→ 5th ADVANCED COURSE ON RADAR POLARIMETRY 2019

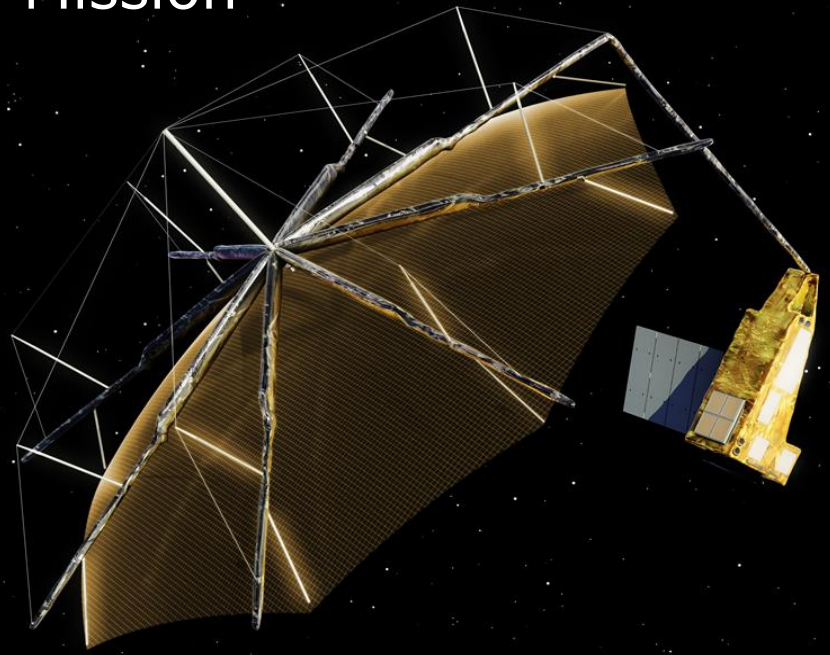
22–25 January 2019 | ESA–ESRIN | Frascati (Rome), Italy

The BIOMASS Mission

Klaus Scipal

24/01/2019

The BIOMASS Mission



ESA's 7th Earth Explorer to be deployed in 2022

An interferometric, polarimetric P-band SAR

Designed to observe forest height and biomass

ESA–DEVELOPED EARTH OBSERVATION MISSIONS

2010

Proba-1

SMOS

GOCE

CryoSat

Meteosat 10 (MSG)

MetOp-B

Proba-V

Swarm

2015

Meteosat 11 (MSG)

Sentinel-1A

Sentinel-2A

Sentinel-1B

Sentinel-2B

Sentinel-3A

Sentinel-3B

Sentinel-5p

Seosat

Aeolus

EarthCARE

Biomass

FLEX

Sentinel-6A

Sentinel-1C

Sentinel-2C

Sentinel-3C

Sentinel-1D

Sentinel-2D

Sentinel-3D

Sentinel-6B

2020

MetOp-C

Sentinel-5A
MetOp-SG-A1

MetOp-SG-B1

MTG-I

Sentinel-4A
MTG-S1

2025

MTG-I2

Sentinel-5B
MetOp-SG-A2

MTG-I3

MetOp-SG-B2

2030

Sentinel-4B
MTG-S2

Science

Copernicus

Meteorology

EUMETSAT

Fate of Anthropogenic CO_2 Emissions (2005-2015)

SOURCES

34.1±1.7 $GtCO_2$/yr 91%

3.5±1.8 $GtCO_2$/yr 9%

PARTITIONING

16.4±0.4 $GtCO_2$/yr
44%

11.5±3.1 $GtCO_2$/yr
31%

9.7±1.8 $GtCO_2$/yr
26%

Global Carbon Project, 2015

What information do we need?

1. We need estimates of **forest biomass, height and disturbances**
2. The **crucial information need** is in the tropics:
   deforestation (~95% of the Land Use Change flux)
   regrowth (~50% of the global biomass sink)
3. Biomass measurements are needed where the changes occur and at the **effective scale of change**: 4 hectares
4. Measurements are needed **wall-to-wall**
5. A biomass accuracy of 20% at 4 hectares, **comparable to ground-based observations**
6. Detection of **deforestation at 0.25 ha**
7. **Repeated measurements** over multiple years to identify deforestation and regrowth

How to measure biomass?

