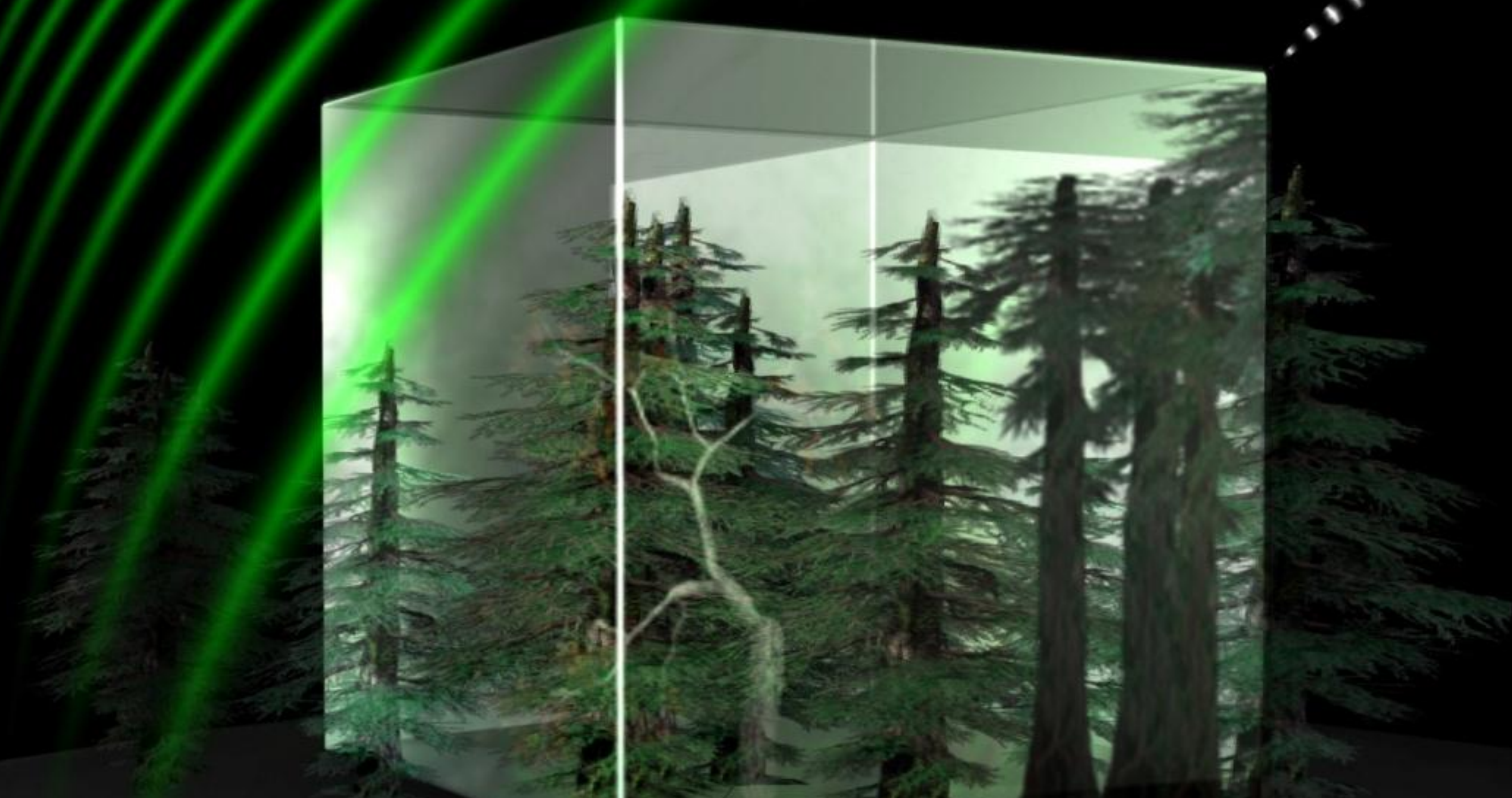
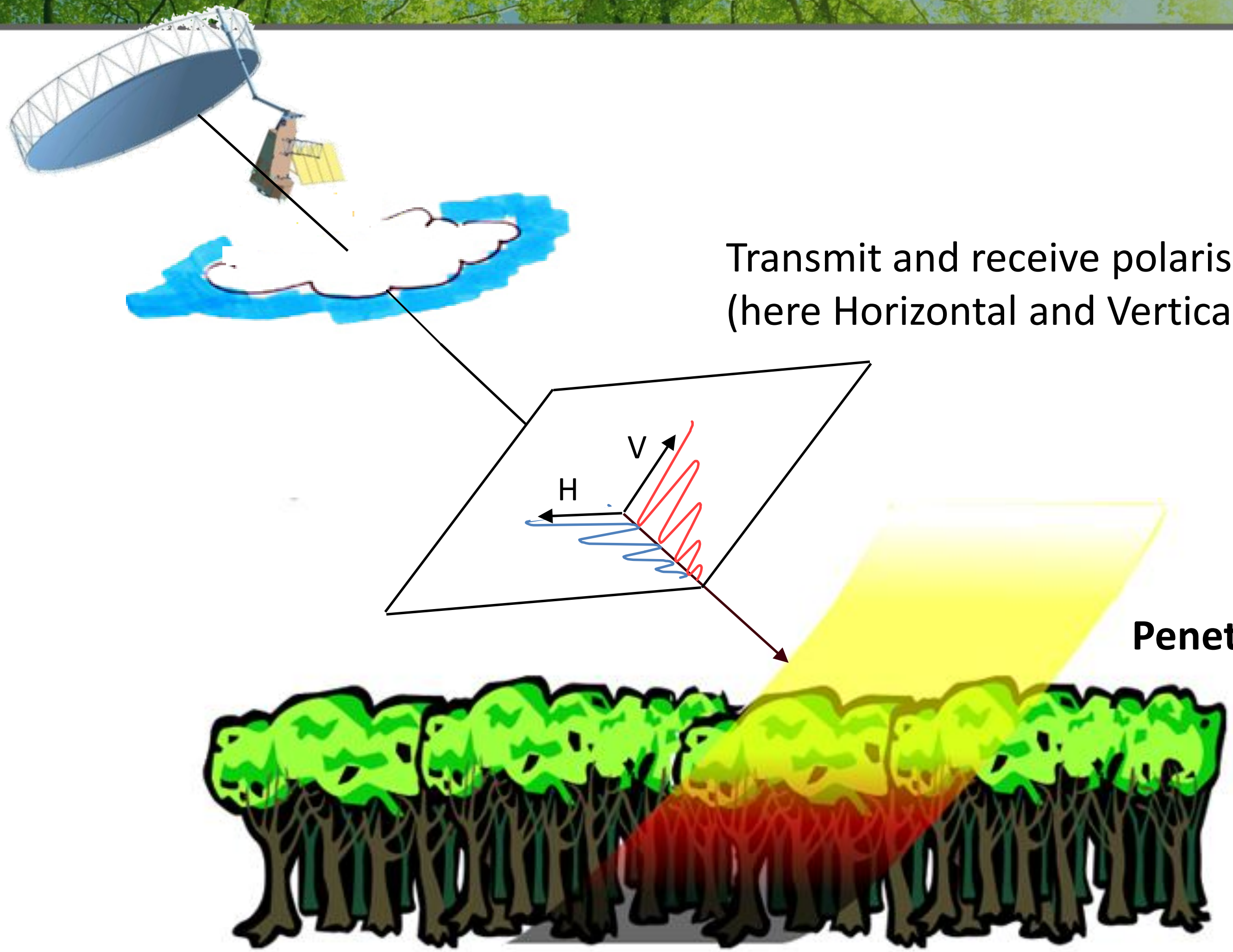
The Biomass mission
How it works, what it measures?



Thuy Le Toan, CESBIO, Toulouse, France
&
The Biomass Mission Advisory Group

Why Synthetic Aperture Radars to observe the world forests ?

Transmit and receive polarised waves (here Horizontal and Vertical)



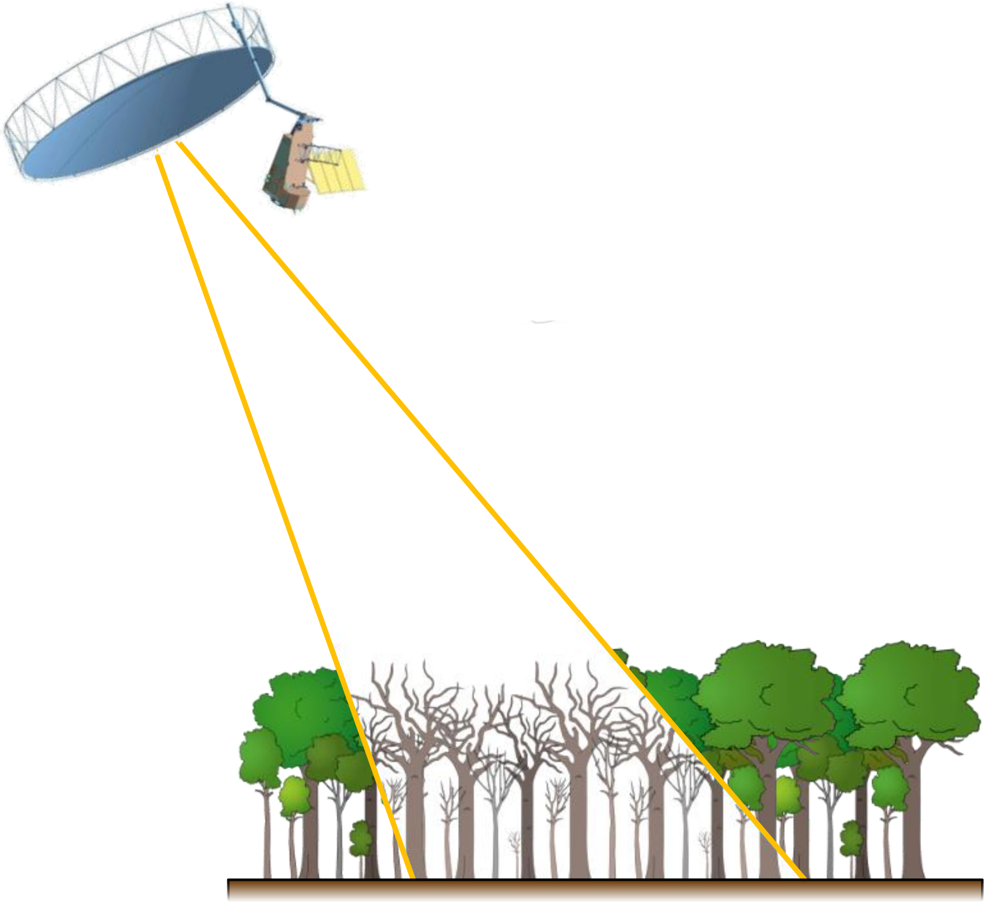
Penetrate into the forest cover

How can biomass be measured from space?

