Centre d'Etudes Spatiales
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Toulouse – France

Impacts of Geophysical Changes on the P-band Pol-InSAR Phase Center of Tropical Dense Forests

EM Simulations & TropiScat Experimental Results

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http://www.onera.fr

Contents

- **Context :**

  Forest biomass retrieval from P-band Pol-InSAR

  (cf. ***Biomass,*** *ESA Earth Explorer 7 candidate mission)*

- **Objective :**

  assess the effects of *temporal decorrelation on Pol-InSAR coherences @P-band & for Tropical dense forests*

- **Method : analysis of temporal decorrelation from :**
  - TropiScat experimental results
  - EM simulations

  } vs 2 types of temporal decorrelation :
  - vegetation water content
  - wind conditions

Outlines

- **Quick reminders on temporal decorrelation**
- **Results from the TropiScat experiment**
- **EM simulations :**
  analysis of TropiScat results
  & transposition to P-band Pol-InSAR airborne/spaceborne Pol-InSAR
- **Specific features to detect/account for temporal decorrelation**

Quick reminders on Temporal decorrelation

Origins

forest changes (vegetation/ground) between SAR passes due to :

- exceptional events (meteo, deforestation/degradation…)
- geophysical changes (diurnal/seasonal)
- motion (wind conditions)

Effects

- affects the Pol-InSAR complex coherences,

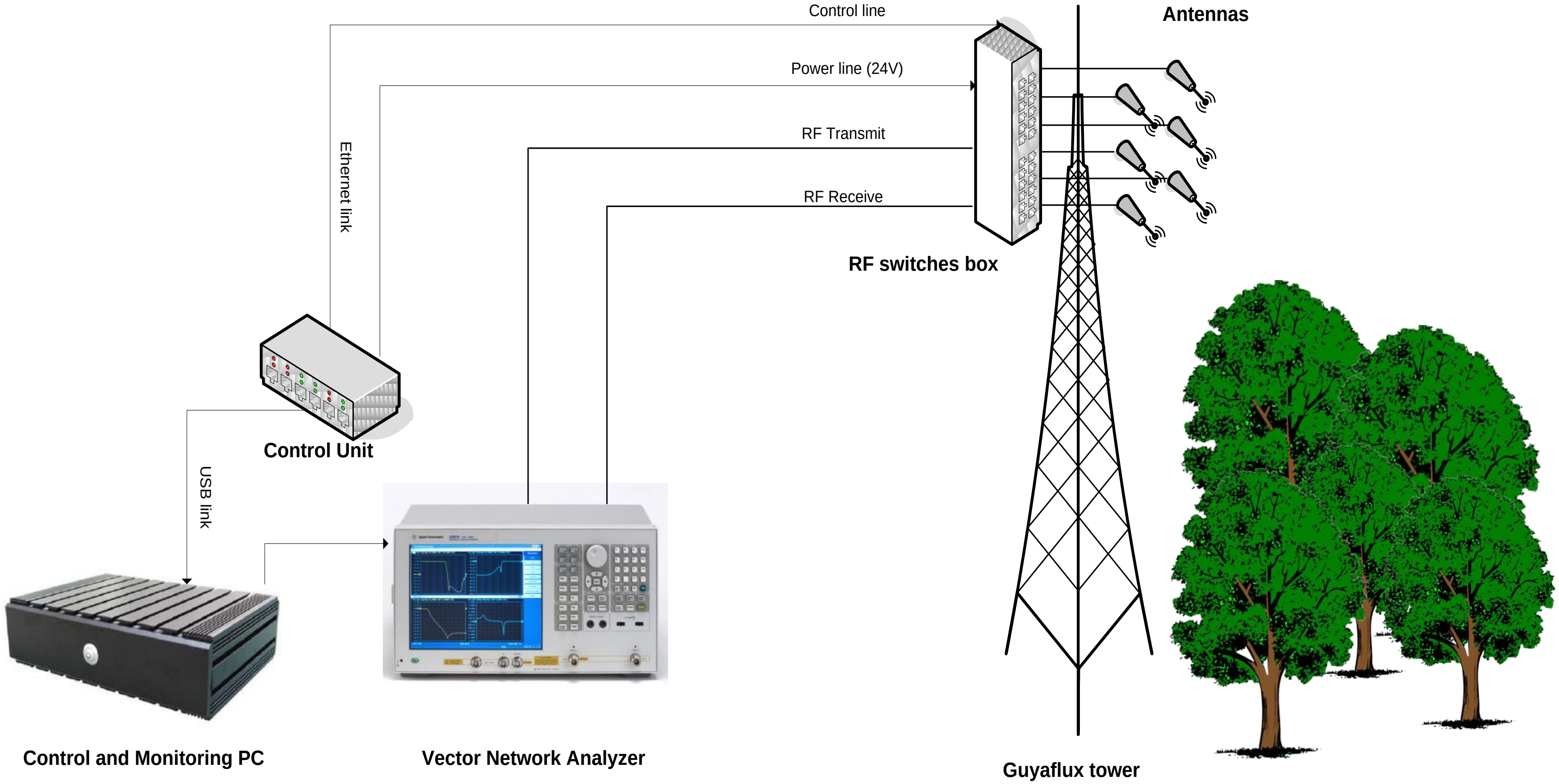
i.e amplitude $\boldsymbol{\gamma} = \gamma_{sys} \bullet \boldsymbol{\gamma_{tmp}} \bullet \gamma_{geo} \bullet \gamma_{vol}$ but also the **interferometric phase**

- leads to forest height misestimation

Recent studies @P band & tropical forests :

- Previous talk from **M. Lavalle et al, '**Tacking temporal decorrelation with the RMOG model'
- **S. Daniel et al**, 'Temporal decorrelation analysis at P band over tropical forest', IGARSS 2011
- **T. Koleck et al,** 'Tropiscat : A polarimetric and tomographic scatterometer experiment in French Guiana forests", IGARSS proceedings, 22-27 July 2012, Munich,Germany.'

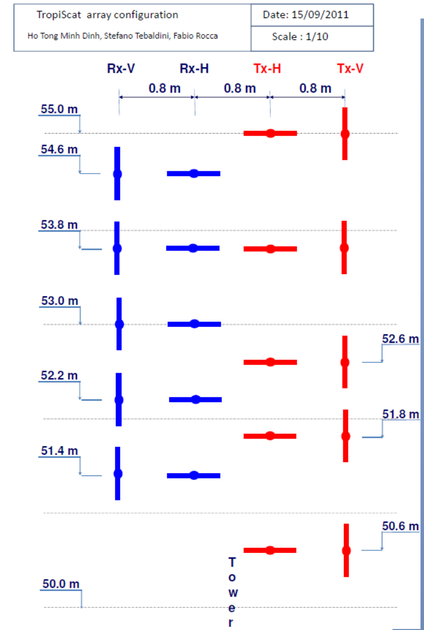
The TropiScat experiment*



Frequency band = 400 MHz to 1 GHz

***T. Koleck**, ; Borderies, P.; Rocca, F.; Albinet, C.; Ho Tong Minh, D.; Tebaldini, S.; Hamadi, A.; Villard, L.; Le Toan,T. "**Tropiscat : A polarimetric and tomographic scatterometer experiment in French Guiana forests**", IGARSS proceedings, 22-27 July 2012, Munich,Germany.