Tree allometry links biomass to

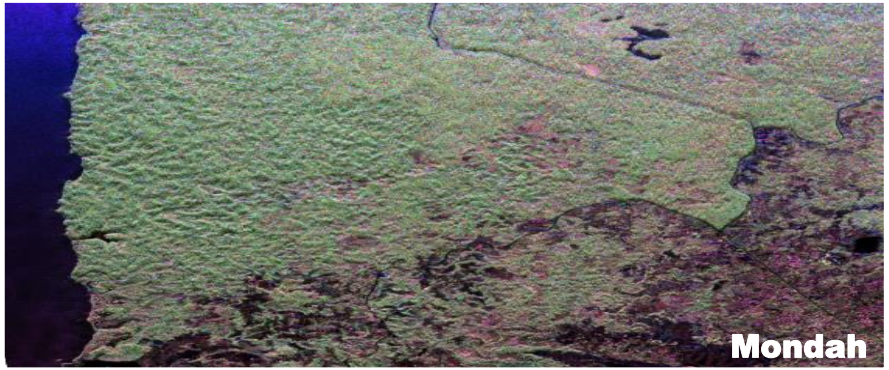
$$AGB = \rho \cdot D^2 \cdot H$$

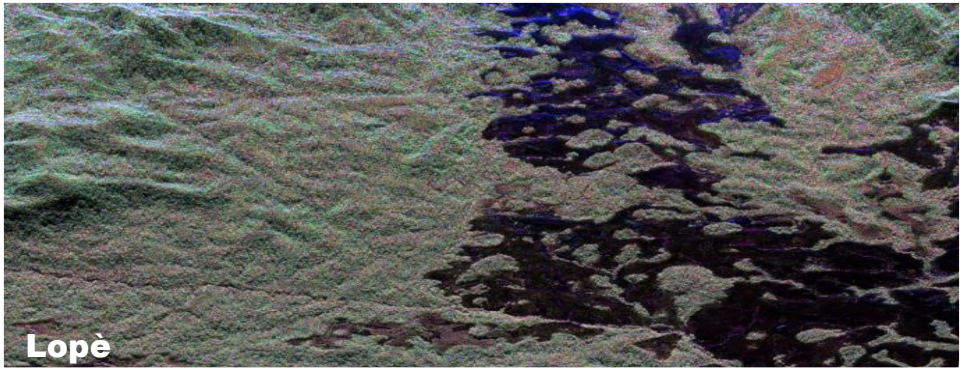
Wood density

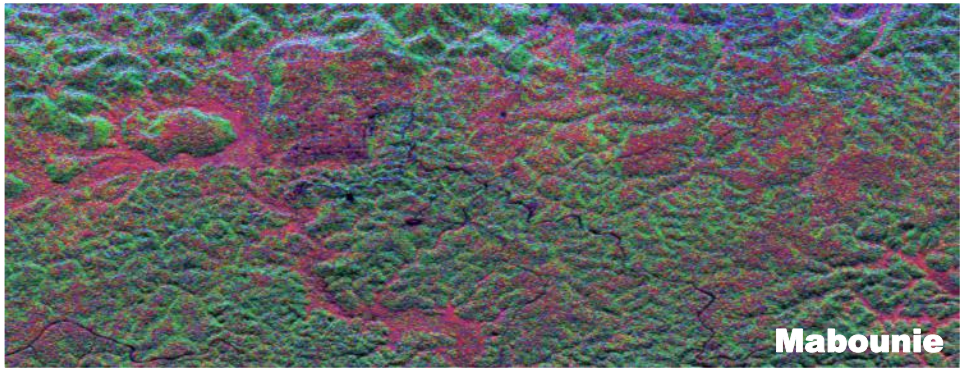
Diameter

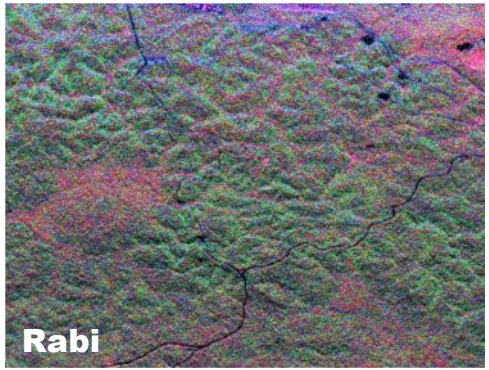
Height

Tropical Forest as seen by DLR's P-band F-SAR



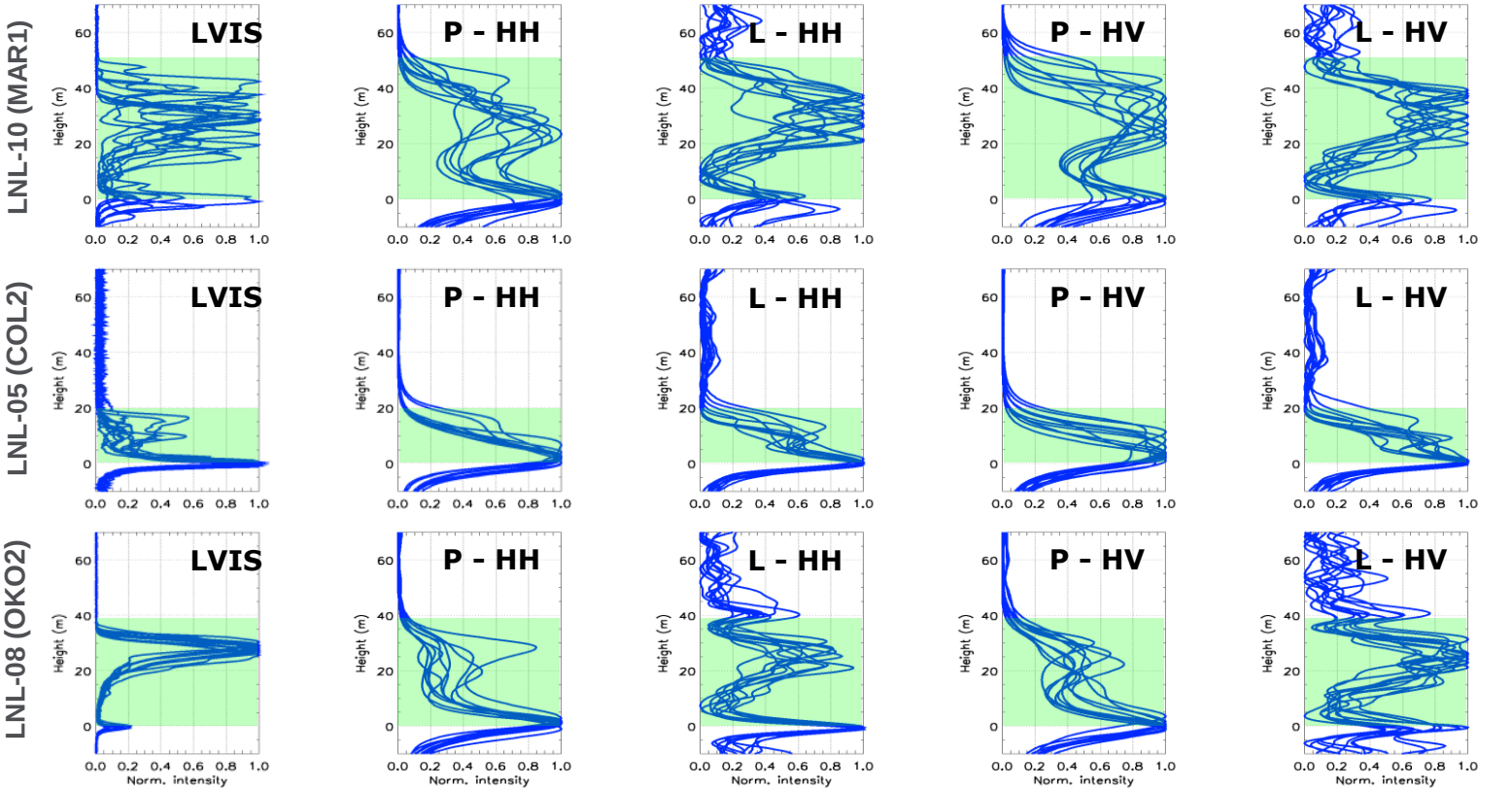






HH+VV HV HH-VV

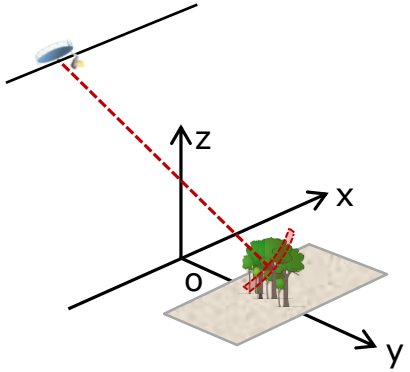
Information content of P-, L- band SAR and lidar

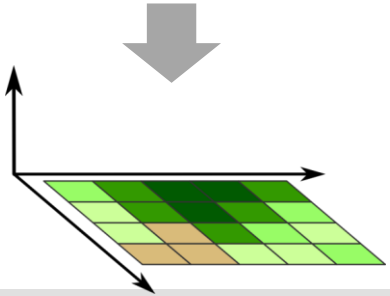


Courtesy: M. Pardini - DLR

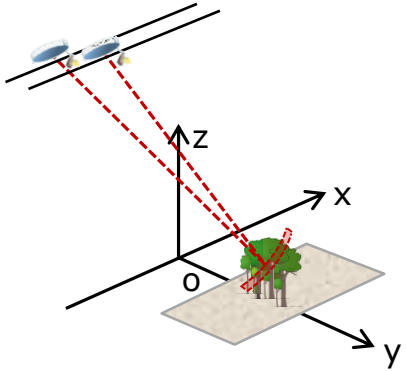
SAR can deliver 3 independent types of information related to biomass

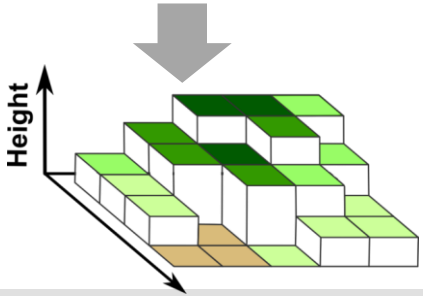
PolSAR
(SAR Polarimetry)



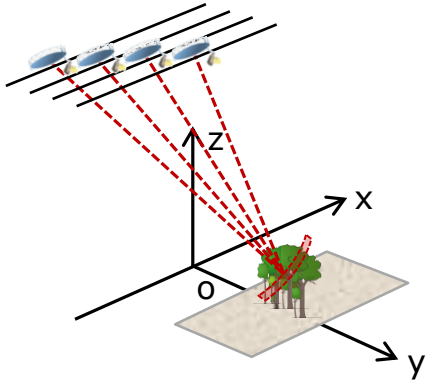


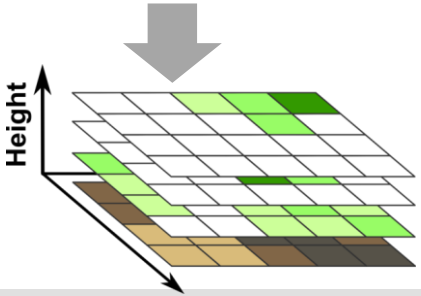
PolInSAR
(Polarimetric SAR Interferometry)