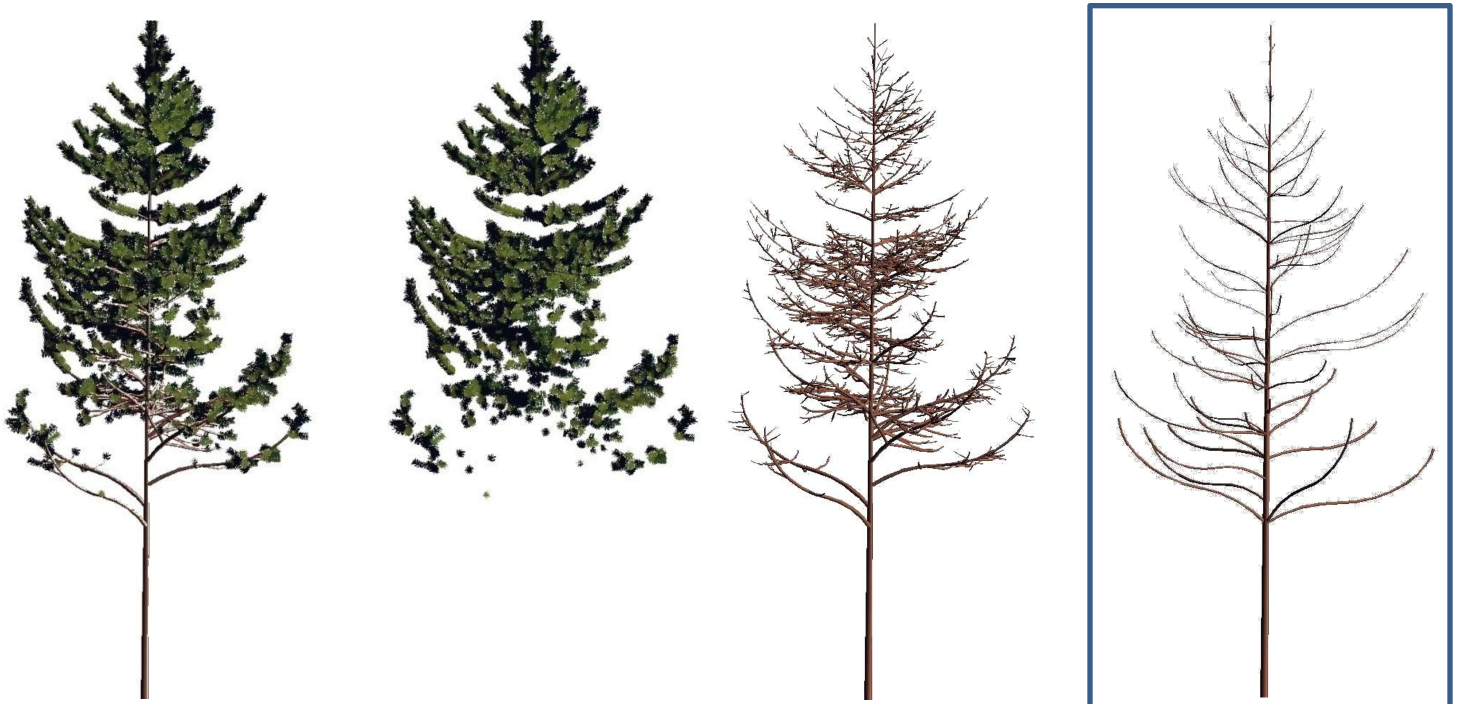
Mapping forest biomass requires a radar sensor with long wavelength:

1. to penetrate the canopy in all forest biomes
2. to interact with woody vegetation elements
3. so that forest height can be estimated with a single satellite

This implies a radar at P-band, of wavelength ~70 cm, the longest possible from space



How the Radars see the trees?

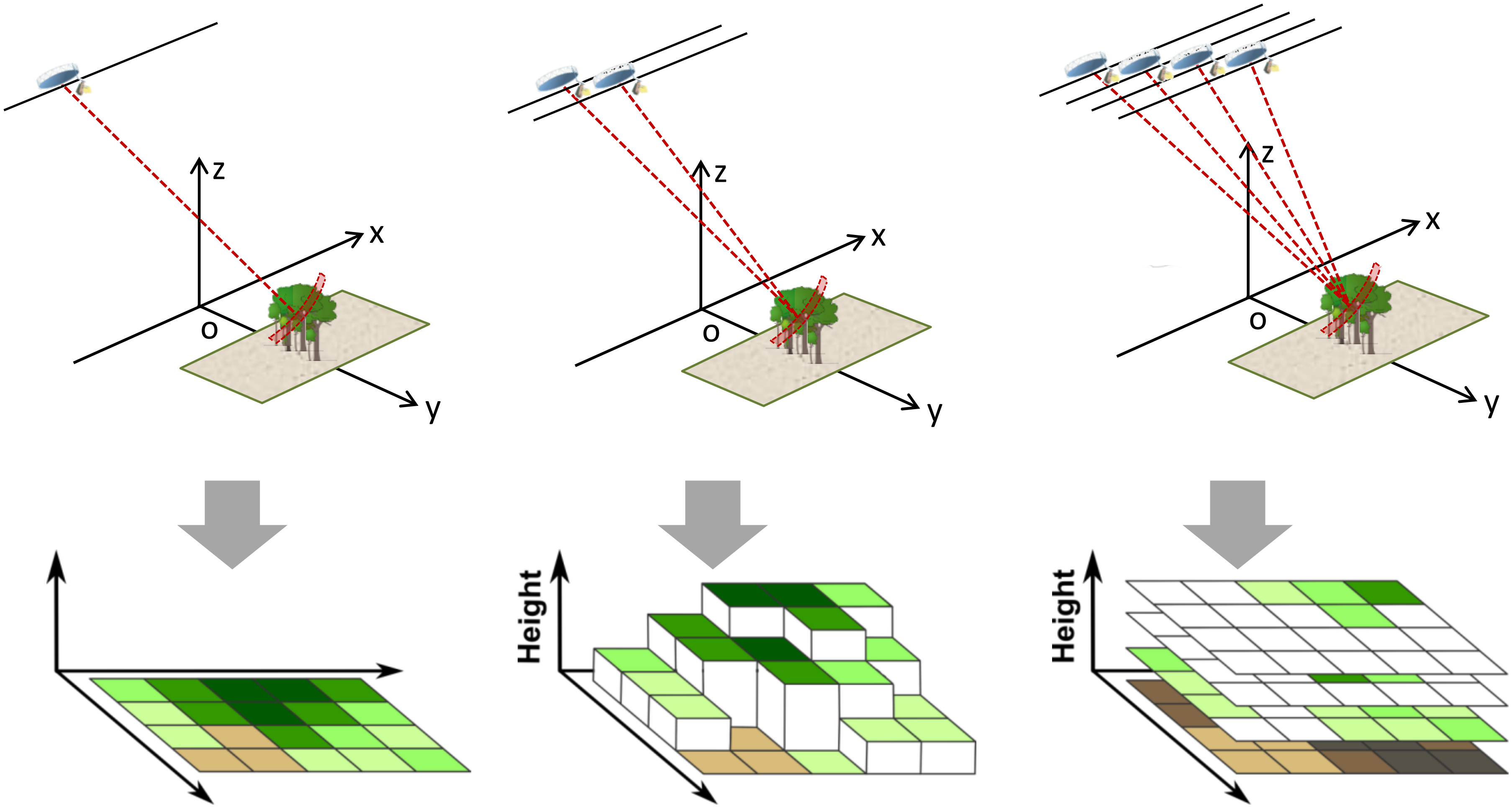


Pinus Nigra	X-band	L-band	P-band	VHF
	λ= 3 cm	λ= 27 cm	λ= 70 cm	λ > 3 m

The P-band SAR, which 'sees' the trunk and (big) branches, provide 'more direct' information on woody above ground biomass

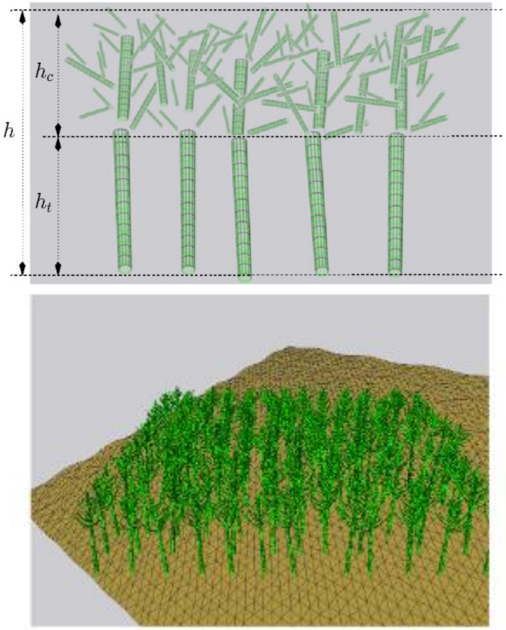
A single P-band satellite can deliver 3 independent types of information for biomass

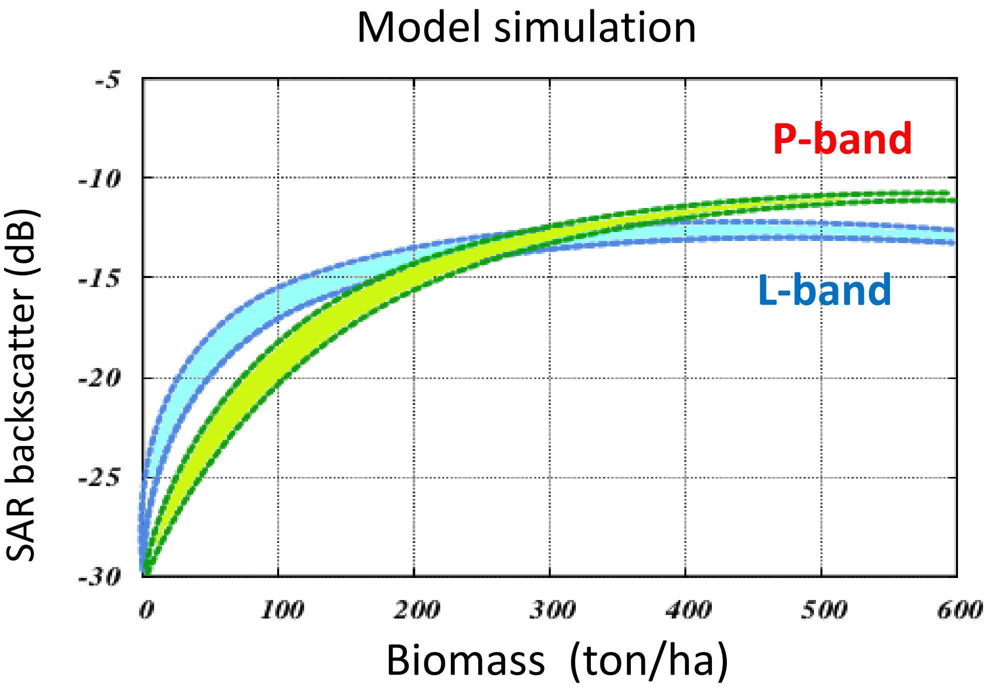
PolSAR	PolInSAR	TomoSAR
(SAR Polarimetry)	(Polarimetric SAR Interferometry)	(SAR Tomography)



