Analyse du potentiel des mesures GNSS-R pour le suivi des états des surfaces continentales

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Outline

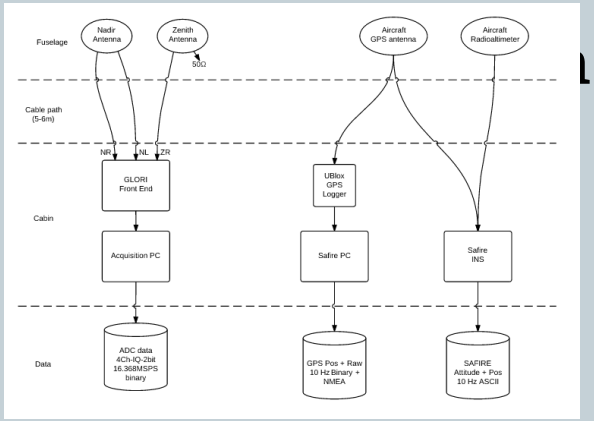
- GLORI campaigns
- Data processing
- GNSS-R signal sensitivity to biomass
- Conclusions

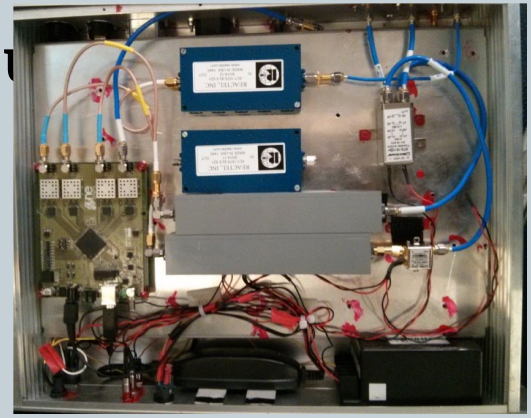
GLORI instrument

GLObal navigation satellite system Reflectometry Instrument

The GLORI instrument comprises three subsystems:

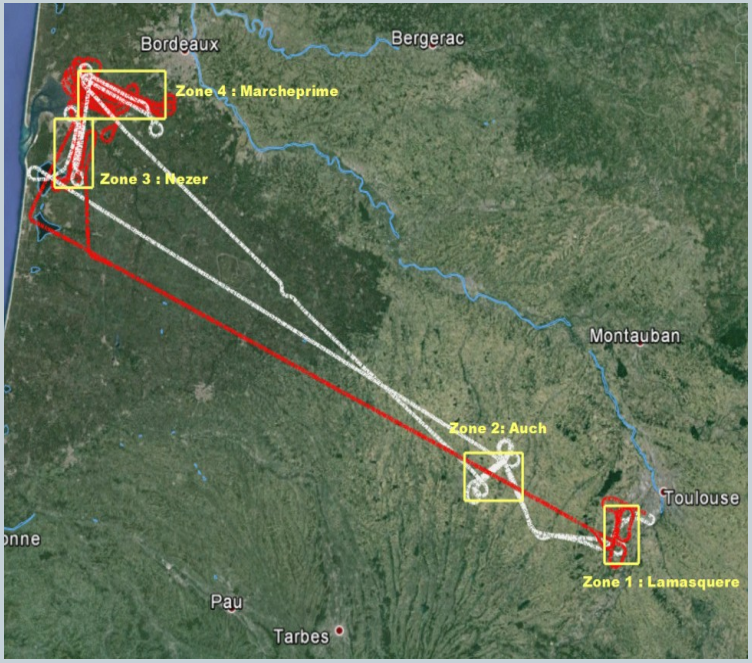
- two antennas (Z: Antcom 42G1215RL-AA-XT-1, N: Cobham DS1563)
- the front-end receiver



