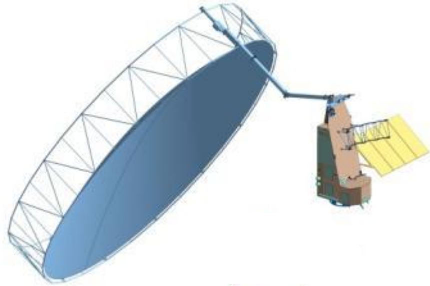
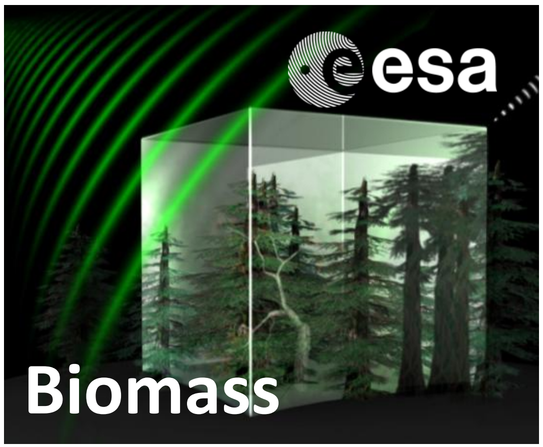




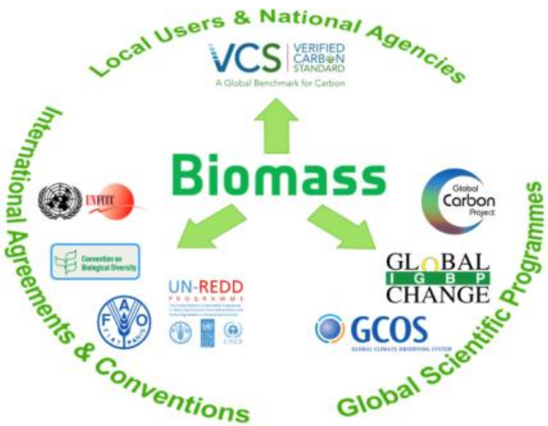
The BIOMASS mission
Quantifying biomass for global carbon assessment

Thuy Le Toan
Centre D'Etudes Spatiales de la Biosphere (CESBIO)
Toulouse, France

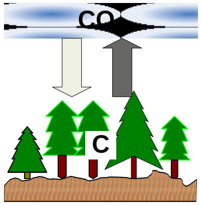
On behalf of the Biomass Mission Advisory Group

Final GlobBiomass User Consultation Meeting, 11-13 September 2017, FAO-Rome, Italy

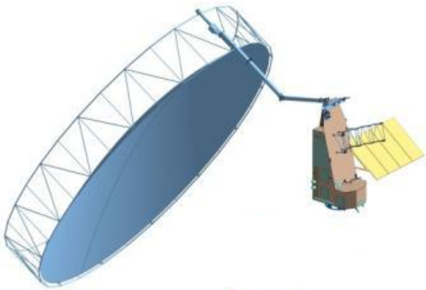
Biomass mission overview



USER SEGMENT



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



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

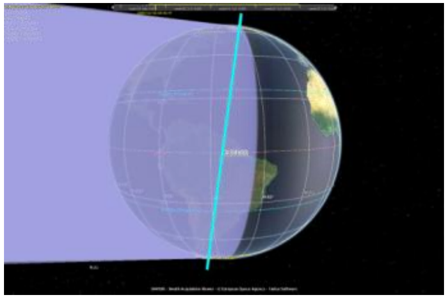
Biomass Mission Elements

GROUND SEGMENT

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

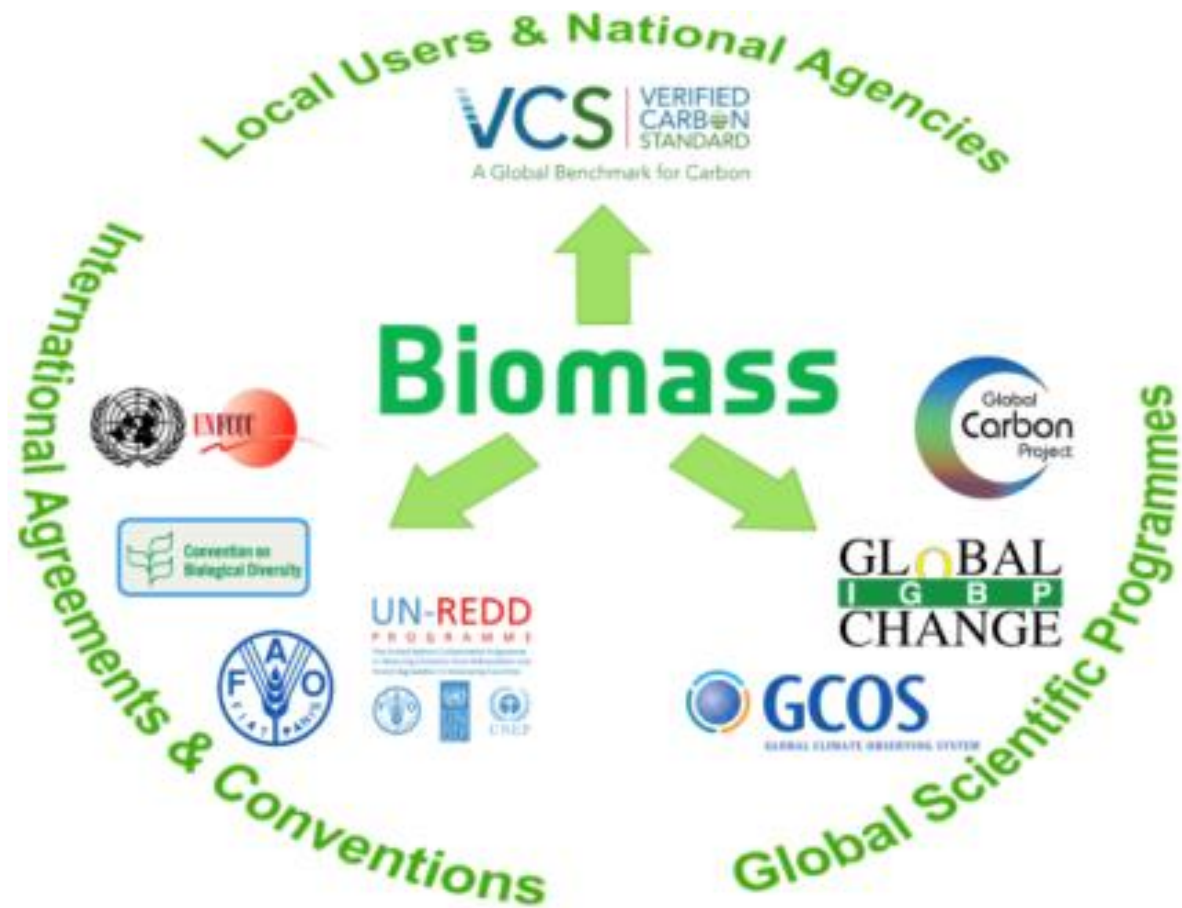
Payload Data Ground Segment
1 Science Data Acquisition Station (Kiruna)
Processing and Archiving Element (ESRIN)
Level-1 and Level-2 data

LAUNCHER
Vega



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

Biomass user communities

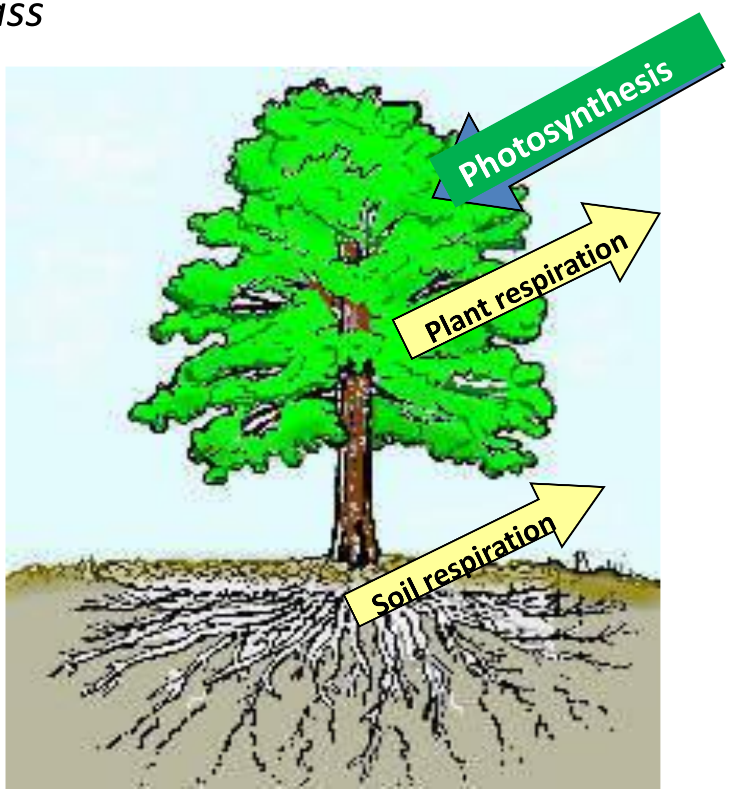


Measuring forest biomass will support
- *The Global Carbon Scientific Programmes*
- *The National Agencies*
- *International Agreements and Conventions*

Forests play a major role in the carbon cycle

Carbon sinks

Photosynthesis uptakes CO_2 from the atmosphere and store it under the form of biomass



Carbon sources

The quantity of burned biomass is directly linked to the amount of CO2 released

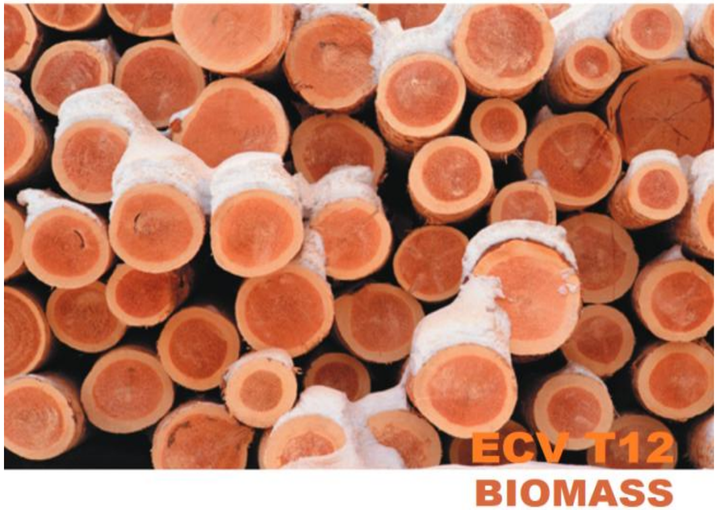
Despite our knowledge of the role of forests, we still have large uncertainties on the spatial distribution, the quantity and dynamics of forest carbon stocks, sources and sinks

We need to measure forest biomass for quantifying carbon sequestration and emission

to

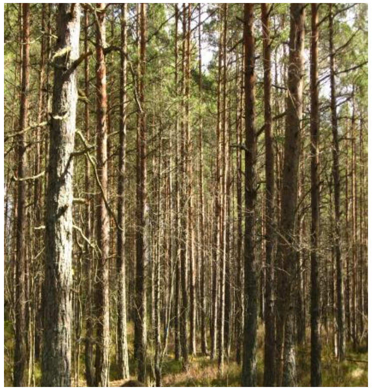
- *accurately model the response of vegetation to climate warming,*
- *plan mitigation and adaptation strategies*

