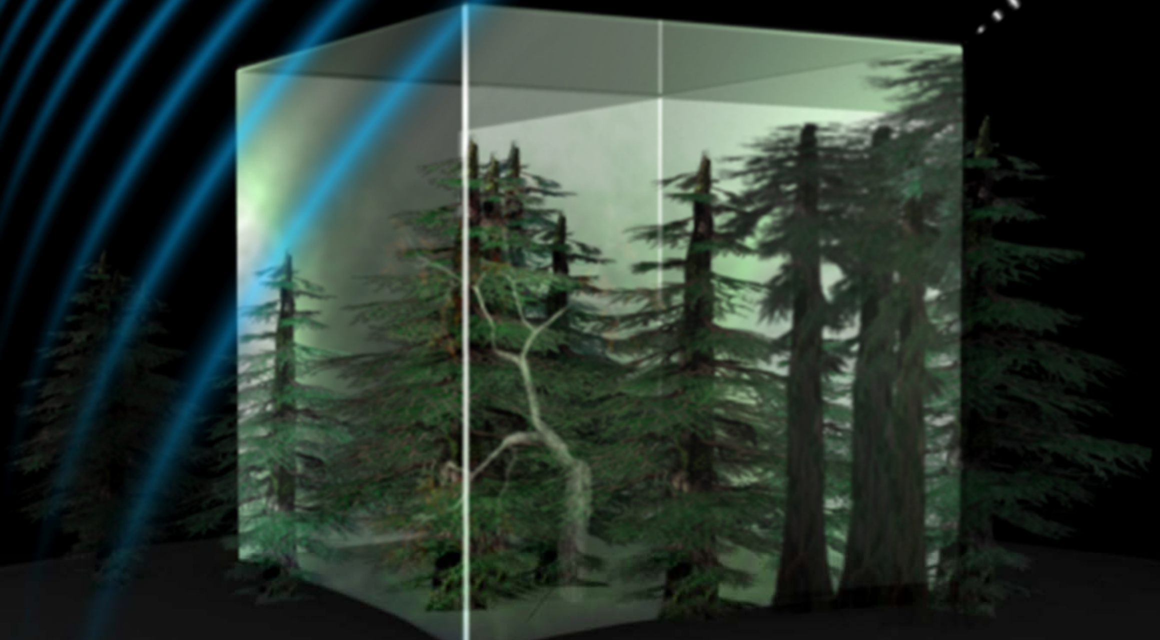
biomass

Science I



EARTH EXPLORER 7 USER CONSULTATION MEETING

An Earth Explorer to observe forest biomass

European Space Agency

Primary Mission Objectives

1. Reducing the major uncertainties in carbon fluxes linked to Land Use Change, forest degradation and regrowth
2. Providing support for International Agreements (UNFCCC and REDD+)
3. Inferring landscape carbon dynamics and supporting predictions
4. Initialising and testing the land component of Earth System models
5. Providing key information on forest resources, ecosystem services, biodiversity and conservation

Secondary objectives

1. Sub-surface geology in deserts
2. DTMs under dense vegetation
3. Glacier and ice sheet velocities

Biomass product requirements

Above-ground biomass (tons / hectare)

- 200 m resolution
- 1 map every 6 months for 4 years
- global coverage of forested areas
- accuracy of 20%, or 10 t ha^{-1} for biomass < 50 t ha^{-1}

Upper canopy height (meter)

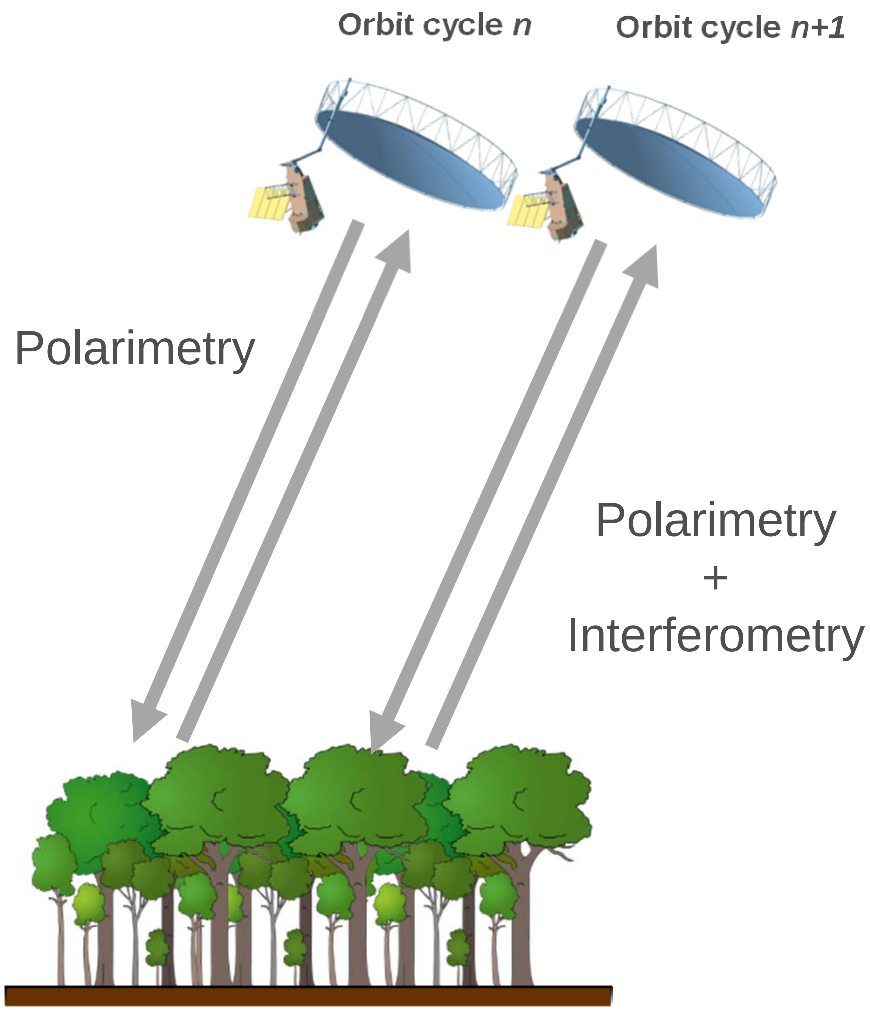
- 200 m resolution
- 1 map every 6 months for 4 years
- global coverage of forested areas
- accuracy of 20-30%

Areas of forest clearing (hectare)

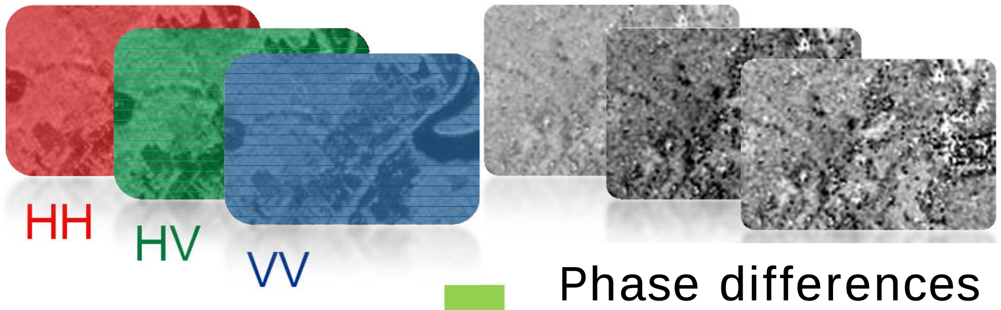
- 50 m resolution
- 1 map every 6 months for 4 years
- global coverage of forested areas
- 90% classification accuracy

Urgently required for IPCC, UNFCCC, REDD, national forest planning

A single P-band satellite can provide both polarimetric and interferometric coverage



Calibration, Ionospheric correction



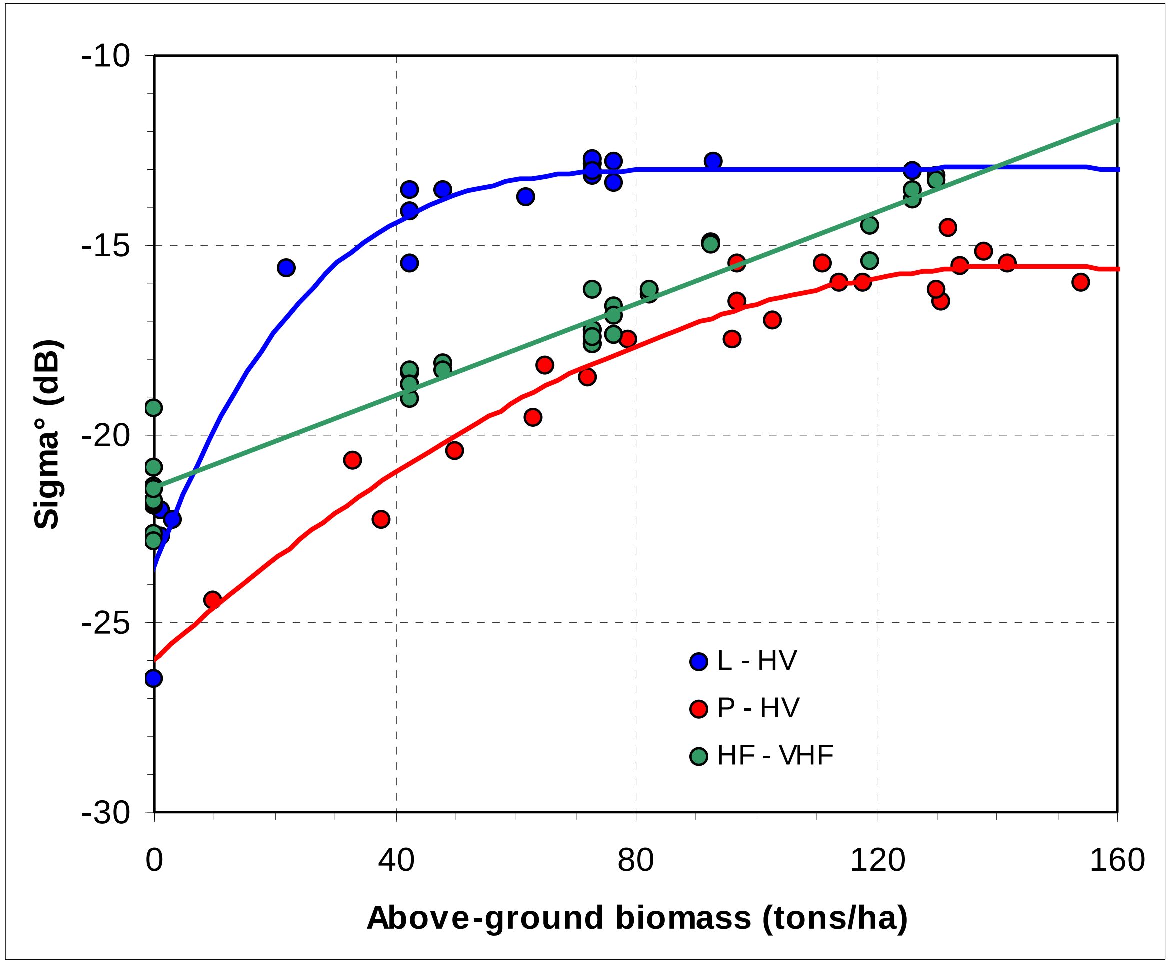
Retrieval algorithm

1. Forest biomass
2. Forest height
3. Forest disturbance

Relation between radar backscatter and above-ground biomass at L, P and VHF bands

