Soil moisture effect on microwave emission under forest canopies

S. Paloscia, P. Pampaloni, E. Santi, S. Pettinato

CNR-IFAC, Firenze (Italy)

A. Della Vecchia, P. Ferrazzoli, L. Guerriero

DISP, Univ. TorVergata, Roma (Italy)

Introduction

- The increasing interest in environmental problems brought the forest ecosystems right in the foreground due to their role in hydrological and biochemical processes.
- In particular, the role of soil moisture under forest canopies is important for the evapotranspiration processes and its estimate can improve the understanding of gas and water exchanges between soil and atmosphere through vegetation.
- Experimental and theoretical studies have shown that microwave remote sensing techniques can contribute to the study of tree parameters.

Outline

- Description of the experiments and analysis of the experimental data
- The effect of forest biomass and soil moisture on microwave emission at L-band
- Sensitivity of L-band emission to soil moisture
- Model simulations and comparison with experimental data

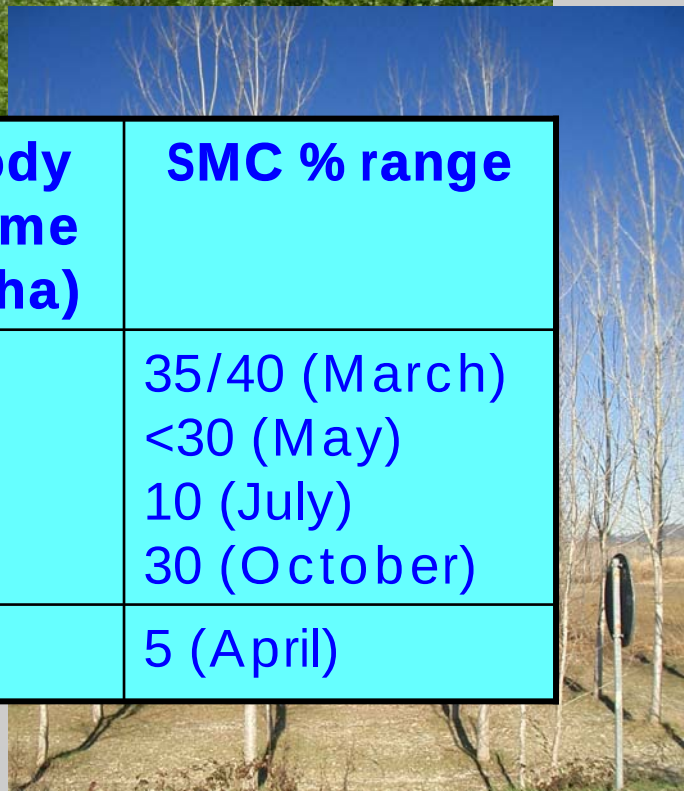
The Experiment

Frequency	Pol.	Incidence Angle	Accuracy
1.4 GHz	V, H	10^o- 60^o	± 0.5 K
6.8 GHz	V,H		
10 Ghz	V,H		
19 GHz	V,H, ±45		
37 GHz	V,H, ±45		

Radiometric measurements at L- (1.4 GHz), C- (6.8 GHz), X- (10 GHz), Ku- (19 GHz), and Ka-band (37 GHz) frequencies were collected, by using an hydraulic boom, in different seasons (winter, spring summer and fall) over some forest plots of poplar (Populus alba) and pine (Pinus italica) in Tuscany