Essential Climate Variables

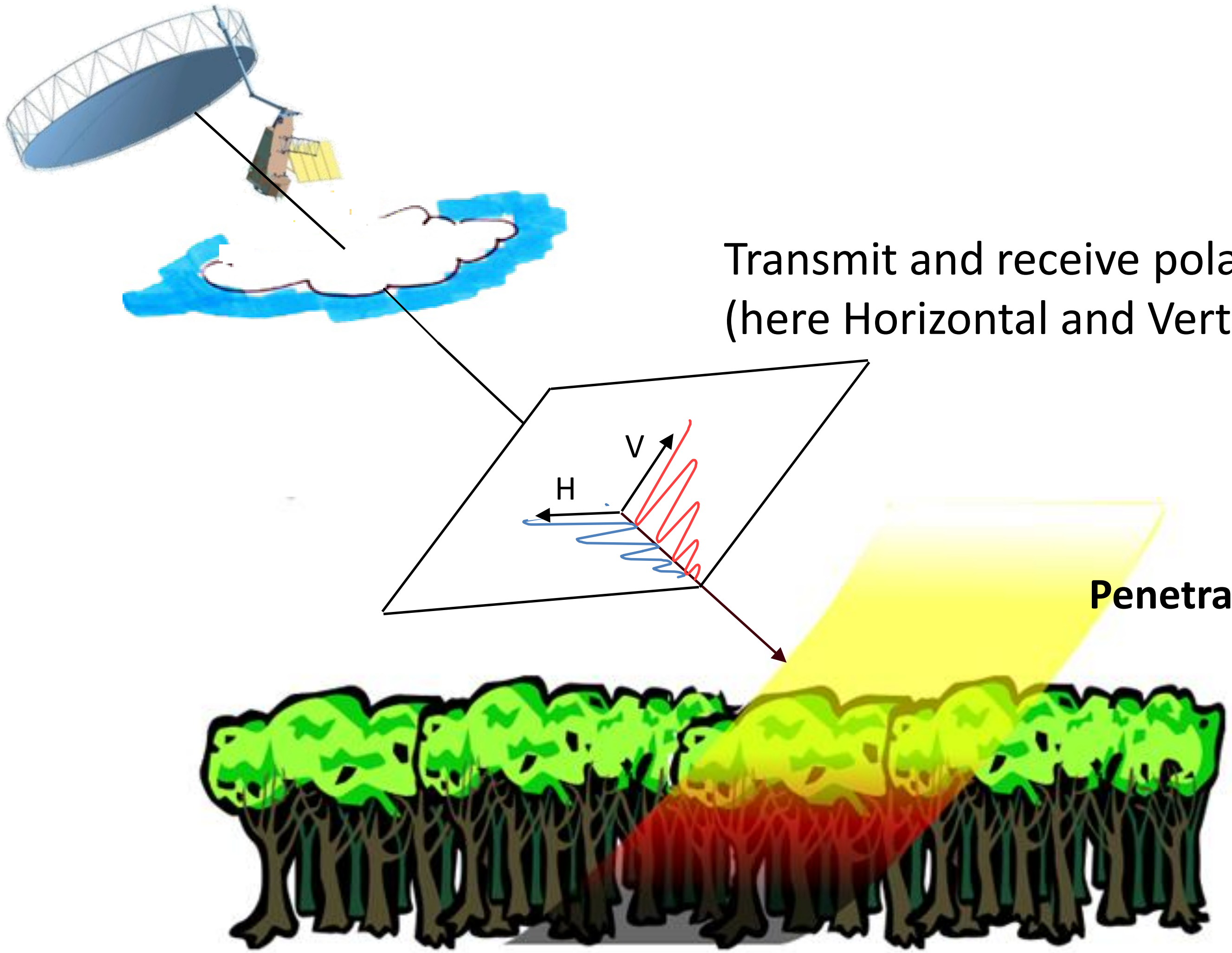


1. Biomass is ~50% carbon
2. Forests hold 70–90% of Earth's above-ground biomass, with the majority of forest biomass located within the Tropics

Biomass = dry weight of woody matter + leaves (tons/hectare)



Why using SARs for forest biomass?



Transmit and receive polarised waves (here Horizontal and Vertical)

Penetrate into the forest cover

How the trees are seen by the SARs ?

Pinus Nigra

X-band
λ= 3 cm
TerraSAR-X
COSMO-SkyMed

C-band
λ= 5 cm
Sentinel-1
RADARSAT

L-band
λ= 27 cm
PALSAR(-2)
NISAR (2022)

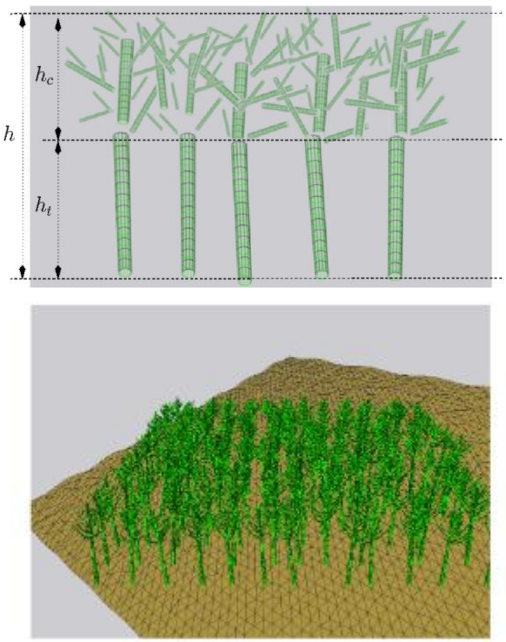
P-band
λ= 70 cm
BIOMASS (2021)

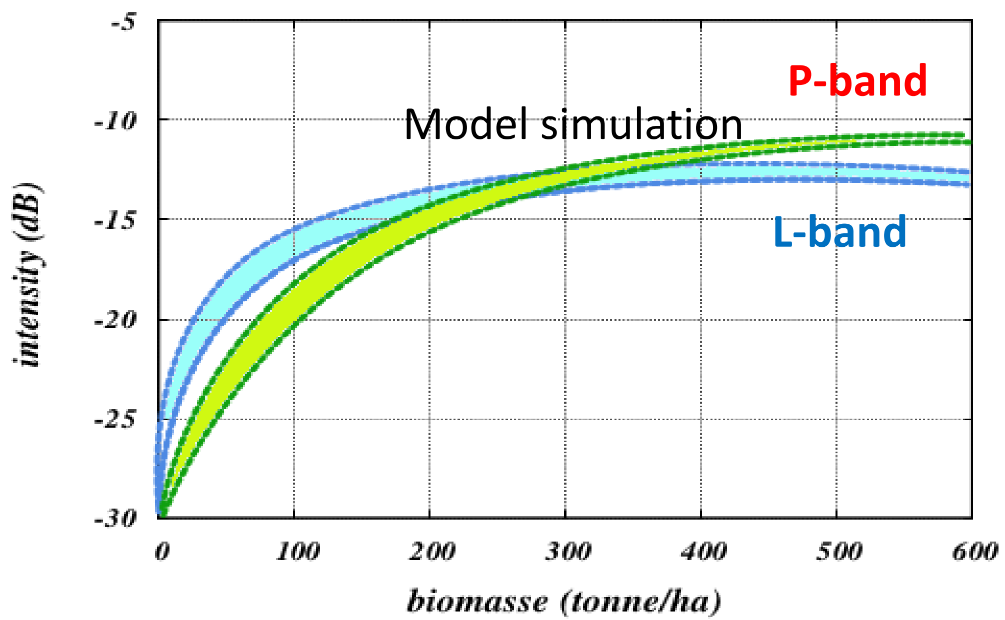
Low frequency SARs: interact with woody tree elements
→ linked to above ground biomass

Research studies established relationships between radar measurements and above-ground biomass

1. Experimental evidence: campaigns conducted in temperate, boreal and tropical forests since early 90s.

2. Physical modelling





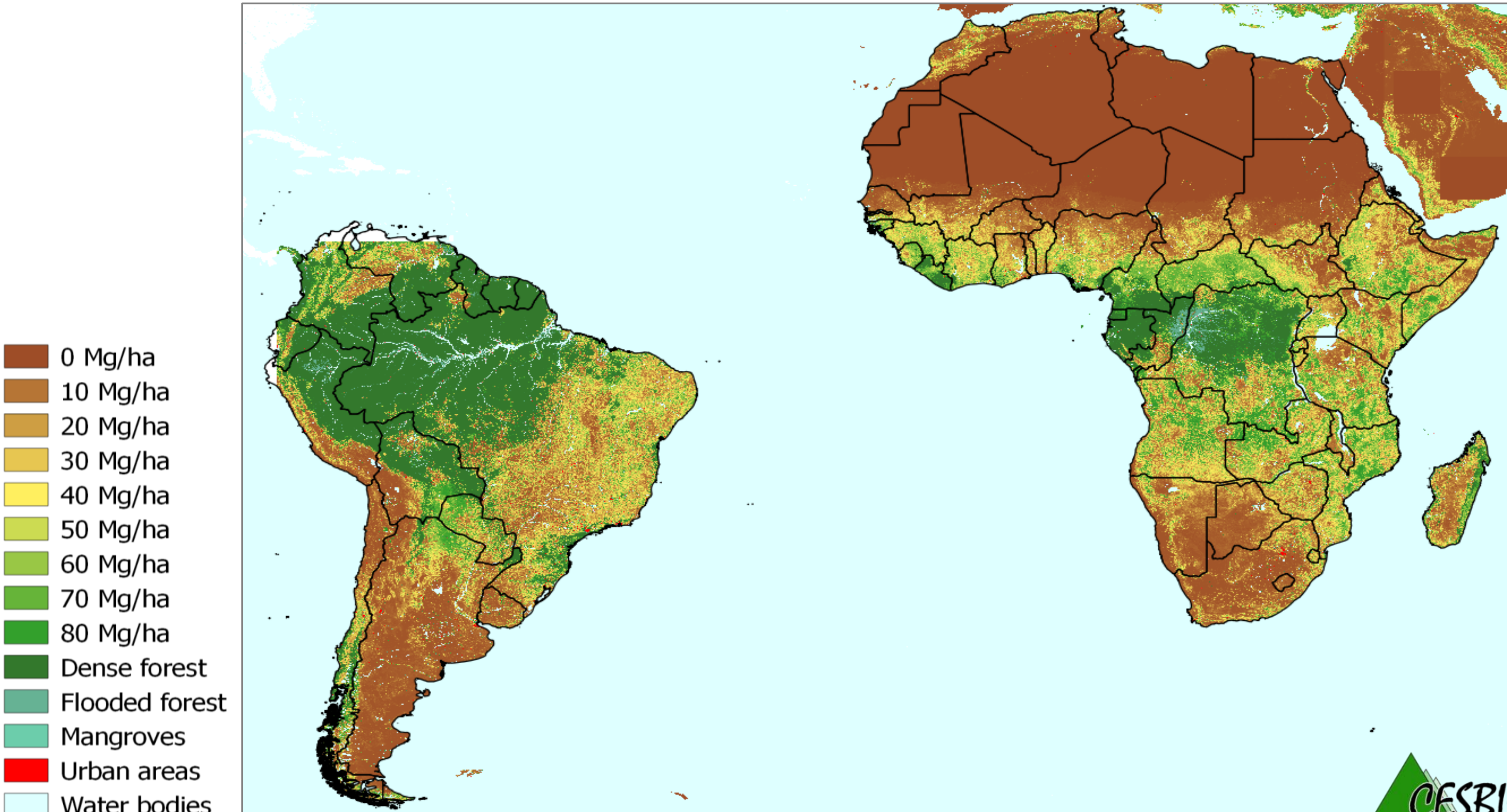
Earlier decrease of sensitivity to biomass at L-band compared to P-band

CESBIO

Biomass mapping using L-band ALOS-PALSAR data for AGB up to 80-100 t/ha

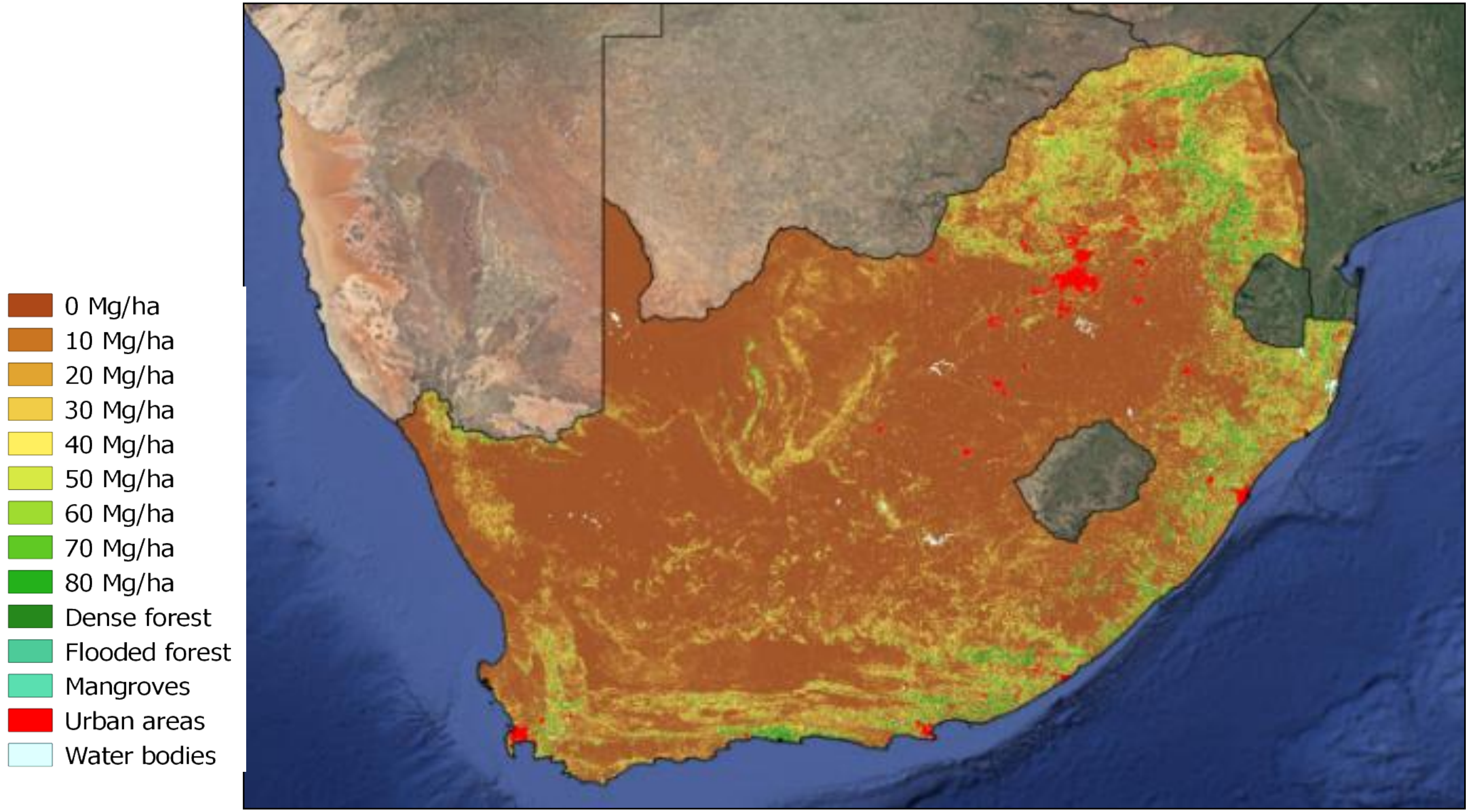
CESBIO Biomass map using ALOS-PALSAR (2010)

