UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH

Monitoratge de la humitat del terreny mitjançant radiometria de microones i reflectometria amb senyals d'oportunitat (GNSS-R)

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i la resta l'equip de radiometria de microones de la UPC

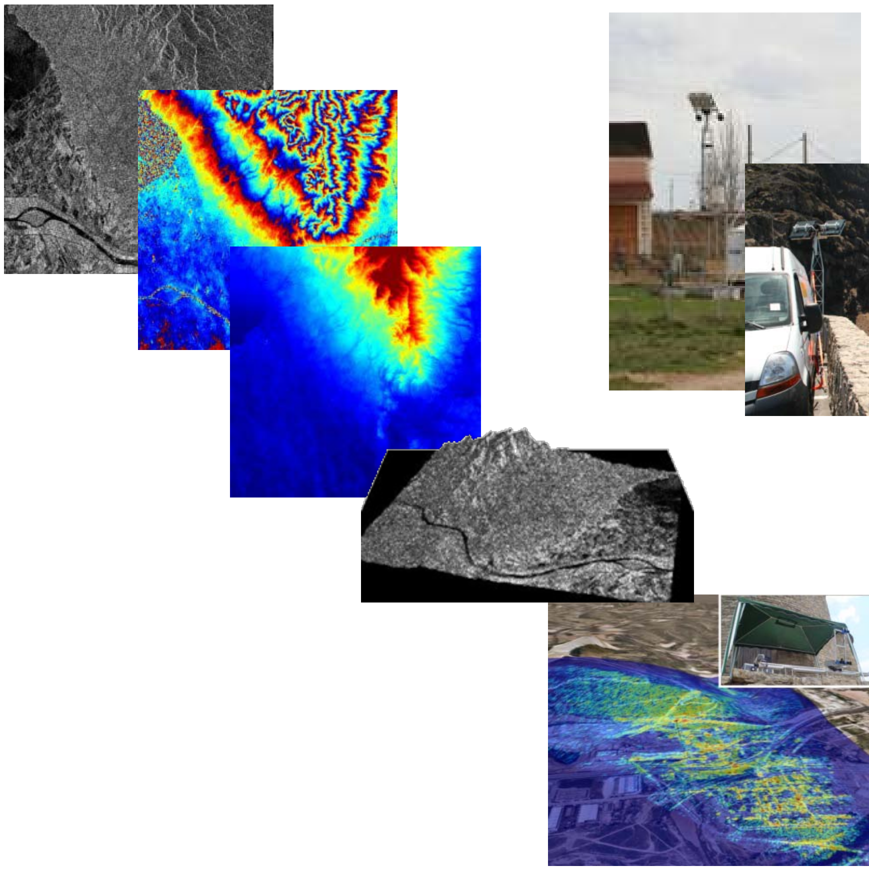
Remote Sensing Lab, Universitat Politècnica de Catalunya
http://www.tsc.upc.edu/rs

Outline:

- Remote Sensing Lab at UPC
- Passive Microwave Remote Sensing Activities
- Microwave radiometry
  - Field Experiments
  - Soil Moisture Retrieval and Pixel Disaggregation
- GNSS-R:
  - DDM
  - Interference pattern technique
- Conclusions: state of the art and current trends

UPC-Remote Sensing Lab Activities

ACTIVE MICROWAVE



PASSIVE MICROWAVE

OPTICAL

http://www.tsc.upc.edu/rs/

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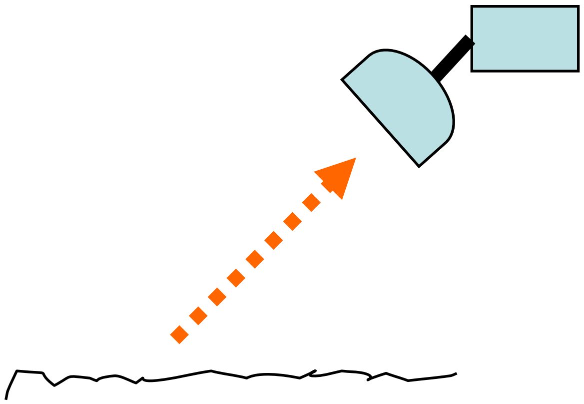
Passive Microwave Remote Sensing activities:

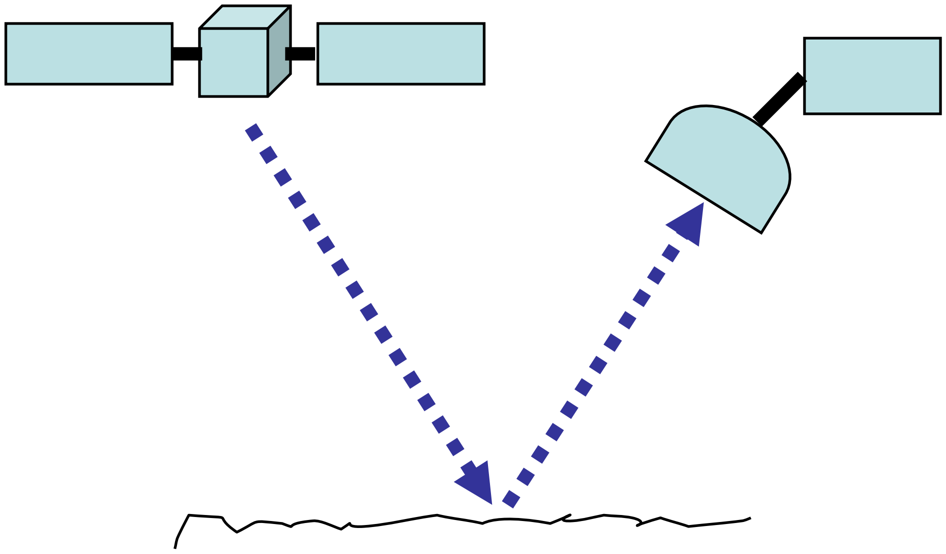
Microwave Radiometry:

- Measures self-emission (T > 0 K)



GNSS-R:

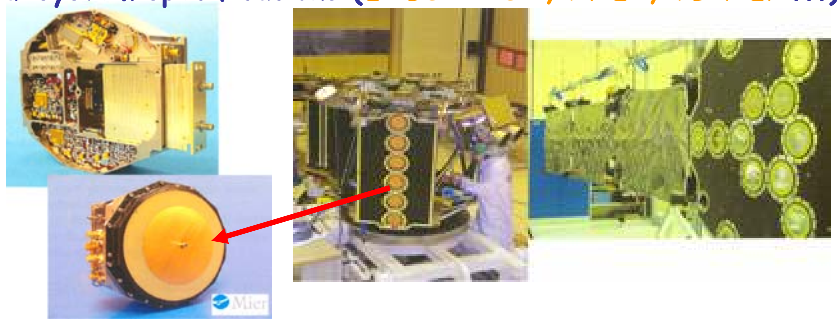
- Uses signals of opportunity from navigation satellites as sources of illumination



Microwave Radiometry (i)

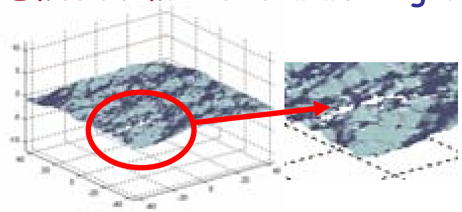
SMOS activities (1993-today)

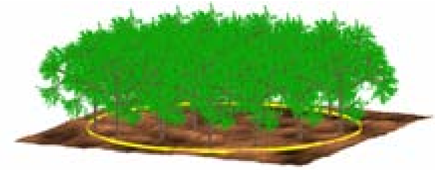
1. Instrument: Analysis, performance, calibration, imaging...
   → Subsystem specificacions (EADS-CASA, MIER, YLINEN...)



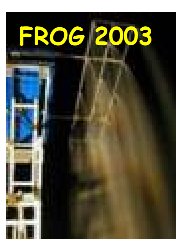
SEPS:
SMOS End-to-end
Performance Simulator

2. Numerical Emission models: sea and vegetation-covered land





3. Field experiments: sea and land emissivity



...

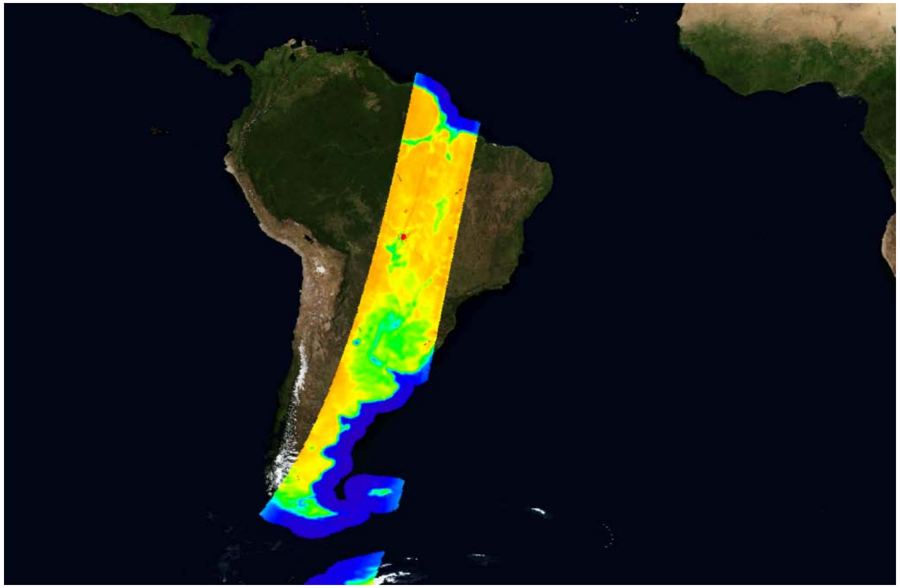
4. Development of sea surface salinity and soil moisture retrieval algorithms from multi-angular radiometric measurements

Collaboration with INDRA Espacio, GMV, DEIMOS Eng.

