Parameterization of the emissivity of forests at L-band (L-MEB in the Level-2 SMOS algorithm)

Jean-Pierre Wigneron, Arnaud Mialon, Jennifer Grant, Yann H. Kerr, Jean-Christophe Calvet, Marc Crapeau, François Demontoux, Maria-José Escorihuela, Silvia Enache Juglea, Heather Lawrence, et al.

Parameterization of the emissivity of forests at L-band (L-MEB in the Level-2 SMOS algorithm)

J-P Wigneron, A. Mialon, J. Grant, Y. Kerr, J-C Calvet, M. Crapeau, F. Demontoux, M-J Escorihuela, S. Juglea, H. Lawrence, V. Mironov, N. Novello, K. Saleh, M. Schwank et al.

Bordeaux, 21 Oct., 2009

INRA
Institut National de la Recherche Agronomique

CESBIO

vrije Universiteit amsterdam

Outlines:

- L-MEB used in the Level-2 SMOS algorithm
- Improving L-MEB: key questions?
- recent results over forests

2. SMOS (Soil Moisture and Ocean Salinity)

Low spatial resolution: ~ 35-50km
Revisit time: Max. 3 days
Sensitivity ~ 2K over land

Goal of accuracy in SM: ~ 0.04 m3/m3

Launch : Nov 2, 2009

Retrieval algorithm: using multiangular and dual polarization TB

Soil moisture & vegetation opacity (τ), ...

-**Level-2 algorithm completed,** now validation activities

the Expert Support Laboratory (ESL) includes CESBIO, IPSL, TOV-Roma

-**based on a forward model L-MEB** (L-band Microwave Emission of the Biosphere)

L-MEB (L-band Microwave Emission of the Biosphere model)

[Wigneron et al., *in book* 06, RSE 07]

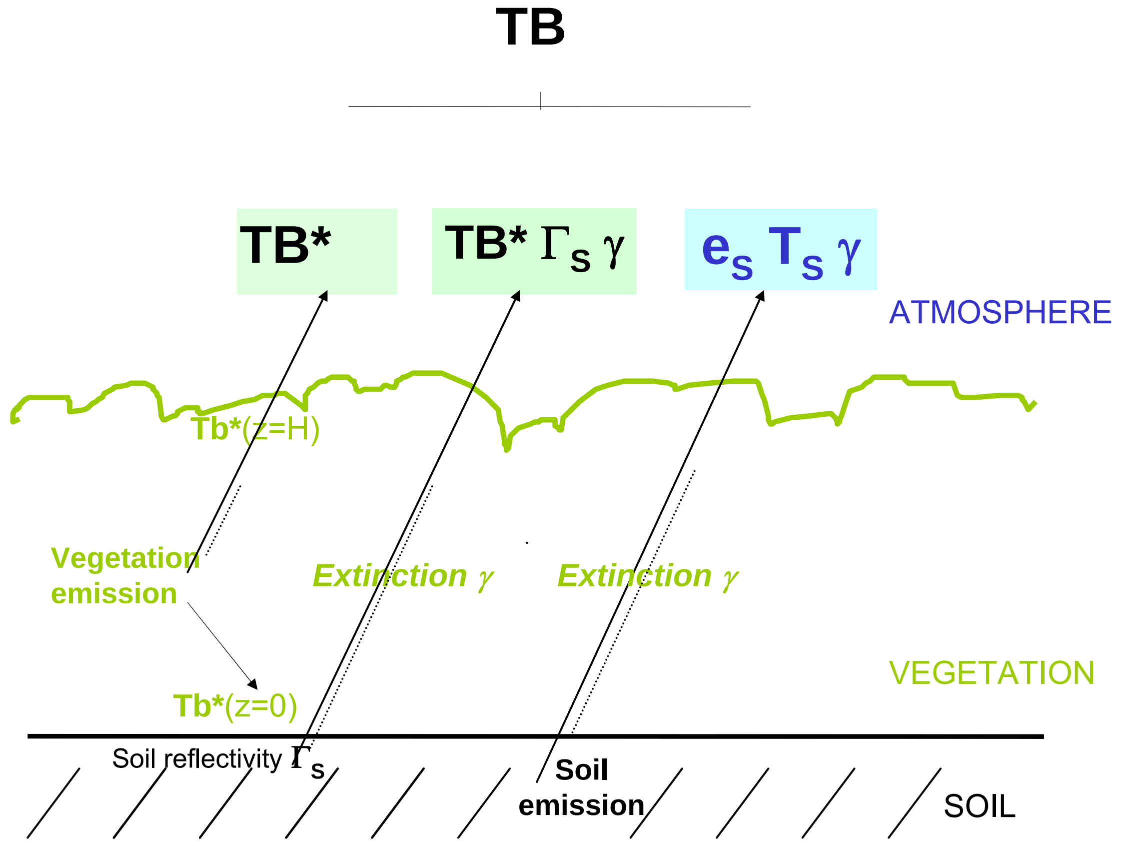
- L-MEB = result of an extensive review of the current knowledge of the microwave emission from vegetation

