Biomass

ESA’s Forest Mission 33 days to launch

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ICE
goce
GRAVITY FIELD
smos
WATER
swarm
MAGNETIC FIELD
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CLOUD AND AEROSOL
biomass
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flex
PHOTOSYNTHESIS
forum
THERMAL RADIATION
harmony
SURFACE DYNAMICS

Fate of anthropogenic CO2 emissions (2014 – 2023)

Sources = Sinks

90%
9.7 ± 0.5 GtC/yr

10%
1.1 ± 0.7 GtC/yr

48%
5.2 ± 0.02 GtC/yr

30%
3.2 ± 0.9 GtC/yr

27%
2.9 ± 0.4 GtC/yr

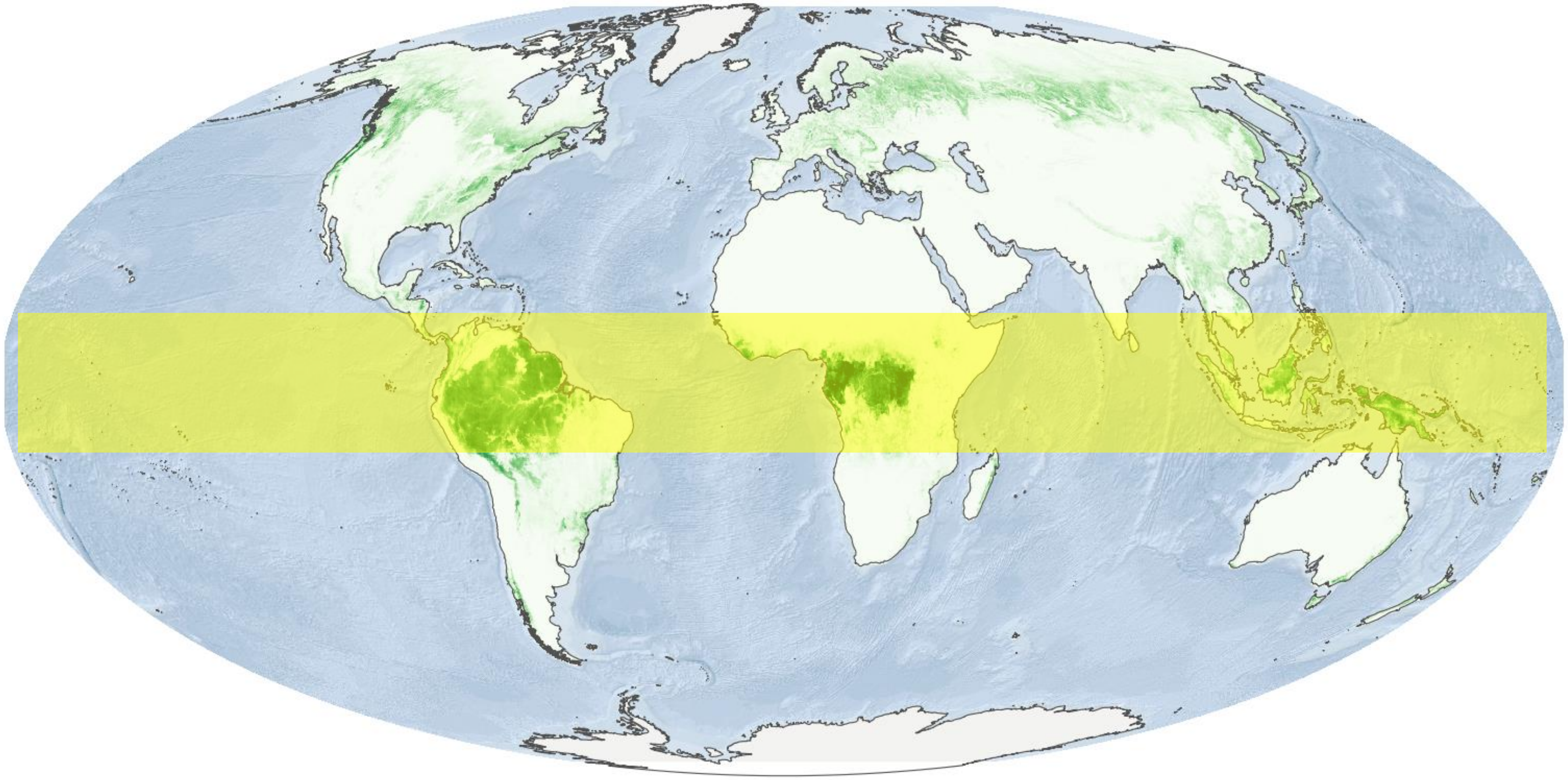
- Land Use Change (**source**) and land uptake (**sink**) have the largest uncertainties in the global carbon budget.
- Land Use Change has a relative uncertainty of 64%!
- This reflects uncertainty in both loss and gain of **biomass**.

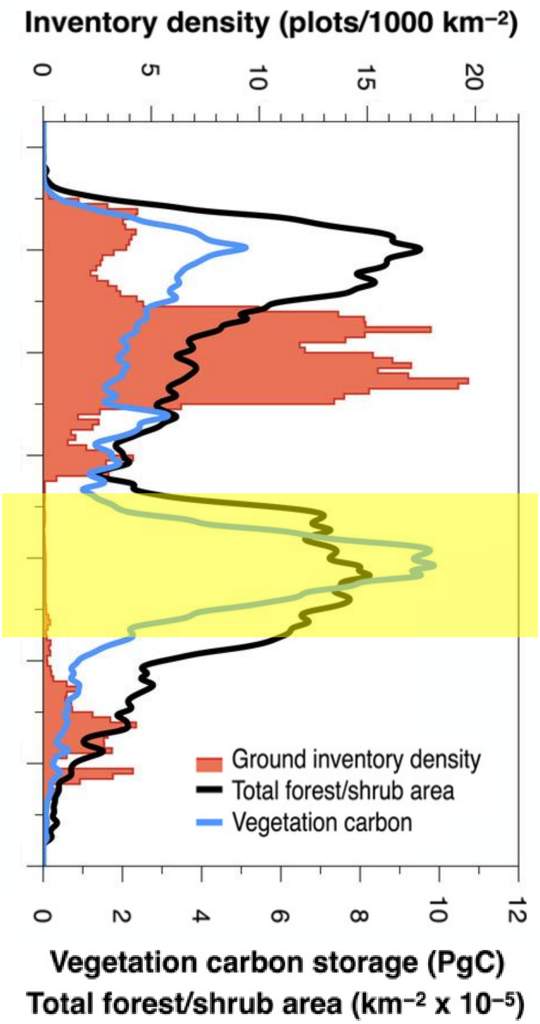
GLOBAL CARBON project

Difference between estimated sources & sinks = -0.5 GtC/yr indicating bias in one or more of the estimates.

Source: Friedlingstein et al 2024; Global Carbon Project 2024

What do we know about biomass?



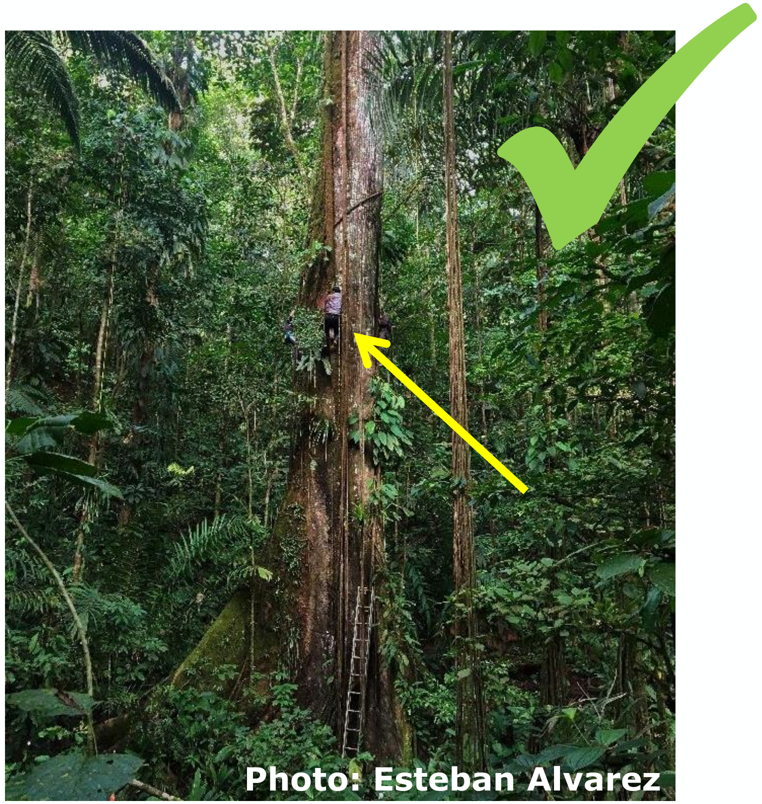


Plot adopted from: Global Change Biology, Volume: 21, Issue: 5, Pages: 1762-1776, DOI: (10.1111/gcb.12822)
Map: Global Above Ground Biomass from the ESA CCI

What information do we need?