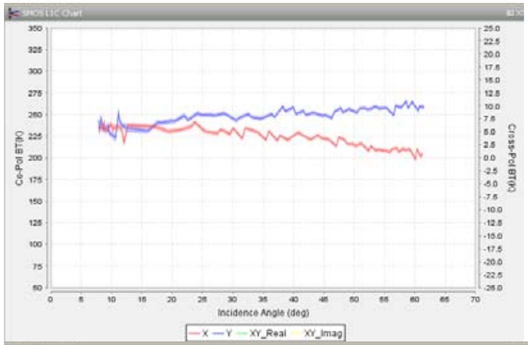
Microwave Radiometry (ii)

Field experiments devoted to improve soil + vegetation <u>emission models</u> using the L-band AUtomatic RAdiometer (LAURA) & for <u>CAL/VAL activities</u>

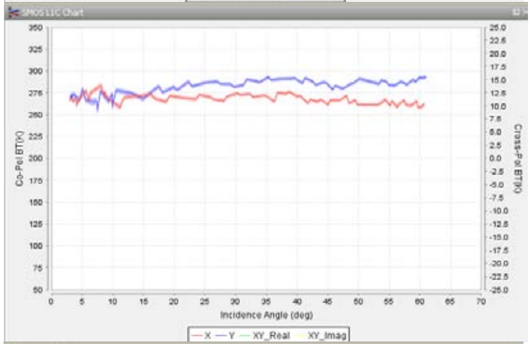
(Dr. A. Monerris, Ph. D. Thesis)



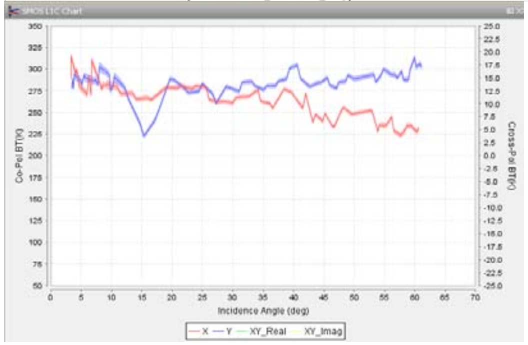
Wet soil + Vegetation



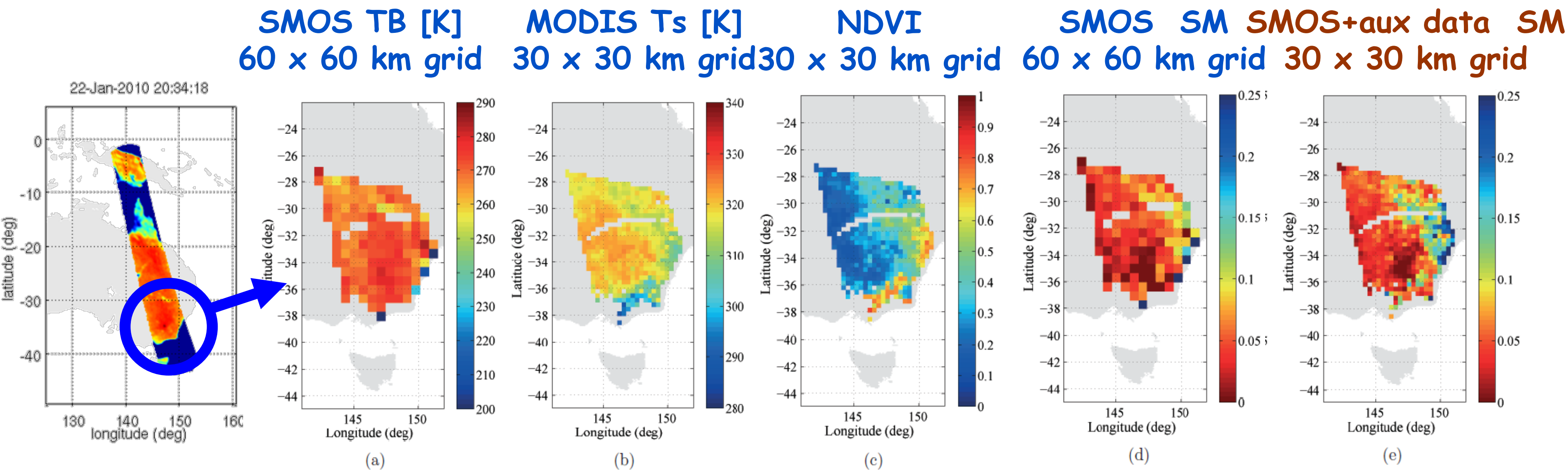
Dry soil + Vegetation



Dry bare soil



Soil moisture retrieval algorithms + data fussion for pixel disaggregation
(Mrs. M. Piles, Ph. D. Thesis work) → ground-truth needed to check data



• Sample results of the application of the algorithm to a SMOS image covering the Murrumbidgee catchment (Australia), from January 23rd, 2010 (6 am).