Physical background

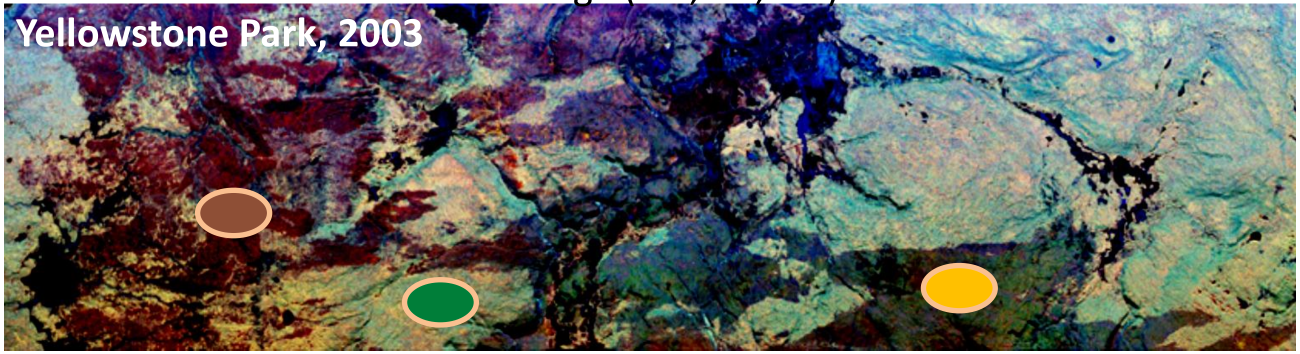
Radar scattering and attenuation are a function of the number, dimension, spatial distribution and dielectric constant of scatterers interacting with the radar waves: radar backscatter intensity increases with biomass until attenuation becomes significant

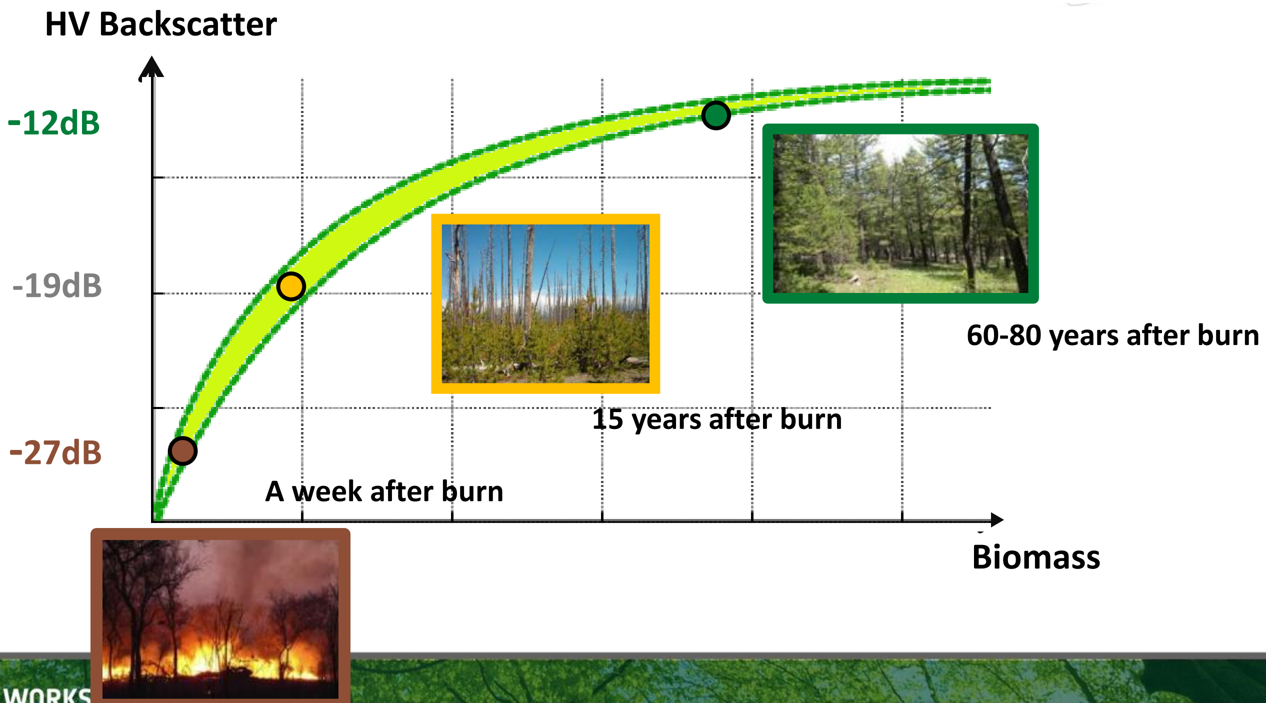




P-band SAR measures biomass and quantifies landscape dynamics

P-band SAR image (HH, VV, HV)





Effects to be understood and accounted for

- Forest structure
- Tree physiology
- Topography
- Soil moisture
- Rain, winds

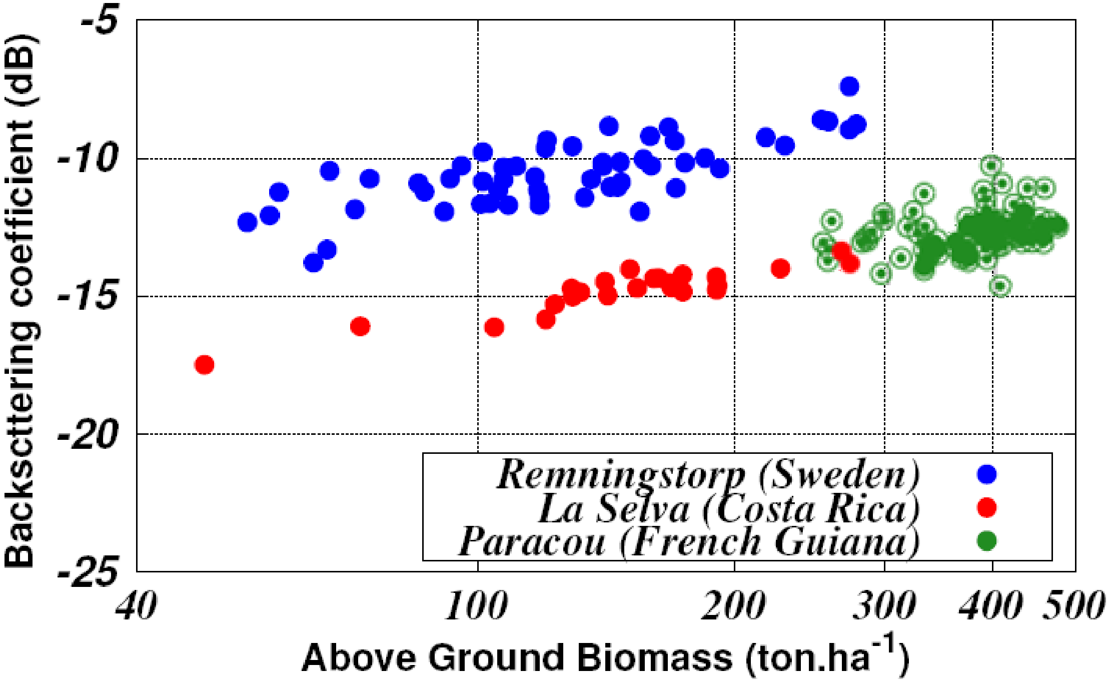
- Ionosphere

Scattering mechanisms differ among forests

Tropical forest,
French Guiana

Boreal forest
Remningstorp, Sweden

Effect of forest structure

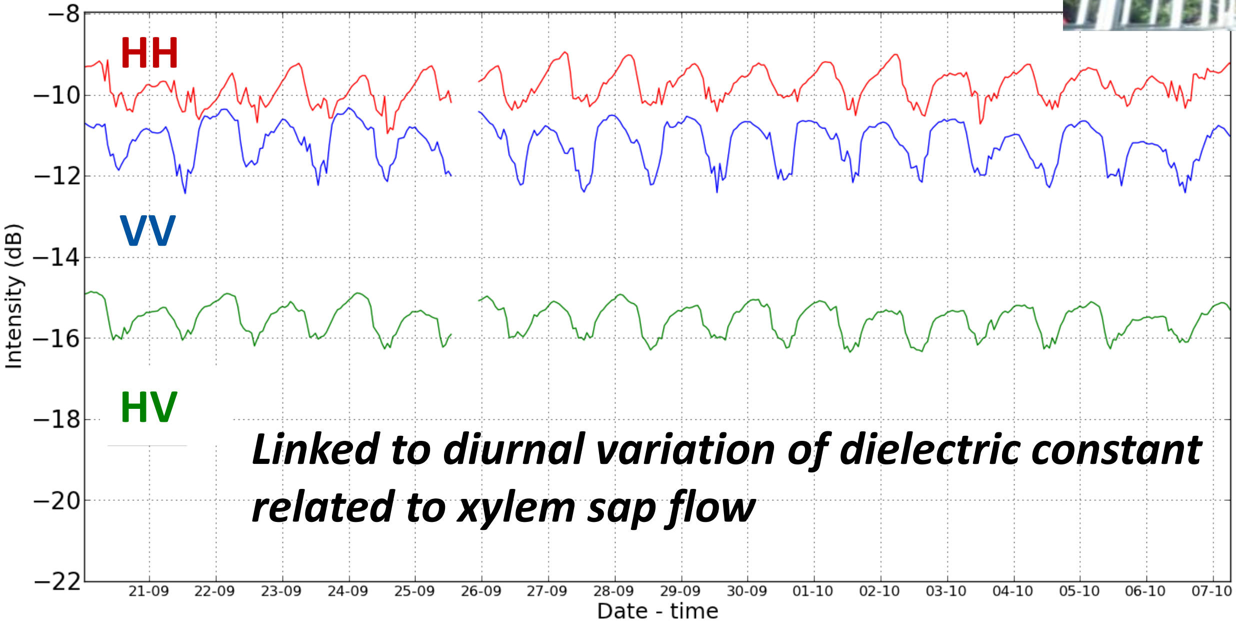


Effect of tree physiology: diurnal cycle of the backscatter

TropiScat Experiment

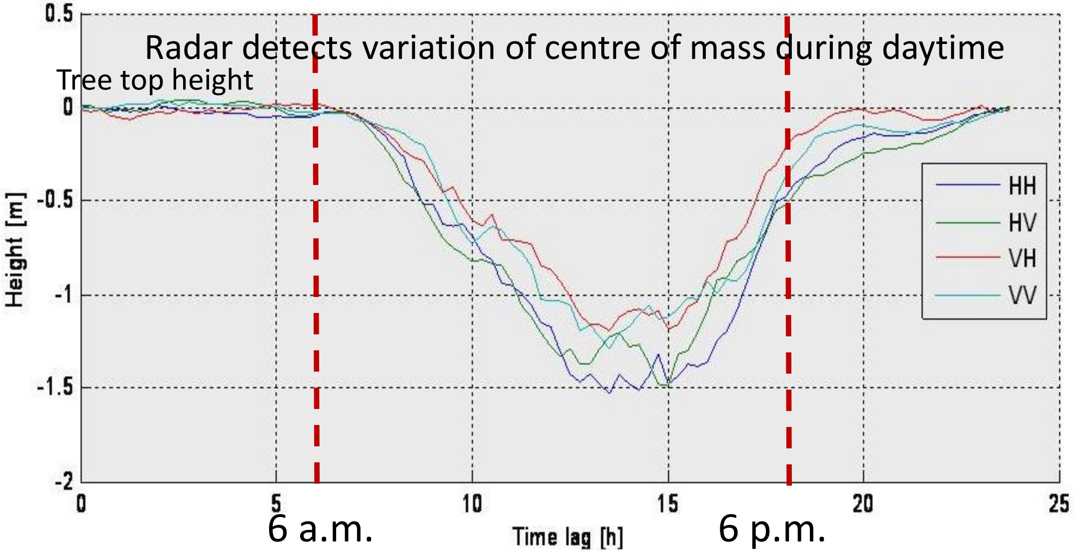
P-band radar measurement from 55m flux tower in French Guiana during long periods since Dec 2011