1. We need estimates of **forest biomass (AGB), height and disturbances**.
2. The crucial **information need is in the tropics.**
3. Biomass measurements are needed where the changes occur and at the **effective scale of change**: hectare scale.
4. Measurements are needed **wall-to-wall** with **repeated measurements** over multiple years to identify deforestation and regrowth.
5. A biomass accuracy of 20% at the hectare scale, **comparable to ground-based observations**.

How to measure the weight of a tree?



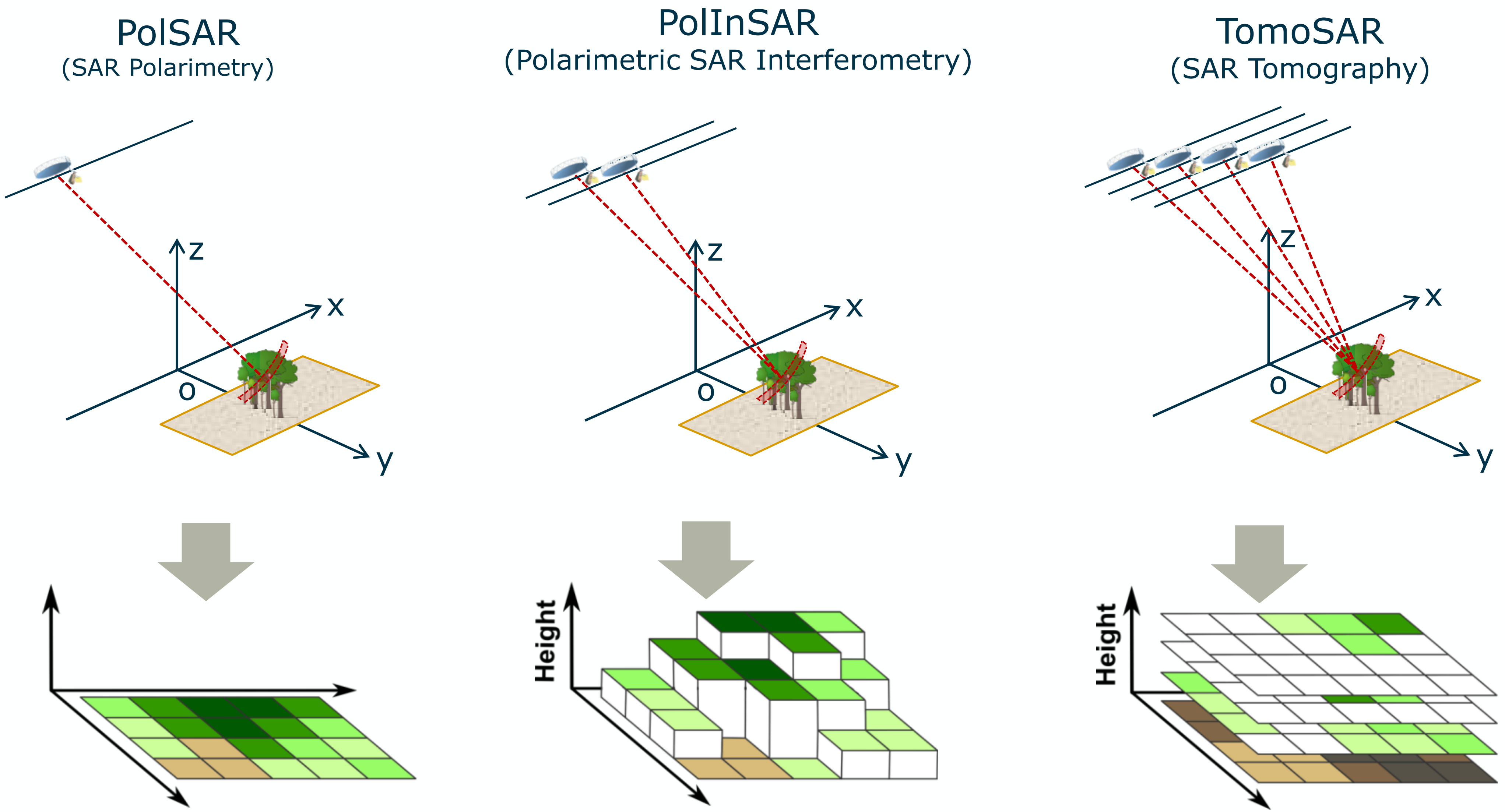
$$AGB = \rho \cdot \left(D/2\right)^2 \cdot H$$

Wood density

Diameter

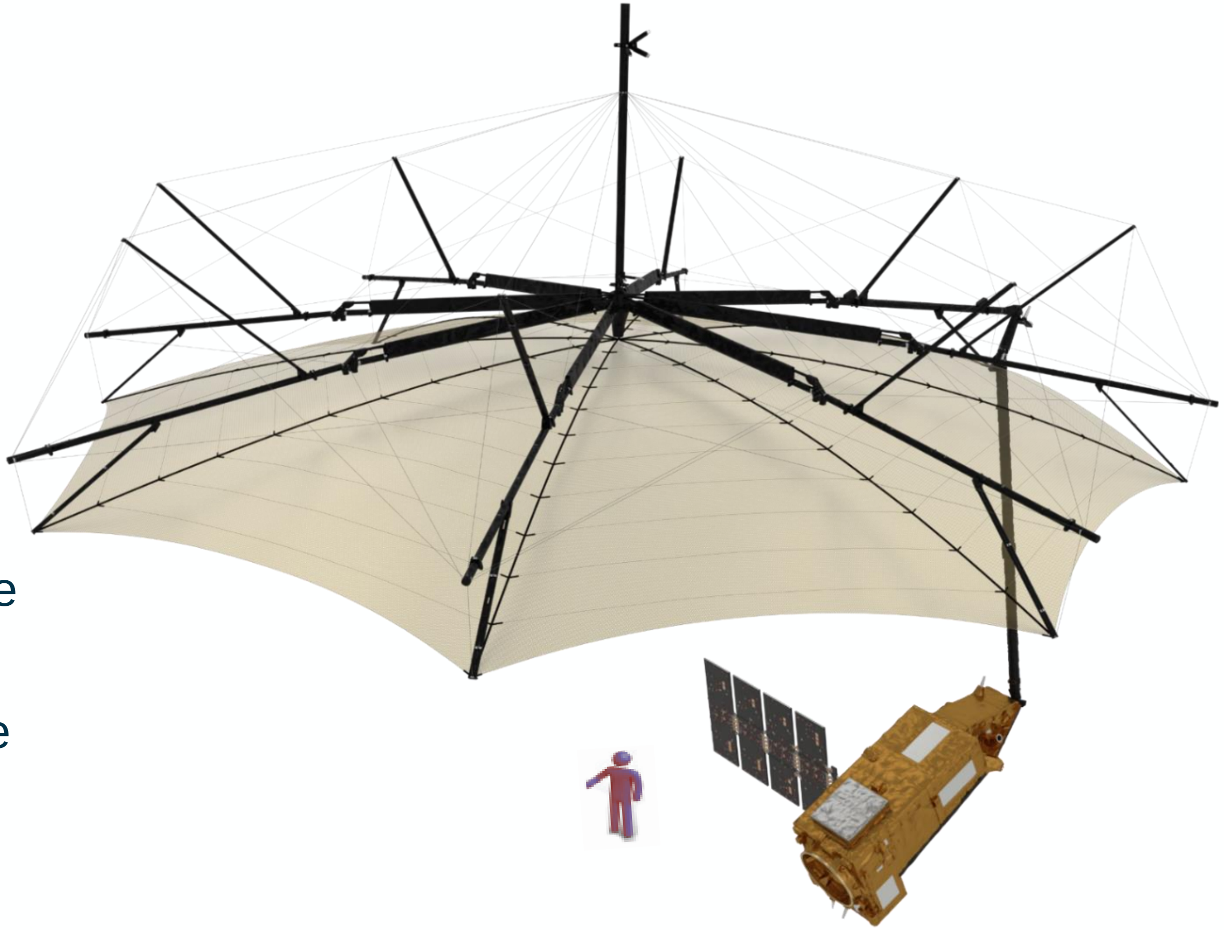
Height

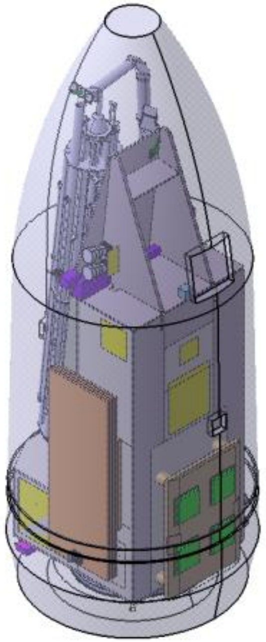
Synthetic Aperture Radar contains structure information



