OUTLINE

I. Radar imaging - Spatial resolution
II. Polarization - Polarimetry
III. Radar response sensitivity
IV. Relief effects
V. Speckle and Filtering

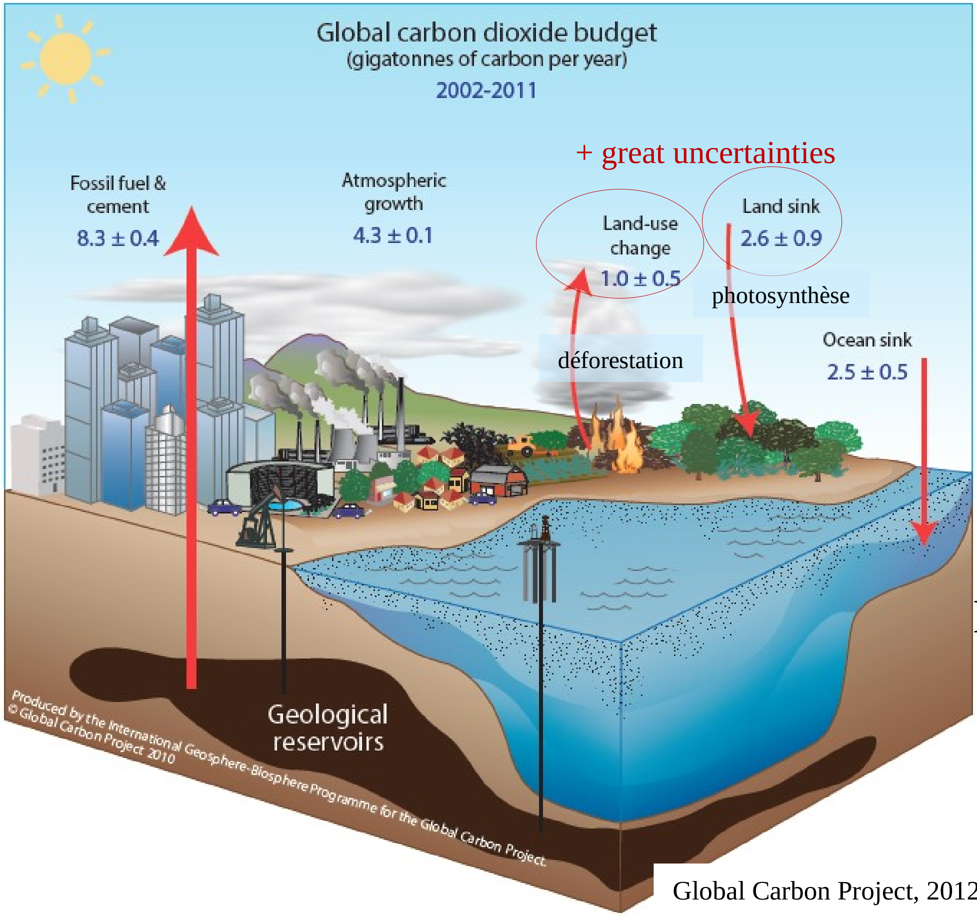
Université Gustave Eiffel

LaSTI
Laboratoire des Sciences et Technologies de l'Information Géographique

TROPICAL RAIN FORESTS MONITORING

Tropical Forests monitoring

Role of biomass in the Carbon Global Cycle?



Global Carbon Project, 2012

C Stock C = 50% Biomass
Forests: 70-90% aerial biuomass

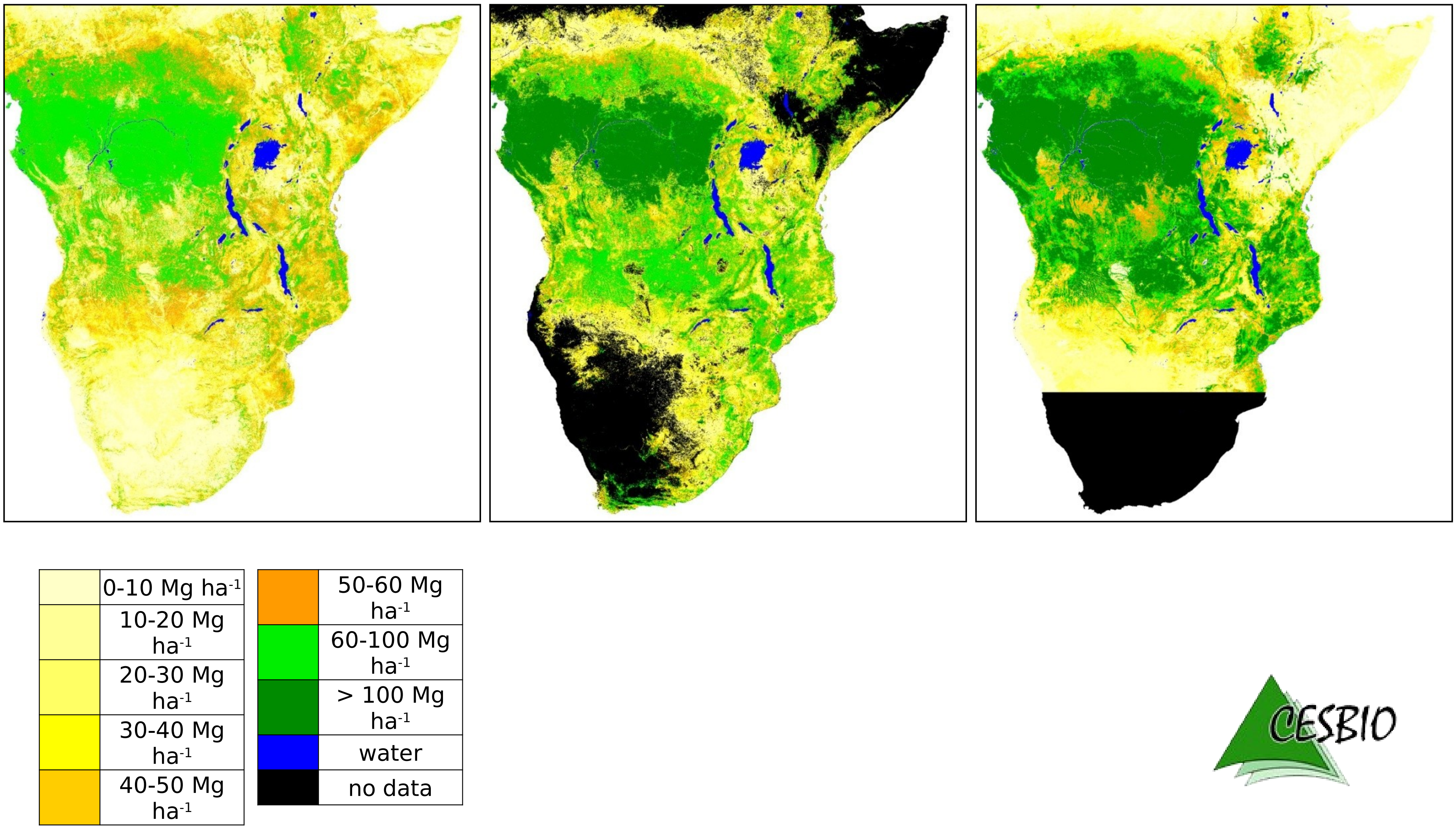
CO_2 flux with land surfaces :
30% flux anthropiques
great uncertainty

Need for forest biomass estimation improvment:
- Spatial distribution
- Stocks
- dynamics

IPCC , UNFCCC

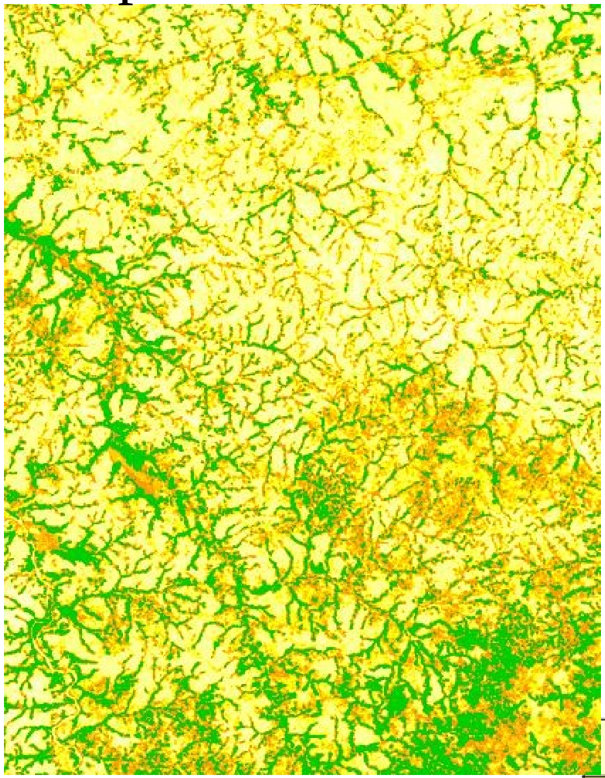
REDD+:
Financial incentive for sustainable forests ==> tropical countries

Mermoz *et al,.* 2016 Saatchi *et al.*, 2011 Baccini *et al.*, 2012

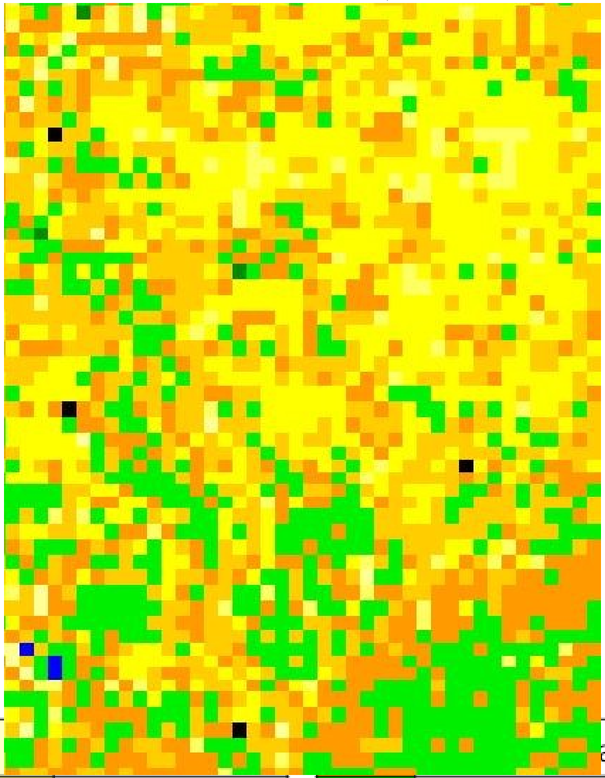


Produit 'Biomasse forestière' Afrique

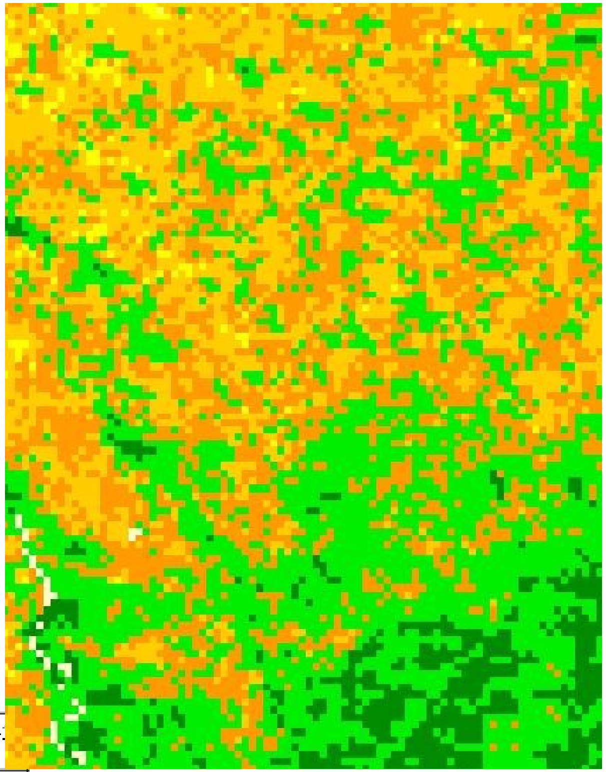
Map from CESBIO



Saatchi et al., 2011



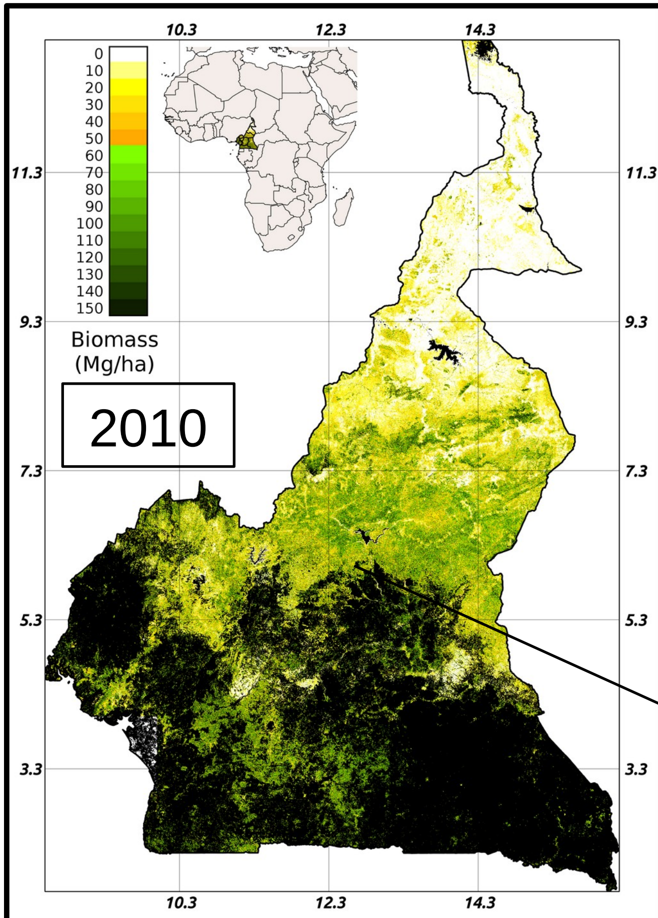
Baccini et al., 2012



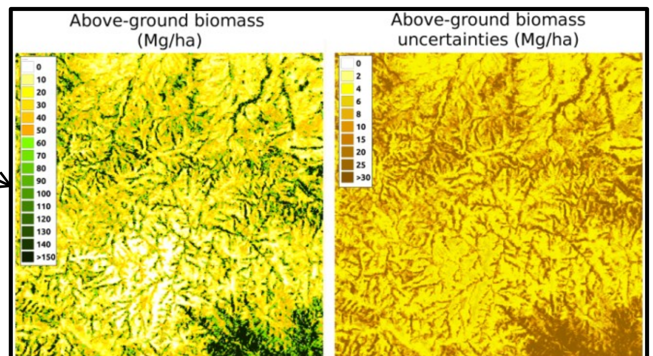
	10-20 Mg ha^{-1}		60-100 Mg ha^{-1}
	20-30 Mg ha^{-1}		> 100 Mg ha^{-1}
	30-40 Mg ha^{-1}		water
	40-50 Mg ha^{-1}		no data