Spatial resolution 25 m



CESBIO

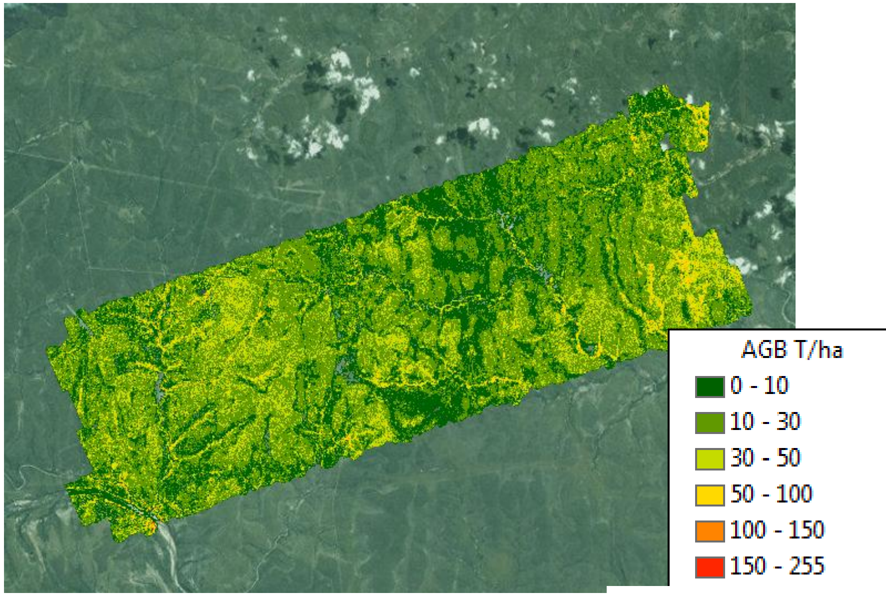
Biomass map of South Africa savanna

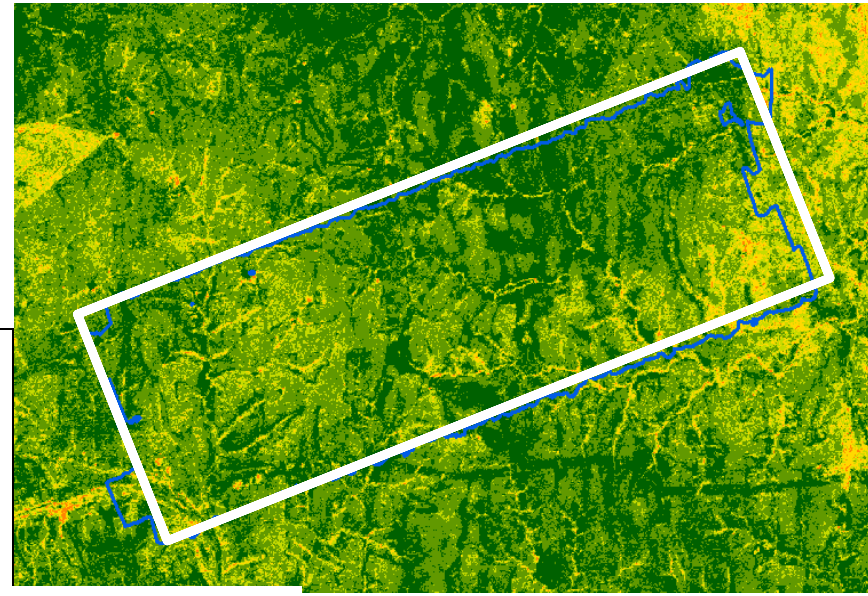


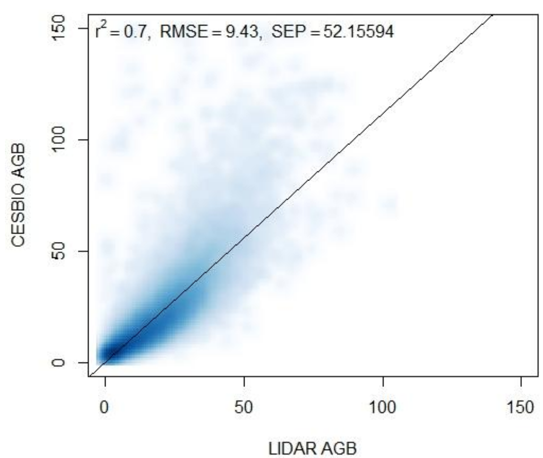
L-band SAR provides mapping of biomass in woody savannah

Biomass map derived from **airborne LiDAR**

CESBIO biomass map from **ALOS PALSAR**







R^2=0.7, RMS= 9.43 t/ha

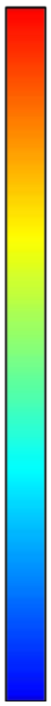
GLOBBIOMASS

CSIR

CESBIO

Bouvet, A. Mermoz, S., Le Toan T., Villard, L., Mathieu, R., Naidoo, L.. **(2017),**. An above-ground biomass map of African savannahs at 25 meters resolution derived from ALOS PALSAR. RSE

For tropical forests biomass, no dedicated sensors

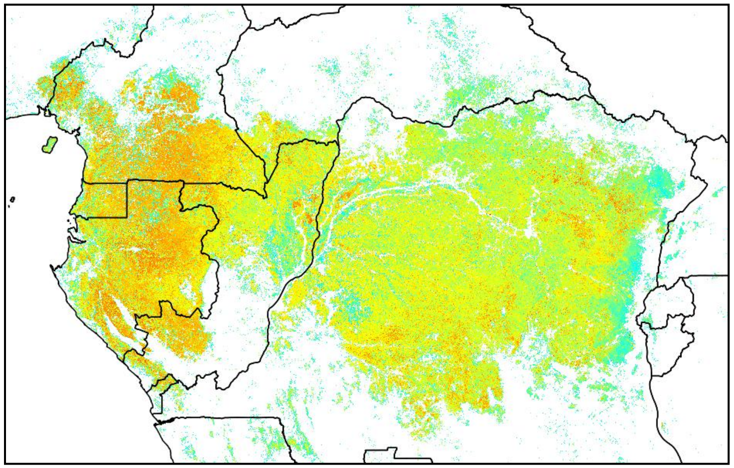


Fair agreement between existing biomass maps

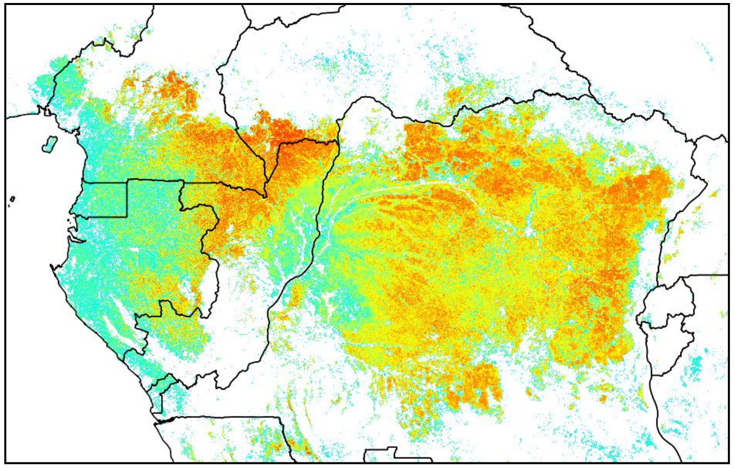
Based mainly on IceSAT/GLAS , MODIS and in situ data

The Congo basin

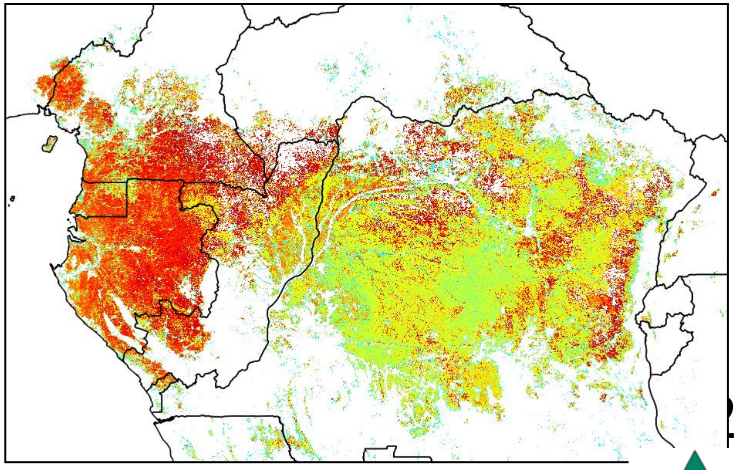
AGB map at 1 km – Saatchi et al.



AGB map at 500 m – Baccini et al.



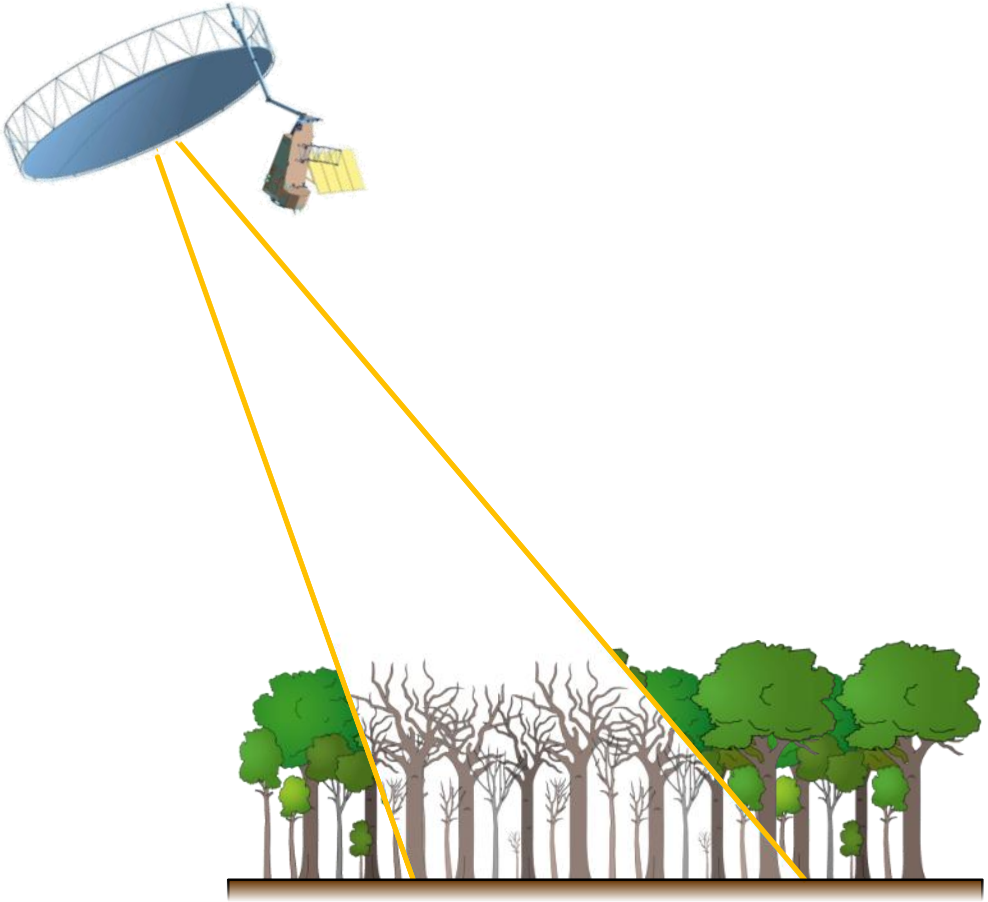
AGB map at 1 km – Avitabile et al.