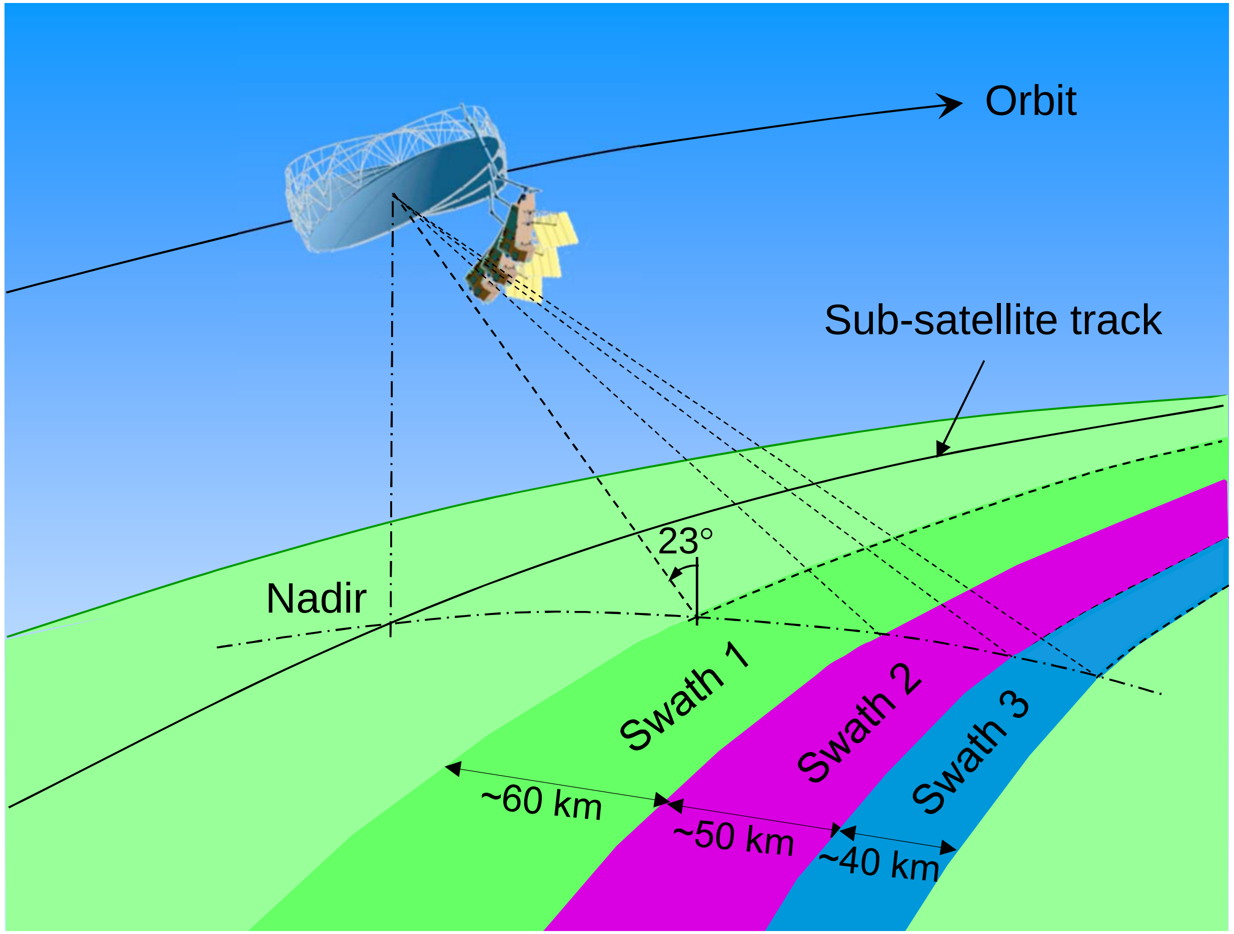
Landes forest, France

L-band SAR: RAMSES
P-band SAR: AirSAR
VHF SAR: Carabas

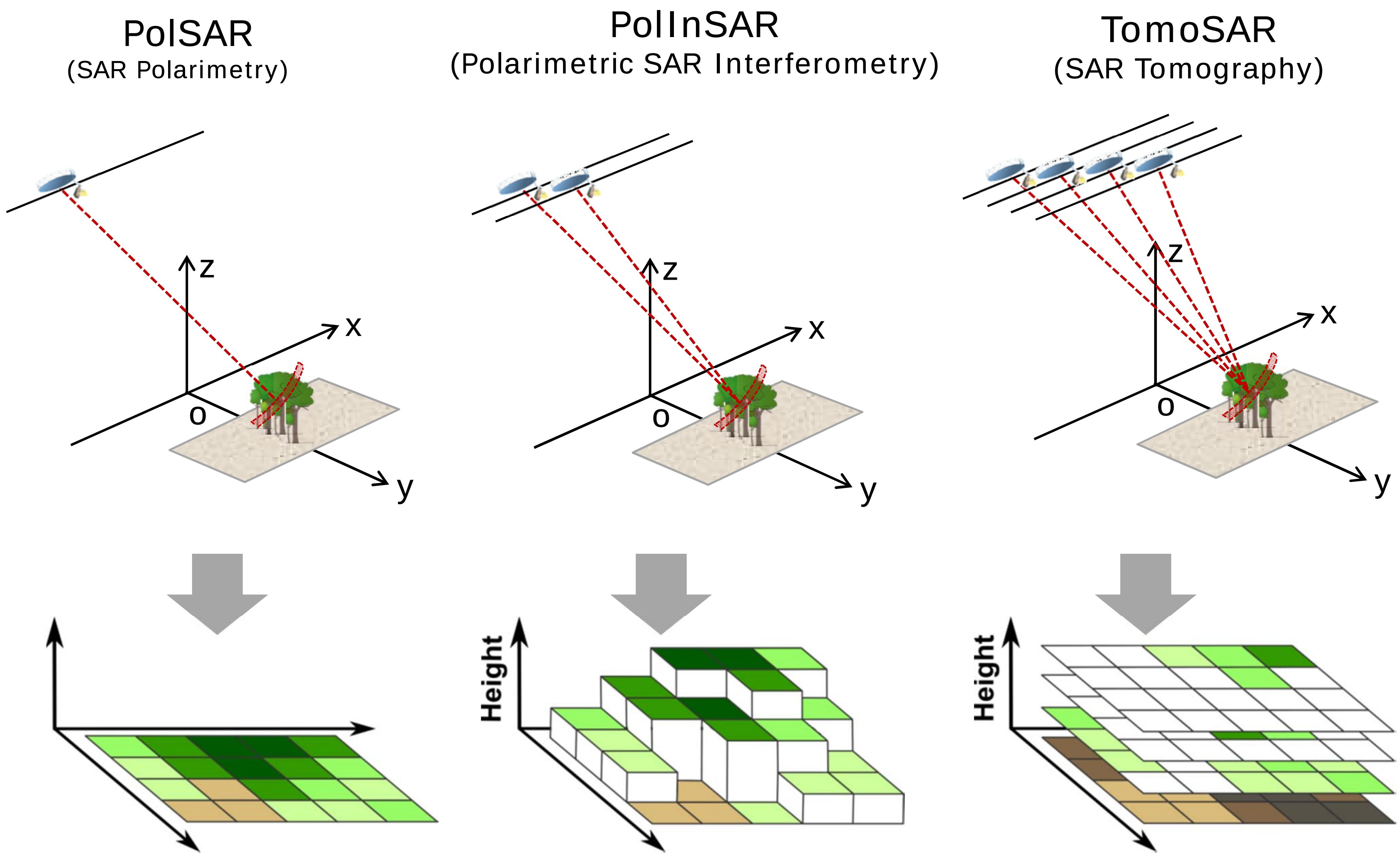


Payload overview

- P-band (435 MHz) Synthetic Aperture Radar (SAR)
- Bandwidth of 6 MHz
- Full polarimetric SAR
- Multi-pass interferometry
- Single antenna beam
- Stripmap mode
- Satellite roll for beam repointing



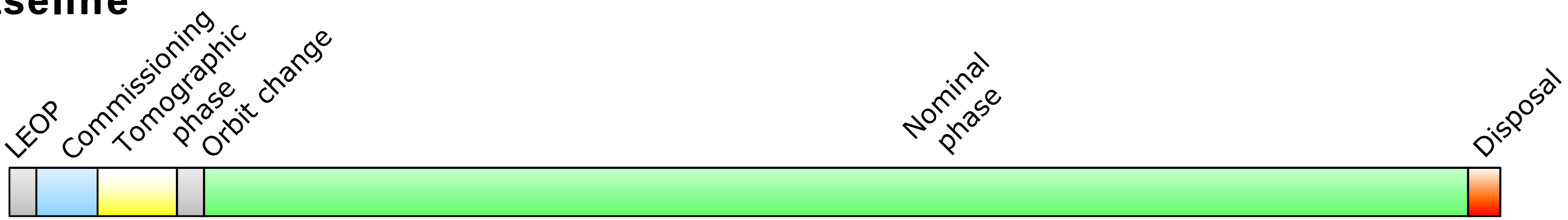
A single P-band satellite can deliver 3 independent types of information for biomass