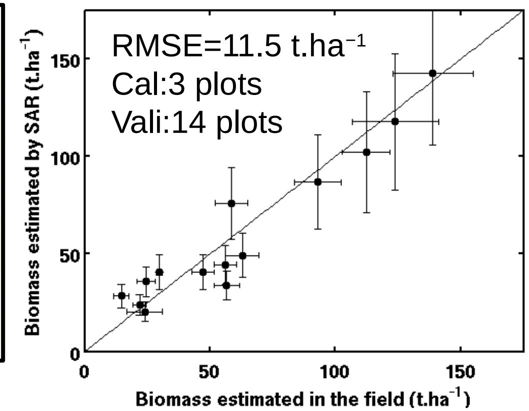
Subset from:
Latitude: 10°S to 5°S
Longitude: 20°E to 25°E

Produit ‘Biomasse forestière’ Cameroun



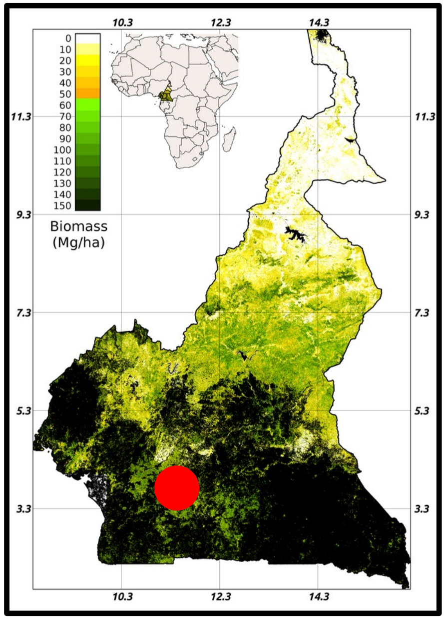
	Surface area (ha)	Mean AGB ($Mg.ha^{-1}$)	AGB (Tg)	Carbon (TgC)
Mosaic forest-croplands	1,811,150	89.5	162.9	81.4
Mosaic forest-savanna	5,187,900	75.6	394.2	197.1
Deciduous woodland	10,352,400	53.3	553.6	276.8
Deciduous shrubland – sparse trees	1,949,000	30.7	59.8	29.9
Others	6,622,340	12.6	83.4	41.7
TOTAL	25,922,790	48.2	1253	**626.9**

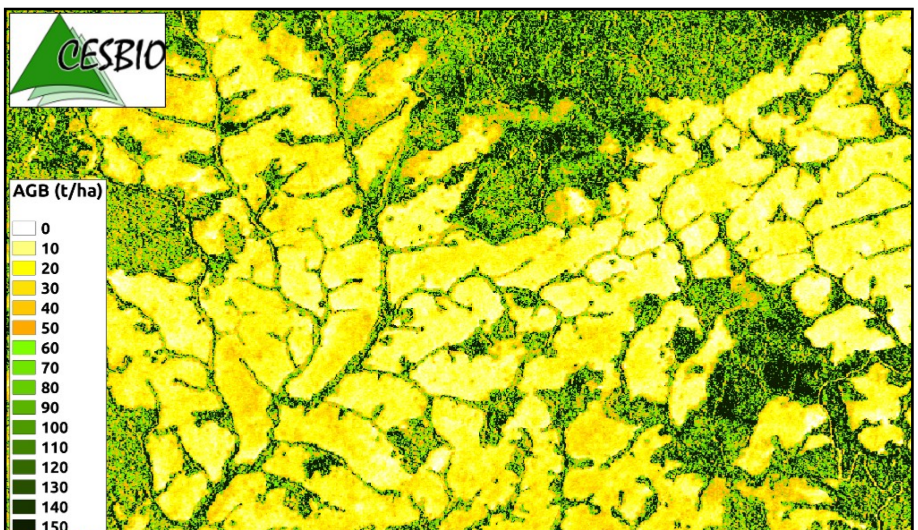


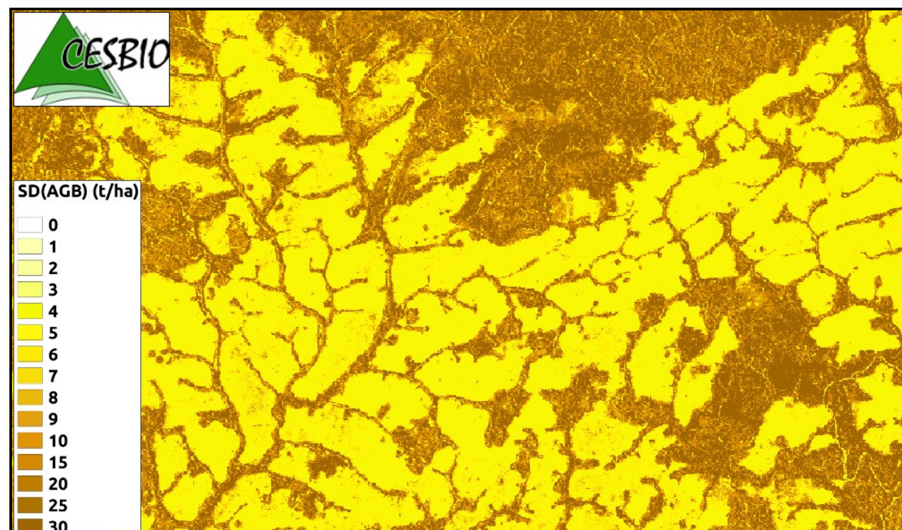


Total aboveground carbon stock:
- This study: 626.9 TgC
- Nasi et al. (2009): 710 TgC

Produit 'Biomasse forestière' Cameroun







Tropical Forests monitoring

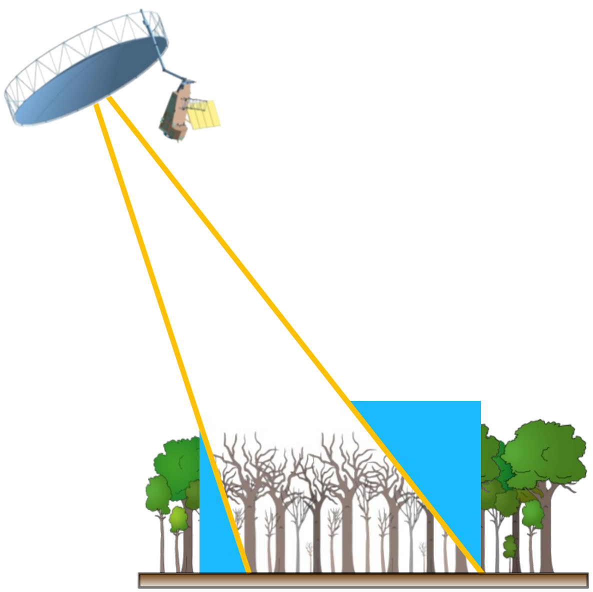
7th ESA Earth Explorer mission: BIOMASS (2022)

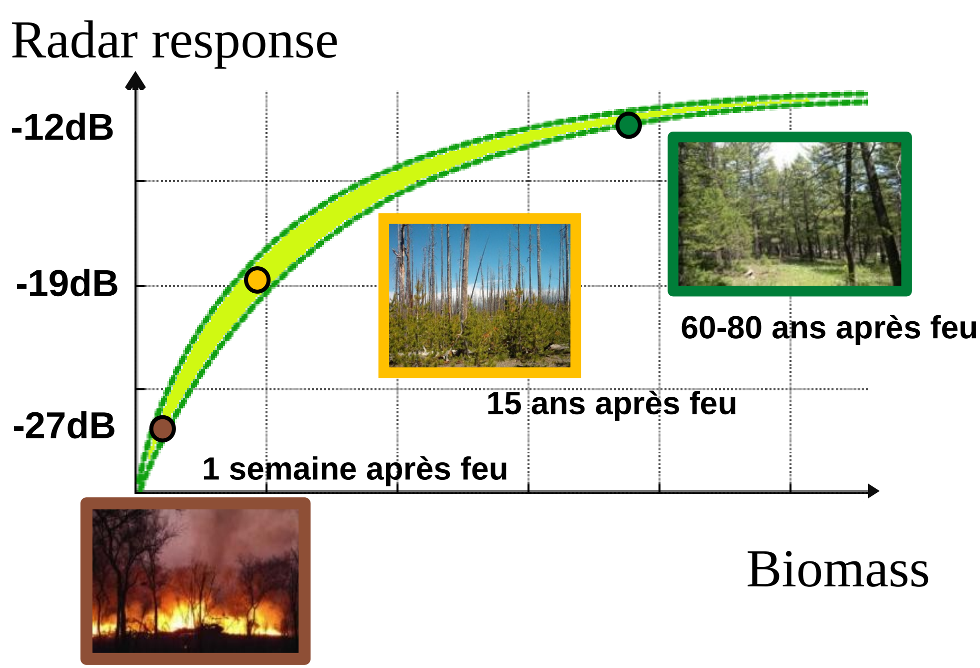
Large wavelength for biomass cartography

1. Canopy penetration for every biomes
2. Interacts with woody elements of vegetation
3. Forest height estimation ability

 P band band P *(λ = 70 cm) largest available wavelength from space*

P Band Radar
(λ = 70 cm)





Tropical froest monitoring

7th ESA Earth Explorer mission: BIOMASS (2022)

A key mission for a better understanding of Global Carbon Cycle

Aerial biomass (t / ha)

- Resolution: 200 m
- 1 map / 6 mois (4-year period)
- Global cover of forested areas
- Precision 20%, or 10 t ha^{-1} for biomass < 50 t ha^{-1}

Canopy height (m)

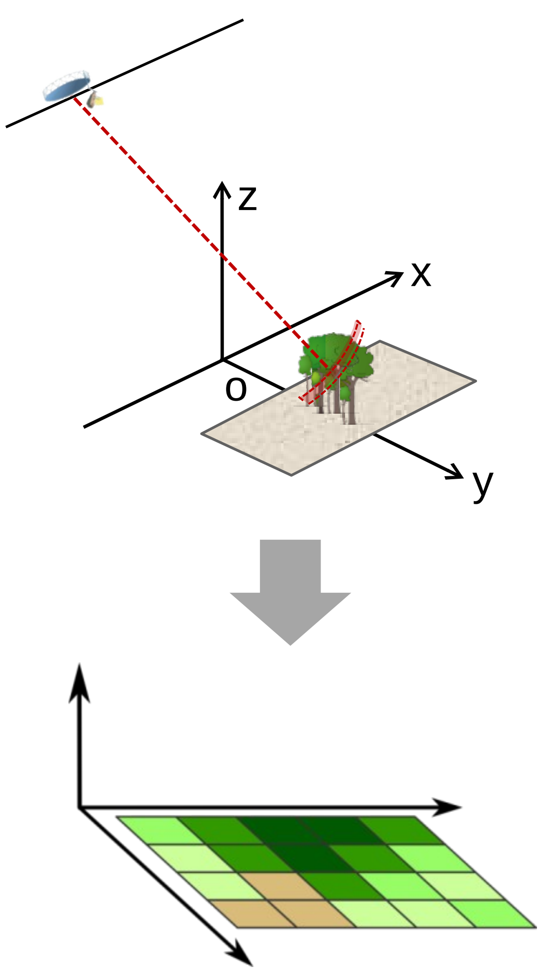
- Resolution: 200 m
- 1 map / 6 months (4-year period)
- Global cover of forested areas
- Precision 20 – 30%

Deforested areas (ha)