What SAR system to measure biomass of all forest biomes?

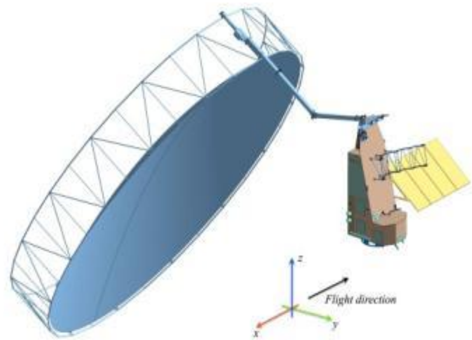
Mapping forest biomass requires a radar sensor with long wavelength:

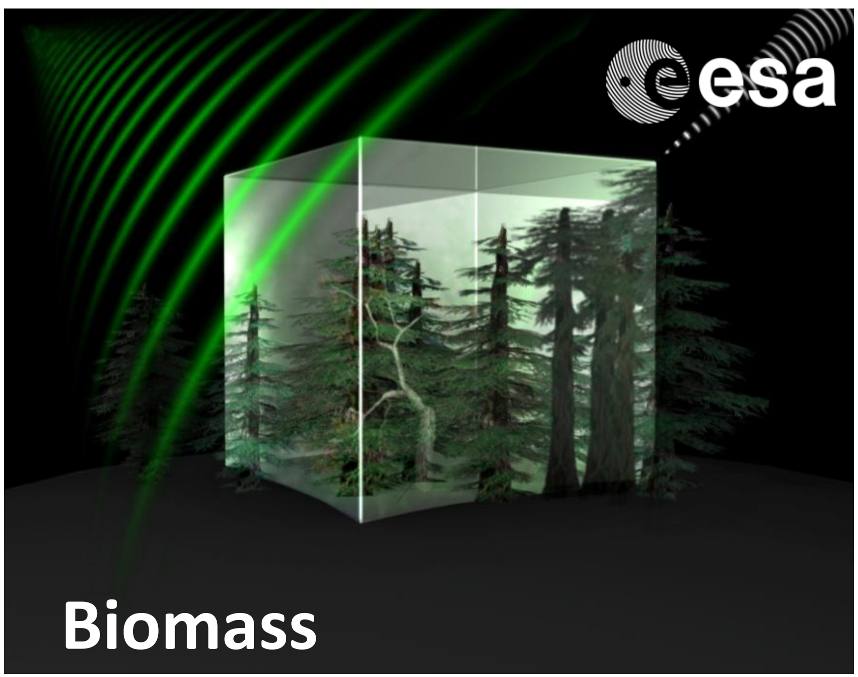
1. to penetrate the canopy in all forest biomes
2. to interact with woody vegetation elements
3. to enable repeat pass interferometry with a single satellite for advanced measurement techniques



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

The Biomass mission was proposed to measure forest biomass





- ESA 7th Earth Explorer mission
- To observe forests of different biomes but focus is on tropical forests, the most critical biome in terms of carbon budget
- To be launched in 2021

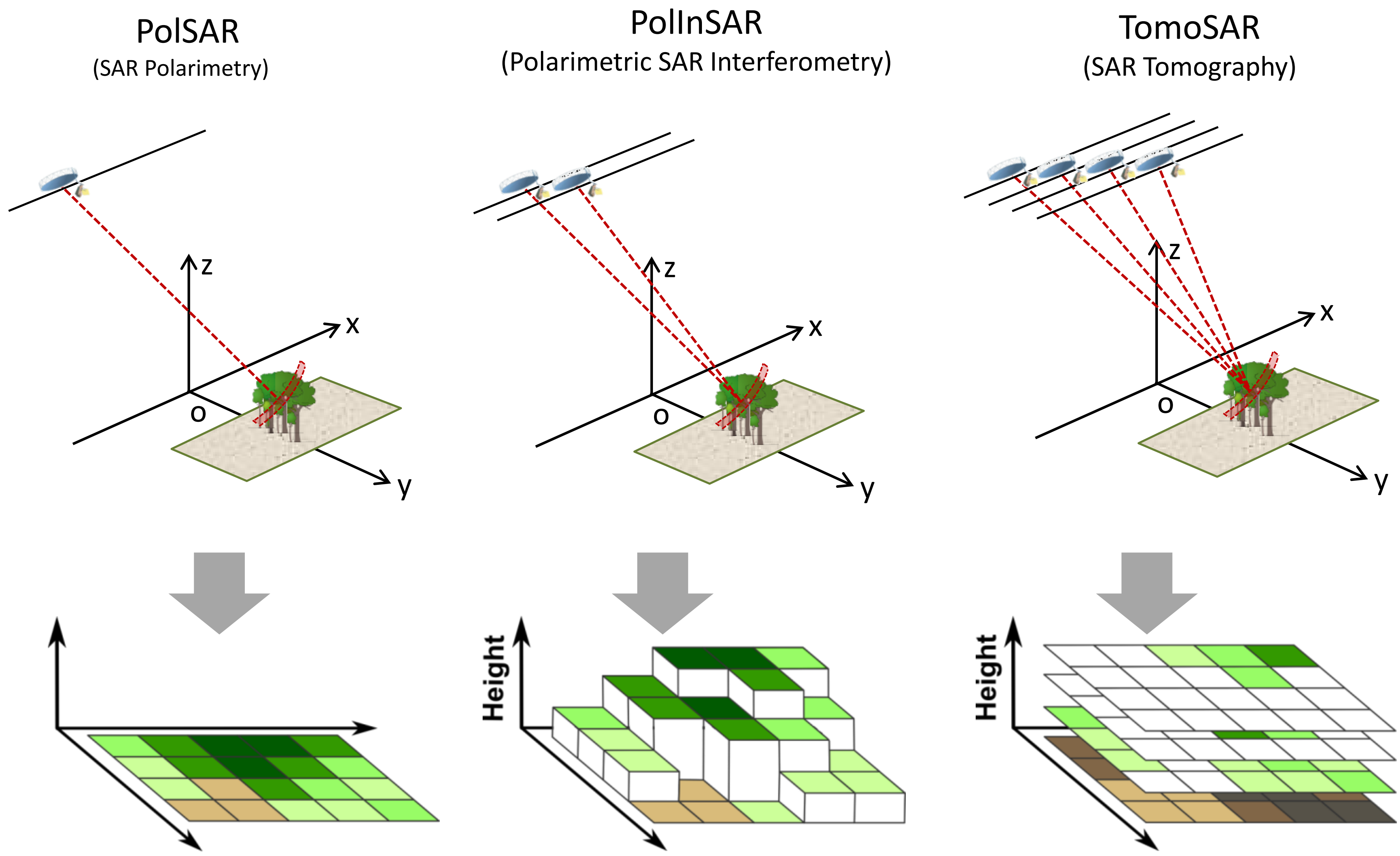
Objective:
To reduce uncertainties in the spatial distribution, the quantity and dynamics of forest carbon stocks, sources and sinks

BIOMASS will map global forest biomass and forest height

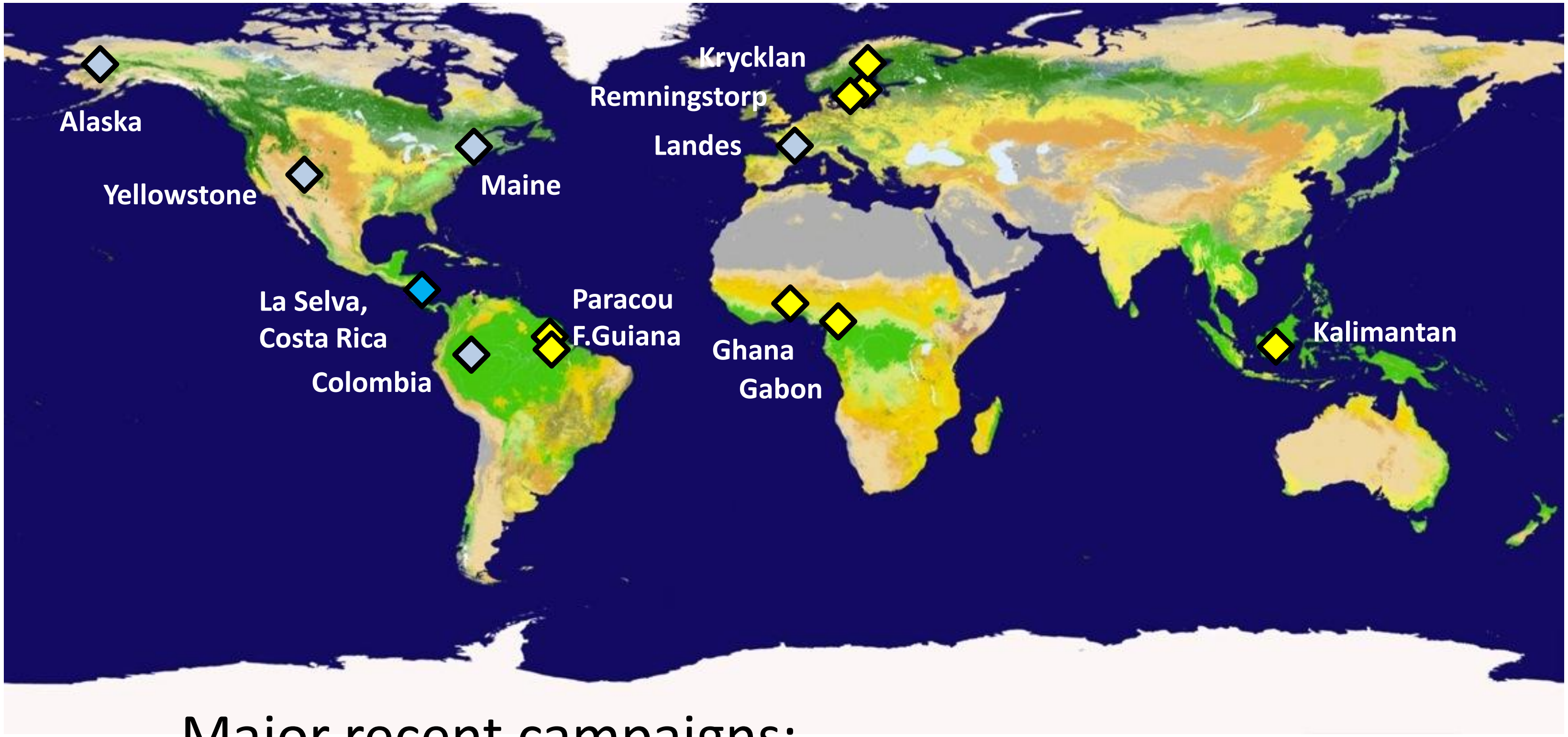
Forest biomass **Forest height** **Disturbances**

1. The **crucial information need** is in the tropics: deforestation (~95% of the Land Use Change flux), regrowth (~50% of the global biomass sink)
2. Biomass accuracy of 20% at 4 hectares
3. Detection of **deforestation at 0.25 ha**
4. **Repeated measurements** over multiple years to identify deforestation and growth