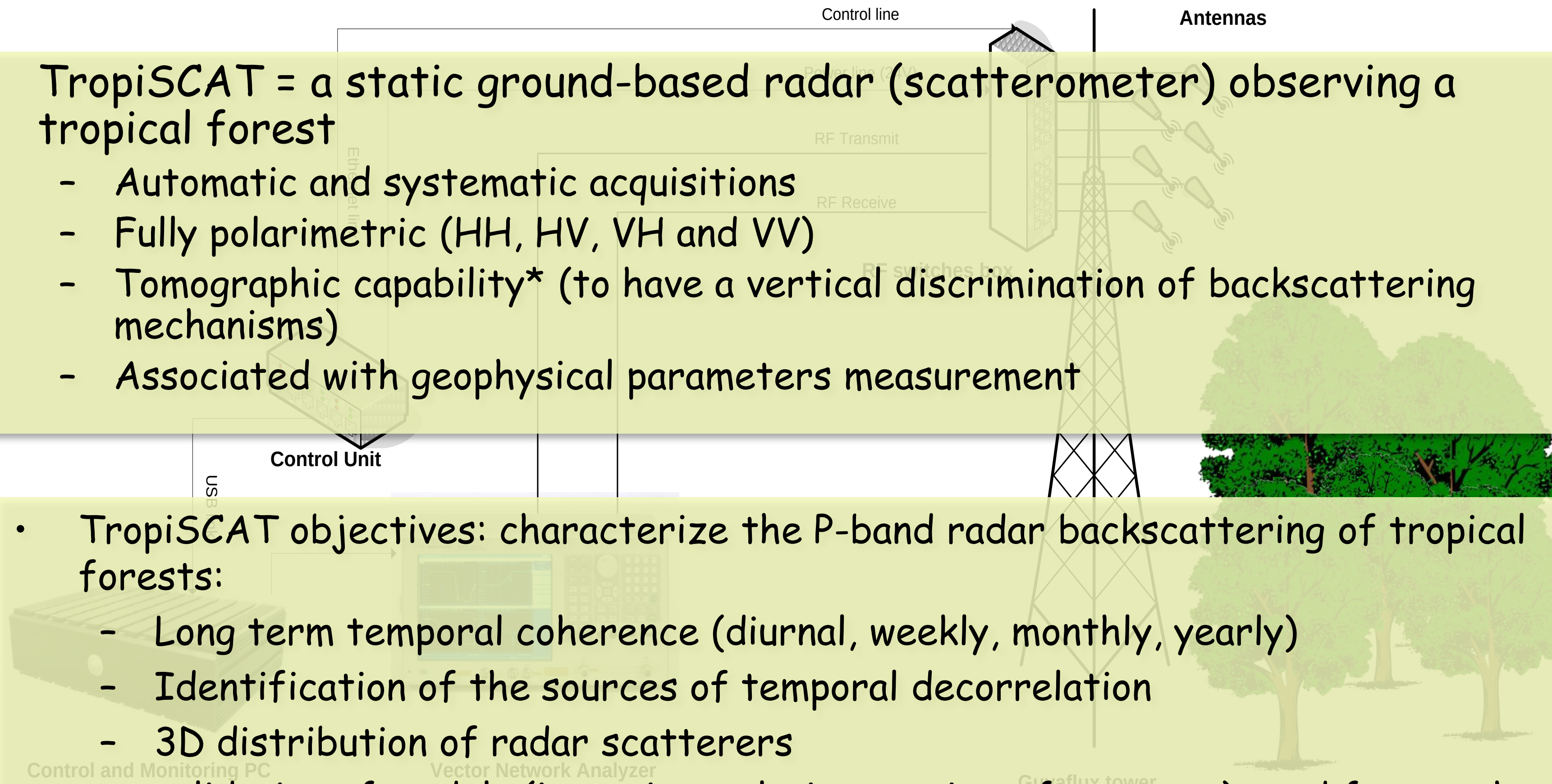
The TropiScat experiment



Guyaflux Tower description:

http://www.ecofog.gf/fr/fonctionnement/guyaflux/

The TropiScat experiment



- TropiSCAT = a static ground-based radar (scatterometer) observing a tropical forest
  - Automatic and systematic acquisitions
  - Fully polarimetric (HH, HV, VH and VV)
  - Tomographic capability* (to have a vertical discrimination of backscattering mechanisms)
  - Associated with geophysical parameters measurement

- TropiSCAT objectives: characterize the P-band radar backscattering of tropical forests:
  - Long term temporal coherence (diurnal, weekly, monthly, yearly)
  - Identification of the sources of temporal decorrelation
  - 3D distribution of radar scatterers
  - validation of models (intensity, polarimetry, interferometry) used for geophysical information retrieval.

***D. Ho Tong Minh, S. Tebaldini, F. Rocca, C. Albinet, P. Borderies, T. Koleck, T. Le Toan , Tebaldini, L. Villard, "TropiSCAT: Multi-temporal MultiPolarimetric Tomographic Imaging of Tropical Forests" , IGARSS 2012 IEEE International proceedings, pp. 1536-1539, 23-27 July**