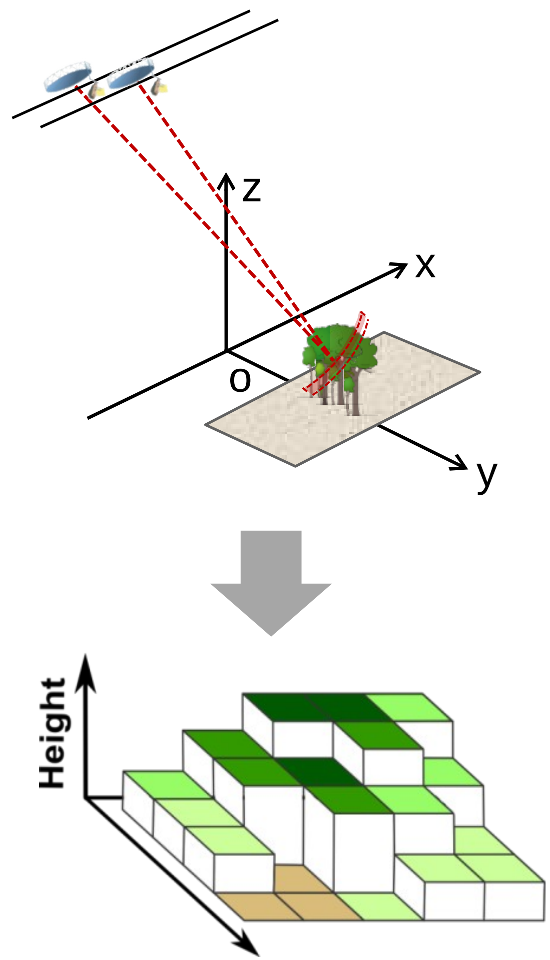
- Resolution: 50m
- 1 map / 6 months (4-year period)
- Global cover of forested areas
- Classification precision: 90%

Biomass Mission

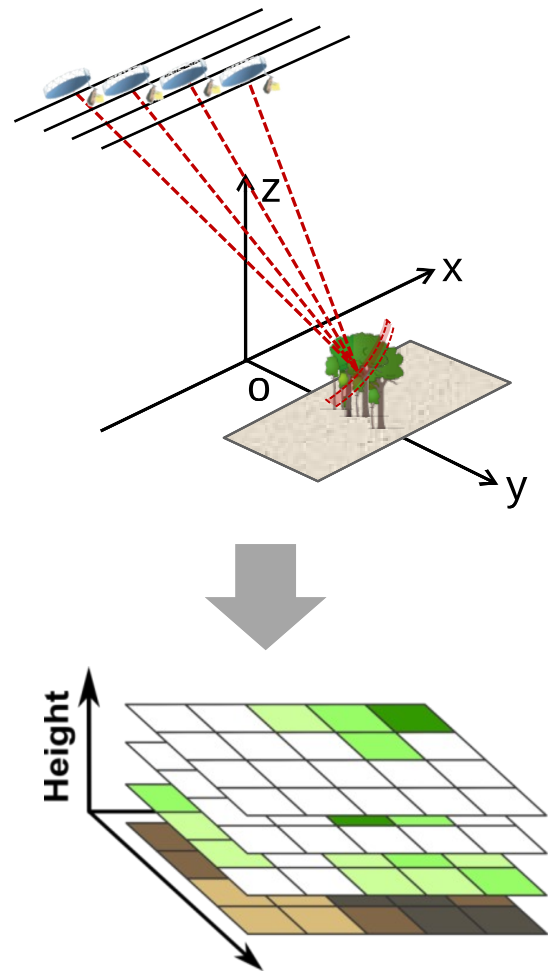
PolSAR
(SAR Polarimetry)



PolInSAR
(Polarimetric SAR Interferometry)



TomoSAR
(SAR Tomography)



Radar response sensitivity

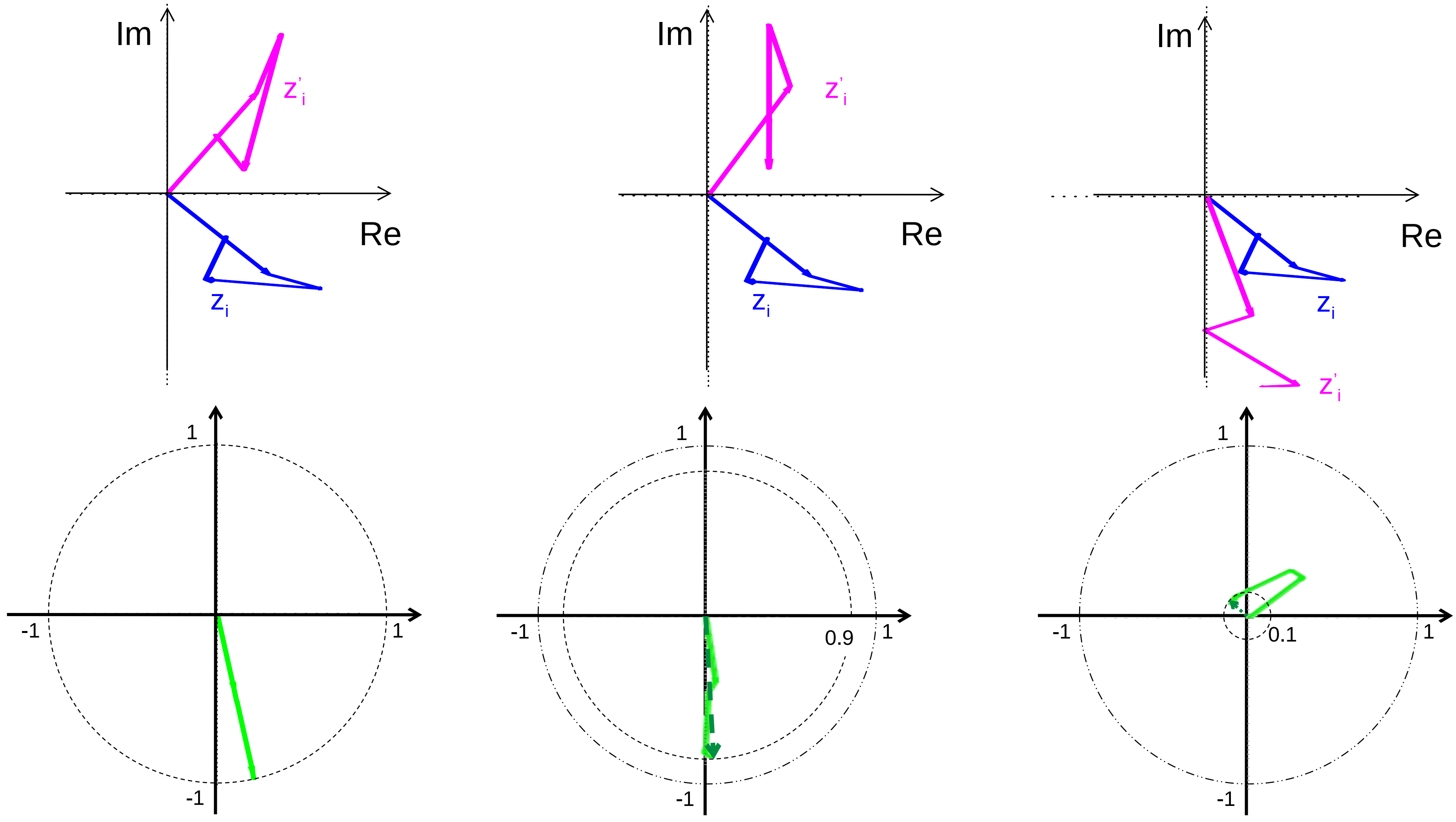
RADAR COHERENCE:

2 radar acquisitions

Temporal geometrical stability ($\leq \lambda$)
of the scatterers within each resolution cell

Complex coherence

$$\rho = \frac{\langle z_i {z'_i}^* \rangle}{\sqrt{\langle |z_i|^2 \rangle \langle |z'_i|^2 \rangle}}$$