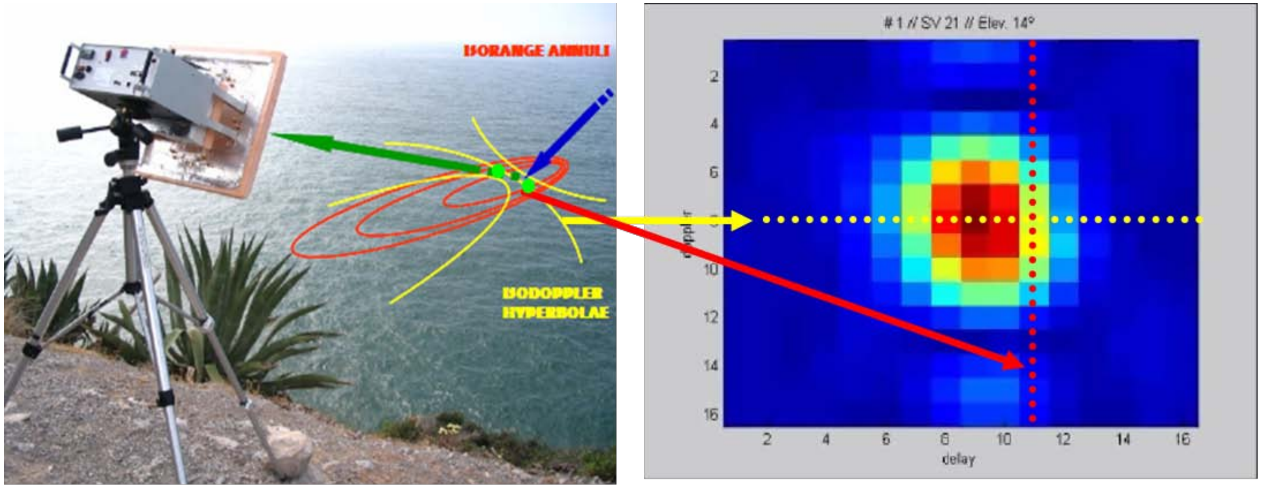
• Empty areas in the images correspond to clouds masking MODIS Ts measurements.

- What can a **GNSS-R reflectometer** measure?
- The most complete information is the **Delay Doppler Map (DDM)** or correlation of the received signal with a replica of the transmitted one at different time lags and Doppler shifts

  $\Rightarrow$ mapping of space (x,y) coordinates into (τ, f_d)

- The cut of the DDM for f_d=0 is usually called a waveform

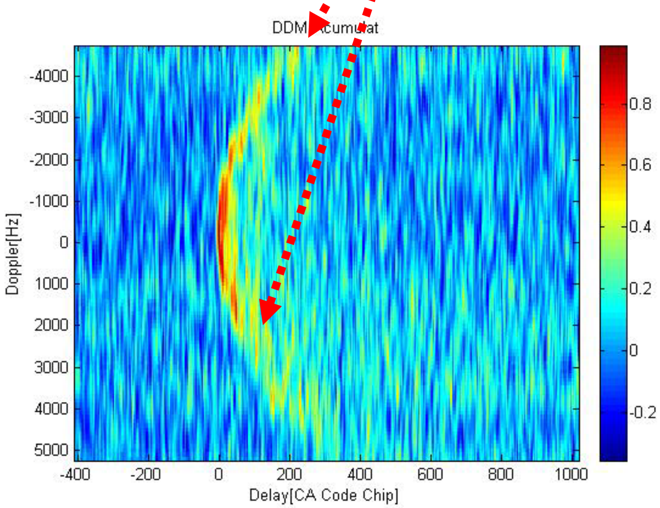
  $\Rightarrow$ most widely used observable



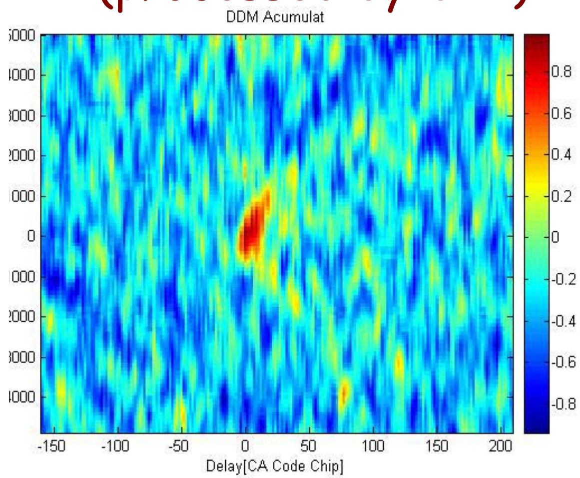
GNSS-R (ii)