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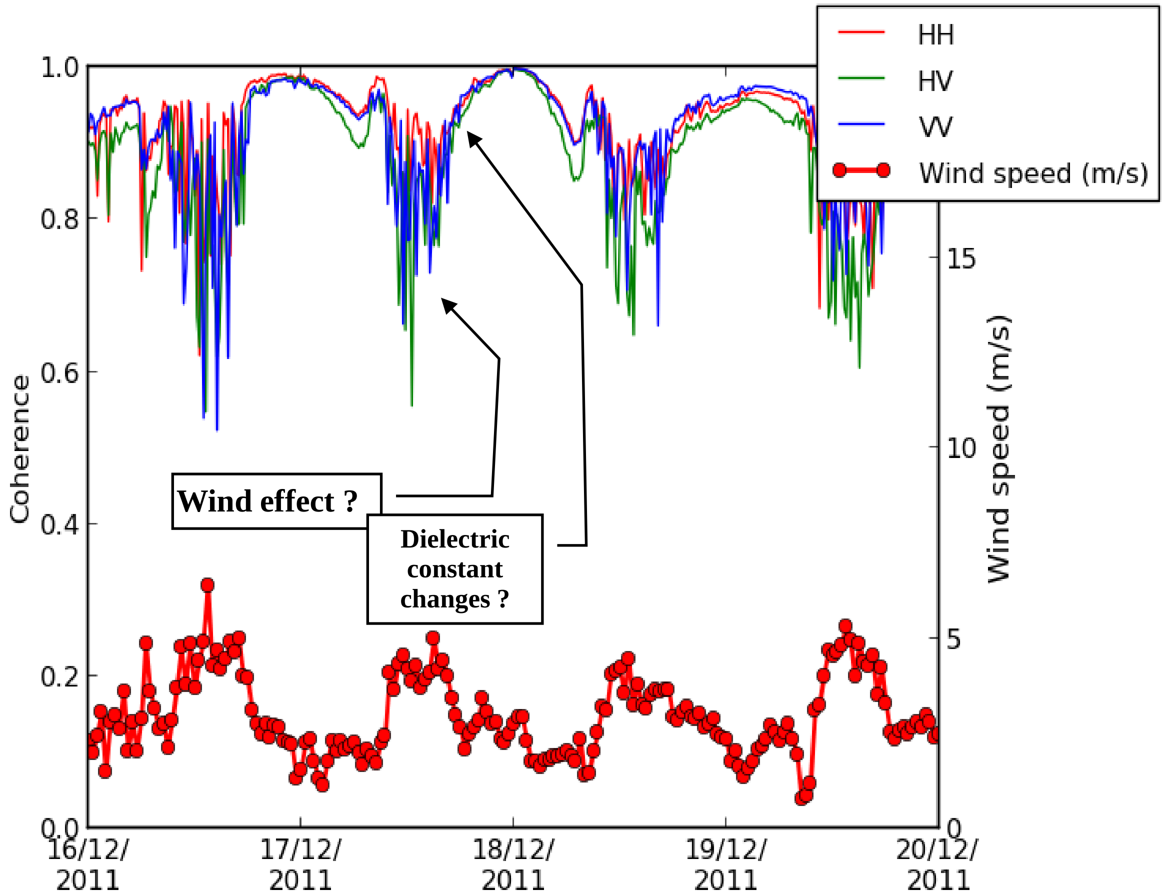
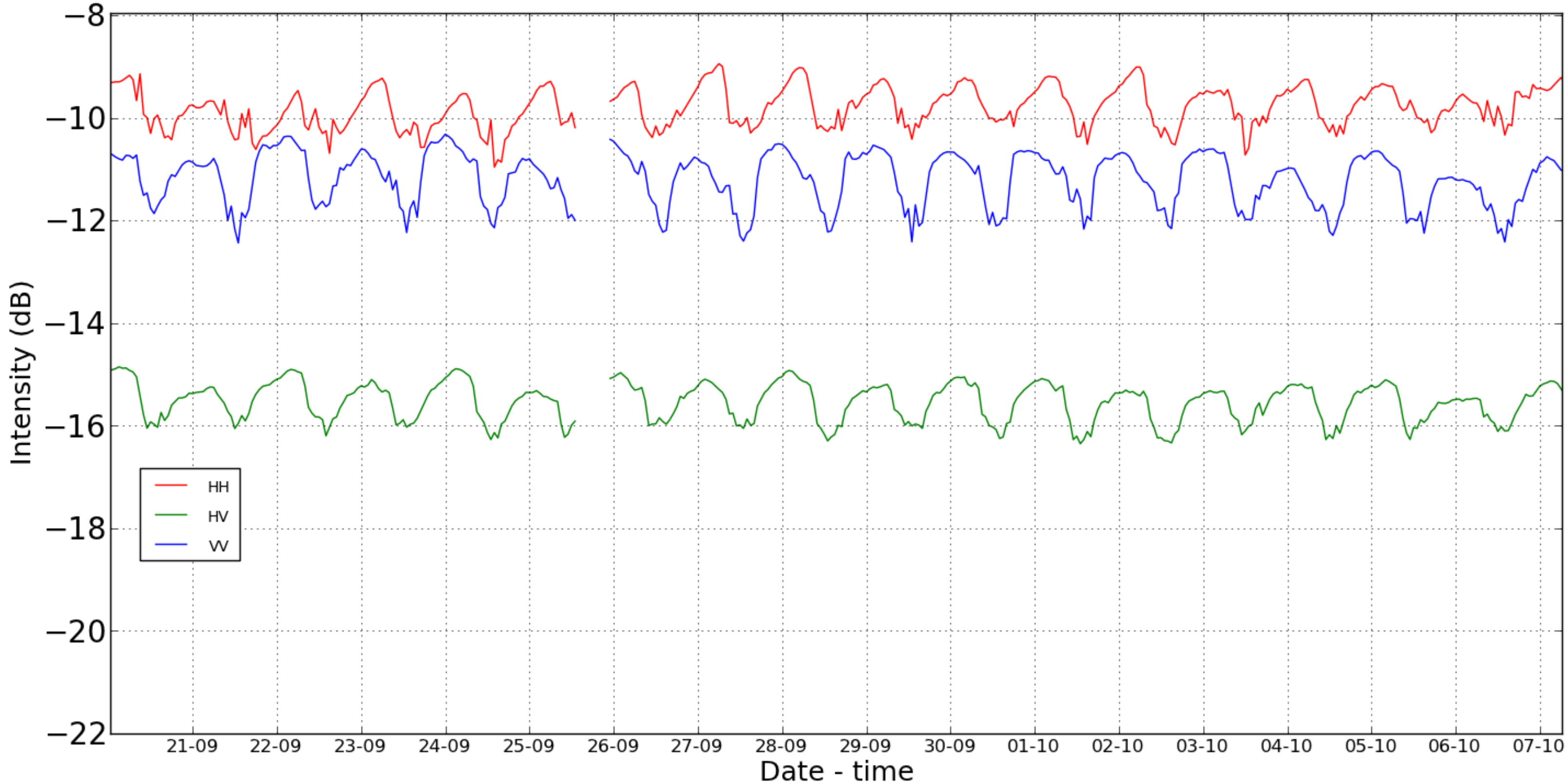
Special/Remarkable Results from TropiScat



Coherence verus time : diurnal cycles can be emphasized

- C. Albinet, P. Borderies, T. Koleck, F. Rocca, S.Tebaldini, L. Villard , T. Le Toan , A. Hamadi, D. Ho Tong Minh, "TropiScat: A ground Based Polarimetric experiment in Tropical forests", IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, , vol. PP, no. 99, pp. 1 –7, 2012.
- A. Hamadi , C. Albinet, P. Borderies, T. Koleck, D. Ho Tong Minh, L. Villard, T. Le Toan: temporal survey of polarimetric tropical forest P-band scattering, submitted to 'Random and Complex media, June 2012.

Experimental Results from TropiScat



Diurnal cycles are also clear for radar intensities

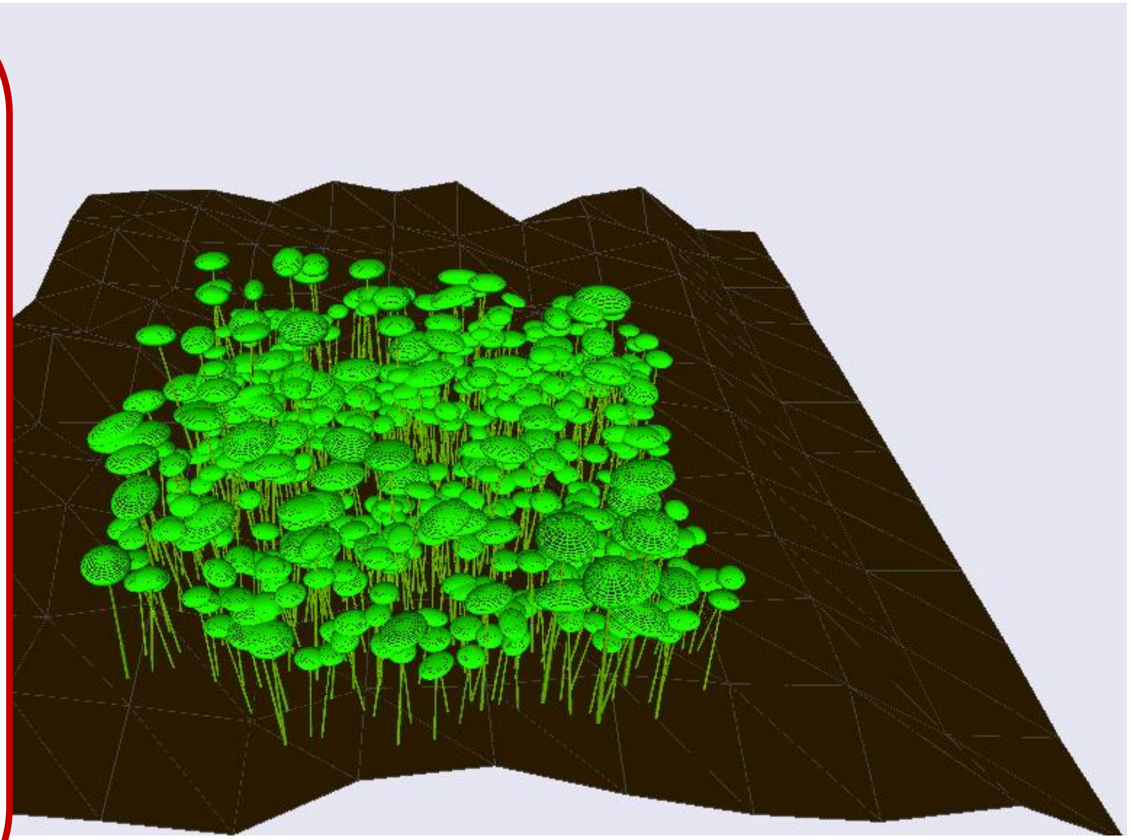
- **C. Albinet, P. Borderies, T. Koleck, F. Rocca, S.Tebaldini, L. Villard , T. Le Toan , A. Hamadi, D. Ho Tong Minh, "TropiScat: A ground Based Polarimetric experiment in Tropical forests", IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, , vol. PP, no. 99, pp. 1 –7, 2012.**
- **A. Hamadi , C. Albinet, P. Borderies, T. Koleck, D. Ho Tong Minh, L. Villard, T. Le Toan: temporal survey of polarimetric tropical forest P-band scattering, submitted to 'Random and Complex media, June 2012.**