|ρ| = 1

|ρ| = 0.9

|ρ| = 0.1

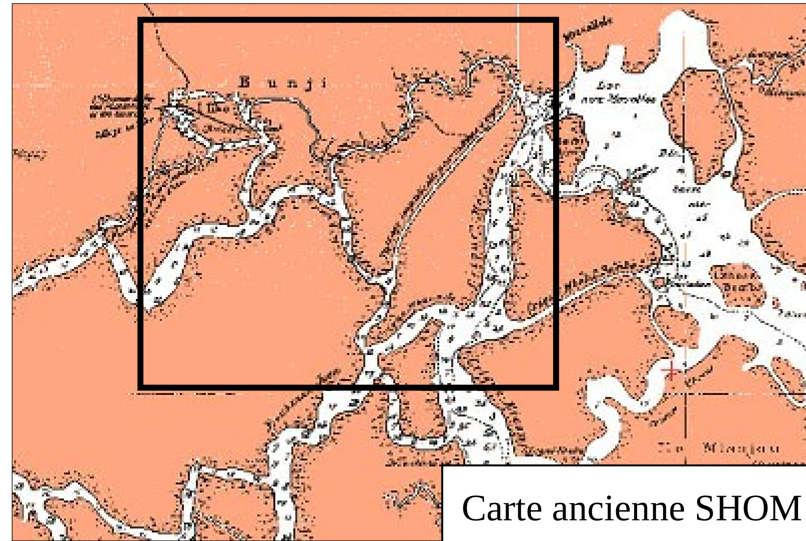
Amplitude

Coherence

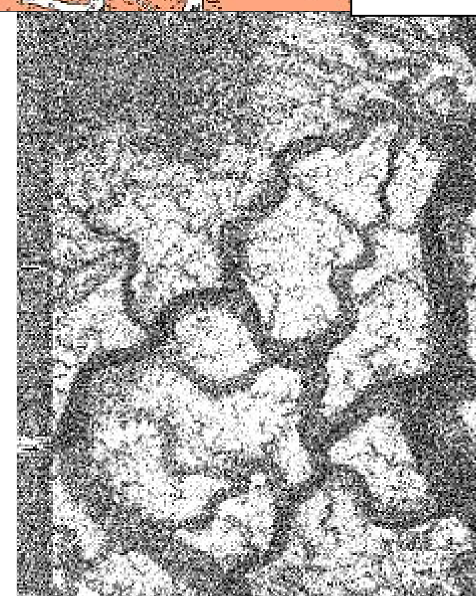
Mount Cameroun, ERS

Radar response sensitivity

Mangroves

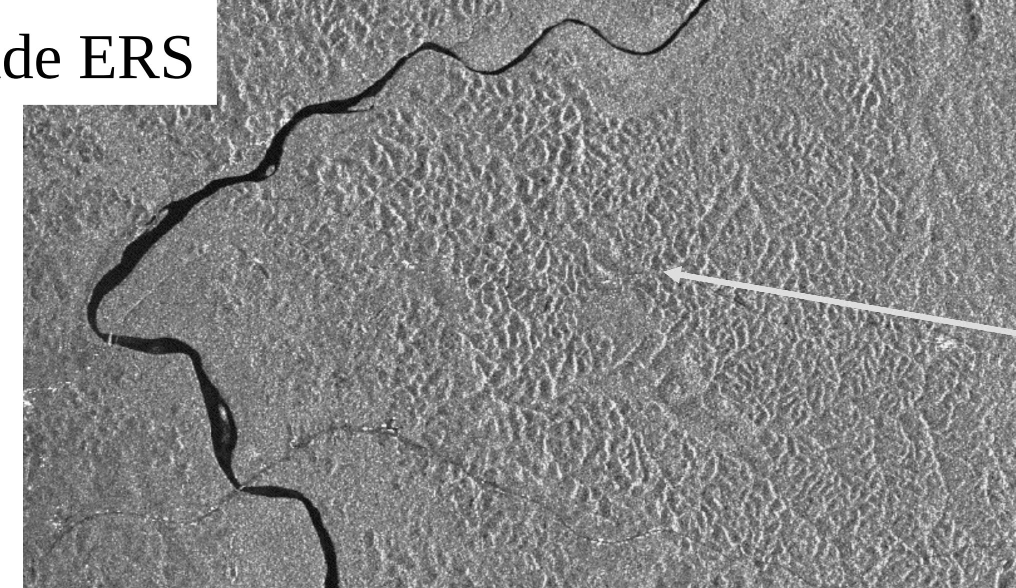


Carte ancienne SHOM

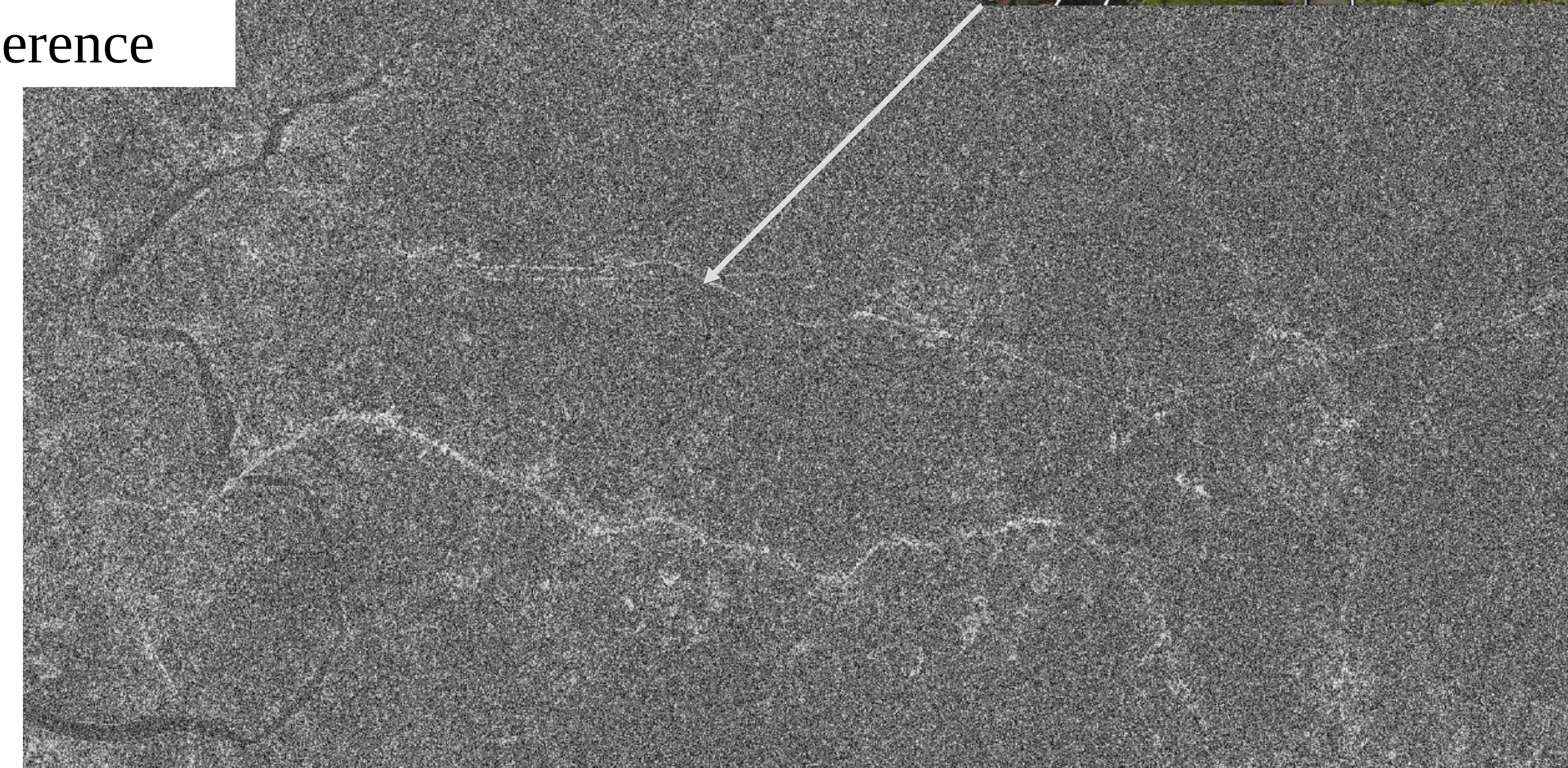


Coherence ERS

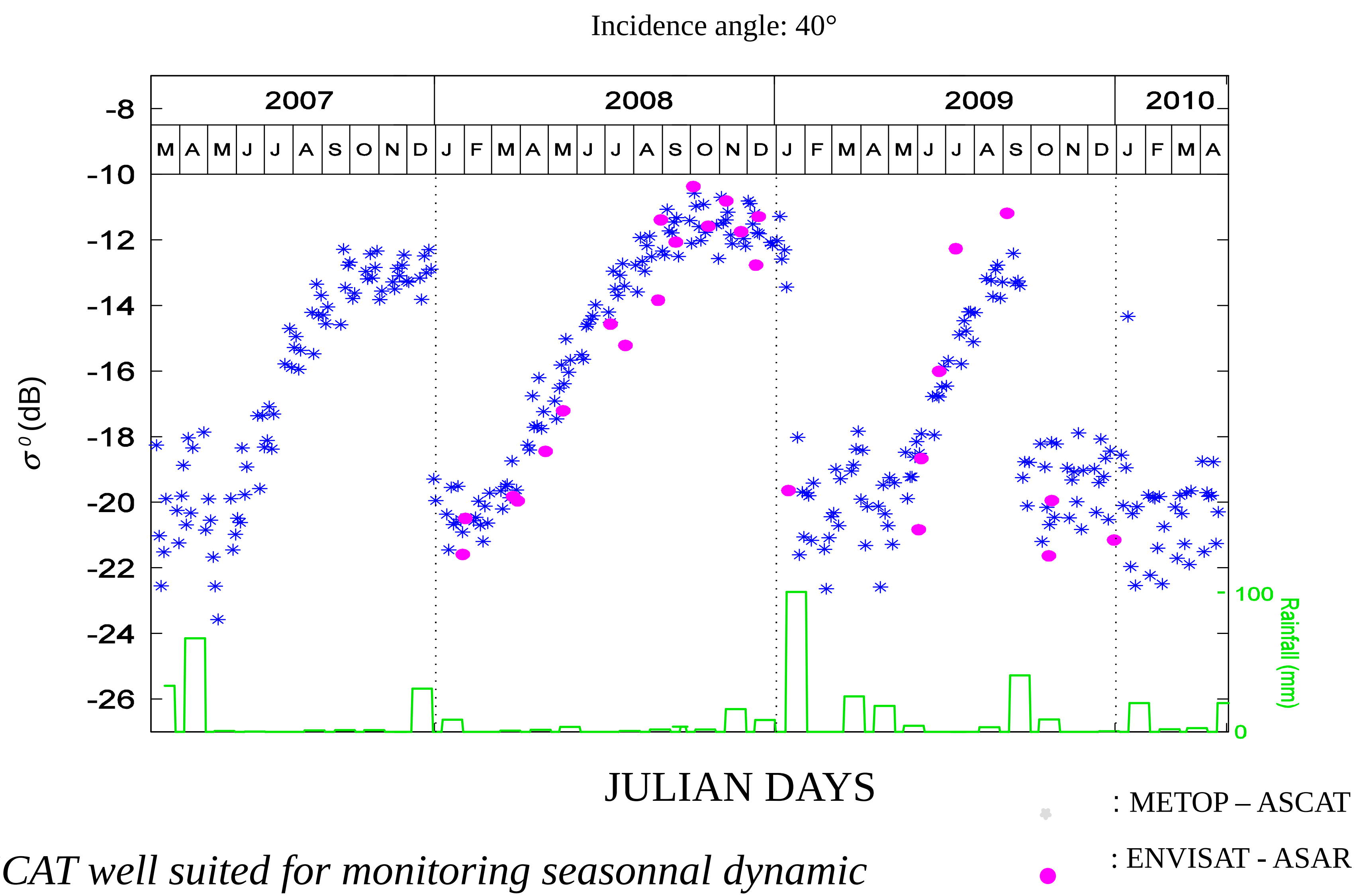
Amplitude ERS



Coherence



ASCAT/ASAR temporal signature over the **Chott el Jerid**

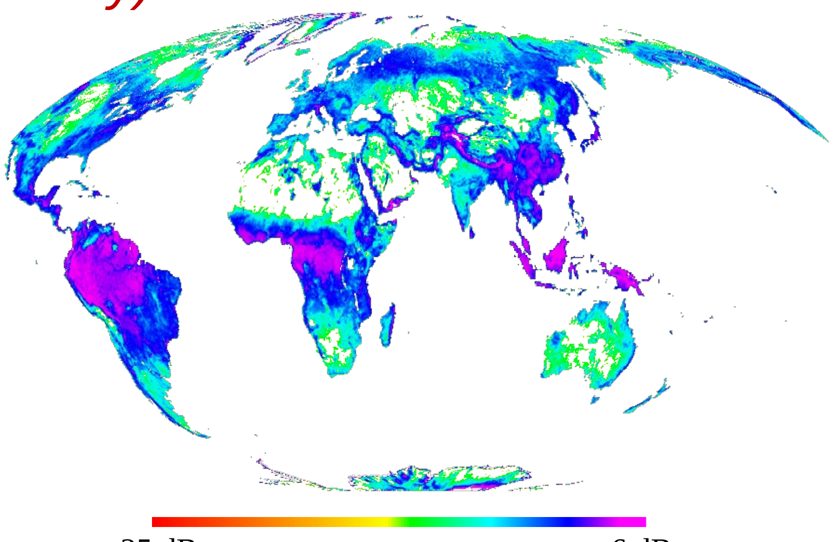


ASCAT well suited for monitoring seasonnal dynamic

Side looking radar sensors

Scatterometers

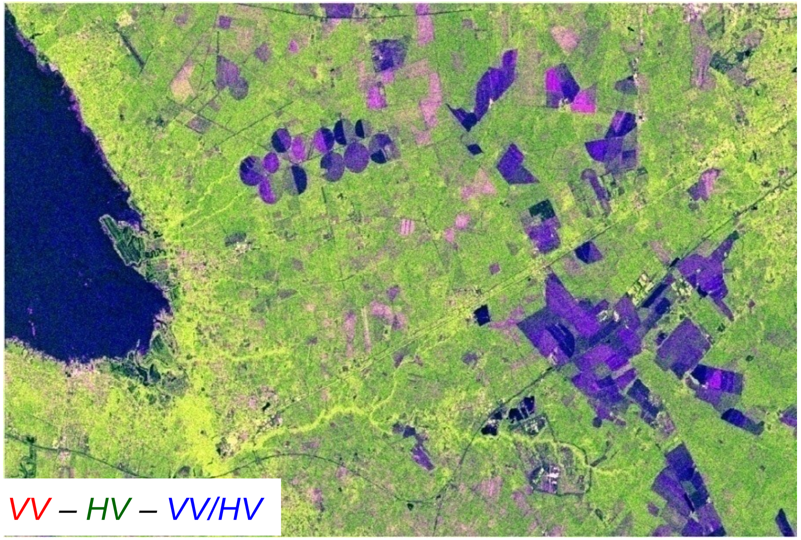
- *Radar eflectivity estimation (σ°)*
  - *low spatial resolution*: *~ 10 – 50 km*
  - *high frequency of acquisitions (~ day)*



Scatt. ERS – May 1992

SAR

- *Surface imaging*
  - *high spatial resolution: ~ 10 m*
  - *low frequency of acquisition (~ month)*



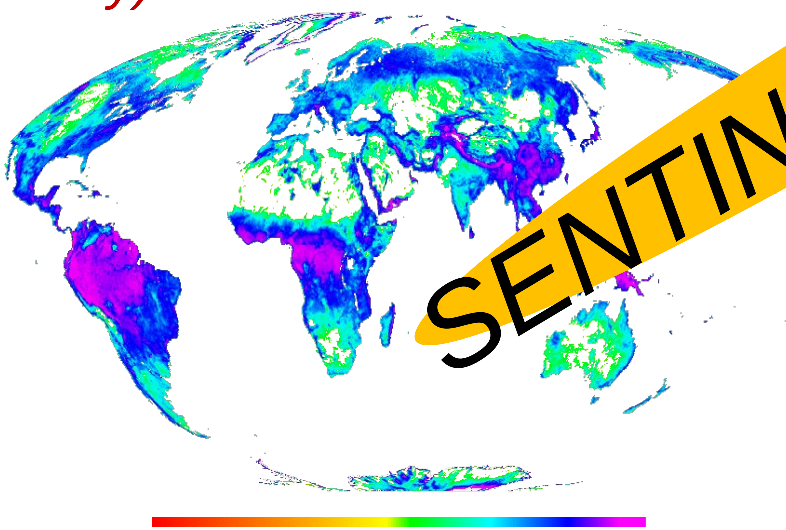
Sentinel-1
Les landes – March 2015

Side looking radar sensors

Scatterometers

Radar eflectivity estimation (σ°)

- *low spatial resolution*: *~ 10 – 50 km*
- *high frequency of acquisitions (~ day)*



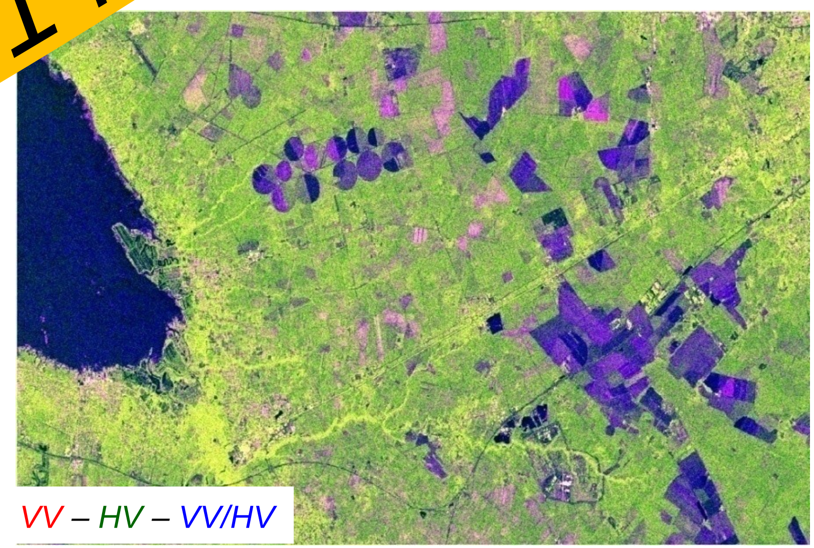
Scatt. ERS – May 1992

SAR

Surface imaging

- *high spati*[...]*tion: ~ 10 m*
- *lo*[...]*cy of acquisition (~ month)*

SENTINEL-1 MISSION



Sentinel-1
Les landes – March 2015

The Sentinel-1 misions

Sentinel-1A: launched the 3rd April 2014
== > SAR data from March 2015

Revisit time: 12 days

6 days!!

