
# The BIOMASS Mission: Overview and Status

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*European Space Agency*

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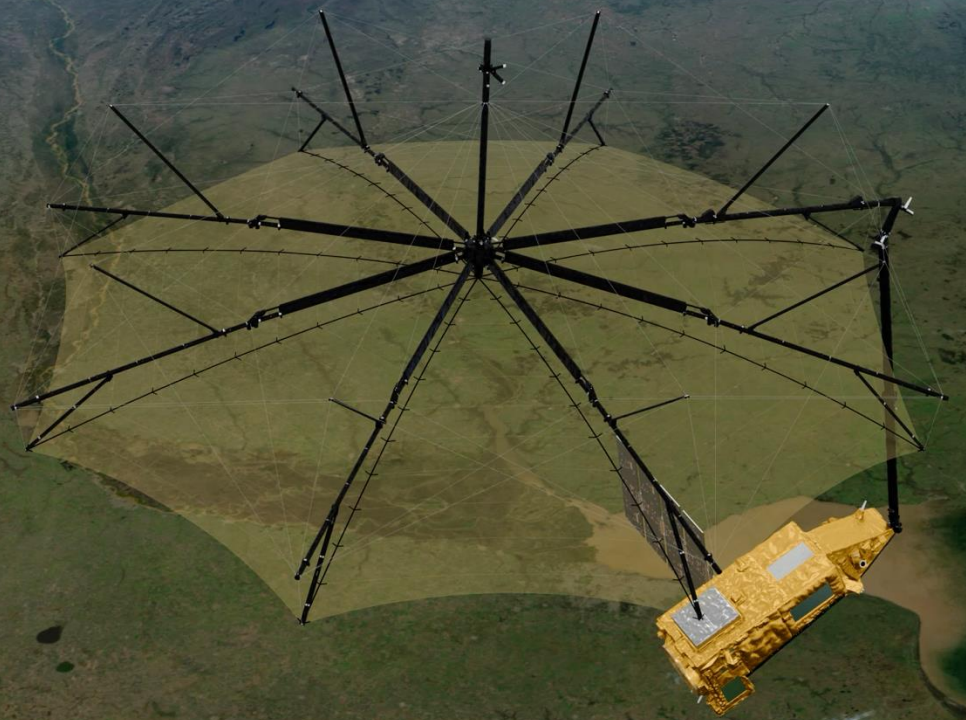
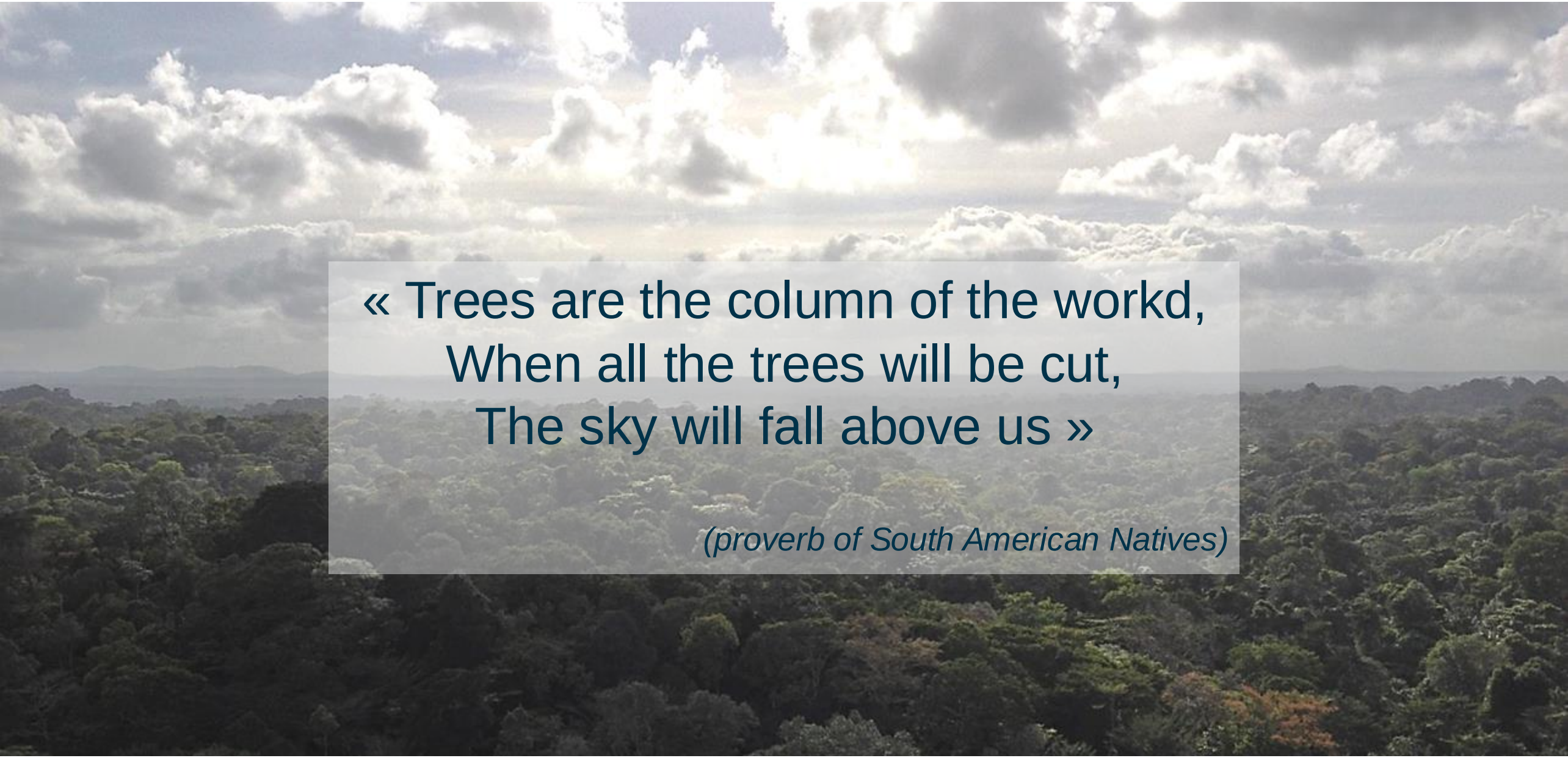
# The BIOMASS Mission