Guyaflux tower
(Guyafor team)



Diurnal variation: ± 0.5 dB requires observation at same time of the day

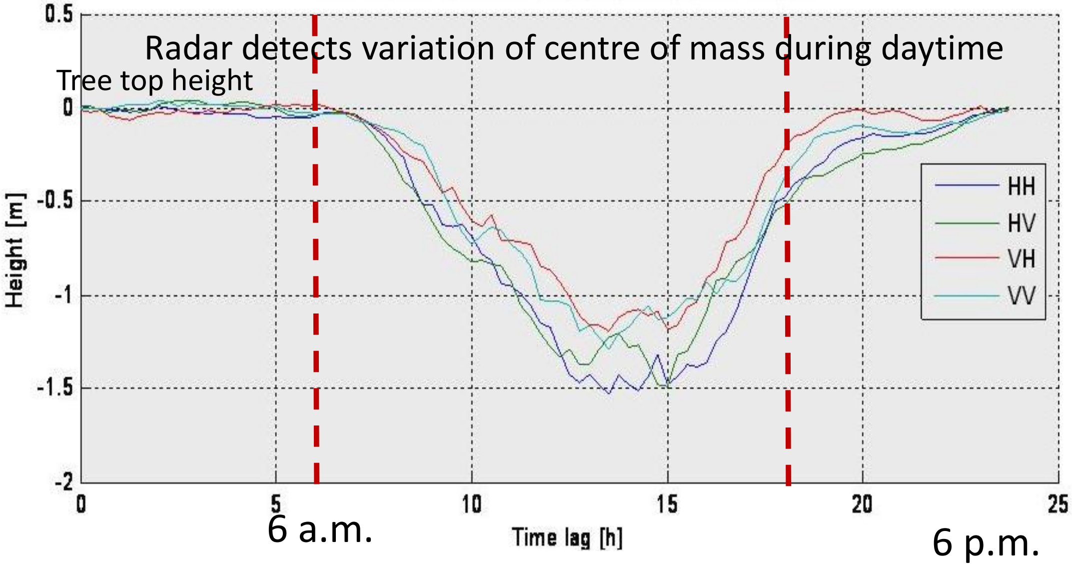
Diurnal cycle of the P-band backscatter

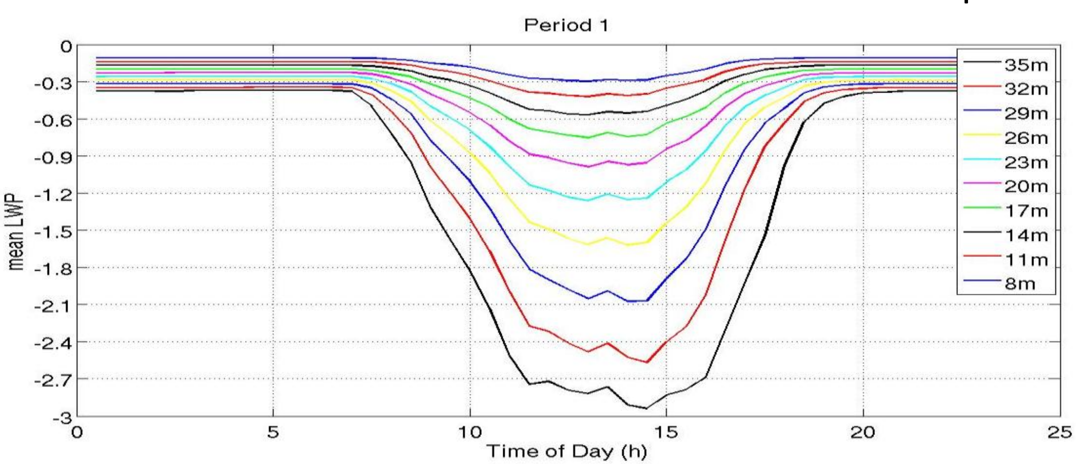


Variation of the Centre of Mass detected by TropiSAR

Orbit for 6am equator crossing time

Diurnal cycle of the P-band backscatter





Variation of the Centre of Mass detected by TropiSAR

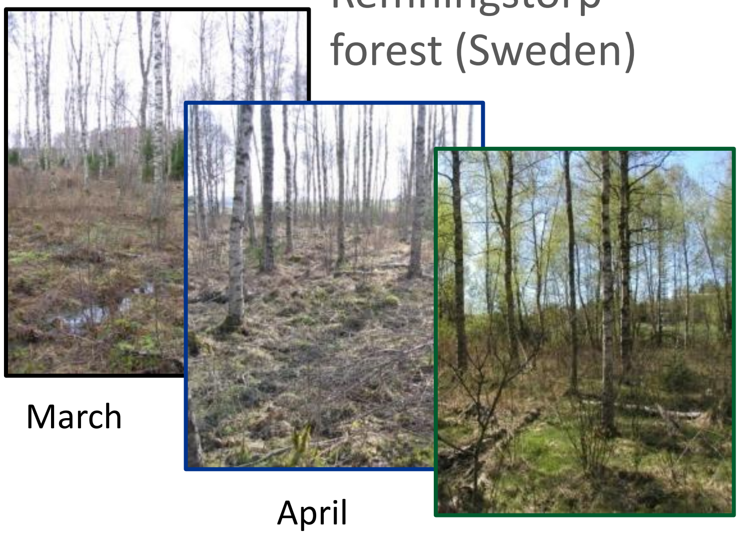
Leaf Water Potential and Sap flow simulated by the SPA model (Uni of Edinburgh) . Input: - air temperature

- atmospheric CO_2 concentrations
- vapour pressure deficit (VPD],
- precipitation
- incoming shortwave radiation
- -wind speed in [m/s]

The timing and direction of the centre of mass detected by the radar match the movement of water within the vegetation

In boreal forest, soil moisture and topography affect the backscatter-biomass relationship

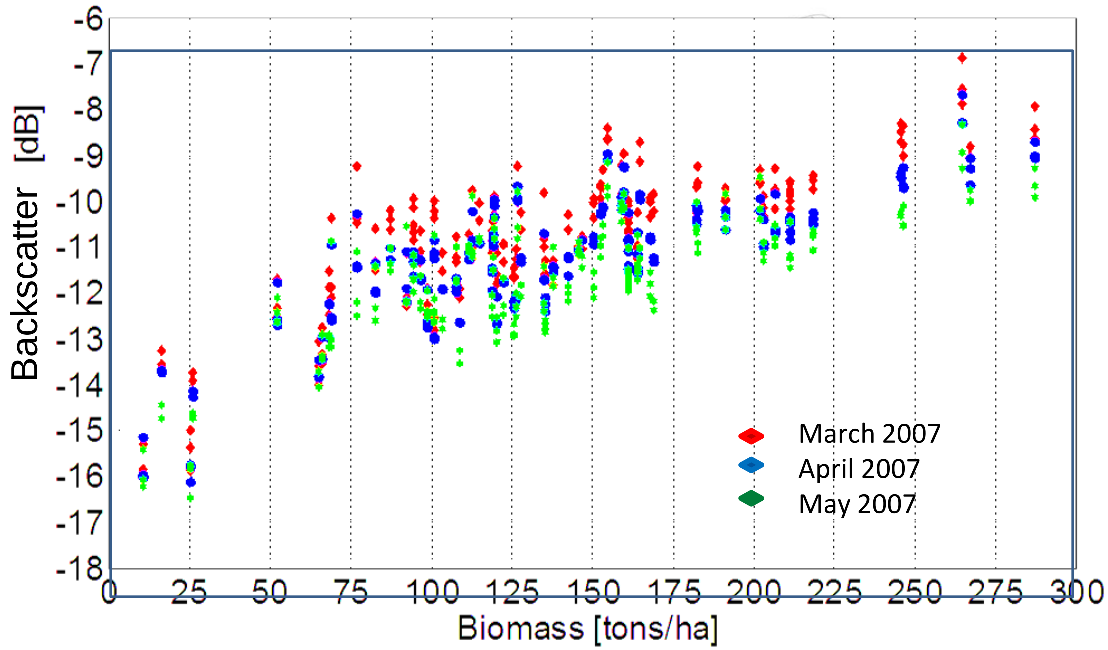
Remningstorp forest (Sweden)



March

April

May



Because the disturbing effects differ among polarisations, all polarisations and a DEM are used to account for environmental and topographic effects.

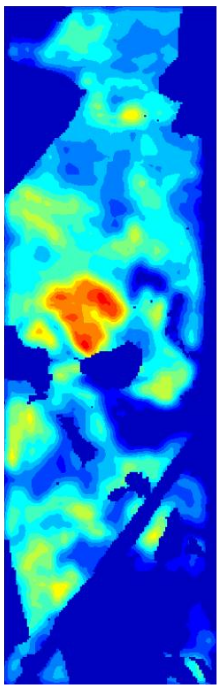
Consistent biomass estimates are obtained after correcting environmental effects

Biomass map, Remningstorp, Sweden

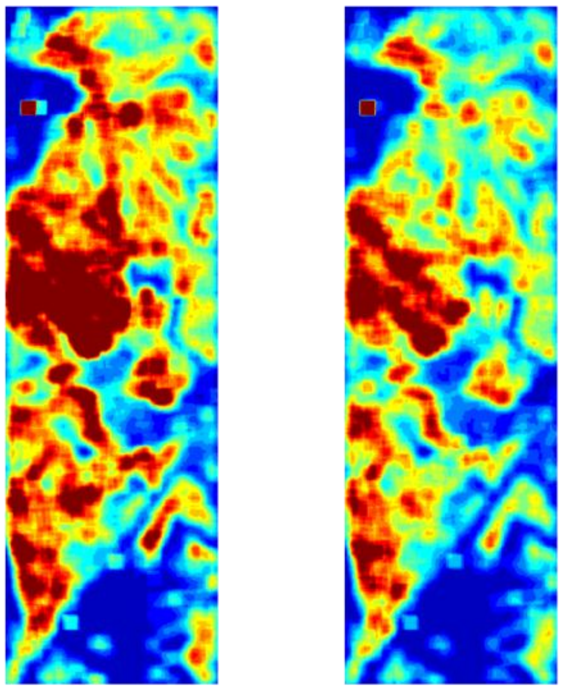
Training at Krycklan

Biomass (ton/ha)

