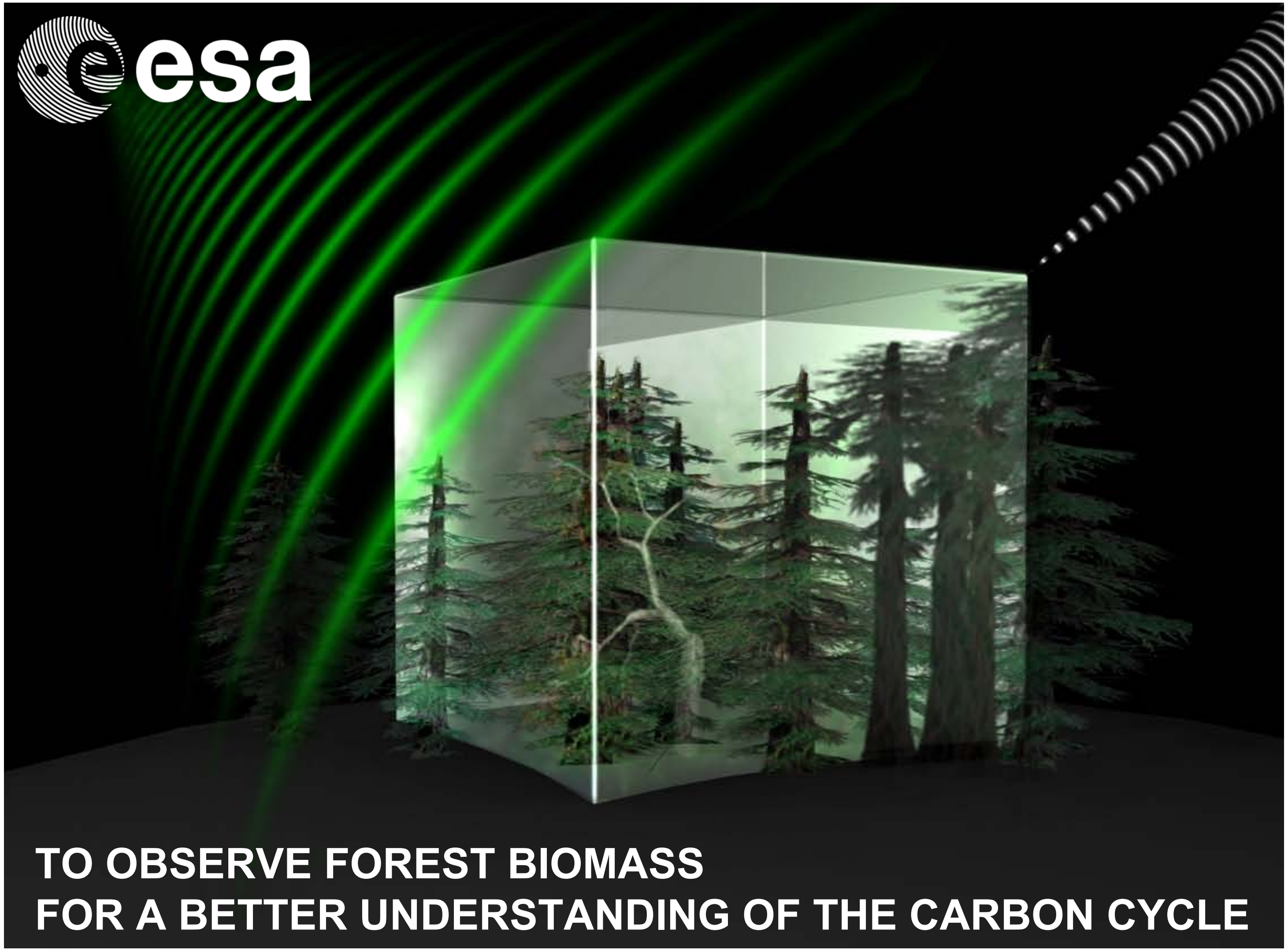
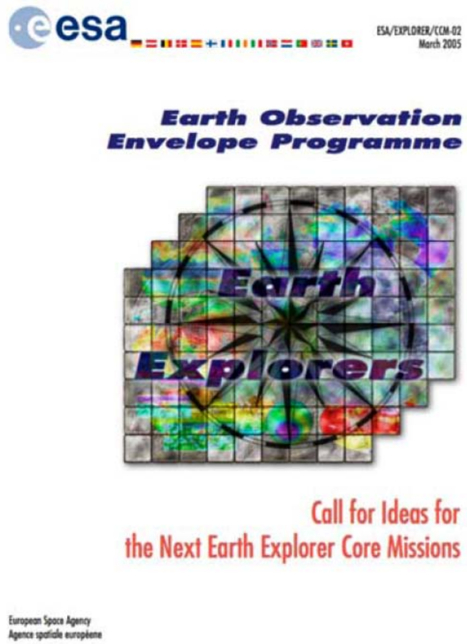
biomass


esa
TO OBSERVE FOREST BIOMASS
FOR A BETTER UNDERSTANDING OF THE CARBON CYCLE

The Third Cycle of Earth Explorer Core Missions



- Call for ideas issued in 2005
- 24 proposals evaluated
- 6 Candidate Missions selected in May 2006 for Phase
- 3 Candidate Missions selected in January 2009 for Phase A
  - **BIOMASS:** BIOMASS Monitoring Mission for Carbon Assessment
  - **PREMIER:** Process Exploration through Measurements of Infrared and millimeter Emitted Radiation
  - **CoRe-H20:** Cold Regions Hydrology High-resolution Observatory
- Final selection mid 2011
- Expected launch 2016

BIOMASS primary science objectives

The BIOMASS mission addresses the largest single source of uncertainty in the global carbon budget: the terrestrial ecosystem.

Objective	Product
Greatly improve current estimates of **forest carbon stocks**	Consistent global maps of **forest biomass and height** at scale of 100 m
Reduce uncertainty in **deforestation emissions** to a level comparable to uncertainty in net ocean flux	Map annual **reductions in biomass** globally
Improve estimates of **terrestrial carbon sinks** from regrowth and reforestation	Map **increases in biomass** globally across mission lifetime

Phase A main activities 2009-2011

1. Improve and further validate biomass and height retrieval algorithms

2. Flight campaign in regions of high forest biomass density to verify the robustness of the retrieval algorithms

3. Define a post-launch protocol for global validation considering different biomes

4. Elaborate potential secondary objectives of the first P-band mission in space.

5. Further investigate on the use of BIOMASS in carbon models

Retrieval algorithms

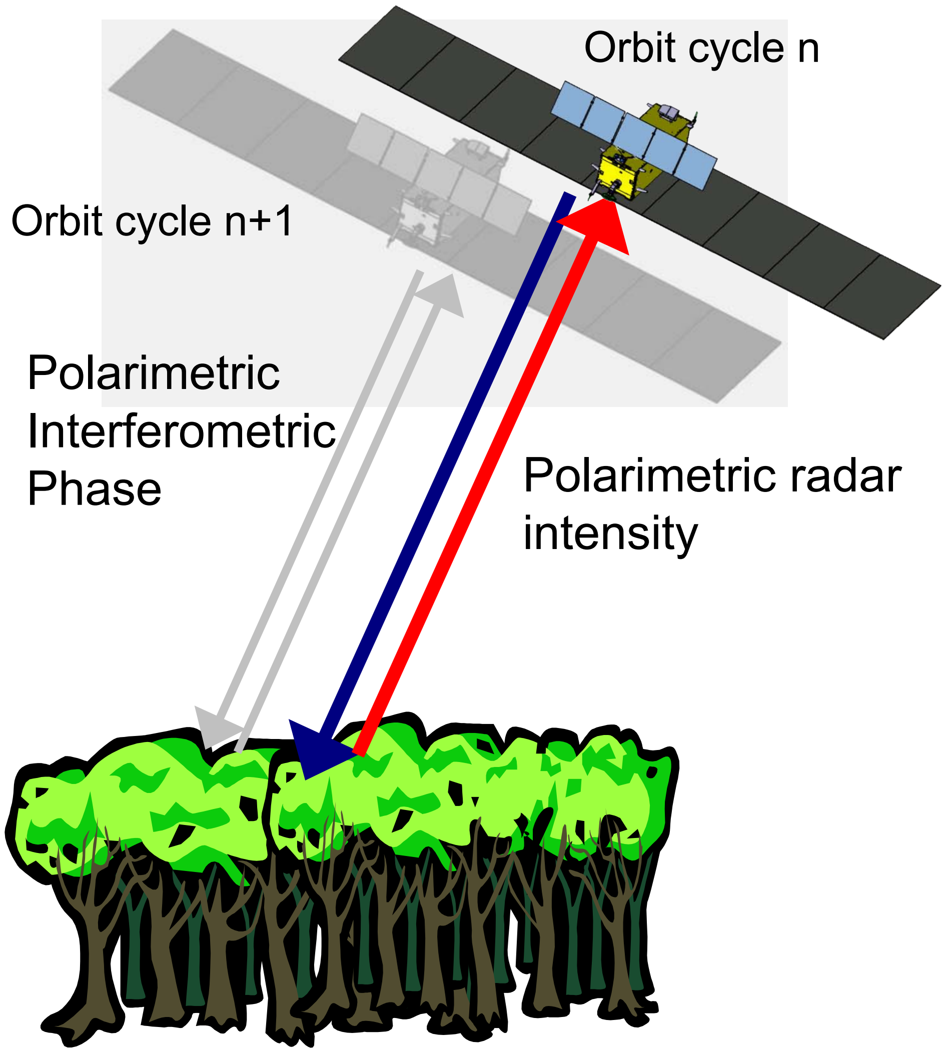
Phase 0

- Biomass retrieval using SAR intensities
- Demonstration PolInSAR height retrieval at 30 day interval
- Preliminary works on combined intensity and PolInSAR

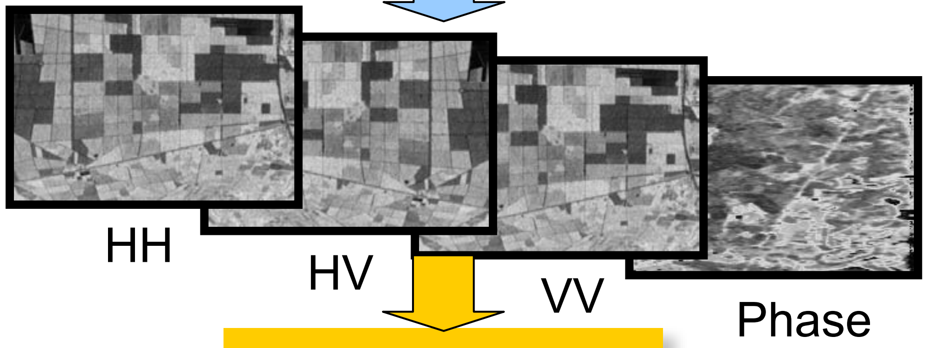
Phase A

- Further validation in areas with topography and at tropical forests
- Exploit PolInSAR coherences and tomography

BIOMASS observation concept



Calibration, Ionospheric correction

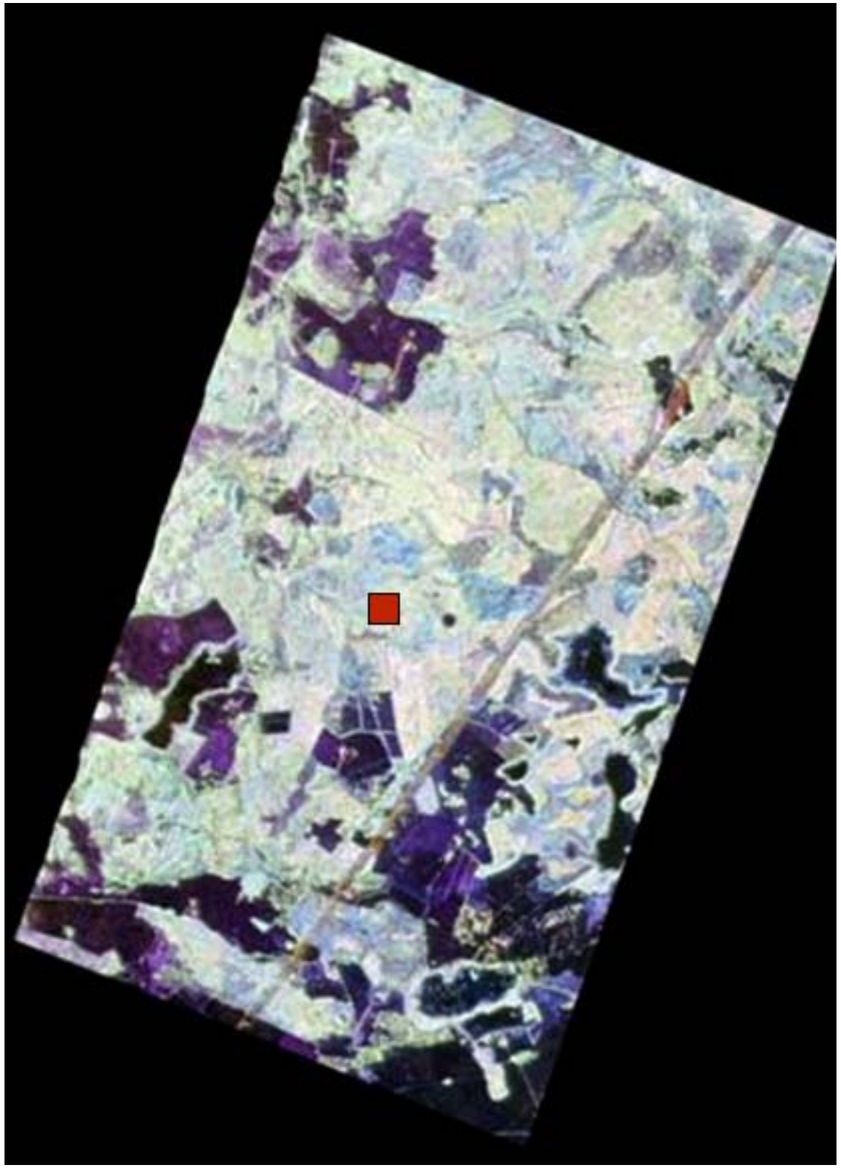


Retrieval algorithm

Geophysical products

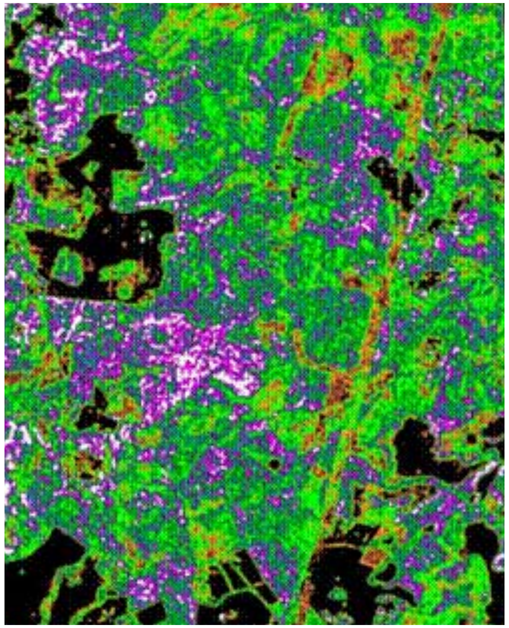
- Forest biomass
- Forest height
- Forest biomass temporal change
- Forest disturbance