Mission key facts

- First civilian P-band SAR in space
- Fully polarimetric system
- Repeat pass interferometric orbits
- Minimum 5 years lifetime
- 18 months Tomographic Phase for one global coverage
- 3.5 years month Interferometric Phase with 5 repeated global coverages

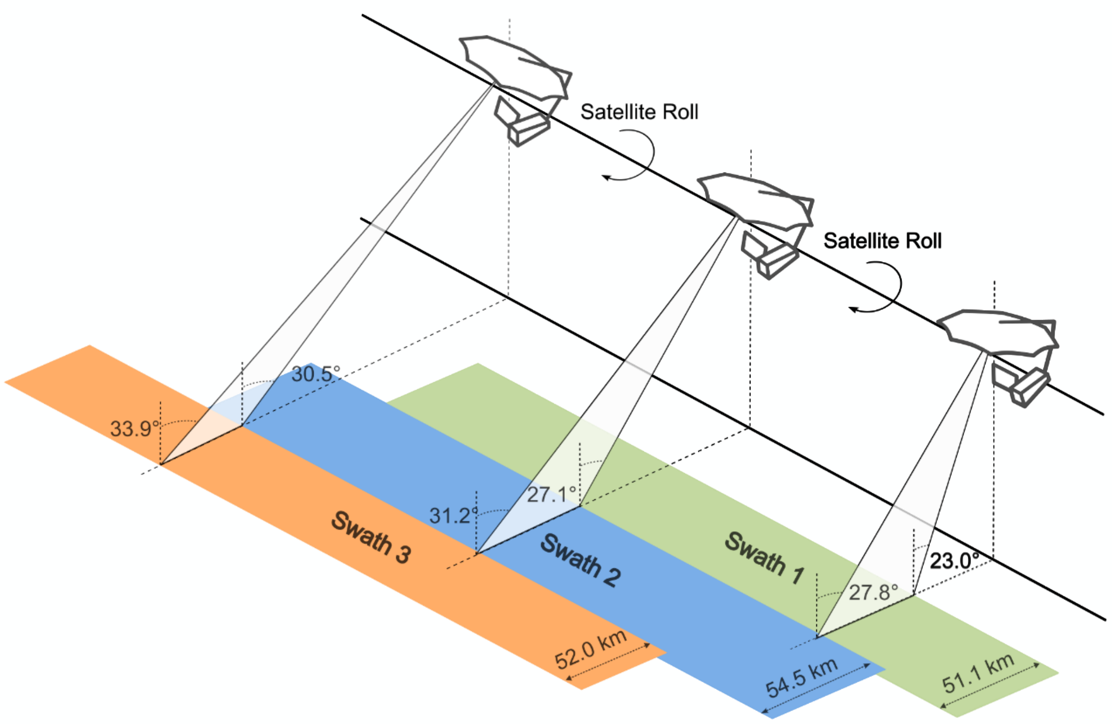




Mission Estimated Performance

System

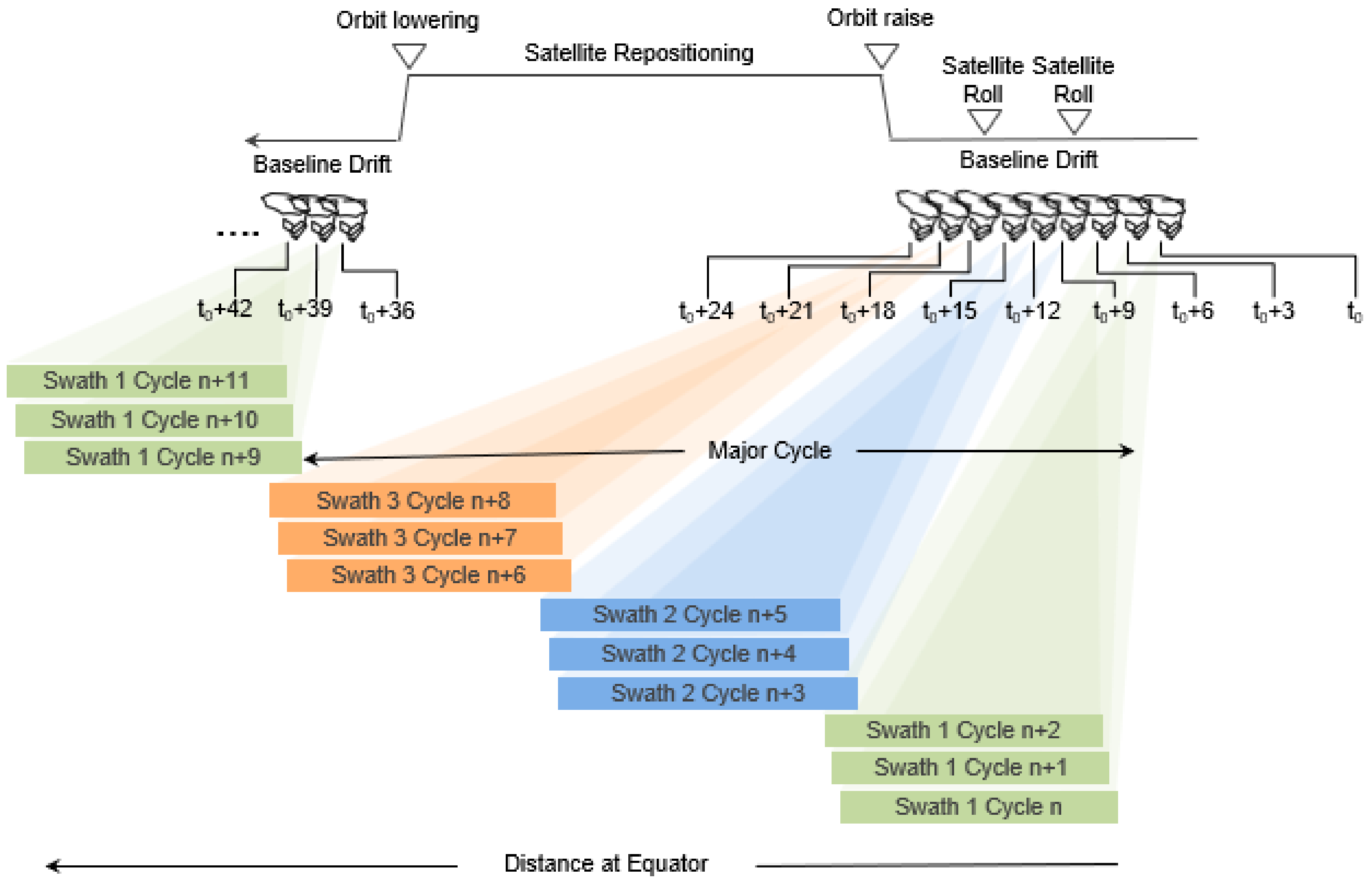
Instrument	Polarimetric SAR operating at 465 MHz (~70 cm wavelength)
Channel Imbalance	≤ -23.5 dB, Tx and Rx combined
Cross-Talk	≤ -33.2 dB
Radiometric bias	≤ 0.23 dB
Radiometric stability	≤ 0.26 dB
Noise Equivalent Sigma Nought	≤ -30.4 dB
Total Ambiguity Ratio	≤ -19.1 dB
Spatial resolution (SLC), range and azimuth	~ 59 m x 8 m
Residual phase error	≤ 4.0 deg, over pulse travel time ≤ 3.7 deg over data take time (12 min)
PSLR along track	≤ -18.0 dB
PSLR across track	≤ -14.1 dB
Geo-location accuracy	≤ 4.1 m
Dynamic range	-30 dB to 5 dB
Swath Width	~ 50 km