Lidar biomass estimate

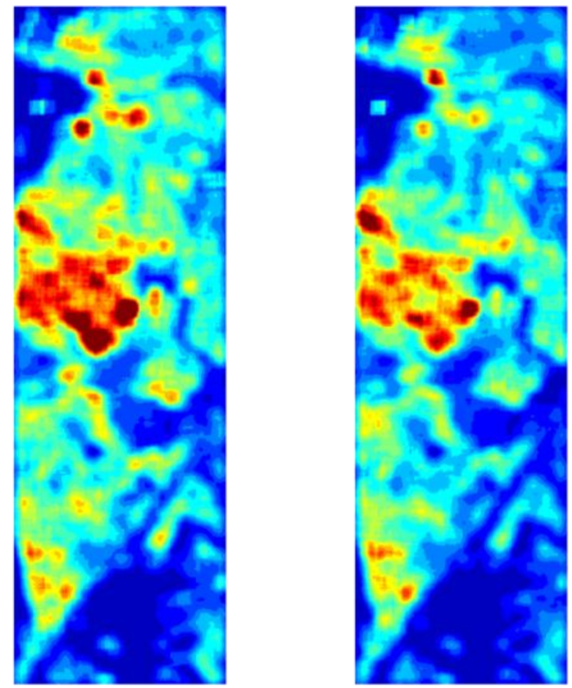


Inversion using single polarisation (HV)



March May

Inversion using multiple polarisations and DEM

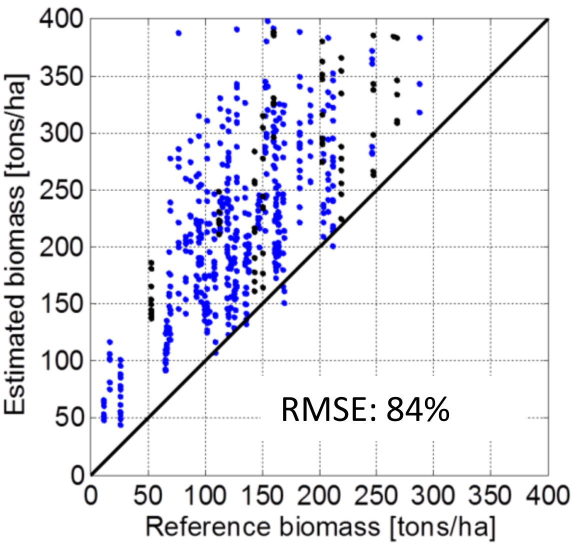


March May

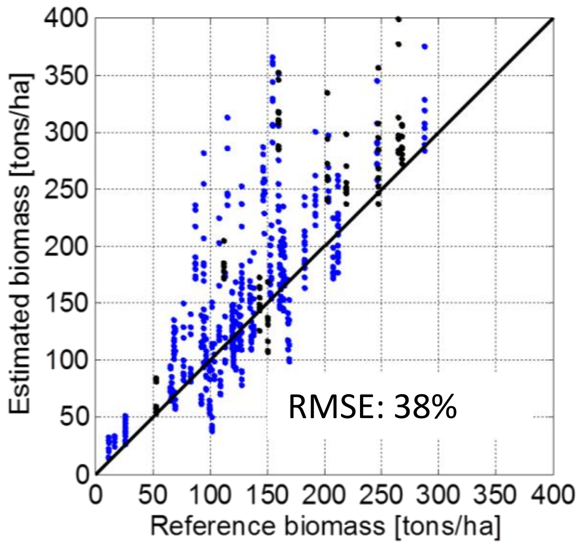
Using polarisation & slope information radically improves measurement accuracy

Remningstorp : varying environmental conditions over 3 months

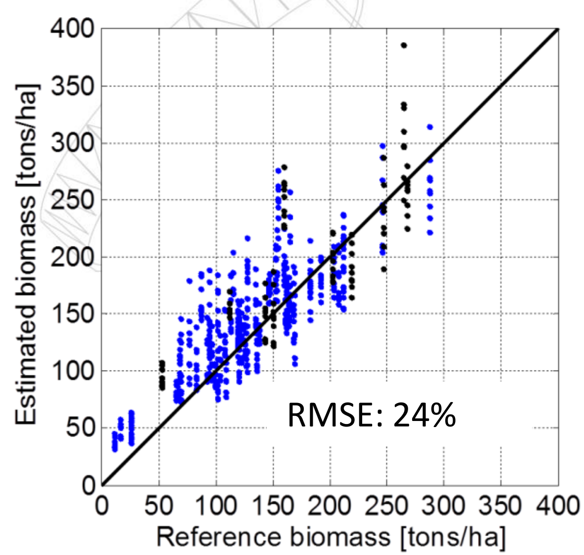
HV only



HV, HH & VV



HV, HH, VV & DEM



Blue - from airborne lidar map, std. error = 25 ton/ha

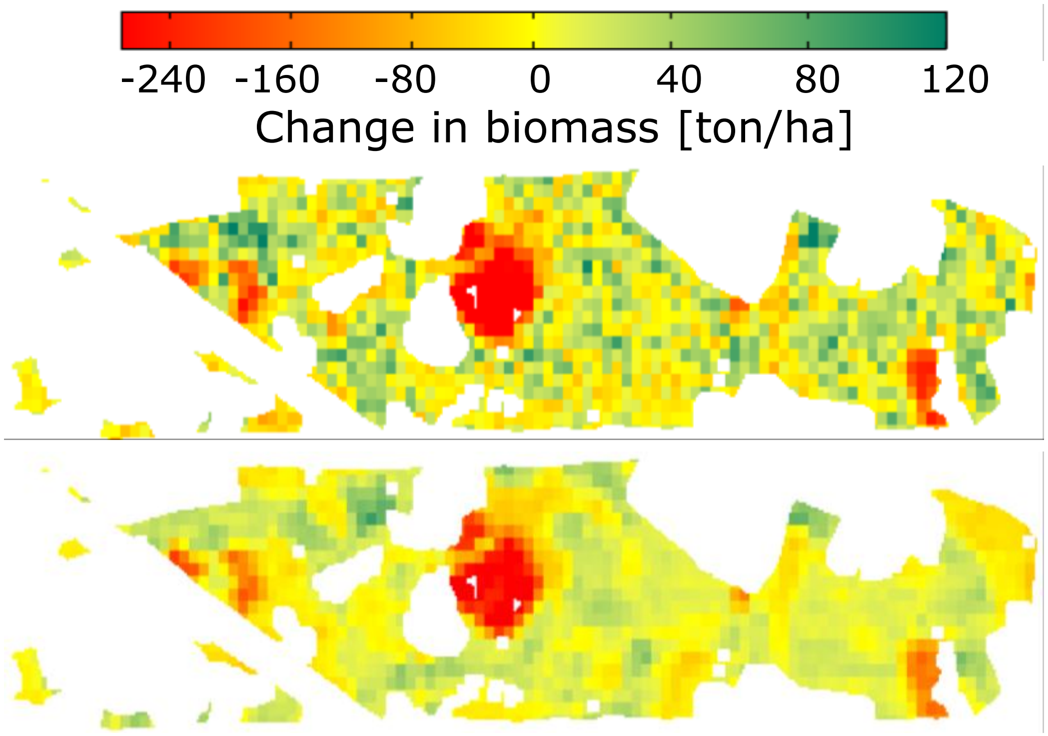
Black - from 80 m x 80 m *in situ* plots, std. error = few %

Training on stratified subset of Krycklan data.

Performance assessed on data from Remningstorp.

Increases & decreases in boreal biomass can be measured over a 4-year period

Change in biomass from spring 2007 to autumn 2010 at Remningstorp; resolution = 200 m



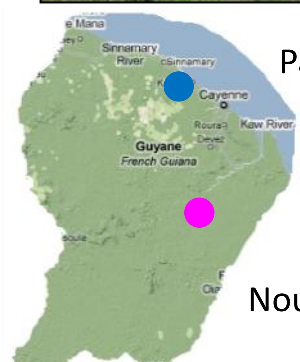
Radar RMSE ~ 20 t/ha (based on 6 reference plots).

Lidar RMSE is comparable (slightly worse).

Biomass will be able to measure a **20 ton/ha change** over a 4-year period.

In tropical forest, topography has important effects on the backscatter-biomass relationship