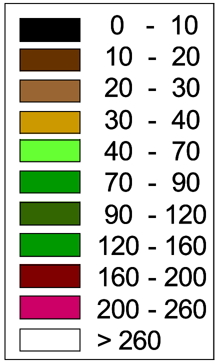
HH, VV, HV



BioSAR Remingstorp forest, Sweden

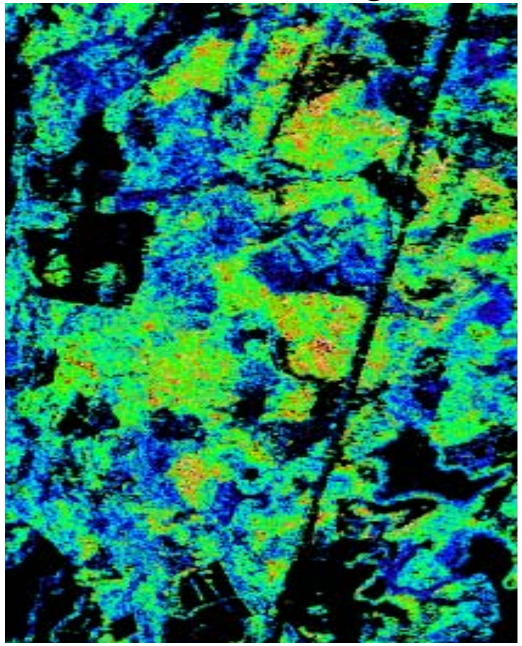
Biomass from Intensity



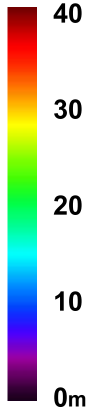


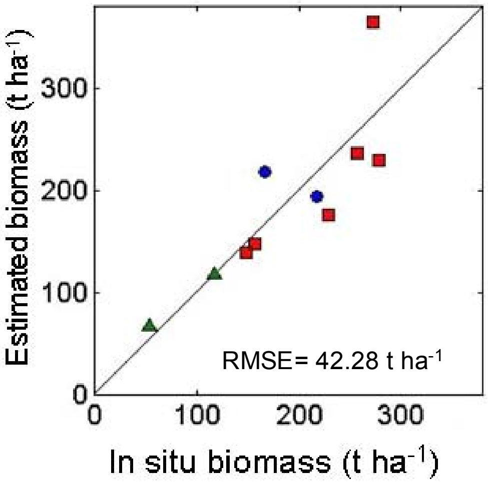
Biomass (ton/ha)

Pol-InSAR height

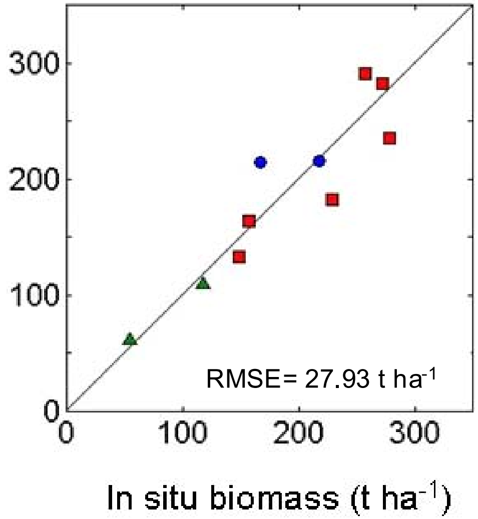


Height (m)





Intensity + Pol-InSAR



SAR Tomography (T-SAR)

Algorithm to characterise forest structure using multi-baseline, polarimetric SAR data

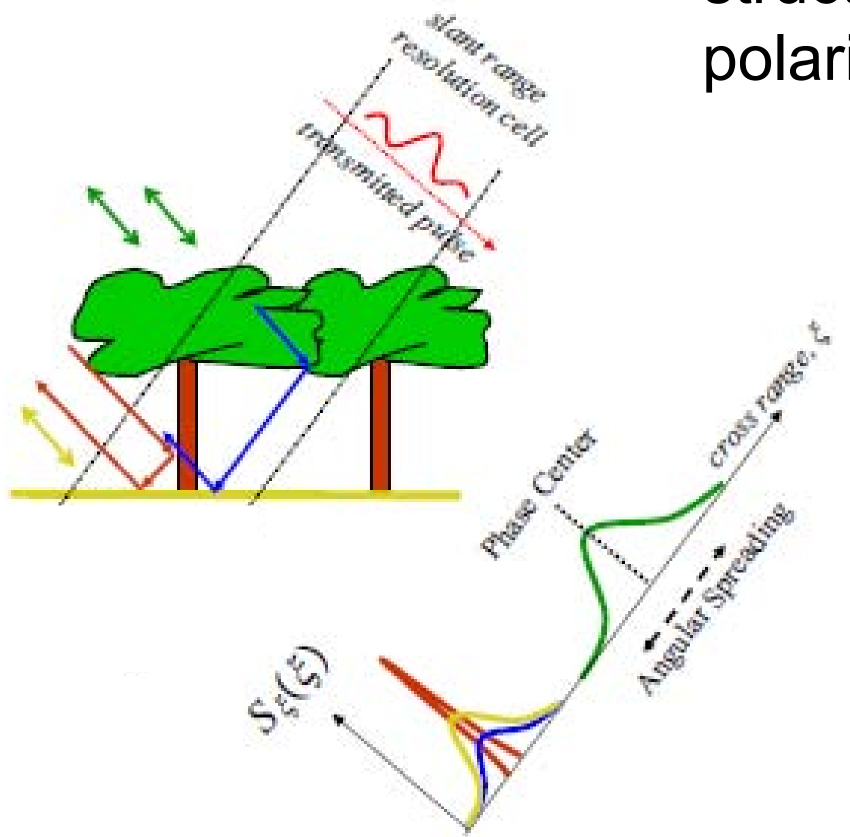
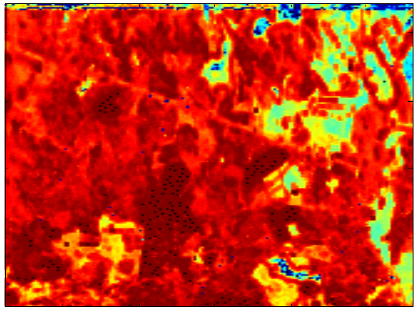


Fig. 2. Pictorial representation of the Fourier Spectra associated to the four scattering mechanisms discussed. Brown: Trunk-ground scattering; yellow: ground backscattering; green: canopy backscattering; blue: canopy-ground scattering.

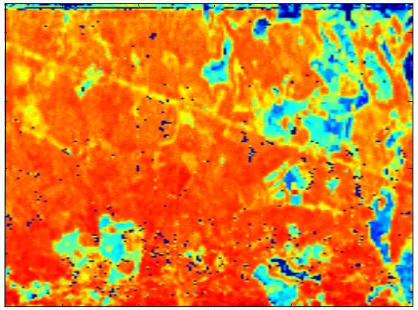
Tebaldini, 2009

Tomography from 9 fully polarimetric images (8 baselines)

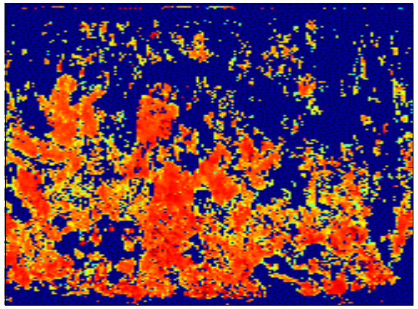
Ground Layer - HH



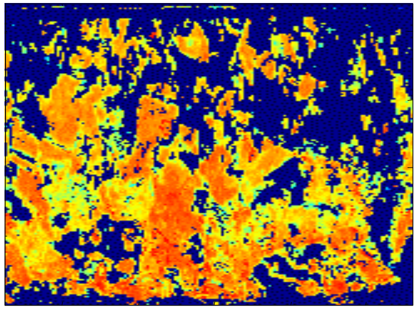
Ground Layer - HV

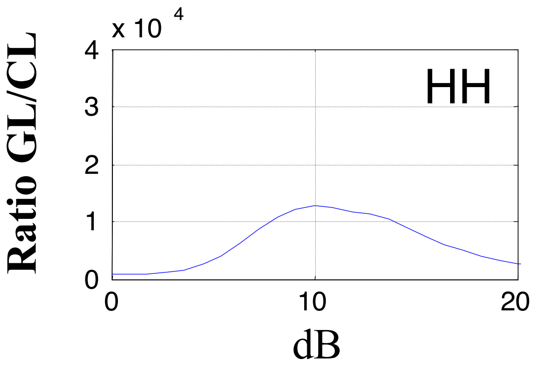


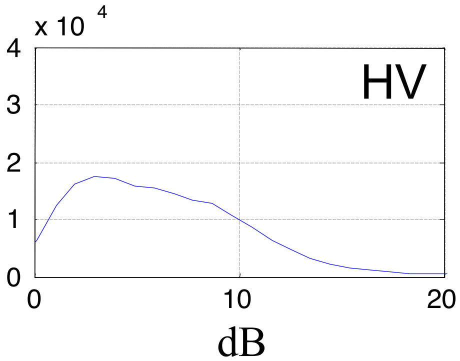
Canopy Layer - HH



Canopy layer - HV







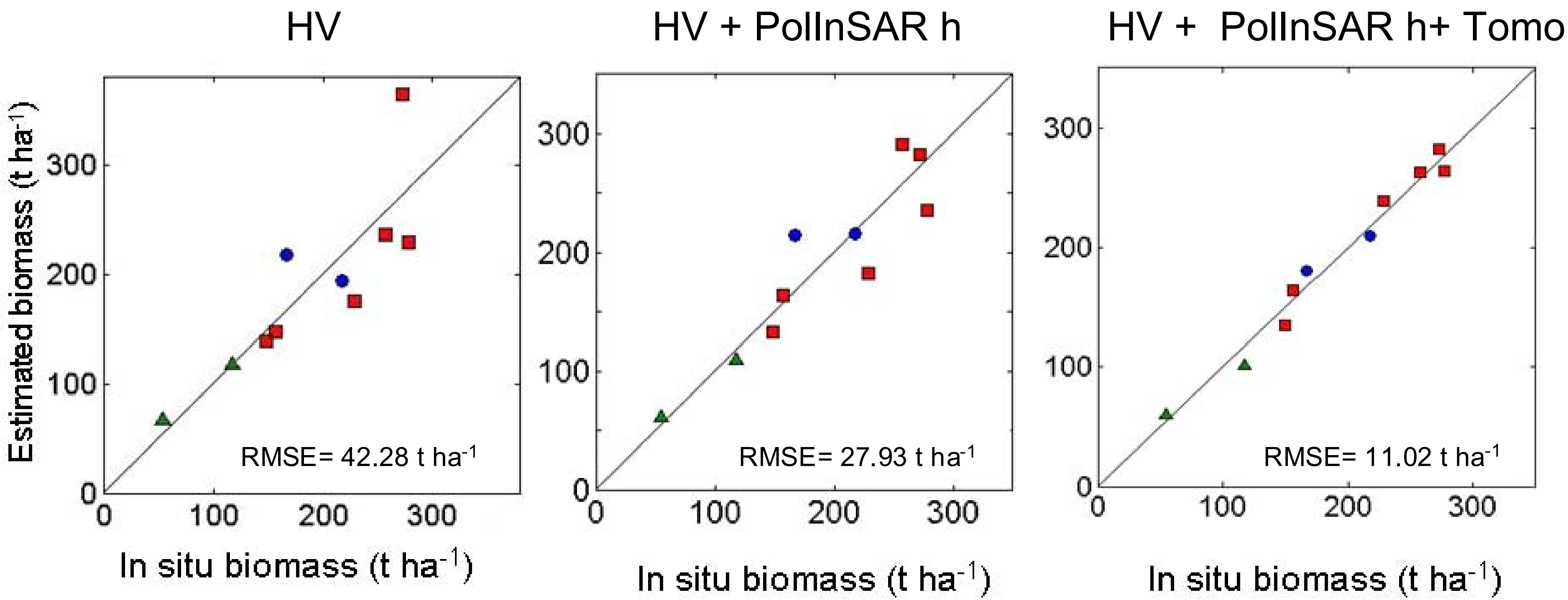
- HH: backscatter from ground level dominates that from canopy level by about 10 dB

- Similar results in VV

- HV: Contributions from ground level are dominant also

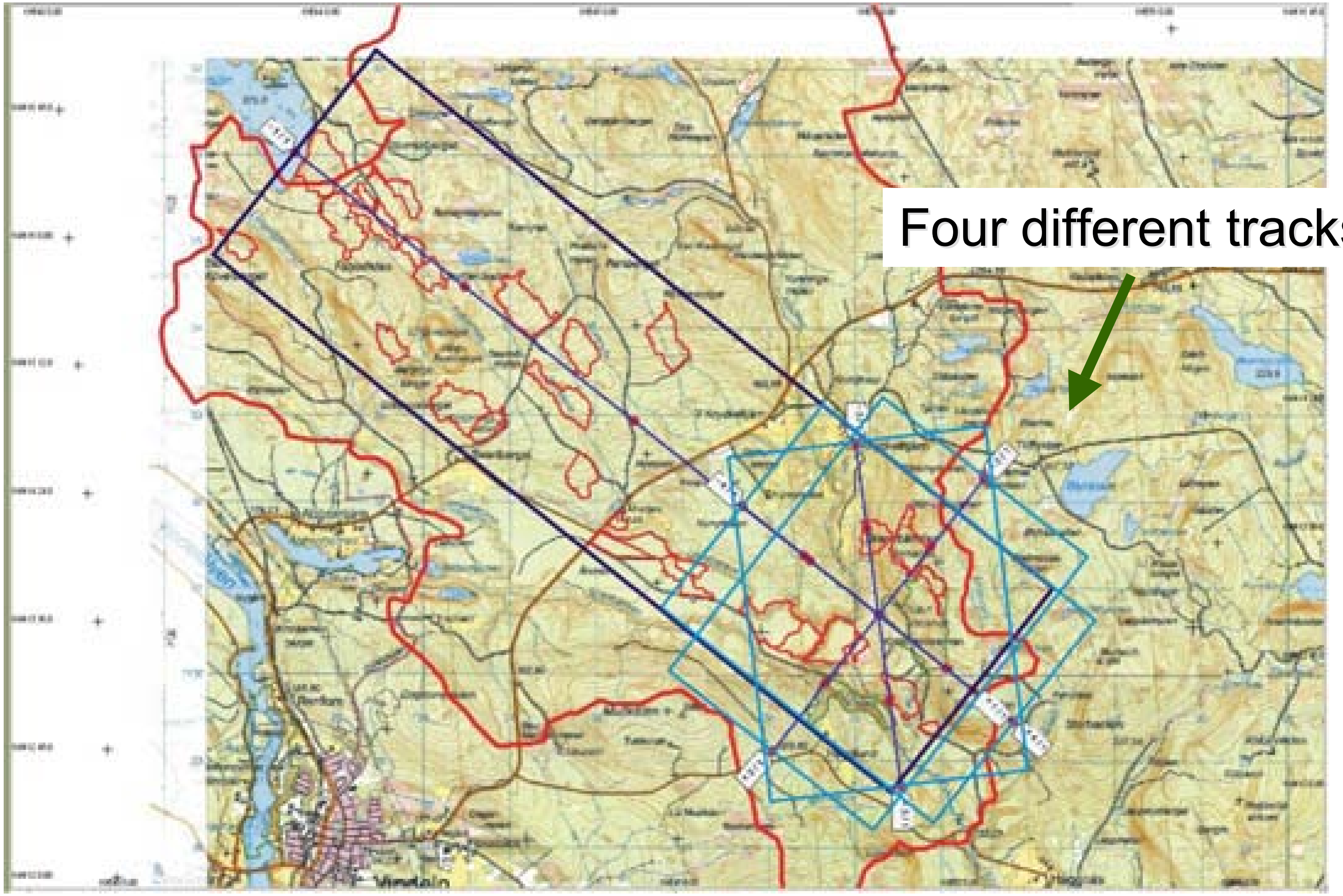
  - Local topography
  - Ground and trunk roughness
  - Ground – canopy interactions
  - Underlying vegetation+ branches