Orbit

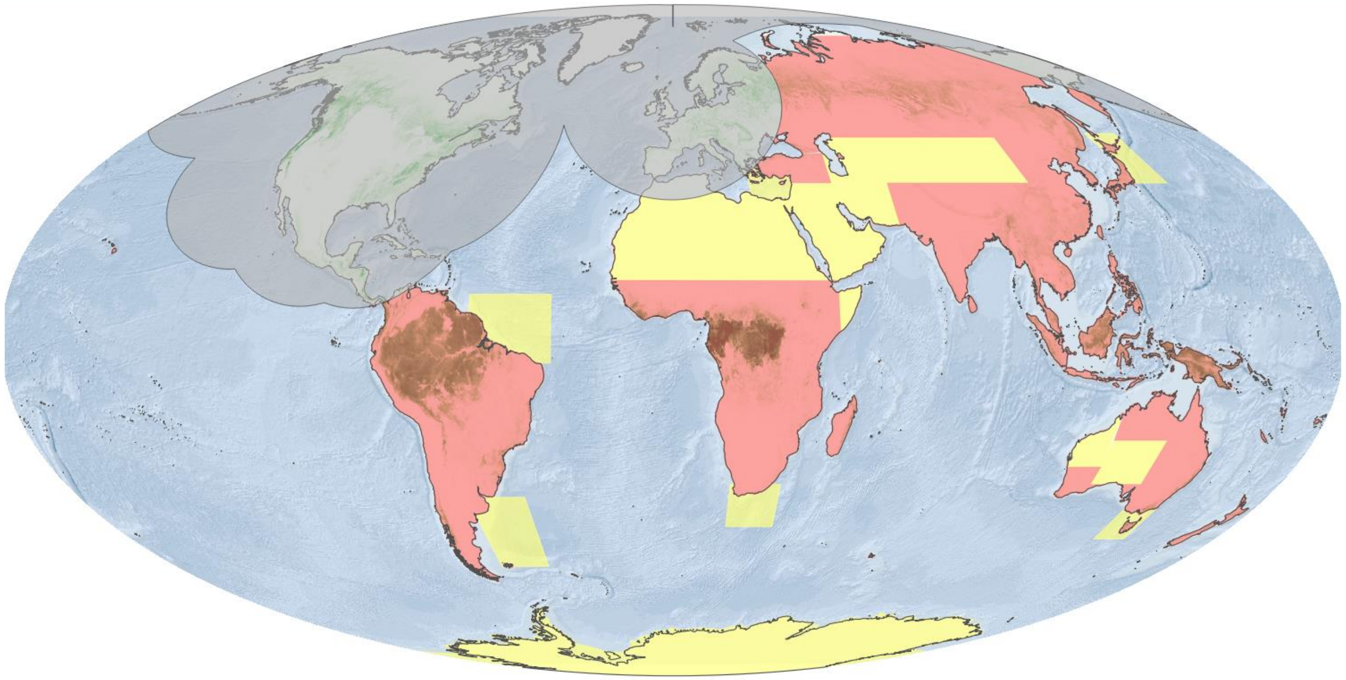
Orbit Type	Sun synchronous, dawn dusk with an LTAN of 06:00
Baseline	East-west drift of 1.5 km (INT) and 0.9 km (TOM)

Achieving Global Coverage



Coverage

- Systematic Acquisitions for forested land (red area)
- Best effort acquisitions for non forested areas (yellow areas)
- Acquisition over Europe and N-America barred by US Space Objects Tracking Radar (SOTR)



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

Biomass Products

Above-ground biomass (tons/hectare)

- 200 m resolution
- accuracy of 20%, or 10 t ha–1 for biomass < 50 t ha–1

Upper canopy height (meter)

- 200 m resolution
- accuracy of 20-30%

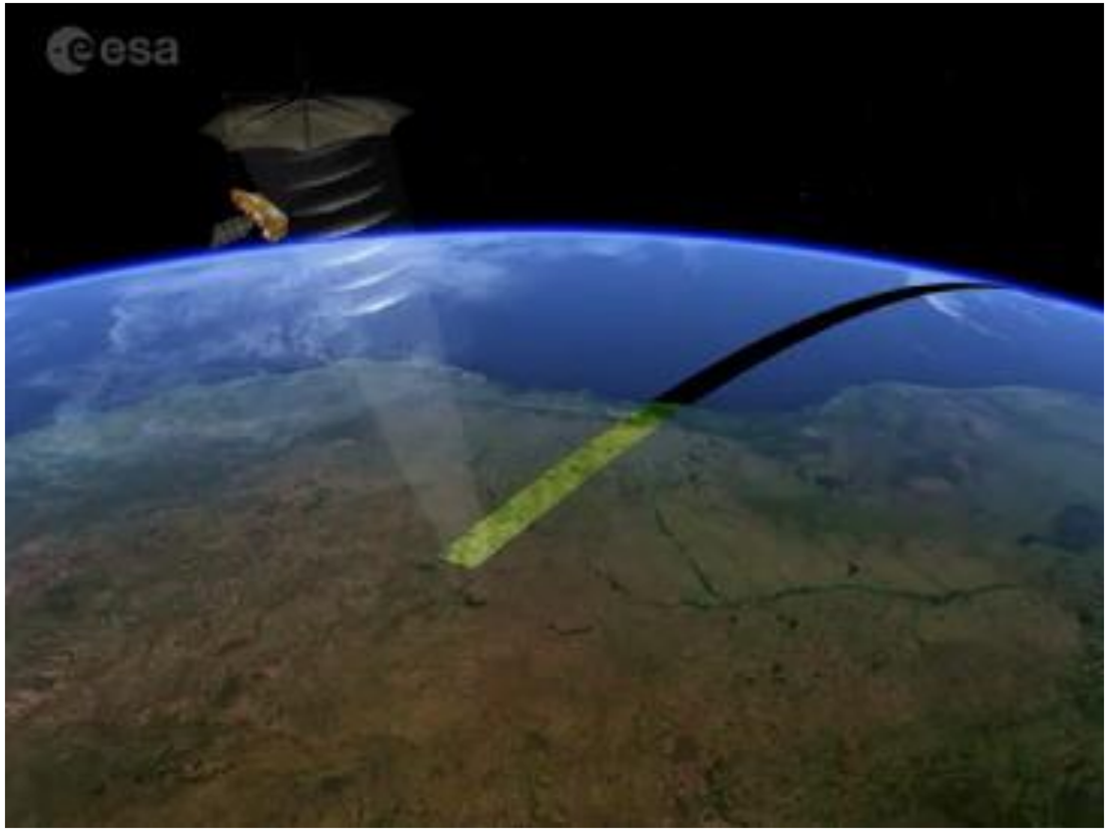
Areas of forest clearing (hectare)

- 50 m resolution
- 90% classification accuracy

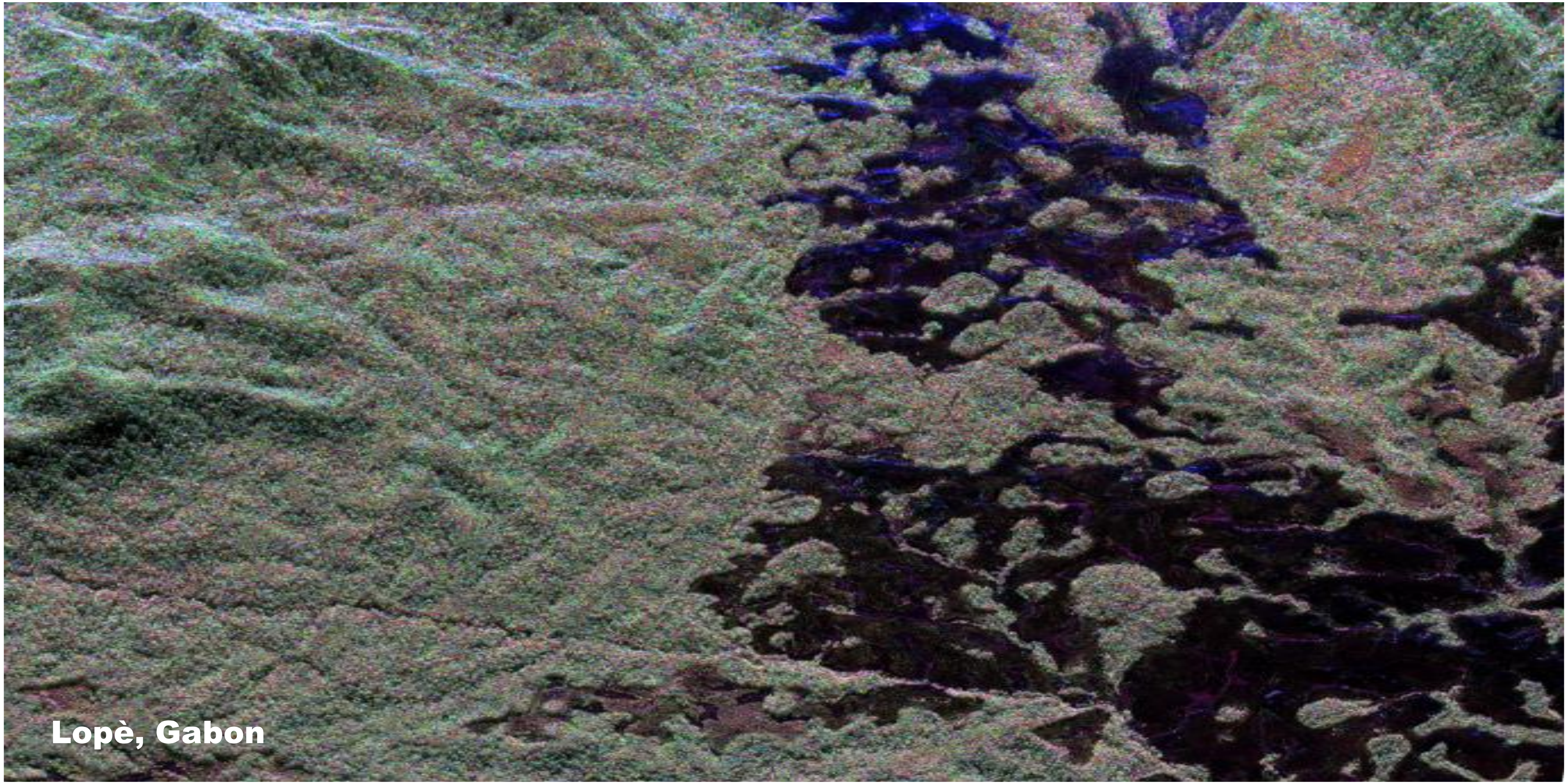
- 1 map every 9 months of all forested areas (excl. SOTR region)