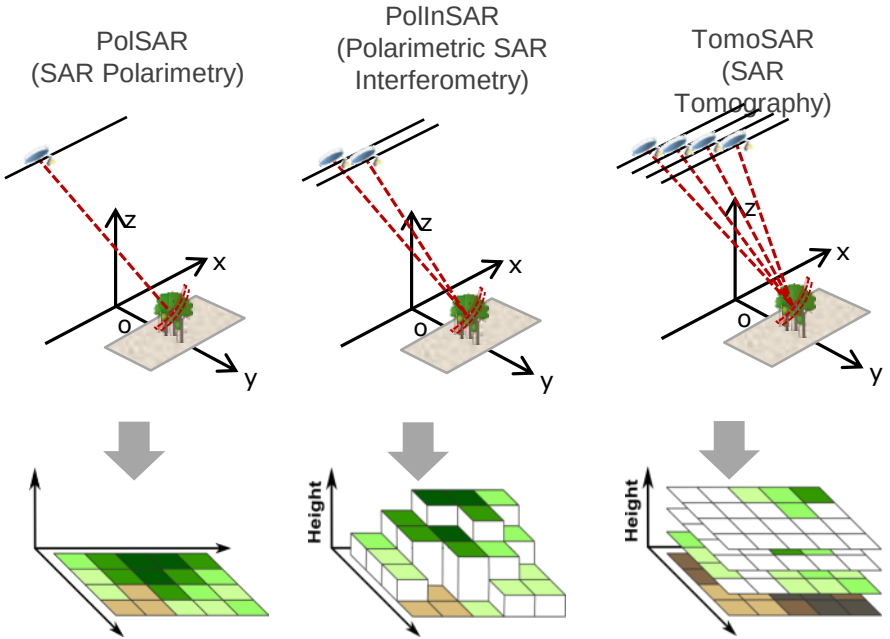


TomoSAR
(SAR Tomography)





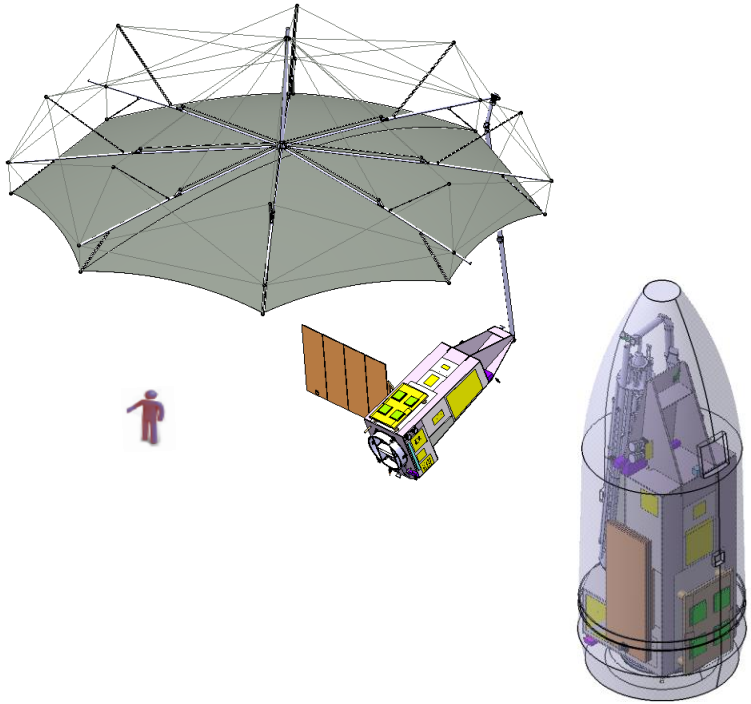
Biomass Mission Concept



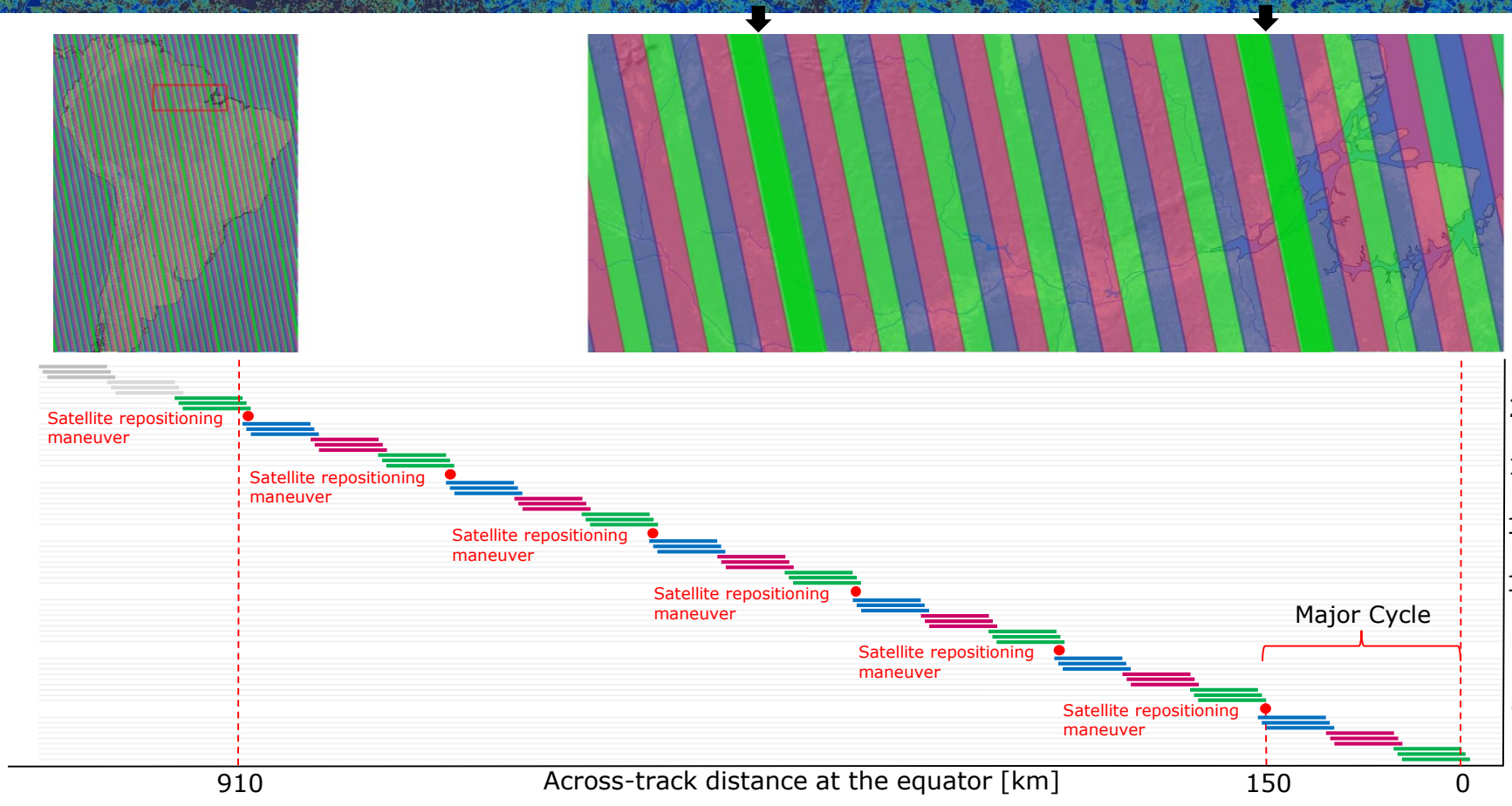
- ✓ Single satellite, operated in a polar sun-synchronous orbit
- ✓ Full polarimetric P-band (435 MHz) Synthetic Aperture Radar with 6 MHz bandwidth
- ✓ Two mission phases: Tomography (year 1), Interferometry (year 2-5)
- ✓ Multi-repeat pass interferometry (3 passes in nominal operations) with a 3 days repeat cycle
- ✓ Global coverage in ~7 months (228 days) on asc. and des. passes
- ✓ 5 years lifetime