- Based on based on R.T. modeling ($\tau-\omega$ model for vegetation)
  & specific parametrisations for roughness, T_effective, angular effects, etc.

- Parameter calibration for a variety of soil/vegetation types
  (crops, prairies, shrubs, coniferous, deciduous forests, etc.)

- Valid ~ in the 1- 10 GHz Range (L-, C-, X-MEB)

Vegetation Emission



$$TB = TB^* + TB^* \Gamma s\, \gamma + (1-\Gamma s)\, Ts\, \gamma$$

TB^* = émission directe de la végétation

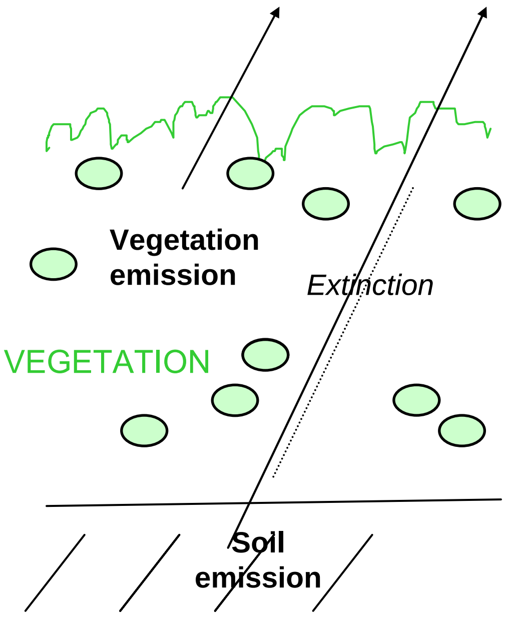
$TB^* \Gamma s\, \gamma$ = émission de la végétation, réfléchie et atténuée

Γs = réflectivité du sol

γ = facteur atténuation de la végétation

$es\, Ts\, \gamma = (1-\Gamma s)\, Ts\, \gamma$ = émission du sol atténuée

$$TB = TB^* (1 + \Gamma S.\gamma) + (1-\Gamma S).Ts.\gamma$$



avec, $TB^* \approx (1 - \gamma).(1-\omega)\, Tv$ (émission directe vég)

$\gamma = \exp(-\tau / \cos\theta)$ (facteur d'atténuation)

Variables principales de surface:

(i) Γs = réflectivité du sol = f (**SM (m3/m3),** texture, rugosité)

(ii) τ = épaisseur optique ≈ b. **VWC**

VWC = contenu en eau de la végétation (kg/m2) (≈ Biomasse en eau)

b = f(type de végétation)

(iii) **Tv= Température du couvert** (Tv ≈ Ts)

(iv) ω =albedo f(type de végétation)

TB est fonction de:

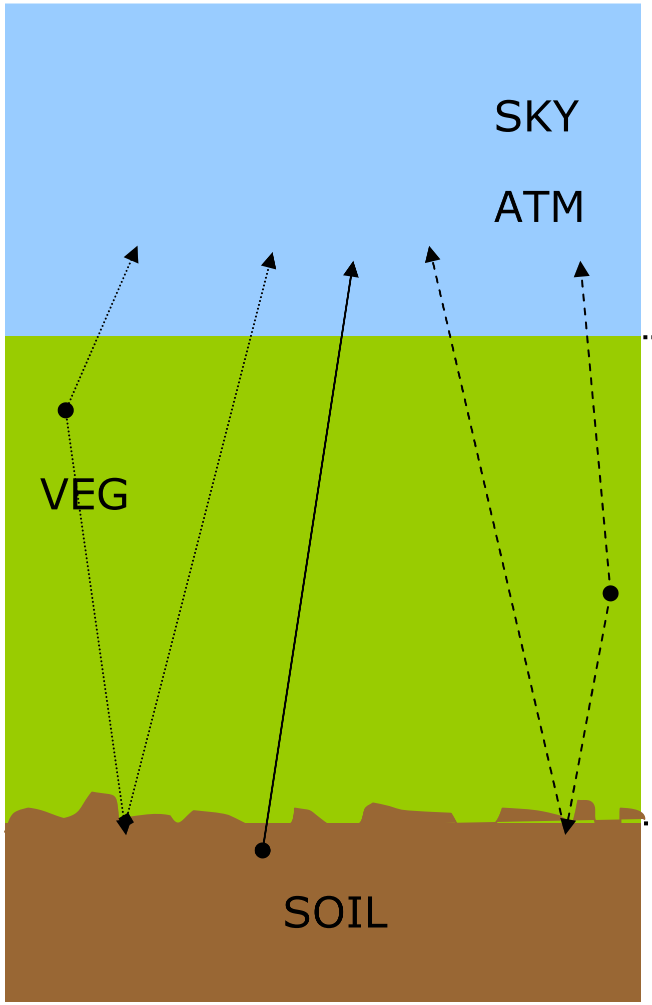
(1) SM (m3/m3),

(2) la biomasse (τ)

(3) Température de surface (Tv ≈ Ts)

autres: type de végétation (b, ω) et de sol (texture, rugosité…)

L-MEB (L-band Microwave Emission of the Biosphere model)



param: HR(SM), NRv, NRh, w0, wb

Zero order solution of radiative transfer equations:

$$TB_{veg}=(1-e^{-\tau/\cos(\theta)})(1-\omega)T_{veg}(1+\Gamma_{soil}e^{-\tau/\cos(\theta)})$$

Accounting for angular effects on τ:

$$\tau(\text{nadir}) = b\ VWC = b'LAI+b''$$

$$\tau_p = \tau_0(\text{nadir})\ .\ (\cos^2(\theta)+tt_p\ \sin^2(\theta))$$

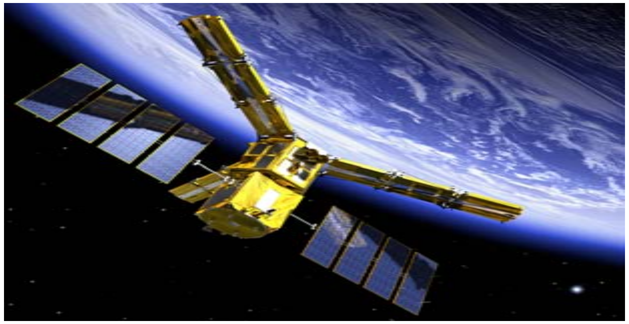
param.: τ_nadir, ω, ttv, tth, b', b''

Roughness, effective temperature:

$$\Gamma_{soil} = \Gamma_{soil\_smooth}\ e^{-HR\ \cos Np(\theta)}\ \text{with}\ HR\ (SM)$$

$$T_G = T_{depth} + C\ (T_{surf} - T_{depth}),\ C = (SM/W0)^{wb}$$

Key questions still pending:



- soil emission: (JC Shi, M. Schwank, A. Mialon, H Lawrence, MJ Escorihuela, …)
  - -surface roughness: link between model / geophysical (STD, Lc, …) param.?
  - -effective roughness = f(SM)?,
  - -model accuracy at rather large angles ($\theta \geq 40°$)?
- soil permittivity: (F. Demontoux, V. Mironov)
  - -model accuracy over a large range of soil types (use of Mironov routine for high sand fraction?)
- low vegetation (E. Lopez, B. Hornbuckle, C. Matzler, P. de Rosnay, JP Walker, …)
  - -dependence of model parameters on the vegetation structure?
  - -relating optical depth TAU with Veg. Water content, or LAI?
  - -effect of interception (flagged currently using PR)?
- natural environment (forests, prairies, etc.): (K. Saleh, M. Schwank…)
  - -modeling litter and interception effects (dry vegetation)
  - -optical depth of forest (large variability boreal -> tropical forets?)
  - -effect of structure, understory?

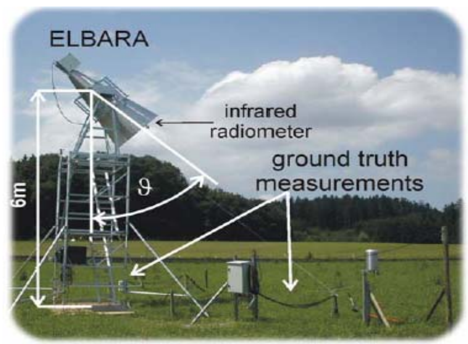
Studies: based on experimental activities for a large range of soil and vegetation conditions:

- SMOSREX (CESBIO, CNRM, INRA, ONERA),
  soil-fallow, Toulouse site, 2003-2009

- BRAY-04-08 (INRA), coniferous forest, Bordeaux
  EMIRAD (TUD), 2004-2008

BRAY - EMIRAD

- ELBARA (ETH, U. of Bern), grass,
  deciduous forest 2004-2006



- …

MELBEX-
EMIRAD
ELBARA

Forest emissivity:

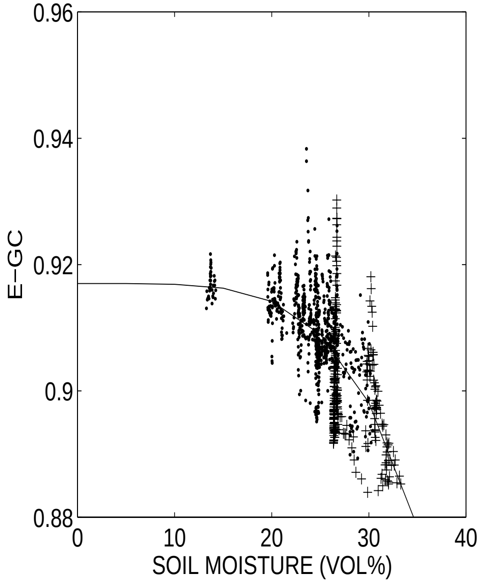
BRAY'2004 experiment: first long term TB exp. over a pine forest (Les Landes, INRA FLUXNET site) **[Grant et al., 2007, 2008, 2009]**

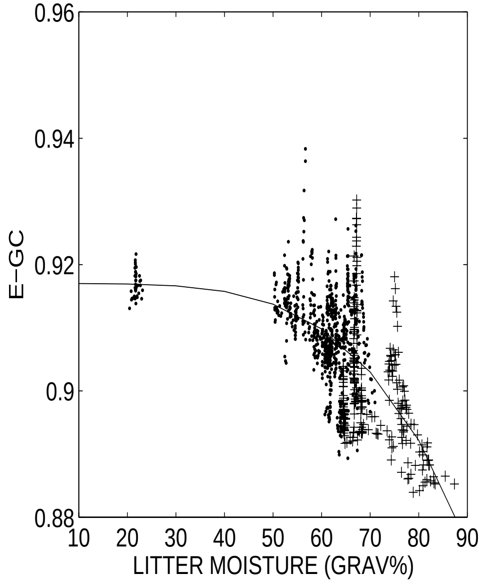
FOSMEX: same over a deciduous forest (JULICH site, ETH Zürich studies) **[Guglielmetti et al., 2007]**