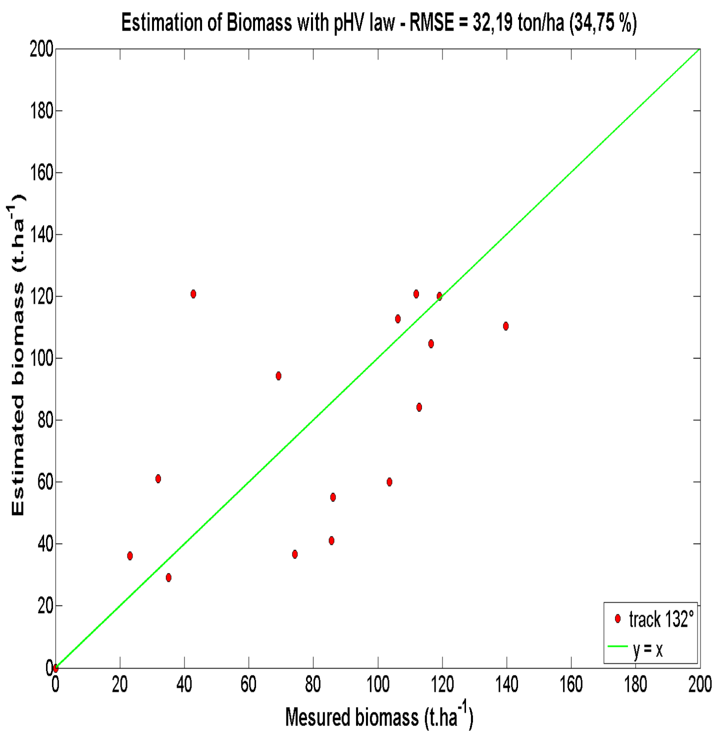
Tebaldini & Rocca, 2009

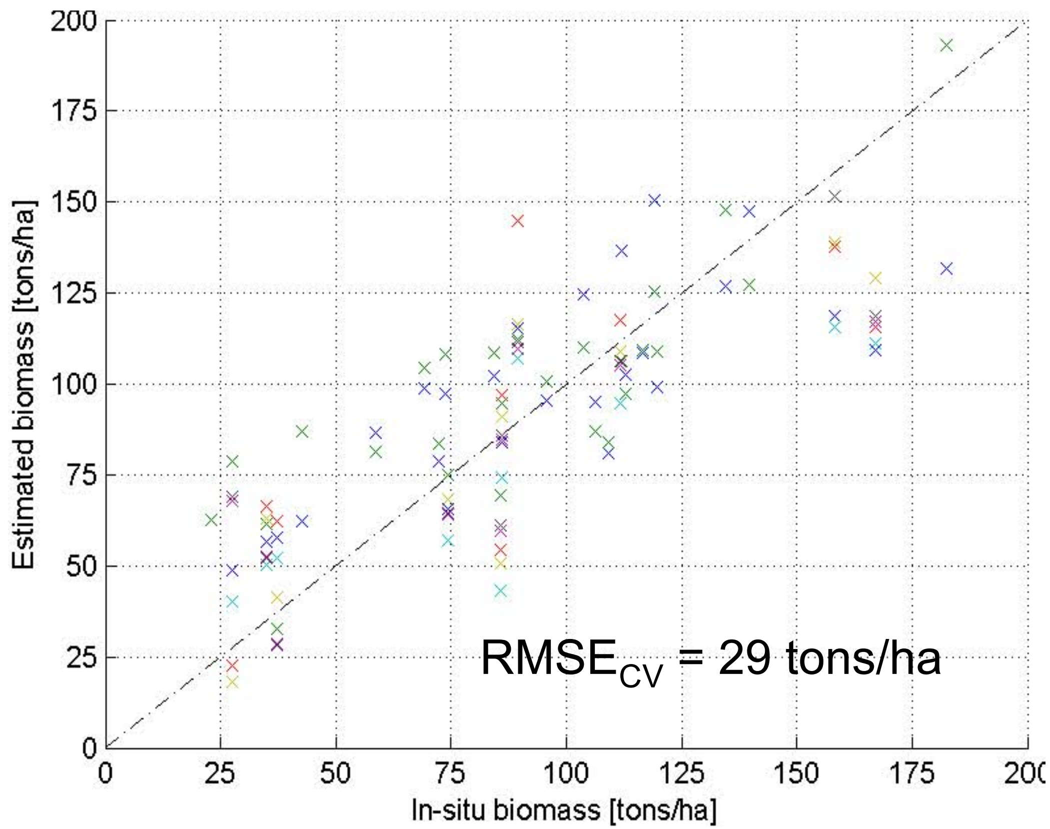

HV
HV + PolInSAR h
HV + PolInSAR h+ Tomo
Estimated biomass (t ha-1)
In situ biomass (t ha-1)
RMSE= 42.28 t ha-1
RMSE= 27.93 t ha-1
RMSE= 11.02 t ha-1
0
100
200
300

BIOSAR-2: Boreal forests with marked topography

October 2008- Kryclan forest, Northern Sweden- ESAR from DLR

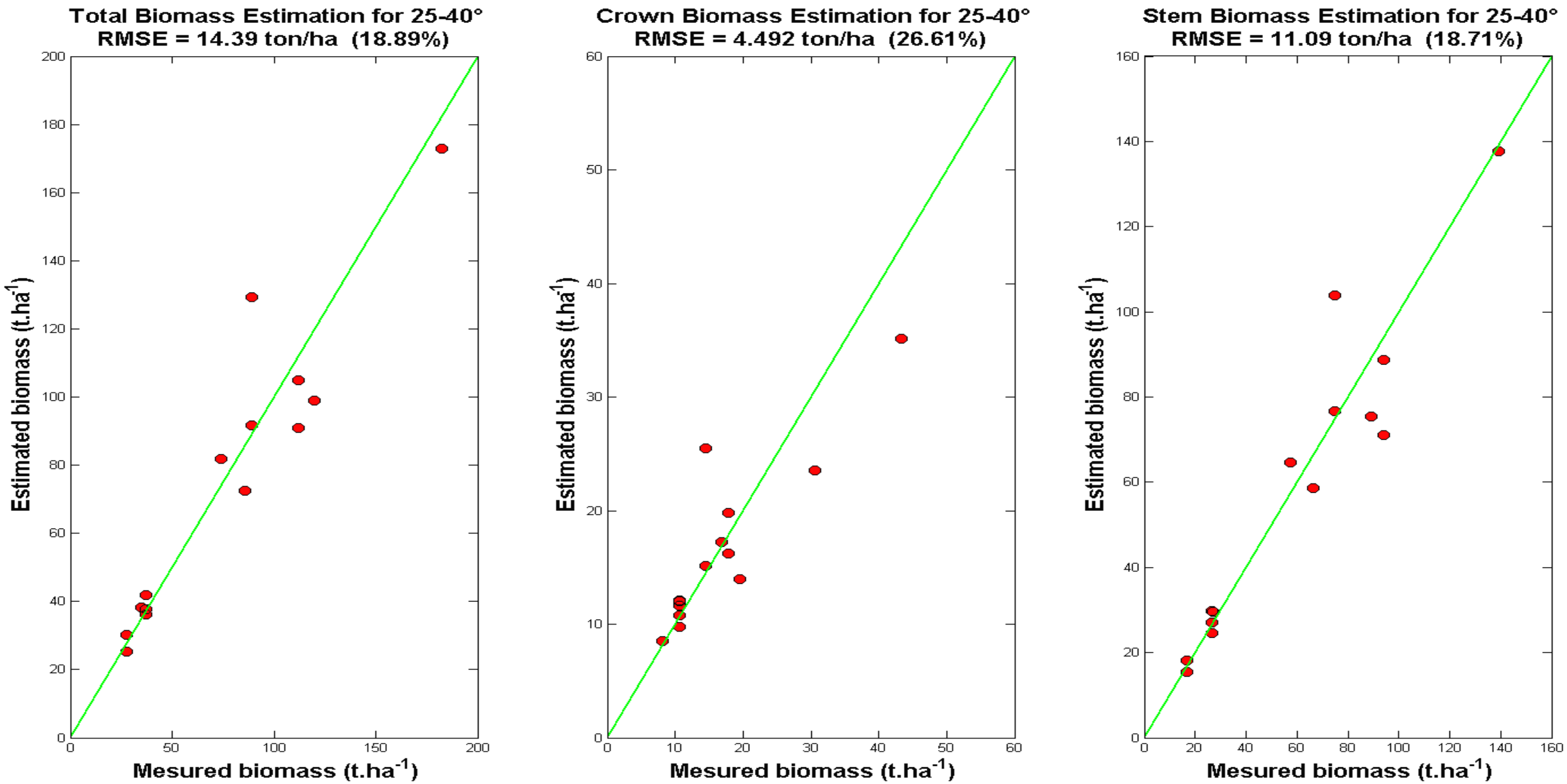






Unsupervised biomass estimates using HV (CESBIO)

Supervised biomass estimates using HV, HH and VV (Chalmers)



Comparison of estimated and measured biomass from data of heading 132° , with data points restriced to radar incidence angle of 25° -40°. Left: total above ground biomass, middle: crown biomass, right: stem biomass. The coefficients used in the inversion are derived from data of headings 42°, 133°, 3 13° et 357°

Retrieval of above ground biomass (crown + stem) using Saatchi et al. 2007 algorithm

Use of intensity and interferometric coherence in biomass inversion

Thuy Le Toan, Julien Valteau, Alexandre Couhert, Franck Garestier

August 2009

❑ Rationale

Ratio of Coherence = linked to biomass through temporal and volume decorrelation ?

$$\gamma = \gamma_{temp} \cdot \gamma_{SNR} \cdot \gamma_{géom} \cdot \gamma_{vol}$$