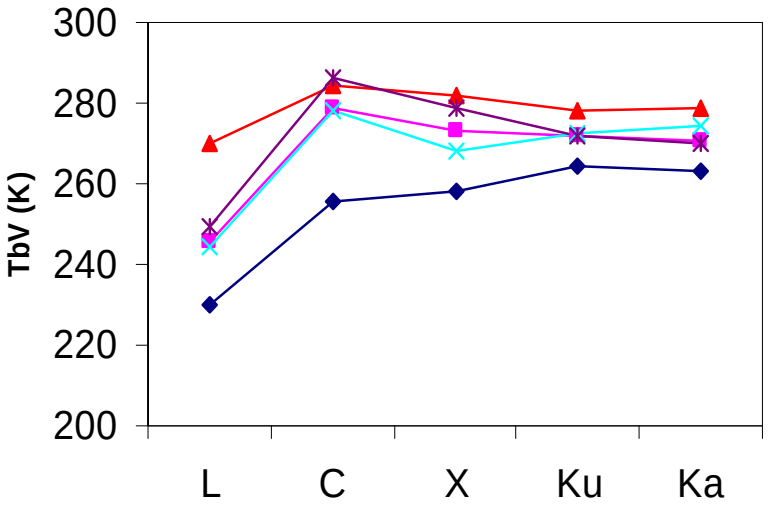
Pine

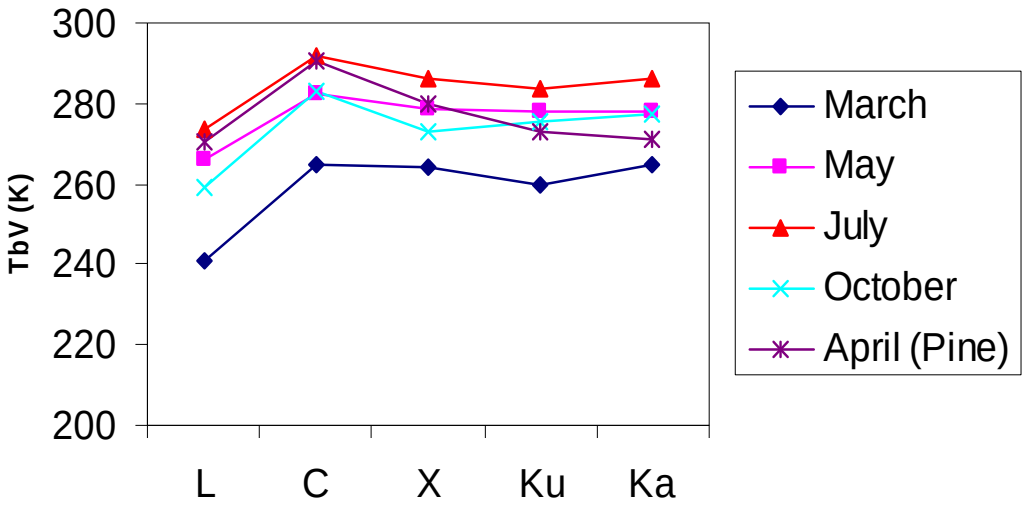
Poplar



	Tree density (m^{-2})	Tree Height (m)	Trunk Diameter (cm)	Woody Volume (m^3/ha)	SMC % range
Poplar	340	18	21.5	160.0	35/40 (March) <30 (May) 10 (July) 30 (October)
Pine	1156	4.25	18.2	131.6	5 (April)