- The “shape” of the DDM depends on:
- Surface where GNSS signals are scattered: sea, ice, land…
  - ⇒ dielectric properties, surface roughness, temporal variability…
- The relative movement of the GNSS transmitter and the receiver
- The DDM must be integrated (coherently and incoherently) to reduce noise

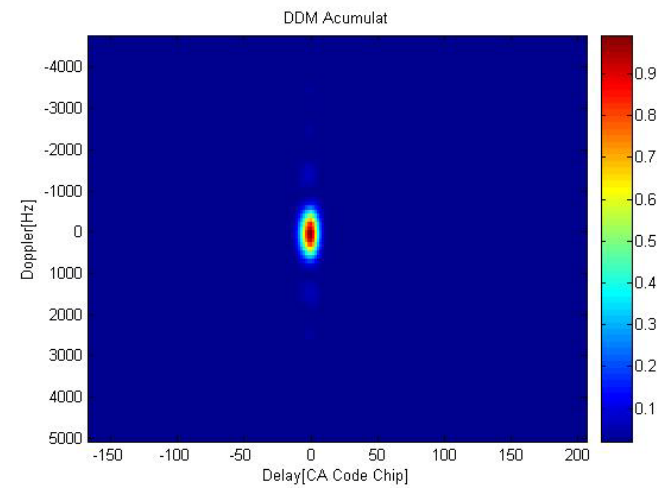
SAMPLE DATA FROM UK-DMC
(processed by UPC)



DDM τ_c = 1 ms, τ_i = 200 ms



DDM τ_c = 1 ms, τ_i = 200 ms



DDM τ_c = 1 ms, τ_i = 200 ms

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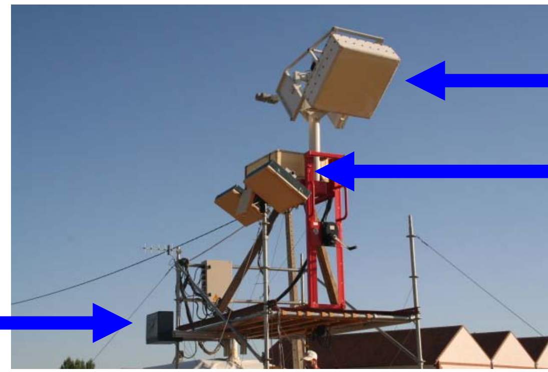
GNSS-R (iii)

- Over land, reflection coefficient increases with soil moisture content

- **GRAJO** (**G**PS and **RA**diometric **J**oint **O**bservations) field experiment conducted at Vadillo de la Guareña (Zamora) with CIALE during SMOS preparatory and CAL/VAL activities

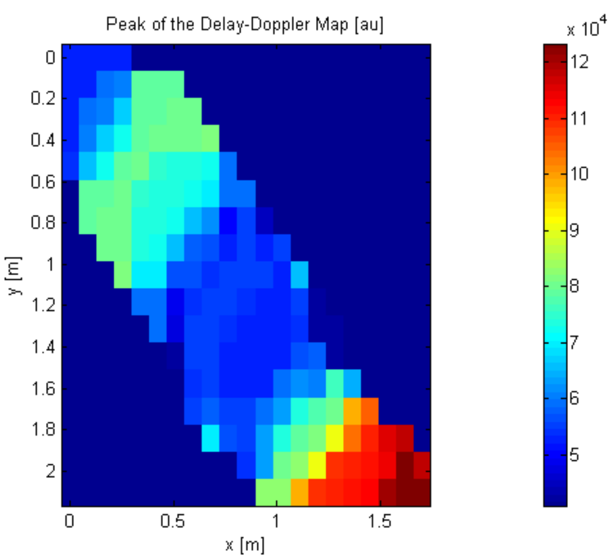


LAURA Radiometer

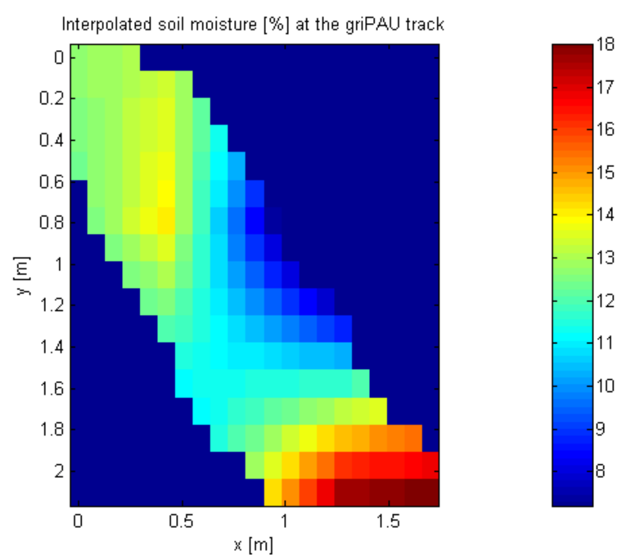
gri-PAU
(Radiometer & GPS Reflectometer)