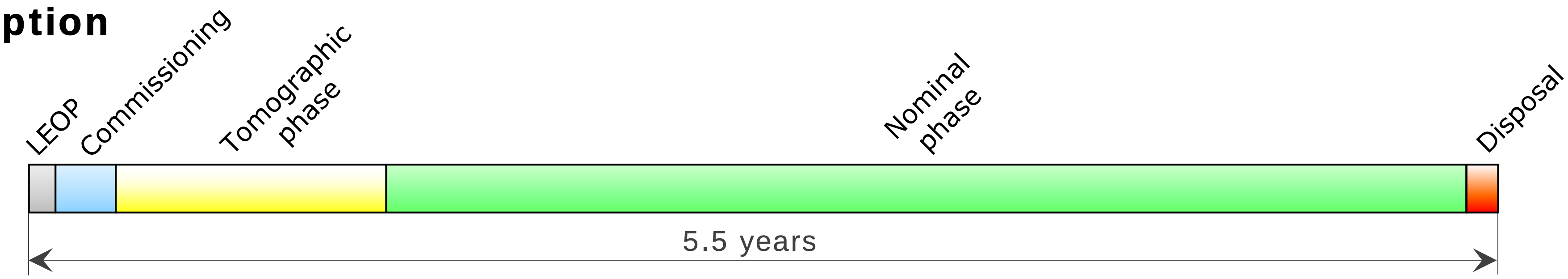
Operations concept

Event	Baseline	Option
Launch & Early Orbit Phase	1 week	
Commissioning	5 months	
Tomographic phase	3 months	1 year
Orbit change	2 weeks	N/A
Nominal phase	4.7 years	4 years
Disposal	9 days	

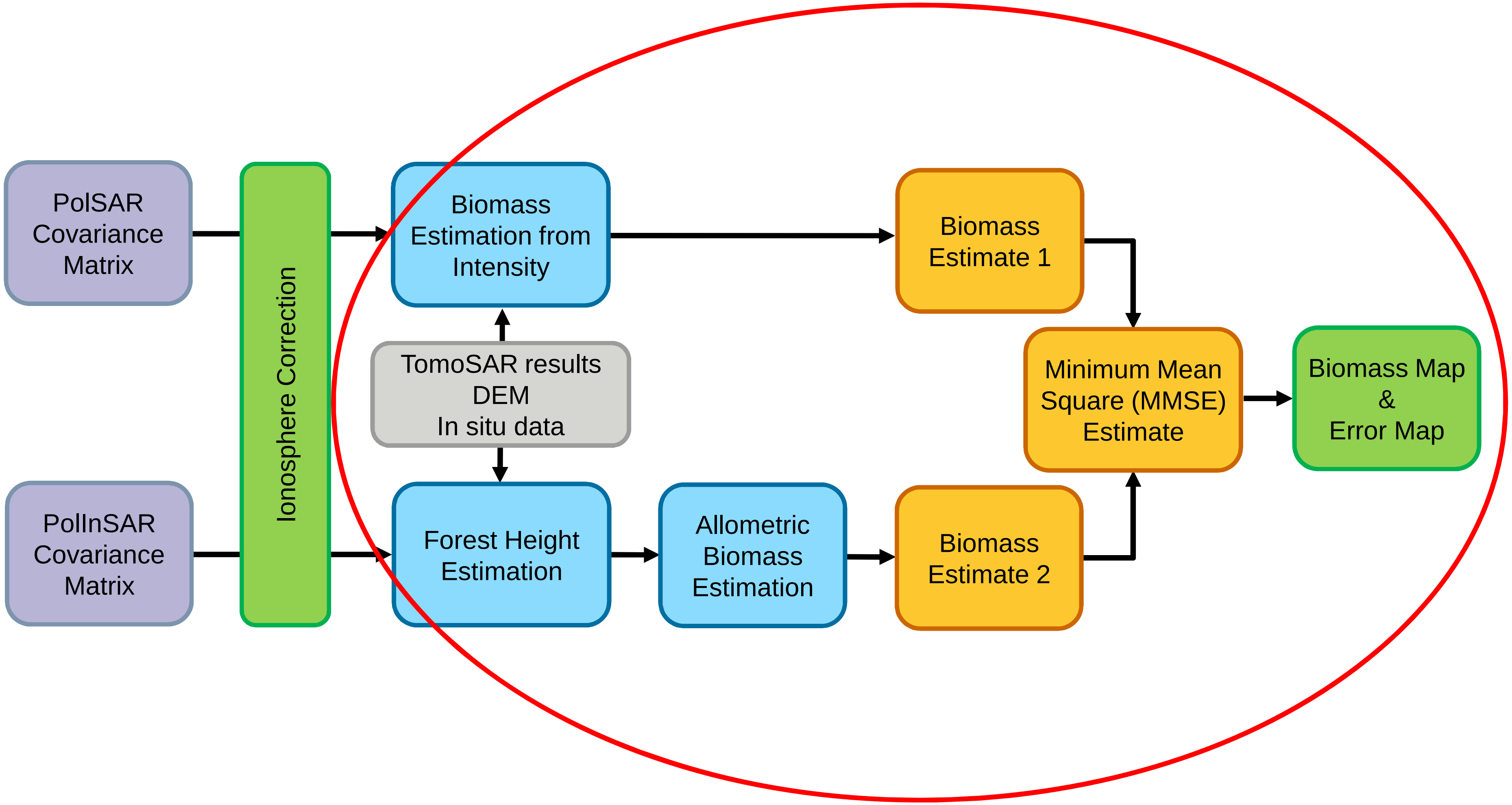
Baseline



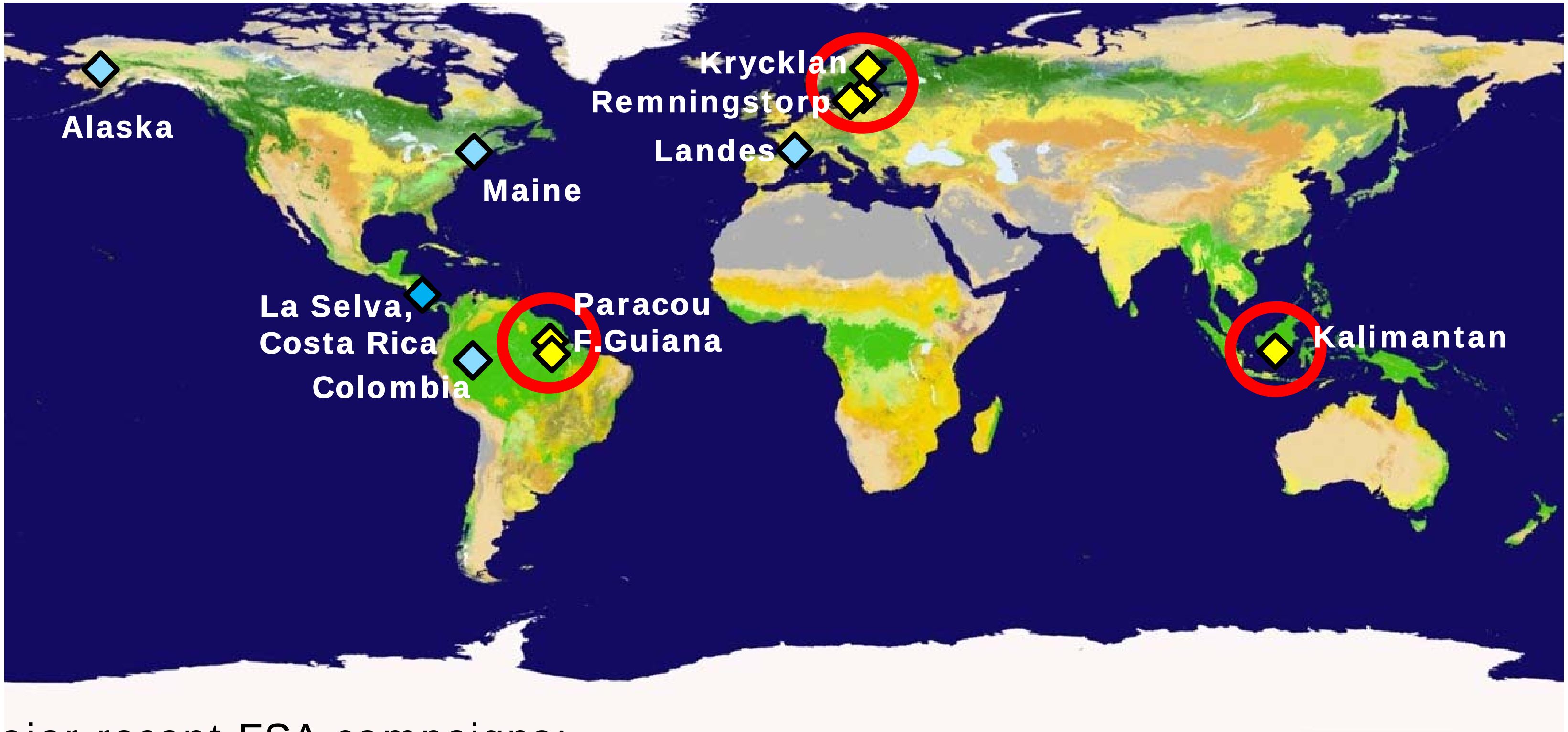
Option



PolSAR and PolinSAR are combined to estimate biomass



Campaigns used to address questions, develop retrieval methods and assess performance



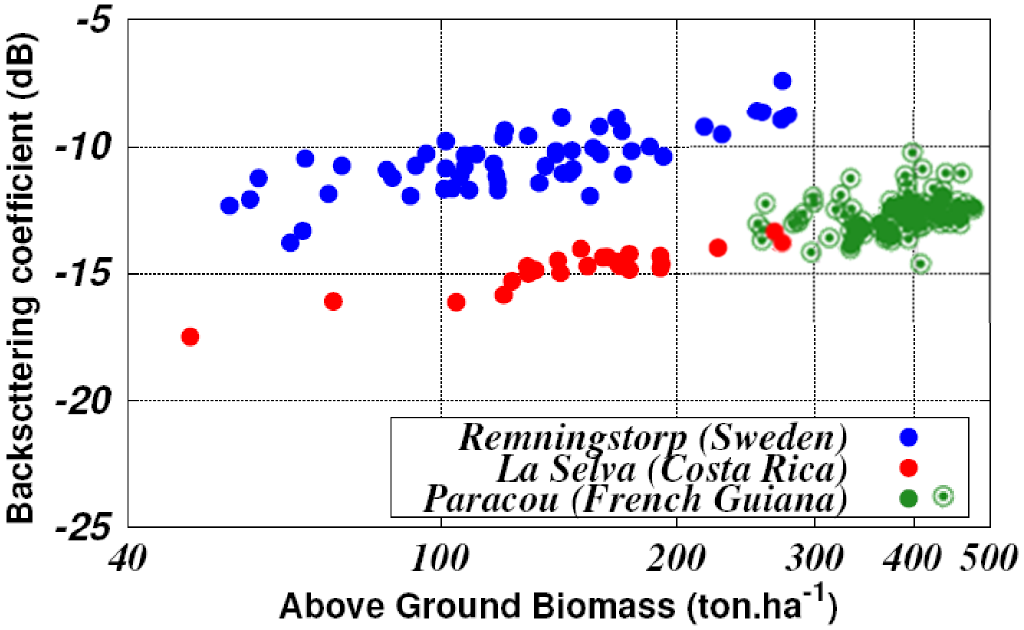
Major recent ESA campaigns:

1. Kalimantan 2004 (Indrex)
2. Remningstorp 2007 (BioSAR 1), 2010 (BioSAR 3)
3. Krycklan 2008 (BioSAR 2)
4. F. Guiana 2009 (TropiSAR), 2011-13 (TropiScat)

◆ ESA campaigns
◆ non-ESA campaigns

Global consistency in the biomass – P-band backscatter relationship

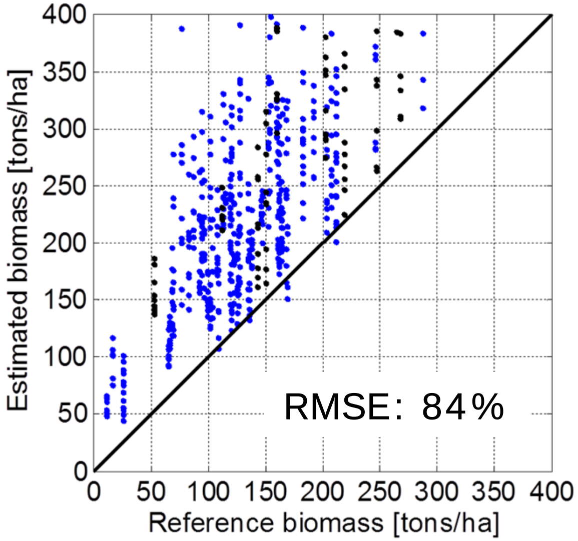
1. Similar power-law relationships between backscatter and biomass are found for all forests where we have data
2. Inversion techniques need to deal with data dispersion and differences between different types of forest



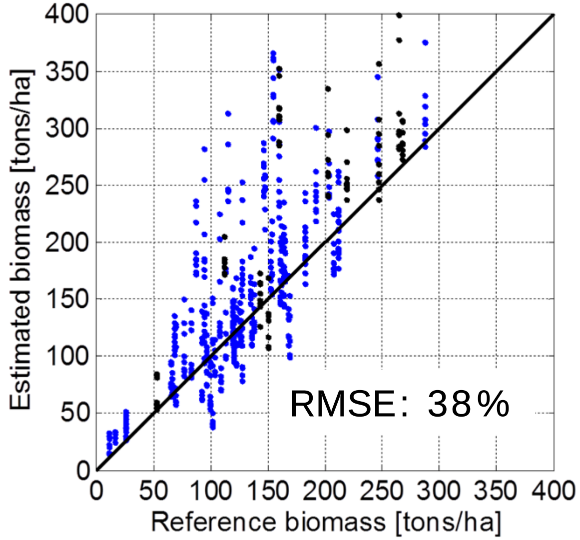
Using polarisation & slope information radically improves measurement accuracy

Remningstorp 70 MHz data: varying environmental conditions over 3 months

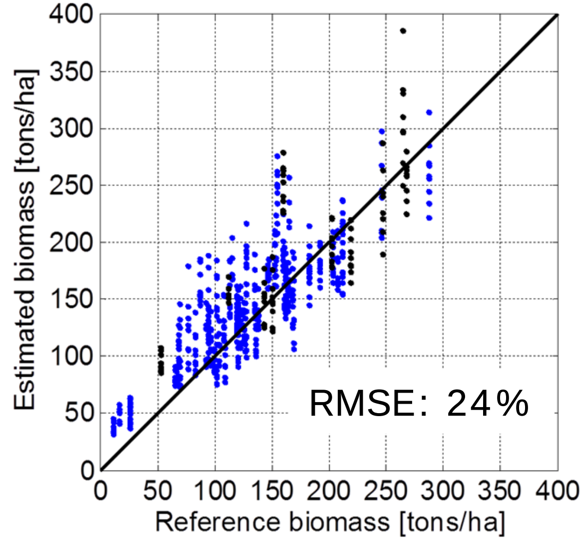
HV only



HV, HH & VV



HV, HH, VV & DEM

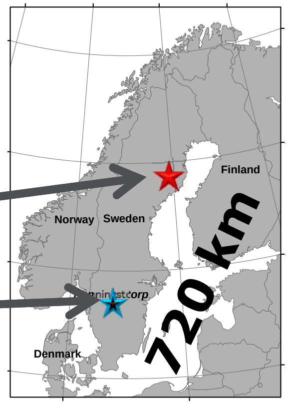


Blue - from airborne lidar map, std. error = 25 ton/ha

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.

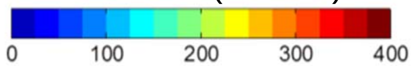


Consistent biomass estimates are obtained after correcting environmental effects

Biomass map, Remningstorp, Sweden

Training at Krycklan

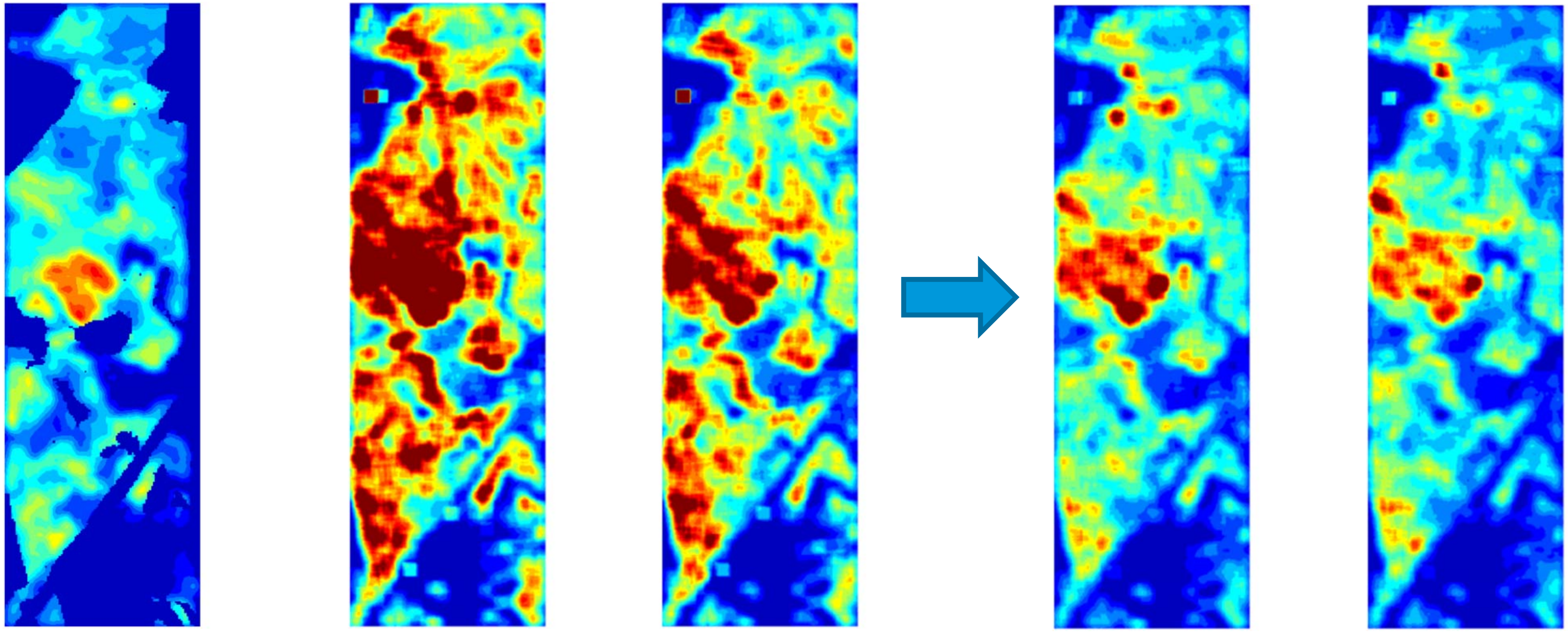
Biomass (ton/ha)



Lidar biomass estimate

Inversion using single polarisation (HV)

Inversion using multiple polarisations and DEM

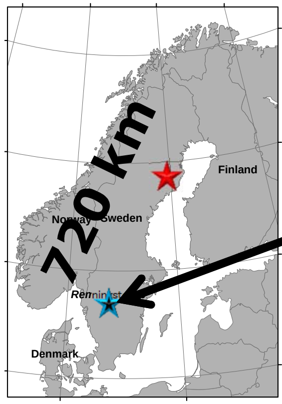


March | May | March | May

Boreal biomass: Biomass performance estimated from campaign data

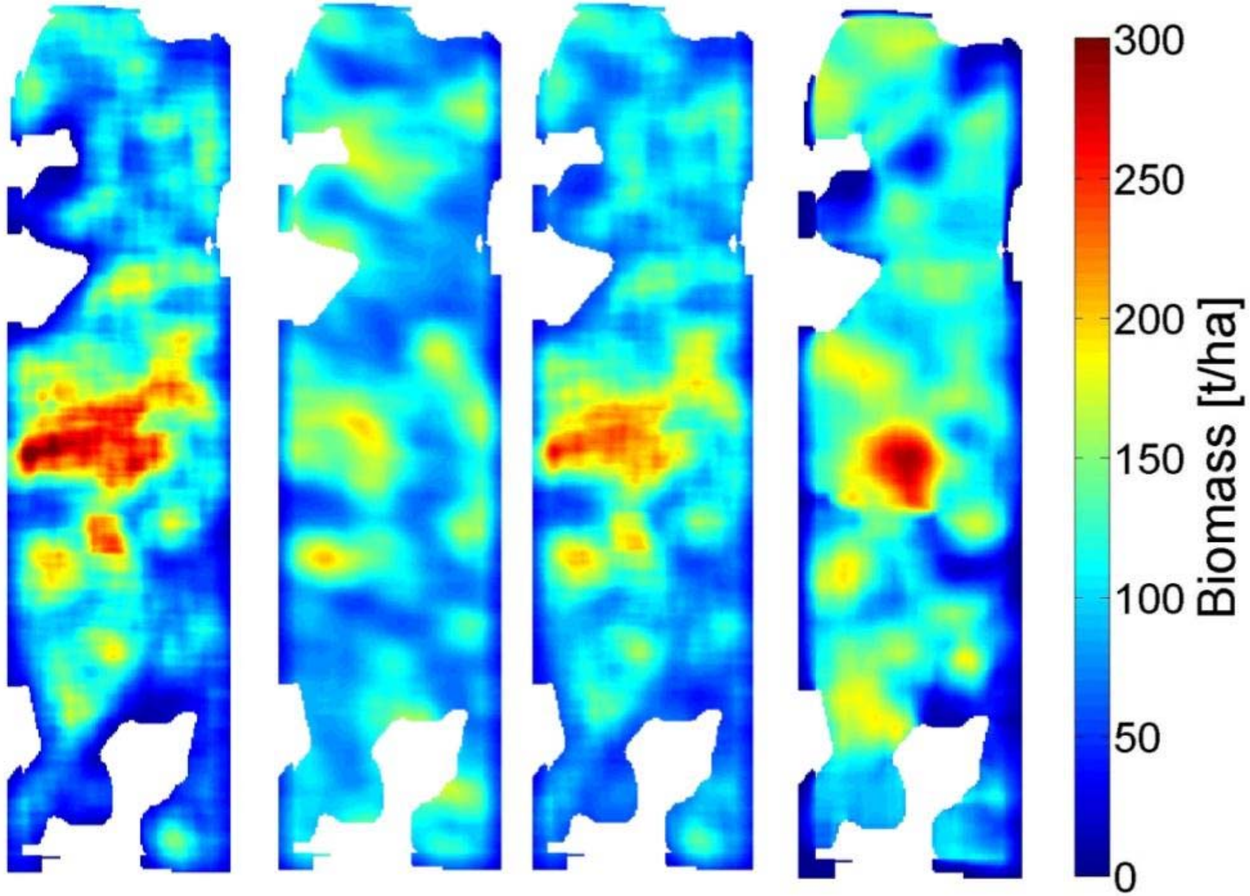
BIOMASS specification (6 MHz bandwidth, 200 m grid)

