SMOSREX: A Long Term Field Campaign Experiment for Soil Moisture and Land Surface Processes Remote Sensing


- Introduction: SMOSREX several-year experiment
- Observing results at various temporal scales
- Investigations in passive microwave radiometry
1. Introduction: SMOSREX experiment

Context:
SMOS: Satellite project (2007) for Global Soil Moisture and Ocean Salinity
SMOSREX: Surface Monitoring Of Soil Reservoir EXperiment
Part of PIRRENE programme (http://wwwe.onecert.fr/pirrene/)

Objectives:
- Development of L-Band direct and inverse algorithms.
- Use of soil moisture remote sensing in soil plant atmosphere interactions studies.

Use of different tools:
- Multi frequency remote sensing (L-Band, TIR, IR, VIS)
- Field measurements (ground, meteo, vegetation)
- Radiative transfer models and land surface models

Long term field experiment 3 years with remote sensing (2003-2005).
Experimental site
ONERA (Fauga-Mauzac, $43^\circ 23' N, 1^\circ 17' E$, at 188m height), located in South-West of France

Meteorological measurements 2001-2004:
Cumulative precipitation respectively: 621, 677, 574, 634 mm
Ground measurements
Meteorological station:
automatic and continuous acquisition (with a 30 min time step) of precipitation, air temperature at 2m, surface fluxes (H/LE), radiative fluxes (solar and infrared), wind speed and direction, dew, air pressure

Soil moisture profiles:
Delta T device probe at 0-5cm (x4), 10cm (x3), 20cm (x3), 30cm (x2), 40cm (x2), 50cm (x2), 60cm (x2), 70cm, 80cm, 90cm.

Soil temperature profiles:
PT100 at 1cm, 5cm, 20cm 50cm and 90 cm

Manual measurements: soil density, soil roughness, soil texture, gravimetric soil moisture, biomass, LAI
SMOSREX:
Multi frequency acquisition

- TIR Pyrometers (KT15): at 40° incidence
- VIS to IR Luminancemeter (Cimel) 5-band:
  837(91), 648(53), 549(85), 450(40), 1640(165) nm

- LEWIS: L-band (1.4GHz)
  L-band radiometer for Estimating Water In Soils

Soil profiles

Bare soil

Fallow

Scanning mode 8 time per day allows LEWIS to monitor Tb on both fallow and bare soil.

at 6 incidence angles from 20 to 60°
2. Observing results 2003-2005

LEWIS radiometer measures the surface brightness temperature, $T_b$ at both $v$ and $h$ polarizations:

$$T_{bv} = e_v T_{eff}$$

and

$$T_{bh} = e_h T_{eff}$$

where $T_b$ and $e$ are the brightness temperature and emissivity.

In order to remove the dependency on surface temperature we use the Microwave Polarization Difference Index, $MPDI$ (or Polarization Ratio):

$$MPDI = \frac{T_{bv} - T_{bh}}{T_{bv} + T_{bh}}$$  \hspace{1cm} (1)
Rain effect - April 2003

SMOSREX measurements on fallow and bare soil

April 2003

TBh

MPDI

Soil Moist

Vol. Soil Moist.

Fallow

Bare soil

Precipitation on fallow and bare soil

Rain

Rainfall on both fallow and bare soil
Soil freezing January 2005

SMOSREX 2005

Brightness temperature

Soil Temperature at 1cm

Soil Moisture and MPDI - bare soil

Relation MPDI/SM

Vol Soil Moist. vs Day of Year

R² = 0.785
Relation MPDI at 40° / soil moisture on bare soil

Stable relation over long time scales including several soil density and roughness modifications.
Standing vegetation and litter intercept and absorb large amount of precipitation. Soil emission significantly attenuated and vegetation emission increases \(\Rightarrow\) Need to detect periods of possible retrieval.
3. Large range of investigations in microwave radiometry

- Long term feature and parameterization of effective temperature
- Bare soil roughness
- Effect of intercepted water by vegetation and litter on the signal
- Multi-spectral assimilation in land surface models

All of these investigations are critical to address the soil moisture retrieval from passive microwave radiometry
3.1. Effective temperature and soil roughness

The $T_{\text{eff}}$ relates $T_b$ to the emissivity ($e$): $e = T_b/T_{\text{eff}}$

**Temperature sensing depth:** the top thickness of the profile below which the radiated energy is divided by a factor $exp(1)$. Temperature sensing depth is larger when soil is getting dry.

For bare soil, strong annual cycle of the penetration depth, down to 30cm.

Long term data set ⇒:

New parameterization of effective temperature: Holmes et al., 2005
Soil dielectric roughness increases with the penetration depth:
Escorihuela et al., 2005
3.2. Effect of intercepted water on the signal

Modeling approach (LMEB) and long term data set allow to separate the different contributions of the vegetation reservoirs to the vegetation optical thickness.

⇒ Important part of the signal due to litter water content and intercepted water
Saleh et al. 2005
Effect of intercepted water on the signal

On fallow plot: rain ⇒ TBv-TBh decreases ⇒ MPDI decreases.

Interception flag MPDI < 0.02

<table>
<thead>
<tr>
<th>MPDI</th>
<th>Rain - 12h</th>
<th>No Rain -12h</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPDI &lt; 0.02</td>
<td>14.6</td>
<td>2.5</td>
<td>17.1</td>
</tr>
<tr>
<td>MPDI &gt; 0.02</td>
<td>12.9</td>
<td>70.0</td>
<td>82.9</td>
</tr>
<tr>
<td>Total</td>
<td>27.5</td>
<td>72.5</td>
<td>100.0</td>
</tr>
</tbody>
</table>

- Direct approach: effect of rain on the signal
  Rain in the last 12h ⇒ MPDI < 0.02 in 53%
  No rain ⇒ MPDI > 0.02 in 97%

- Inverse approach: detection of periods with intercepted water
  MPDI < 0.02, ⇒ rain in the last 12h in 85% of the cases
  MPDI > 0.02, ⇒ no rain in the last 12h in 84% of the cases

Saleh et al. 2005
4. Conclusions

- SMOSREX: for the preparation of SMOS mission, long term data set of L-band temperature as well as ground measurements and multi-spectral remote sensing on both natural fallow and bare soil.

- Long term features of the microwave emission in various conditions allows to address the following issues, critical for soil moisture retrieval:
  - penetration depth and related modification of soil dielectric roughness
  - Very strong effect of intercepted water on vegetation and litter on the microwave emission and consequence for soil moisture retrieval
  - definition of interception flags from multi-angular and bi-polarized signal, suitable to define periods of possible soil moisture retrieval.

- Open news investigations in land surface processes modeling and multi-frequency assimilation in land surface schemes
  - necessity to improve the modeling of the litter microwave emission.
  - interception flags for other vegetation types and up-scaling to satellite pixel size.
L band radiometry

LEWIS L-band radiometer for Estimating Water In Soils

- Cornet Antenna
- 1.4 GHz,
- H and V Polarizations
- Beamwidth 13.5 °
- 3m long, 200kg
- Thermal regulation: 47.20 °C
- No rear lobe
- Automatic scanning mode

Informations:
PIRRENE: http://www.eonecert.fr/pirrene/
SMOS & SMOSREX: http://www.cesbio.ups-tlse.fr/us/indexsmos.html