SMIGOL reflectometer

DDM peak



SM



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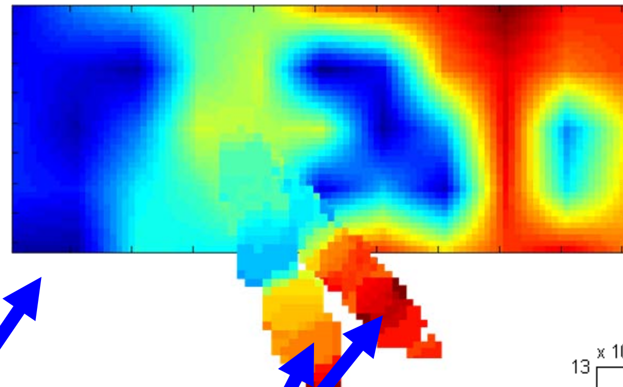
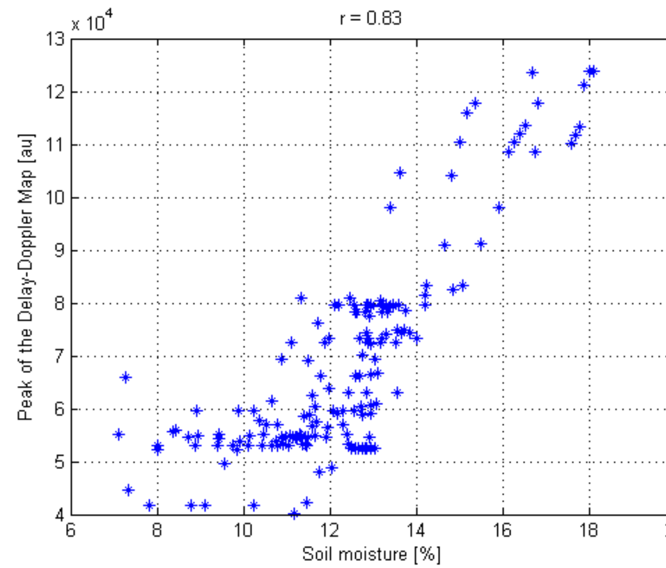
GNSS-R (iv)

- High correlation between DDM peak variations and measured SM
- Saturation at low SM values due to noise



