Comparative Analysis of Temporal Decorrelation at P and L bands over Tropical forests: EM Simulations & Results from Tower based Experiments

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Context → Forest height and biomass estimation based on Pol-InSAR heights (cf. future L or P band spaceborne missions, esp. Biomass)

Objective → assess, anticipate and correct the effects of temporal decorrelation on repeat-pass Pol-InSAR coherences over tropical forests

Method → analysis of temporal decorrelation, based on:
- Experimental data resulting from ground based scatterometers ([Tropi,Afri]Scat)
- EM simulations, using modeling of forest scattering specifically design to perform sensitivity analysis on:
  • Forest & meteorological parameters (e.g. veg. water content, wind)
  • Radar parameters (e.g frequency, incidence angle)
Brief reminders on temporal decorrelation

Highlights on TropiScat and AfriScat experiments
  → Focus on diurnal cycles at P & L results measured with TropiScat

EM modeling: to better understand the underlying physics, anticipate and predict changes of configurations (radar, observed forest)

Comparative analysis:
  • Experimental & simulated diurnal variations at P-band
  • Extension to L band

Relating P and L-bands temporal decorrelation
Temporal decorrelation...

**Origins:**
- forest changes (vegetation/ground) between SAR passes due to:
  - exceptional events (meteorological, deforestation/degradation...)
  - geophysical changes (diurnal/seasonal)
  - displacements (wind conditions)

**Effects:**
- affects the magnitude of Pol-InSAR complex coherences, mostly considered as a linear and real factor:
  \[ \gamma = \gamma_{\text{tmp}} \cdot \gamma_{\text{sys}} \cdot \gamma_{\text{geo}} \cdot \gamma_{\text{vol}} \]
- but depending on its origins (e.g. evapotranspiration, sub-canopy winds), the interferometric phase is also impacted

**Dependent on Radar frequency,**
- given:
  - the dielectric constant as function of VWC & f:
    \[ \varepsilon = P(\text{VWC, } f) \]
  - the impacts of displacements regarding wavelength
  - + set of scatterers involved (cf. scattering phase centers)
Tower-based scatterometers

Flux-tower: calculate the Net Ecosystem Exchange of CO2, CH4, N2O from Eddy Co-Variance measurements
TropiScat*: ESA-CNES experiment, leaded by T.Koleck (PI,CESBIO)
Started in Dec 2011, from Guyaflux tower (French Guiana)

AfriScat**: same operating system & features than TropiScat,
planned for 1 year, to be installed in February

*first presentation at POLinSAR-2011
** cf. Poster Session (T.Koleck, C. Albinet et Al.)
AfriScat Experiment

Objective: comparative analysis with TropiScat data, given different sites (esp ground topography, forest structure, environmental conditions) but similar identical operating system & acquisition modes
TropiScat Experiment

- **TropiSCAT**: a static ground-based radar (scatterometer) on top of the 'Guyafux' flux-tower
  - Automatic and systematic acquisitions
  - Polarimetric capabilities (HH, HV, VH and VV)
  - Tomographic acquisitions (enable voxels with vertical resolution)
  - Continuous bio/geo-physical/meteorological measurements (as flux tower)

[Image of TropiSCat Experiment]

Guyafux Tower description:

http://www.ecofog.gf/fr/fonctionnement/guyaflux/
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• **TropiSCAT objectives**:
  time series analysis of backscatter from a tropical dense forest
  → Long term temporal coherence (diurnal, weekly, monthly, yearly)
  → Identification of the sources of temporal decorrelation
  → 3D distribution of radar scatterers
  → validation of EM models (esp. coherent EM model based on discrete description of the forest) further used for retrieval of forest height & biomass

Diurnal cycles at P-band

Wind effect?

Dielectric constant changes?


Outlines

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Relating P and L-bands temporal decorrelation
EM modeling with MIPERS
(Multistatic Interferometric & Polarimetric model for Remote Sensing)

**Scene description**

Discrete geometrical description based on canonical shapes (cylinders, ellipsoids) statistically distributed (Monte-Carlo process)

2 possible descriptions for tropical forests:
- a) based on layers
- b) based on tree architecture models (adapted from TROLL*)

Underlying topography modeled with 3D triangular facets

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*J. Chave et al, ‘Study of structural, successional and spatial patterns in tropical rain forests using TROLL, a spatially explicit forest model’, Ecological Modelling, 1999.*
EM modeling with MIPERS
(Multistatic Interferometric & Polarimetric model for Remote Sensing)

Coherent modeling based on the DBWA (Distorted Born Wave Approximation) and scattering matrices of canonical shapes.