Results analysis from EM modeling & MIPERS (Multistatic Interferometric & Polarimetric model for Remote Sensing)

Scene generation :

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

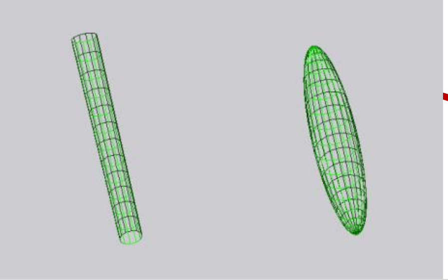
Tropical forest case :
- Underlying topography
- multi-species with 3 classes of DBH
- Scene generation
- allometric equations from the TROLL model*



*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 using MIPERS
(Multistatic Interferometric & Polarimetric model for Remote Sensing)

EM calculations

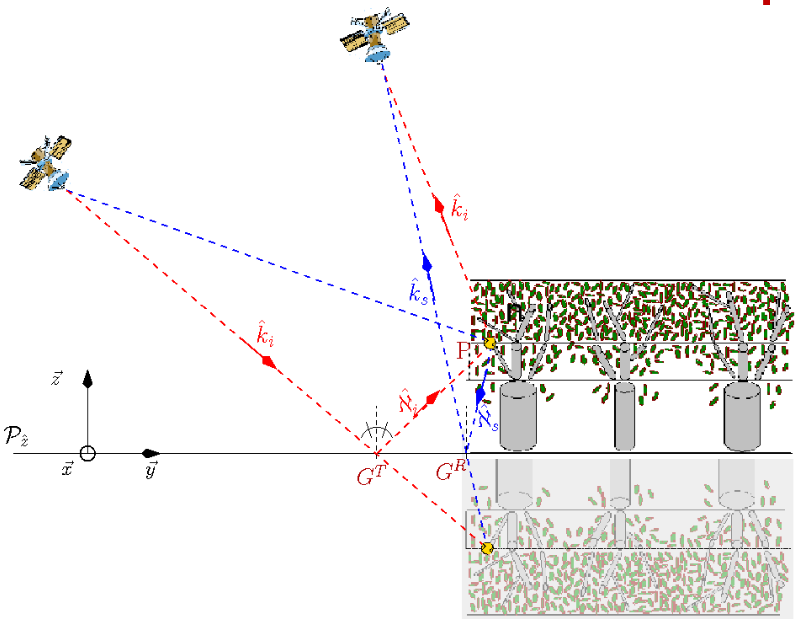


dimensions & dielectric constant

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

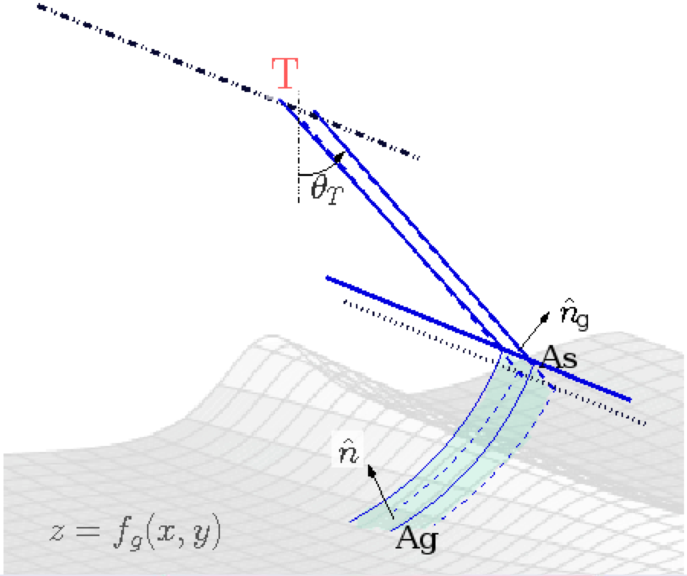
Accounts for several contributions :

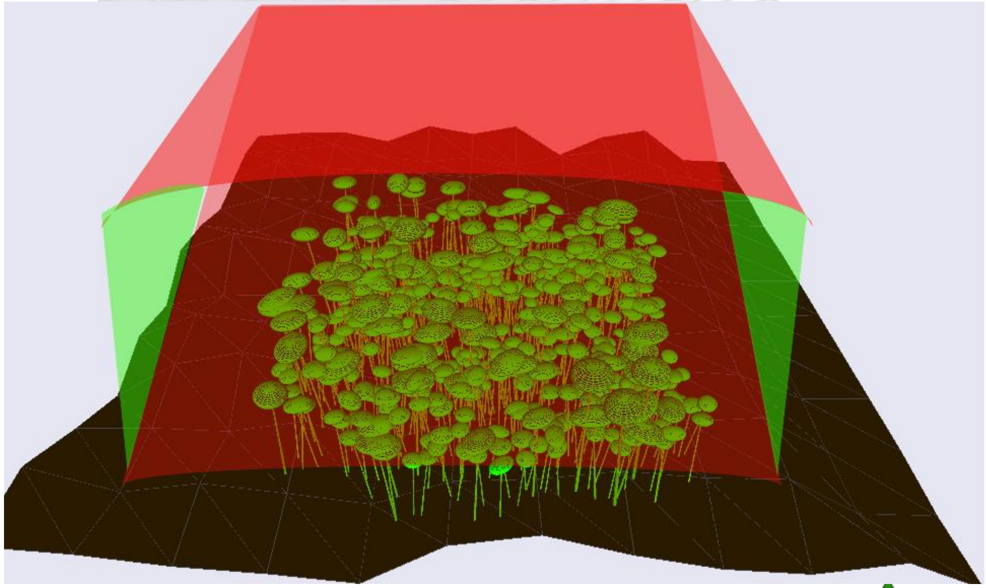
- **single scaterring mechanisms from vegetation scatterers and the ground**
- **multiple scattering mechanisms resulting from coupling effects between vegetation and ground**