Spectra





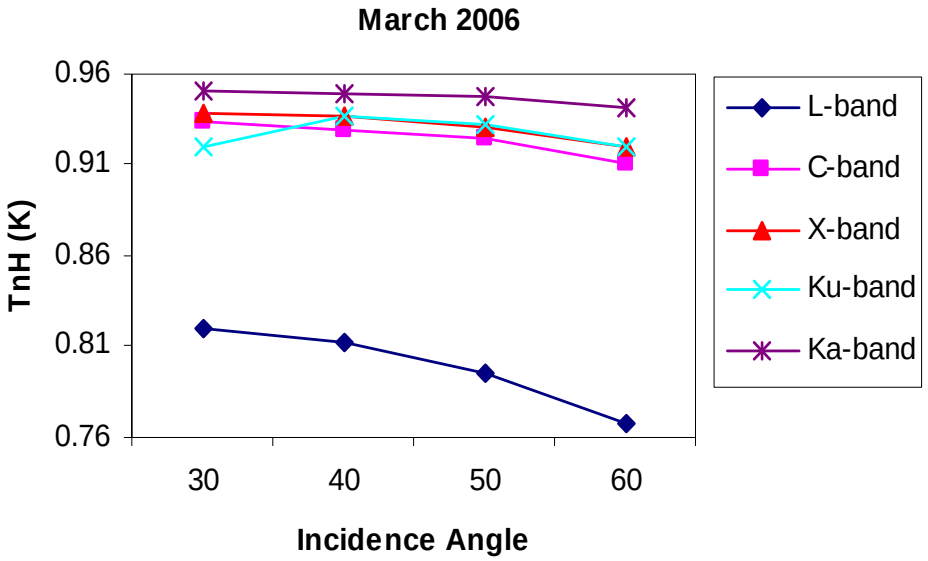
Theta=60°

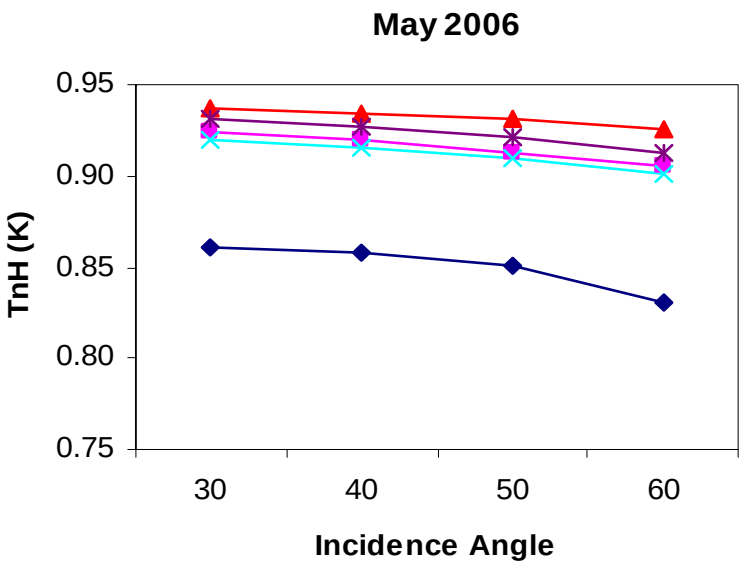
Theta=30°

Angular trends

Poplar (March & May)