From a radar pulse to tons of biomass per hectare

- A complex 100 W radar pulse, 30 microseconds long, will be sent out 3000 times per second
- Reflected pulses as low as 0.0000000000001 Watts can be used
- Then comes the complex Synthetic Aperture Radar processing to form an image
- Then scientists enter: their algorithms can convert the “radar images” to maps of tons of biomass per hectar



Challenge – Retrieve forest biomass and height



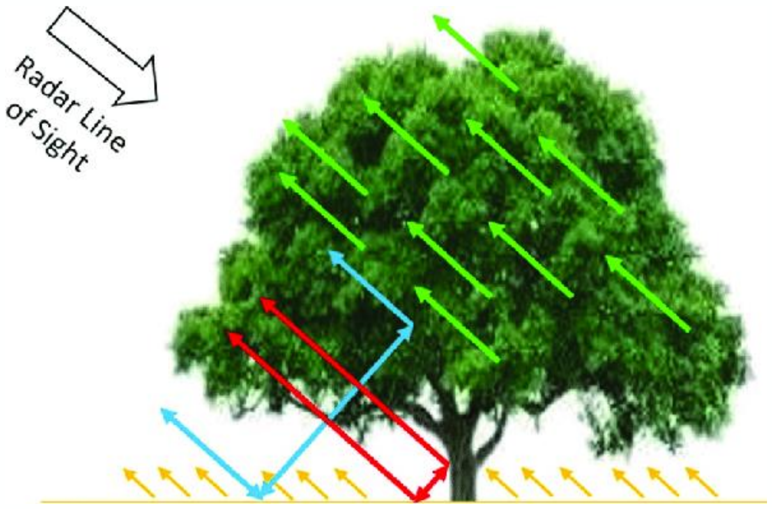
Tropical Forest as seen by DLR's P-band F-SAR

HH+VV HV HH-VV

How can we use Biomass to retrieve AGB

Retrieval algorithm

- Scattering can be described by three terms volume + double bounce + soil, such as in the Truong Loi Model below



$$\sigma_{pq} = \text{volume} + \text{double} - \text{bounce} + \text{soil}$$

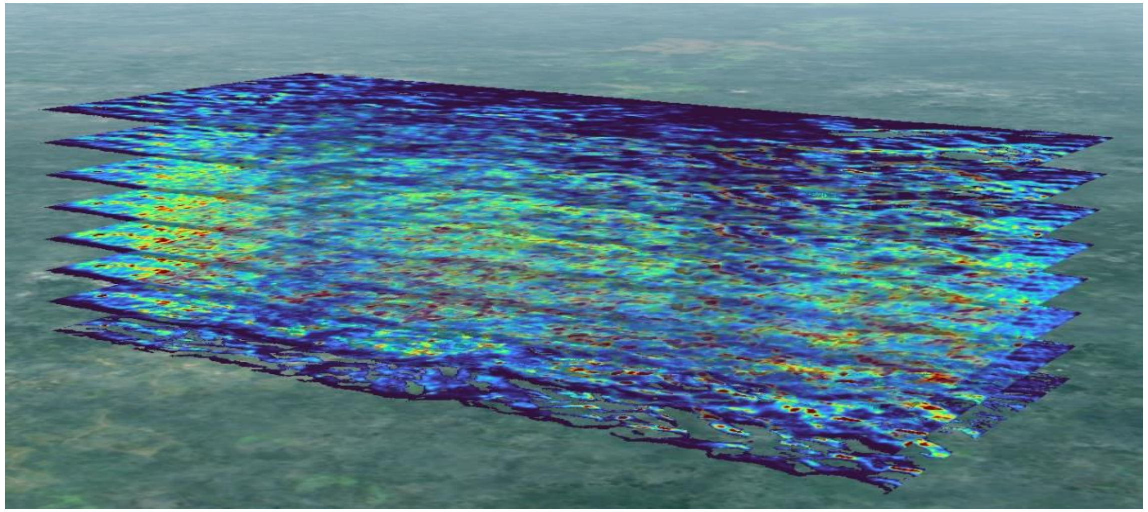
$$= A_{pq} W^{\alpha_{pq}} \cos\theta \left(1 - \exp\left(-\frac{B_{pq} W^{\beta_{pq}}}{\cos\theta}\right)\right) + C_{pq} \Gamma_{pq} W^{\delta_{pq}} \sin\theta \exp\left(-\frac{B_{pq} W^{\beta_{pq}}}{\cos\theta}\right)$$

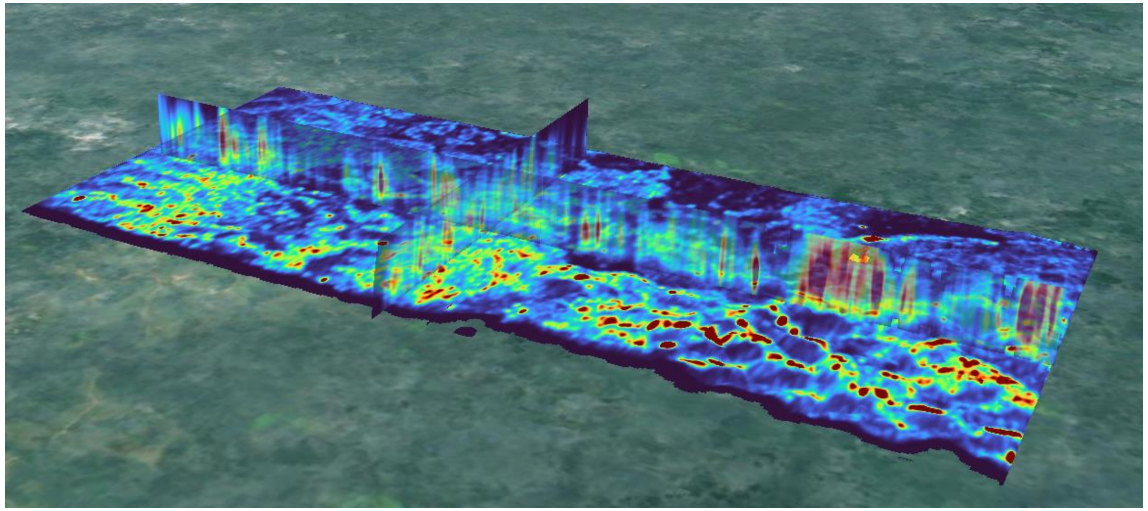
$$+ S_{pq} \exp\left(-\frac{B_{pq} W^{\beta_{pq}}}{\cos\theta}\right)$$

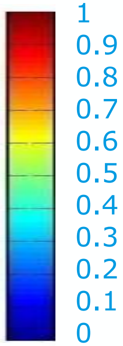
W = AGB
θ = incidence angle
pq = polarization

Tomographic SAR

3D image of the forest







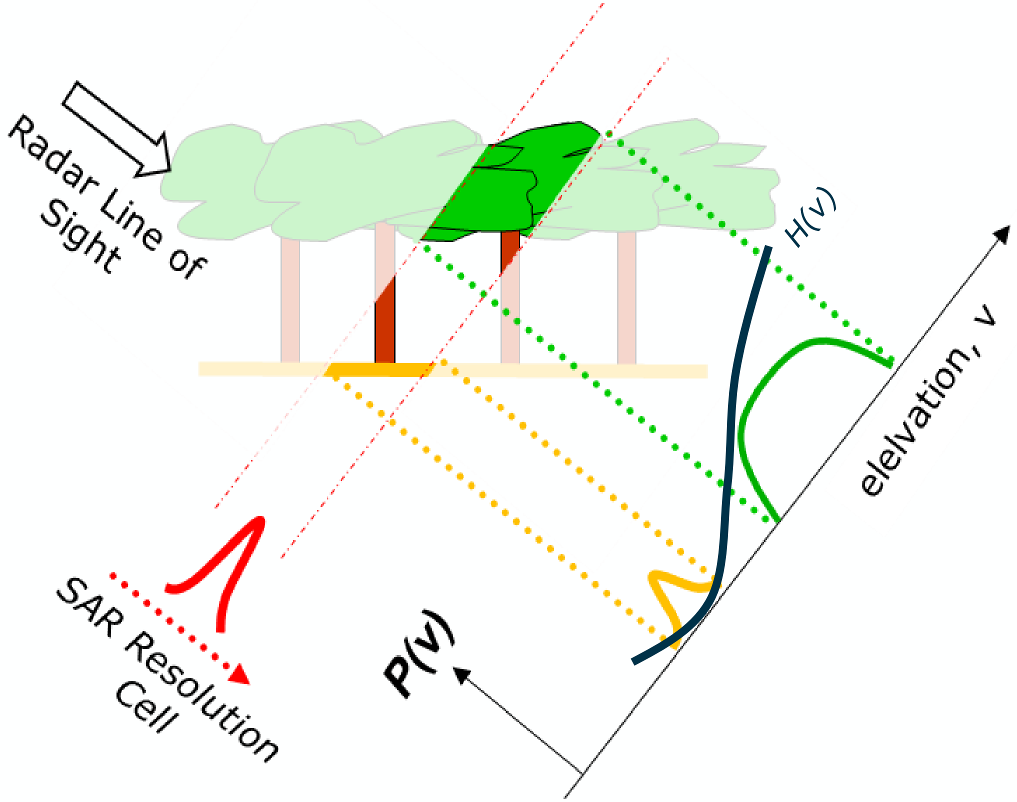
Normalised backscatter intensity

The Biomass AGB retrieval: Interferometric ground notching

Ground cancellation: the ground cancellation technique was developed to preserve the advantages of SAR Tomography during Mission lifetime.