Deduced from HV (VH) coherence, and reduced in ratio

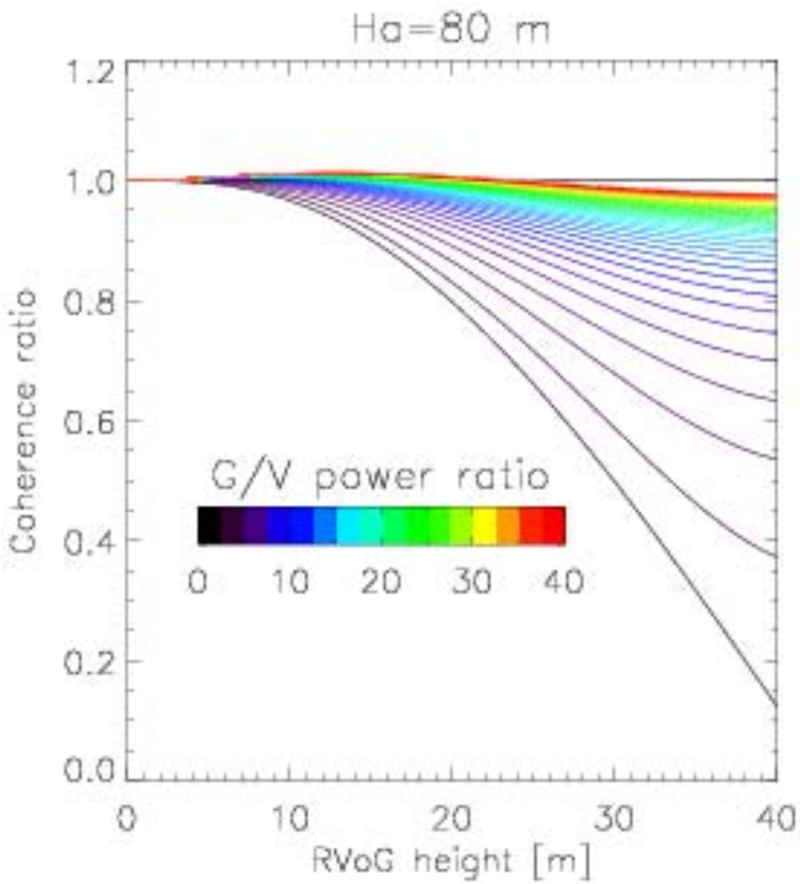
Reduced by ratio between polarisations

❑ Simulation

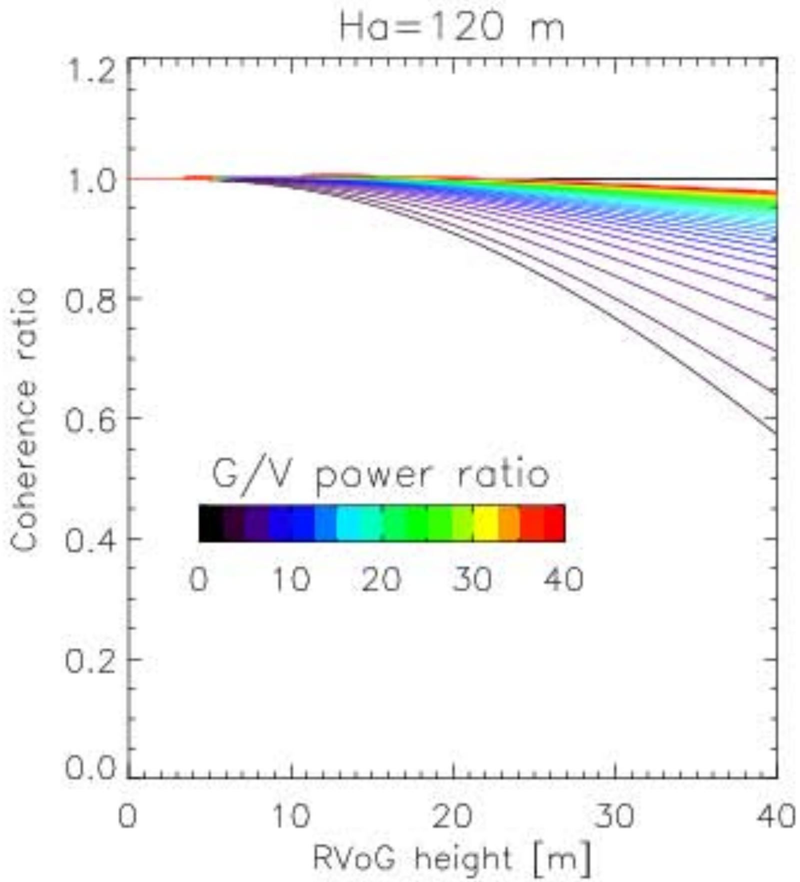
❑ Test on data

Simulation of the ratio between coherence HV and coherence VV

Hypothesis: Mean attenuation 1 dB/m
Same temporal decorrelation HV and VV



G/V ratio
of tree
canopy

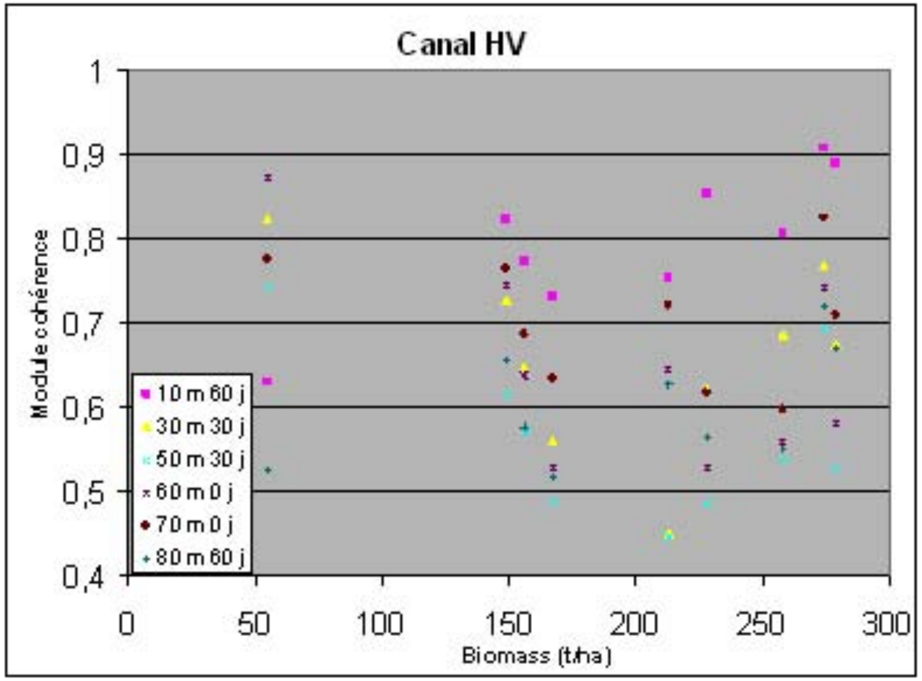


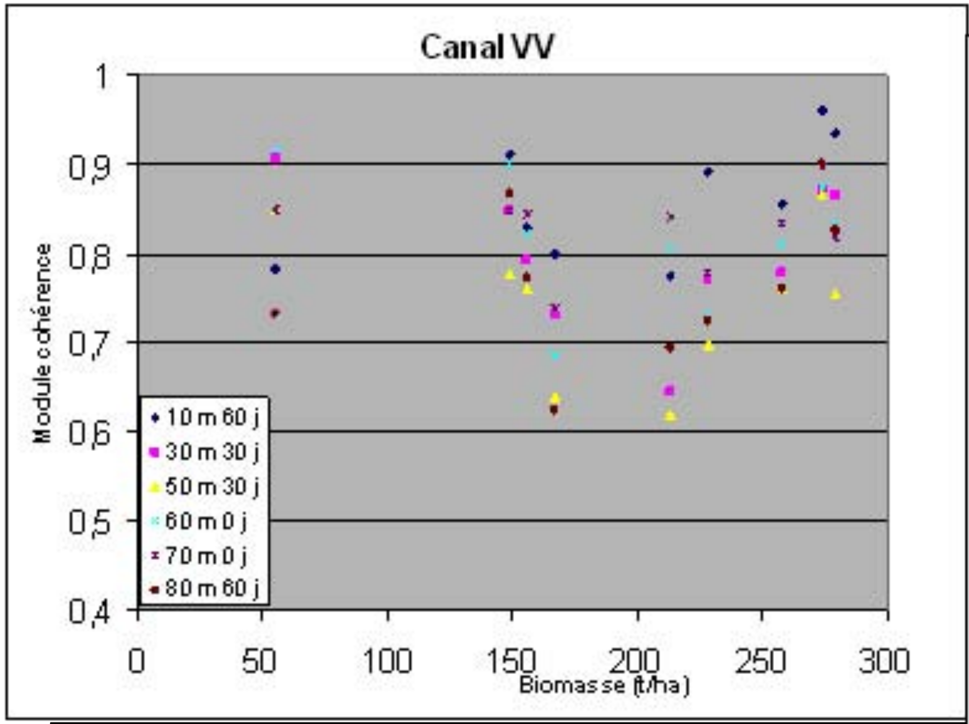
Coherence ratio of forest layer: sensitivity to layer height
depends on baseline

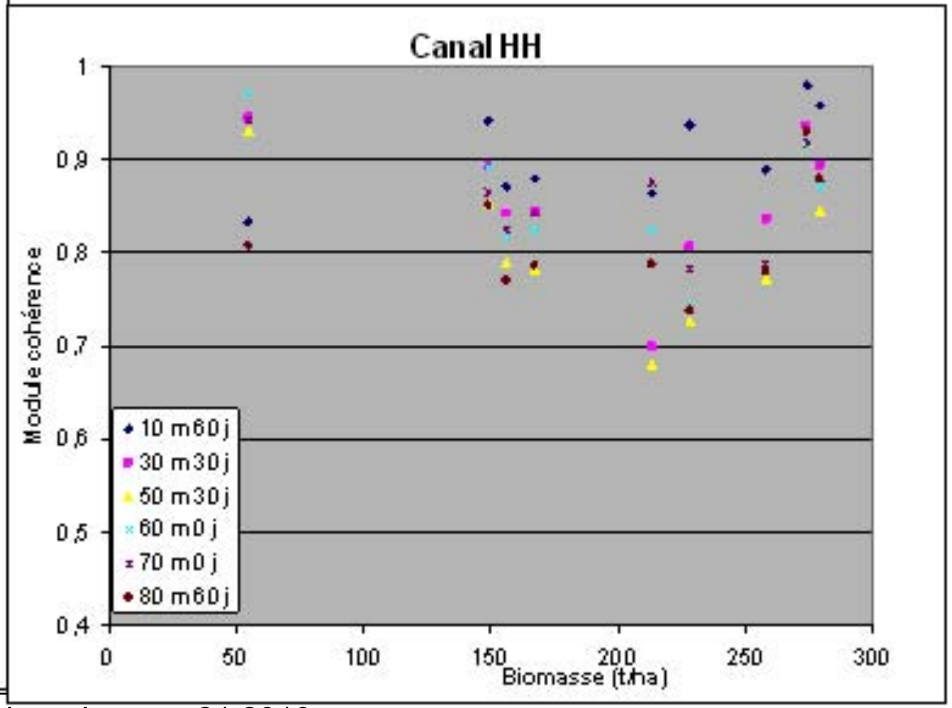
Testing

P-band Coherence, Remningstorp forest
Temporal interval 0 , 30, 60 days
Baselines: 10 m, 30 m; 50 m, 70 m, 80 m

Ground data: 10 reference stands
of 80 m x 80 m

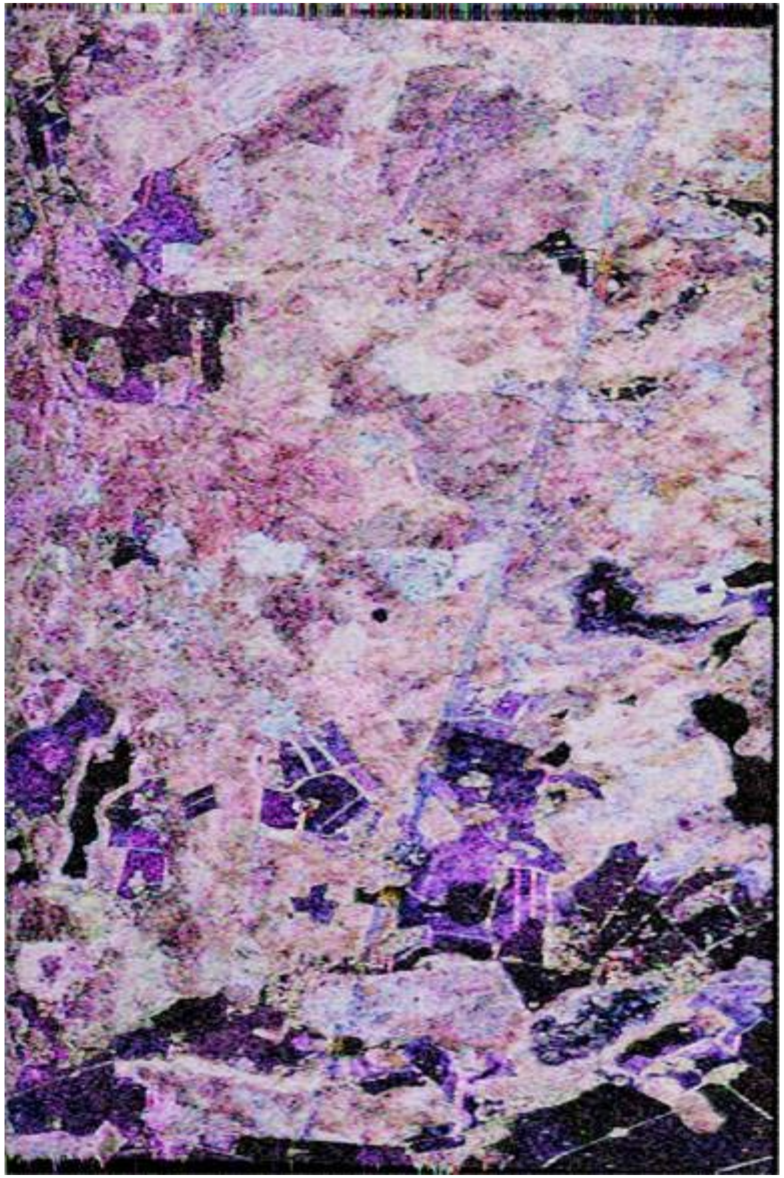






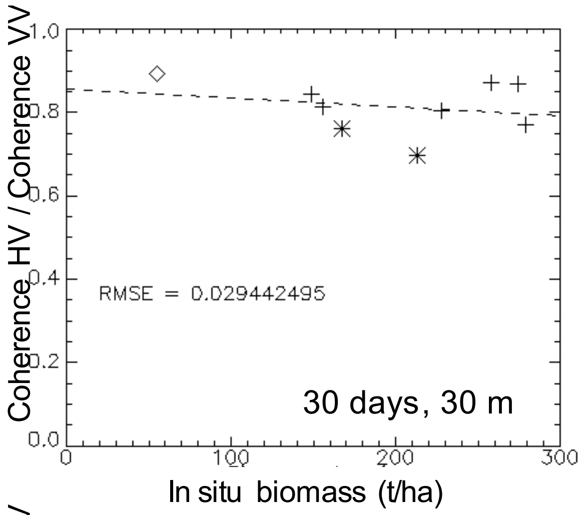
Interferometric coherence maps

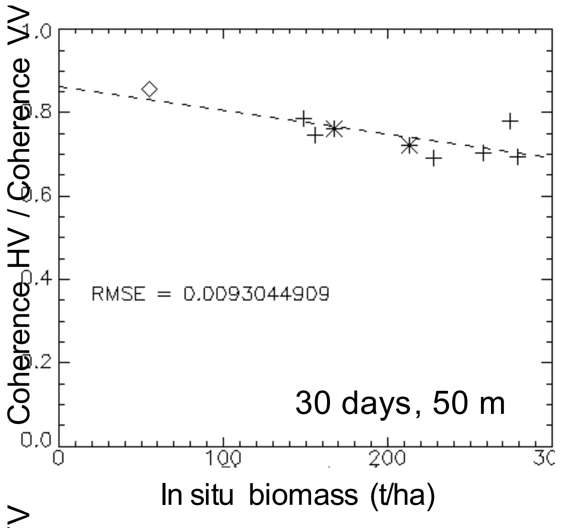
Module 70 m 0 day Phase

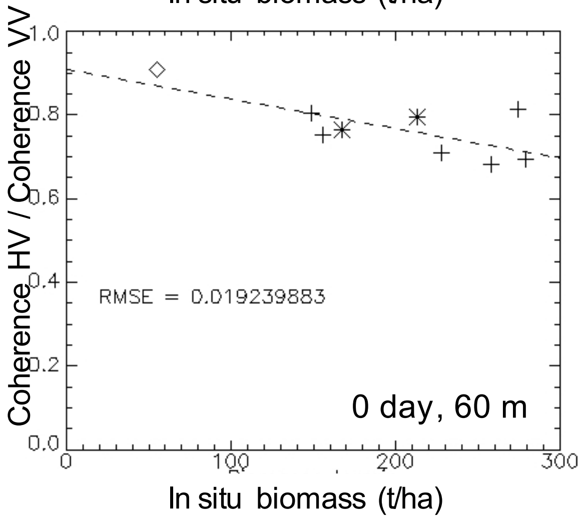


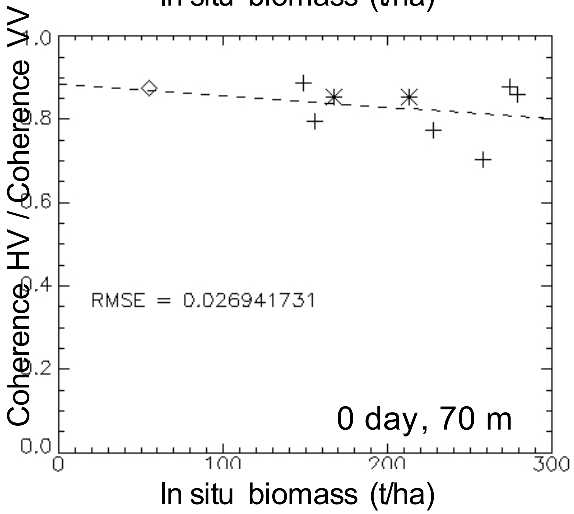
HH (blue), HV (green) VV (red)

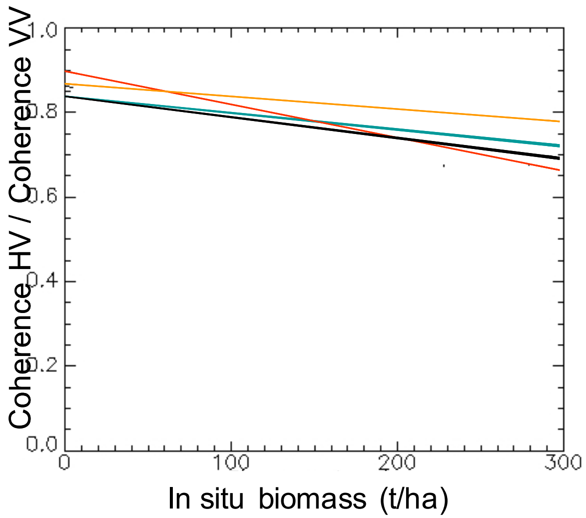
Ratio of HV coherence / coherence VV vs in situ biomass