Tn=Tb/Tir





SMC 35-40 %

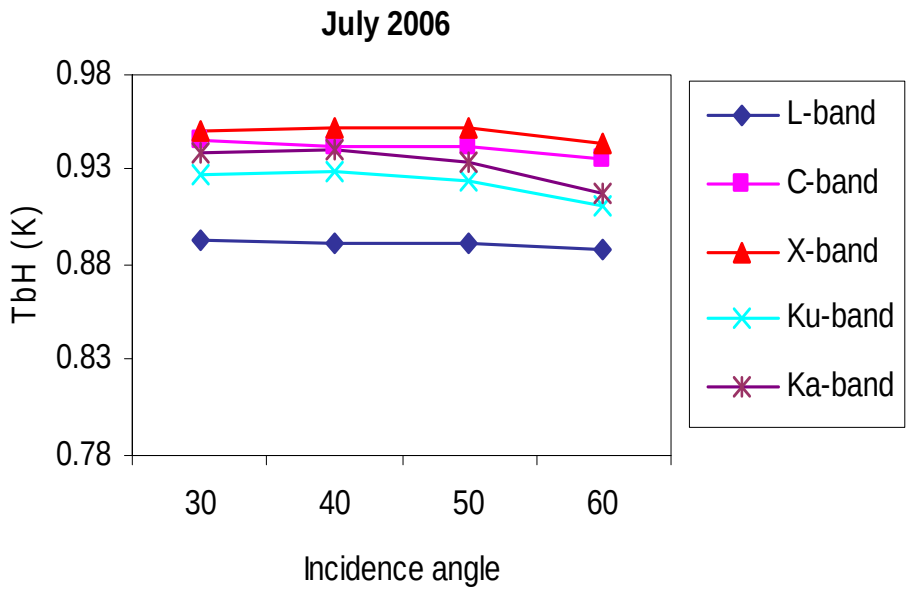
SMC<30 %

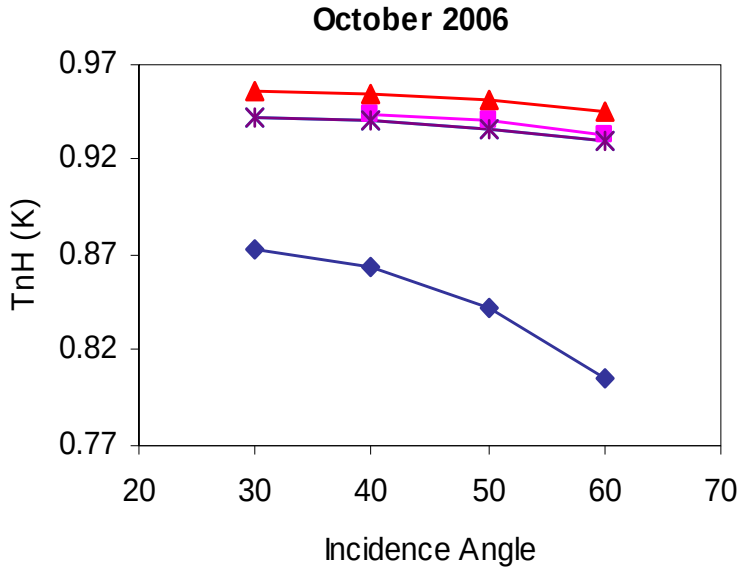
Undestory (0.7kg/m2)

Angular trends

Poplar (July & October)

Tn=Tb/Tir





SMC 10 %

Dry, rough bare soil

SMC 30 %

Bare, rough soil

Spectra & Angular trends

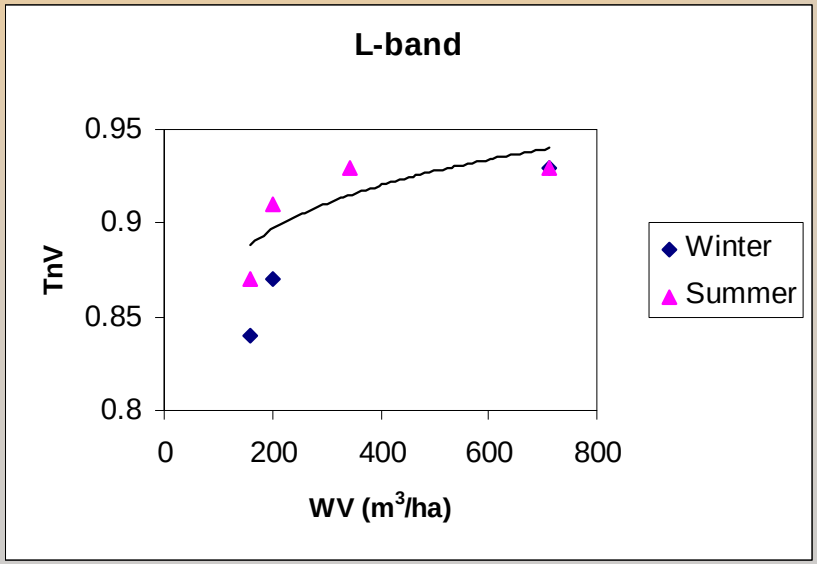
- In spectra, Tb is increasing from L to C bands and after that flat or slightly decreasing
- The difference between March and July at L-band is mainly due to the changes in SMC
- Pines show a higher emission with respect to Poplars
- The angular trend is almost flat, mainly at the high frequencies. At L-band the trend is flat in July, when vegetation is at its maximum development and SMC is low.
- Differences in L-band emission are mainly due to the changes in soil conditions (soil moisture and understory)
- For dense forests, the sensitivity to soil moisture is small. Further experiments are needed, especially for less dense forests

The effects of forest biomass and SMC

- In order to better investigate the effect of forest biomass and soil moisture under forest canopies, data collected in the past, during airborne campaigns carried out on some forest plots in Tuscany, were considered in addition to poplar data
- Data collected in both winter and summer were taken into account
- For this investigation on the effects of soil moisture, forests with Woody Volume ≤ 200 m3/ha were selected