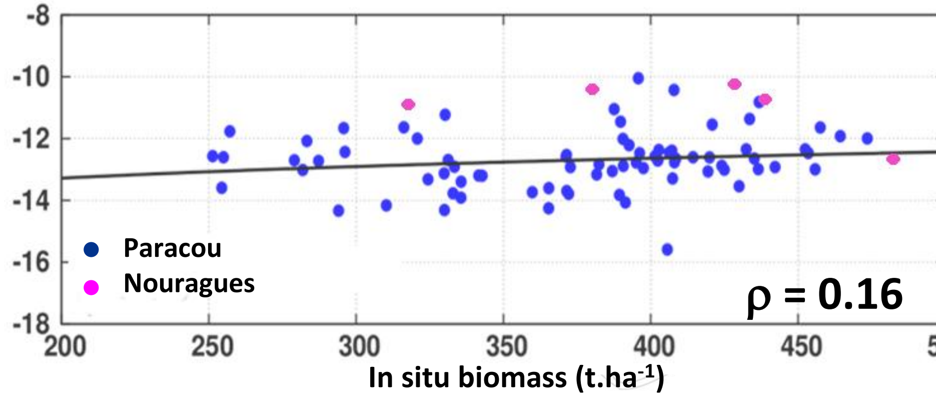
Tropical forest,
French Guiana



Paracou

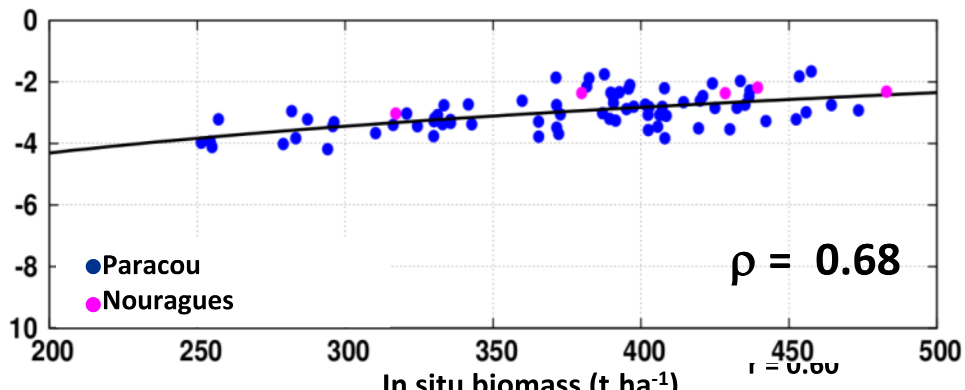
Nouragues

Backscatter at single polarisation (HV) in dB



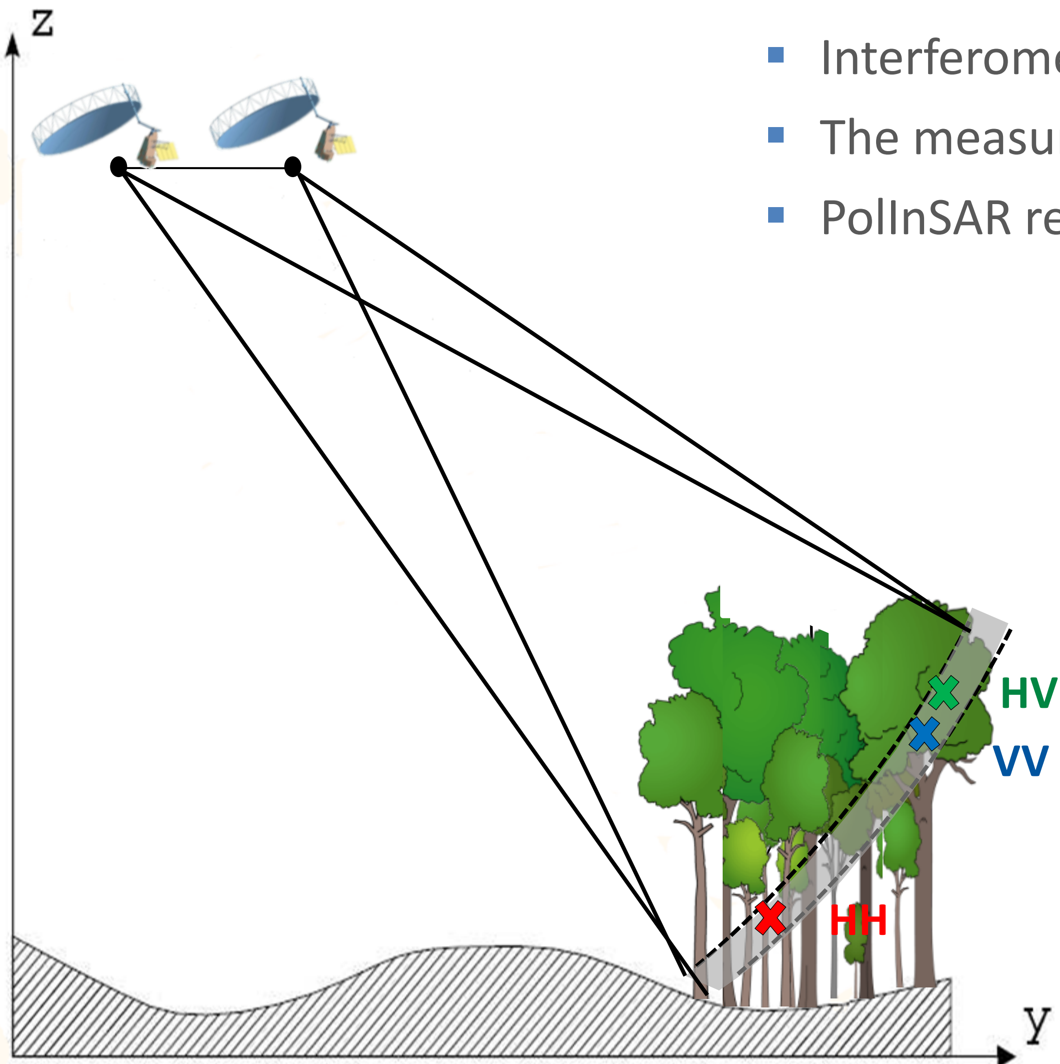
Correction for topographic effects and scattering mechanisms using polarimetry and a DEM.

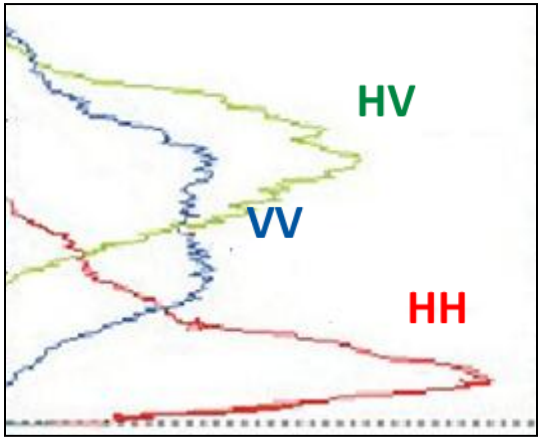
Polarimetric biomass indicator (dB)



PolInSAR provides an estimate of forest height

- Interferometry provides height information
- The measured height depends on polarisation
- PolInSAR retrieves canopy height using models



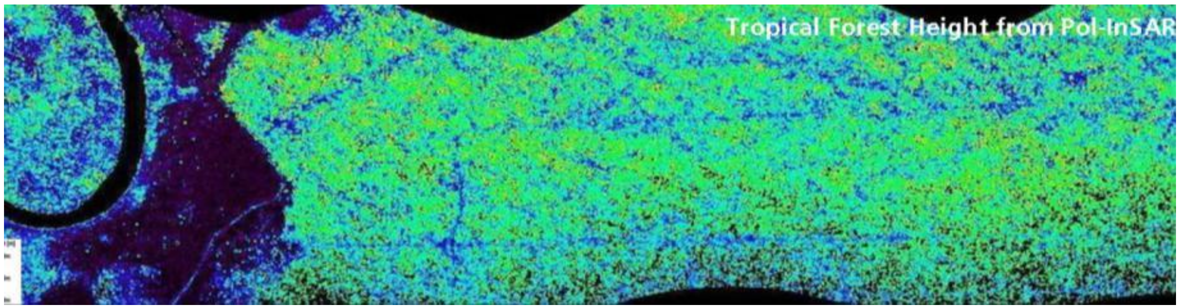


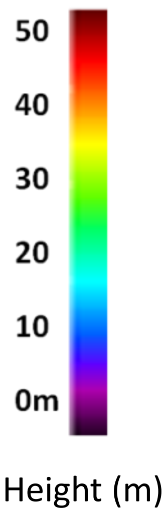
PolInSAR has mapped height over tropical and boreal sites