EM modeling with MIPERS

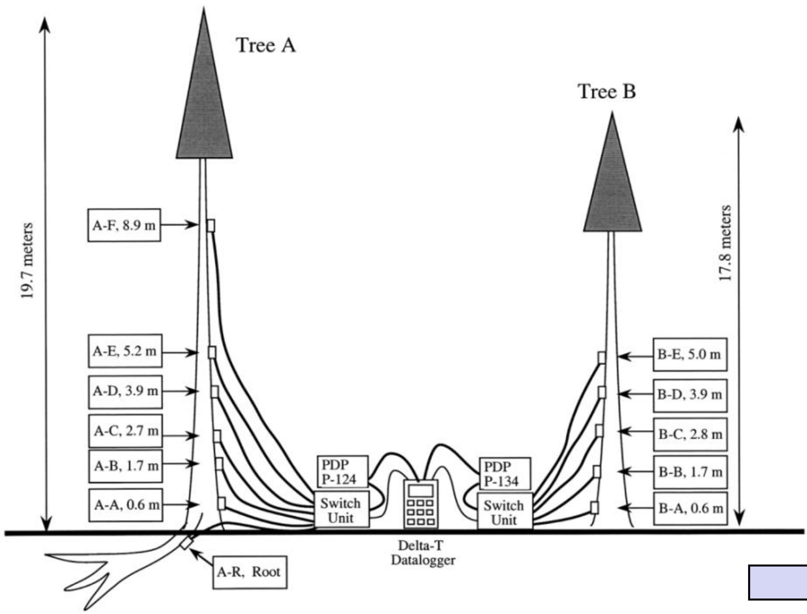
EM calculations

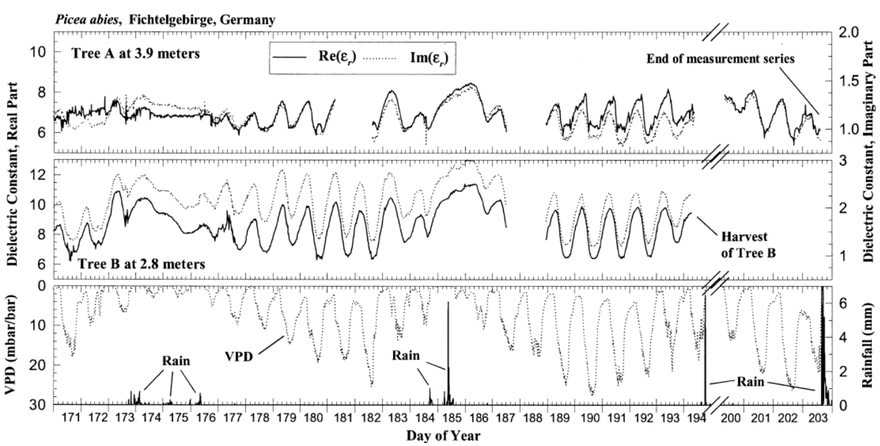


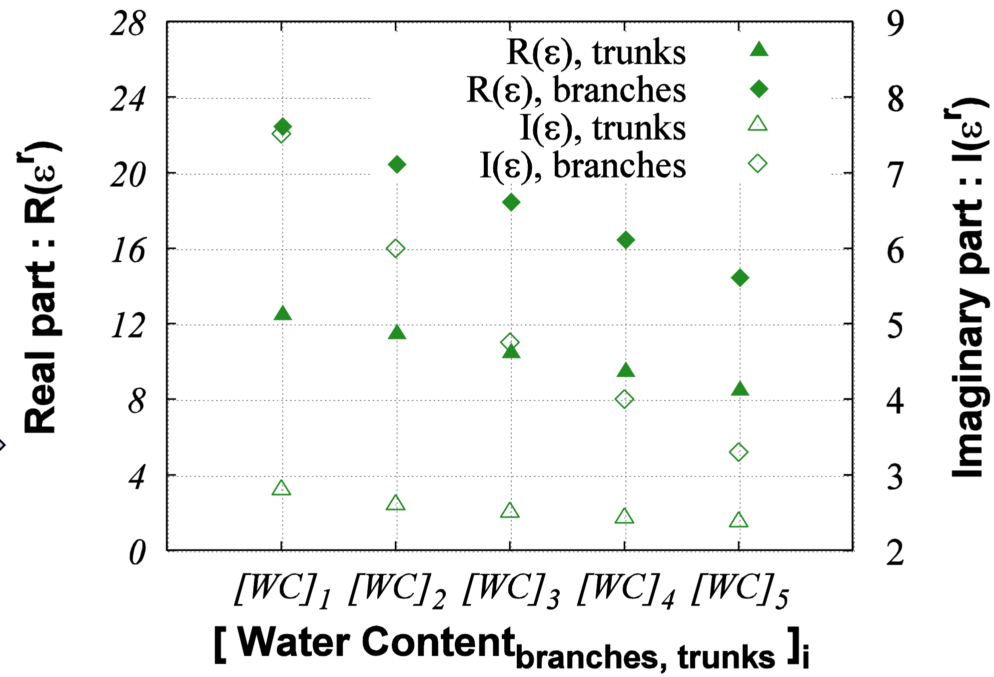


Coherent summation to generate Radar observables : Polarimetric and Interferometric SAR measurements + non measurable quantities related to individual contributions (branches, trunks, ground and for each scattering mechanism)

Analysis of TropiScat results : modeling changes of vegetation water content

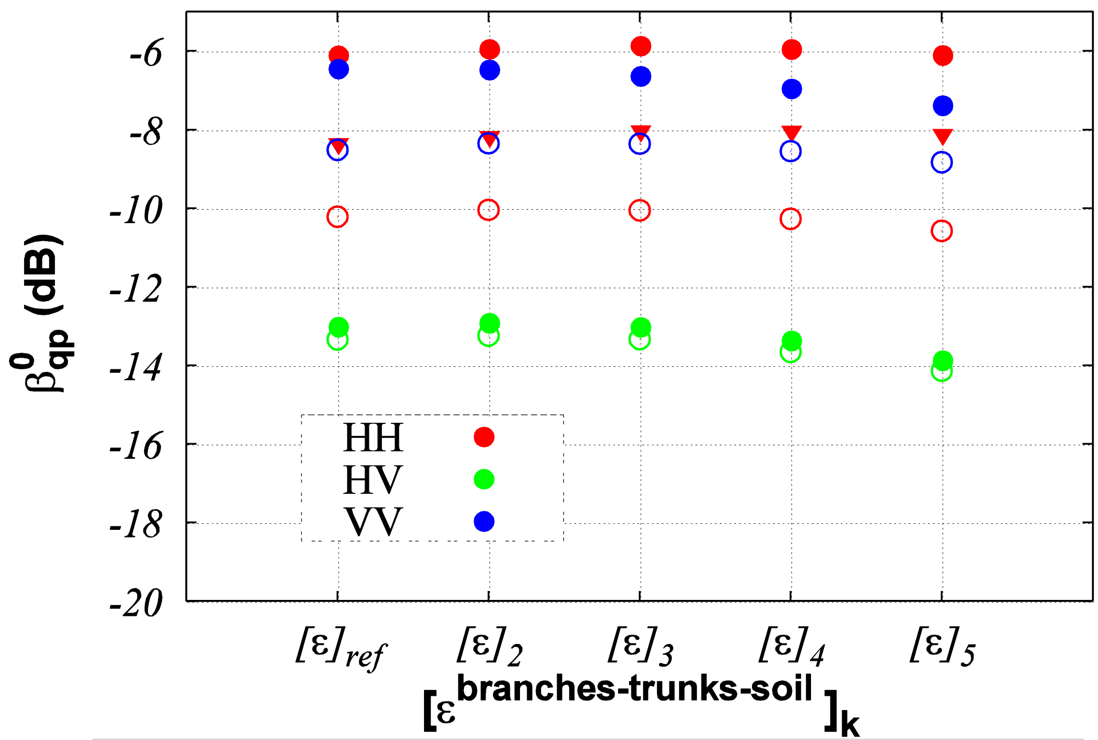






K. McDonald et al : Diurnal and Spatial Variation of Xylem Dielectric Constant in Norway Spruce (Picea abies [L.] Karst.) as Related to Microclimate, Xylem Sap Flow, and Xylem Chemistry , IEEE TGRS vol 40, 2002

Analysis of TropiScat results : modeling changes of Vegetation Water Content

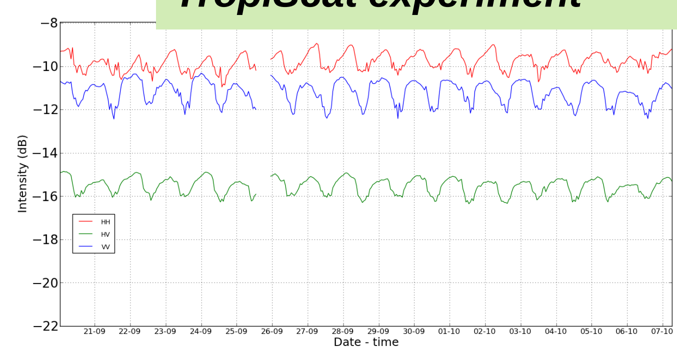


Intensities :
HV : volume
VV : volume and direct ground
HH : volume and specular ground (coupling)

