RECENT ADVANCES IN THEORETICAL STUDIES OF L-BAND ACTIVE AND PASSIVE REMOTE SENSING OF FORESTS

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1. INTRODUCTION

Modeling the interactions between forests and L-band microwaves is important for several objectives. The most common application, which has been the subject of several investigations, is the use of radar to monitor biomass [1,2]. Several studies have indicated lower frequencies to be the most useful for this purpose, since are less affected by the saturation problem. Although P-band measurements have proved to be better suited to this purpose, L-band is the lowest frequency band among available in present (ALOS) or near future spaceborne SAR's. In the recent years, also the problem of L-band emission from soils covered by forests has received increasing attention, mainly due to the development of the SMOS Project, a satellite carrying an L-band radiometer on board. The objective of the mission over land is soil moisture monitoring.

L-band passive measurements provide accurate estimates of moisture (the SMOS radiometric mission is going to provide soil moisture at unprecedented accuracy) albeit at large scale. However, knowledge of moisture variation at lower scales are expected to be of crucial importance where anthropic activity is important. These scales call for SAR measurements, but the difficulties in enhancing the accuracy of moisture retrieval from SAR data, which appreciably suffers the effects of roughness and vegetation, is well known by the remote sensing community. In this framework, the synergistic use of active and passive measurements is proposed.

It is recognized that these studies may benefit from model simulations. Models may single out the contributions of single components (e.g. soil and forest canopy) to the overall scattering or emission. Moreover, they may be helpful to predict the performance of future systems, when available experimental data are scarce. In this presentation we study the advantages of assembling the complementary capabilities of SAR and of a passive radiometer showing simulations of backscattering coefficient and emissivity of forests at L-band.

First, model outputs are compared with experimental data of backscattering coefficient and emissivity in order to show the model reliability. Afterwards, a parametric study will be presented with the aim of evaluating the dependence of the backscattering coefficient and of the emissivity on the biomass and on the Soil Moisture Content: different scenarios will be simulated considering various values of mean *dbh* (trunk diameter at breast height) and tree densities (per unit surface). In this way the performance of simultaneous active and passive measurements on forest sites will be highlighted.

2. THE ELECTROMAGNETIC MODEL

The model developed at Tor Vergata University is based on the radiative transfer theory, and adopts a discrete approach. Vegetation elements, such as trunks, branches, and leaves (or needles) are represented by means of dielectric objects of canonical shapes, i.e. cylinders and discs. Extinction cross sections and bistatic scattering cross sections are computed using suitable electromagnetic theories. Contributions of single elements are then combined by using a multiple scattering algorithm. The same algorithm is used to combine vegetation scattering with soil scattering, and the bistatic scattering coefficient is computed. The value in the backward direction gives the backscattering coefficient, while the emissivity is obtained by the energy conservation law, i.e., integrating the bistatic scattering coefficient through the whole upper hemisphere. Details of the procedure are given in [3, 4], and are not repeated here.

In the recent version, also the contribution of the litter has been included. The soil is assumed to be overlaid by a dielectric layer, representing the litter [5]. Furthermore, using allometric equations and empirical formulas derived by literature, the geometrical and physical variables required by the electromagnetic model can be computed, according to the procedure indicated in details in [6].

3. COMPARISON WITH EXPERIMENTAL DATA

In the past years, several campaigns were carried out with the NASA/JPL AIRSAR in order to study the correlations between radar backscatter and forest parameters. They were accompanied by ground measurements like those performed in Hawaii [2] which were used as input to the active Tor Vergata model. Also, data collected during the MAESTRO-1 campaign over the Dutch Flevoland site are available. Comparisons between model data and backscattering measurements at L-band have been performed and will be shown. The overall Root Mean Square (RMS) of the model error indicates a generally good correspondence.

Simulated values of emissivity were compared with results of various experiments. A multitemporal set of brightness temperatures was collected during the “Bray 2004” experiment in Les Landes forest [7], and comparisons with model simulations are given in [5]. Model outputs were also compared against experimental data collected during the autumn 2004 in the Jülich site (Germany) [8] and with airborne radiometric measurements over forests were carried out in Tuscany in summer 1999 and winter 2001 [9]. Other valid comparisons were done with radiometric measurements collected by the L-band AMIRAS instrument over boreal forests in Finland [10].

The observed forest sites included both broadleaf species and coniferous species. In the simulations, available ground data has been used as input for the growth model, in order to get all the variables for describing the forest geometrical parameters. In the presentation, the comparisons will be critically summarized, showing that the model reproduces well the absolute values, as well as the effects of biomass and seasonal variations.

4. PARAMETRIC STUDY

Taking advantage of the model developed at Tor Vergata, which is able to simulate both backscattering coefficient σ^0 and emissivity *e* under a unified approach, parametric simulations of σ^0 and *e* will be presented for the case of broadleaf and coniferous forests. Simulations at L-band will be shown focusing on two applications: sensitivity to soil moisture beneath forest and sensitivity to biomass. The theoretical performance of simultaneous active and passive measurements will be presented under different observation angles and soil roughness conditions. Furthermore, the dependence on tree *dbh* and tree density will be studied. In particular, it can be observed that, due to the opposite trend of σ^0 and *e* wrt Soil Moisture Content, the quantity $\sigma^0 /(1-e)$ maximizes the sensitivity to forest biomass and it is scarcely influenced by SMC, also for very low biomass values. Therefore, it can be proposed as a parameter which decouples the vegetation variables from the soil variable.

5. REFERENCES

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