% sand, 13.6% clay to 87% sand, 3.4% clay depending on location within the site. Tree heights average about 12 m, with DBH (diameter at breast height) varying from 4 to 29 cm. Surface roughness was very small, with an RMS roughness height < 0.5 cm. The forest floor had a surface layer of loose debris/needles and an organic transition layer above the soil.

In addition to our regular active/passive data, a separate radar experiment with and without corner reflector under trees was carried out in fall 2009. The goal of this experiment was to measure forest opacity directly by radar as an independent estimate. The data were collected at a 45º incidence angle and at about 20 different azimuth locations to get an average estimate.

The L-band microwave instrument system used in this study is called ComRAD for Combined Radar/Radiometer. The system is mounted on a 19-m hydraulic boom truck and has been developed jointly by NASA/GSFC and George Washington University. It includes a dual-pol 1.4 GHz radiometer and a quad-pol 1.25 GHz radar sharing the same 1.22-m parabolic dish antenna with a 12° field of view.

3. TECHNIQUES TO DETERMINE FOREST OPACITY

In this paper, forest optical depths were calculated by three independent techniques.

(1) *Multi-Angular Approach ("Effective"):* The principle of this approach depends on exploiting multi-angular data in order to retrieve simultaneously geophysical products such as soil moisture and vegetation characteristics [4]. The algorithm uses an iterative approach, minimizing a cost function computed from the differences between measured and modeled brightness temperature data, for all available incidence angles. It provides "effective" vegetation parameters [1]. Recently, this approach was also tested by using L-band microwave measurements over a coniferous (pine) and deciduous forest [5].

(2) *Foldy Approach ("Theoretical"):* The propagation constant is determined by the forward scattering amplitudes of each of the tree constituents, averaged over all particle sizes and angle orientations [2]. Since the forward scattering amplitude of an arbitrary particle is a complex quantity, then this medium will attenuate the wave. This technique requires detailed measurements of size/angle distributions and dielectric constants of the tree constituents (trunk, branches, and leaves). These data were obtained by destructive tree sampling. The calculated forest parameters in this technique represent "theoretical" values.

(3) *Trihedral Corner Reflector Approach ("Measured")*: Trihedral corner reflectors are widely used for external radar calibration since they yield large backscattering radar cross sections over wide azimuth and elevation angular ranges. This approach is based on the expected strong return from a corner reflector under trees. It assumes that coupling between the corner reflector and the surrounding trees is small. Basically, the difference between measurements with and without the corner reflector under trees provides the loss in propagation through trees. The forest loss factor represents the "measured" value.

4. REFERENCES

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