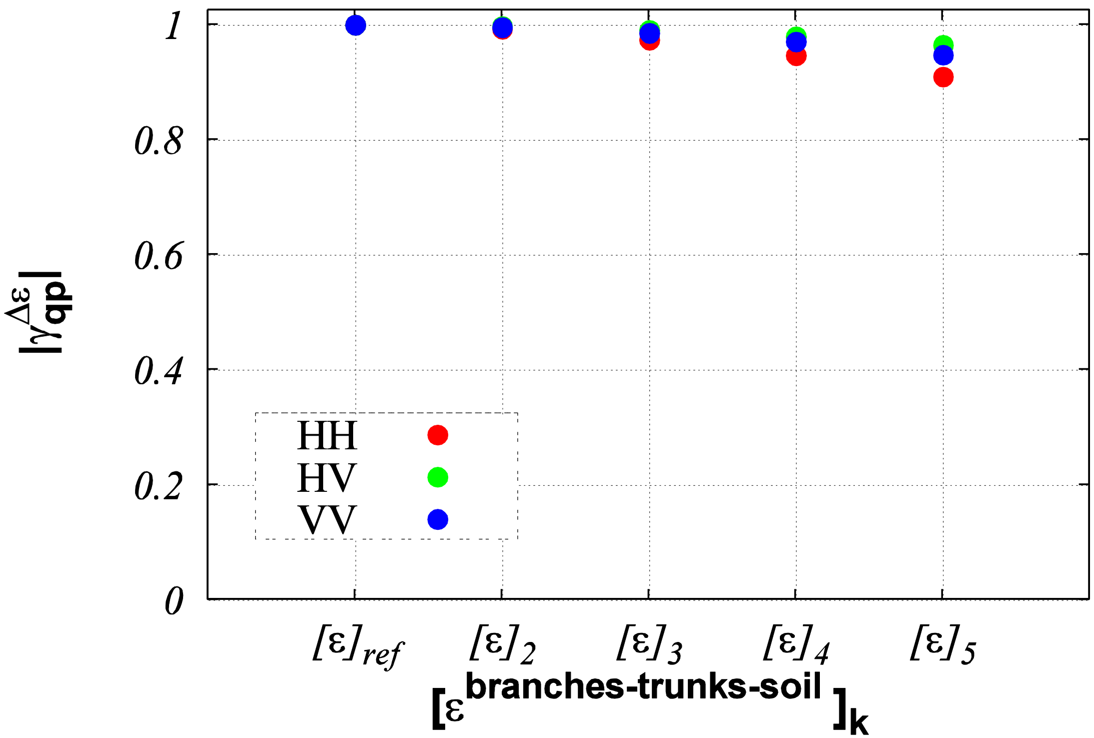
Lower variation in HH since double bounce part is more stable

Intensities versus changes of dielectric constant
Total : filled points
Double bounce : triangles
Volume : non-filled circles

Changes (<1dB) similar to the the ones measured by TropiScat experiment



Analysis of TropiScat results :
modeling changes of Vegetation Water Content

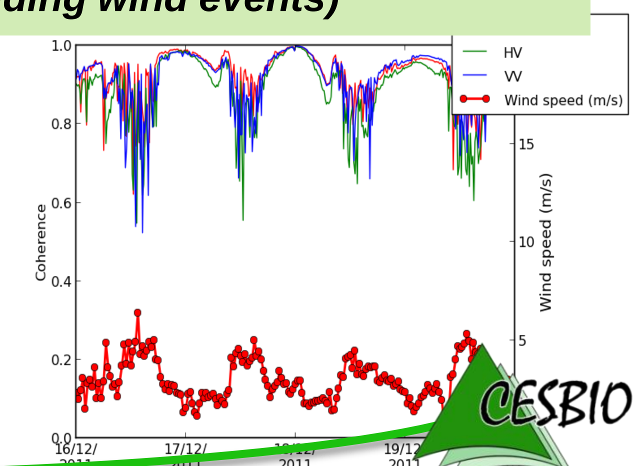


Temporal coherences versus changes of dielectric constant

Decorrelation within 0.1

More important in HH since both volume and double bounce are involved

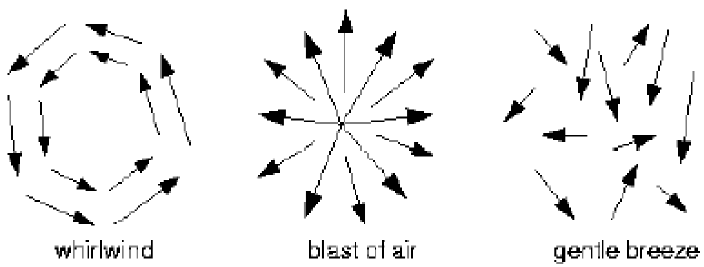
Decorrelation values in good agreeement with the ones measured during the diurnal cycle, excluding wind events)

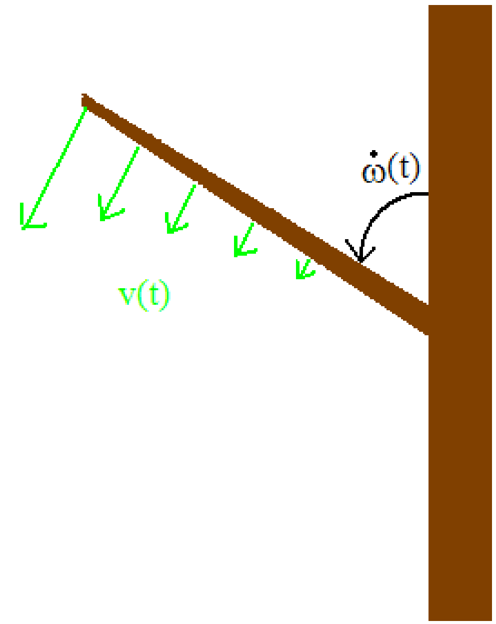


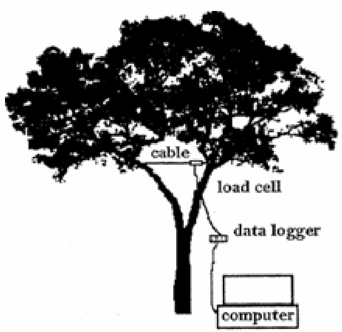
Analysis of TropiScat results : modeling wind effects on scatterers

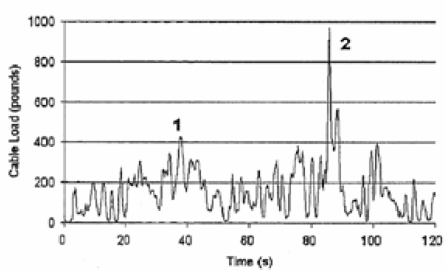
Wind gusts modeling :

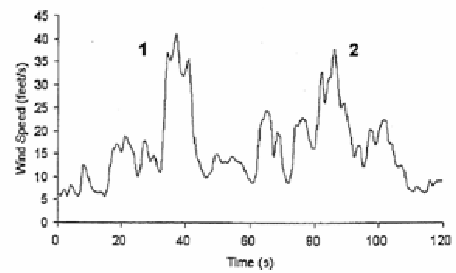
- Propagation of the vertical velocity field to the innner canopy field
- Resulting displacement according to :
  - Frequency modes of the tree*
  - Variation of the branch insertion angles (hyp : single rotation axis)