Sentinel-1B: launched the 22th April 2016
== > SAR data from September2016

Revisit time: 12 days

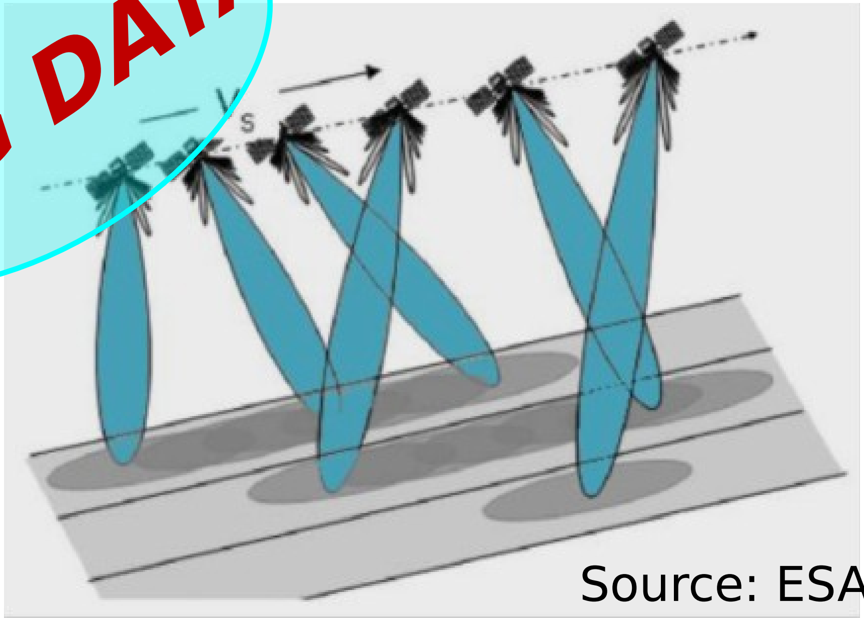
- C band
- Spatial resolution: 20 m
- Swath width: 250 km
- Two polarizations over land surfaces: VV and VH

SAR → **SENTINEL-1** → **Scatte**

Acquisitions period: ***12 days*** (S1-A) – ***6 days***(S1- A+B)

Planned mode over land surfaces: ***Interferometric Wide (IW)***

BIG DATA



Source: ESA

2 Polarisations: ***VV –VH***

Swath: 250 km (3 sub-swaths)

GRD Products :

Spatial resolution: **20 m**

Pixel: 10 m

SLC Products

Spatial resolution: 3 x 20 m;

Pixel: 2 x 14 m (rge x az.)