The sensitivity to forest biomass

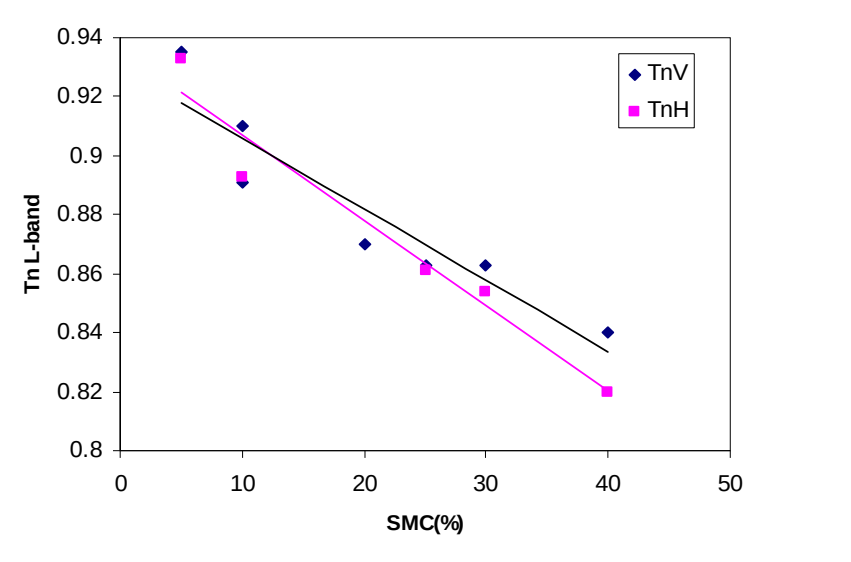
- By comparing winter and summer measurements it is evident that, at low values of biomass, the difference between summer and winter values of Tn is appreciable and probably due to the SMC effect, whereas at high values of biomass the difference in Tn is negligible



$TnV=0.03Ln(SMC) + 0.72$

$R^2 = 0.65$

Sensitivity to SMC



$TnV = -0.002SMC + 0.93 \quad R^2 = 0.88$

$TnH = -0.003SMC + 0.94 \quad R^2 = 0.95$

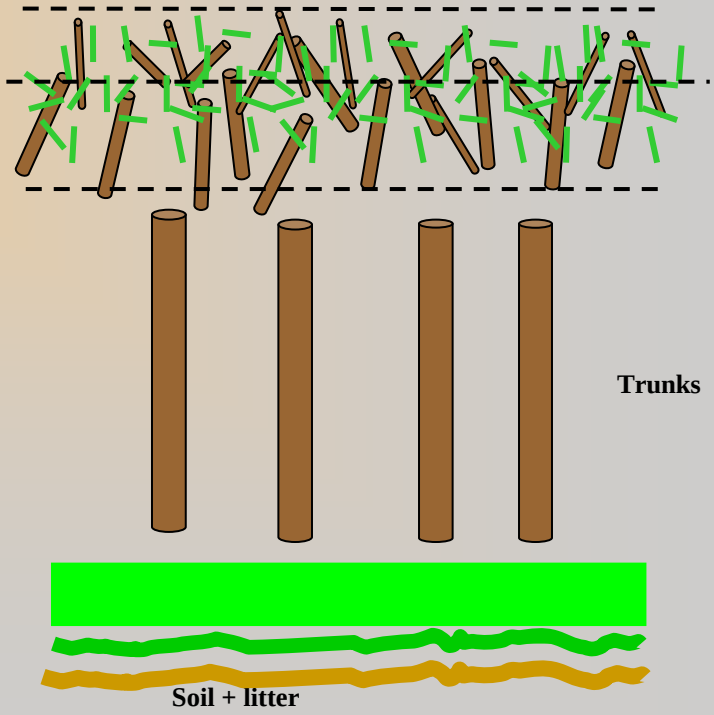
By considering forests with biomass ≤ 200m³/ha, the direct relationship between Tn at L-band and SMC is evident.