**ESA’s 7th Earth Explorer to be deployed in 2025**

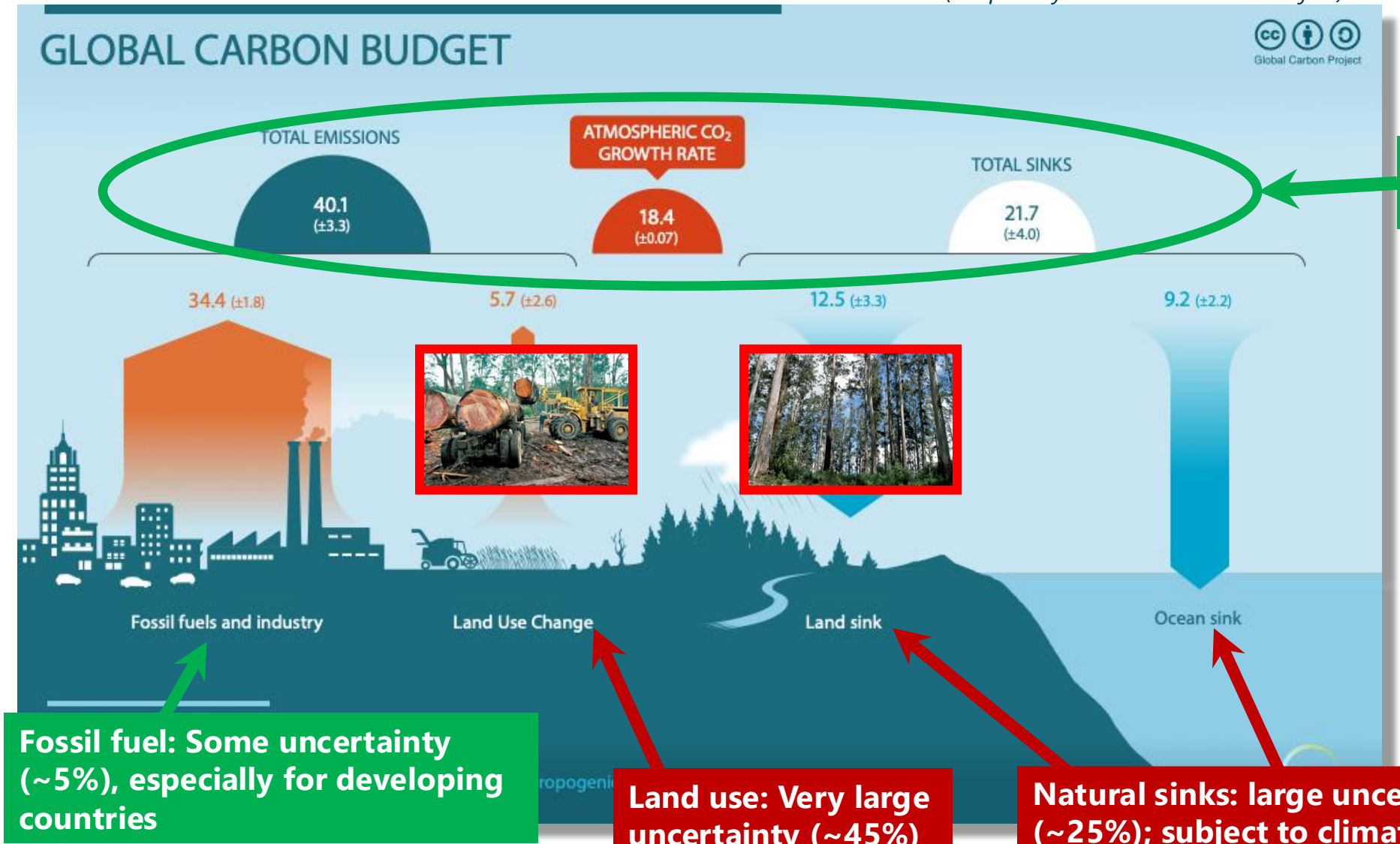
**An interferometric, fully-polarimetric P-band SAR**

**Designed to observe forest height and biomass**


« Trees are the column of the workd,
When all the trees will be cut,
The sky will fall above us »
(proverb of South American Natives)

# The Science Question: How well do we understand the CO2 fluxes ?

*(Graphic by the Global Carbon Project)*




**Top level global budget is well understood**

**Fossil fuel: Some uncertainty (~5%), especially for developing countries**

**Land use: Very large uncertainty (~45%)**

**Natural sinks: large uncertainties (~25%); subject to climate feedbacks**

# Beyond Carbon: Changes in forest affect the benefits we gain from forests

Changes in forest have major effects on the socio-economics, material, energy, protective, biodiversity & cultural benefits offered by forests.

# 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**
   - deforestation (~95% of the Land Use Change flux)
   - regrowth (~50% of the global biomass sink)
   - Where we have least information and knowledge.
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 Above Ground Biomass (AGB)?

AGB: *"Dry mass of live or dead matter from tree or shrub"*

Tree allometry links biomass to:

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

Wood density — $\rho$

Diameter — $D^2$

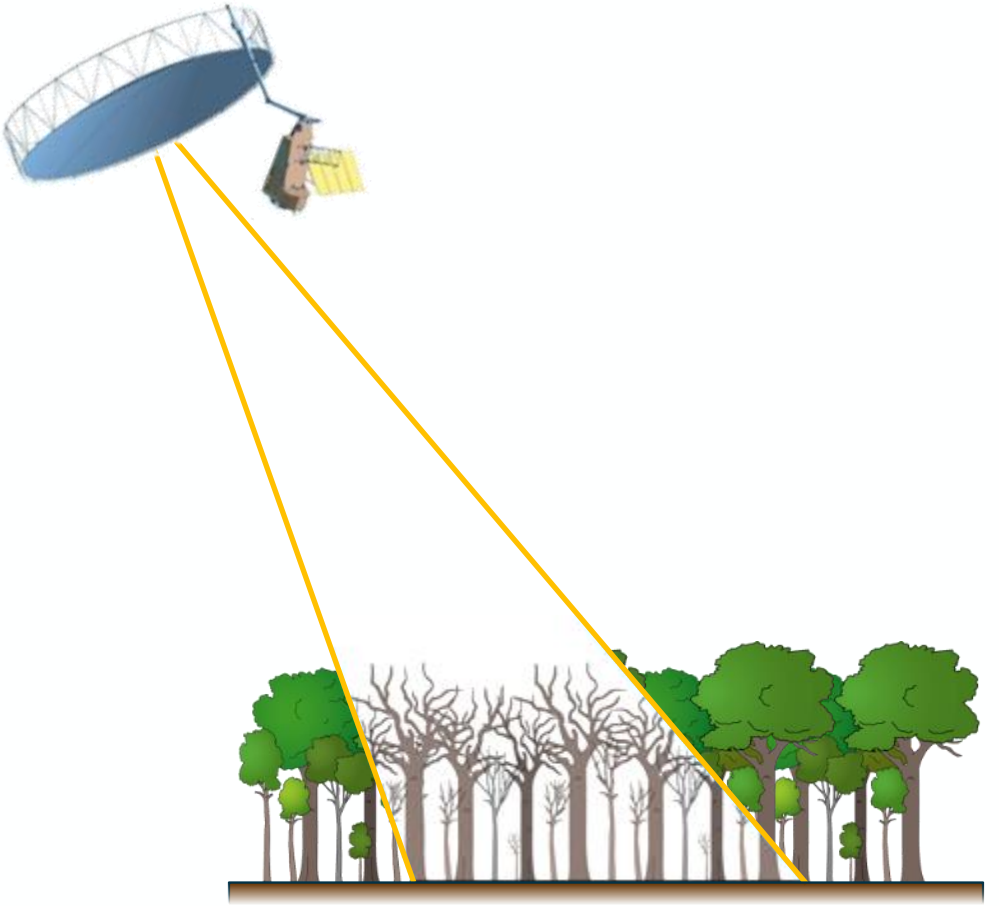
Height — $H$

# Why a P-band SAR to measure the world forest biomass?

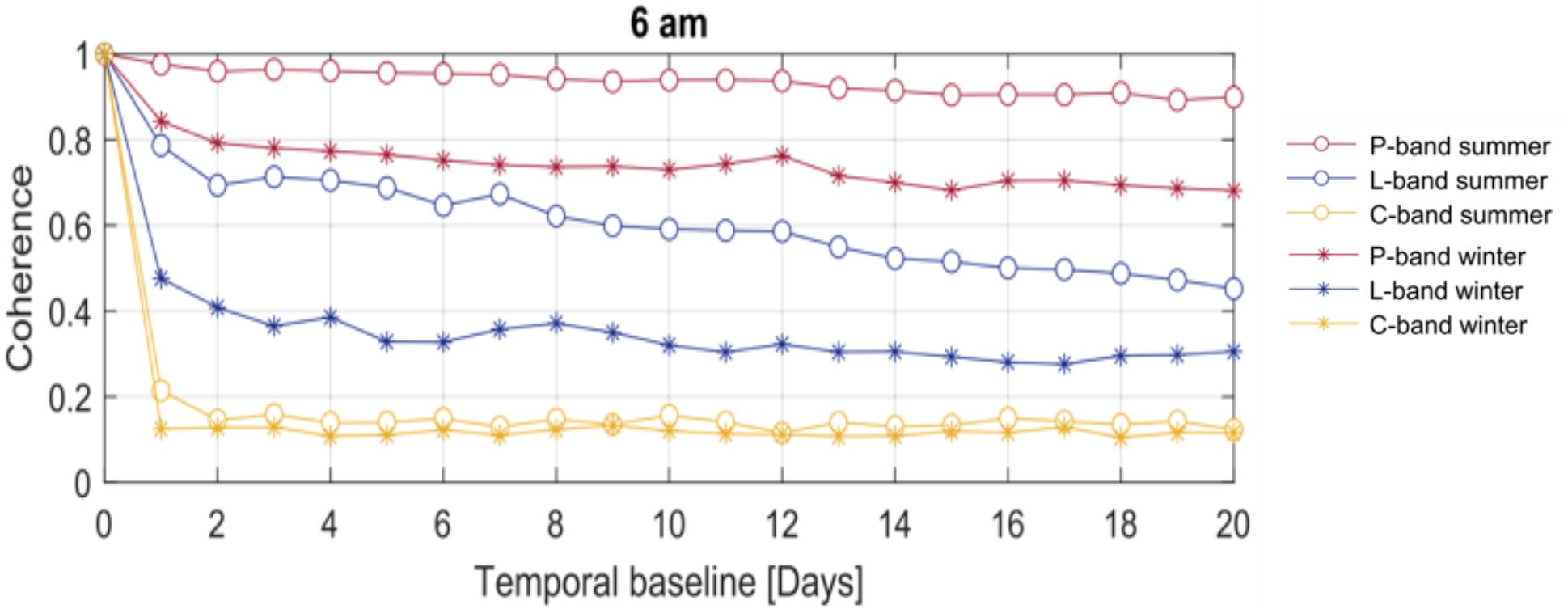
**Mapping forest biomass requires a radar sensor with long wavelength:**