The Bayesian approach

$$B_{estim} = \int_B B \cdot \frac{P(R_{\gamma^0_{HV}})\, P(R_{\gamma^0_{HH}})\, P(R_{\frac{mchv}{mcvv}})}{\gamma^0_{HV_{theo}}\, \gamma^0_{HH_{theo}}\, \frac{mchv}{mcvv}theo}\, d_B$$

Where *R* is random variable representing sources of random noise

$$R = \frac{D_{meas}}{D_{theo}}$$

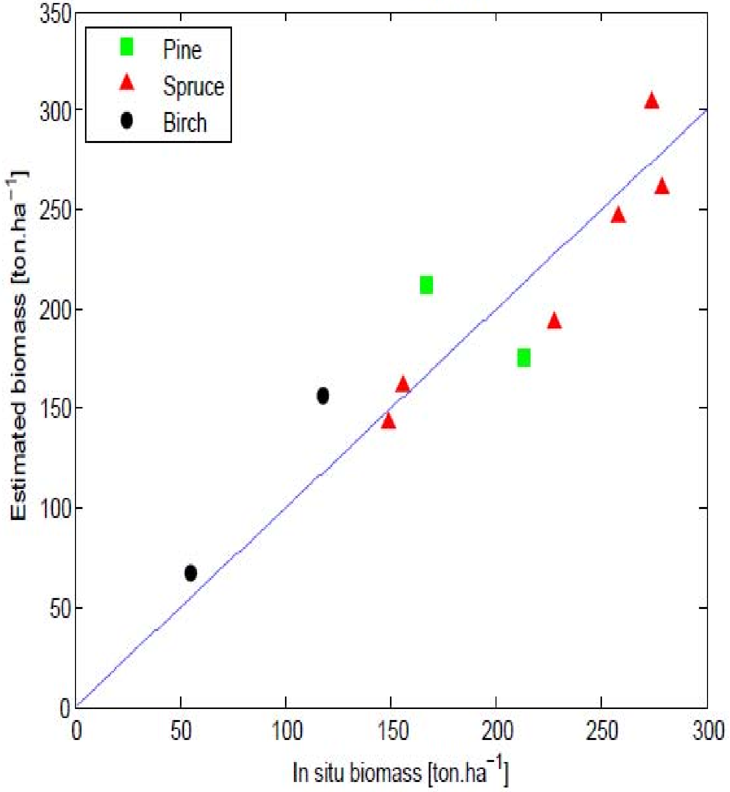
D_{meas} is measurement (HV, HH and coherence ratio)

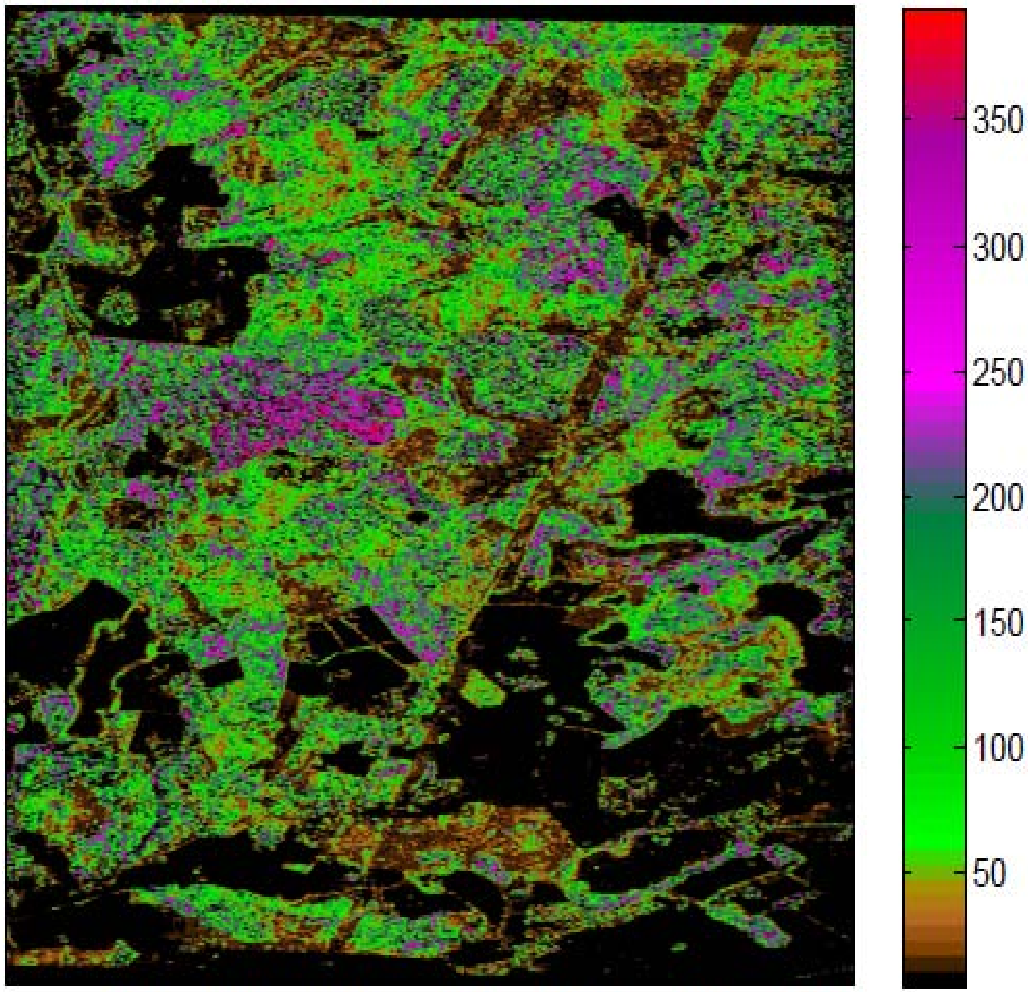
D_{theo} is theoretical values of D given B

$$D_{theo} = f(B)$$

Bayesian estimation of biomass using γ^{0}_{HV}, γ^{0}_{HH} et mchv / mcvv, RMSE = 28 ton/ha

Bayesian estimation of forest biomass using γ^{0}_{HV}, γ^{0}_{HH} et mchv / mcvv, RMSE = 28 ton.ha



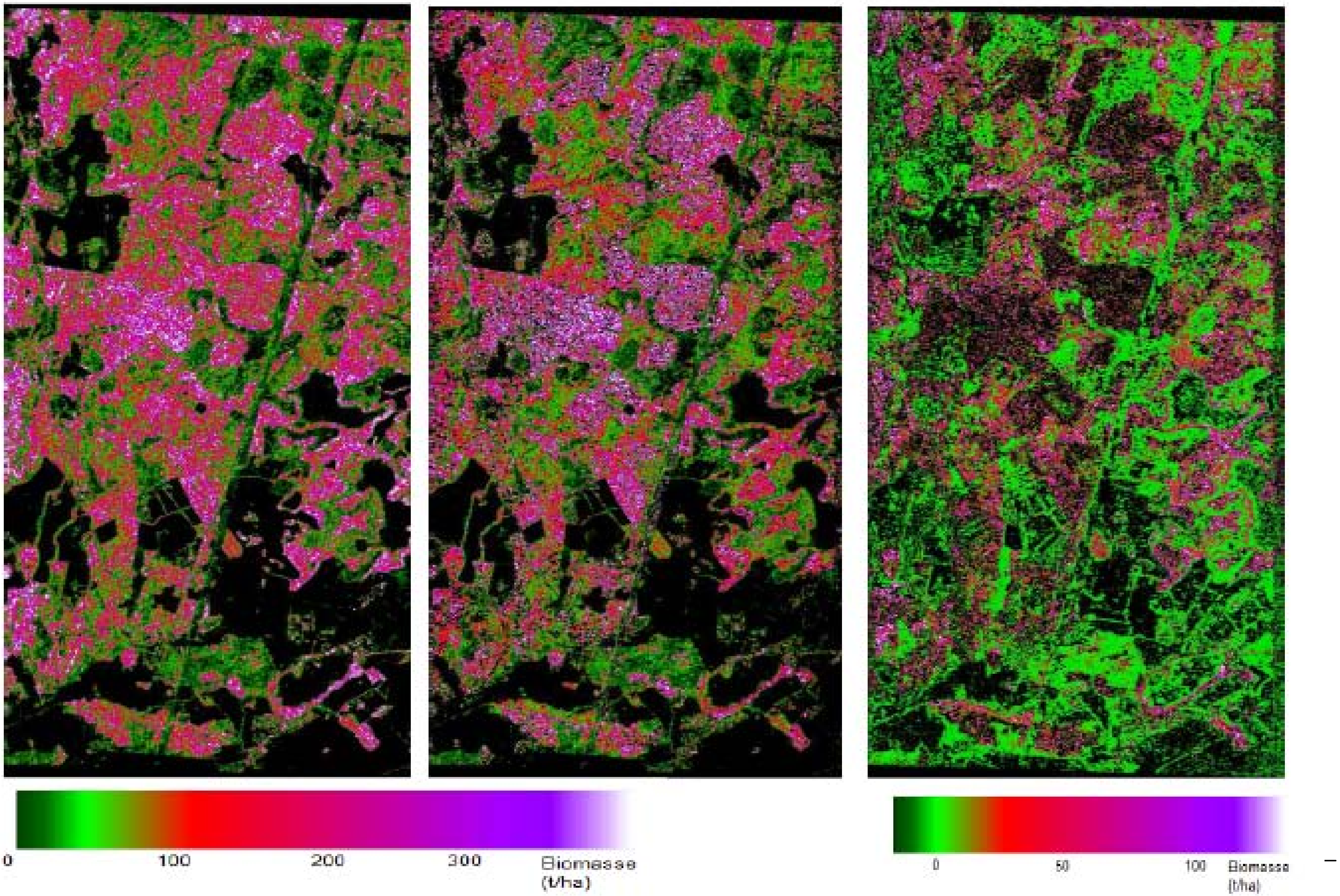


Bayesian inversion of biomass

HV

HV and coh HV/coh VV

Map of the difference



Flight campaigns

Phase 0

BIOSAR-I : Remningstorp, Sweden, March -May 2007
To test 0, 30, 60 day repeat PolInSAR

BIOSAR-2: Kryclan, Sweden, October 2008
To validate methods on forests with strong topograhy