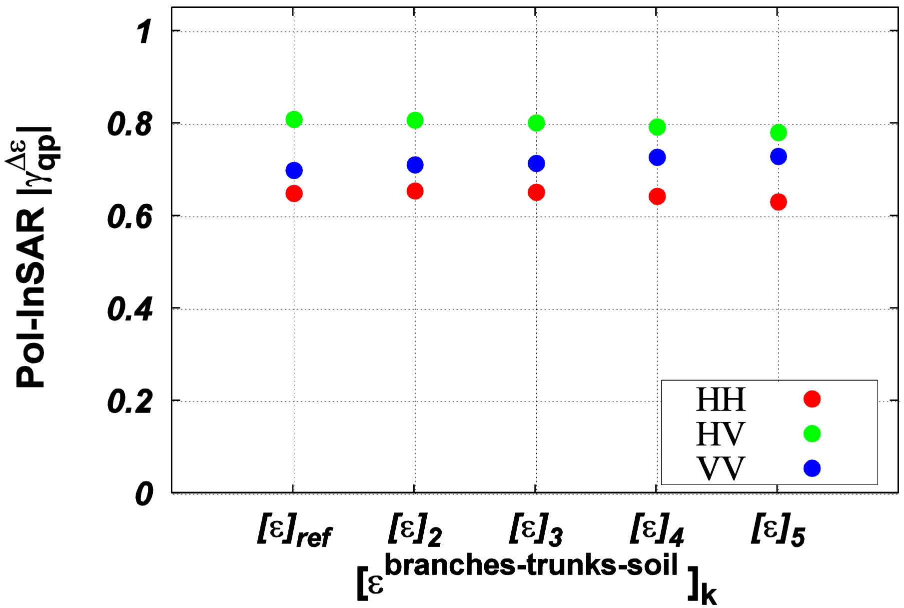


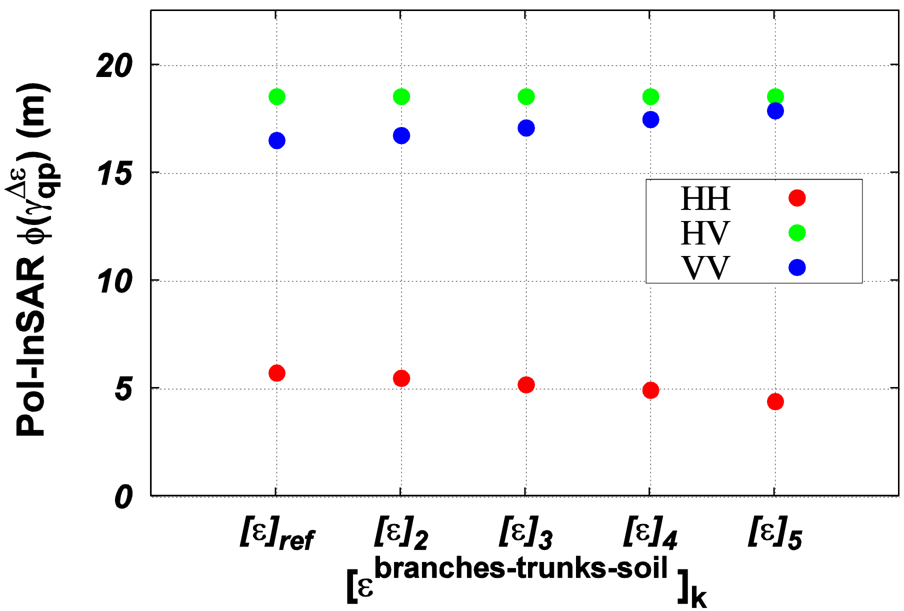


*J. Keyser J. Beaudoin. Simulation levels of detail for plant motion. In *ACM Siggraph/ Eurographics Symposium on Computer Animation, 2004.*

*C. Tomasi J. Shi. Good features to track. In *Proc. of the Conference on Computer Vision and Pattern Recognition*

Modeling changes of Vegetation Water Content : impact on Pol-InSAR coherences





Pol-InSAR coherences (amplitude & phase) including temporal decorrelation versus changes of dielectric constant

Pol-InSAR configuration :
ha = 70 m,
radar incidence 38°

Impact is different for polarizations according to their respective scattering ratios :
HV phase center quite stable
whereas HH/VV decreases/increases

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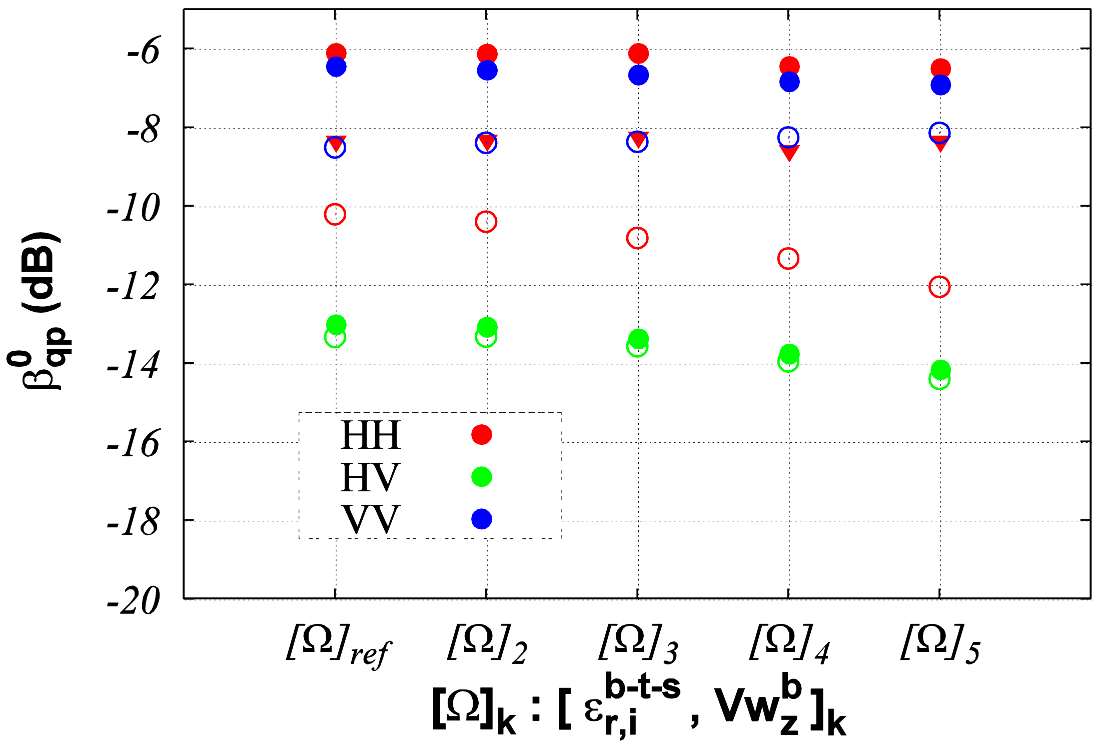
Analysis of TropiScat results : modeling wind gusts effects on scatterers



Similar behaviour as for VWC changes only

As for TropiScat : the standard (cf. nominal values for vertical motions) diurnal cycle of the intensiities is not impacted by wind

Intensities versus changes of dielectric constant and vertical motion between acquisitions
Total : filled points
Double bounce : triangles
Volume : non-filled circles