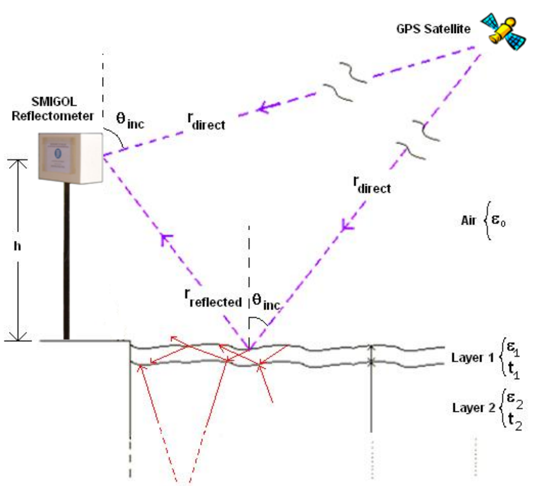
Two GNSS-R tracks overlaid on SM map

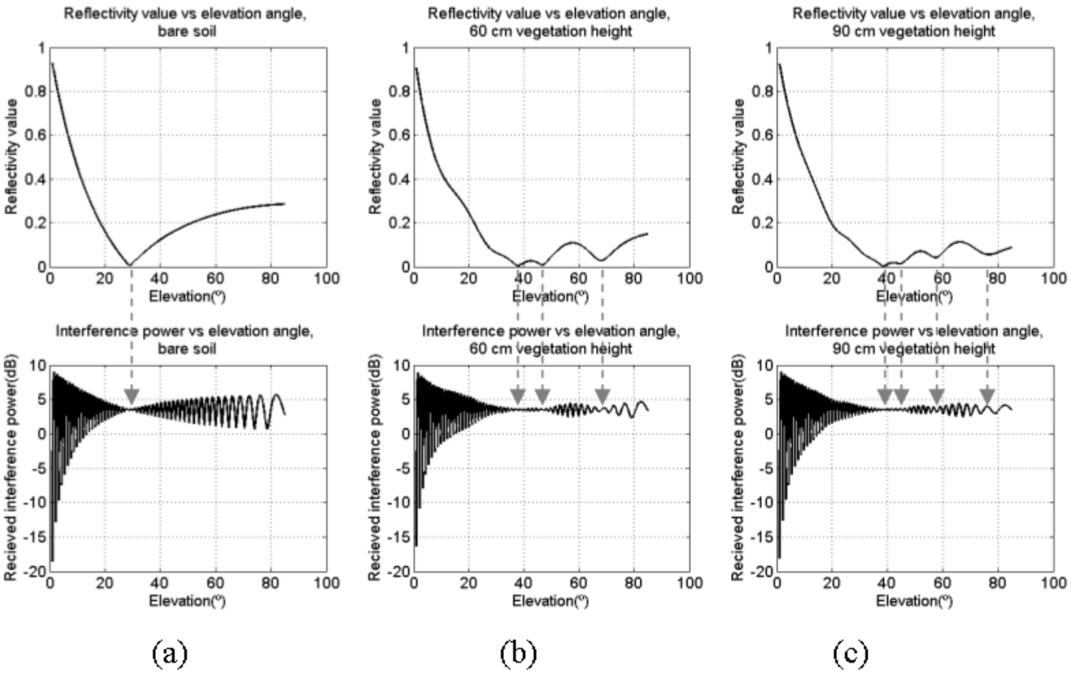


(Mr. E. Valencia, Ph. D. Thesis work)

GNSS-R (v)

• **Interference-Pattern Technique** measures the shape of the received power as a function of the satellite elevation at vertical polarization
• A notch appears at the Brewster angle ($\Gamma_v \approx 0$) $\Rightarrow$ depends on SM
• If there is vegetation $\Rightarrow$ multiple "reflections" in vegetation layer
$\Rightarrow$ more notches $\Rightarrow$ position dependent on vegetation height

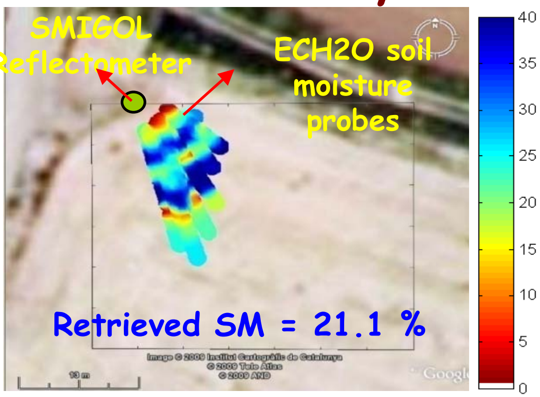




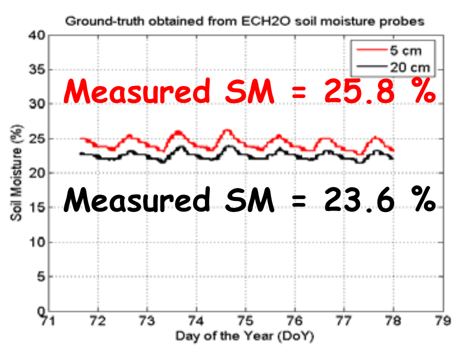
(Mrs. N. Rodríguez, Ph. D. Thesis work)

GNSS-R (vi)

PALAU Field Experiment

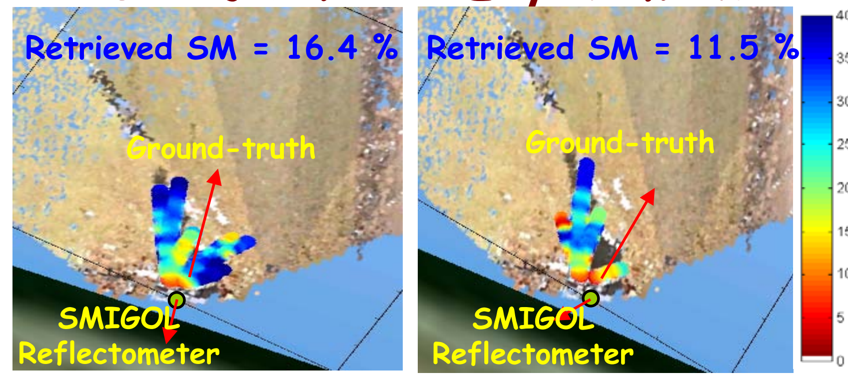


Soil moisture map derived in presence of vegetation, 11/3/2008
map scale = 13 m



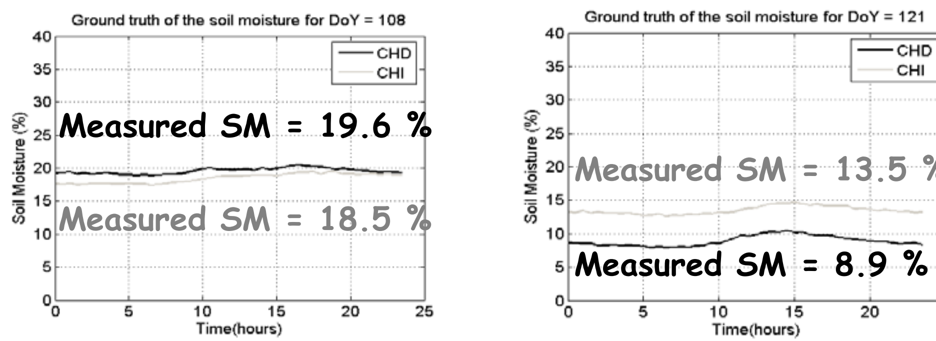
Ground-truth for the soil moisture of the ECH2O probes, from 11th of March (DoY=71) to 17th of March (DoY=78).