Biomass Mission Requirements

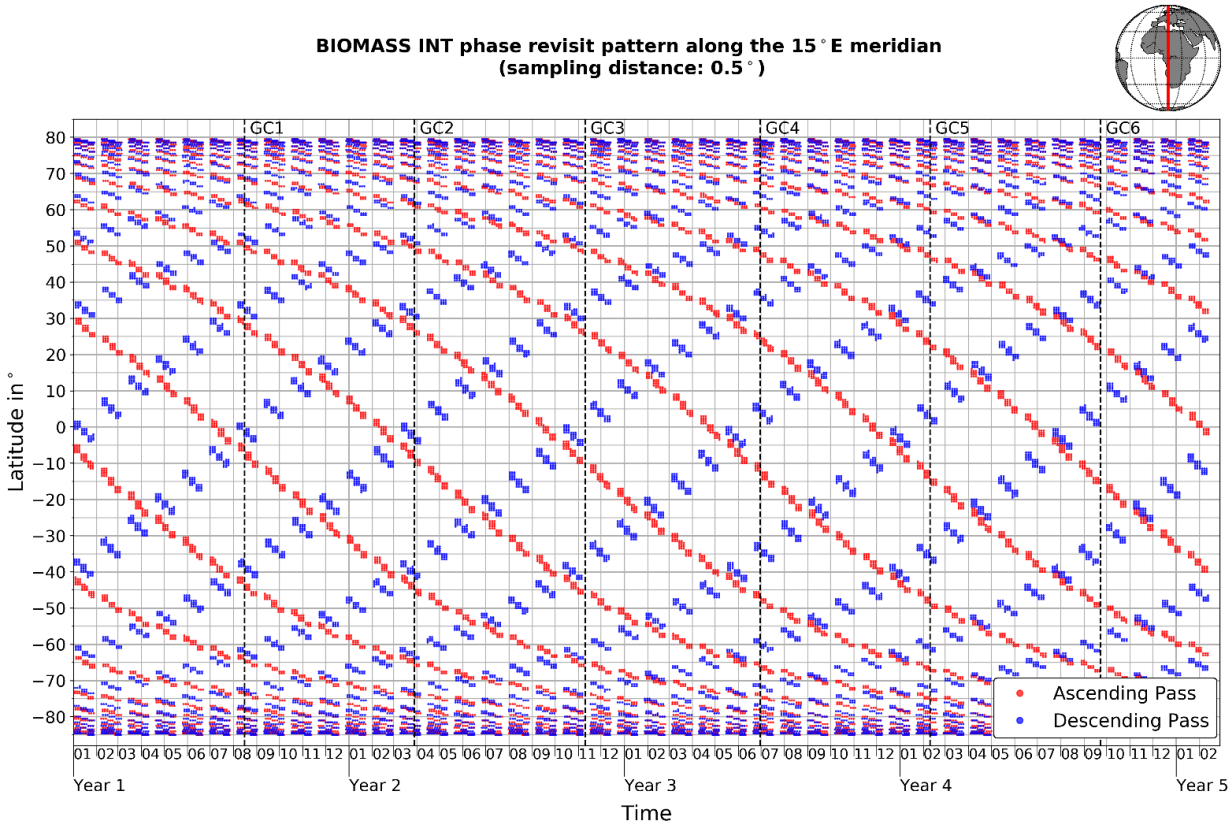
Key Parameters	
Sensitivity (NESZ)	≤ -27 dB ✓
Total Ambiguity Ratio	≤ -18 dB ✓
SLC resolution	≤ 60m x 8m ✓
Dynamic Range	35 dB ✓
Radiometric Stability	≤ 0.5 dB ✓
Radiometric Bias	≤ 0.3 dB ✓
Crosstalk	≤ -30 dB ✓