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

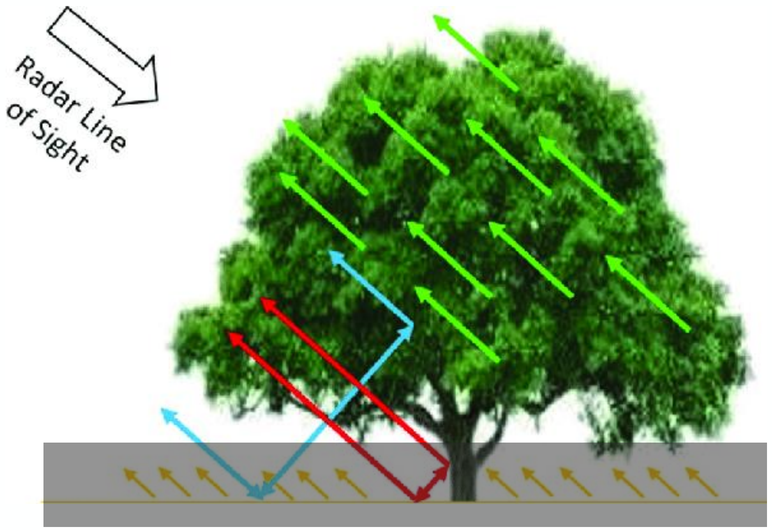
Principle: SLC = projection of modulated target reflectivity along elevation.



How can we use Biomass to retrieve AGB

Retrieval algorithm

- The starting point of the inversion algorithm is the volume + double bounce + soil



$$\sigma_{pq} = \text{volume} + \text{double bounce} + \text{soil}$$

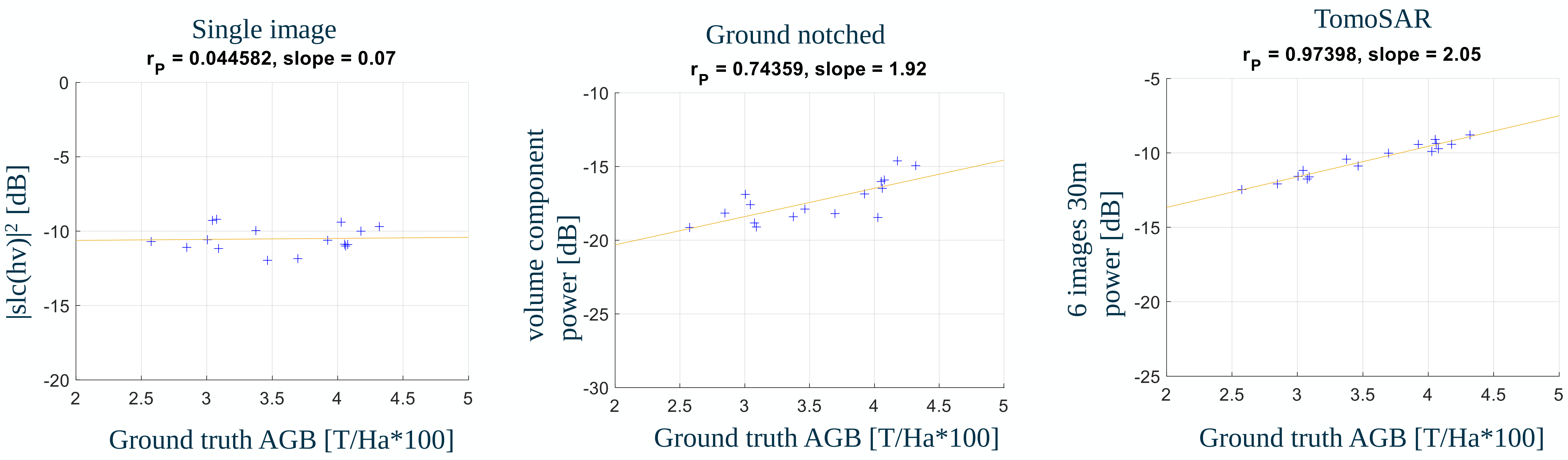
$$= A_{pq} W^{\alpha_{pq}} \cos\theta \left(1 - \exp\left(-\frac{B_{pq} W^{\beta_{pq}}}{\cos\theta}\right)\right) + C_{pq} \Gamma_{pq} W^{\delta_{pq}} \sin\theta \exp\left(-\frac{B_{pq} W^{\beta_{pq}}}{\cos\theta}\right)$$

$$+ S_{pq} \exp\left(-\frac{B_{pq} W^{\beta_{pq}}}{\cos\theta}\right)$$

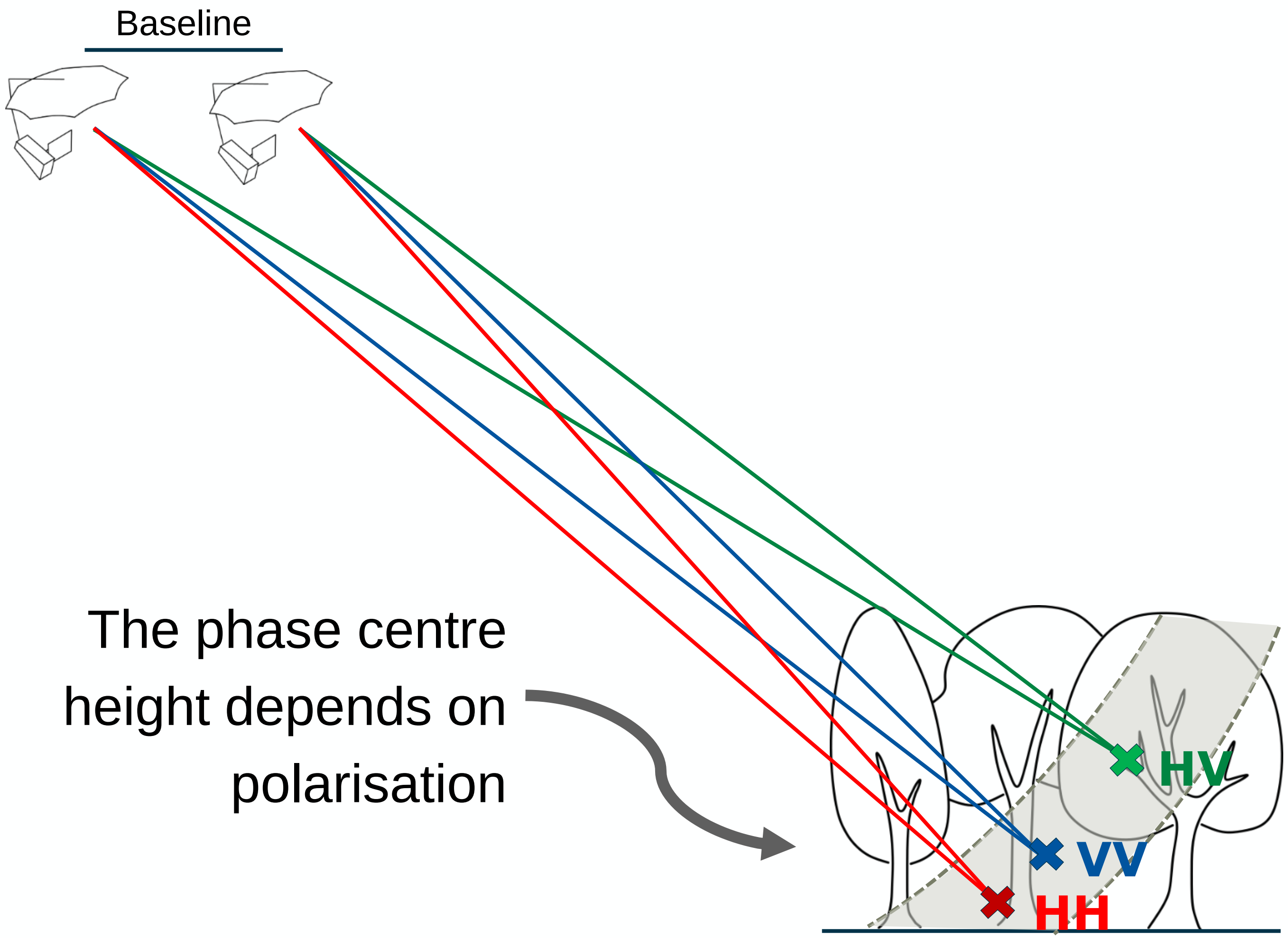
For both low and high attenuation this reduces to a power law whose parameters can be estimated from the data using limited ground data:

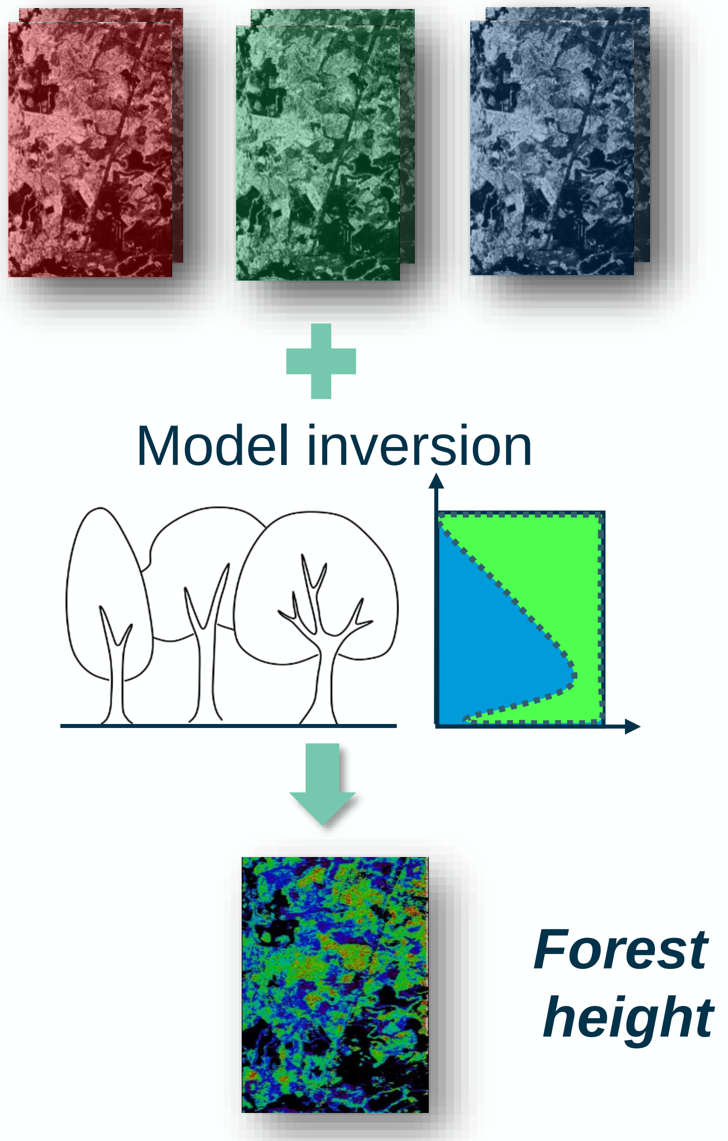
$$s_{PQi} = log\left(\sigma_{pq}^{v}\right) = l_{PQ} + \alpha_{PQ} w_i + n_{PQ} c_i$$

AGB vs P-band backscatter

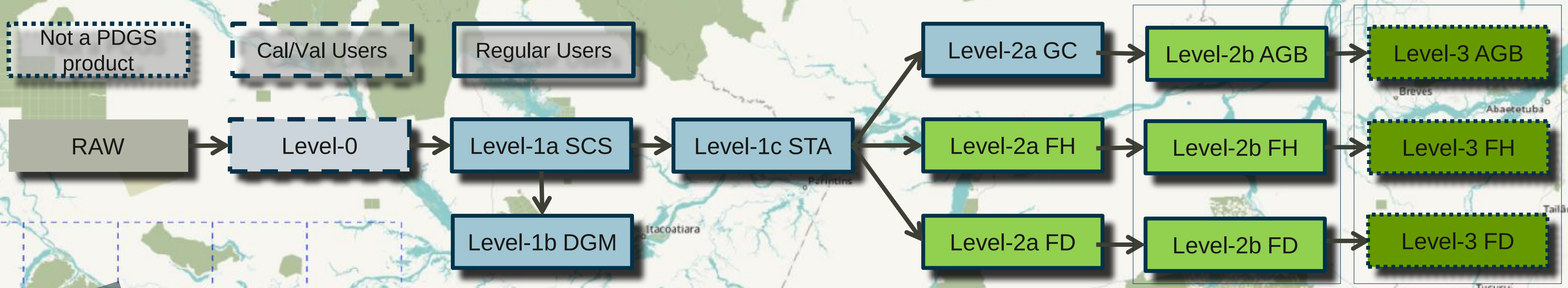


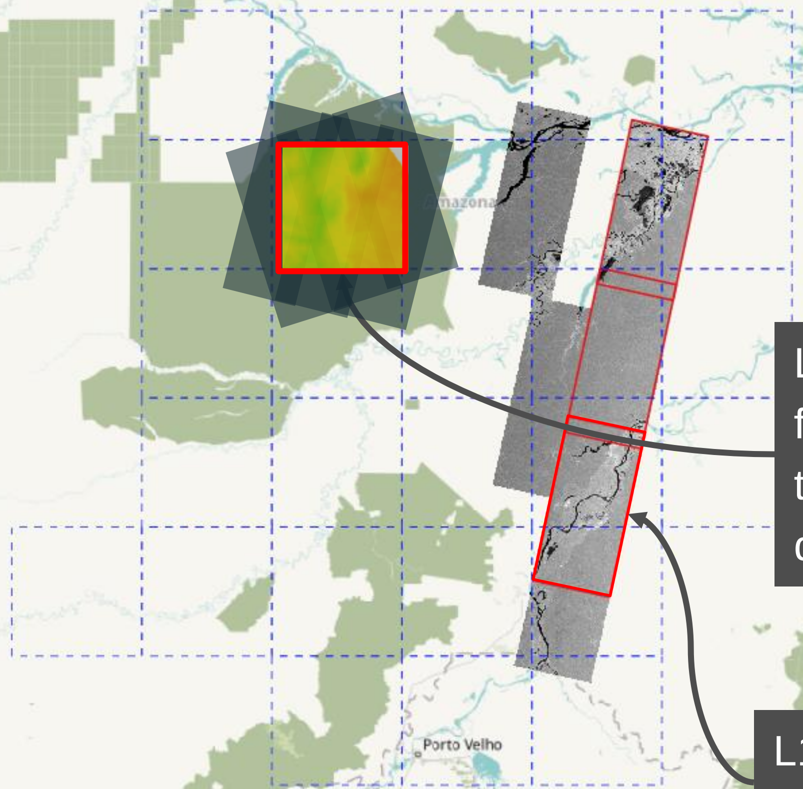
Polarimetric Interferometric SAR





BIOMASS Algorithms and Product layout





L2b and L3 products combine L2a frames from ascending and descending tracks and are provided on a pre-defined tile grid of 1º x 1º