PolSAR algorithm trained at Krycklan, located 720 km from Remningstorp



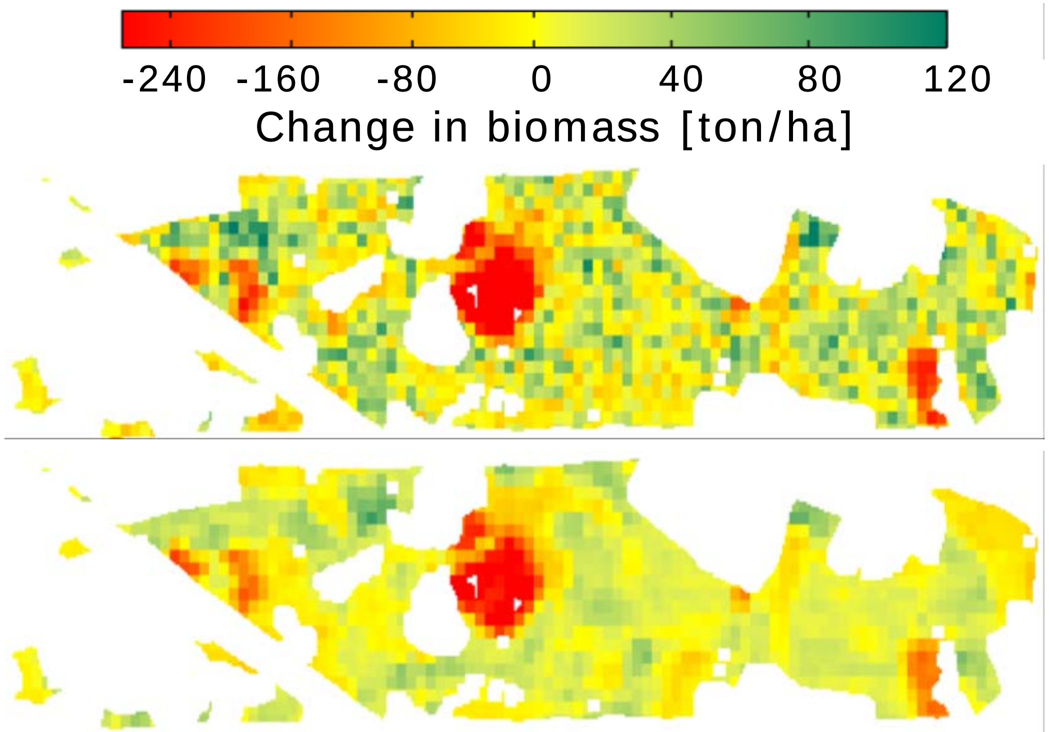
RMSE = 28 %

PolSAR PolInSAR Combined Reference (from lidar)



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



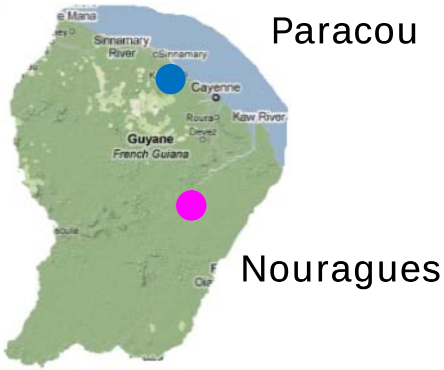
Radar RMSE ~ 20 t/ha (based on 6 reference plots).

Lidar RMSE is comparable (slightly worse).

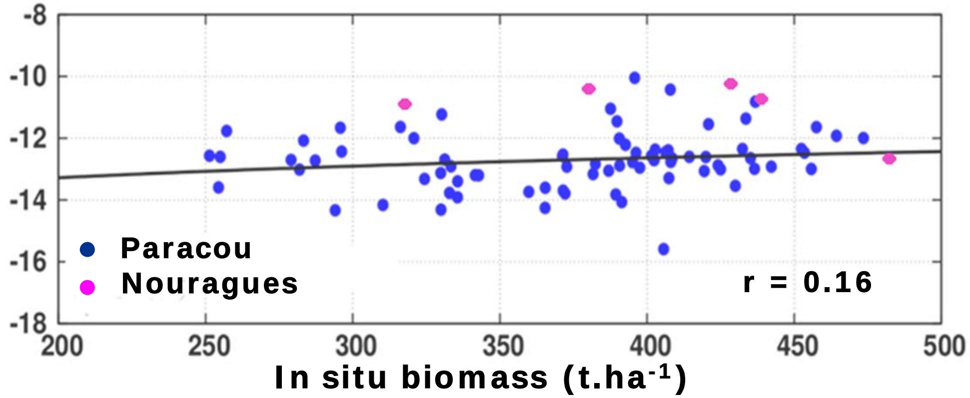
Biomass will be able to measure a **20 ton/ha change** over a 4-year period.

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

Tropical forest, French Guiana

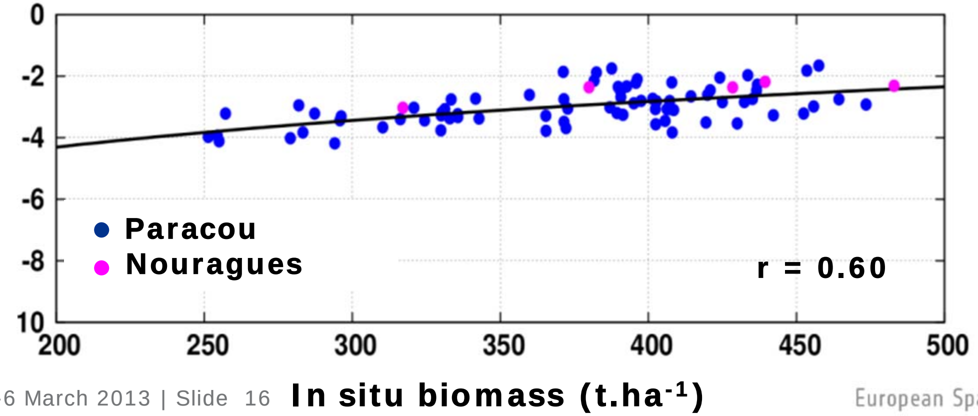


Backscatter at single polarisation (HV) in dB



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

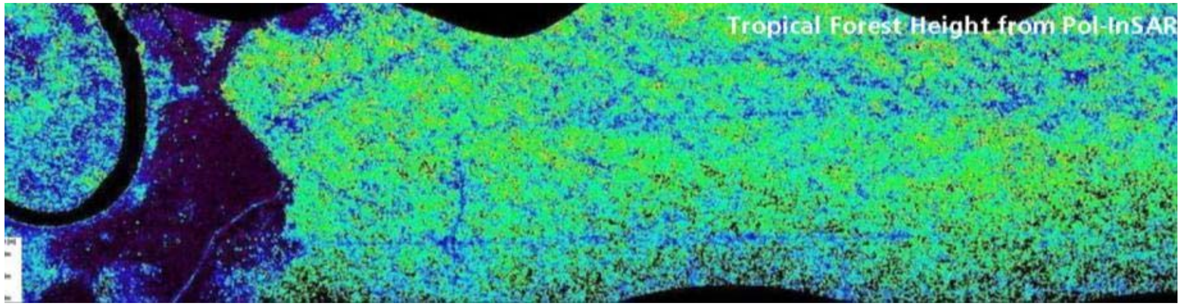
Polarimetric biomass indicator (dB)