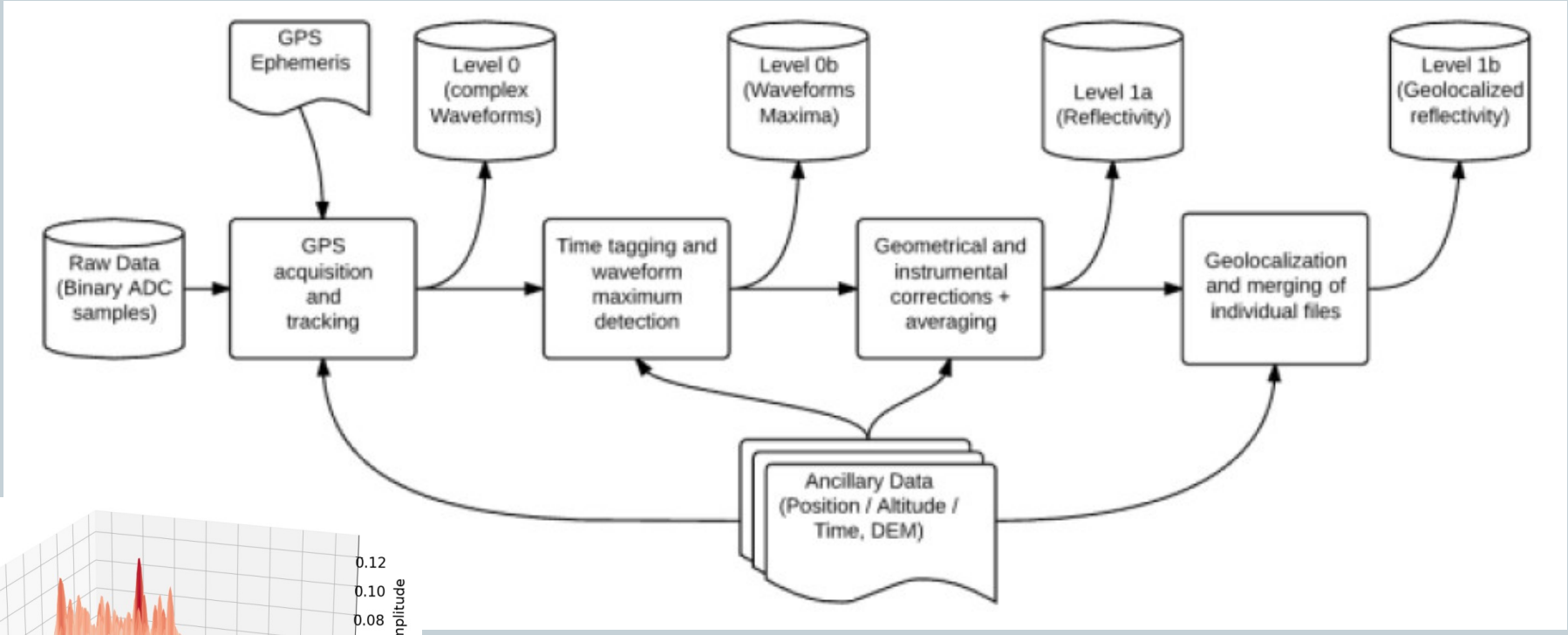


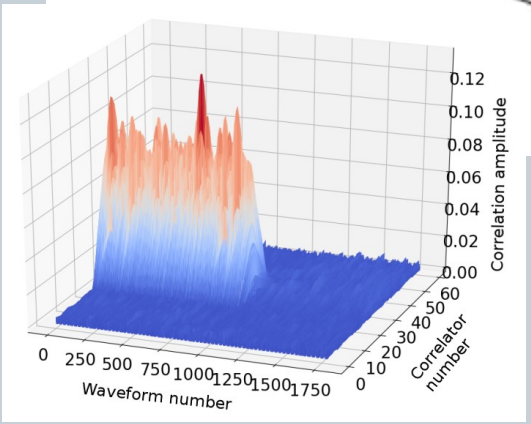
GLORI campaigns

- Instrument characteristics
  - Dual pol (LHCP & RHCP) hemispherical antennas
  - 4 synchronized RF channels L1 centered, 8MHz BW
  - Direct down conversion, 10MSPS, IQ
  - Relative channel calibration
- Flight characteristics
  - 600 m AGL, 100 m/s
- Dataset
  - 5 flights over 4 areas of interest + lakes
  - 2 weeks span (June – July 2015)
  - 15 hours of raw data recording



GNSS-R data processing

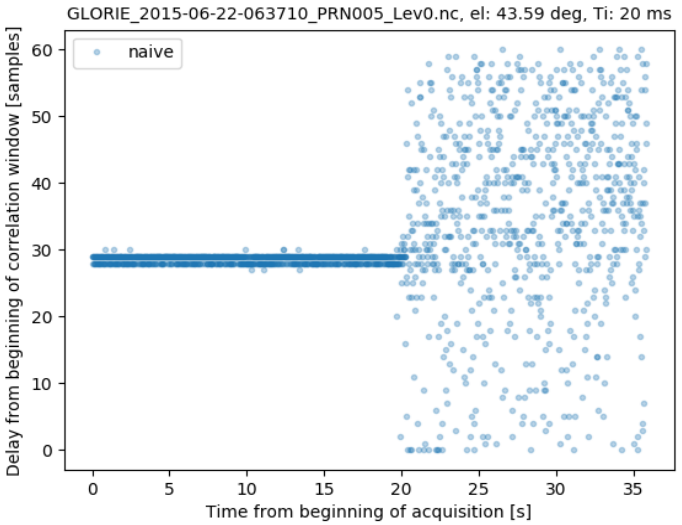


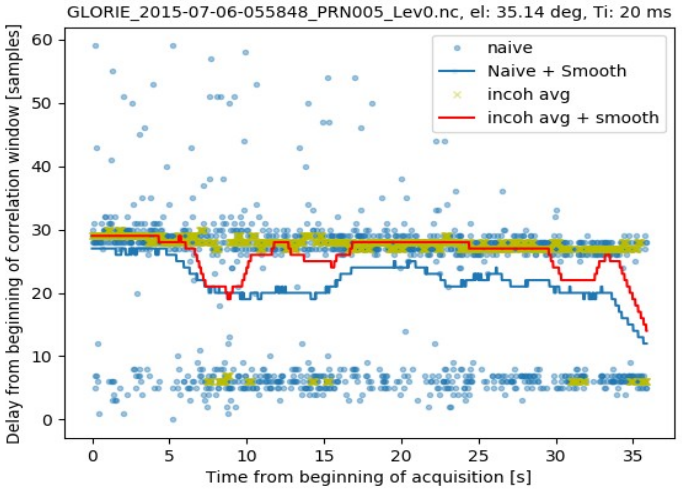


GLORI data processing

Four approaches to the improvement of peak detection are proposed *[Motte and Zribi, 2017]*:

- Smoothing of the peak locations determined with the naive method (NS)
- Incoherent averaging used to improve the SNR (IA)
- Incoherent averaging + smoothing (IAS)
- Implementation of an algorithm using the above, in addition to adaptive filtering over the delay range, designed to mitigate the direct signal contributions (DM)

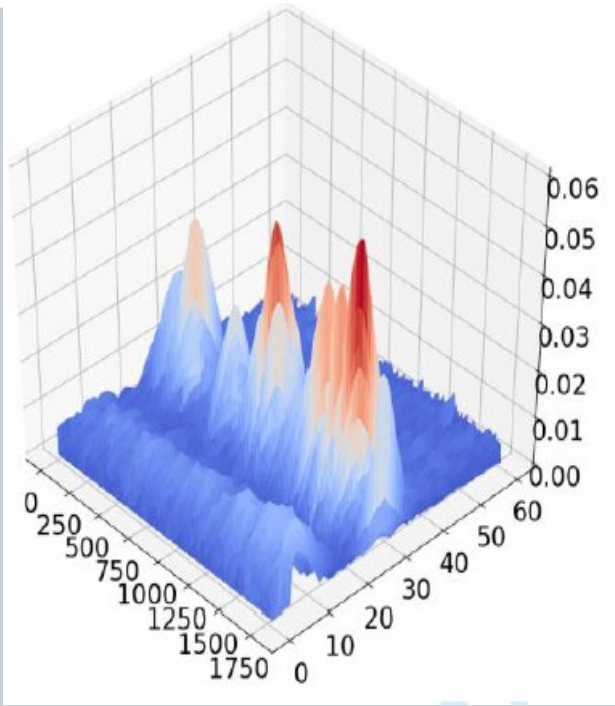




GNSS-R observables

- Integration time:
  - Coherent integration time : 20ms
  - Incoherent integration time : 240ms
- GNSS-R observables of interest:
  - Interferometric Complex Field