L1 a/b/c and L2a products are provided as standard frames

BioPAL

biopal@esa.int

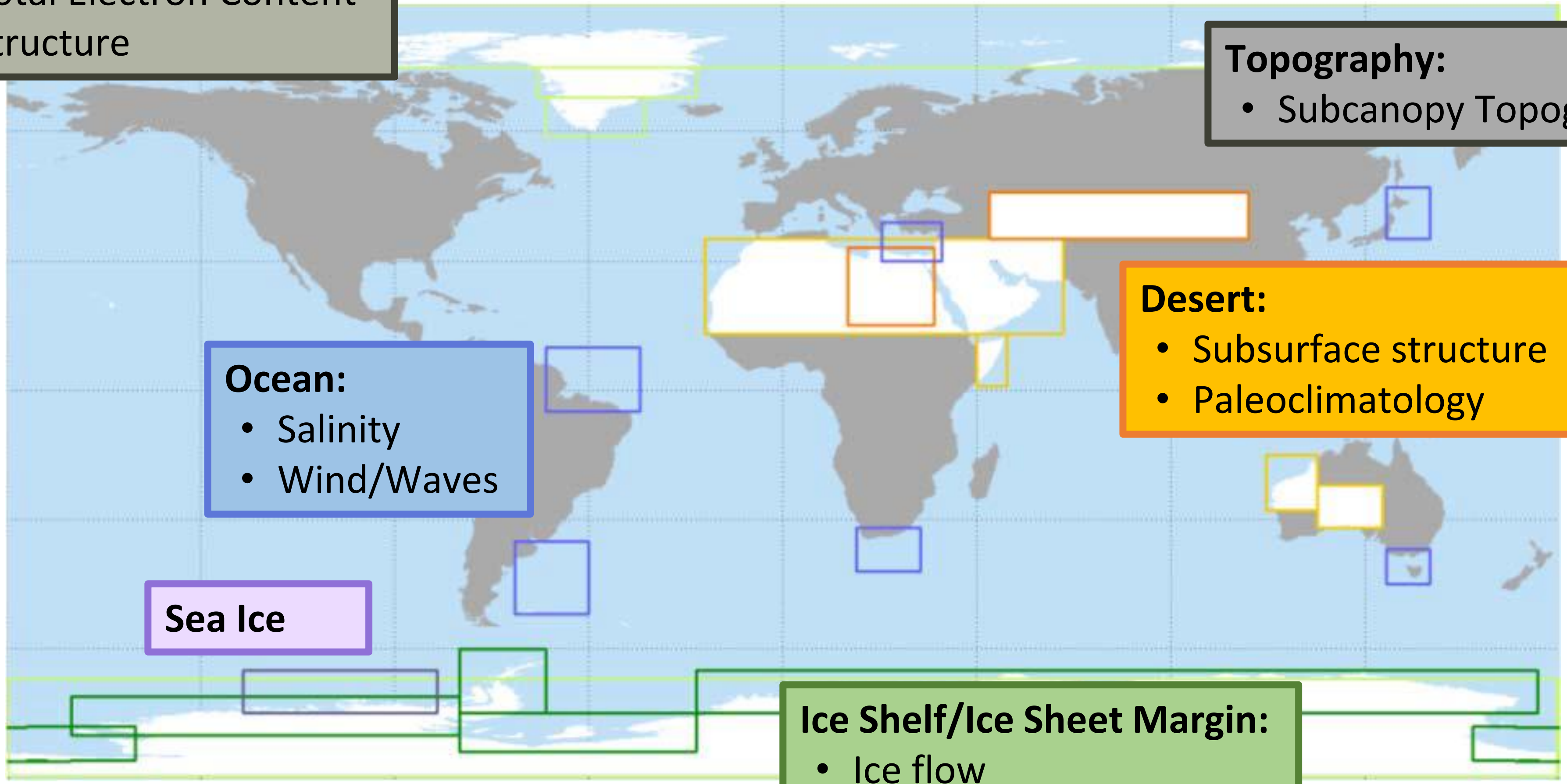
biopal.org

github.com/BioPAL

BIOMASS beyond forests

Ionosphere:
- Total Electron Content
- Structure

Topography:
- Subcanopy Topography



Desert:
- Subsurface structure
- Paleoclimatology

Ocean:
- Salinity
- Wind/Waves

Sea Ice

Ice Shelf/Ice Sheet Margin:
- Ice flow
- Ice Structure
- Bathymetry

Summary – BIOMASS a true Earth Explorer

1. BIOMASS is ESA's Forest mission. The satellite is in Kourou and currently undergoes final testing. We will launch on 29th April 2025.

2. BIOMASS is the first P-band SAR in space. It is a true Earth Explorer, we will face a lot of unknowns but also a lot of exciting research opportunities.

3. It is the first Earth Explorer not only sharing its data open and free but also following Open Source best practices for its higher level processors.

4. 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 ...

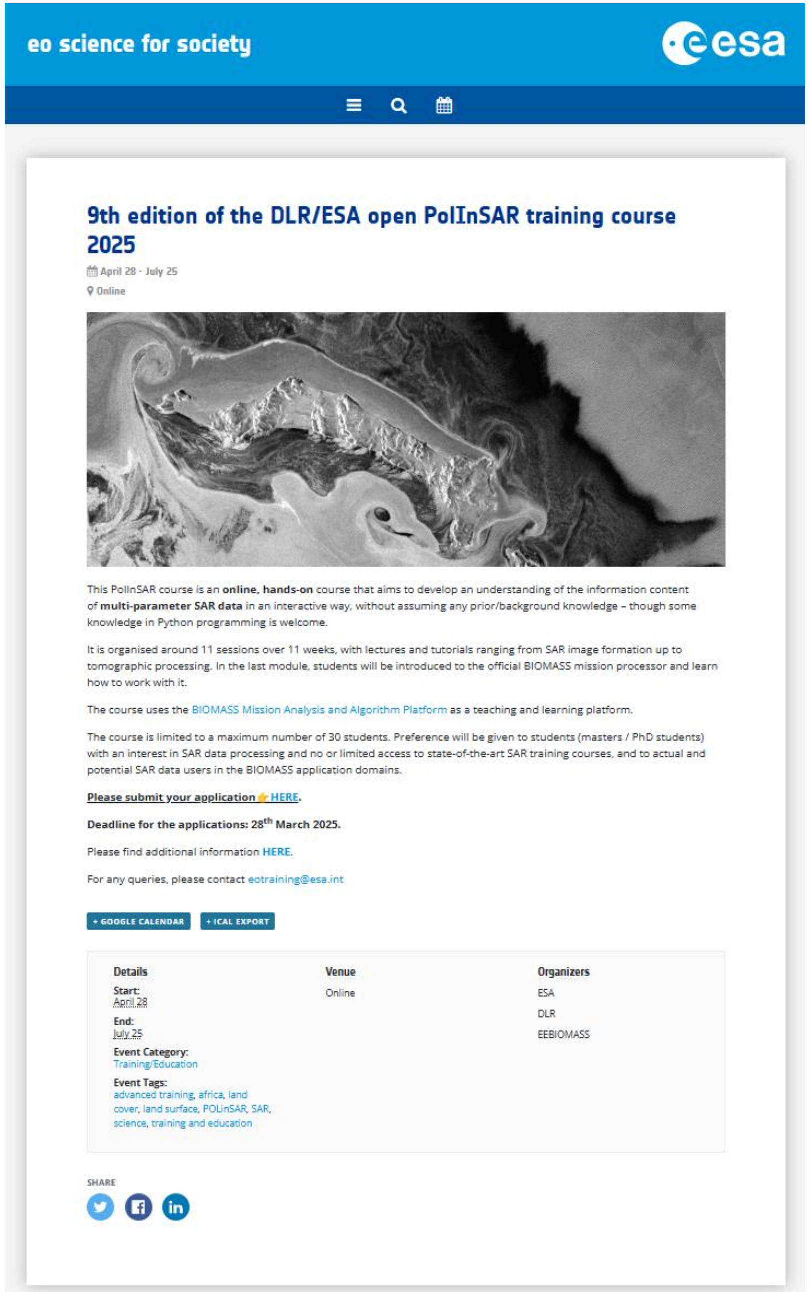
Training Opportunities

https://eo4society.esa.int/event/9th-edition-of-the-dlr-esa-open-polinsar-training-course-2025/

1. **DLR and ESA organize a virtual PolInSAR Training course.**
   - 11 modules in 11 weeks
   - Starting from basic SAR principles going up to Tomographic processing.
   - **Next Course starts 28th April**
   - **Application Deadline 28th March**

2. **Open to Non ESA Member states. Preference given to**
   - Students with expertise in related fields.
   - Young career scientists (MSc, PhD level).

3. **Resources are made available on the BIOMASS Mission Algorithm and Analysis Platform.**
   - Minimizing the barrier to join the course - tools and computing resources are free.
   - Opportunity to familiarize with innovative Ground Segment Infrastructure
   - Opportunity to familiarize with the BIOMASS missions and its processors


eo science for society

esa

9th edition of the DLR/ESA open PolInSAR training course 2025

April 28 - July 25

Online

This PolInSAR course is an **online, hands-on** course that aims to develop an understanding of the information content of **multi-parameter SAR data** in an interactive way, without assuming any prior/background knowledge – though some knowledge in Python programming is welcome.

It is organised around 11 sessions over 11 weeks, with lectures and tutorials ranging from SAR image formation up to tomographic processing. In the last module, students will be introduced to the official BIOMASS mission processor and learn how to work with it.

The course uses the BIOMASS Mission Analysis and Algorithm Platform as a teaching and learning platform.

The course is limited to a maximum number of 30 students. Preference will be given to students (masters / PhD students) with an interest in SAR data processing and no or limited access to state-of-the-art SAR training courses, and to actual and potential SAR data users in the BIOMASS application domains.

Please submit your application HERE.

Deadline for the applications: 28th March 2025.

Please find additional information HERE.

For any queries, please contact eotraining@esa.int

+ GOOGLE CALENDAR + ICAL EXPORT

Details	Venue	Organizers
Start: April 28	Online	ESA
End: July 25		DLR
Event Category: Training/Education		EEBIOMASS
Event Tags: advanced training, africa, land cover, land surface, POLinSAR, SAR, science, training and education		

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Thank you