Temporal monitoring of seasonal variations of land surfaces

Radar Backscattering Coefficient σ^0

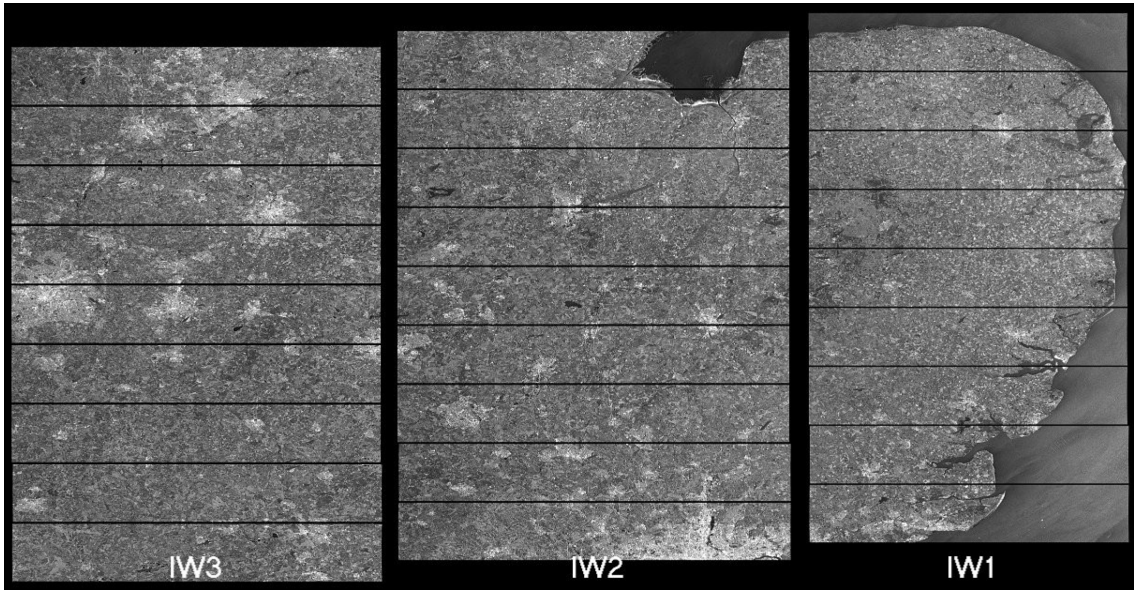
Interferometric Coherence $|\rho|$

SENTINEL-1 INTERFEROMETRIC WIDE,MODE

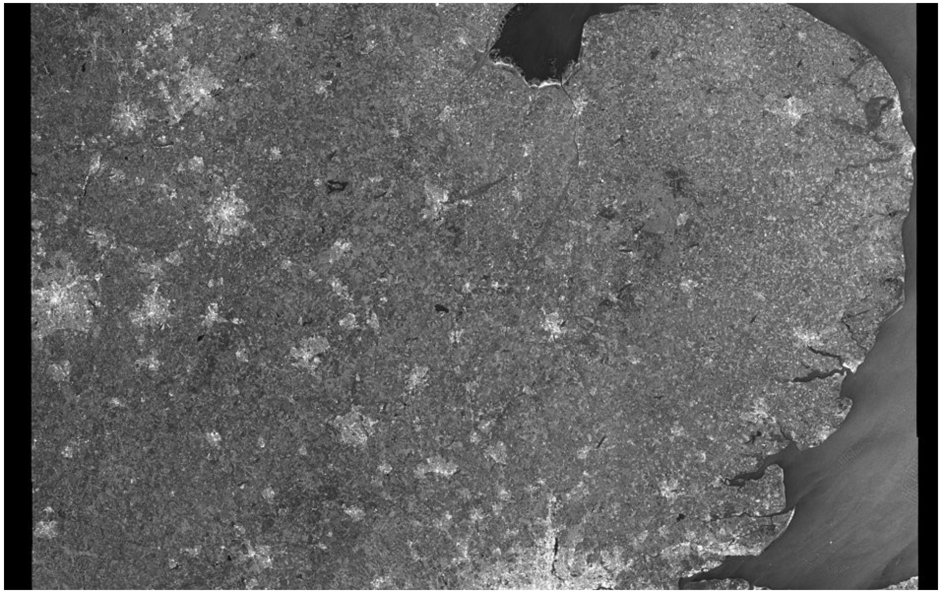
3 subswaths

SLC products

8 bursts

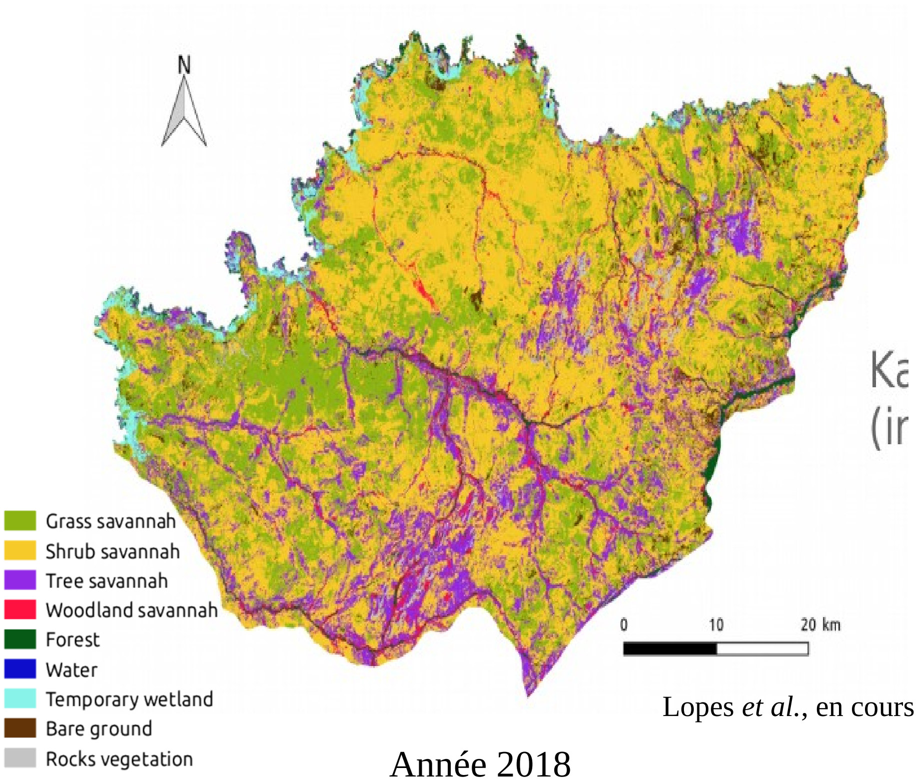


GRD products



Sentinel: Apport des séries temporelles

Formations végétales
Parc de la Pendjari, Bénin



Lopes *et al.*, en cours

Année 2018
Données Sentinel-1 et -2

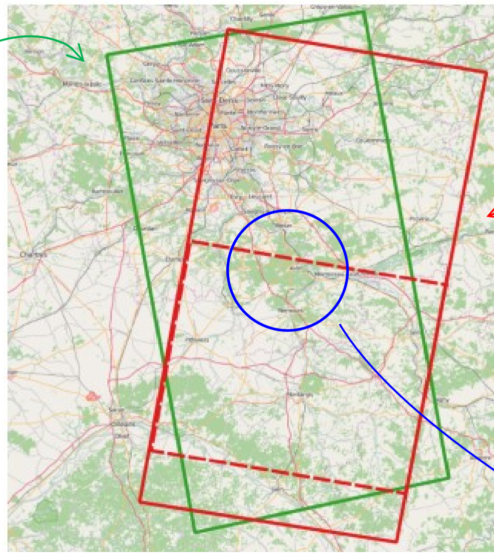
Données Sentinel *(Big Data)*

Fouille de donnees
Intelligence artificielle
Deep learning

Complémentarité optique / radar

Acquisitions over the Paris region

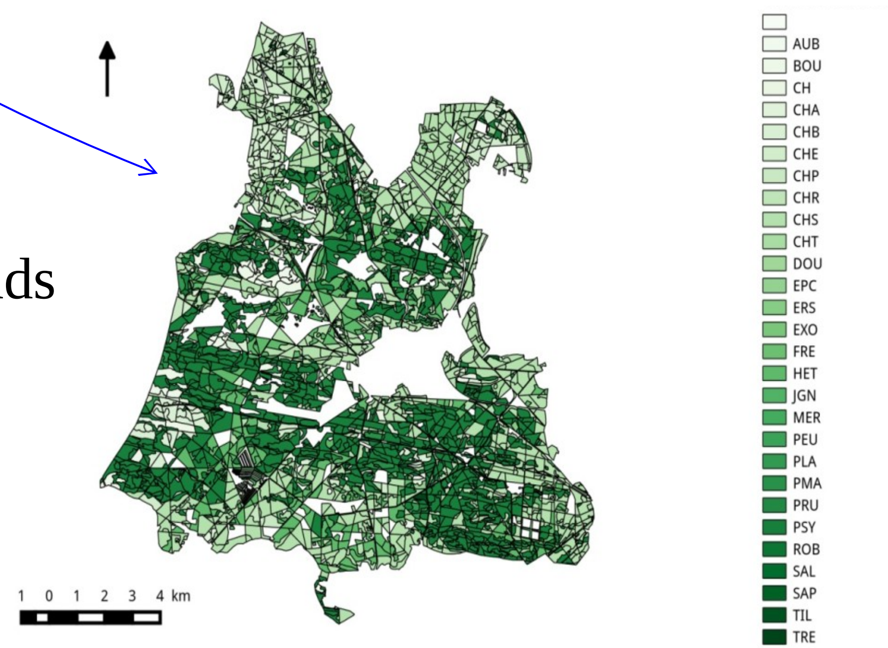
Orbite 59



Orbite 110

Fontainebleau Forest

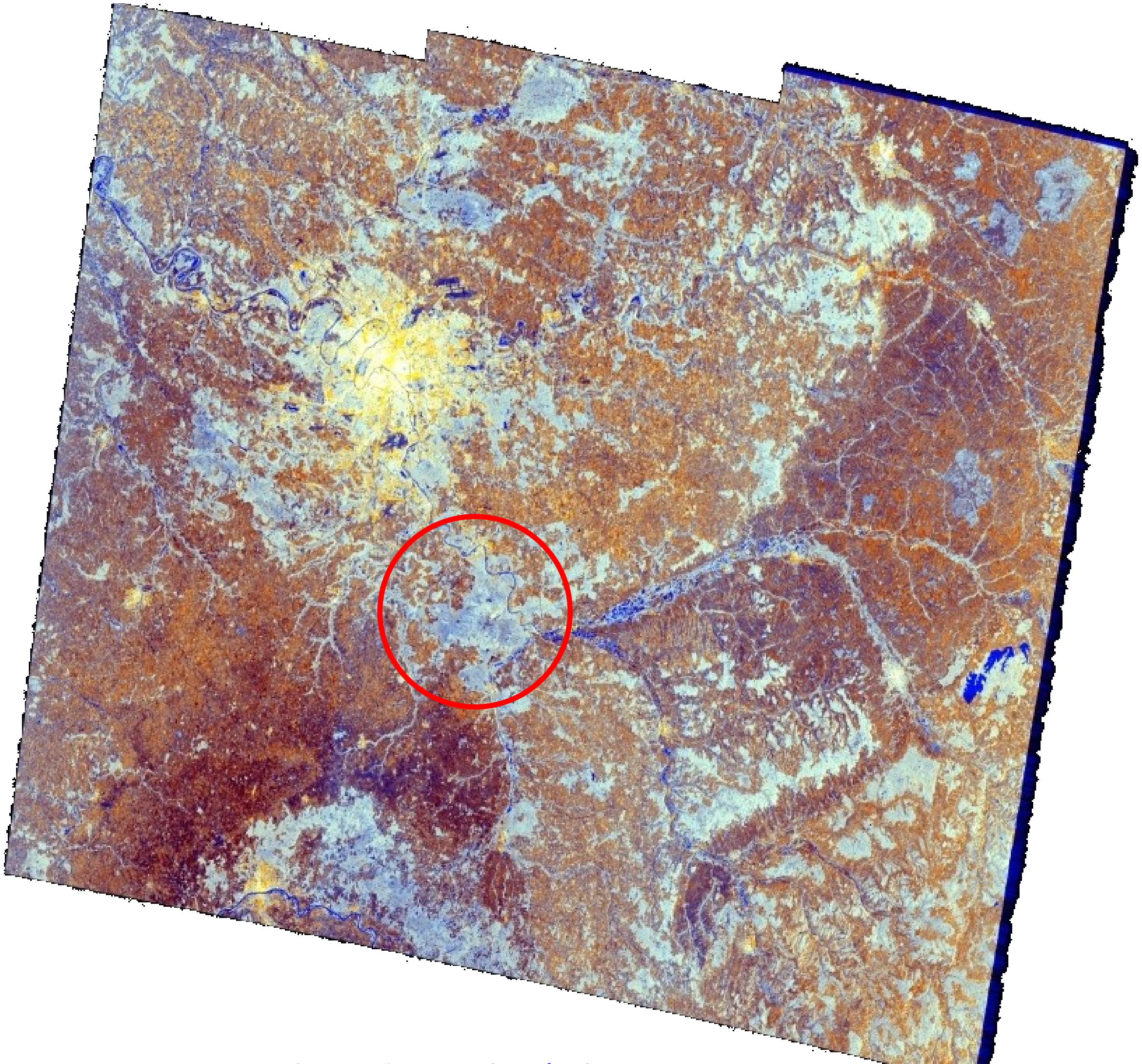
Oaks, pines and beeches stands



Collab. ESE / Paris Sud

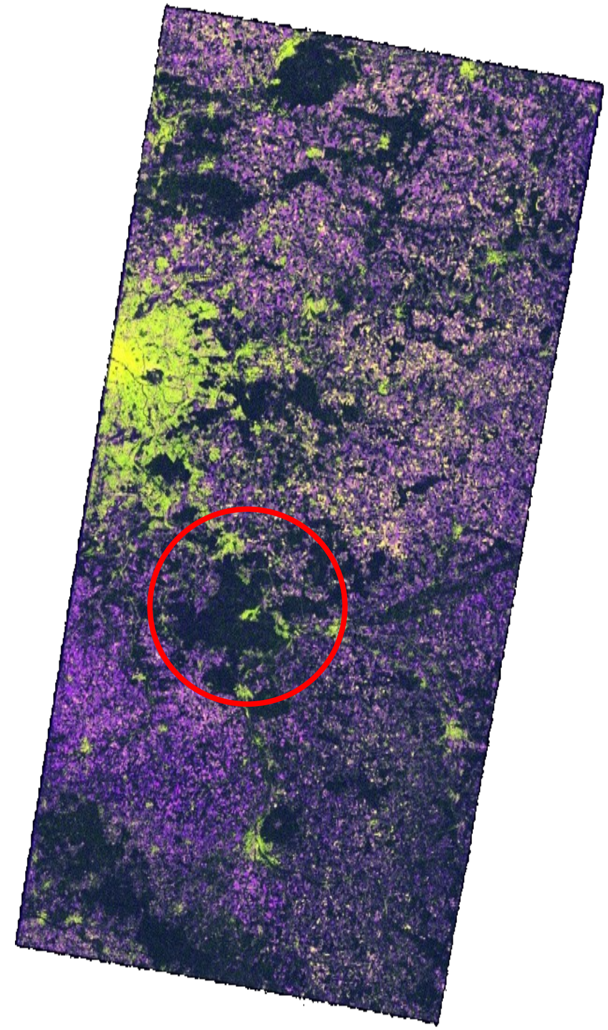
18th March 2015 IW Acquisition

Radar reflectivity (σ^0) image



σ^0_{VV} - σ^0_{VH} – σ^0_{VH} / σ^0_{VV}

18 – 30 March coherence image

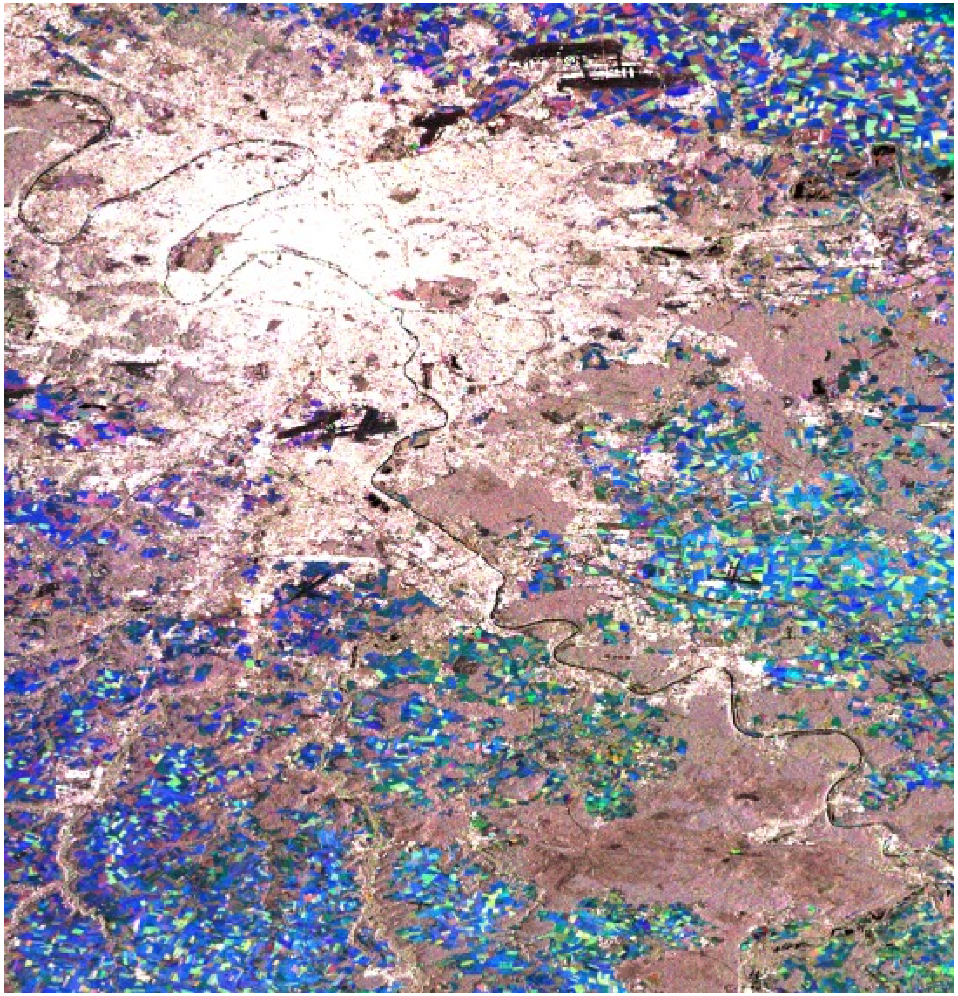


$|\rho_{VV}|$- $|\rho_{VH}|$– $|\rho_{VV}|$ / $|\rho_{VH}|$

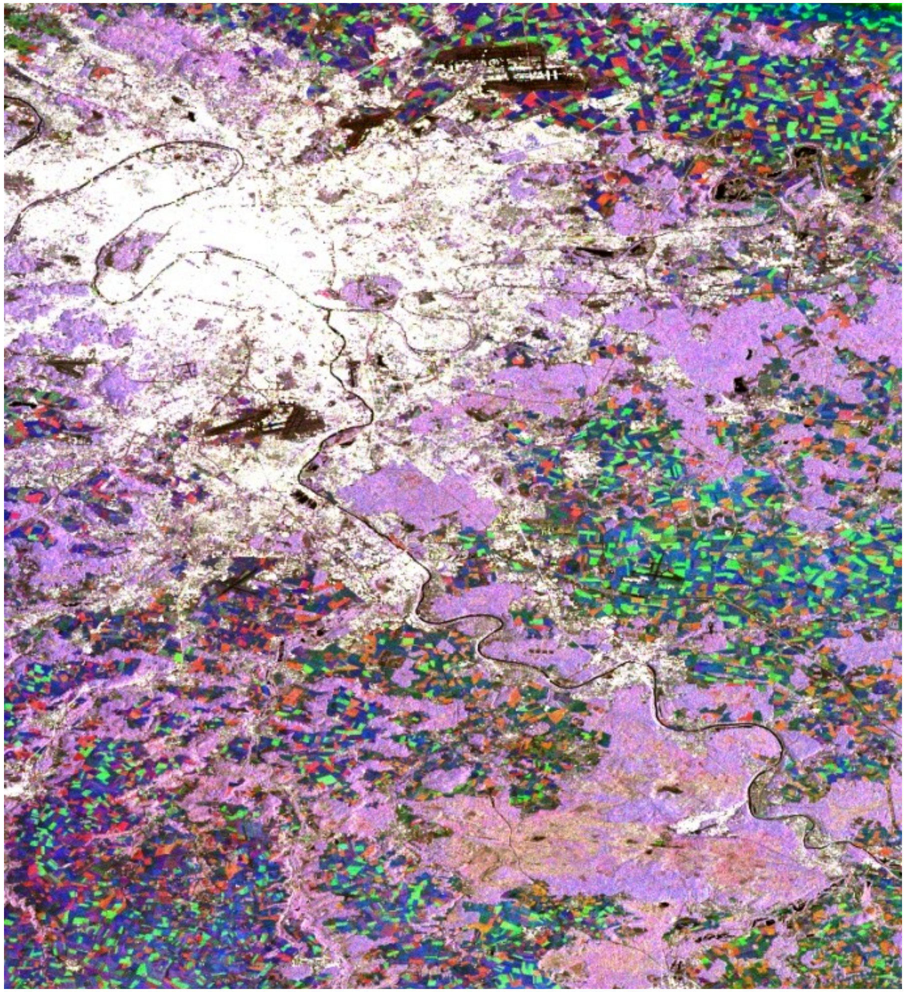
σ^0 Color composite image

5 May - 2 Sept. - 19 Dec. 2015

Polarisation ***VV***



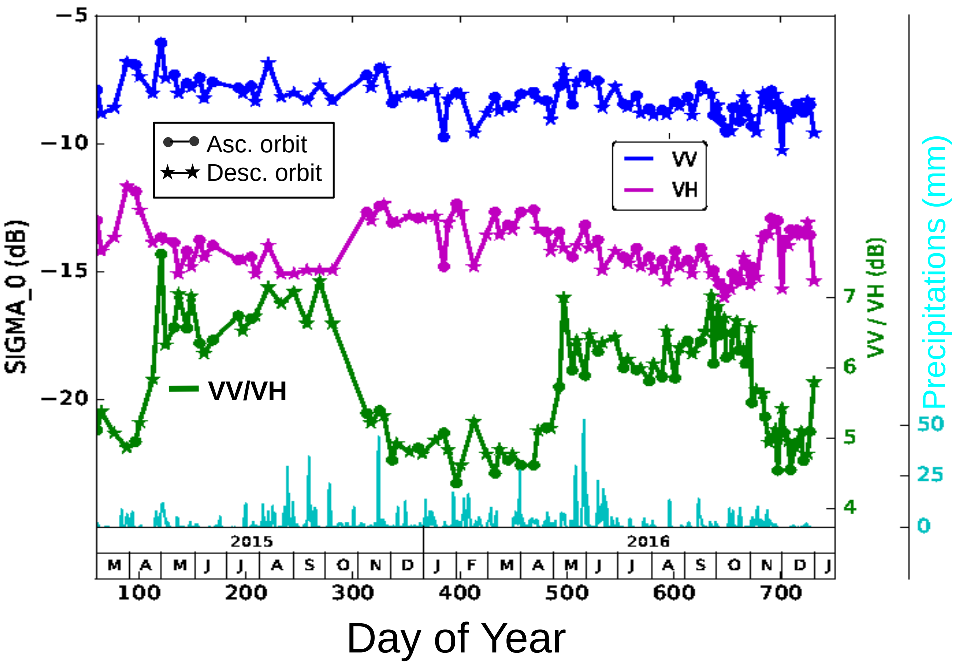
Polarisation ***VH***



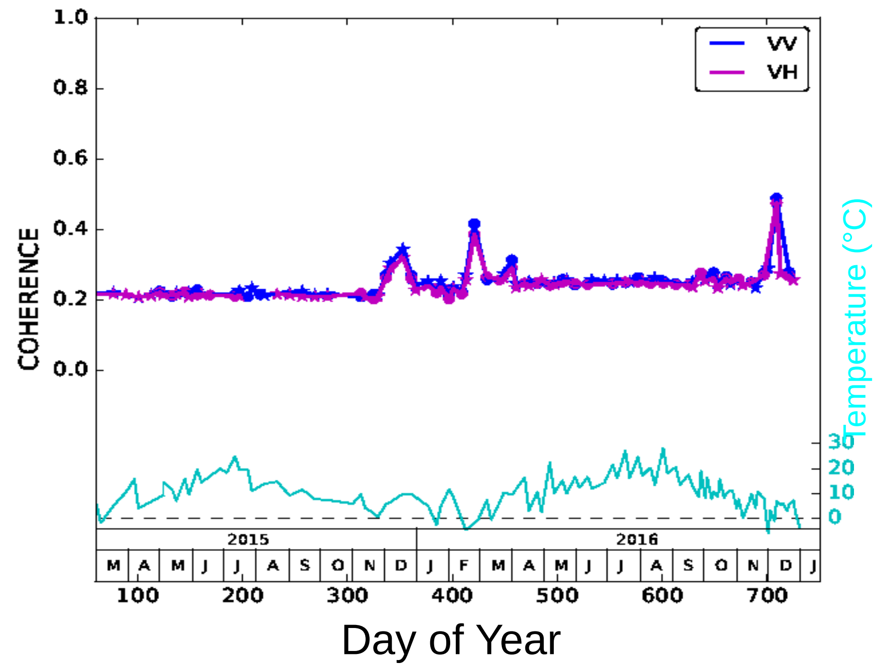
- *High spatio-temporal variability over crop fields*