Global Coverage Strategy

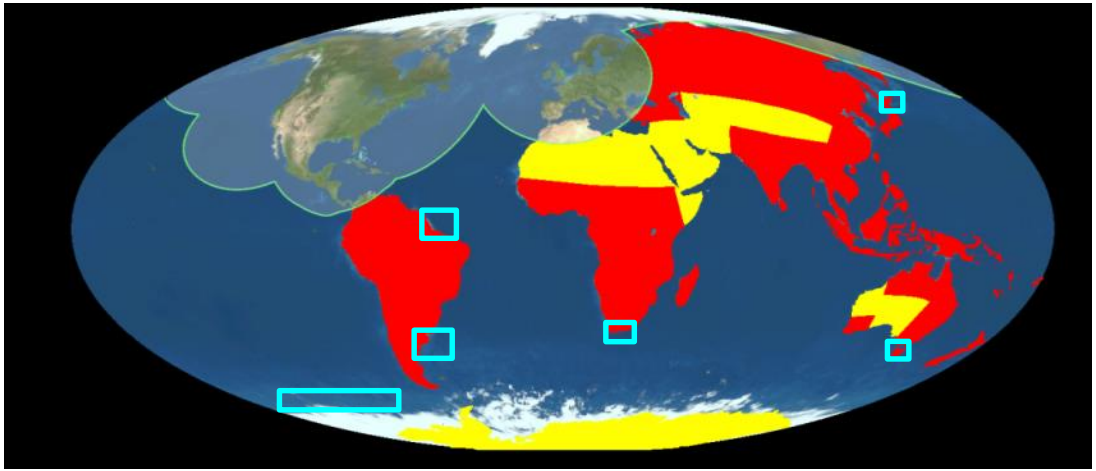


Global Revisit Pattern



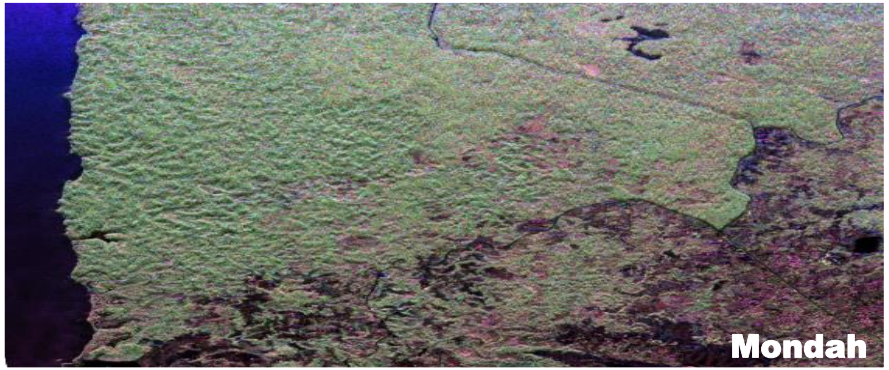
Coverage

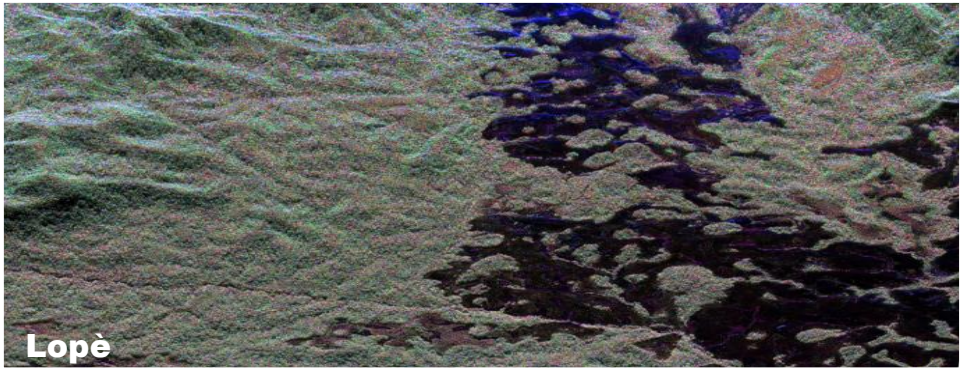
1. Systematic Acquisitions for forested land (red area)
2. Global coverage in 7.5 months (INT phase) and 14 months (TOM phase).
3. Best effort acquisitions for non forested areas (yellow + ocean/sea ice ROIs)
4. Acquisition mask restricted by US Space Objects Tracking Radar (SOTR)

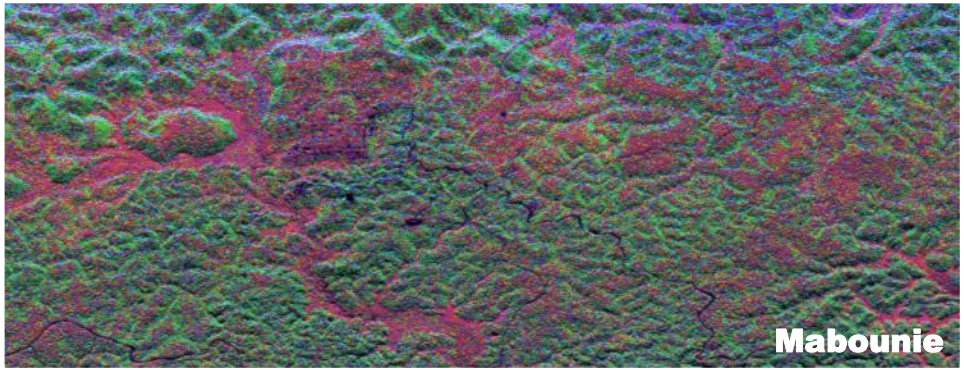


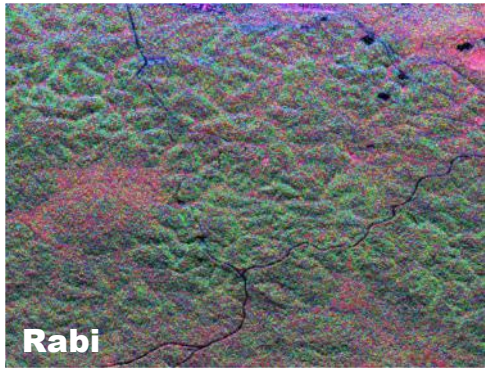
(Red = Primary objective coverage mask, Yellow = Secondary objective coverage mask)