Airborne data were collected in V pol. only

Model Simulations

The sensitivity to soil moisture has been investigated also by using a discrete radiative transfer model (Ferrazzoli and Guerriero, 1996):

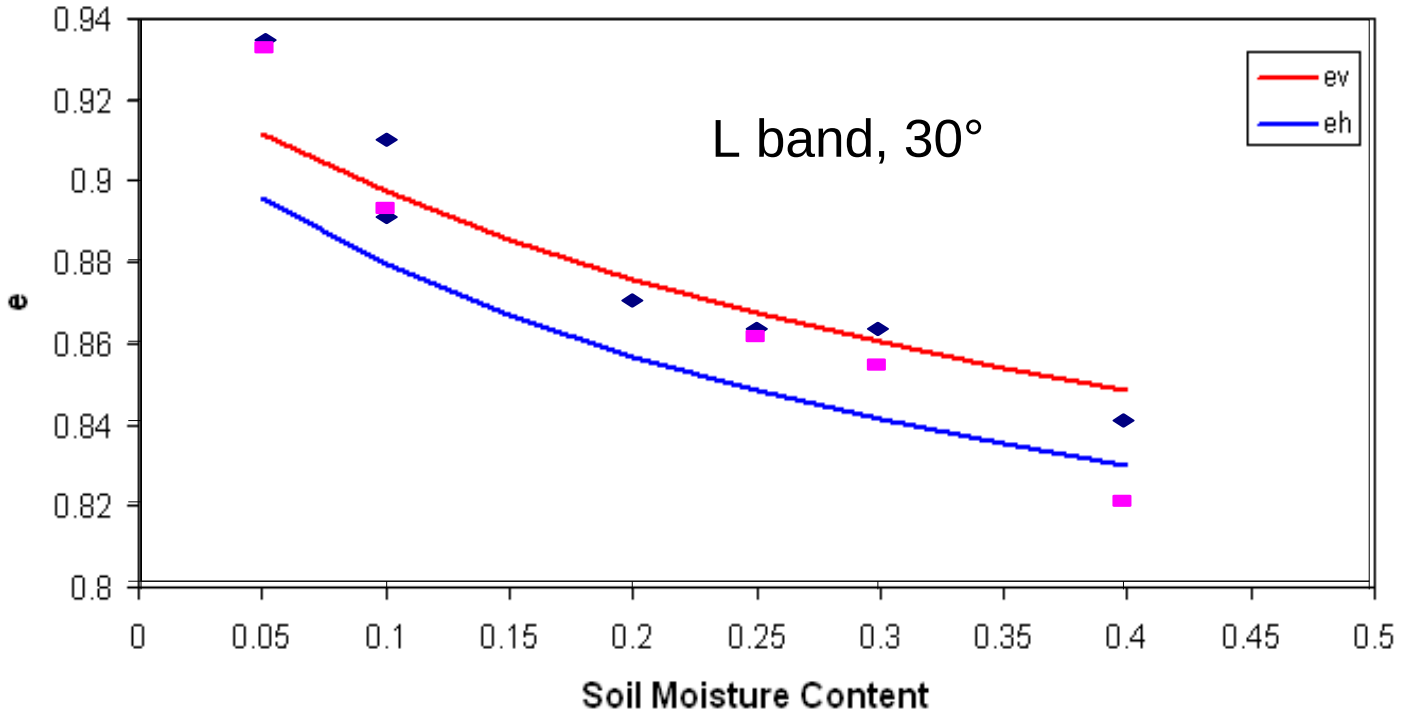
- **Trunks and branches as cylinders,**
- **Leaves as discs,**
- **Soil as a half-space,**
- **Litter as a dielectric layer with multiple reflections at interfaces (Della Vecchia et al., 2007)**



Model Simulations

First of all, the e(SMC) trend has been simulated with:

- **soil, trunk, and leaf variables derived by ground data of Poplar plot**
- **branch variables by allometric equations**