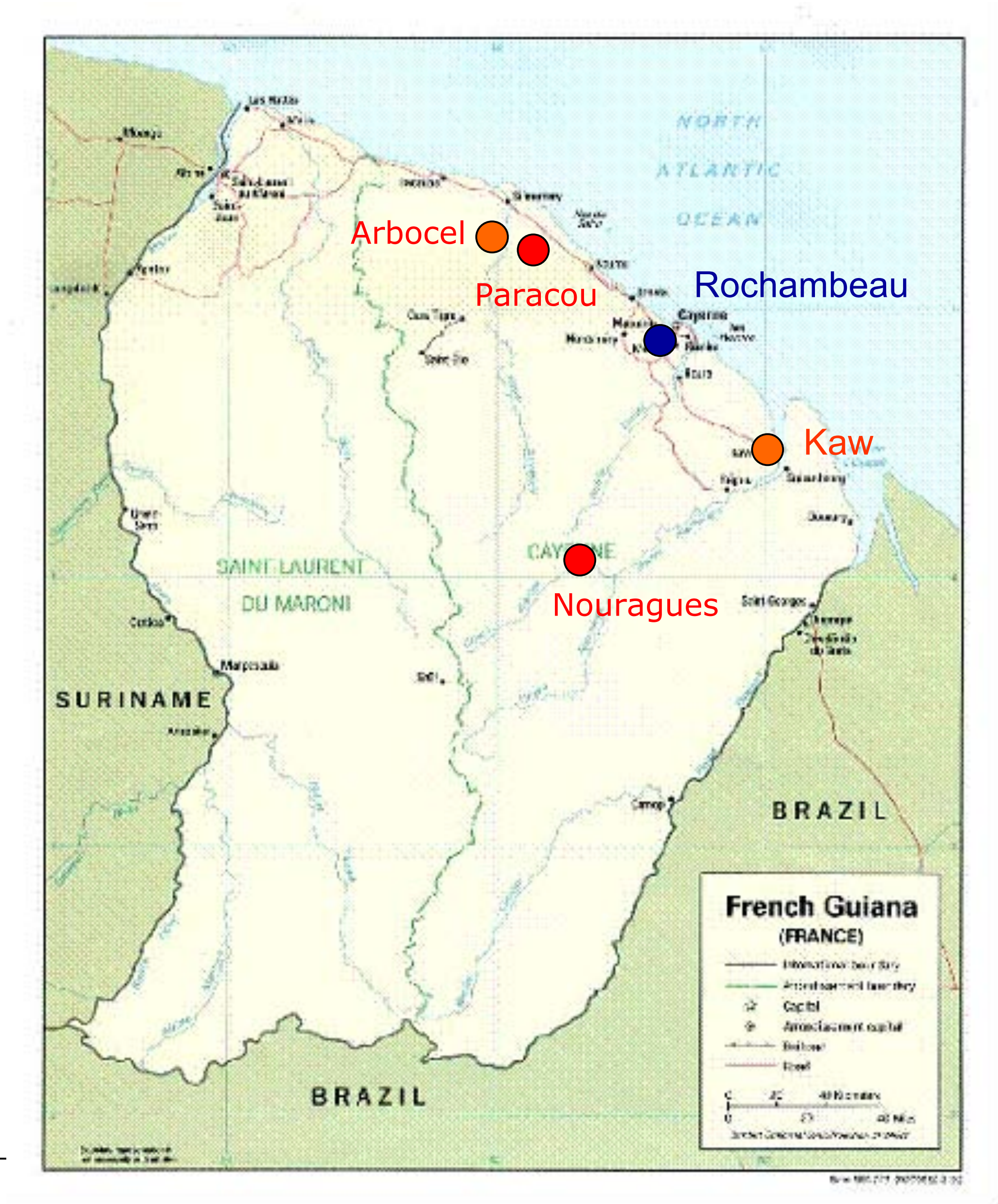
Phase A

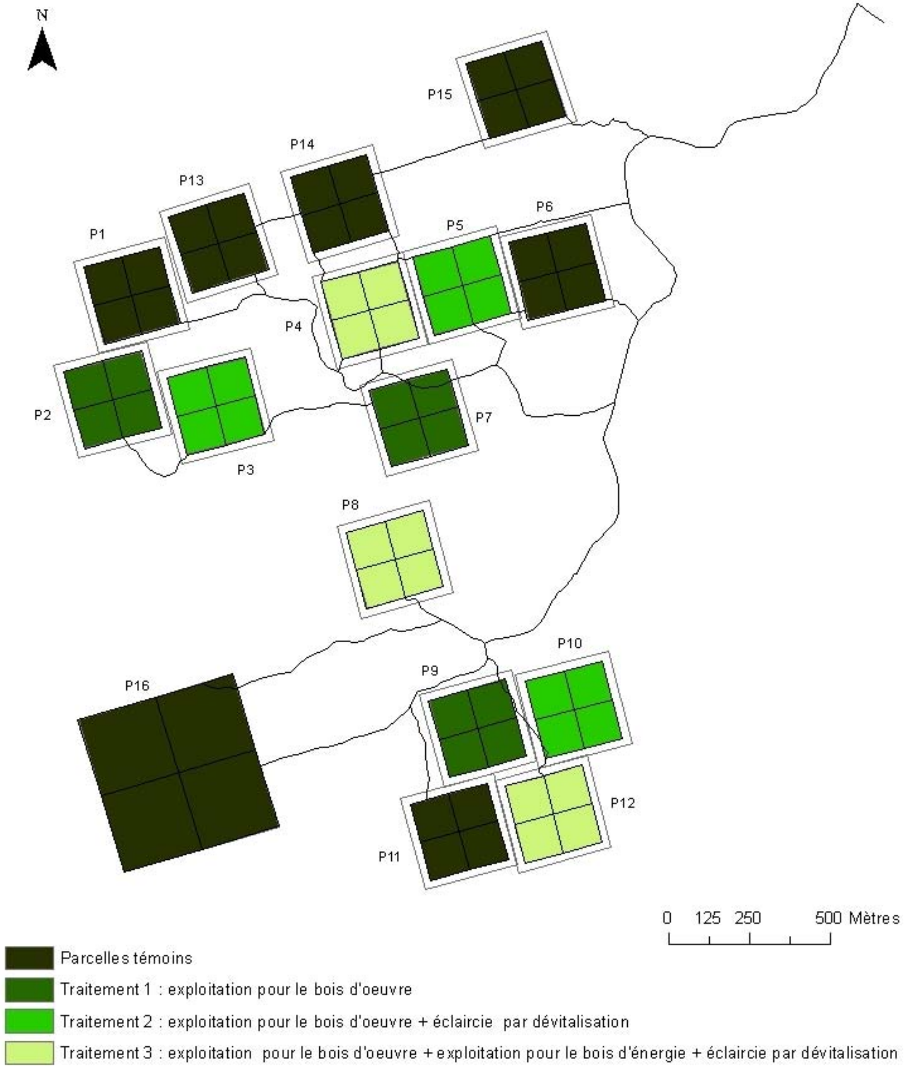
TropiSAR: French Guiana, August 2009

Candidate experiments:

Ground based radar over forest in F. Guiana
Flight campaign in Gabon

CESBIO


NORTH
ATLANTIC
OCEAN
Arbocel
Paracou
Rochambeau
Kaw
Nouragues
SAINT LAURENT
DU MARONI
SURINAME
BRAZIL
BRAZIL
French Guiana
(FRANCE)


N
P15
P14
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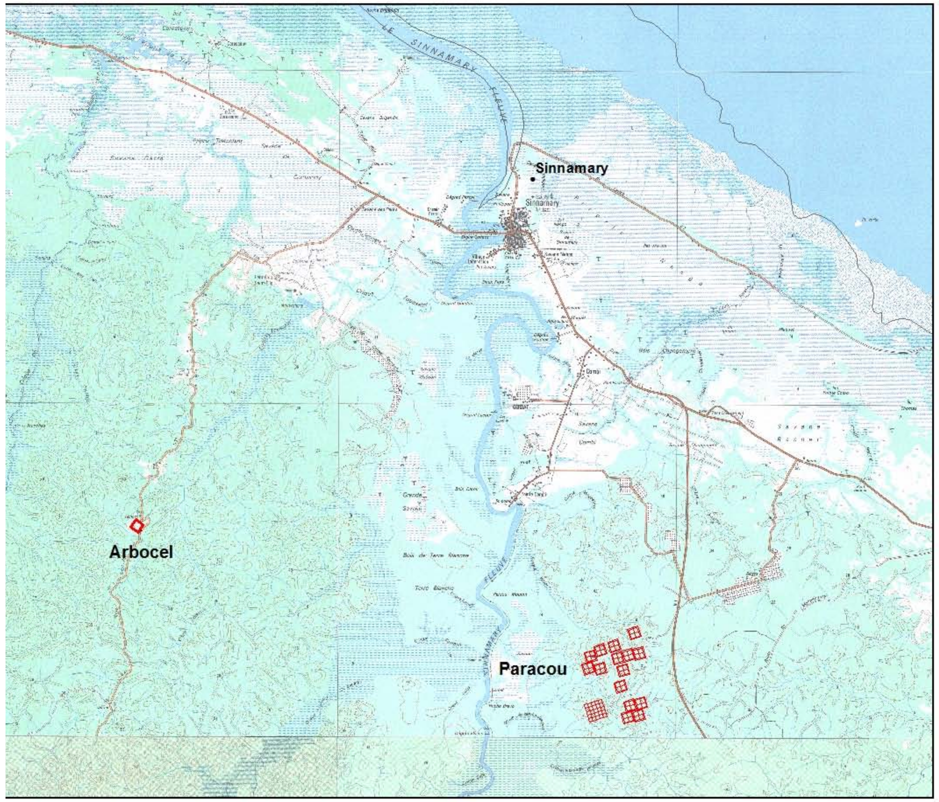
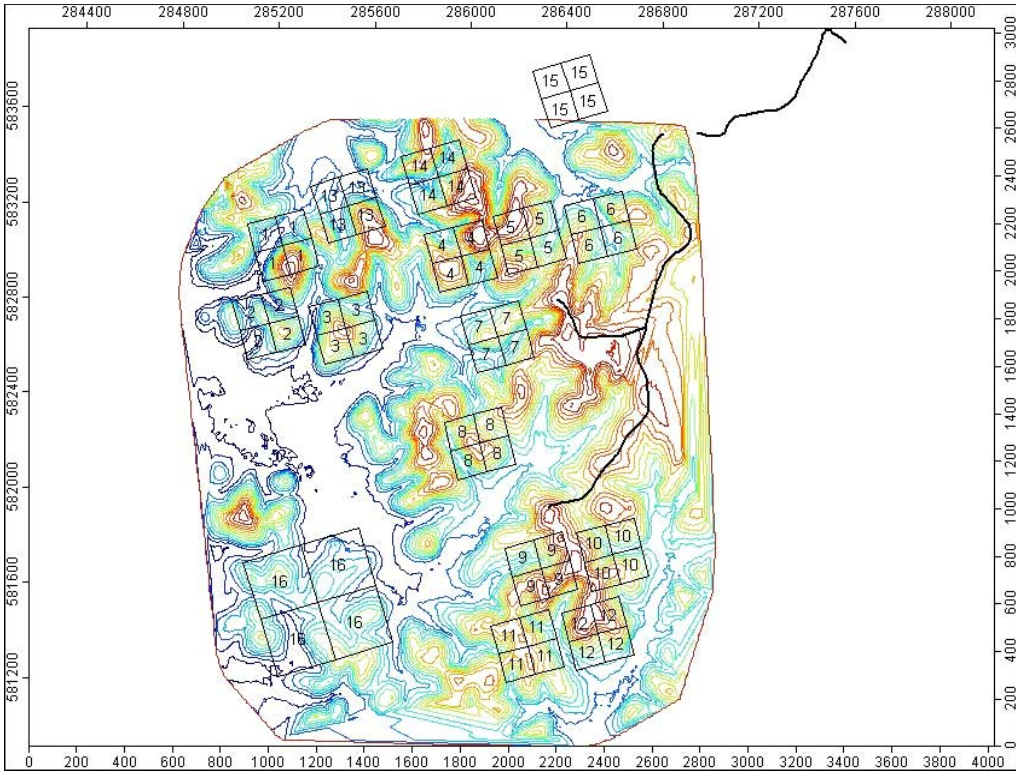
P1
P5
P6
P4
P2
P3
P7
P8
P10
P16
P9
P12
P11
0 125 250 500 Mètres
Parcelles témoins
Traitement 1 : exploitation pour le bois d'oeuvre
Traitement 2 : exploitation pour le bois d'oeuvre + éclaircie par dévitalisation
Traitement 3 : exploitation pour le bois d'oeuvre + exploitation pour le bois d'énergie + éclaircie par dévitalisation


Sinnamary
Arbocel
Paracou

Lidar


284400 284800 285200 285600 286000 286400 286800 287200 287600 288000
583600 583200 582800 582400 582000 581600 581200
0 200 400 600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600 2800 3000 3200 3400 3600 3800 4000
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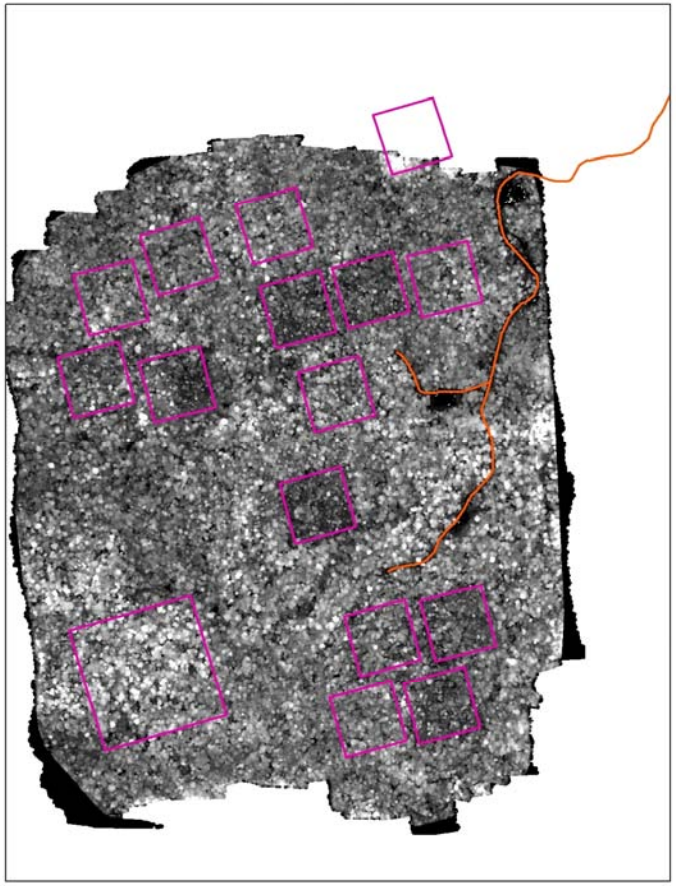
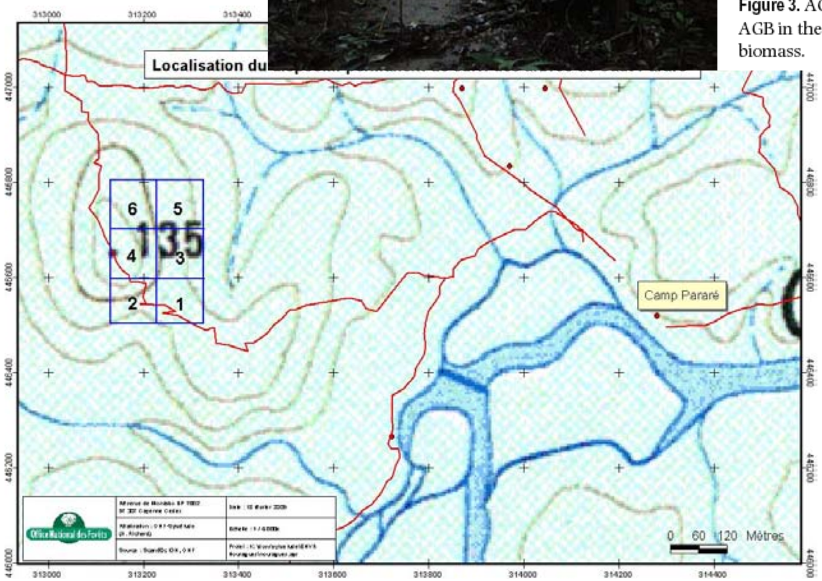




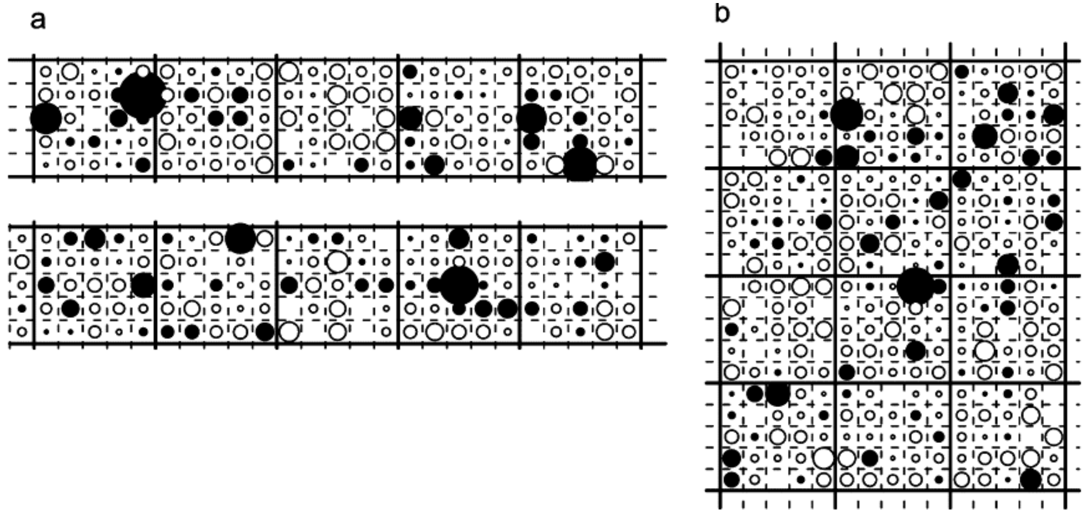
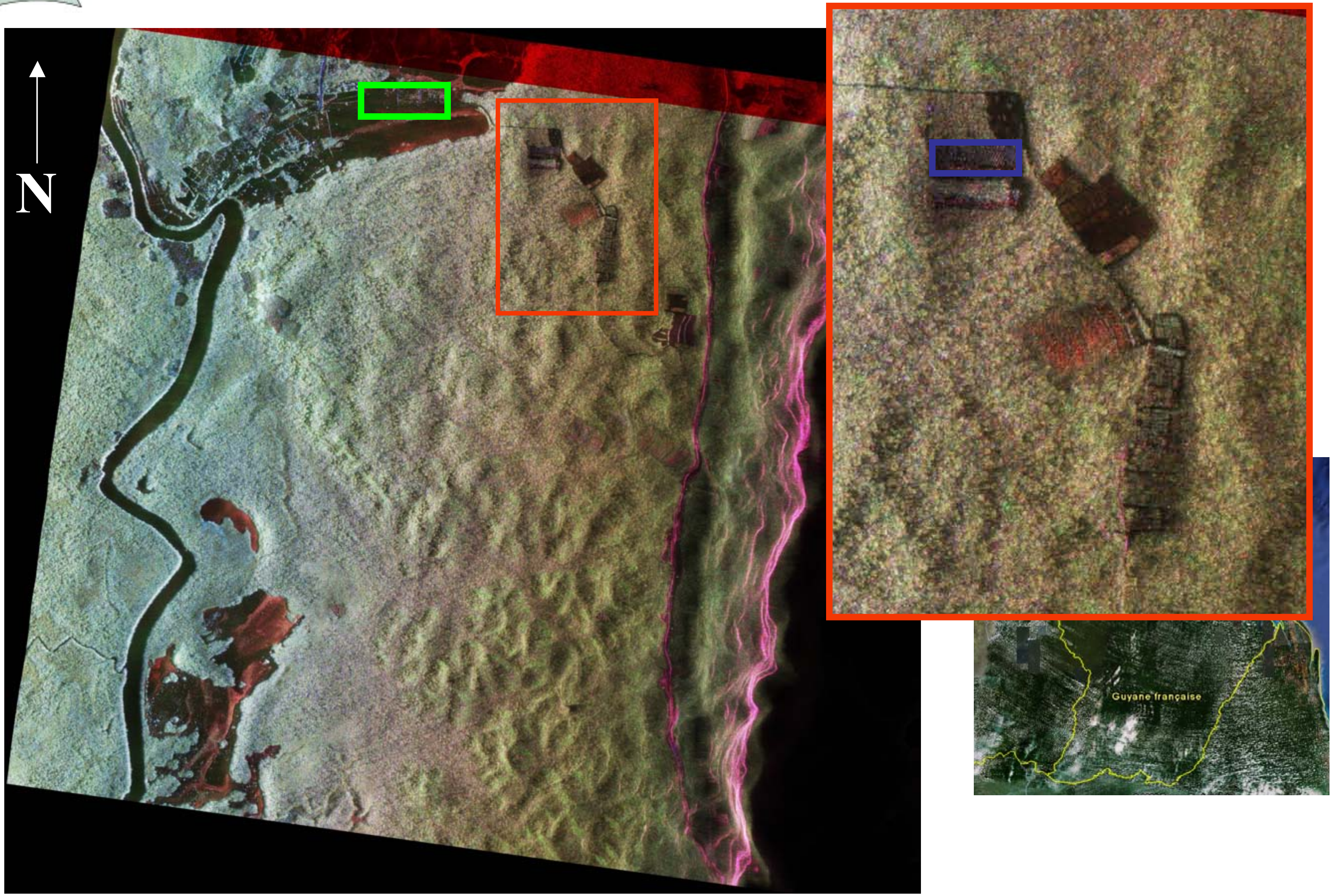