AfriSAR sites as seen by P-band by DLR's F-SAR





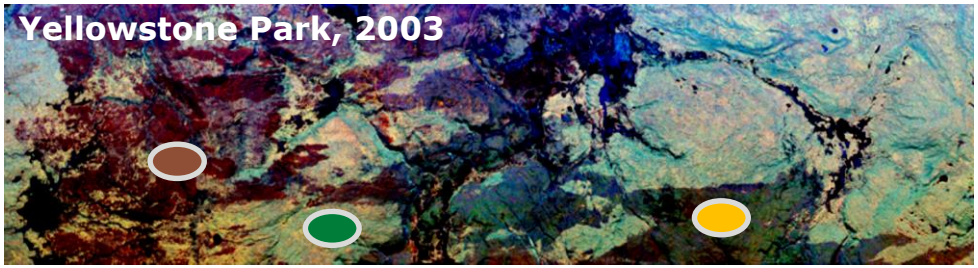


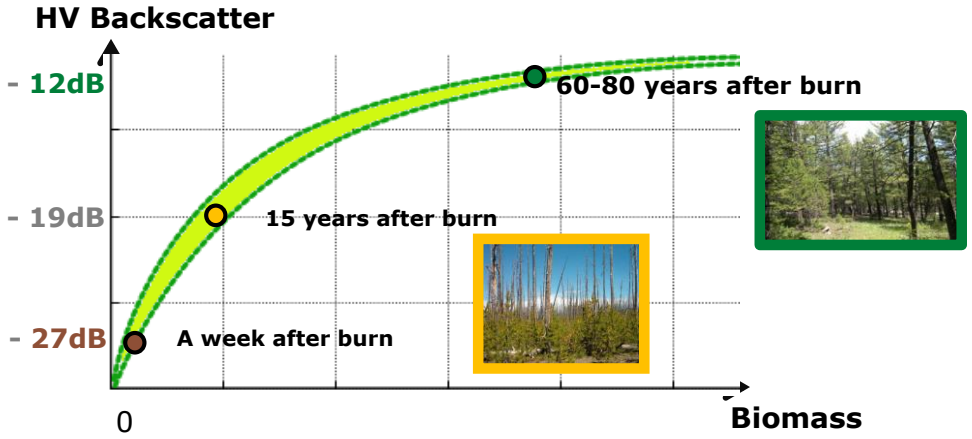


HH+VV HV HH-VV

P-band SAR measures biomass and quantifies landscape dynamics

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

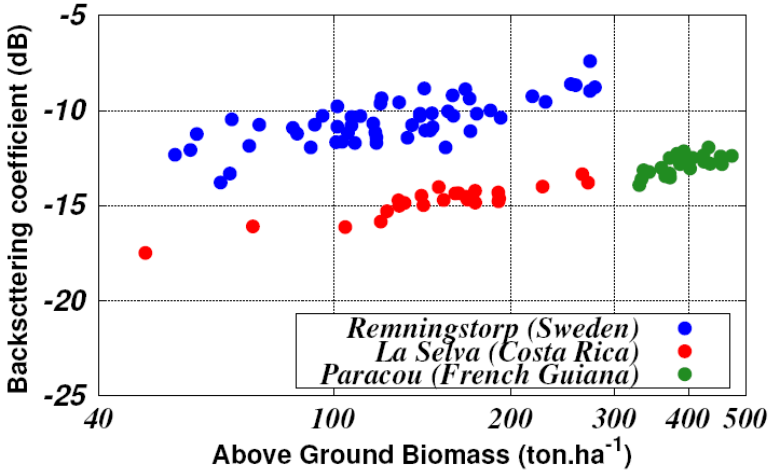




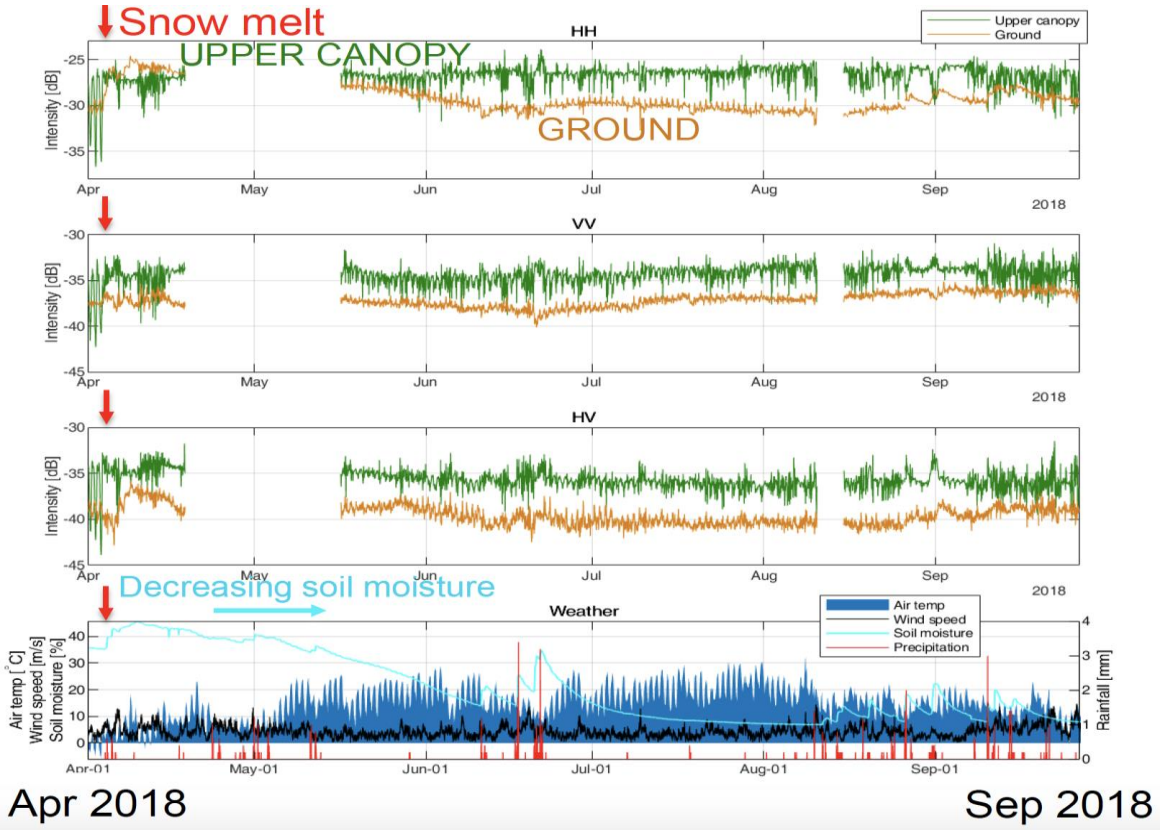
Global consistency in the biomass – P-band backscatter relationship

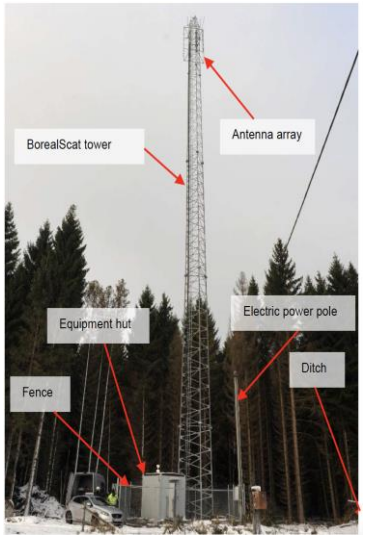
The simplest inversion: Similar power-law relationships between backscatter and biomass are found for all forests where we have data

$$\log(AGB) = a + b \cdot \gamma^0_{HV}$$



Strong variations in backscatter signal





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CHALMERS
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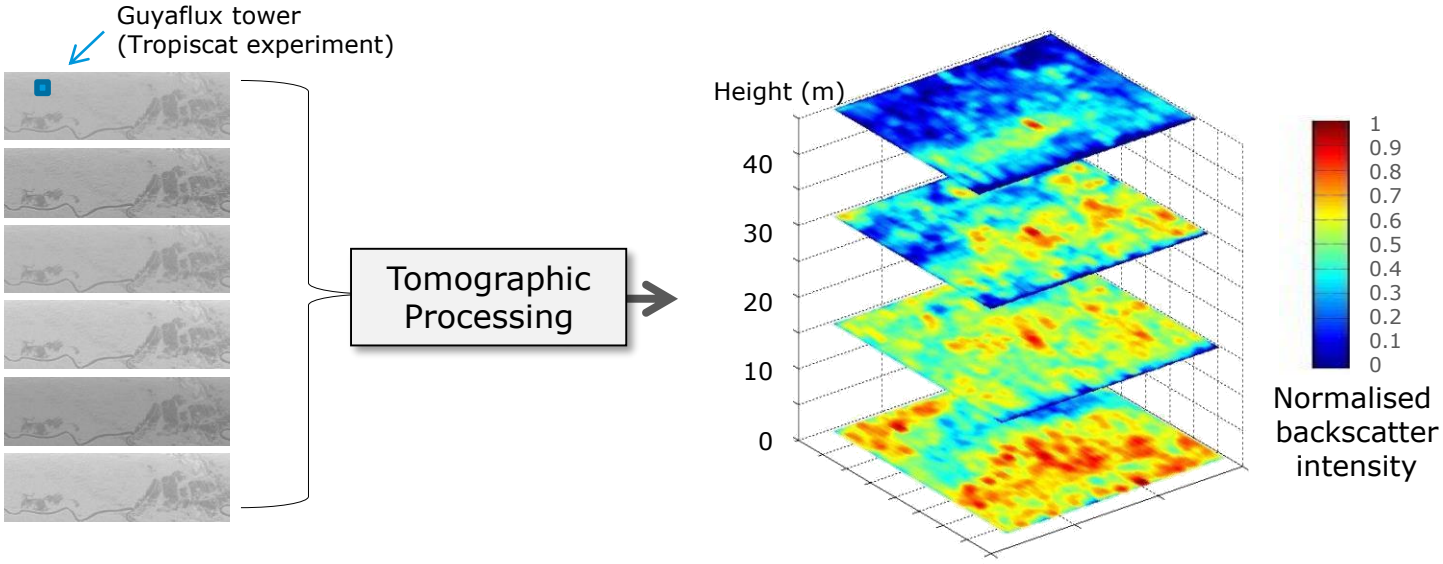
Key challenge - how to estimate biomass

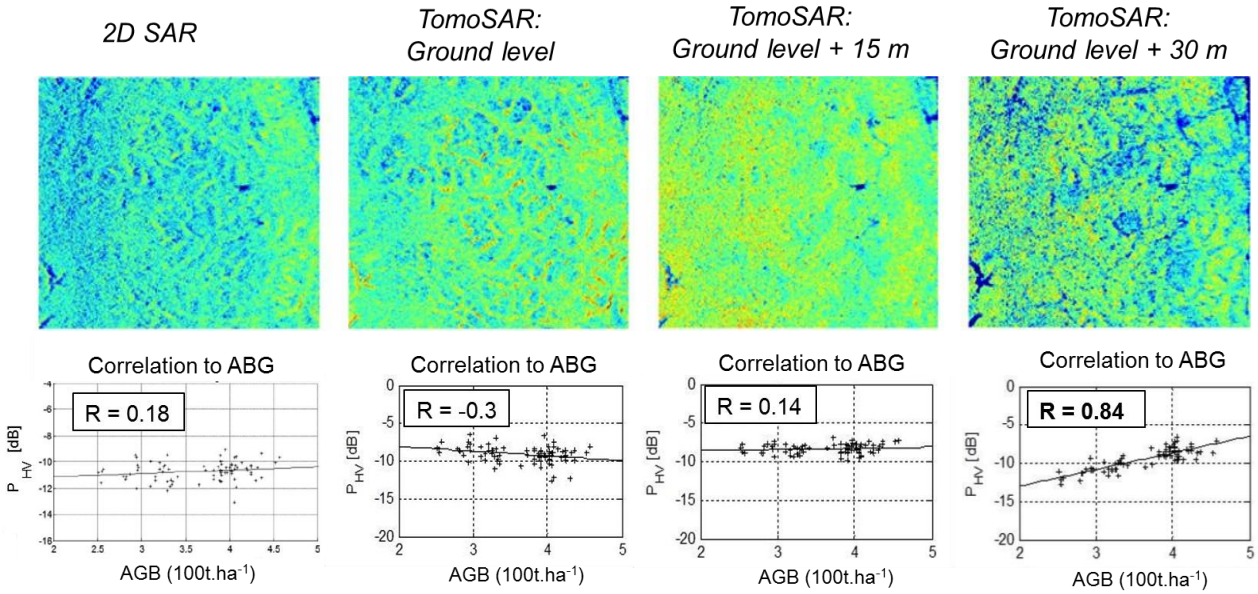
1. Loss of sensitivity in the high biomass range even at P-band.
2. Environmental nuisance factors (vegetation and soil water changes, freeze/thaw, wind, …).