$$ICF_{corr} = \frac{|Y_{r,\max}| - B_r}{|Y_{d,\max}| - B_d} e^{j(\phi_{r,\max} - \phi_{d,\max})} \frac{G_d}{G_r}$$



  - Apparent surface reflectivity

$$\Gamma_{pq} = \left| \left(\frac{Y_{r,q}(\Delta\tau, f)}{Y_{d,p}(0, f)} \right) \right|^2$$

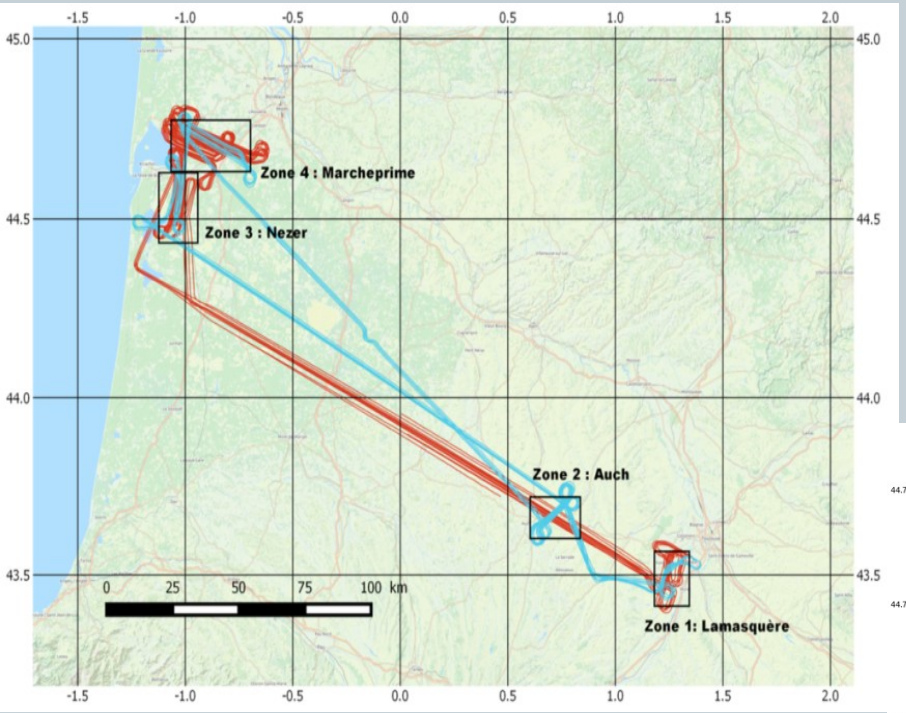
$$\Gamma'_{pq} = \left\langle |ICF_{corr}|^2 \right\rangle - \sigma^2_{ICF_{corr}}$$