Oaks stand

Radar Backscat. Coeff. σ^0



Coherence $|\rho|$



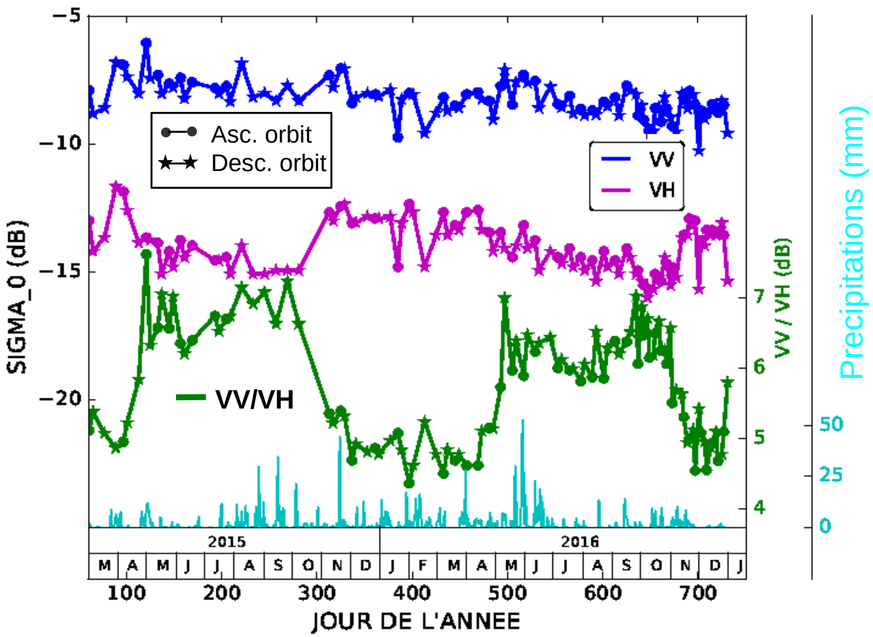
- No seasonal cyle s^0_{VV}
- Seasonal cycles^0_{VH} ==> $\sigma^0_{VV} / \sigma^0_{VH}$

(yearly amplitude 3 dB)

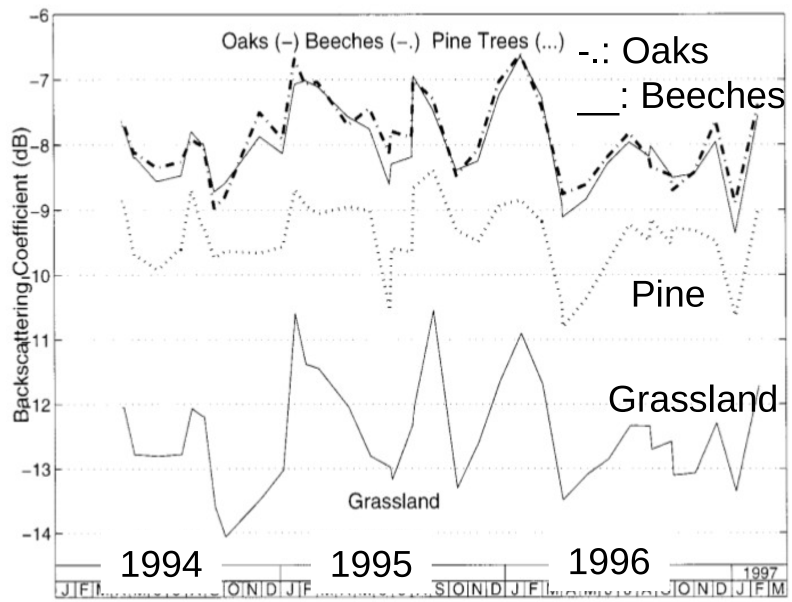
- signal low and constant (Mar. - Nov.)
- $|\rho_{VV}|$ et $|\rho_{VH}|$ Identical
- higher values for low temperatures

Oaks stand

Radar Backscat. Coeff. *s* [0]



ERS *(VV) temporal signature*

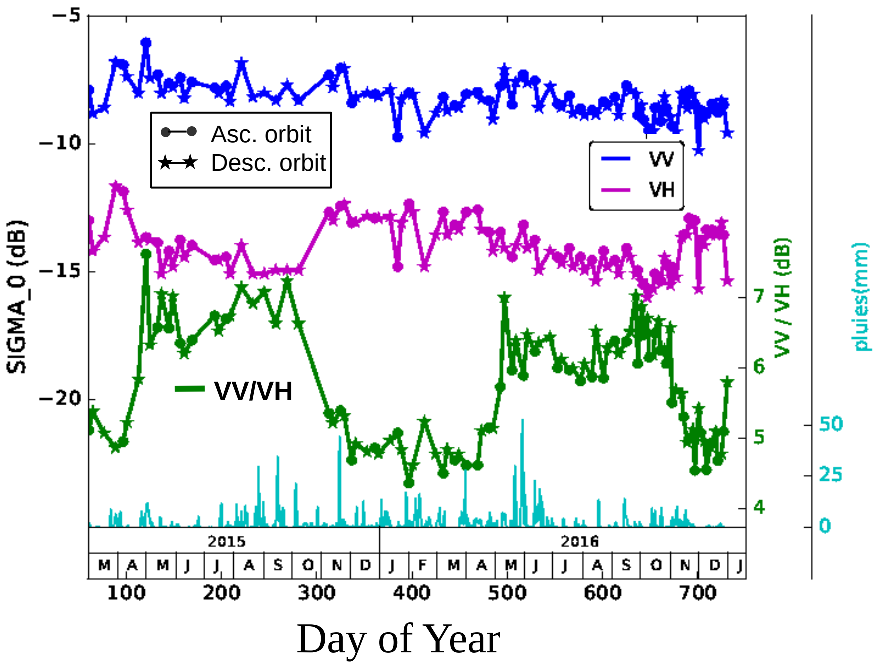


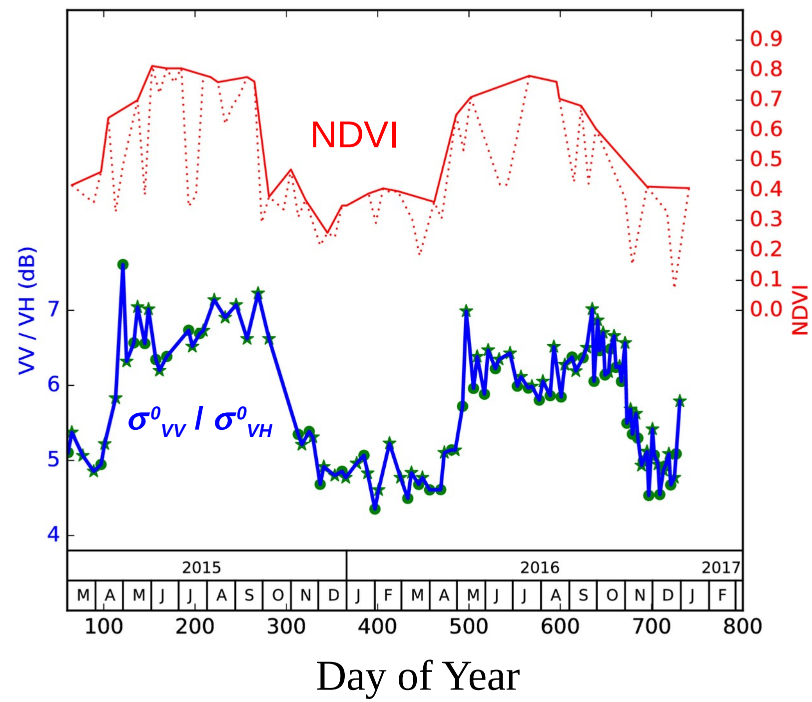
Proisy et al., 1999

- no seasonal cycle in VV pol.
- Seasonal cycle σ^0_{VH} ==> $\boldsymbol{\sigma^0_{VV} / \sigma^0_{VH}}$

Oaks stand

Radar Backscat. Coeff. σ^0

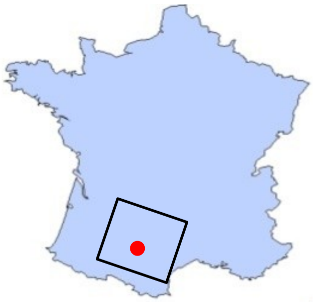


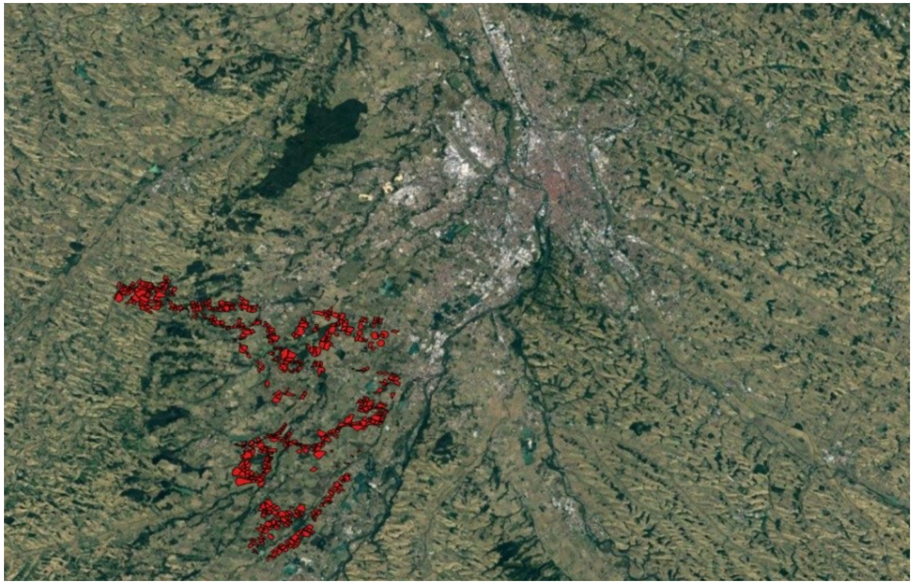


σ^0_{VV} / σ^0_{VH} and NDVI in phase

C band sensitive to foliar activity

Crops monitoring – Lamasquère region





in situ survey (CESBIO)

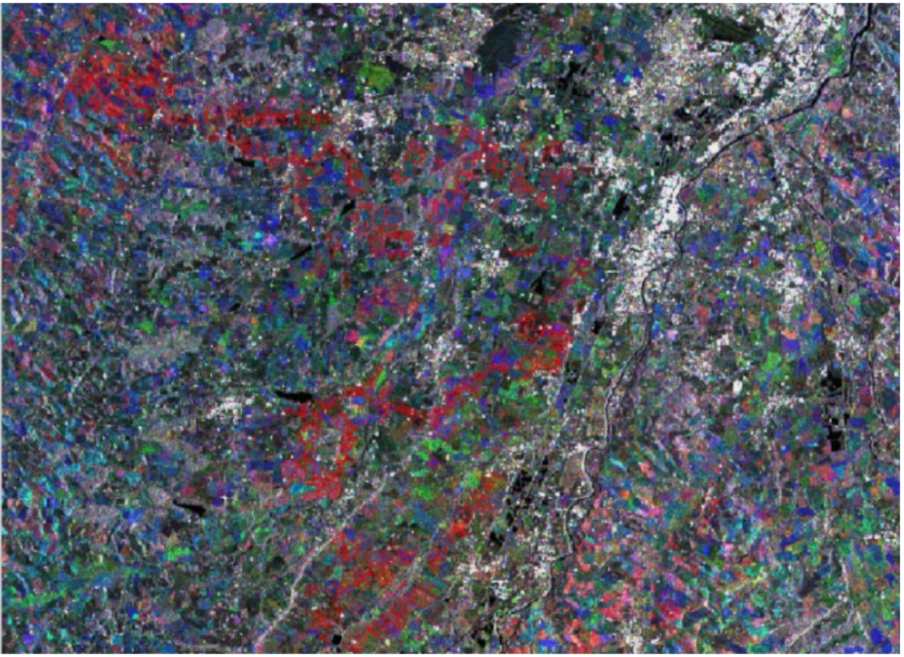
Winter crops: wheat, barley, rapeseed

Summer crops: soybean, sorghum, maïze, sunflower

Agricultural area (Lamasquère region)