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

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



Tomographic imaging in Paracou

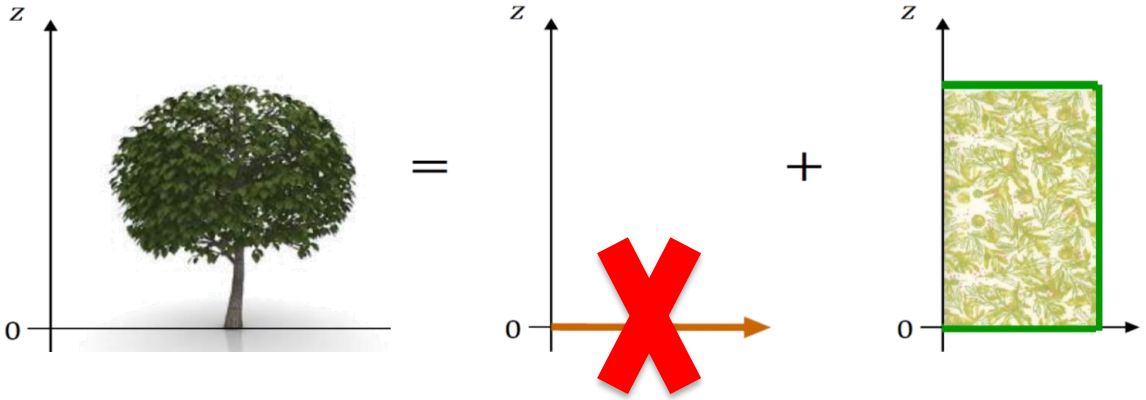


D. Ho Tong Minh et al., "Relating P-band SAR tomography to tropical forest biomass", TGRS, Feb. 2014.

Key challenge - how to estimate biomass

1. Loss of sensitivity in the high biomass range even at P-band.
2. Environmental nuisance factors (vegetation and soil water changes, freeze/thaw, wind, …).

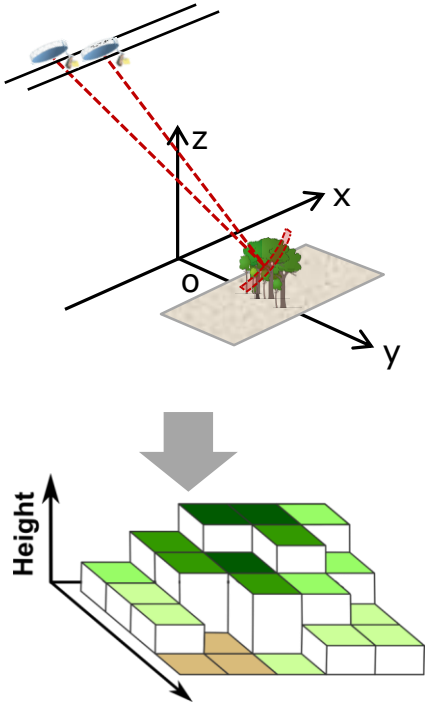
Biomass enables a new approach to tackle these problems: notch out the ground



SAR can deliver 3 independent types of information related to biomass

PolInSAR

(Polarimetric SAR Interferometry)



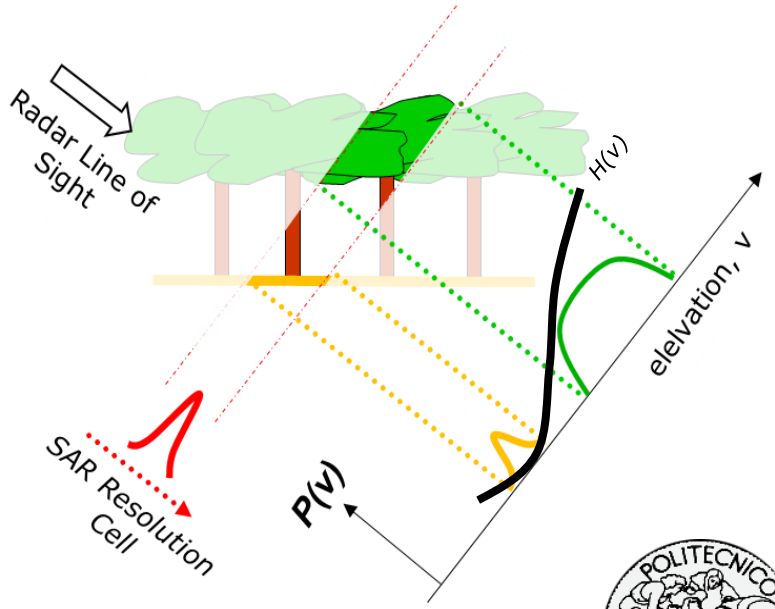
Interferometric ground notching

Idea: cancel out ground scattering by taking the difference between two phase calibrated SLC BIOMASS images