Height maps from PolInSAR

Tropical forest

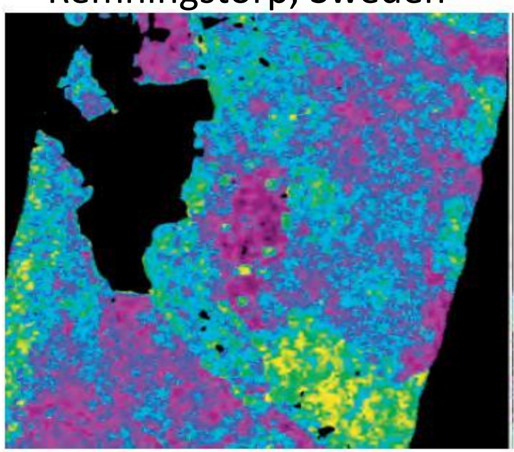
Kalimantan, Indonesia

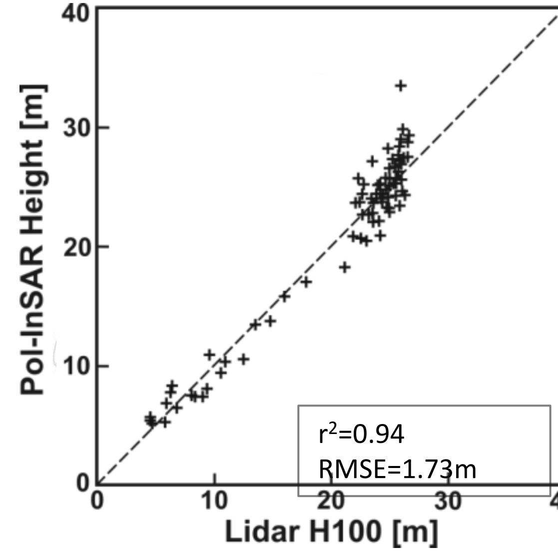


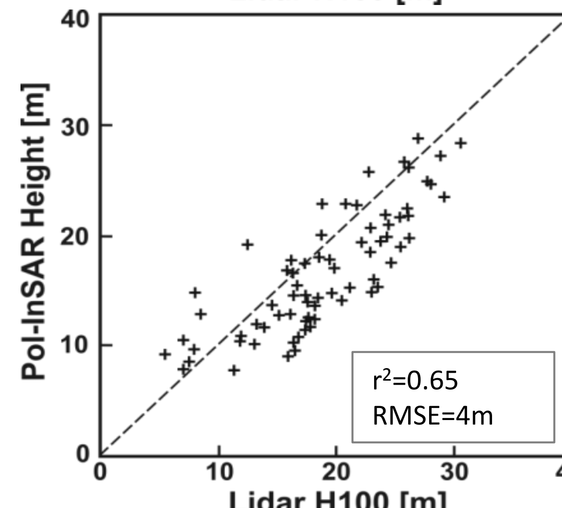


Boreal forest

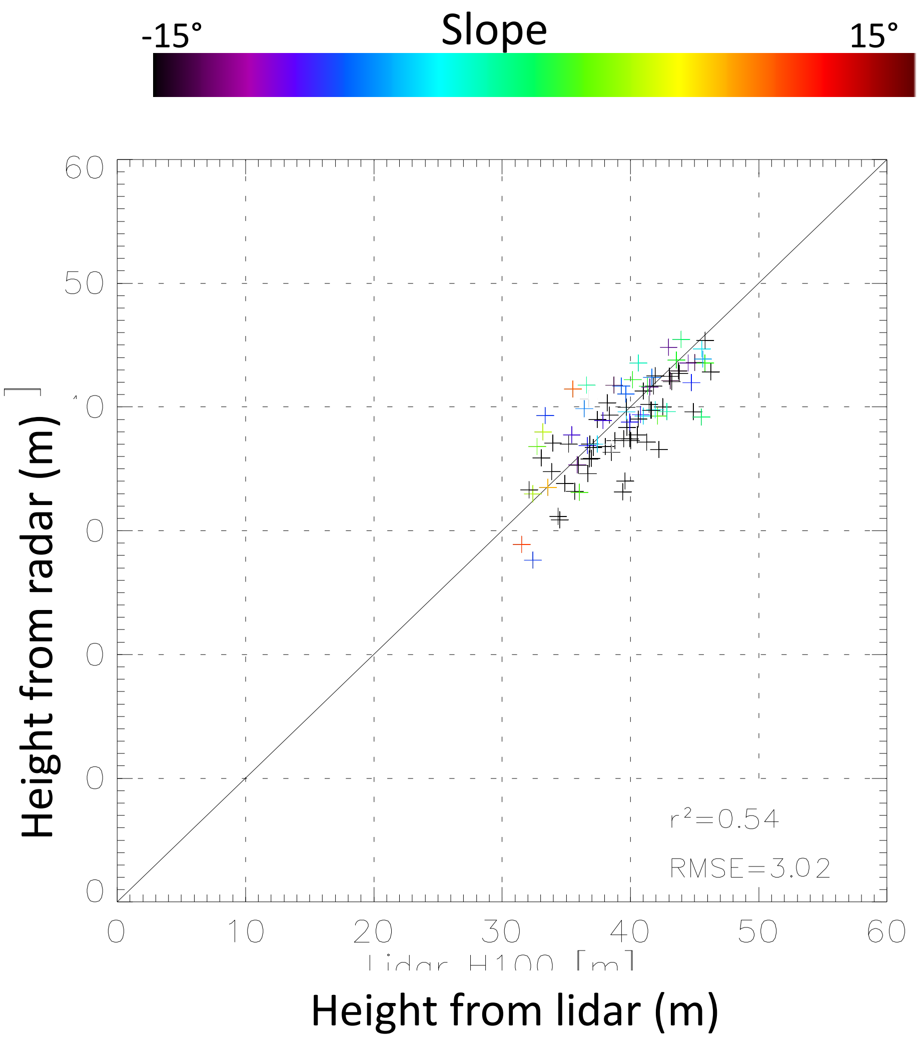
Remningstorp, Sweden







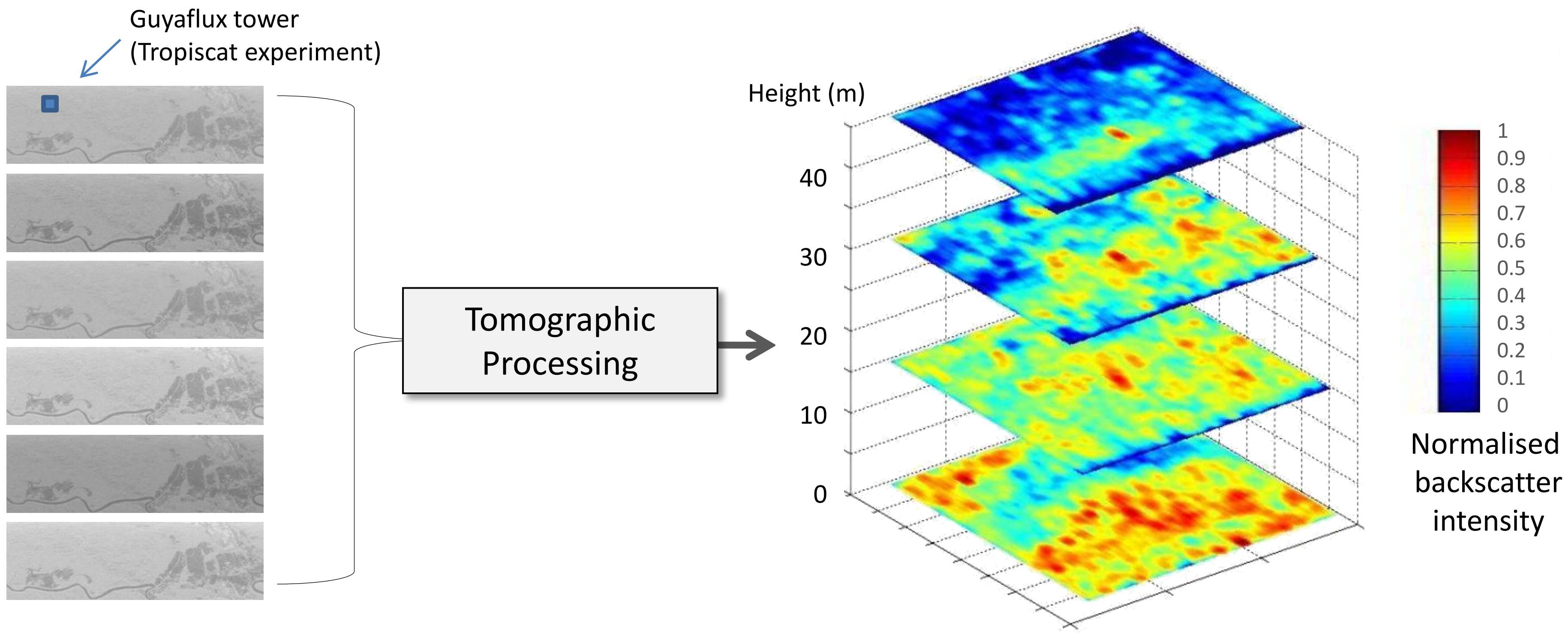
Unbiased heights are recovered by PolinSAR in dense tropical forest with steep slopes



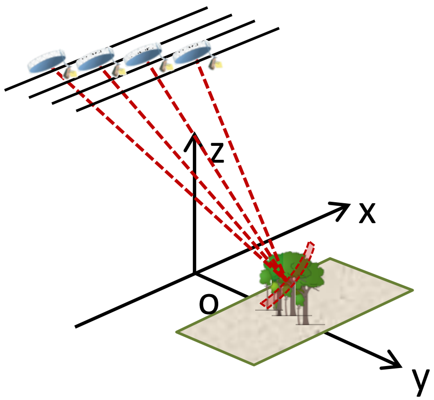
- Indrex campaign Oct. 2004 (Indonesia, tropical forest).
- Lidar measurements acquired in Aug. 2011.

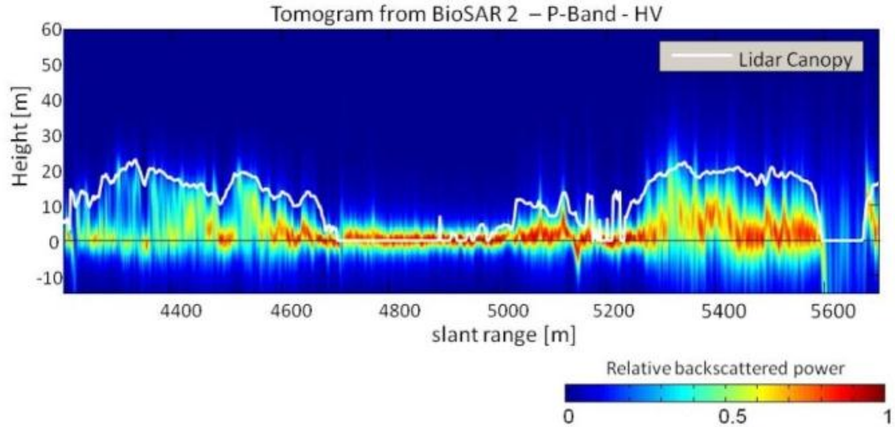
SAR tomography, a new concept to explore 3D forest structure

Generates images of different forest layers from multi-orbit SAR images

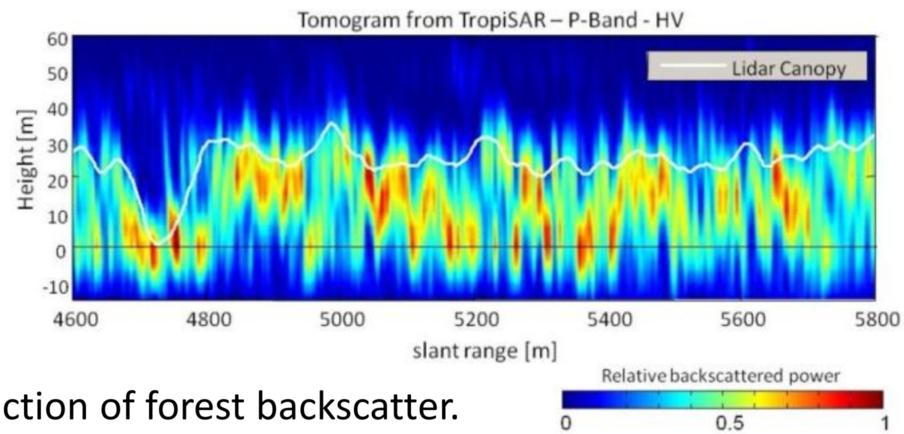


Biomass TomoSAR will image the forest in 3 D





Boreal forest
Kryclan, Sweden

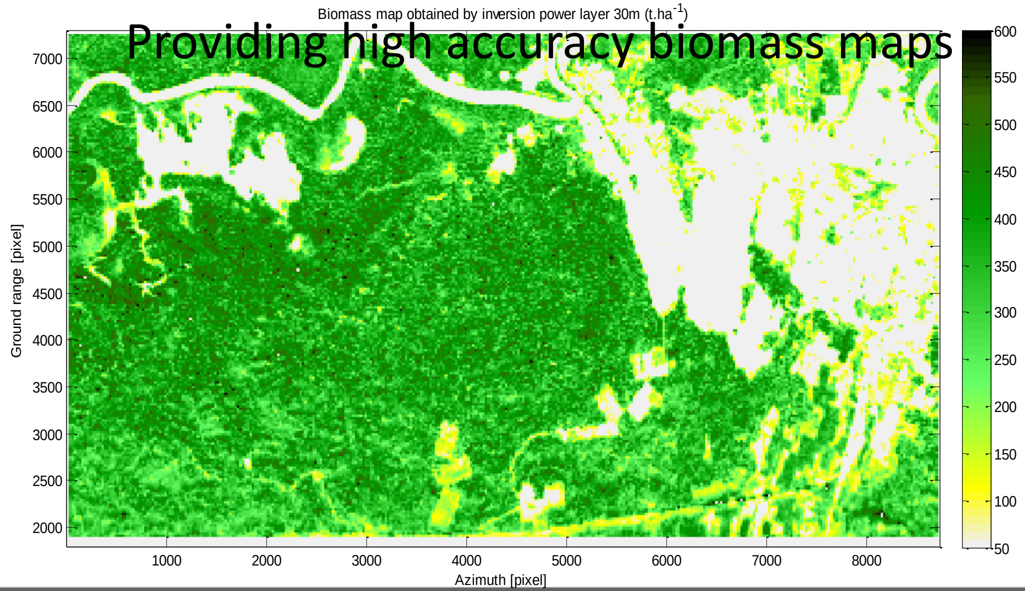


Tropical forest
Paracou, French Guiana

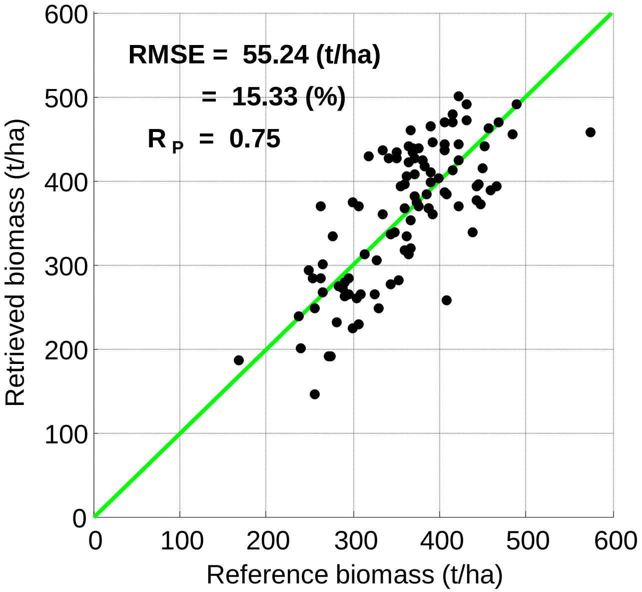
TomoSAR:

1. Provides a 3D reconstruction of forest backscatter.
2. Allows an interpretation of scattering processes
3. Gives guidance to the PolSAR and PolInSAR retrieval algorithms