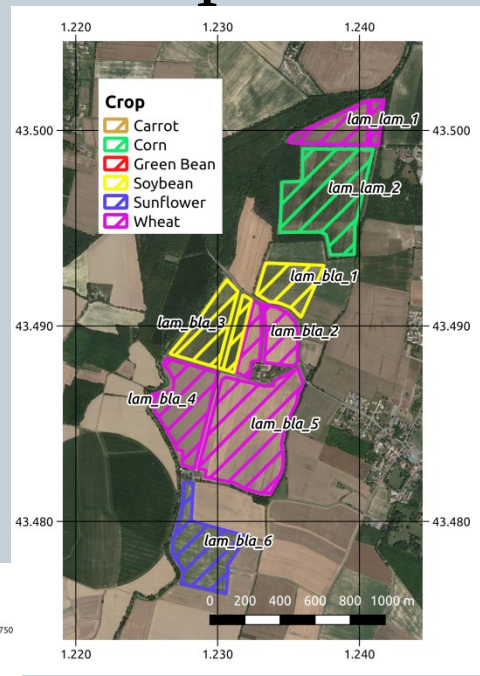
$$SNR = (|Y_{r,max}| - B_r)/B_r$$

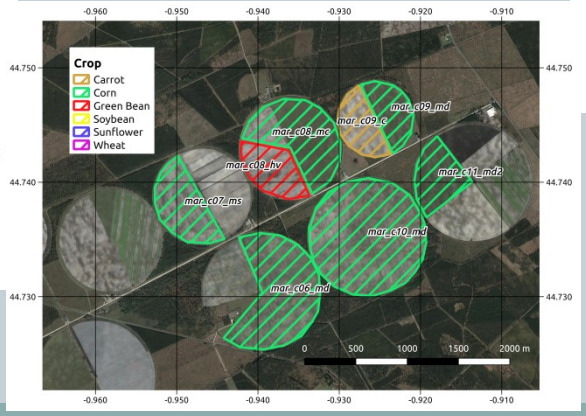
  - Signal to Noise Ratio

GLORI data

- Two agriculture sites: Marcheprime, Lamasquère
- South West of France





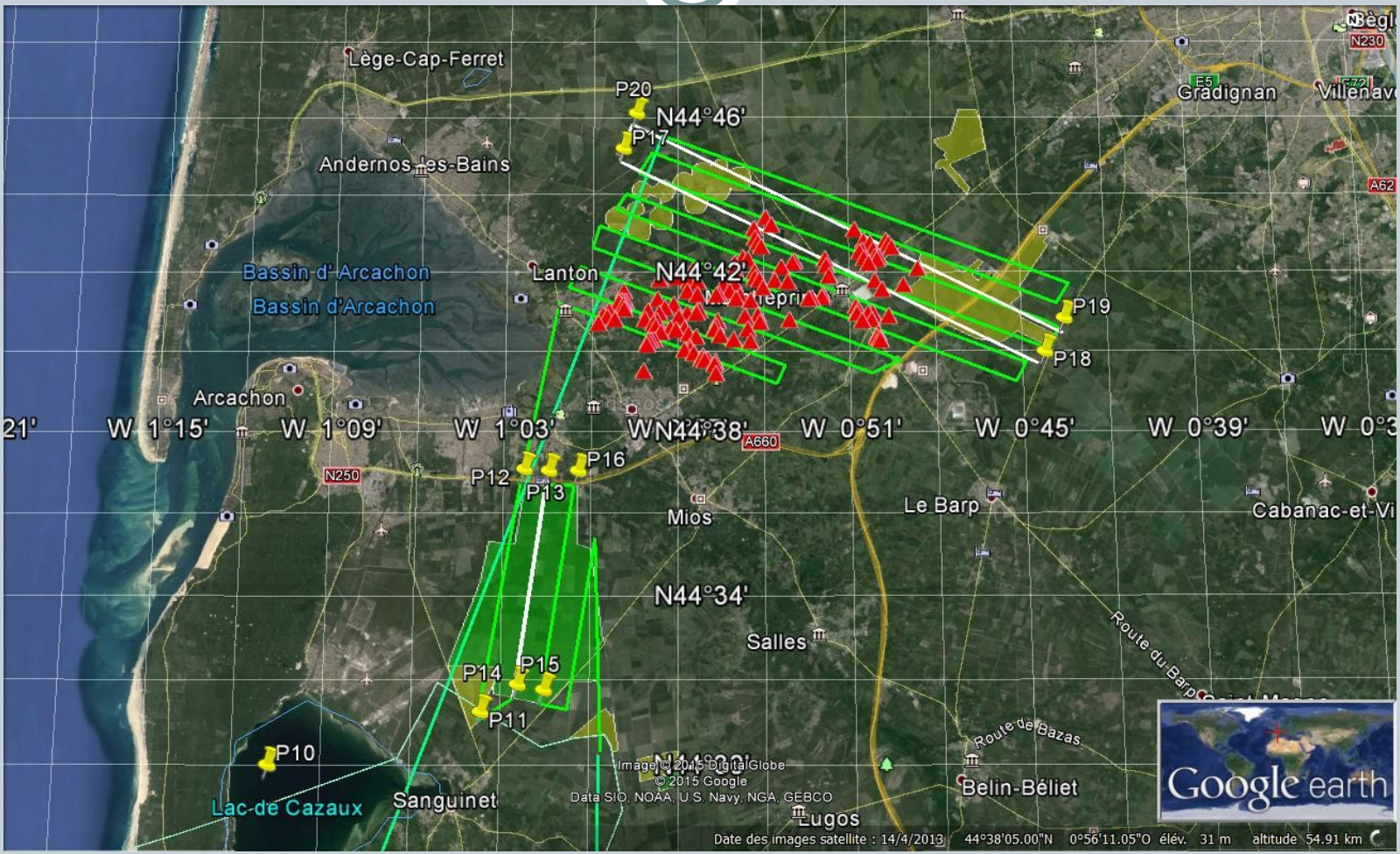


In Situ ground measurements

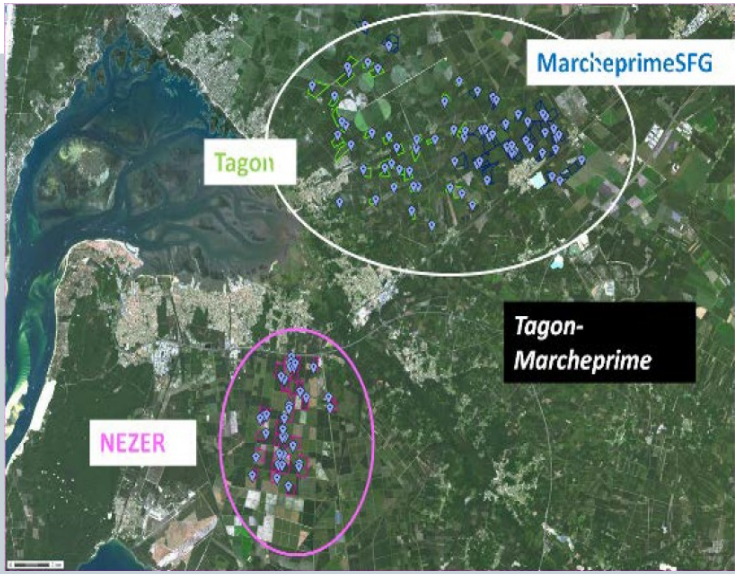
- Parameters:
  - Soil moisture (SM)
  - Roughness
  - Vegetation cover height
  - Leaf Area Index (LAI)

Date	Soil moisture (m3/m3)	LAI (m^2/m^2)	Hv (cm)
22/06/2015	[0.04-0.23]	[0-5.3]	[16-104]
25/06/2015	[0.1-0.22]	-	-
29/06/2015	[0.04-0.24]	[0-6.1]	[0-154]
03/07/2015	[0.08-0.21]	[0-6.18]	-
06/07/2015	[0.09-0.23]	[0-6.2]	[0-197]

