The TropiSAR campaign in French Guiana: SAR data set and first PolInSAR analysis

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1 ONERA
2 Institut Fresnel
3 CNES
4 CESBIO
5 EDB
6 CIRAD
7 ESA
8 IRD

Under fundings from ESA, CNES and ONERA
Overview

- The campaign
- The in-situ dataset
- The SAR dataset

PolInSAR analysis of the data
- Temporal decorrelation analysis
- Height estimation from PolInSAR
Translating objectives into flight scenario

- **TropiSAR objectives**
  - Evaluate the BIOMASS mission concept over tropical forests
  - Provide a dataset for algorithm validation

- **Radiometric analysis**
  - Reference plots with the high biomass (up to 520t/ha)

- **Temporal decorrelation analysis**
  - Identical trajectories flown on different dates (23 days)

- **PollInSAR & Tomography**
  - Vertically shifted trajectories (100ft and 50ft)
    - Adequate altitude of ambiguity throughout the swath
    - Six vertically shifted trajectories
      - 0 ft, 50ft, 100ft, 150ft, 200ft, 250ft
The in-situ database
based on permanent plots
From the Guyafor project
(L Blanc and J Chave)
Censused data
28 plots – 157 ha
98150 localised and measured trees
(all trees with diameter > 10cm)
Biomass: 100t/ha - 520t /ha

<table>
<thead>
<tr>
<th>Site</th>
<th>Forest type</th>
<th>Census date</th>
<th>Number of plots</th>
<th>Total census size</th>
<th>Number of trees</th>
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<tbody>
<tr>
<td>Paracou</td>
<td>Mature rain forest</td>
<td>2009</td>
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<td>Arbocel</td>
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<td>484</td>
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<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>28</strong></td>
<td><strong>157.51</strong></td>
<td><strong>98150</strong></td>
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TropiSAR: the sites

- Paracou
- Arbocel
- Nouragues
- Rochambeau
- Kaw
### TropiSAR, the waveform

<table>
<thead>
<tr>
<th>Parameter</th>
<th>P-Band</th>
<th>L-Band</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geometry</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Altitude [ft,m]</td>
<td>13000/3962</td>
<td></td>
</tr>
<tr>
<td>Velocity [m/s]</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>Waveform</td>
<td></td>
<td></td>
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<tr>
<td>Mode</td>
<td></td>
<td></td>
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<tr>
<td>Peak Power [W]</td>
<td>500</td>
<td>200</td>
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<tr>
<td>Actual PRF [kHz]</td>
<td>2.5</td>
<td>5</td>
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<tr>
<td>Sampling rate [MHz]</td>
<td>500</td>
<td>500</td>
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<tr>
<td>Bandwith [MHz]</td>
<td>260-460</td>
<td>1250-1400</td>
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<tr>
<td>Processed wave length [m]</td>
<td>0.652 – 0.896</td>
<td>0.214-0.24</td>
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<tr>
<td>Processed Bandwidth [MHz]</td>
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<td>1250-1400</td>
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<td>Relative bandwidth [%]</td>
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<tr>
<td>Range Resolution [m]</td>
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<tr>
<td>Azimuth resolution [m]</td>
<td>1.5</td>
<td>1.0</td>
</tr>
<tr>
<td>Range pixel spacing [m]</td>
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<tr>
<td>Azimuth pixel spacing [m]</td>
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<td>0.75</td>
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<tr>
<td>Near Range [m]</td>
<td>4350</td>
<td>4350</td>
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<tr>
<td>Nb of pixels in range</td>
<td>4000</td>
<td>2600</td>
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<tr>
<td>Incidence angle range [°]</td>
<td><strong>24-62</strong></td>
<td><strong>24-47</strong></td>
</tr>
<tr>
<td>TROPISAR</td>
<td>Description</td>
<td>Date</td>
</tr>
<tr>
<td>----------</td>
<td>-----------------------------------</td>
<td>------------</td>
</tr>
<tr>
<td>Vol 0</td>
<td>Validation/calibration</td>
<td>10-August</td>
</tr>
<tr>
<td>Vol 1</td>
<td>Standard</td>
<td>12-August</td>
</tr>
<tr>
<td>Vol 2</td>
<td>Tomographie Nouragues</td>
<td>14-August</td>
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<tr>
<td>Vol 3</td>
<td>Standard</td>
<td>17-August</td>
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<tr>
<td>Vol 4</td>
<td>Tomographie Paracou</td>
<td>24-August</td>
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<tr>
<td>Vol 5</td>
<td>Standard</td>
<td>30-August</td>
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<tr>
<td>Vol 6</td>
<td>Standard</td>
<td>01-Sept</td>
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</table>