BIOMASS combines advanced techniques to enhance retrieval performances



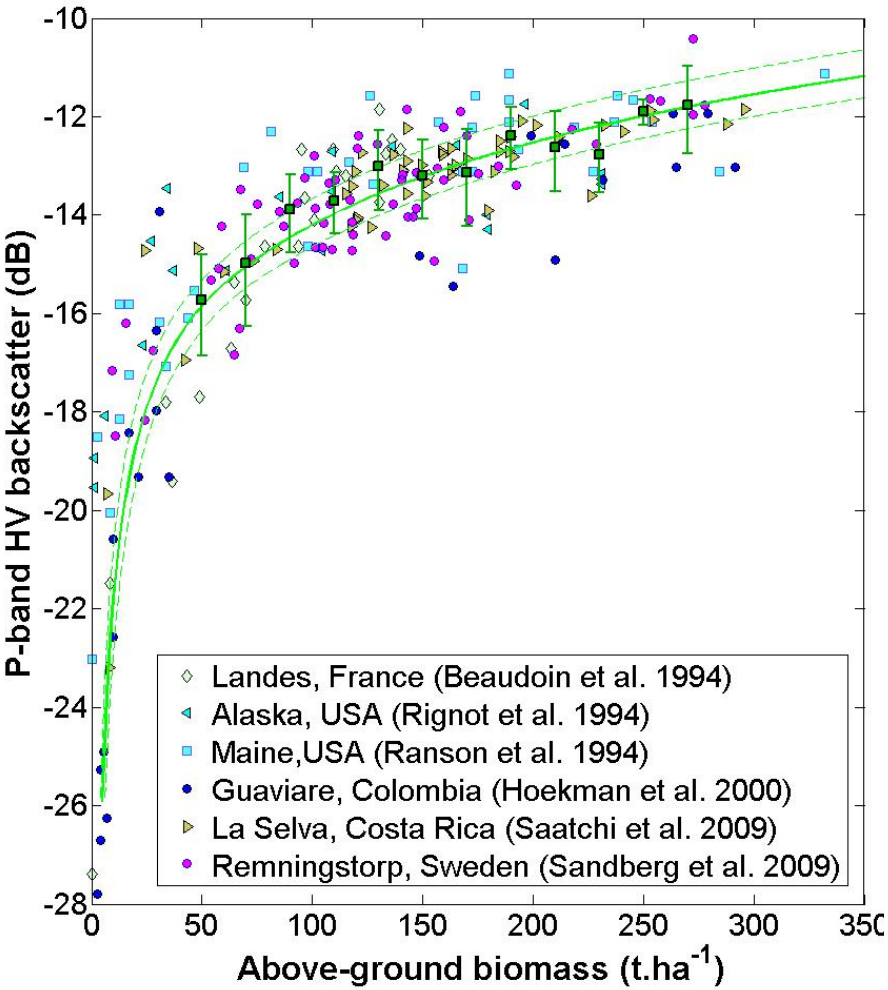
Campaigns used to develop observation concept



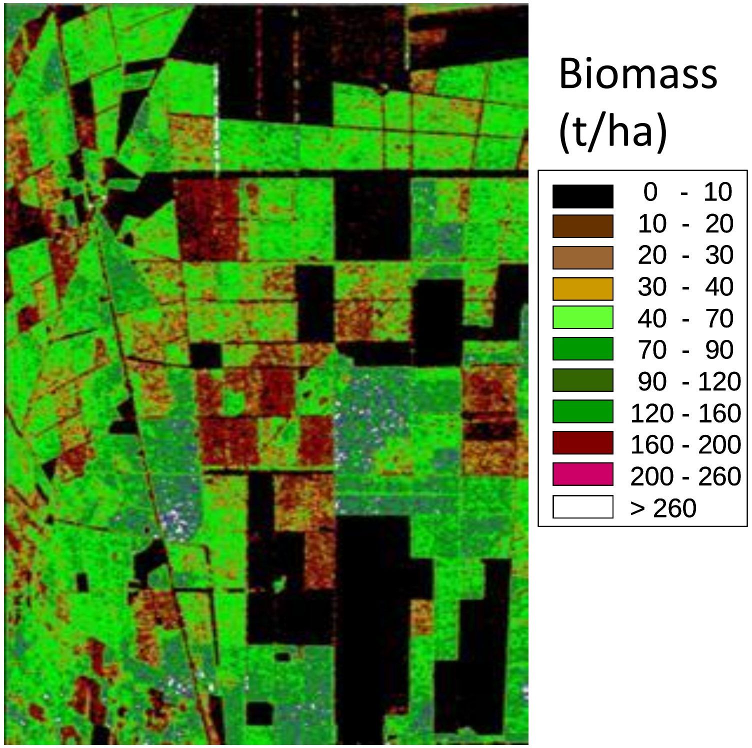
Major recent campaigns:

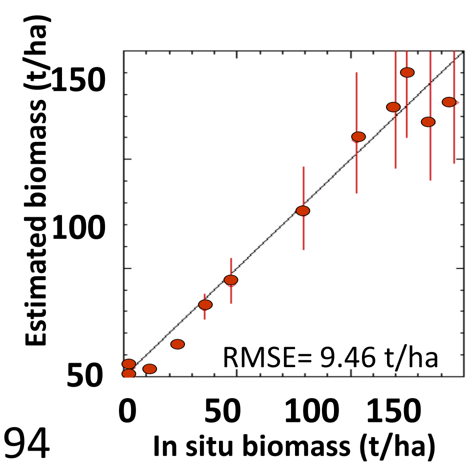
1. F. Guiana 2009 (TropiSAR), 2011-13 (TropiScat)
2. Gabon (AfriSAR) 2015, 2016
3. Ghana (AfriScat), 2016-2017

PolSAR: past experimental results showed consistency in the SAR intensity-biomass relationship



Le Toan et al., RSE 2011

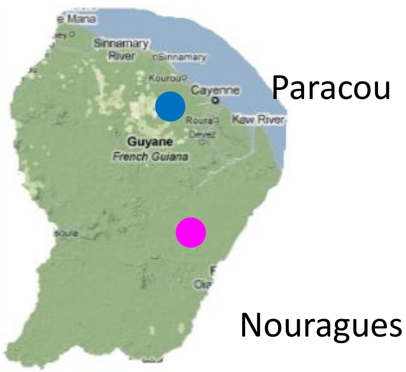




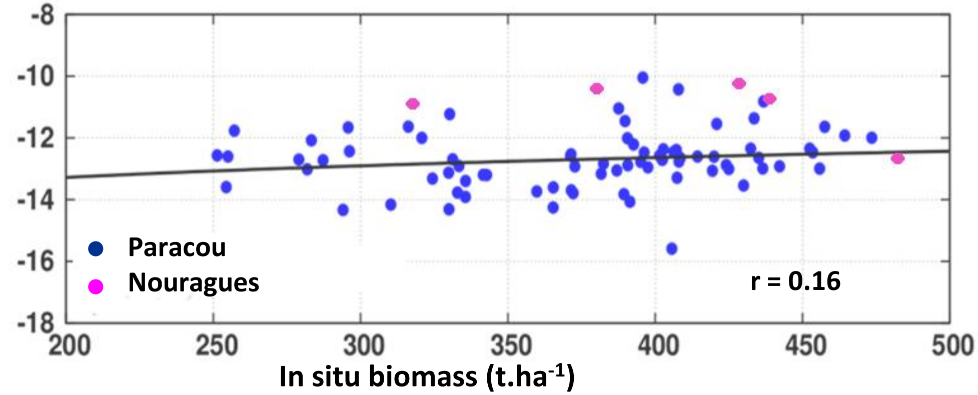
Beaudoin et al., 1994

POLSAR: For high biomass, topography (and other effects) obscure the SAR sensitivity to AGB

Tropical forest,
French Guiana

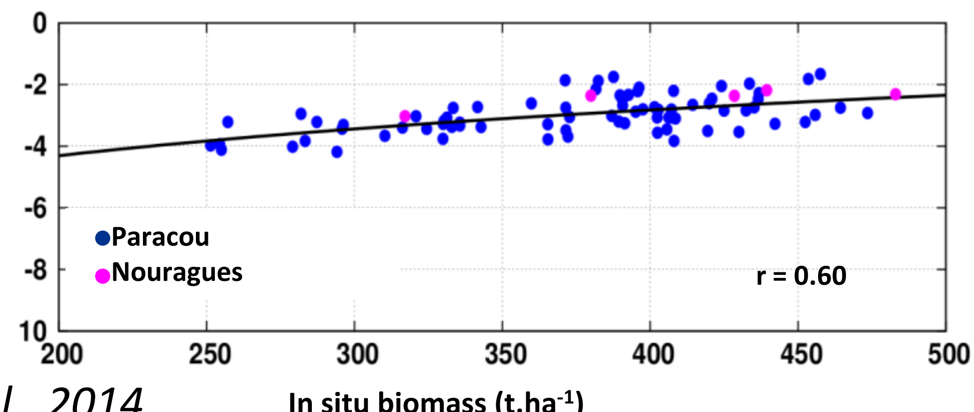


Backscatter at single polarisation (HV) in dB



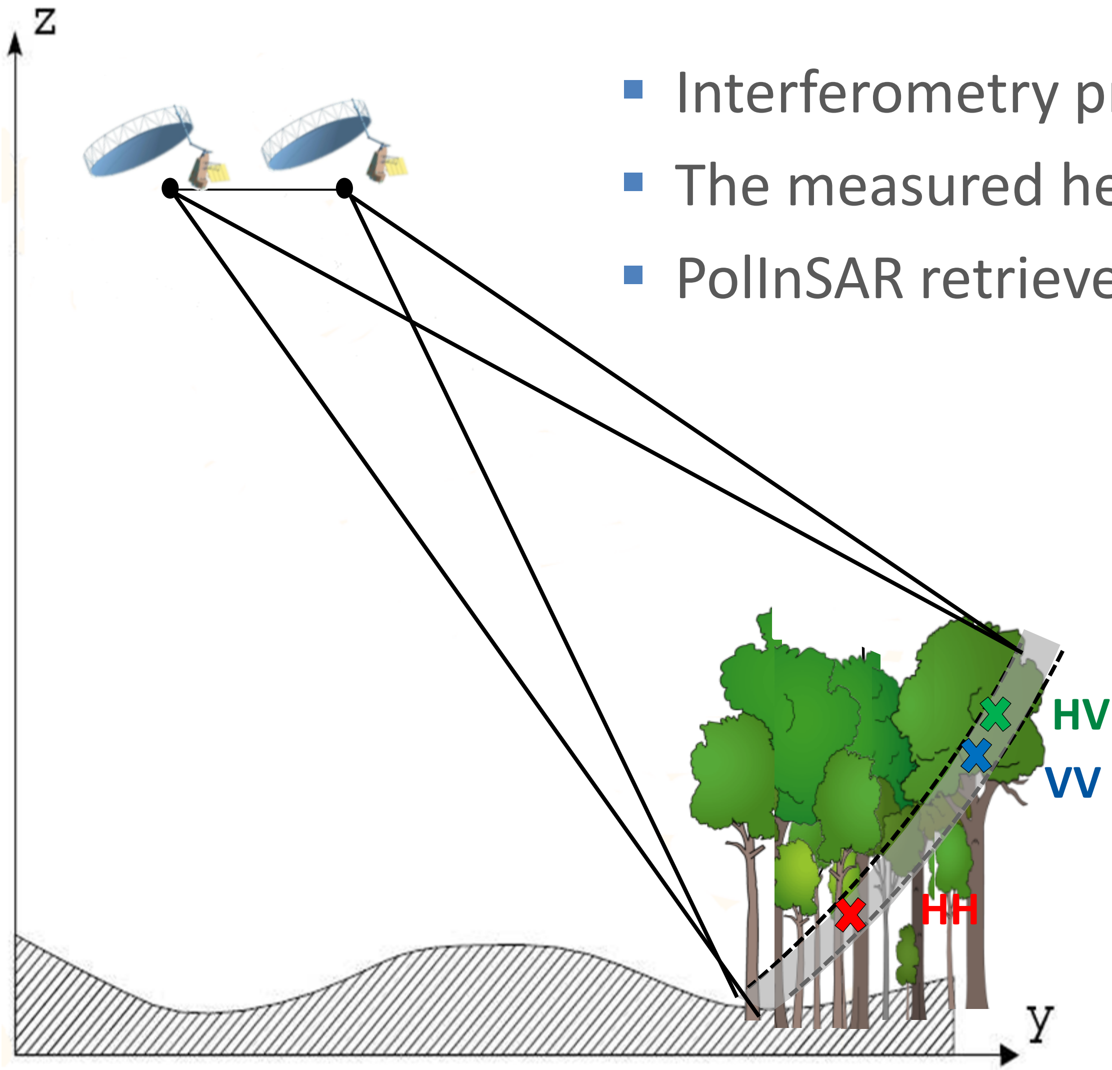
Correction for topographic effects and scattering mechanisms using polarimetry and a DEM.