Δ TB ~ 12-15 K between dry / wet conditions
(Δe ~ 0.04)

Emirad (TUD, Copenhagen)

Emissivity = f(SM, LM)



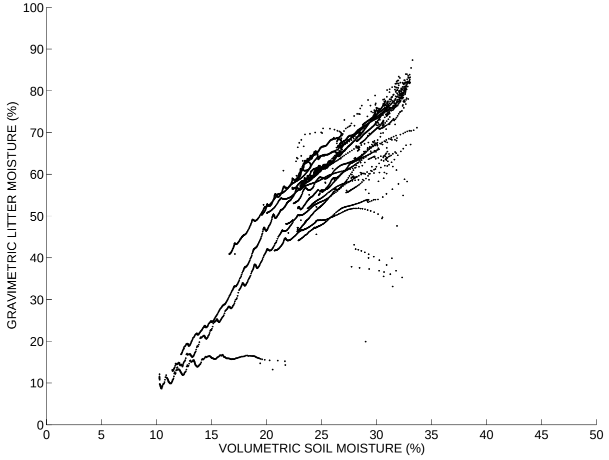


Litter & understory effects

-strong relation between Soil & Litter moisture

-Question pending: Are limited emissivity variations due to soil, litter, understory, trees..; ?

Litter Moisture



Soil Moisture

[Grant et al., RSE, 2007]

Bray coniferous forests

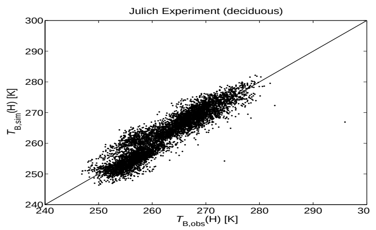
Combined analysis of Bray (coniferous, INRA site), FOSMEX (deciduous, Julich site), NAFE'06 (Eucalytus, Australia)

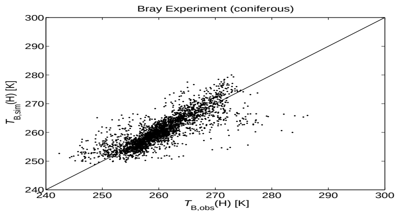
[Grant et al., 2007, 2008, 2009]

Accuracy of L-MEB: ~ 3K,

-surface roughness: HR ~ 1 - 1.2 (both sites)
-ω = 0.07
-low angular effects: ttP ~ 0.7 - 1

-tau_$_{NAD}$ ~ 0.4-0.6 (sparse coniferous –eucalyptus forests)
-tau_$_{NAD}$ ~ 1 (dense deciduous forest)