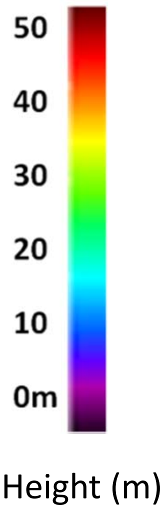


PolInSAR has mapped height over tropical and boreal sites

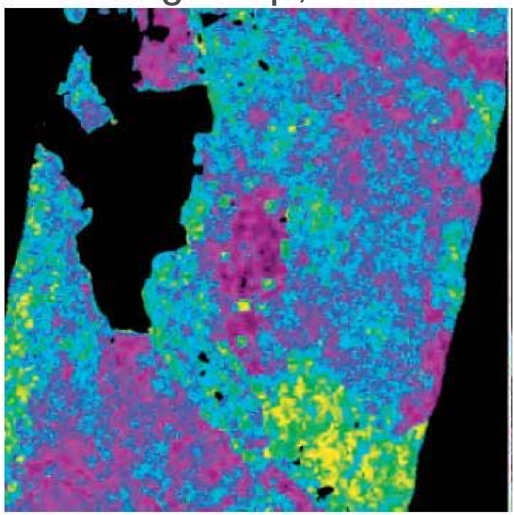
Height maps from PolInSAR

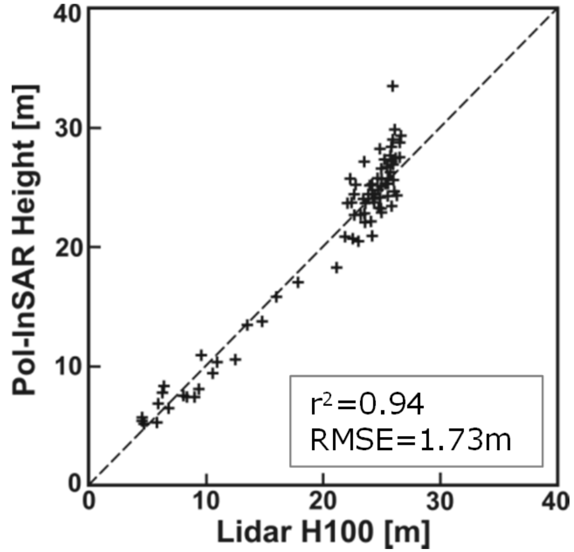
Tropical forest
Kalimantan, Indonesia

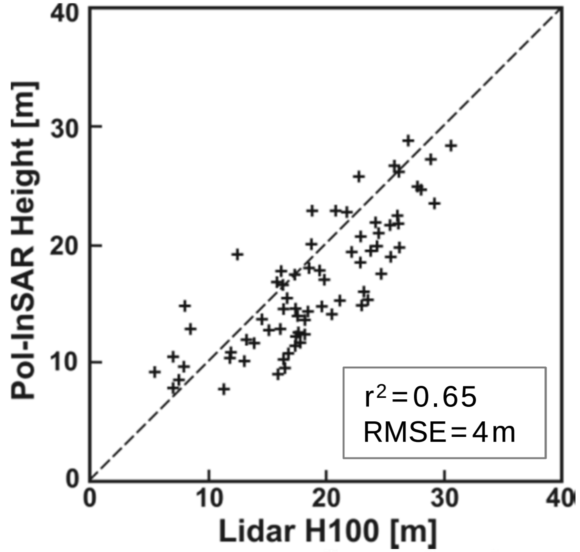




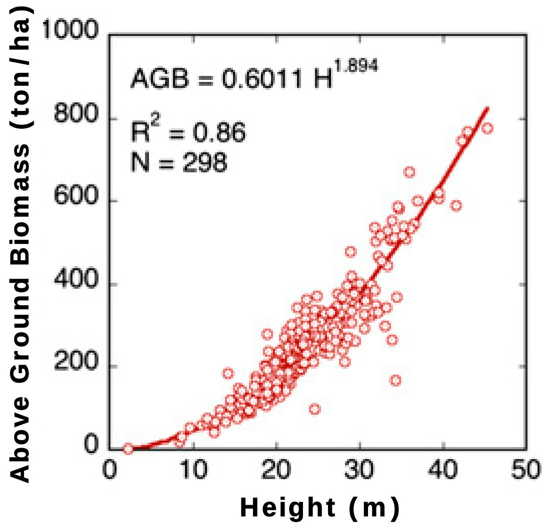
Boreal forest
Remningstorp, Sweden





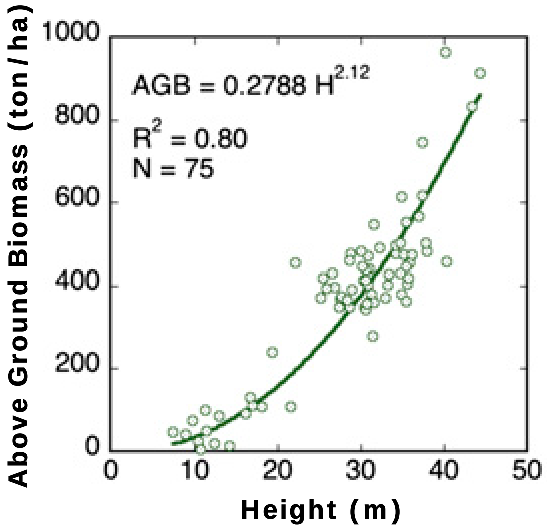


Allometry converts height to biomass



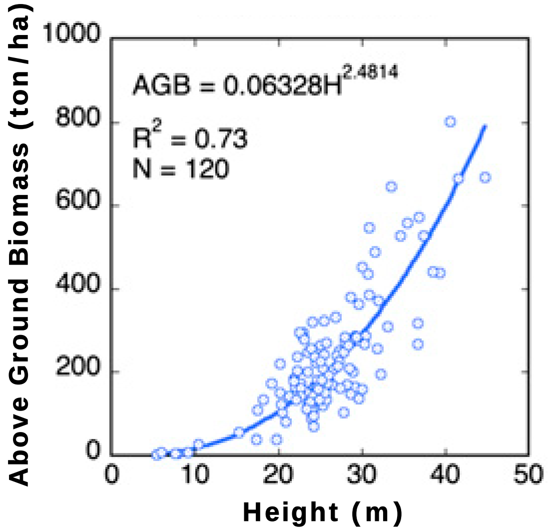
South America

To estimate biomass requires relationship between biomass and height (allometry)

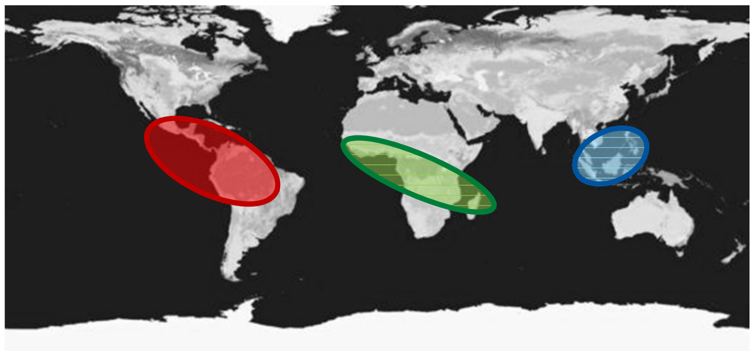


Sub-Saharan Africa

Allometric equations derived from 493 in situ plots in tropical forests

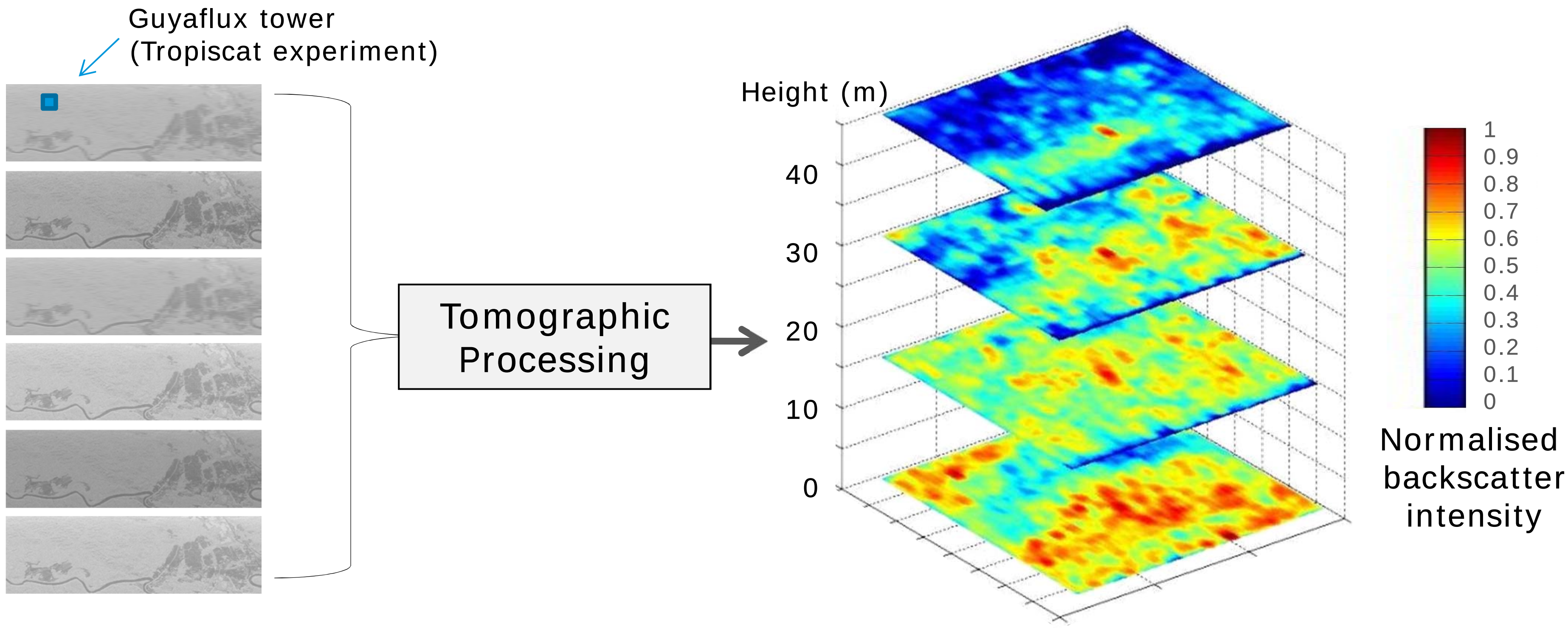


South-East Asia

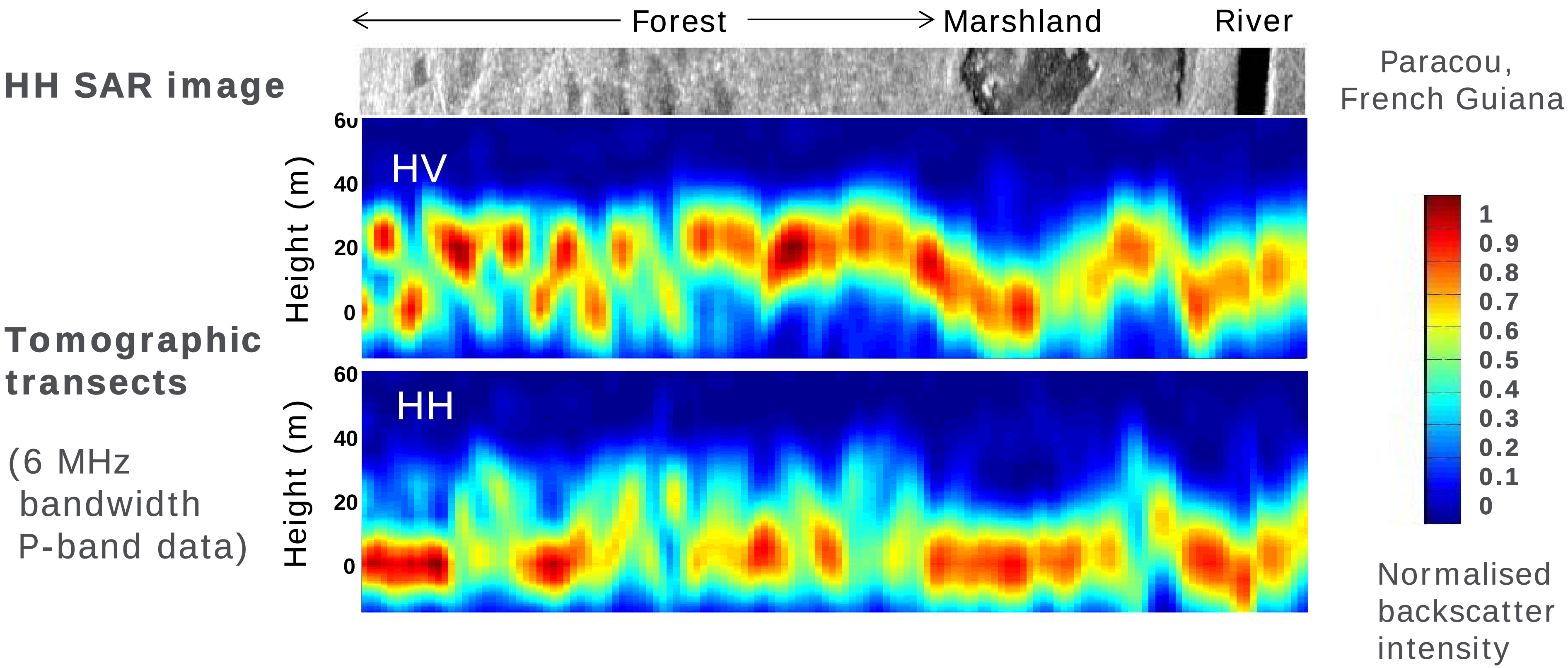


SAR tomography, a new concept to explore 3D forest structure

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



SAR tomography provides basic information to improve Biomass retrieval algorithms