Principle: SLC = projection of modulated target reflectivity along elevation

Master: $s_1 = \int P(z) \cdot dz$

Slave: $s_2 = \int P(z) \cdot exp(jk_z z) \cdot dz$

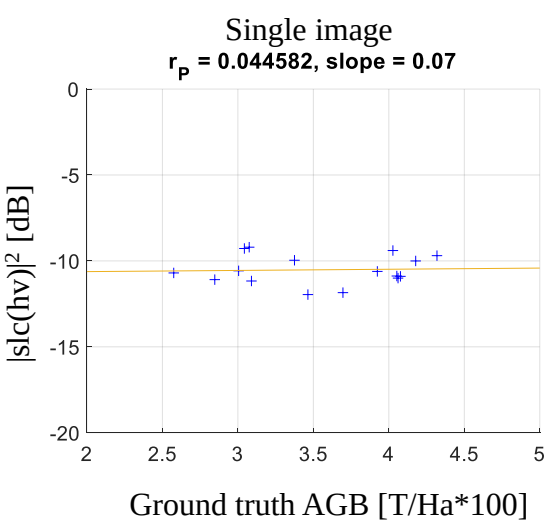


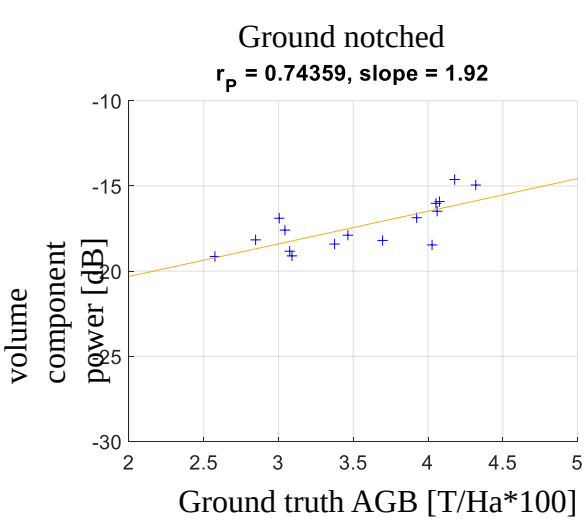
Ground notched image = Slave – Master

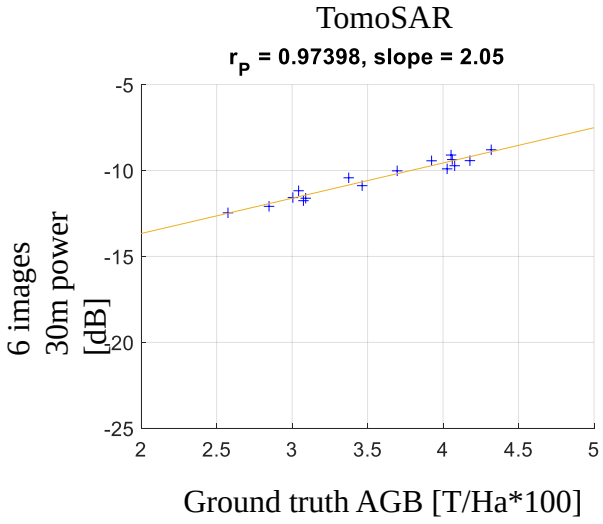
$$d = s_2 - s_1 = \int P(z) \cdot H(z) \cdot dz$$

H(z) = Vertical Impulse Response Function (IRF)

AGB vs TropiSAR backscatter







Ground rejection greatly improves correlation and sensitivity

What information will we get from Biomass

Above-ground biomass (tons/hectare)

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

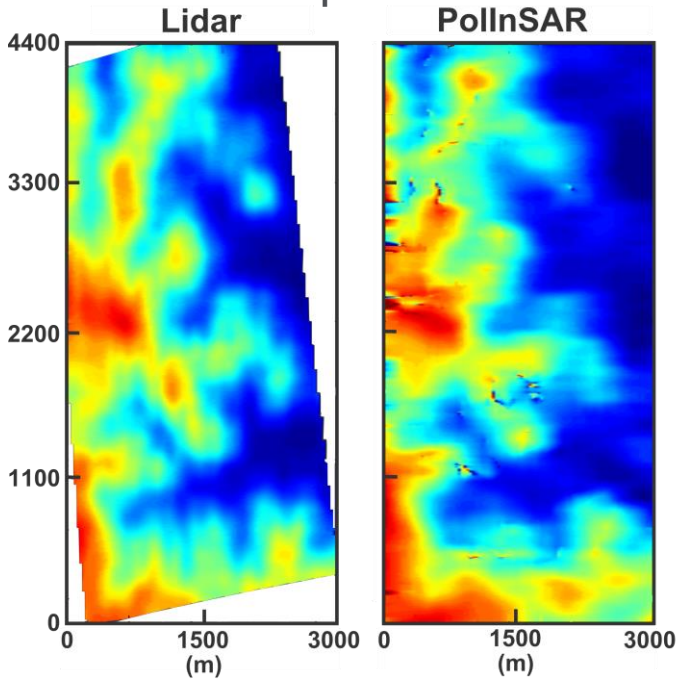
Upper canopy height (meter)

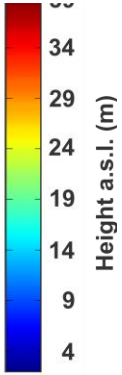
- 200 m resolution
- 1 map every 6 months
- global coverage of forested areas
- accuracy of 20-30%

Areas of forest clearing (hectare)

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

Biomass will allow DEM production under dense tropical canopies





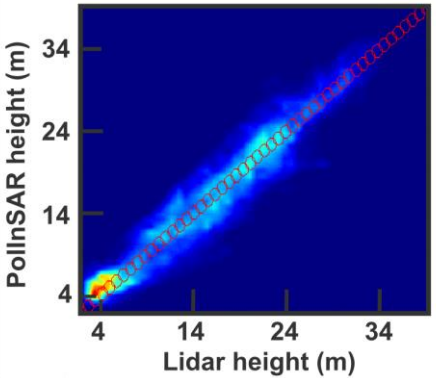
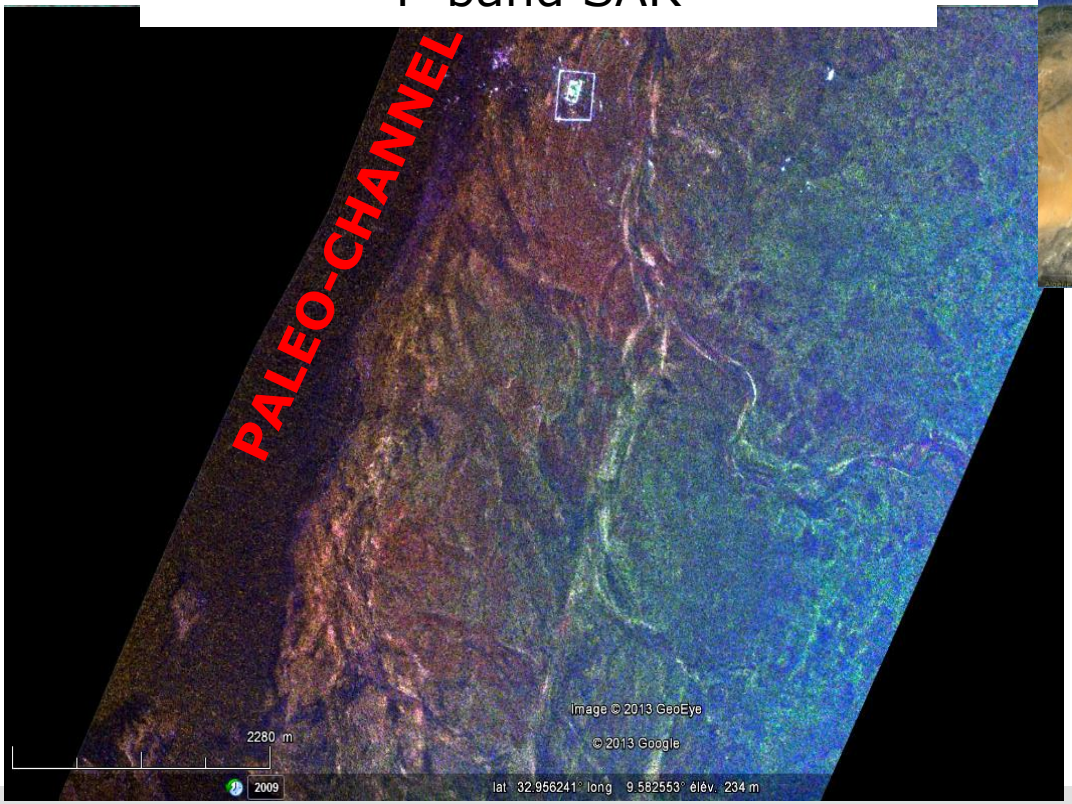


Image courtesy of P. Dubois-Fernandez

90m x 90m DEM feasible with **~ 2 m height accuracy** from Biomass

P-band enhances subsurface imaging in arid zones

P-band SAR



Summary – BIOMASS a true Earth Explorer

1. BIOMASS implementation started in Nov. 2013. We just kicked-off Phase-C (CDR planned in 2019). We are working towards a launch in 2022.

2. BIOMASS is the first P-band SAR and first radar tomographic space mission; it is a true Earth Explorer with a lot of unknowns and exciting science for global biomass mapping.

3. The new unique vision of Earth from Biomass will extend beyond forests and into measurements of ice, sub-surface geomorphology in deserts, topography, the ionosphere, ocean ...