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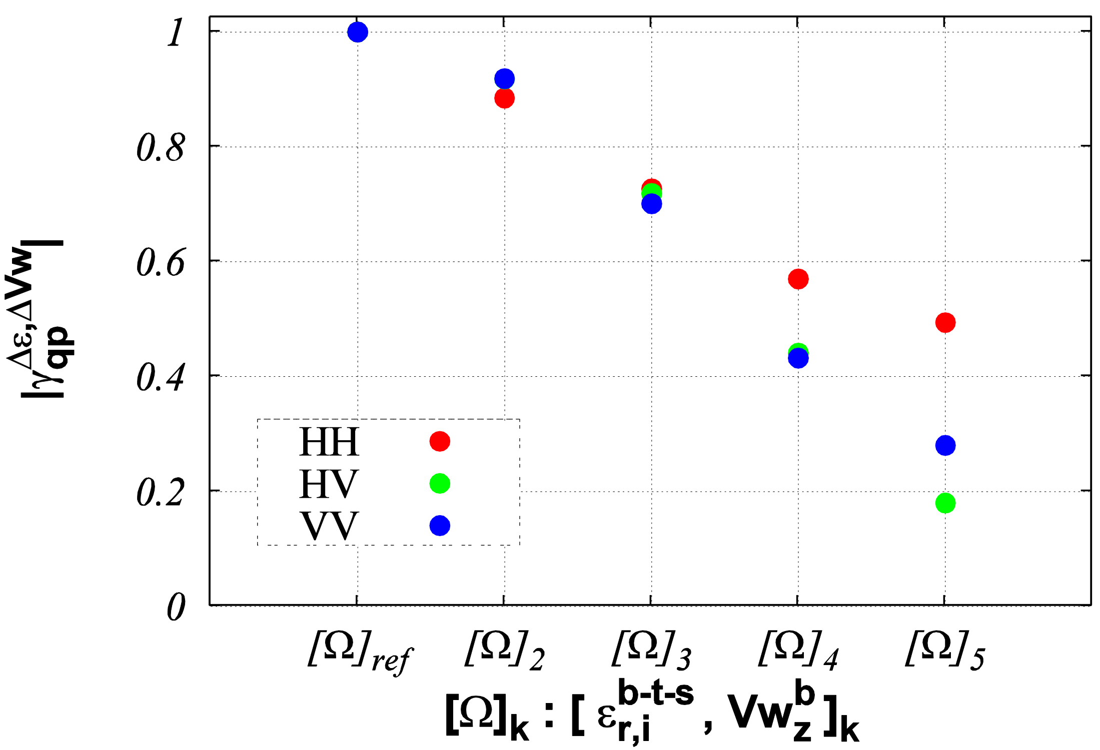
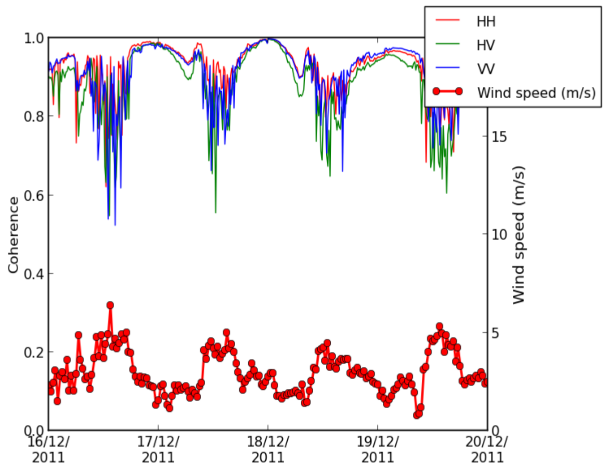
Analysis of TropiScat results :
modeling wind gusts effects on scatterers

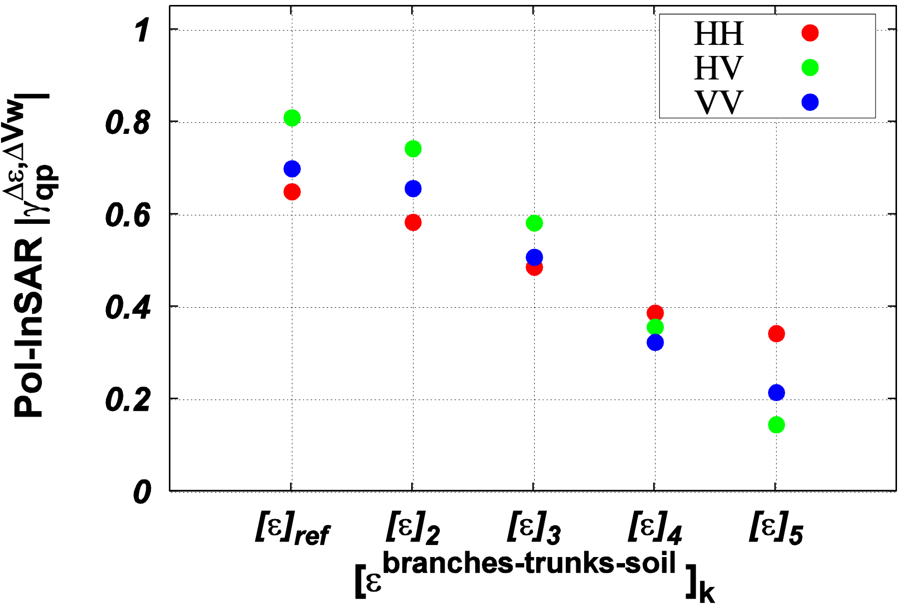


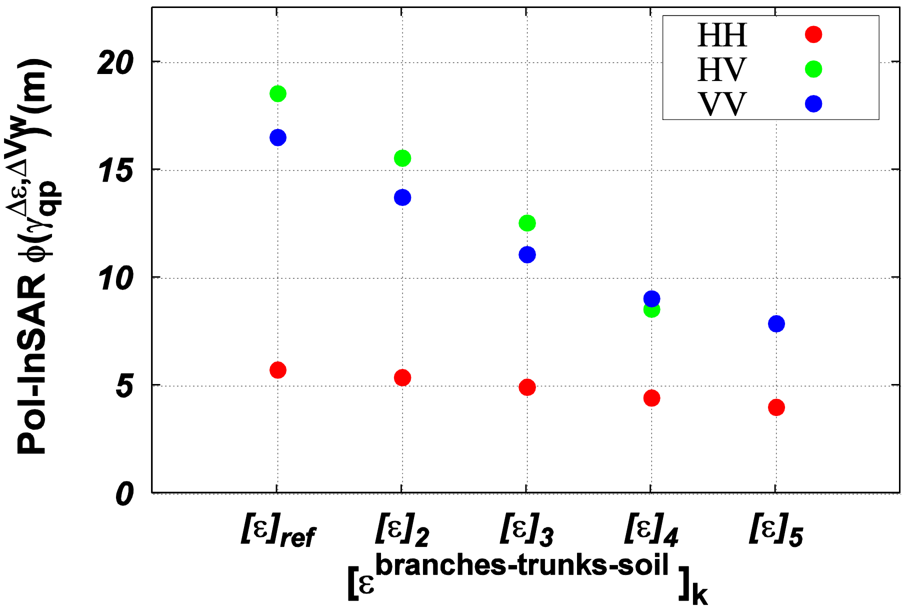
Temporal coherences versus changes of dielectric constant and wind gusts

Coherences (esp HV) are much more sensitive to displacements between passes, as suggested by TropiScat measurements :



Modeling scatterers displacements due to wind gusts
Impact on Pol-InSAR coherences





Pol-InSAR coherences (amplitude & phase) including temporal decorrelation versus changes of dielectric constant

Pol-InSAR configuration :
ha = 70 m,
radar incidence 38°

Impacts depend also on polarizations according to their respective scattering ratios and the sensitivity of the scatterers to wind gusts :
Strong decrease of HV phase center, reaching lower value than the VV one

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Summary and Conclusions

- The simulated cycles of the radar intensities and coherences are in good agreement with the TropiScat measurements. It confirms and quantifies the two impact factors : from diurnal changes due to vegetation water content and from displacement s due to wind gusts

- Decorrelation due to dielectric changes can be modeled as a linear process (which is fundamental to assess the expected coherences for spaceborne mission) unlike decorrelation from wind gusts, much more important.

- These results have been extended to Pol-InSAR coherences, for airborne/spaceborne configuration (incidence, interferometric sensitivity).

- Due to different scattering ratio, the hv Pol-InSAR phase center is the most sensitive to wind gusts but the most stable regarding dielectric changes, hence encouraging prospects to detect/correct temporal decorrelation from the retrieved DEM.

- Further investigations have to be conducted to improve the models of wind fields and dielectric variations, esp for tropical forests and concerning branches (collaboration with ECOFOG in Kourou, measurements derived from leaf water potential)