Figure 3. AGB changes in the plots across 20 × 20-m subplots. Grand plateau plot (a) and petit plateau plot (b). White circles represent an increase of AGB in the corresponding subplot, while black circles represent a decrease. The size of the circles is proportional to the net change in above-ground biomass.

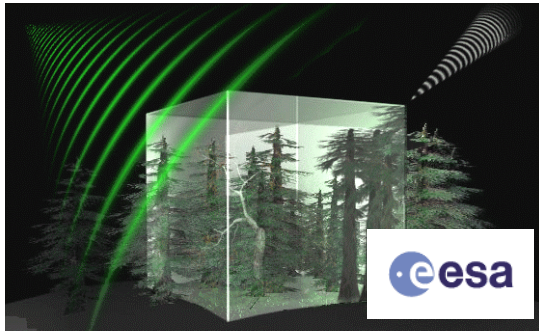

N
Guyane française

MARAIS DE KAW - VOL 5 -

VH

HH

The use of biomass measurements in carbon models



Forest biomass: essential in carbon budget calculation and poorly known.

BIOMASS Primary objectives:

- Map forest biomass worldwide.
- ➔ Monitor deforestation.
- ➔ Monitor forest regrowth and afforestation.

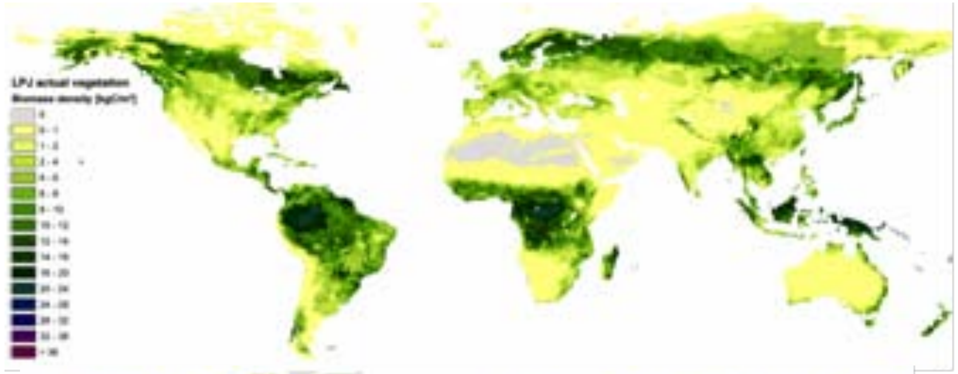
Large impact on the calculation of the carbon budget of terrestrial ecosystems

Question: can we also use biomass measurements to improve process based models aimed at calculating forest carbon fluxes?