GRAJO Field Experiment



(a) (b)

Soil moisture map derived in presence of vegetation, 18/4/2009-1/5/2009
map scale = 27 m

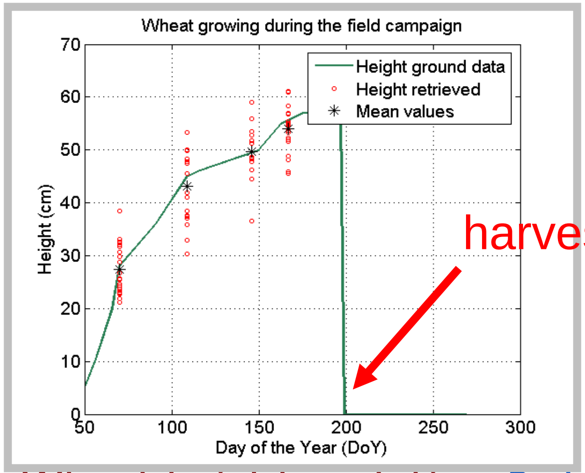


(a) (b)

Ground-truth of the soil moisture provided by CIALE and University of Salamanca team for DoY=108 and DoY=121.

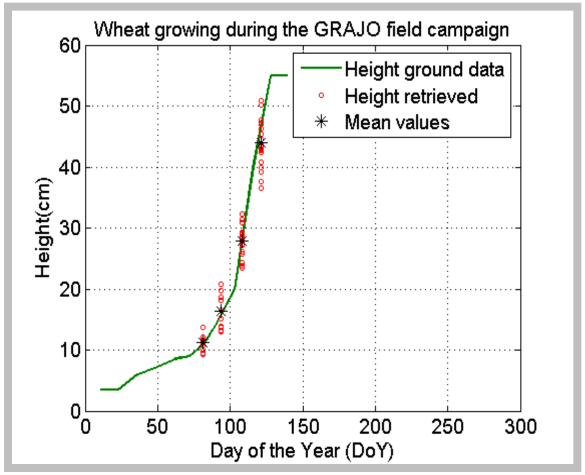
GNSS-R (vii)

PALAU Field Experiment

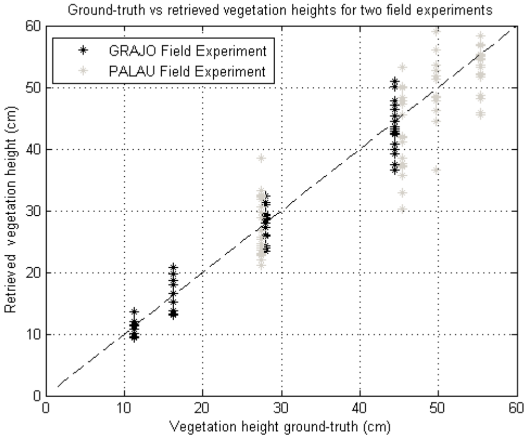


Wheat height evolution. Data processed on 11/3, 19/4, 26/5 and 16/6 for all available satellites

GRAJO Field Experiment



Wheat height evolution. Data processed on 22/3, 4/4, 18/4, and 1/5 for all available satellites



Conclusions (i)

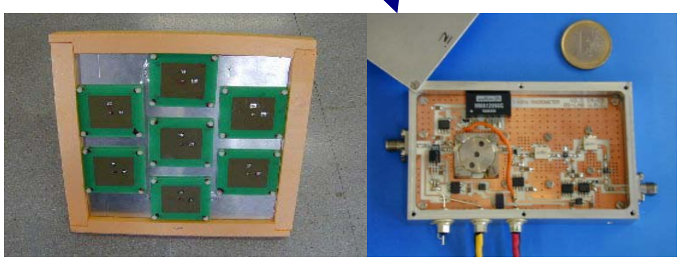
- SM retrieval by Microwave Radiometry is well stablished today
- SM retrieval using GNSS-R is a promising technique

**And soil moisture monitoring not from the ground…
but close to:**

Conclusions (ii)

- Receiver miniaturization allows to board microwave radiometers and GNSS-Reflectometer in R/C small aircrafts to make SM maps
- Ground-based ⇒ high revisit time, high spatial resolution, poor coverage
- Space-borne ⇒ "poor" revisit time, poor spatial resolution, large coverage
- Airborne ⇒ in between + needed to make the "connection" between them

h < 300 m



(Mr. X. Bosch Ms C Thesis work and
Mr. R. Acevo Ph. D. Thesis work)

TB map
Marquesa beach
Ebro river mounth

SM map
Vadillo de la Guareña
(Zamora)