Measurements over Landes forest



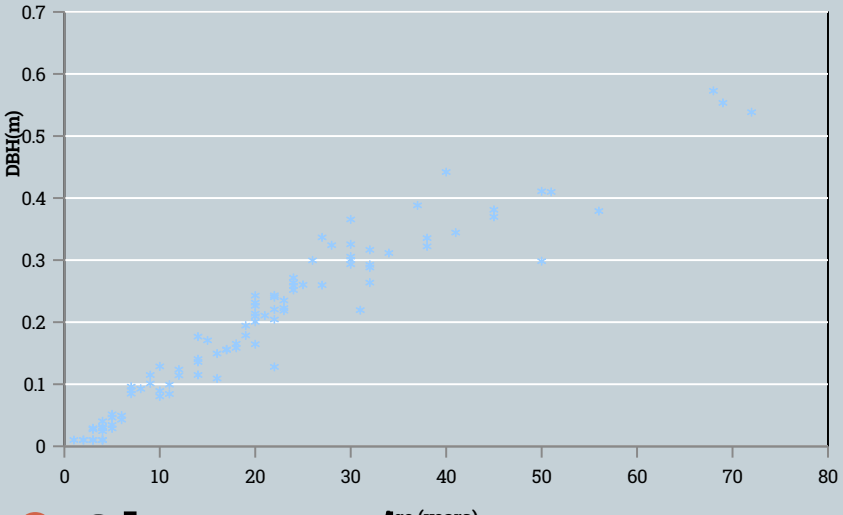
In situ ground measurements

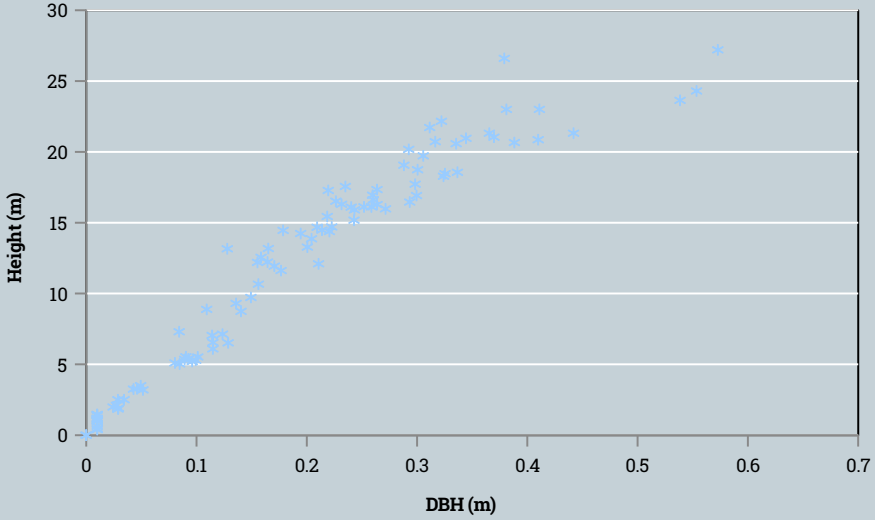


- Silvicultural practices
  - Parameters:
    - Age
    - Diameter (DBH)
    - Height
    - Density
    - Estimation of Above Ground Biomass (AGB) from allometric equations
    - Qualitative description of ground cover
  - Extent
    - 3 areas
    - 100+ stands
    - Biomass up to 150 t/Ha

In situ ground measurements

- DBH vs age and Height vs DBH

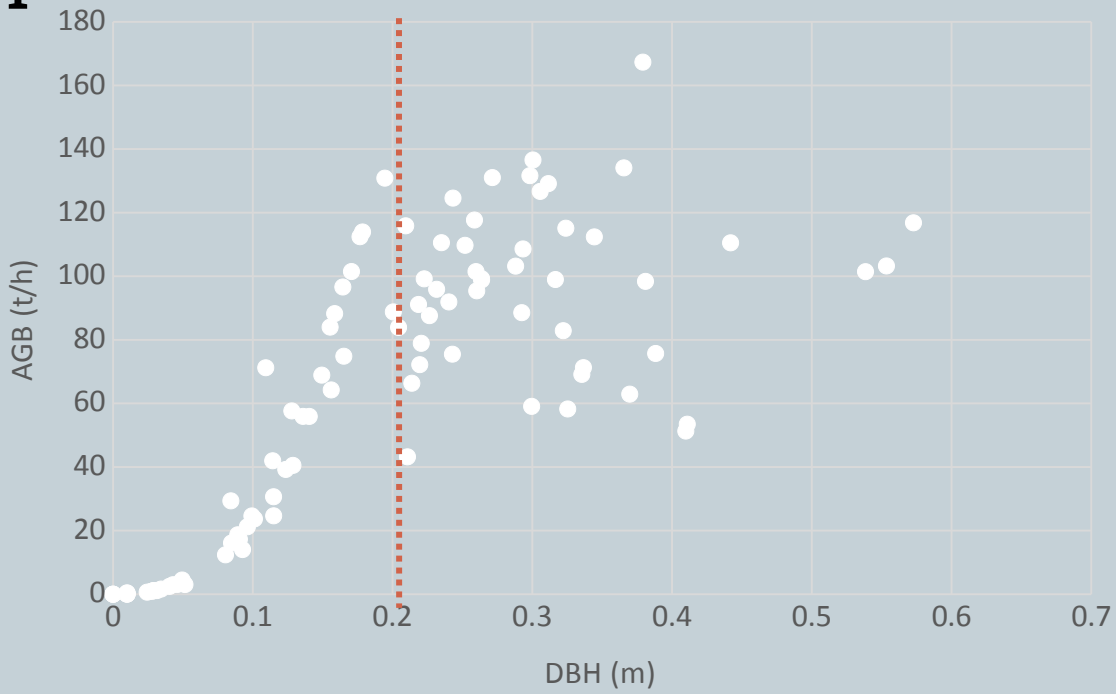




- Observations:
  - A strong correlation is observed between mean DBH and stand age, resulting from the incremental change in trunk diameter over time.
  - A strong correlation is shown between mean tree height and mean DBH.