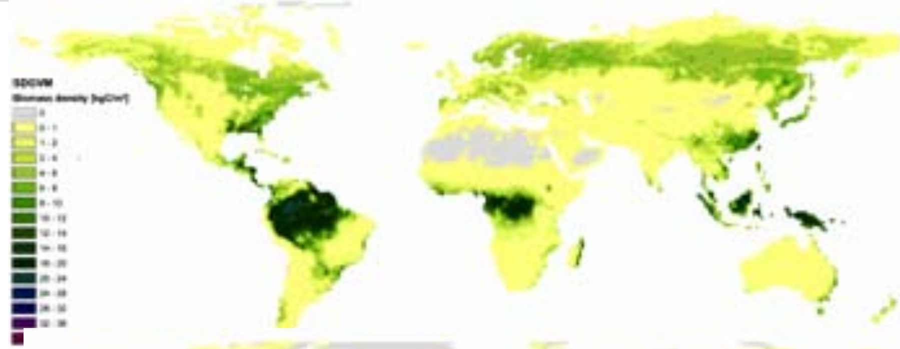
Biomass density estimates by models

Schaphoff et al., 2009

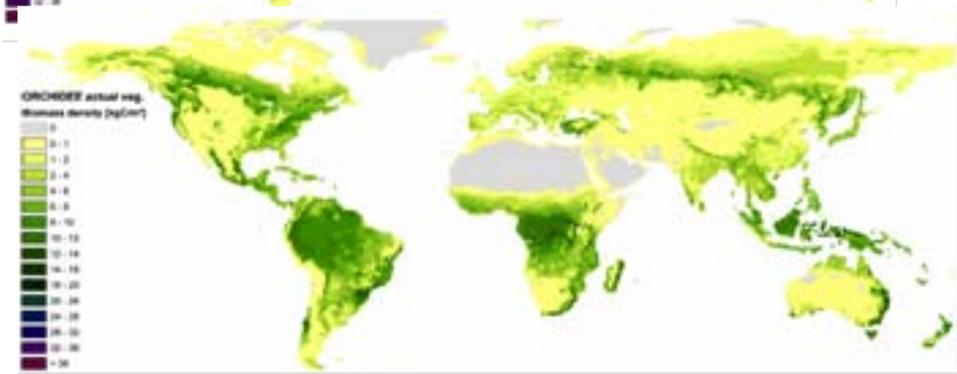
LPJ

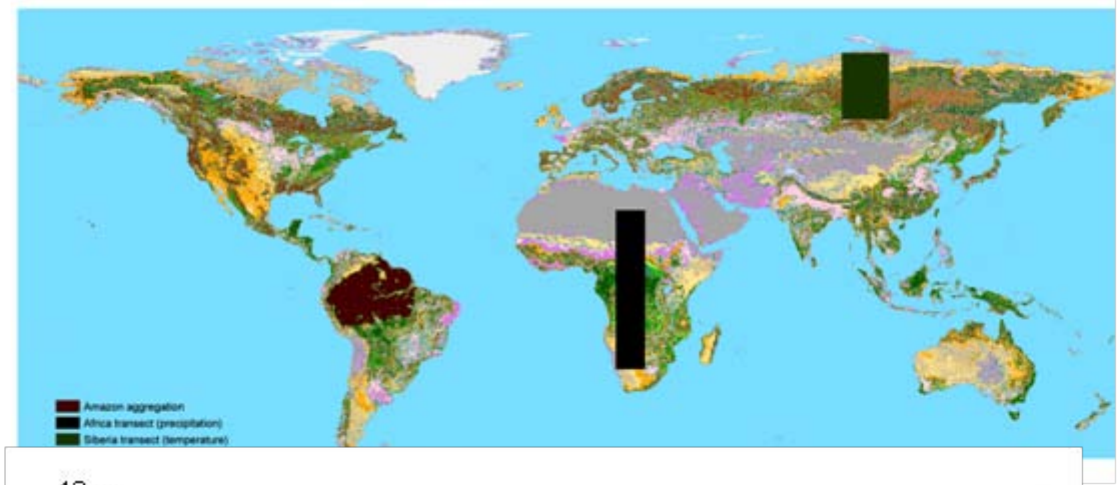


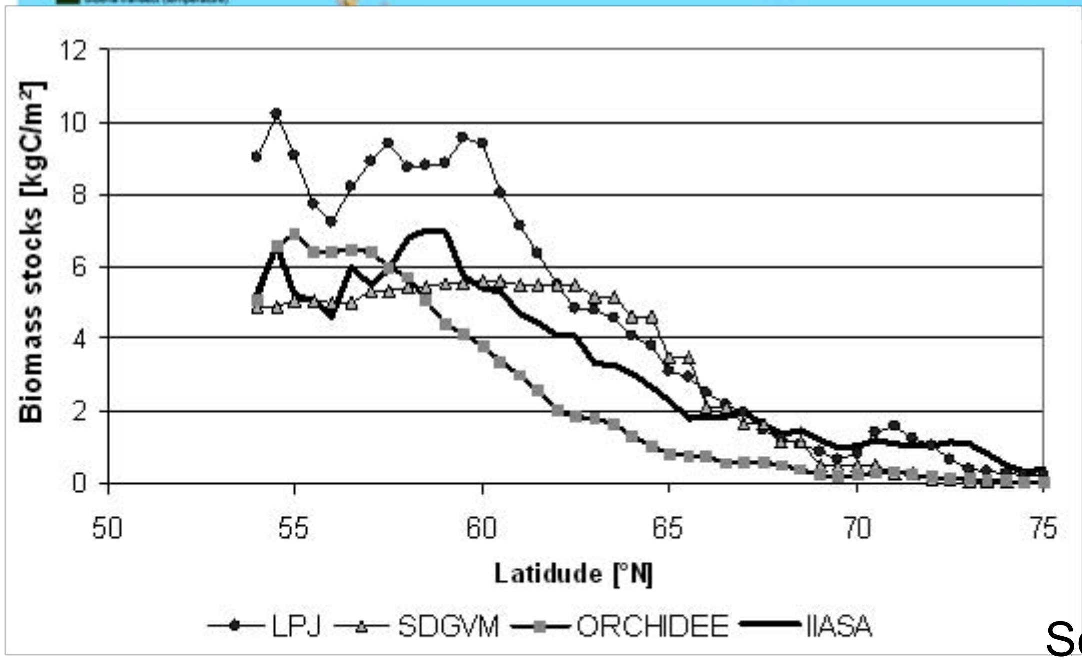
SDGVM



ORCHIDEE







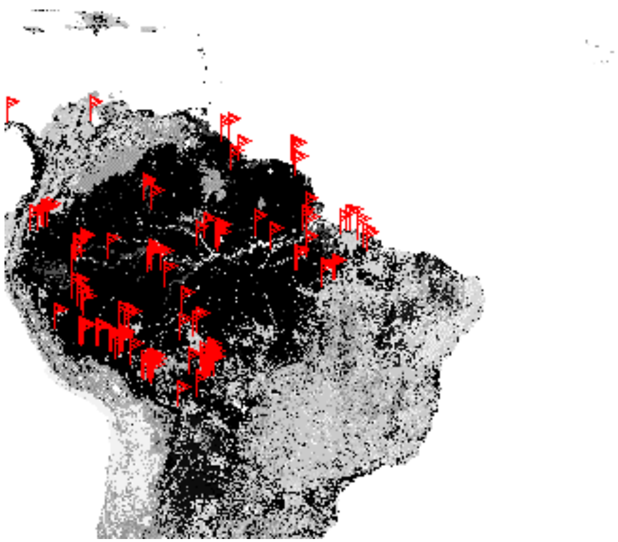
Siberia Transect

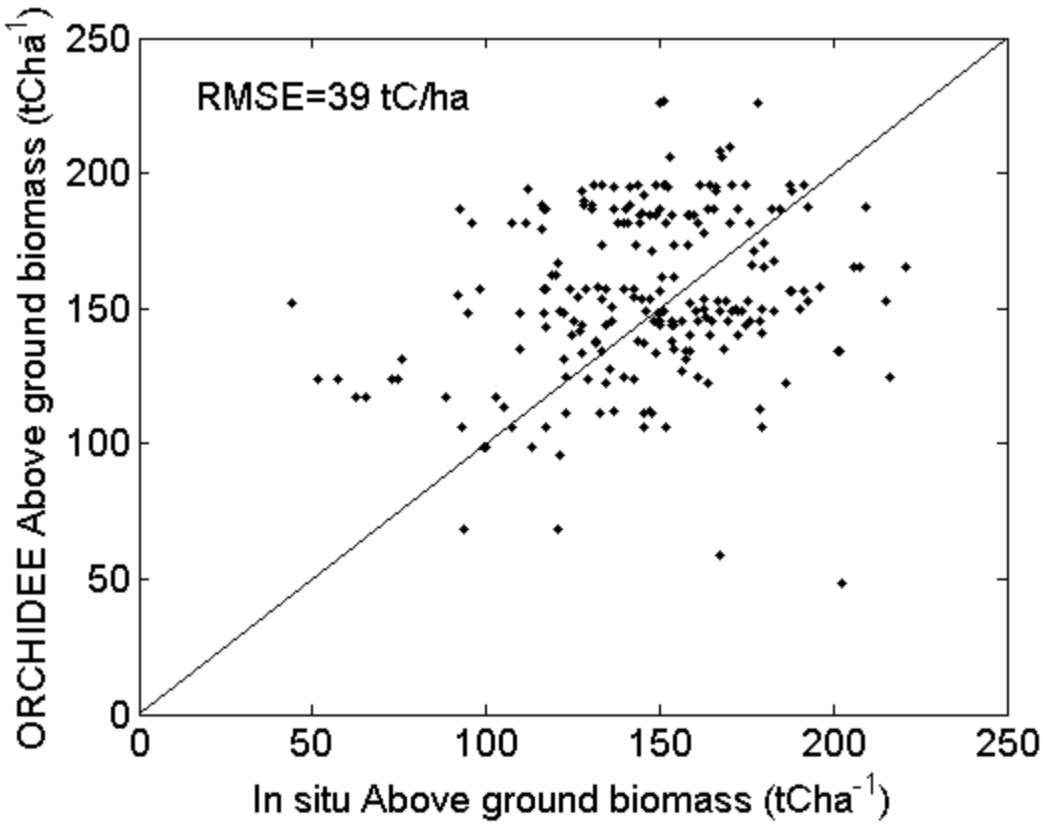
Schaphoff et al., 2009

Need to reconsider the models to ingest the actual biomass

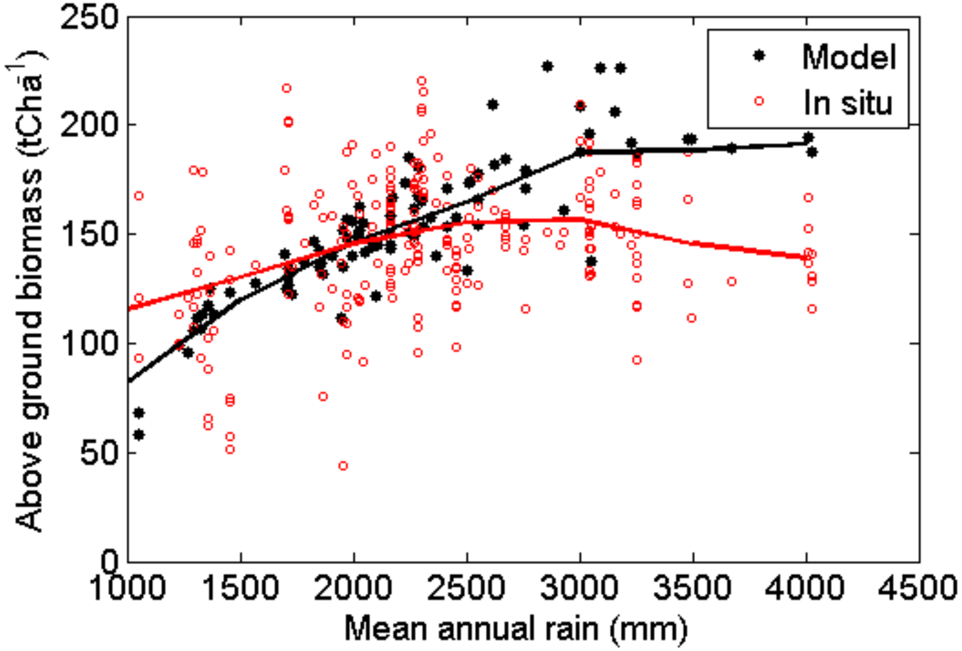
Integration of biomass data in the dynamic vegetation model ORCHIDEE

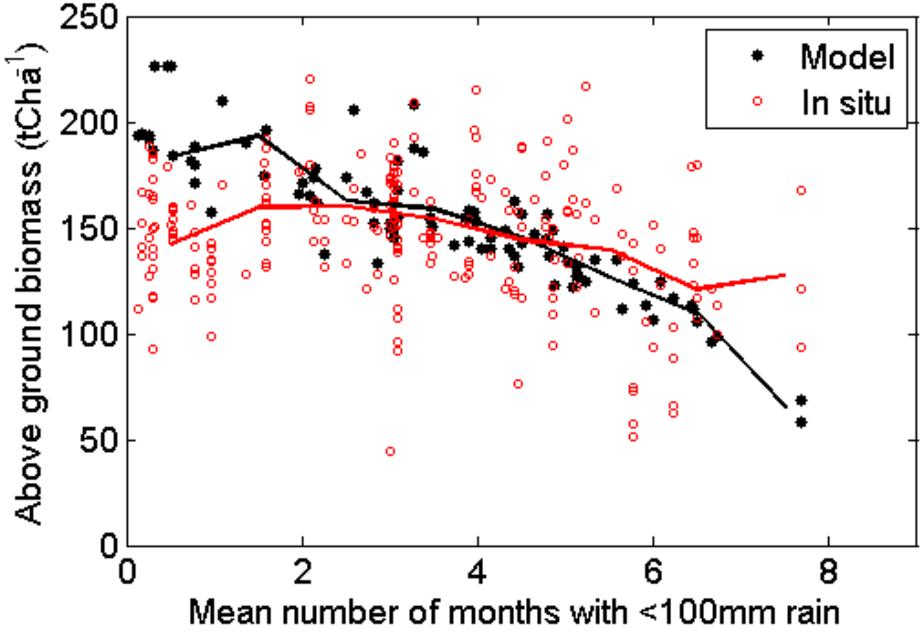
In situ Biomass measurements compiled in Malhi et al. 2007
223 sites in Amazonia





N. Delbart, N. Viovy, P. Ciais, and T. Le Toan , EGU 2009





Simulated biomass: realistic simulations, except for very dry forests (underestimation) or very wet forests (overestimation).

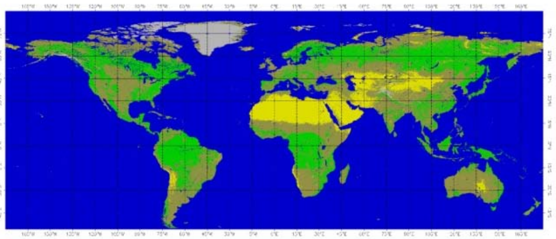
Respect climatic gradients, not local heterogeneity→ model needs improvement

Mission architecture overview

GROUND SEGMENT

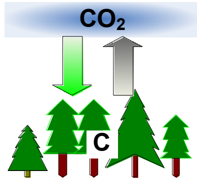
Flight Operations Segment
1 TT&C Station (Kiruna), S-Band
Flight Operation Control Center (ESOC)

Payload Data Ground Segment
1 Science Data Acquisition Station (Svalbard)
Processing and Archiving Element (ESRIN)



Auxiliary Data
Land cover maps
Digital Elevation Models

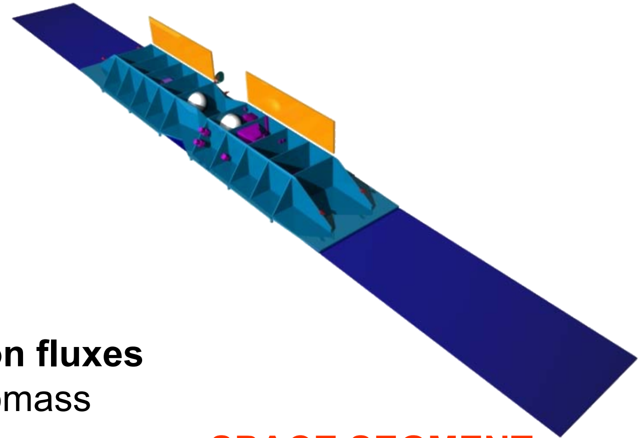
USER SEGMENT
Carbon cycle modellers/Research Centres



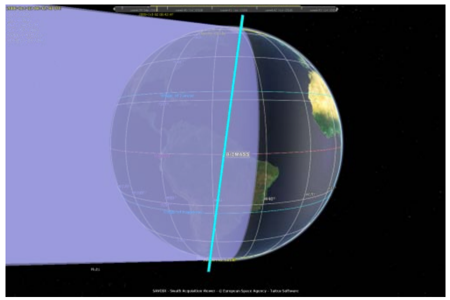
SUBJECT
Terrestrial carbon stock/carbon fluxes
by measurement of forest biomass

BIOMASS Mission Elements

LAUNCHER
Soyuz/Vega

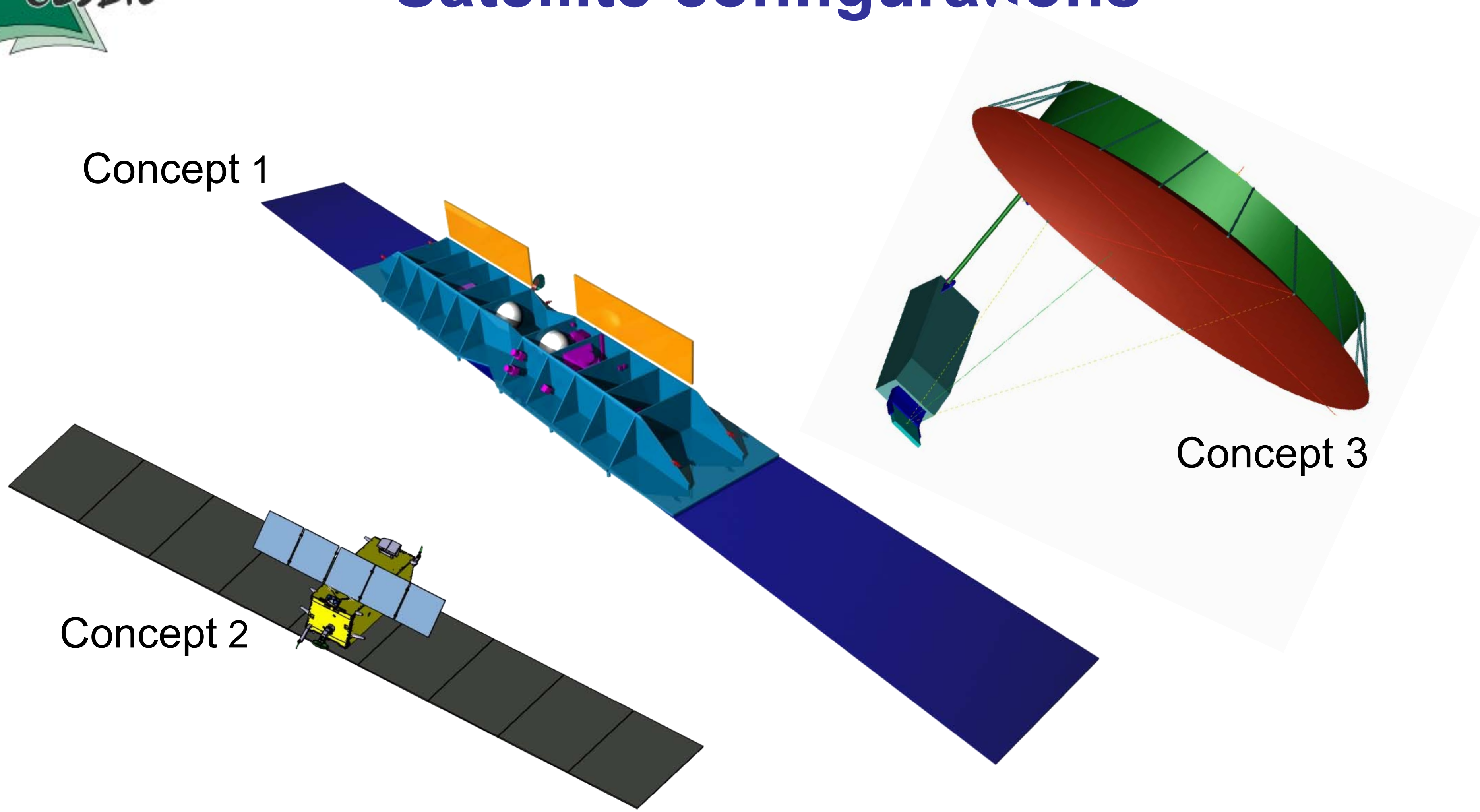


SPACE SEGMENT
Single Spacecraft, 1200 - 2600 kg,
800 - 1200W
Payload: P-band SAR
5 year lifetime



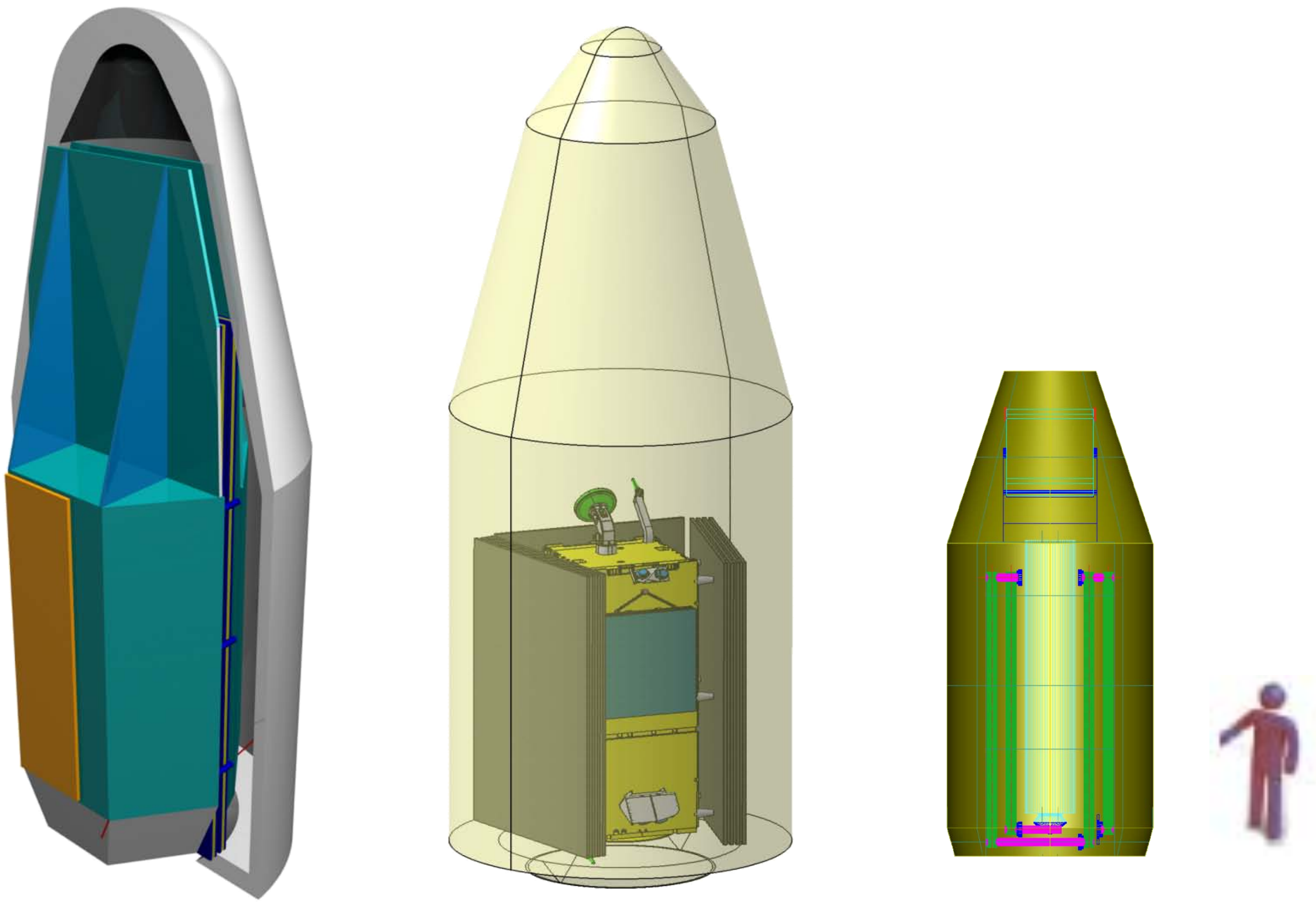
ORBIT
Sun-synchronous,
local time 05:00, 640 km,
27 to 39-day repeat cycle

Satellite configurations



Mass	1200-2600 kg	Power	800-1200 W
Data storage	400-700 Gb	Data Downlink	260-290 Mb/s

Stowed configurations in launcher fairings



Concept 1 in Soyuz Concept 2 in Soyuz Concept 3 in Vega