Temporal decorrelation analysis - PolInSAR

Tomography - PolInSAR

23 days
### Calibration site: Rochambeau

![Map of Rochambeau calibration site]

<table>
<thead>
<tr>
<th>Flight Identifier</th>
<th>Flight date</th>
<th>Calibration zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>TROPISAR00</td>
<td>10/08</td>
<td>T1: Yes, T2: Yes, T3: Yes, T4: No, T5: Yes, Dr: Yes</td>
</tr>
<tr>
<td>TROPISAR01</td>
<td>12/08</td>
<td>T1: Yes, T2: Yes, T3: Yes, T4: Yes, T5: Yes, Dr: Yes</td>
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<tr>
<td>TROPISAR02</td>
<td>14/08</td>
<td>T1: Yes, T2: Yes, T3: Yes, T4: Yes, T5: Yes, Dr: Yes</td>
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<tr>
<td>TROPISAR03</td>
<td>17/08</td>
<td>T1: Yes, T2: Yes, T3: Yes, T4: Yes, T5: Yes, Dr: Yes</td>
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<td>TROPISAR04</td>
<td>24/08</td>
<td>T1: Yes, T2: No, T3: Yes, T4: No, T5: Yes, Dr: Yes</td>
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<td>TROPISAR05</td>
<td>30/08</td>
<td>T1: Yes, T2: No, T3: Yes, T4: No, T5: Yes, Dr: Yes</td>
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<tr>
<td>TROPISAR06</td>
<td>01/09</td>
<td>T1: Yes, T2: No, T3: Yes, T4: No, T5: Yes, Dr: Yes</td>
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</table>
## Data quality assessment

- Summary

<table>
<thead>
<tr>
<th></th>
<th>P-Band</th>
<th>L-Band</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calibration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiometric accuracy</td>
<td>+/- 0.5dB</td>
<td>+/- 0.5dB</td>
</tr>
<tr>
<td>Co-polar phase accuracy</td>
<td>1° +/- 2.2°</td>
<td>-1° +/- 4°</td>
</tr>
<tr>
<td>NE-Sigma0 [dB]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25-35°</td>
<td>-30</td>
<td>-33</td>
</tr>
<tr>
<td>35-45°</td>
<td>-32</td>
<td>-35</td>
</tr>
<tr>
<td>Cross-Talk Level [dB]</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-25</td>
<td>-30</td>
</tr>
<tr>
<td>Geometric accuracy</td>
<td>(if altitude is known)</td>
<td>&lt; 10m</td>
</tr>
</tbody>
</table>
First analysis

- Temporal decorrelation at P Band
- PolInSAR height estimation at P Band
TropiSAR images: Paracou
Database over Paracou

Temporal Shift

<table>
<thead>
<tr>
<th>Flight</th>
<th>Temporal Shift</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
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</tr>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>

Vertical Shift

<table>
<thead>
<tr>
<th>Paracou</th>
<th>Nb of acquisition processed</th>
<th>NB of dataset available</th>
</tr>
</thead>
<tbody>
<tr>
<td>P band</td>
<td>13</td>
<td>18</td>
</tr>
<tr>
<td>L band</td>
<td>9</td>
<td>14</td>
</tr>
<tr>
<td>Total</td>
<td>22</td>
<td></td>
</tr>
</tbody>
</table>

: available at L band
TROPISAR: temporal decorrelation
Interferometric coherence wrt temporal baseline

- 2 days
- 4 days
- 7 days
- 14 days
- 20 days
- 22 days

Range: 0.10-0.15 m³/m³
PolInSAR height estimation

Based on the RVoG* model

* Cloude, Papathanassiou and Treuhaft
Preliminary analysis

From previous work on planted forest, the volume only coherence is not observed at P-Band *. Is this still true in the tropics?