In situ ground measurements

- AGB vx DBH

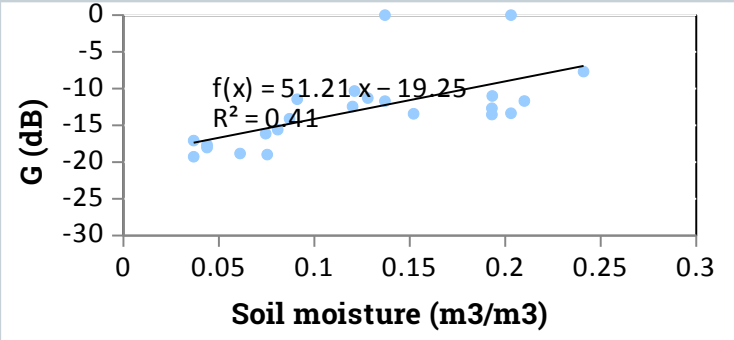


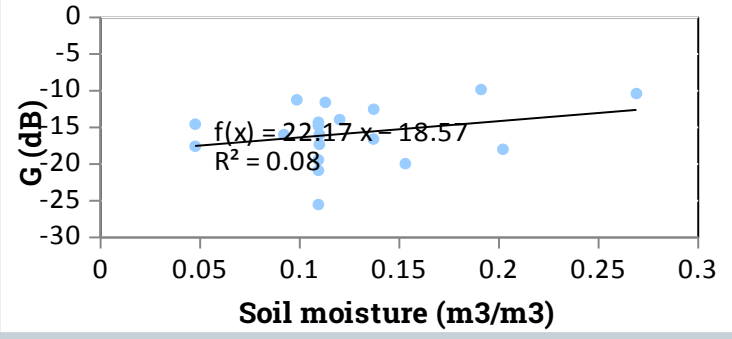
- Observations:
  - It can be seen that there is a clear increase in biomass with increasing DBH until the latter parameter reaches the value of ~ 0.2 m.

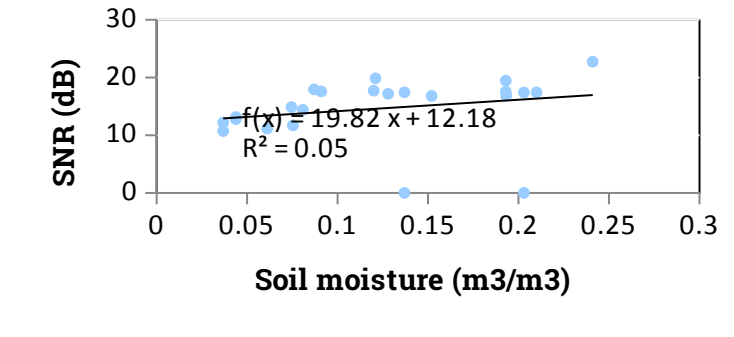
GNSS-R data=f(moisture)

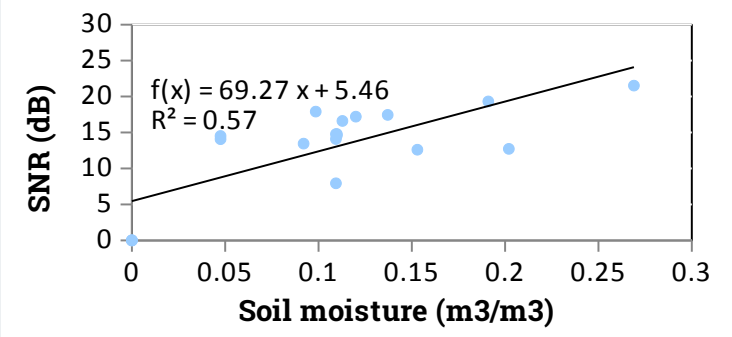
- Elevation angle: 50-70°

LAI<1







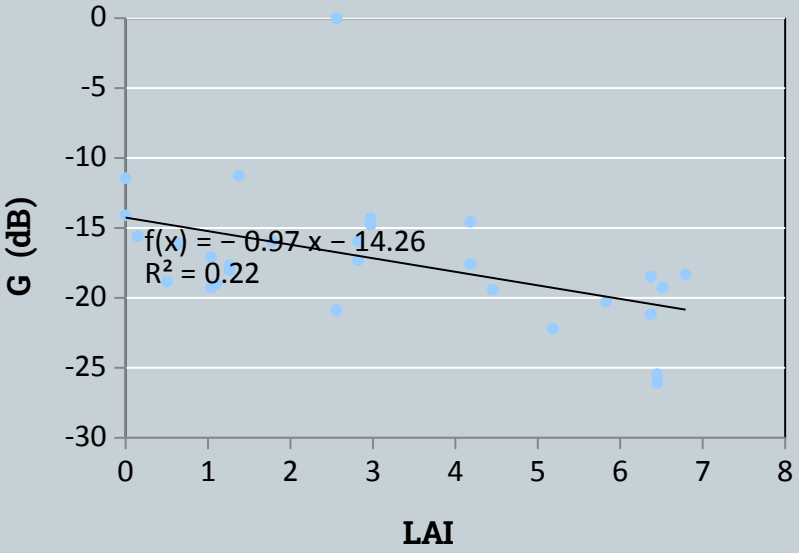


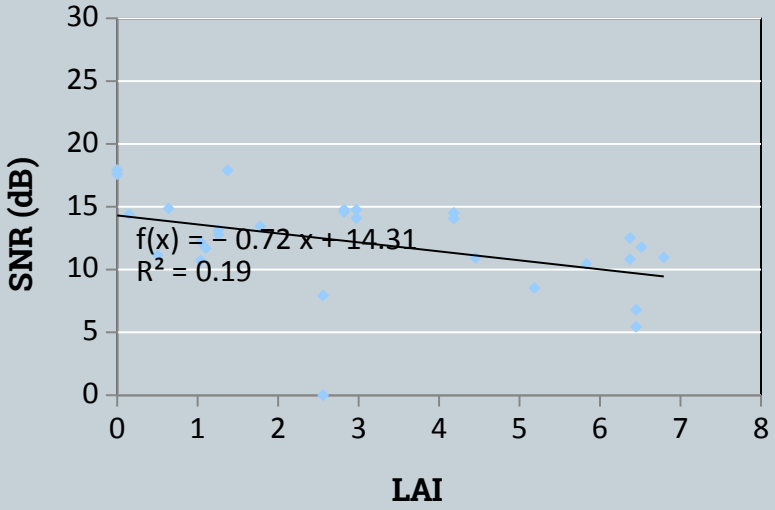
LAI>1

- Conclusions:
  - Decreasing of sensitivity to soil moisture with LAI increasing
  - Approximately the same sensitivity for G and SNR