Polarimetric biomass indicator (dB)



Villard et al., 2014

Pol-InSAR provides the canopy height estimates



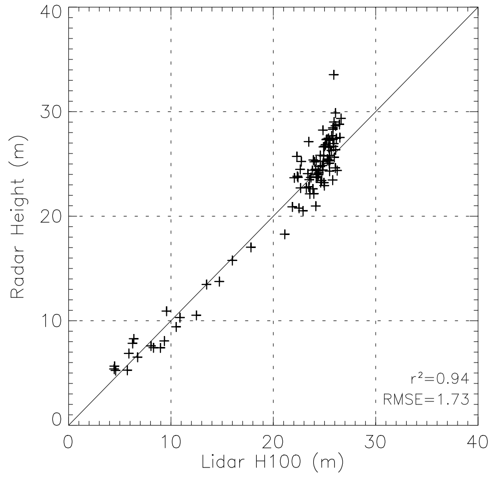
- Interferometry provides height information
- The measured height depends on polarisation
- PolInSAR retrieves canopy height using models

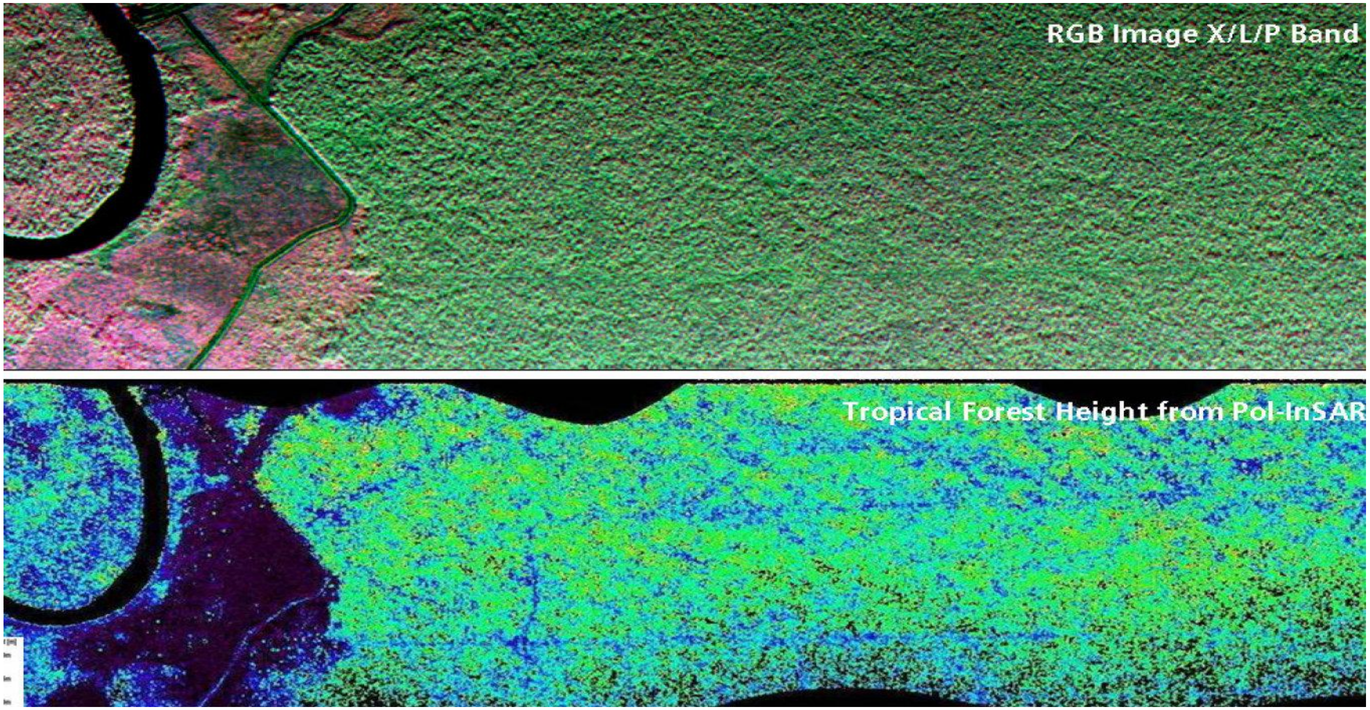
Key requirement:

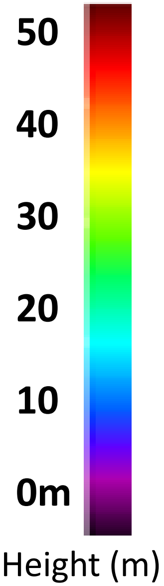
High temporal correlation between two images, hence P-band is essential

PolInSAR provides the canopy height estimates

Hajnsek et al., IEEE GRS 2009





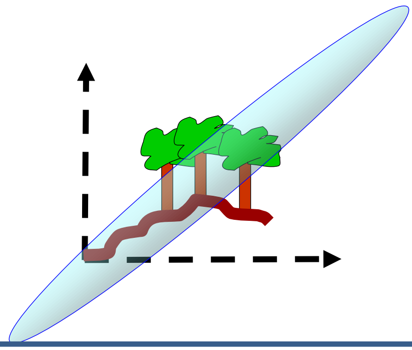


Peat Swamp forest, Mawas, Kalimantan

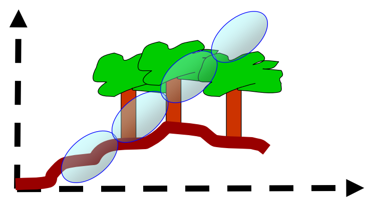
TomoSAR provides 3 D images of the forests

Tomography generates images of different forest layers from multi-orbit SAR acquisitions

SAR resolution cell

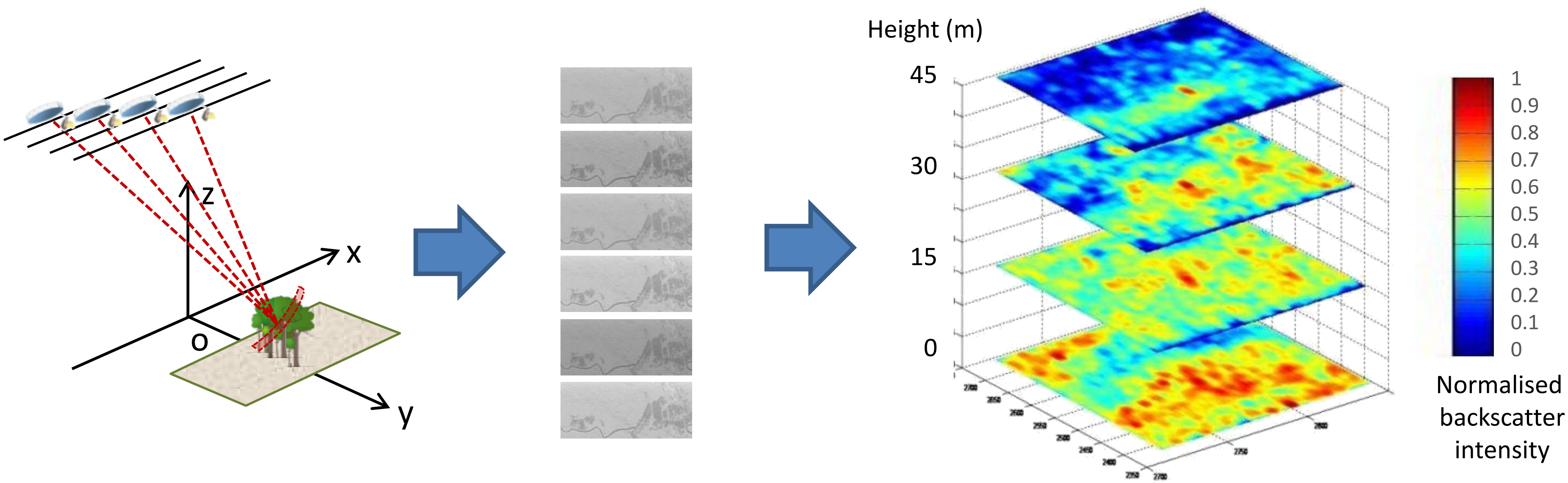


SAR Tomography resolution cell

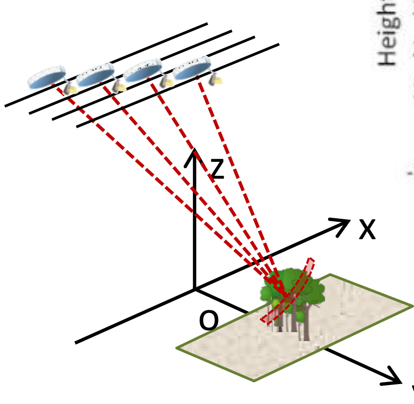


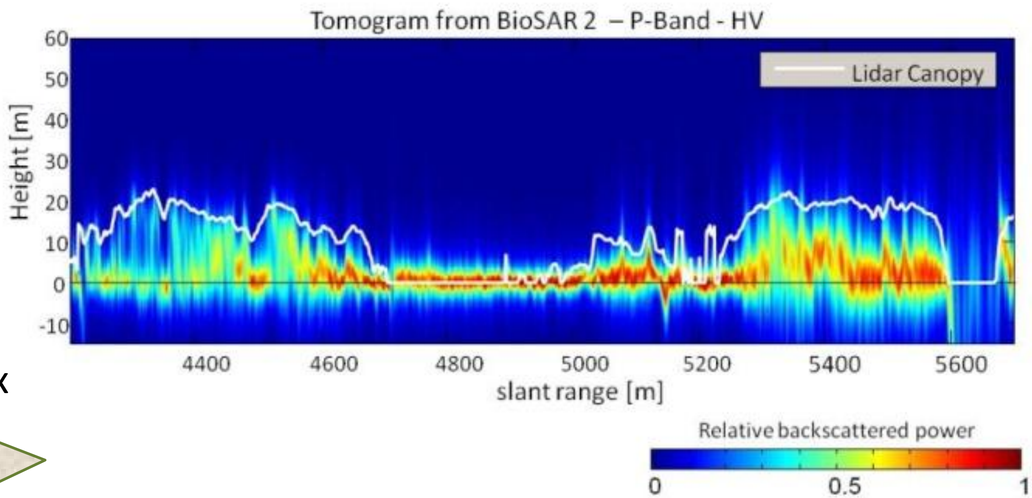
Enables Isolation of:

- Canopy
- Ground
- Topography

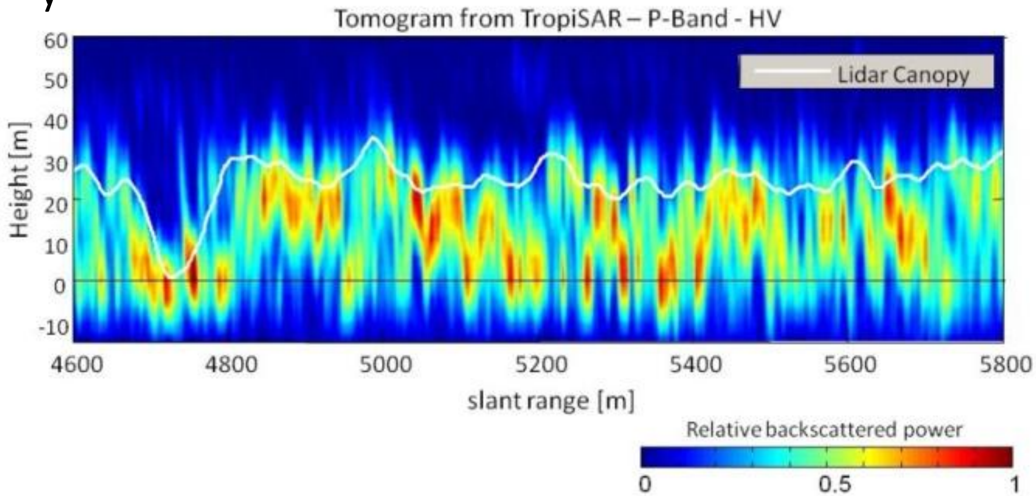


TomoSAR provides 3 D images of the forests



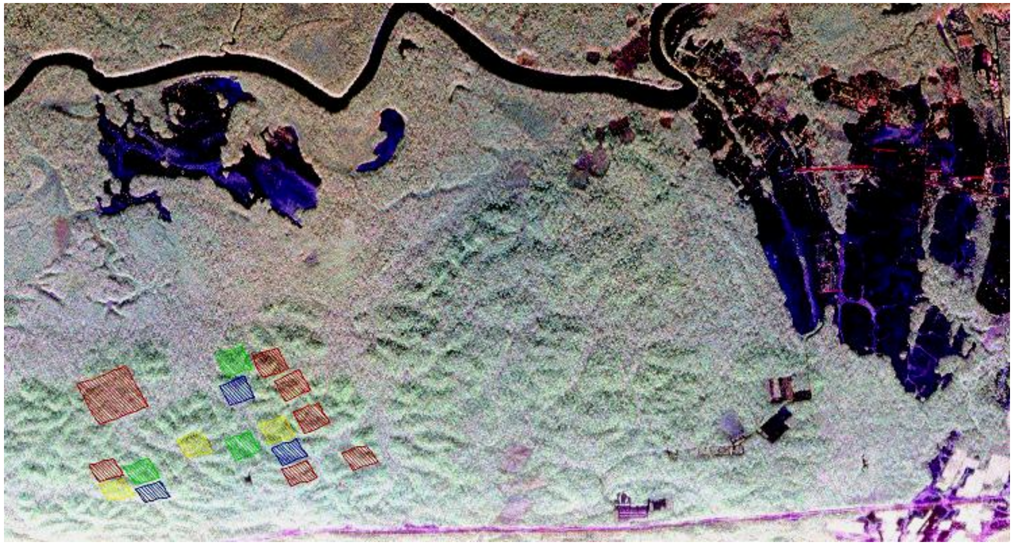


Boreal forest
Kryclan, Sweden

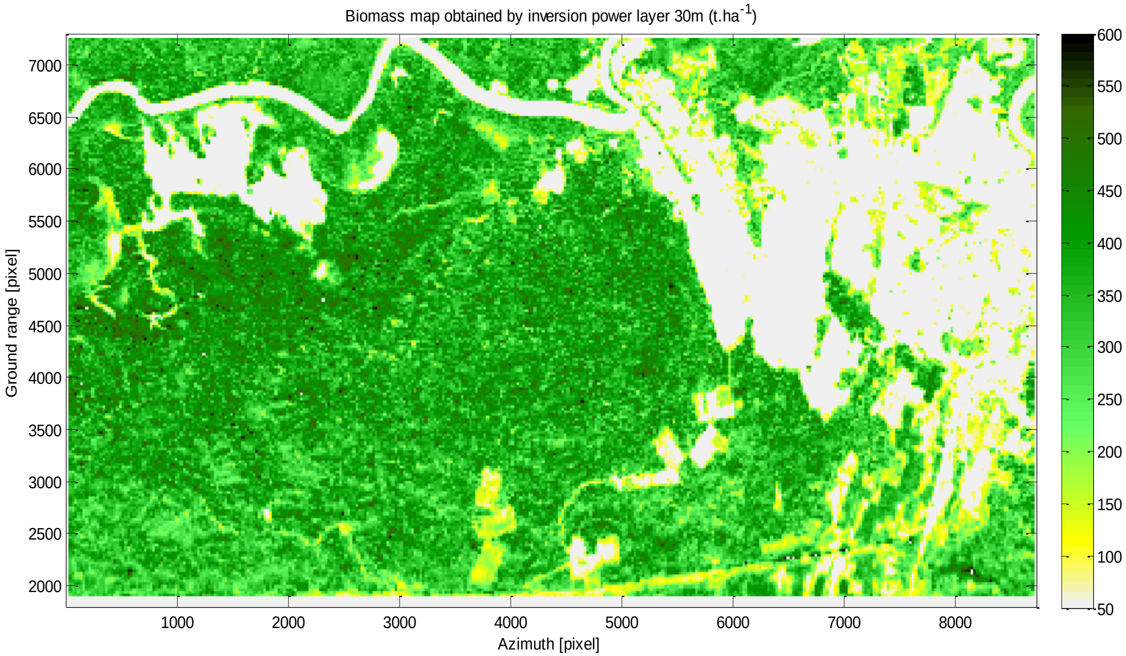


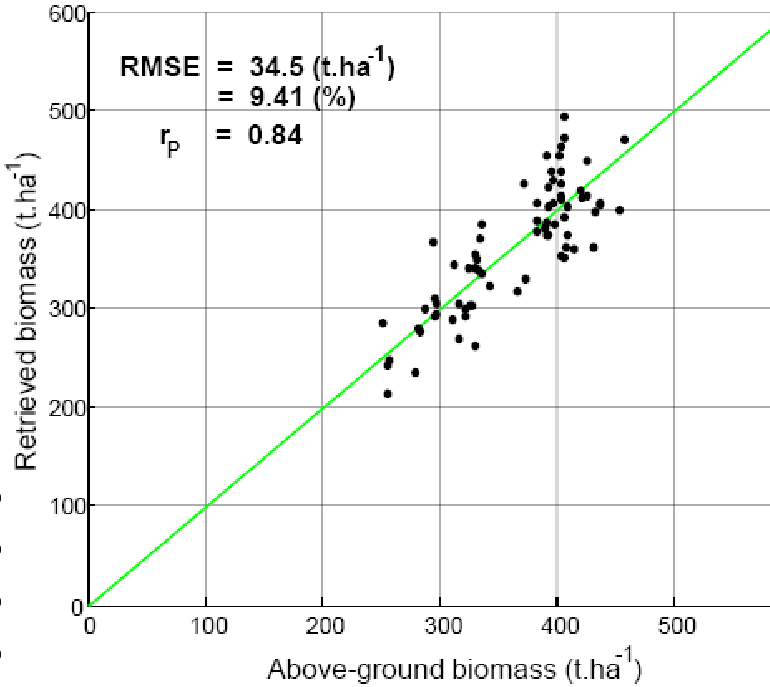
Tropical forest
Paracou, French Guiana

SAR Tomography provides high accuracy biomass maps



P-band SAR image





Ho Tong et al., 2015, 2016

BIOMASS map at 50 m, by tomography

The recent AfriSAR campaign in Gabon, Africa

1. Testing, comparing algorithms on 4 tropical forest sites
2. P- and L-band PolInSAR and TomoSAR
3. Flights in July 2015 and February 2016 to test seasonal variations
1. NASA collaboration on 2016 flights with the LVIS and UAVSAR systems
2. Other data:
   - Airborne small footprint lidar
   - Plot data
   - Soil moisture
   - TanDEM-X

Sethi-ONERA P-band
(F: 430 Mhz, B: 50 Mhz)

FSAR-DLR P-band
(F: 435 Mhz, B: 50 Mhz)

esa
European Space Agency
Agence spatiale européenne

AGEOS

Parcs Gabon

ONERA
THE FRENCH AEROSPACE LAB

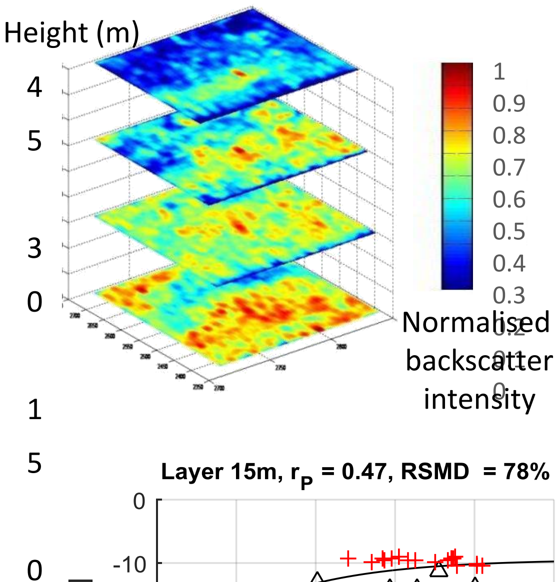
DLR Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center

NASA

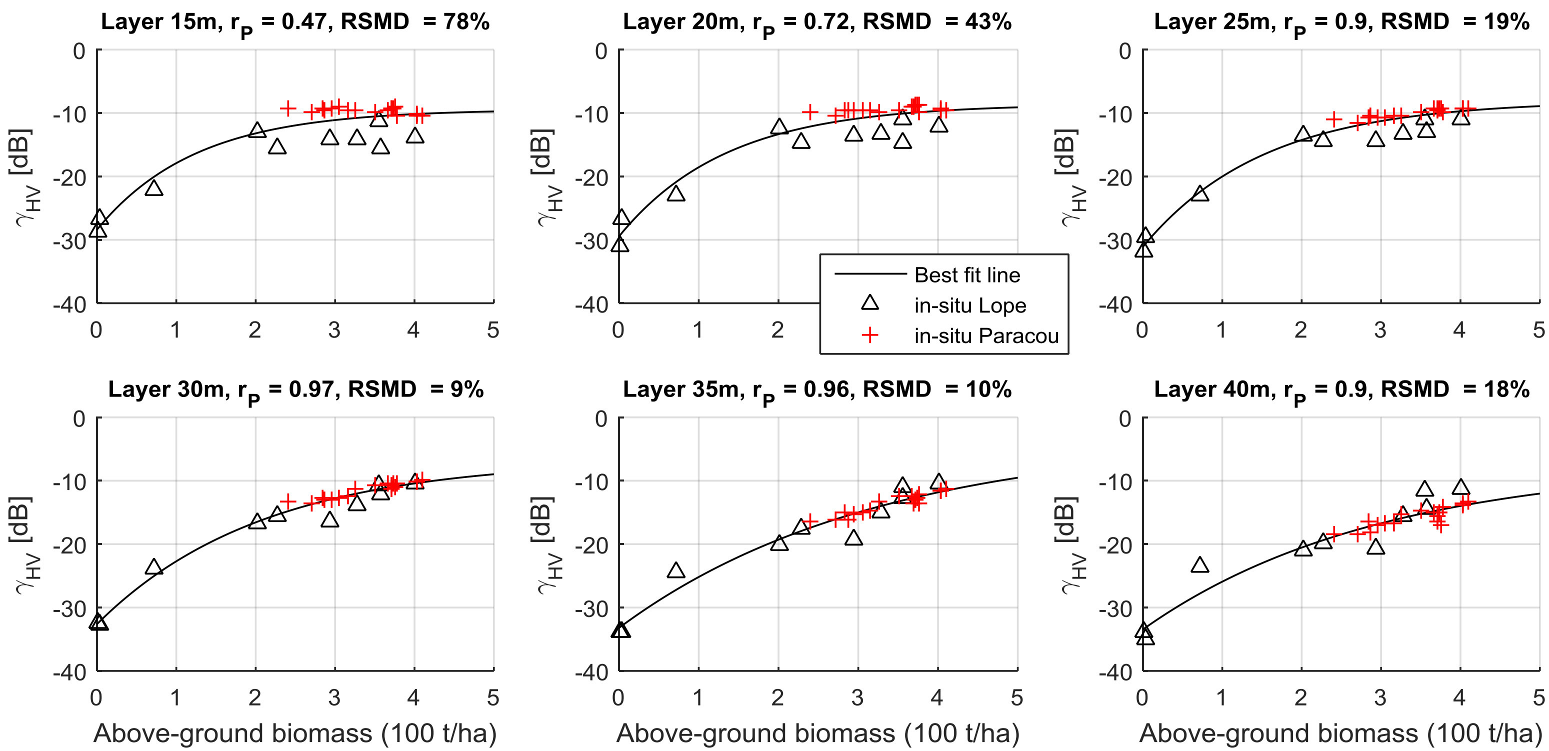
UCL

CESBIO

Consistent measurements in French Guiana and in Gabon



HV intensity of TomoSAR layers at 15, 20, .., 35, 40 m
Red: French Guiana (2009)
Black: Gabon (2015)



Tower based experiments to test long term variation of the SAR measurements

1. Static tower-based radar observing a forest
2. Automatic and systematic acquisitions of fully polarimetric data (HH, HV, VH and VV)
3. Tomographic capability (to have a vertical discrimination of backscattering mechanisms)
4. Associated with in situ measurements

Tropiscat

- **Experiment in French Guiana**
- **Measurements every 15 mn**
- **Started in 2011 , end 2013 (with interruptions)**

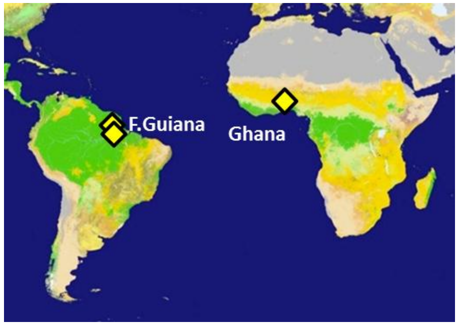
Afriscat

- **Experimentna in Ghana**
- **2 x 3 hours per day: 4:30-7:30 am/pm**
- **Started on 20/07/2015, end 4/05/2017**

esa European Space Agency Agence spatiale européenne

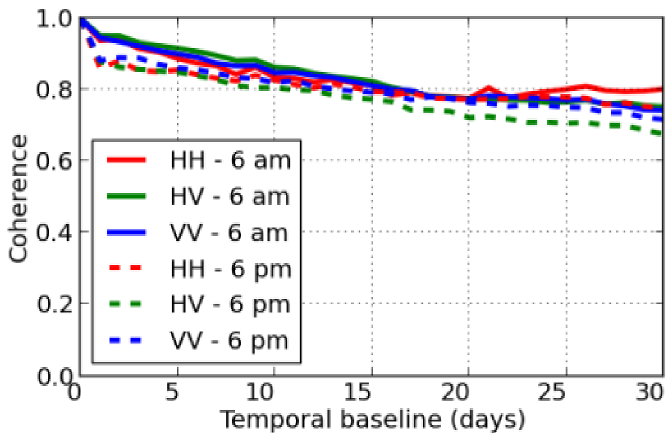
CESBIO ONERA THE FRENCH AEROSPACE LAB POLITECNICO MILANO

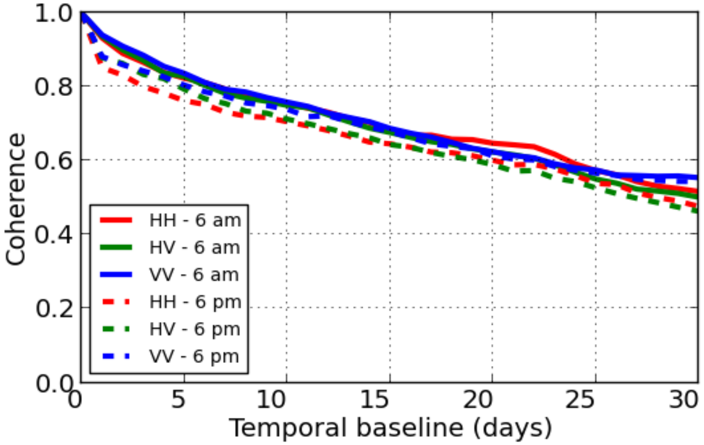
Measure of long term coherence for Biomass repeat pass interferometry