Accounts for several contributions:

- Single scattering mechanisms from vegetation scatterers and the ground
- Multiple scattering mechanisms resulting from coupling effects between vegetation and ground

Geometrical dimensions & dielectric constant
EM simulations
Modeling Dielectric Changes

Wind gusts modeling*:
- Propagation of the vertical velocity field into the inner canopy
- Resulting displacement according to:
  - Frequency modes of the branches
  - Variation of the branch insertion angle (single rotation axis hypothesis)

*C. Tomasi, J. Shi. Good features to track. In Proc. of the IEEE Conference on Computer Vision and Pattern Recognition
*Xuhui Lee, “Air motion within and above forest vegetation in non-ideal conditions”, Forest Ecology and management, 2002
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\[ EI \frac{\partial^4 y}{\partial z^4} = -\rho S \frac{\partial^2 y}{\partial t^2} \]
\[
\text{or } \frac{\partial^4 y}{\partial z^4} + k^4 \frac{\partial^2 y}{\partial t^2} = 0, \text{ with: } k^4 = \frac{\rho S}{EI} w^2\]
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\[ Y_i(z) = A \cos(k_i z) + B \cosh(k_i z) + C \sin(k_i z) + D \sinh(k_i z) \]
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\[ \begin{align*}
  Y(0) &= 0, & \frac{\partial Y}{\partial z} &= 0 \\
  \frac{\partial^2 Y}{\partial z^2}(L) &= 0, & \frac{\partial^3 Y}{\partial z^3}(L) &= 0 \\
  F_z &= \rho_a \frac{C_d}{2} 2\pi L \sin \psi_{ins} v_z^2
\end{align*} \]
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\]

\[
F_z = \rho_a \frac{C_d}{2} 2\pi L \sin \psi_{ins} v_z^2
\]

\[
d\psi_{ins} = \frac{64 \rho_a c_d}{\pi \alpha_i^4 E} \sin \psi_{ins} v_z^2 \frac{L}{D}^3
\]
Dielectric values vs time of day

Wind velocity vs time of day
Simulations Results
Modeling diurnal cycles at P-band

Simulated decorrelation
HH, HV, VV
Simulations Results
Modeling diurnal cycles at P-band

Impact of dielectric variations

Simulated decorrelation
HH, HV, VV
Simulations Results
Modeling diurnal cycles at P-band

Impact of convective wind

Simulated decorrelation
HH, HV, VV
Simulations Results
Modeling diurnal cycles at P-band

TropiScat results

Simulated decorrelation

HH, HV, VV
Simulations Results
Modeling diurnal cycles at L-band

Simulated decorrelation
HH, HV, VV
Simulations Results
Modeling diurnal cycles at L-band

TropiScat results
HH, HV, VV

Simulated decorrelation
HH, HV, VV
Simulations Results
Diurnal cycles at P and L-bands

- **P-band**
  - HH, HV, VV
  - Differences due to dielectric changes

- **L-band**
  - HH, HV, VV
Simulations Results
Diurnal cycles at P and L-bands

P-band

L-band

HH, HV, VV

Differences due to convective winds
Support validation of EM models: given multi-factorial nature of temporal decorrelation, the good fit between simulated & experimental results at both P & L-band help to dissociate the effects attributed to dielectric changes or convective wind.

Main differences between L&P:
- As expected (given ratio displacement/wavelength), wind effects are much more severe for decorrelation at L-band, but this study quantifies the differences → retrieval prospects of subcanopy flows? (relevant issue in forest ecology)
- More surprising is the more important L-band decorrelation due to VWC diurnal cycles, despite smaller dielectric variations (but accentuated by higher contribution from smaller vegetation scatterers (with higher VWC)
- Applications: this study suggests a systematic difference between decorrelation at P&L-bands, → hence prospects of synergies between L and P band missions, supported by EM simulations to account for varying parameters (e.g. time of acquisitions)

On-going investigations:
- Beyond diurnal cycles, analysis of long term decorrelation, as function of meteorological events (esp. cumulative effects of water-falls)
- Given impacts of forest structure or forest biomass (cf. gt=f(AGB), ground topography
  How general are these results?
  ...to be investigated with the upcoming results from AfriScat
Thank you for your attention

& thank you for your questions...