GNSS-R data=f(LAI)

- sm<0.1m3/m3
- Elevation angle: 50-70°





- Conclusions:
  - Highest sensitivity to vegetation dynamic for low elevation angle data

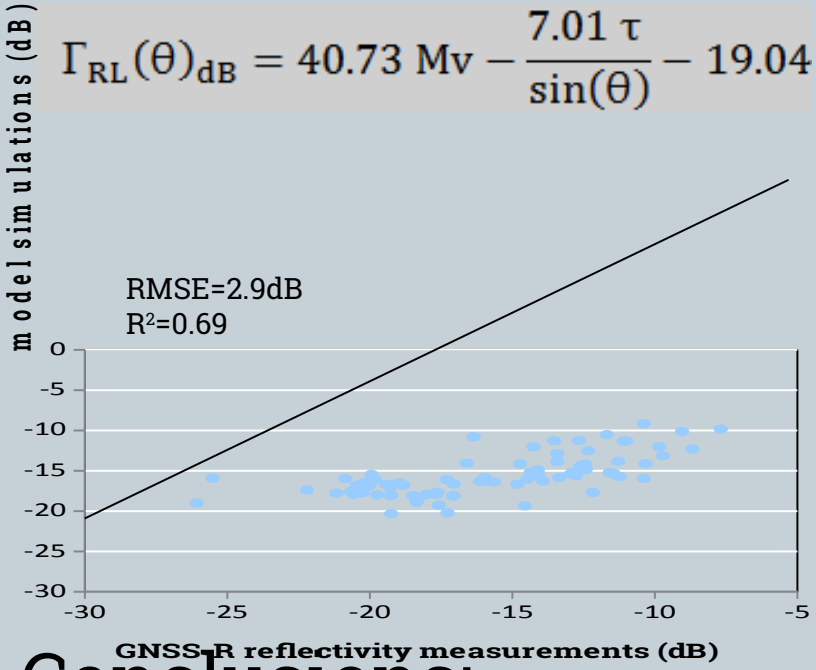
GNSS-R signal=f(Mv, τ)

- Models

$$\tau = 0.06\,LAI$$

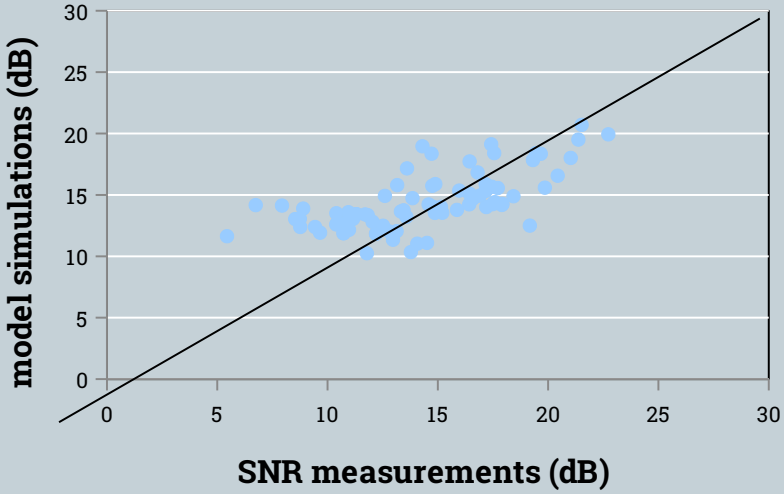
$$\Gamma_p(\theta)_{dB} = \alpha Mv + \frac{\beta LAI}{\sin(\theta)} + \delta$$

$$\Gamma_{RL}(\theta)_{dB} = 40.73\ Mv - \frac{7.01\ \tau}{\sin(\theta)} - 19.04$$



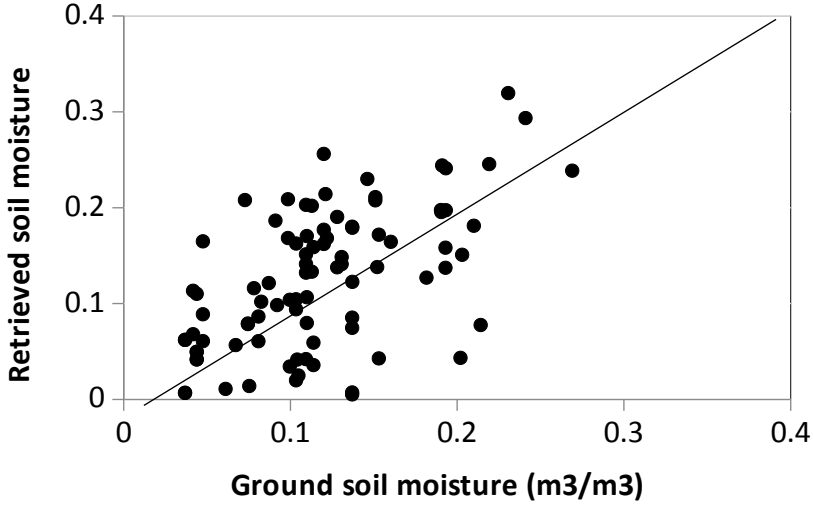
$$SNR(\theta)_{dB} = 39.78\ Mv - \frac{0.33\ LAI}{\sin(\theta)} + 10.79$$