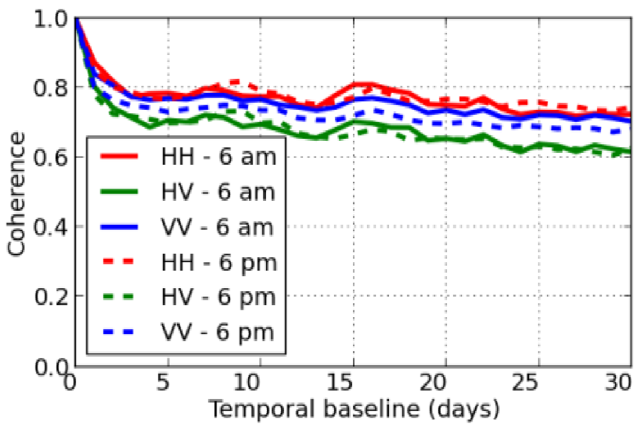


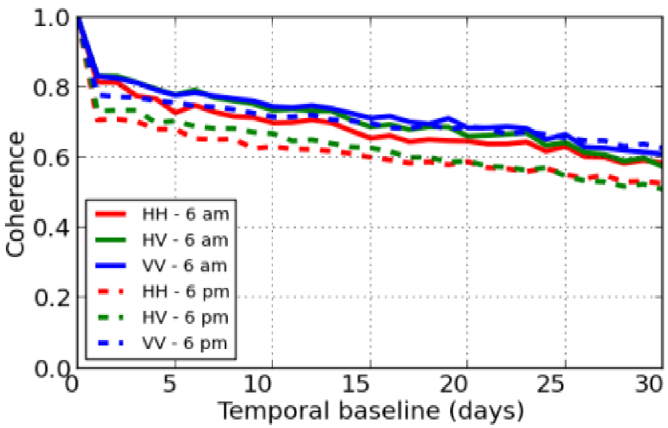
TropiScat (French Guiana)

AfriScat (Ghana)



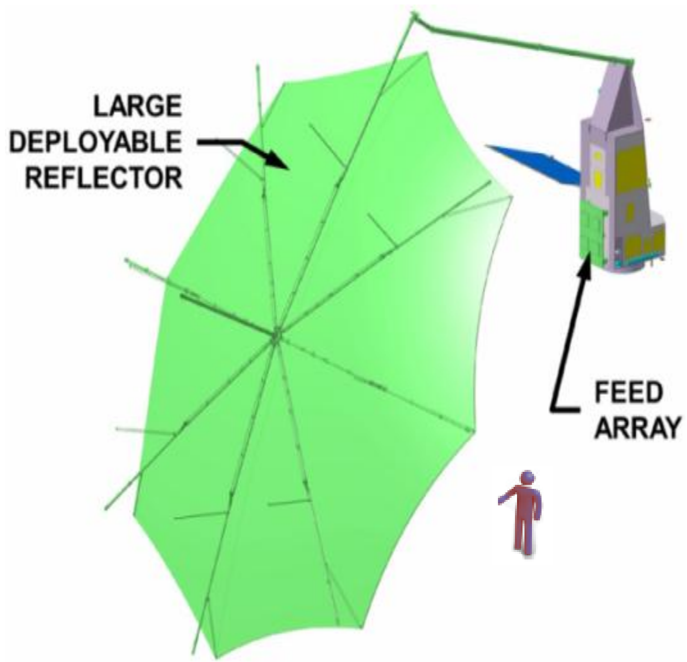






Biomass mission key parameters

Key Parameters	
Sensitivity (NESZ)	≤ -27 dB
Total Ambiguity Ratio	≤ -18 dB
SLC resolution	≤ 60m x 8m
Dynamic Range	35 dB
Radiometric Stability	≤ 0.5 dB
Radiometric Bias	≤ 0.3 dB
Crosstalk	≤ -30 dB
Channel Imbalance	≤ -34 dB



European Space Agency
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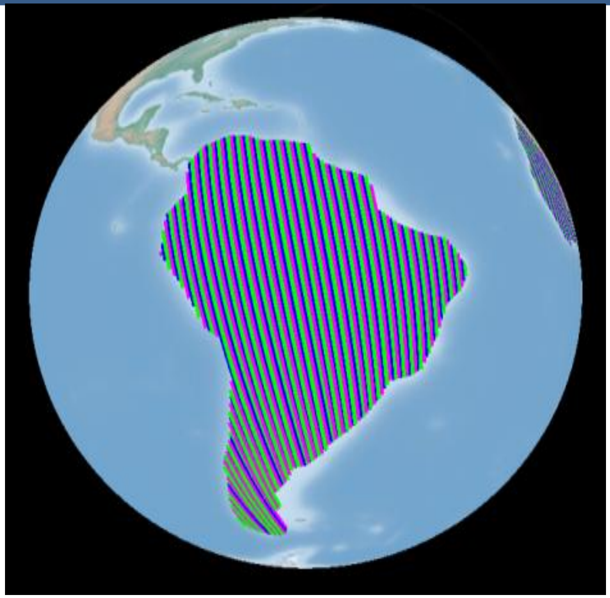
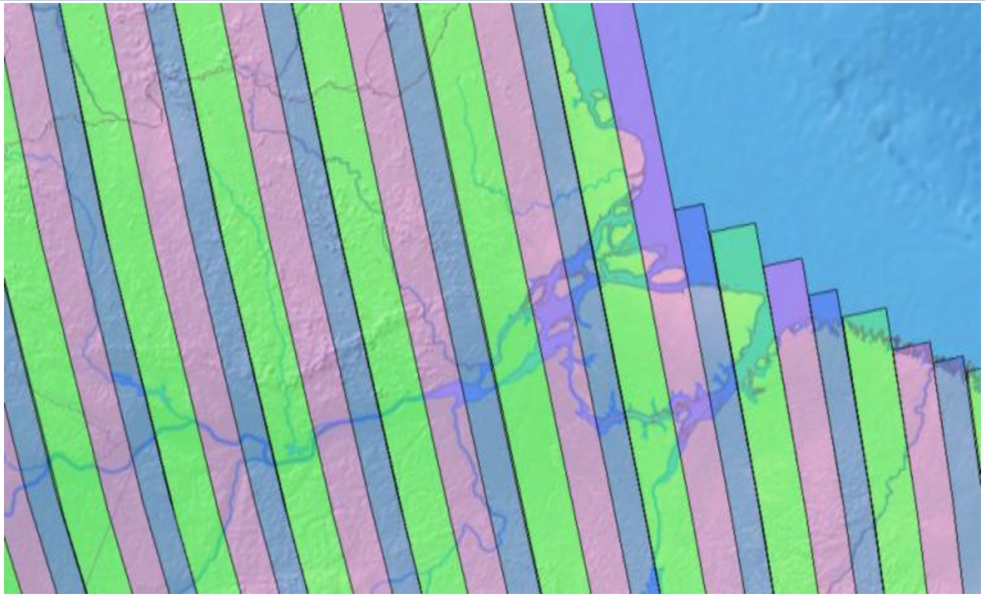
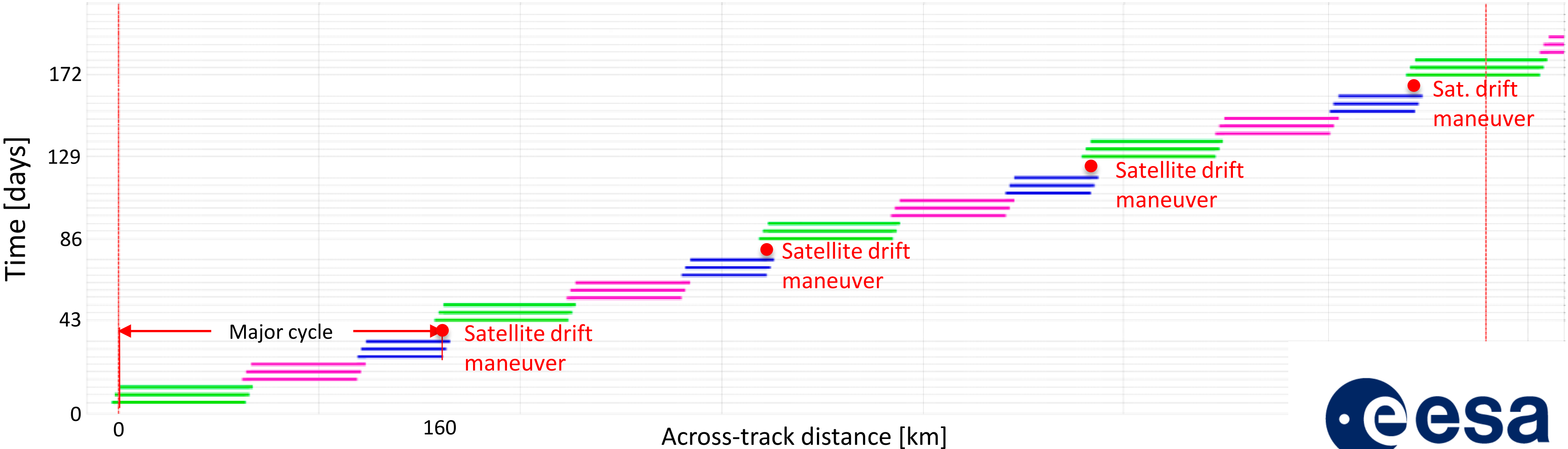
Global Coverage Strategy







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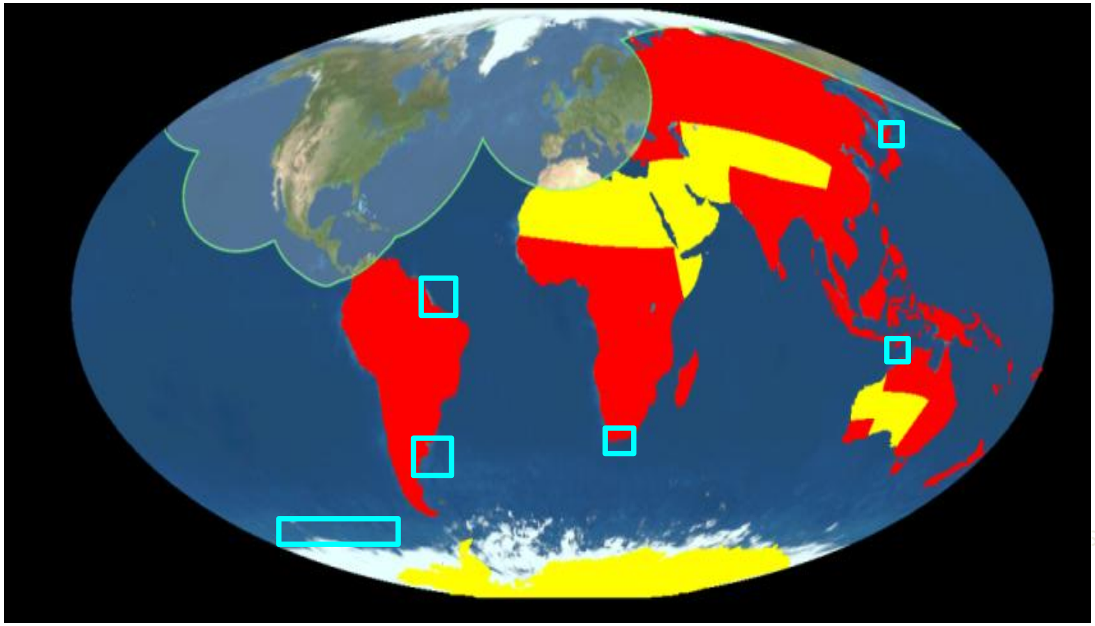
Biomass coverage

1. Acquisition mask restricted by US Space Objects Tracking Radar (SOTR)
2. Systematic Acquisitions for forested land (red area) in both ascending and descending passes.
3. Best effort acquisitions for non forested areas (yellow + ocean/sea ice ROIs)



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Works in progress

- **Algorithm Development and improvement**

  Using campaign data and physical modelling

  Biomass Retrieval Algorithm Intercomparison eXercise #1 – BRIX-I

  https://earth.esa.int/web/sppa/meetings-workshops/hosted-and-co-sponsored-meetings/brix

- **Work on sustainable Forest Observing System** (network of permanent plots for method training and validation).

  Collaboration ESA, NASA for Biomass, GEDI and NISAR

- **Prepare for use of future products** (studies, workshops)

The Biomass Science Team

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