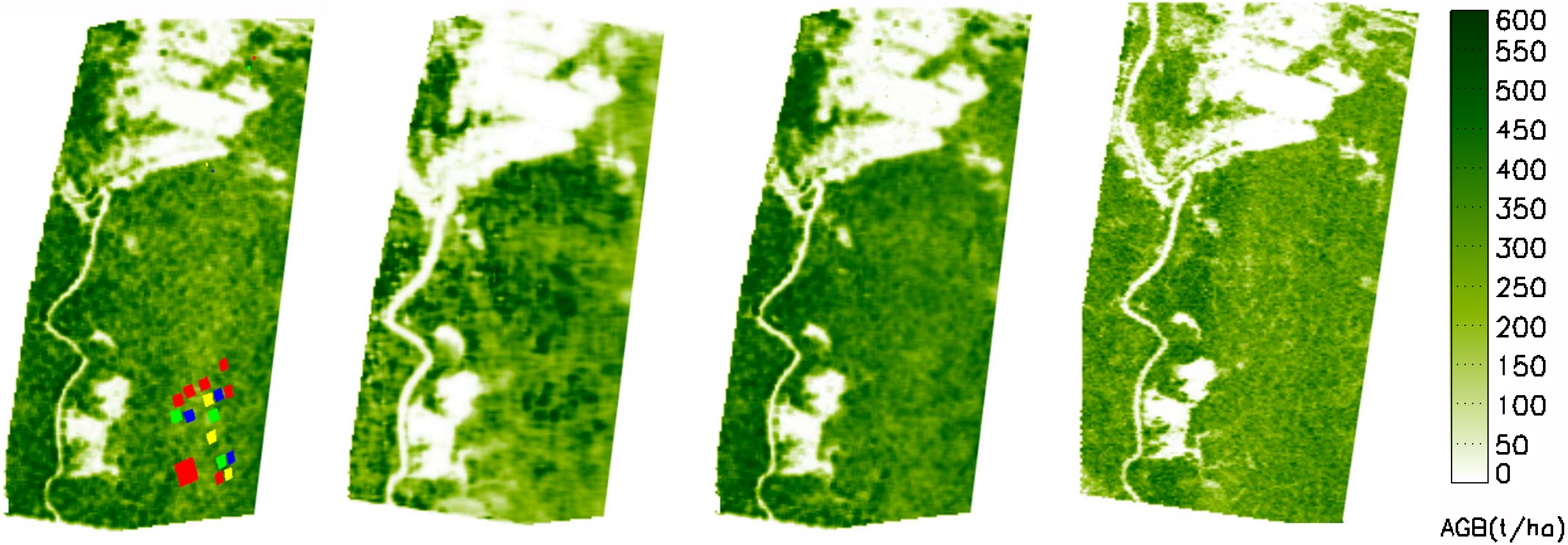


TomoSAR:

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.

Combining estimators improves performance in tropical forests (1)

PolSAR | PolInSAR | PolSAR + PolInSAR | Tomography



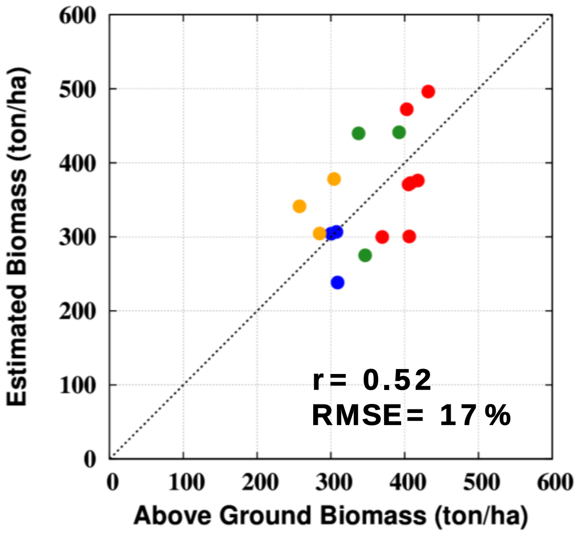
17 % | 15 % | 12.5 % | 10 %

$$\frac{\text{RMS biomass error (estimated - in situ)}}{\text{mean biomass}}$$

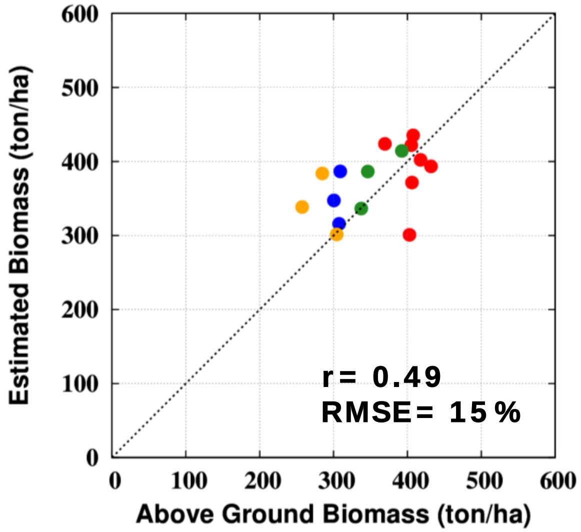
Paracou, French Guiana, 6 MHz data; in situ biomass = 260-430 ton/ha

Combining estimators improves performance in tropical forests (2)

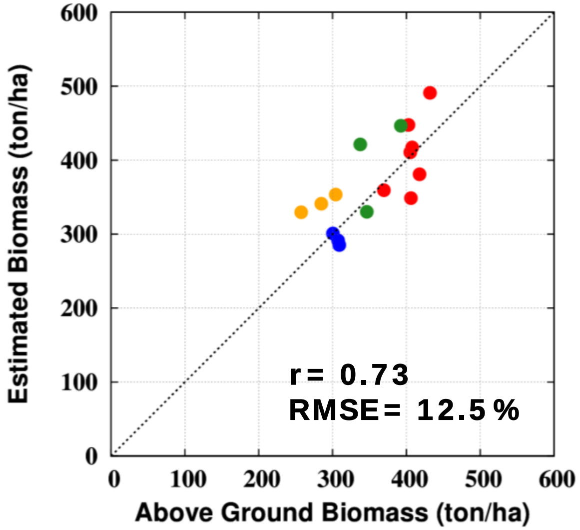
PolSAR



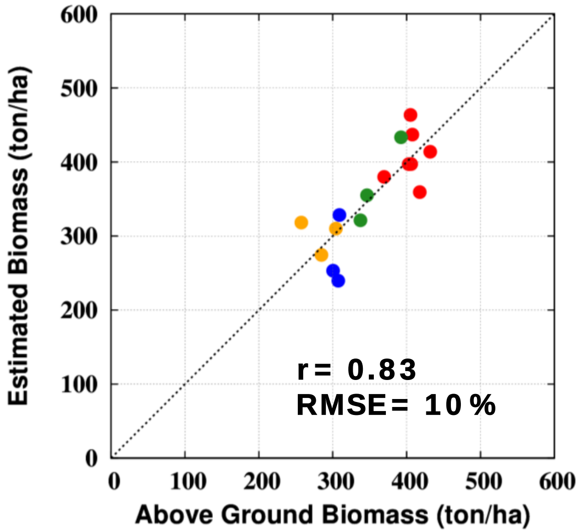
PolInSAR



PolSAR +
PolInSAR



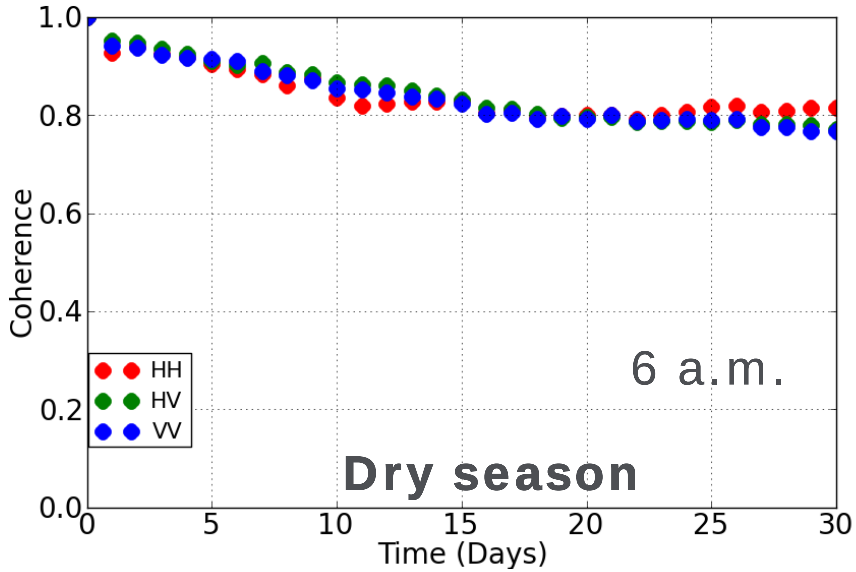
TomoSAR
(30 m layer)

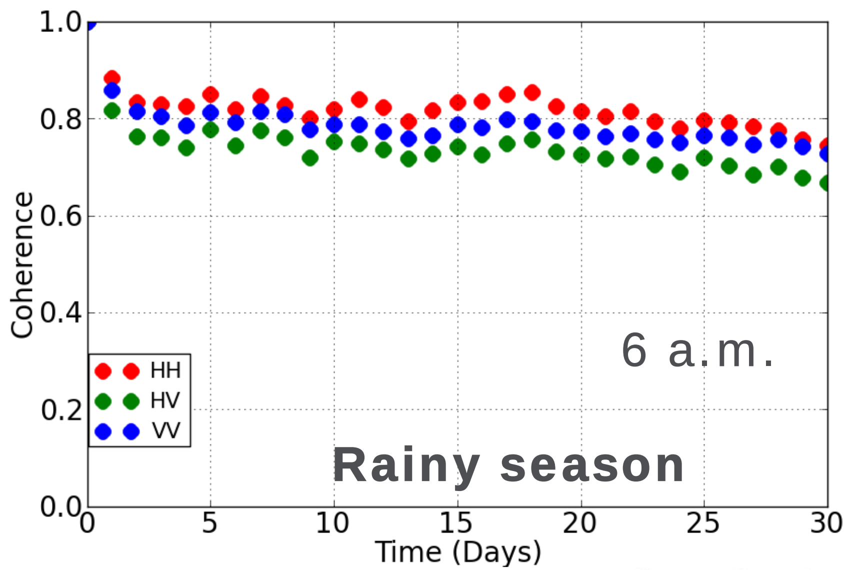


Seasonal variation: coherence is higher in the dry season, giving better height estimates

TropiScatt experiment:

- Tower-based P-band tomographic measurements.
- Measurements every 15 minutes.
- Started December 2011, still running.





