Results from the GLORIE GNSS-R Airborne campaign for land applications

Erwan Motte\textsuperscript{1}, Mehrez Zribi\textsuperscript{1}, Pascal Fanise\textsuperscript{1}, Dominique Guyon\textsuperscript{2}, Sylvia Dayau\textsuperscript{2}, Jean Pierre Wigneron\textsuperscript{2}

\textsuperscript{1}CESBIO Toulouse France
\textsuperscript{2}INRA Bordeaux, France
Background

• Study of the Interactions of the GNSS-R signal with land surface (roughness, soil moisture) and vegetation (Forests, crops)

• Previous dedicated missions:
  – SMEX02 (Masters, Katzberg 2002)
  – LEiMON & GRASS (Egido 2010-2011)

• Current knowledge
  – Sensitivity of GNSS-R to soil moisture
  – Usefulness of RHCP polarization
  – Sensitivity to forest biomass
Rationale of the GLORIE campaign

• Gather an extended dataset for GNSS-R land application studies
• Verify the current knowledge
• Further explore
  – Effect of measurement geometry
  – Effects of crop types
  – Effect of Forests
  – Other modulations (Galileo?)
• Provide data for bistatic scattering models
• Develop inversion methods
Aircraft measurements dataset

- **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 data processing

- Raw data to geolocalized reflectivity
  - Clean replica waveform generation (L0)
  - Waveform maximum extraction & time tagging (L0b)
  - Instrumental calibration (antenna, direct signal, noise) and computation of reflectivity (L1a) incoh avg = 240ms
  - Geolocation and conversion to shapefiles (L1b)

- Improvements
  - Tracking of the specular point in non optimal configurations
  - Correction for Antenna Gain
  - Correction of the direct signal in the case of strong multipath
  - Correction for RHCP xPol

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

\[
\Gamma'_{pq} = \left\langle |ICF_{corr}|^2 \right\rangle - \sigma_{ICF_{corr}}^2
\]
In situ ground truth dataset – Agricultural

• Parameters:
  - Soil moisture
  - Roughness
  - vegetation cover height
  - Leaf Area Index (LAI)
  - vegetation water content
  - NDVI from optical EO

• Extent
  - 3 areas
  - 30 fields
  - Several crop types
In situ ground truth dataset - Forests

- **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
Distribution of Measurements

Forests

Agricultural
Results: Agricultural Areas LHCP (1)

All elevations (30-90) -> Sensitivity to vegetation height and soil moisture
Results: Agricultural Areas LHCP (2)

Multi linear fit: Soil Moisture and vegetation Height : $r^2=0.7$
Results: Agricultural Areas LHCP (2)

Low elevation (30-60)

- Veg +, SM -

High elevation (60-90)

- Veg -, SM +
Results: Agricultural Areas Pol Ratio

Only improvement: correlation with vegetation height at high elevation angle (60-90), no improvement for soil moisture.
Preliminary Results: Forest

Saturation after 50 t/Ha or 10m. Effect of cover?
Further investigations

• Instrument: NT1065 chip
  – 4 channels with 1 or 2 LOs
  – Simultaneous L1/L2/L5
  – Up to 36MHz Bandwidth
  – Low cost, high integration

• Processing
  – Moving towards open source GNSS-SDR (multi constellation, multi frequency, GPU ready-> Real time?)

• Modelling
  – Modelling of soil moisture / Vegetation/ forest effects on GNSS-R signals

• Inversion
  – Develop robust inversion algorithm for soil moisture and vegetation (based on incidence angle dependance, Polarization)
Summary and Conclusions

• A campaign dedicated to the analysis of polarimetric airborne GNSS-R sensitivity to land parameters was successfully performed, with more than 15 hours of raw data recorded.

• A large amount of ground truth was collected, mostly related to soil moisture, crop and forest biomass parameters.

• New processing techniques were studied to be able to work with the full dataset (low elevation angle), perturbed direct signal, cross polarization issues.

• Analysis of the Data over agricultural areas show a good correlation with vegetation height, related to biomass for these crops, and a moderate correlation with soil moisture.

• Preliminary analysis with forest data shows limited correlation with biomass, saturation at low biomass, probably linked to the presence of a thick vegetation cover on the ground.

• Electromagnetic modeling of the scattering and attenuation mechanisms is needed to better understand the observations and move towards an efficient inversion algorithm.
Thank you

erwan.motte@cesbio.cnnes.fr