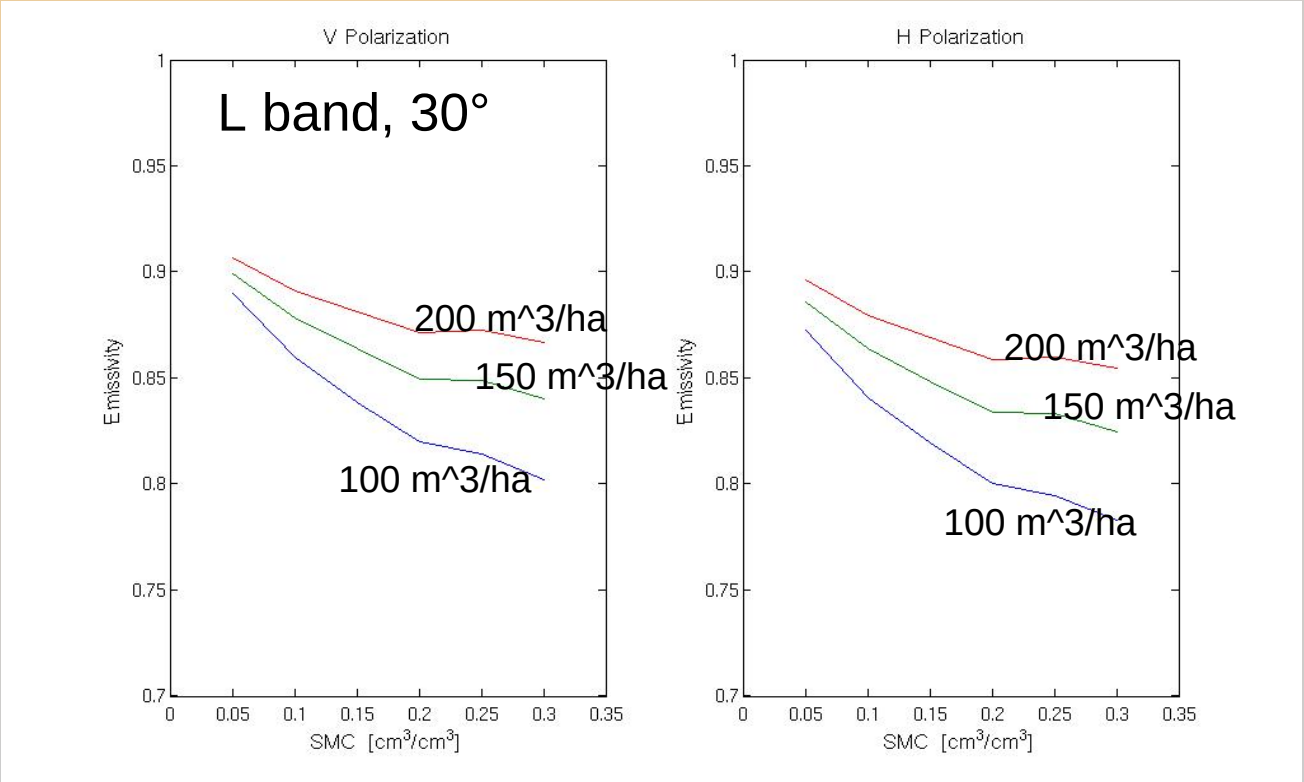


Model Simulations: Extended to natural forests

Input data were related to overall volume by allometric equations, whilst litter thickness was related to leaf biomass.

We observe that e(SMC) slopes are lower, due to:

- **litter**
- **higher values of (branch volume)/(trunk volume) ratio**



Conclusions - I

- Radiometric microwave experiments were carried out on two plots of poplar and pine in Tuscany. Measurements were performed at L, C, X, Ku and Ka bands at different incidence angles, in H and V polarizations.
- Frequency spectra show that Tb is generally increasing from L to C bands and after that almost constant. Pine showed higher values of emission at all frequencies.
- The angular trends were generally flat at the high frequencies. At L-band the trend is flat in July, when vegetation is well-developed and SMC is low.
- These new data were compared with those collected by aircraft in past years on some forest plots in Tuscany

Conclusions - II

- Looking at the sensitivity of L-band emission to forest biomass, a difference between *Tn* collected in winter and summer was observed, but only at relatively low values of biomass. This difference could be attributed to the variations of soil moisture
- By directly comparing Tn at L-band vs. SMC, for forests with WV≤ 200m^3/ha, an evident correlations was observed, with high determination coefficients at both V and H polarizations (R^2=0.88 and 0.95)
- Model simulations reproduce fairly well the e(SMC) trend for the Poplar plot.
- The same model predicts lower values of sensitivity to SMC for natural forests, with the same total woody volume. These lower values can be explained by the presence of litter and the greater woody volume of branches.