Tomography analysis from Rocca and Tebaldini

Height inversion from PolInSAR using RVoG

- Volume only coherence is not observed

- The PolInSAR RVoG inversion is not possible unless …

- Two options:
  - Single baseline analysis with a know extinction coefficient
    - Simple technique
    - If baseline is well selected, the choice of the extinction has a low impact on the result
  - Multibaseline analysis
    - Complex technique
    - In a single satellite setup, this will add temporal decorrelation…
Height inversion from PolInSAR

LIDAR DEM | SAR image | LIDAR Canopy H

Slope | Ha | Interferometric coherence

$0m - 40m$ | $20m - 50m$

$-10°$ | $30°$ | $40m$ | $80m$

*LiDAR data: courtesy of GUYAFOR project, Gregoire Vincent*
PolInSAR versus Lidar height

PolInSAR height estimation on a 19x19 sliding window

Lidar height was first projected into the radar geometry

Lidar mean height over a 19x19 sliding window

Bias <1m
RMSE=4.03m
Zoom over a flat area

Bias <1m
RMSE=3.0 m
Effect of topography

Bias <1m
RMSE=4.3m
Paracou experimental site

- More than 550 woody species
- 16 plots established since 1984
- Regularly censused
- Different thinning treatments
- Control (undisturbed plots)

Comparaison over the measured plots

1986-1987
For analysis on forest recovery rate
Paracou plot height variations

We are looking for a 6m variation

Height is an important parameter in this case as it is a marker of the forest degradation

75 trees (diameter > 40cm) removed per ha en 1987
Lidar histograms versus PolInSAR histograms

Lidar
- Plot 11 Reference
  - mean = 30.15
  - std = 3.43
  - most pop. bin = 31.43

PolInSAR
- Plot 11 Reference
  - mean = 30.15
  - std = 3.43
  - most pop. bin = 31.43

Lidar
- Plot 12 T3
  - mean = 28.56
  - std = 3.61
  - most pop. bin = 26.83

PolInSAR
- Plot 12 T3
  - mean = 28.56
  - std = 3.61
  - most pop. bin = 26.83
Conclusions

- P & L band SAR and in-situ data available through ESA
  - 52 datasets over 2 main sites + 2 sites
    - 23 days – 6 vertical baselines – 7 flights
  - Extensive in-situ data
    - Biomass measurements
    - Measurements (DBH) for 98000 trees, height for 700 trees

- First results from PolInSAR analysis
  - Low temporal decorrelation
  - PolInSAR height estimation over tropical forest using a single baseline approach is performing well over flat areas
  - Proper baseline selection is essential
Perspectives

- PollInSAR single-baseline analysis
  - Effect of temporal decorrelation
  - Robustness and error propagation (fixed attenuation coefficient, ..)
  - Explore the tomographic results
  - Topographic correction
  - Compact-pol performance in tropical forest
  - Spaceborne resolution

- Understanding Lidar measurements for comparison to PollInSAR measurements

- Height is not a complete proxy for the biomass
  - PollInSAR height combined with radiometric information

- Multi-baseline approach
The team for the campaign TropiSAR

- ONERA
  - P Dubois-Fernandez
  - Radar operation
    - O Ruault du Plessis
    - G Bonin - R Baqué
    - P Fromage - D Heuzé
  - Processing and Calibration
    - H Oriot - C Coulombeix
    - H Cantalloube
    - S Daniel (ONERA-CNES)
  - Analysis: Aurelien Arnaubec
- CESBIO
  - Thuy le Toan
  - Yannick Lasne – Ludovic Villard
  - Thierry Koleck
- EDB – CIRAD
  - Jérôme Chave – Maxime Réjou-Méchain
  - Lilian Blanc
- IRD
  - Michel Petit
- ESTEC
  - Malcolm Davidson
- CNES
  - Selma Cherchali

Under fundings from ESA, CNES and ONERA
Thank you
Questions?