Slow variation in backscatter ⟶ PolSAR retrieval must adapt to moisture changes

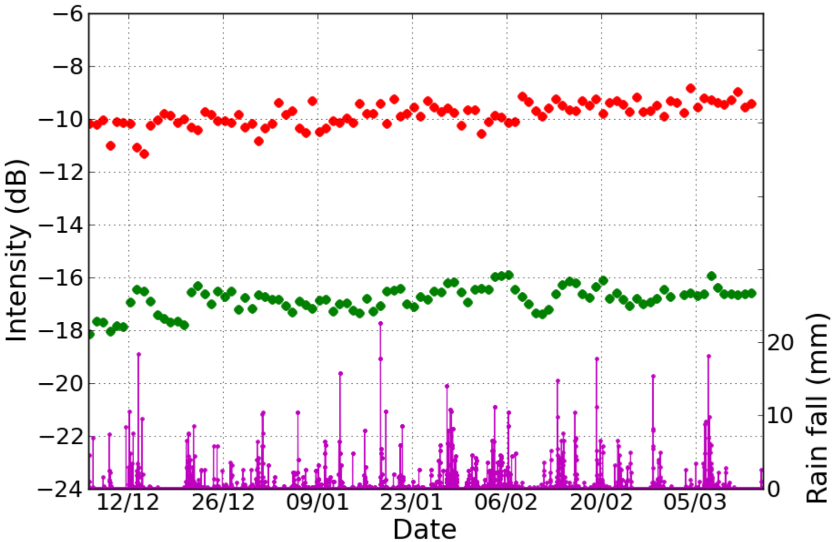
esa

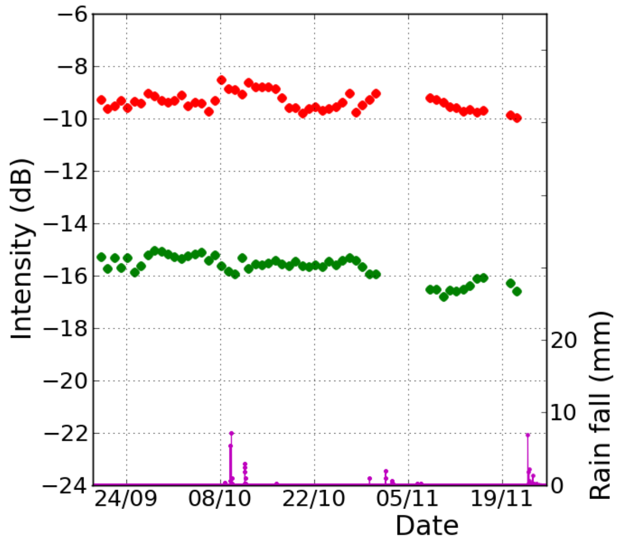
Rainy season 2011-2012

Dry season 2012

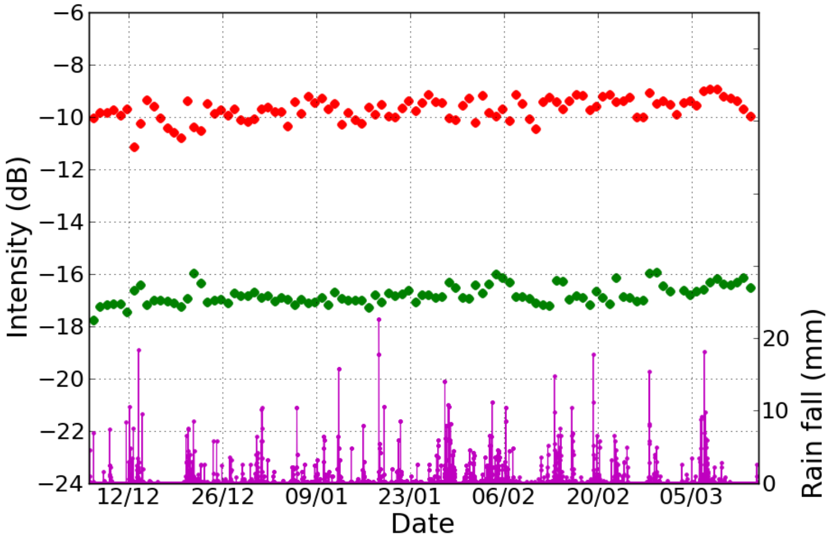
● HH
● HV

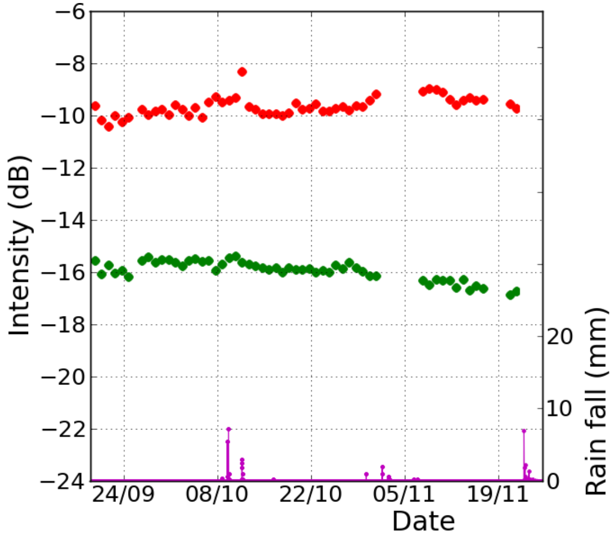
6 am



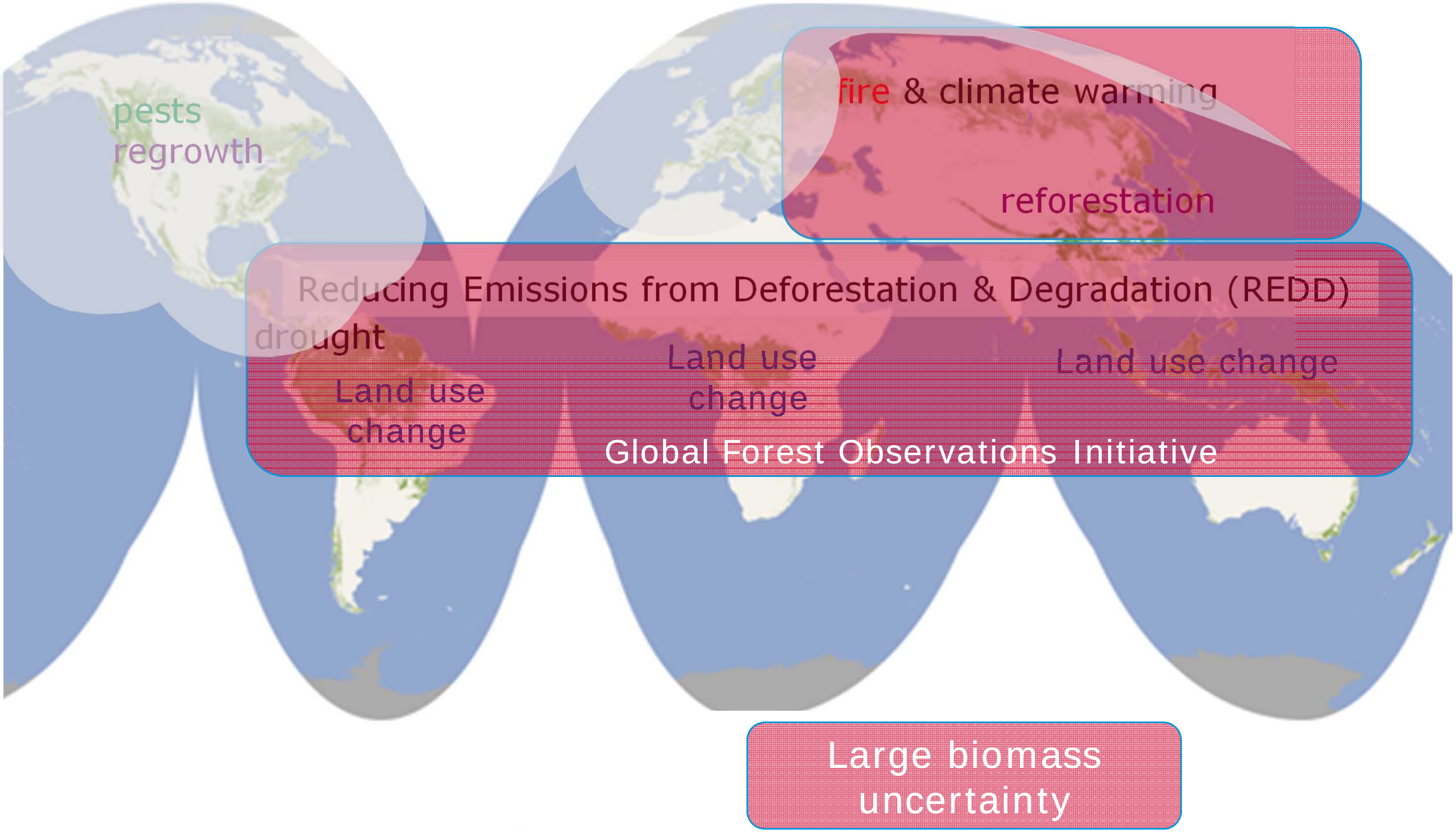


6 pm





Space Object Tracking Radar constraints have little effect on primary mission objectives



Biomass performance: forest summary

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 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 Reference Documents

http://esamultimedia.esa.int/docs/EarthObservation/SP1324-1_BIOMASSr.pdf

http://esamultimedia.esa.int/docs/EarthObservation/EE7_Biomass_Addendum_to_RfS_Final.pdf