P-band tomography for AGB mapping



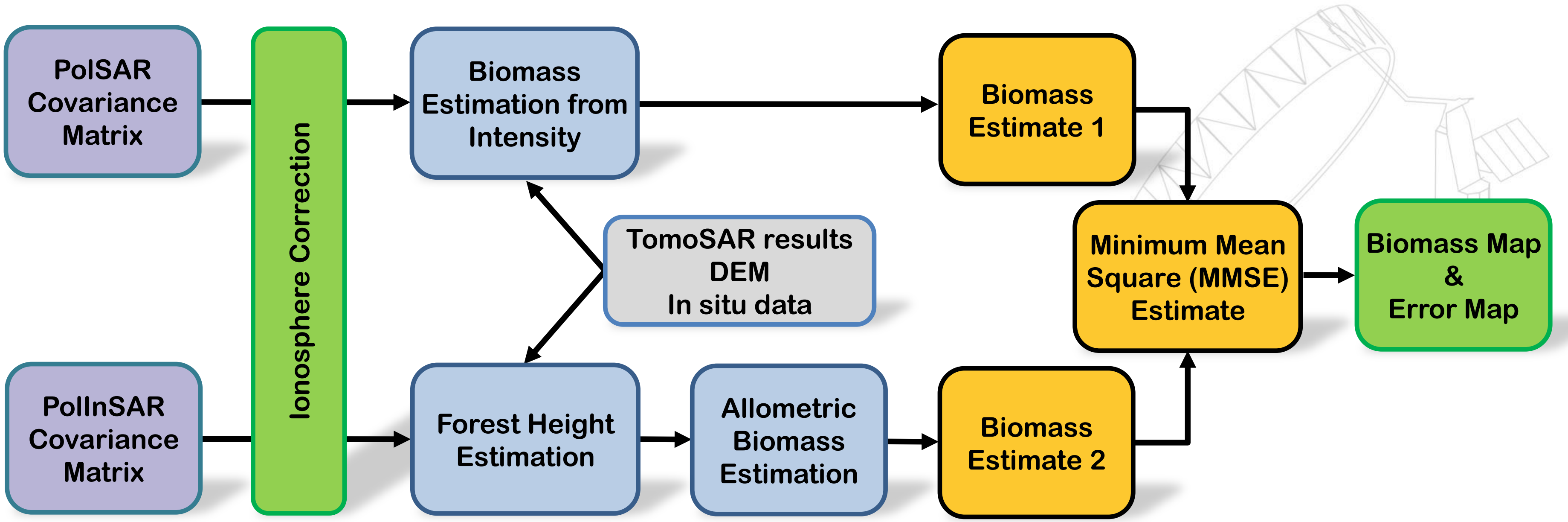
Paracou, tropical forest
112 in-situ plots : 100 m x 100 m



AGB map at 50 m,
by tomography

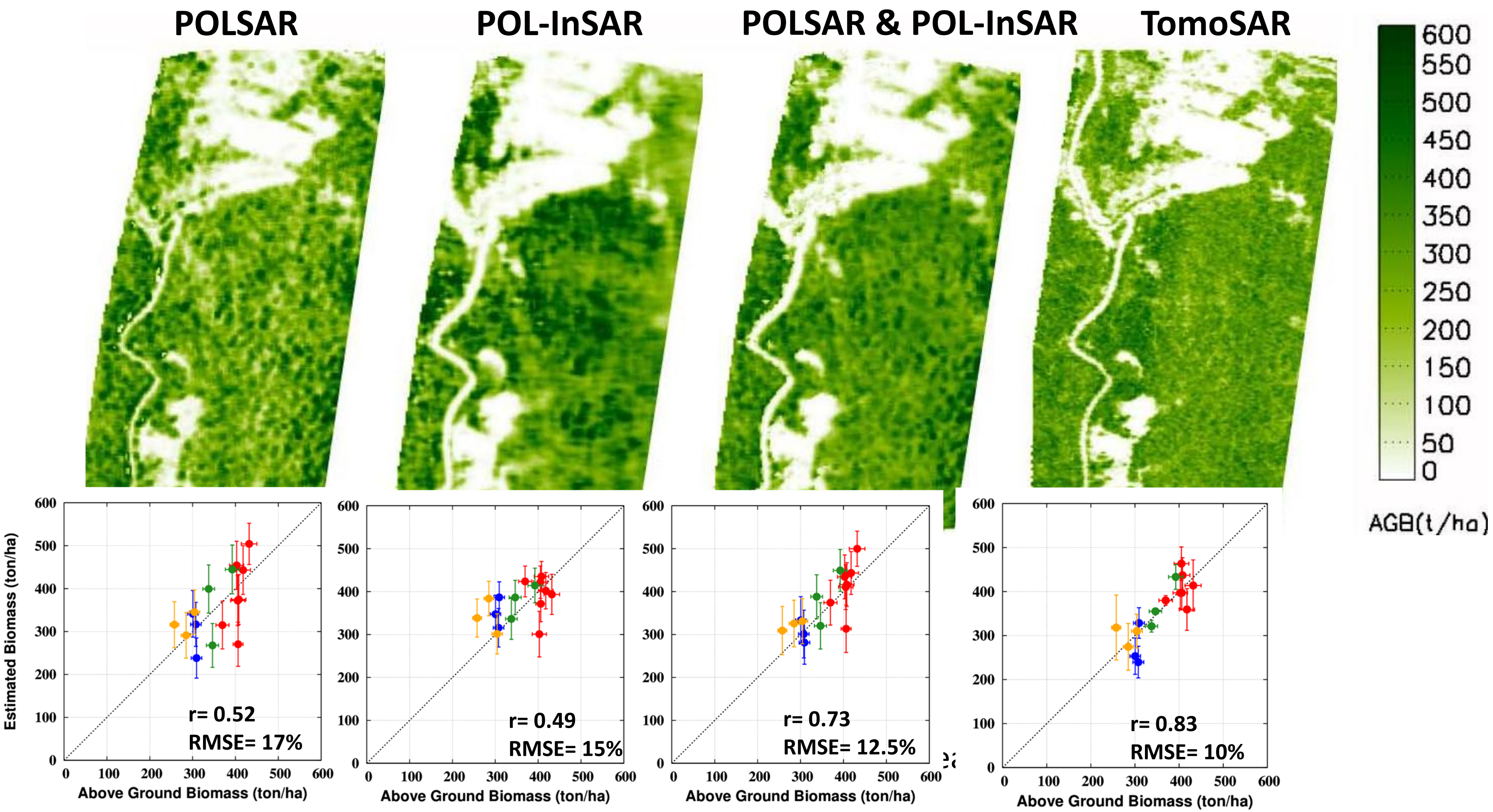
BIOMASS tomographic phase :
> 4 baselines for 1 strip map
1 year operation
A global coverage

Biomass retrieval algorithm



The retrieval performances are evaluated taking into account of the Biomass specifications (resolution, noise..)

Combining estimators improves performance in tropical forests



Paracou, French Guiana, 6 MHz data; in situ biomass = 260-430 ton/ha

Thuy Le Toan, CESBIO

State-of-the-art: how well Biomass measures forest biomass, height and disturbances

1. In boreal forests, **geophysical variability** limits biomass inversion; simulations indicate biomass relative RMSE ~30% .

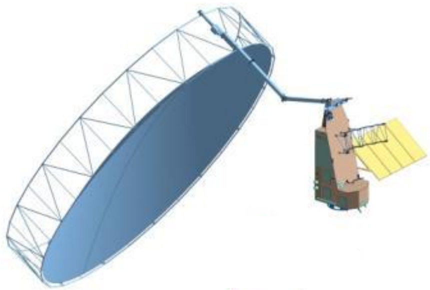
2. In tropical forests, **topography** is the limiting factor; expected relative RMSE < 20% for biomass > 120 t/ha, decreasing as biomass increases. Slow seasonal trends in backscatter need adaptive algorithms.

3. Relative RMSE of height:
   - < 20% for all biomass values in the tropics
   - between 20% and 30% for boreal forests with biomass > 100 t/ha.

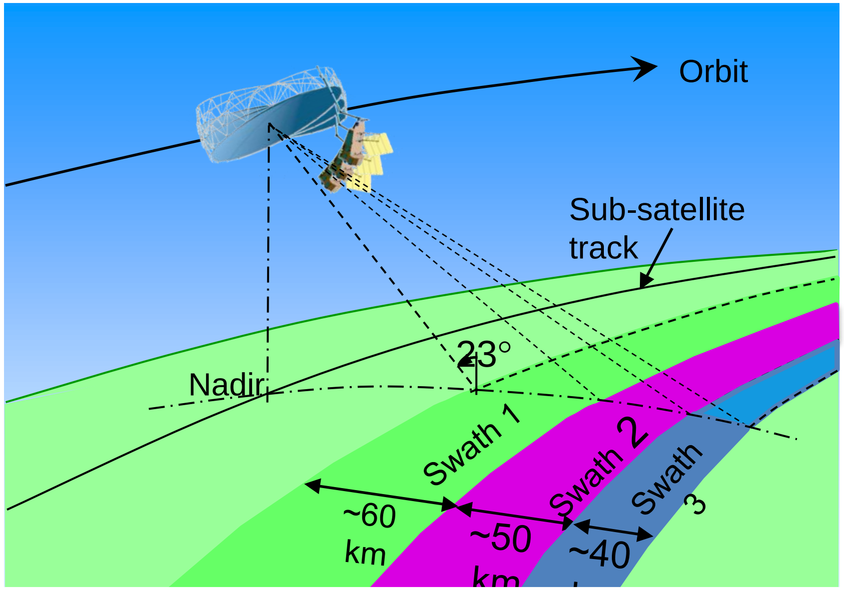
4. Deforestation removing ~80% of high biomass tropical forests should be detectable with 90% accuracy at 50 m resolution.

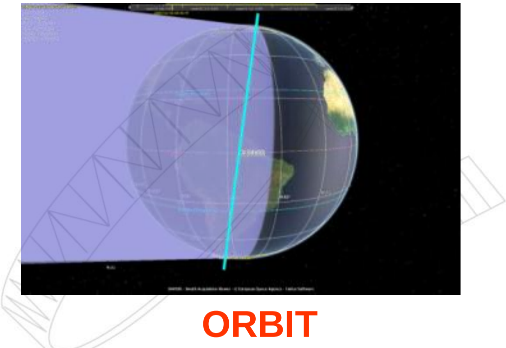
5. Boreal observations show that biomass changes of ~ 20 t/ha can be detected over a 4-year period.

Biomass Mission Elements



SPACE SEGMENT
Single Spacecraft
Mass: ~1200 kg
Power: ~1500 W
Payload: P-band SAR





ORBIT
Drifting sun-synchronous
Local time 06:00, 635-672 km,
Repeat cycle: 17 days (Baseline)
3-4 days (Option)

LAUNCHER
Vega/Antares/PSLV

What do we need?

1. Consolidate and improve retrieval methods.
2. Conduct experiments to extend the scope of observations
3. Establish Reference in situ network (and lidar data) for model calibration and result validation
4. Exploit Synergy with other EO data
5. Prepare for use in C flux estimations

Waiting for BIOMASS

They will know finally how much we count !