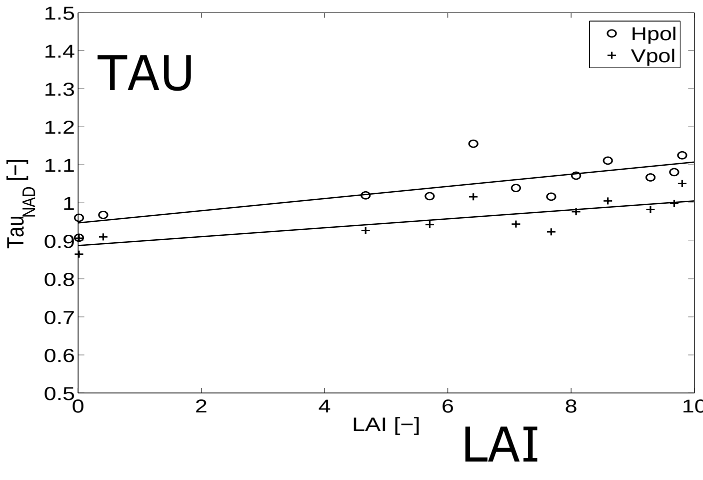




-Transmissivity Γ ~ 0.35 -0.65 at nadir (~50%)
→ surface effects are strong

-low effects of leaves: Δ Γ ~ 0.03

-low sensitivity to SM is not explained by trees



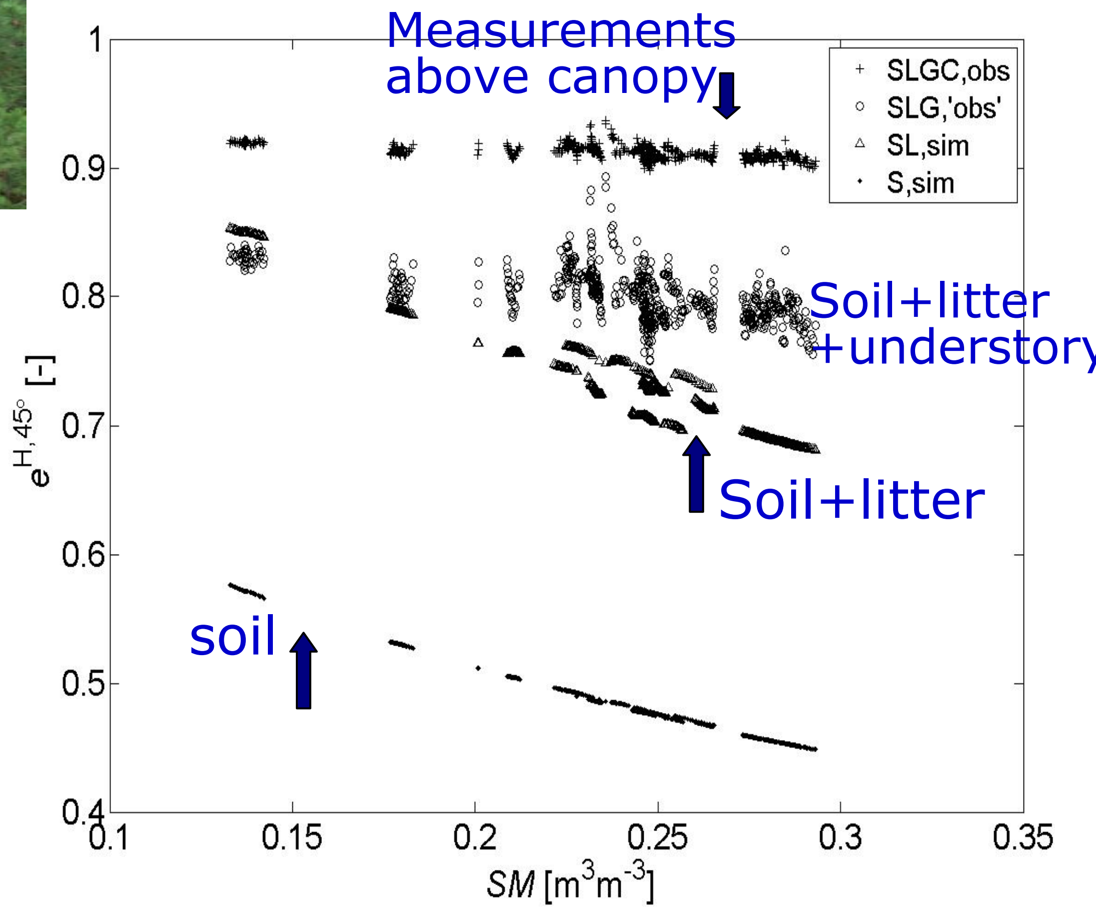
Modelling soil –litter based on a coherent approach (Wilheit model) and dielectric transition model

[Grant et al., 2009]

Over the Bray coniferous site:

-Litter: → increase in emissivity, but low effects on sensitivity

-Combined effects of understory and trees → sensitivity



Soil Moisture

Forests signatures - Conclusions



-L-meb: ~3K accuracy for long term experiments over 3 forest sites (coniferous, deciduous, eucalytus)

-low sensitivity to soil moisture (~10-15K change in TB, Δe ~ 0.04) could be related to:

-litter (effects depend a lot on moisture and thickness)

-understory (+ strong interception effects by dead vegetation material)

-trees (transmissivity ~ 50% over temperate forests)

-generalisation to other forest types…