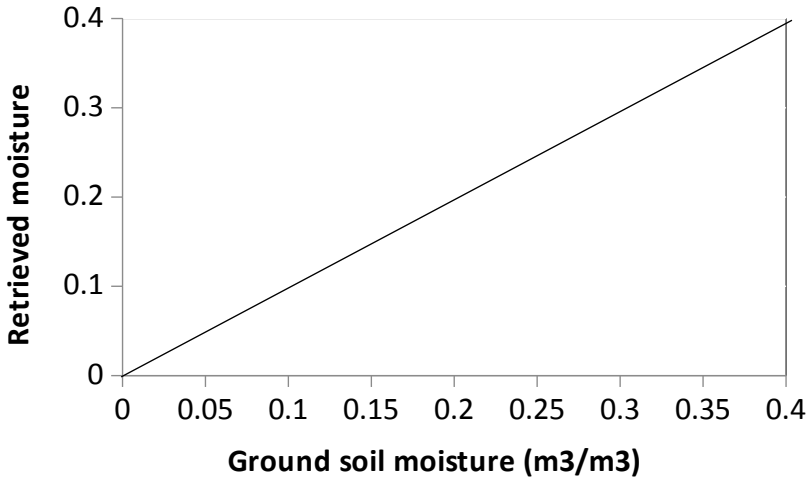
$$SNR(\theta)_{dB} = 39.78\ Mv - \frac{5.5\ \tau}{\sin(\theta)} + 10.79$$



- Conclusions:
  - Good agreement between proposed models and GNSS-R data

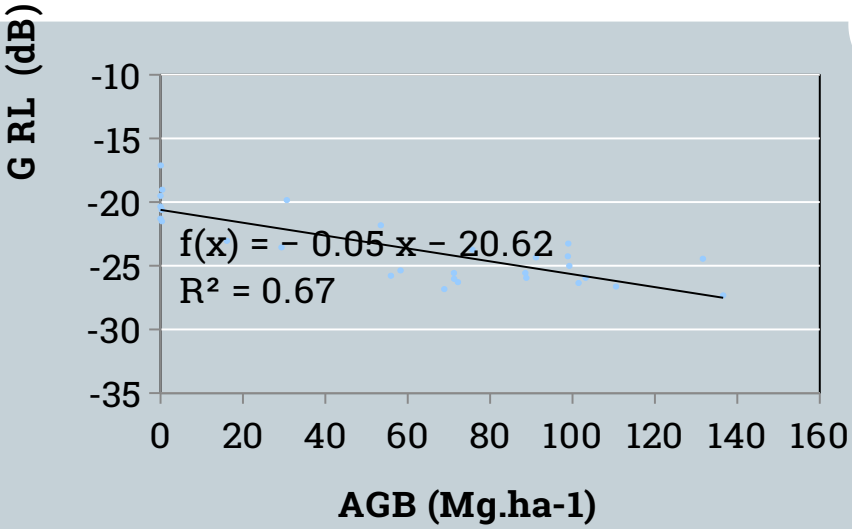
Moisture retrieval

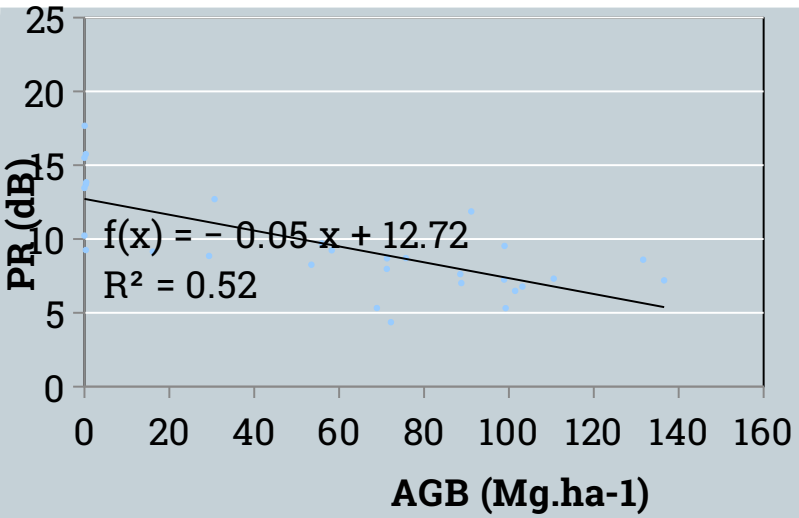




- Conclusions
  - Results of GLORI confirm the potential of GNSS-R measurements to retrieve soil moisture *[Zribi et al., 2016]*.
    - They propose precise levels of sensitivities to moisture and vegetation, useful to the analysis of TDS data.
    - A simple model based on relationship between GNSS-R signals, moisture and VOD is proposed, adapted to a satellite application

Data sensitivity to AGB (70-90º)





- Conclusions:
  - The observed reflectivity and PR decrease monotonically with increasing AGB
  - The dynamic ranges are equal to 11dB and 14dB for GRL and PR, respectively, for all values of AGB.
  - When a simple linear relationship is assumed between the GNSS-R observables and AGB, sensitivities of -0.051 dB/[Mg.ha-1] and -0.053 dB/[Mg.ha-1]

Conclusions

- GLORI airborne instrument developed to analyze potential of GNSS-R to retrieve land surface parameters
- Proposed analysis based on an airborne campaigns over agricultural and forest sites in South West of France
- GNSS-R sensitivity to soil moisture observed for G and PR.
- GNSS-R data sensitivity to AGB is observed for G and

Conclusions

- Semi-empirical proposed inversion allows reasonable precision for soil moisture (RMSE~6%)
- Empirical proposed inversions allow reasonable precision for AGB (RMSE~30t/ha)
- Application of GNSS-R with satellite new missions TechDemoSat and CYGNSS

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THANK YOU FOR YOUR ATTENTION!

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