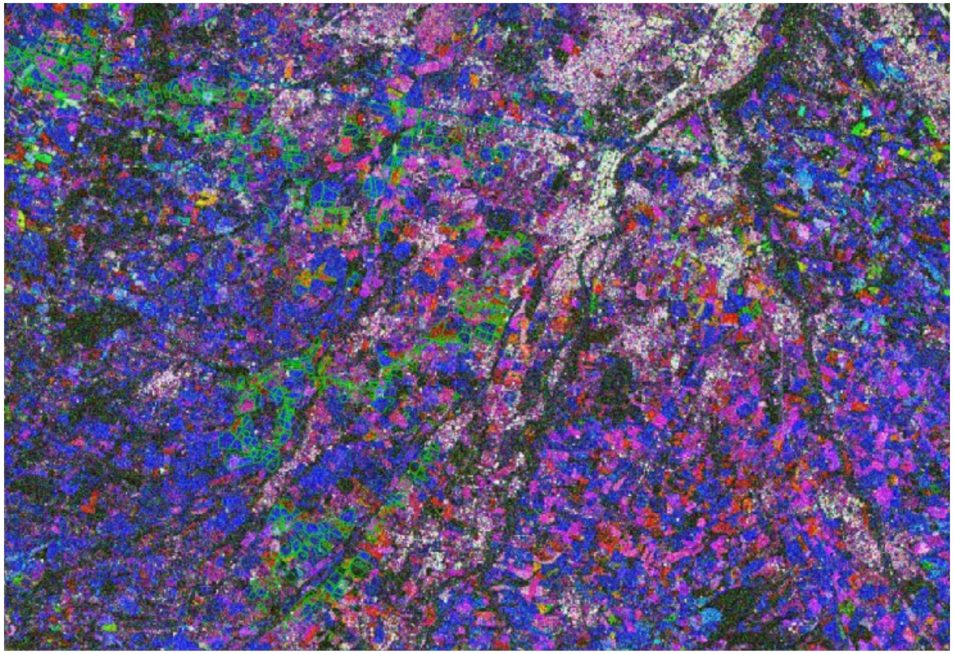
Multi-temporal color-composite images

Radar Backscatterin Coeff.



10 June- 14 Sept. – 7 Dec.

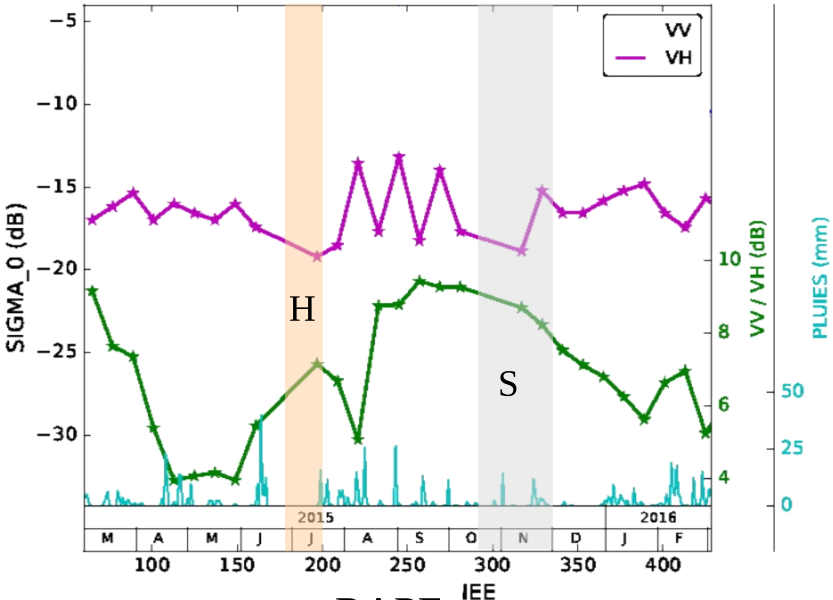
Cohérence



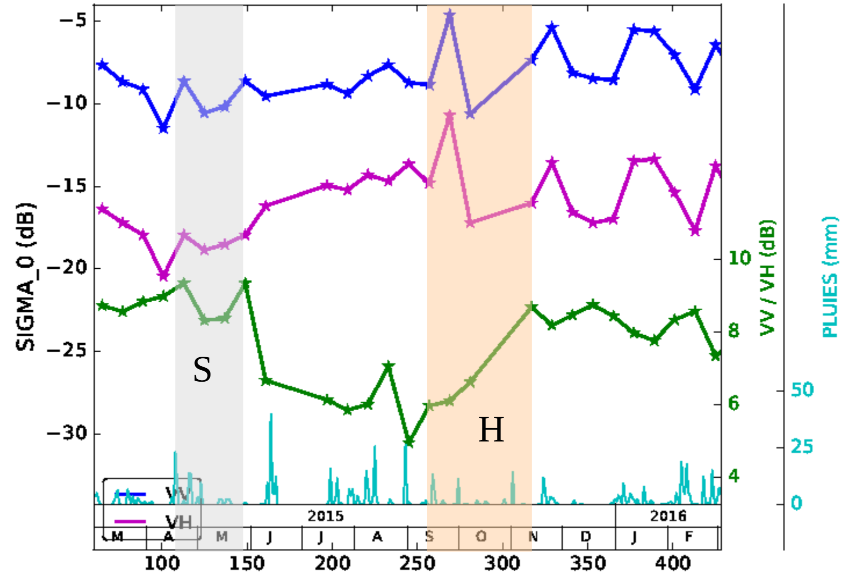
4-16 Jul .- 9-16 Aug. – 7-19 Dec.

CROP FIELDS: Temporal profile σ^0

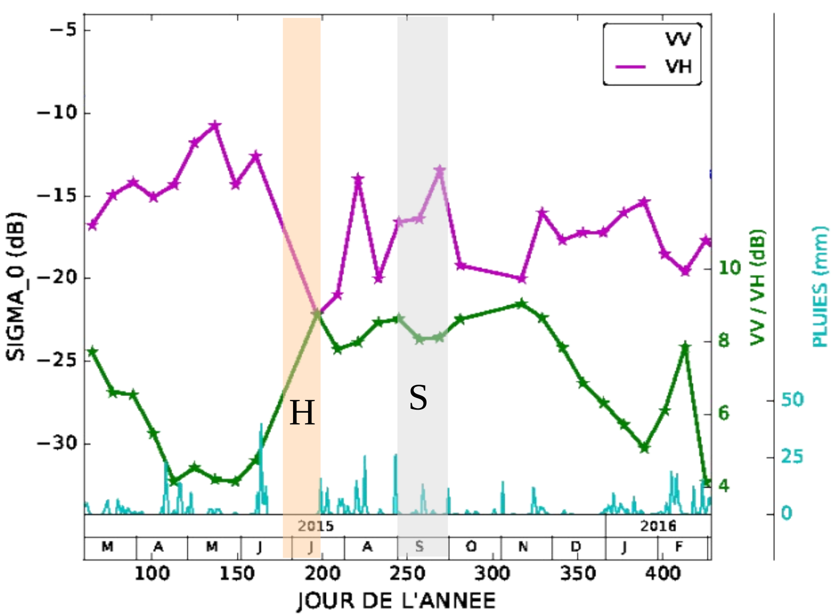
WHEAT



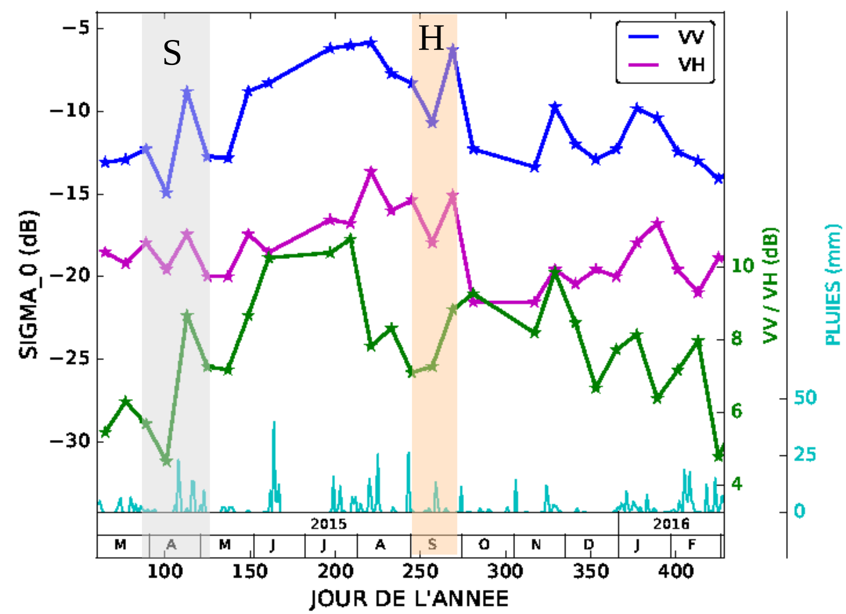
CORN – SOYA - SORGHUM



RAPE

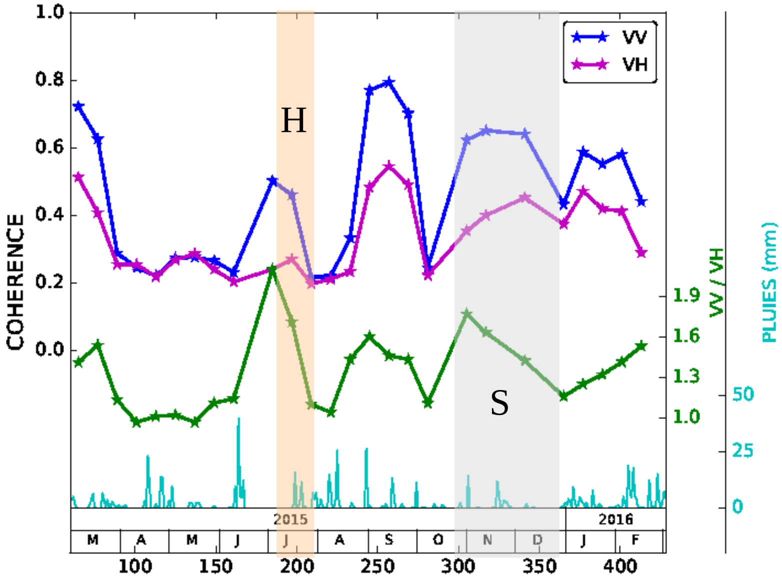


SUNFLOWER

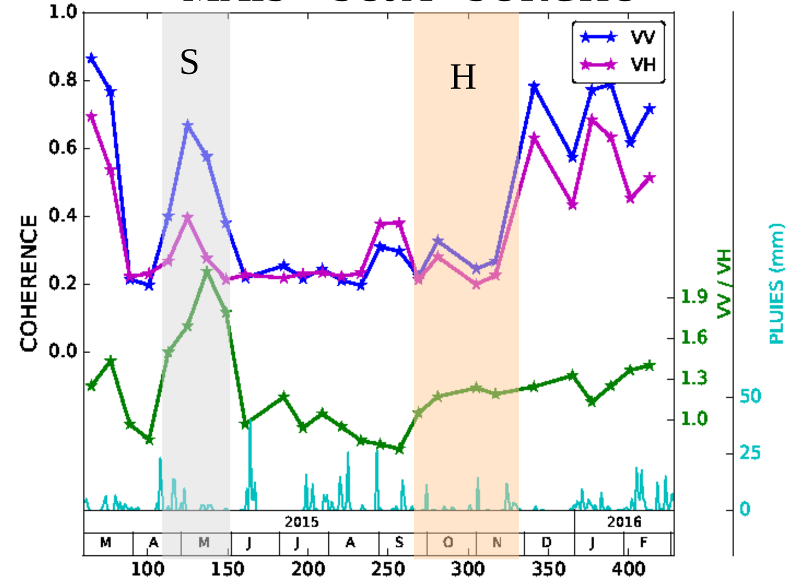


CROP FIELDS: Temporal profiles coherence

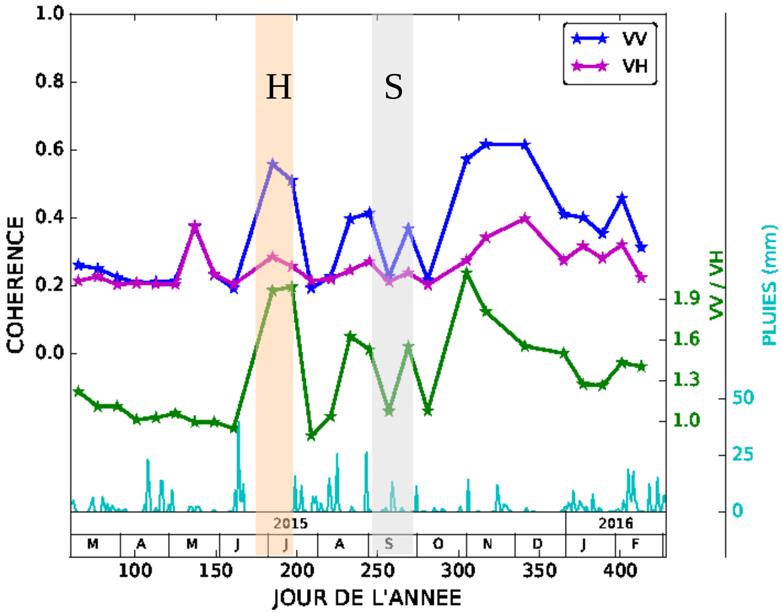
BLE - ORGE



MAIS – SOJA - SORGHO



COLZA



TOURNESOL