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**



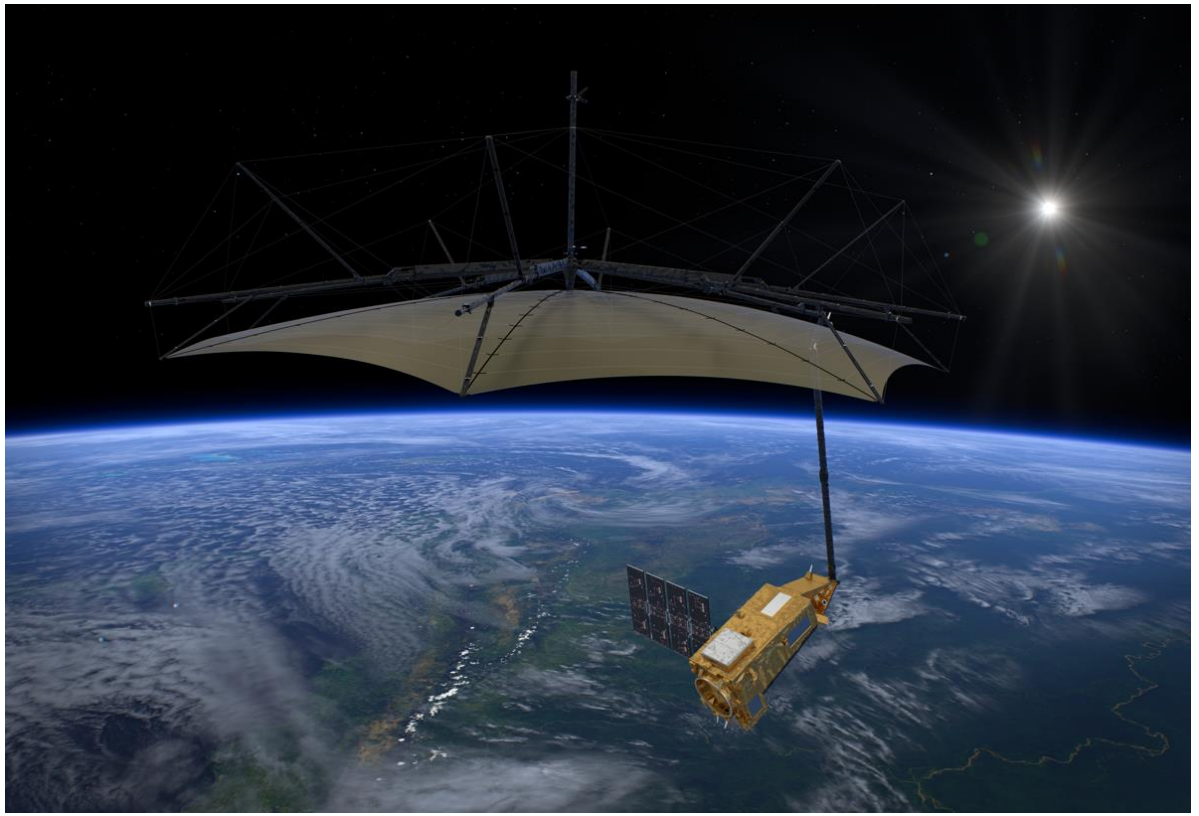
# Choice of frequency



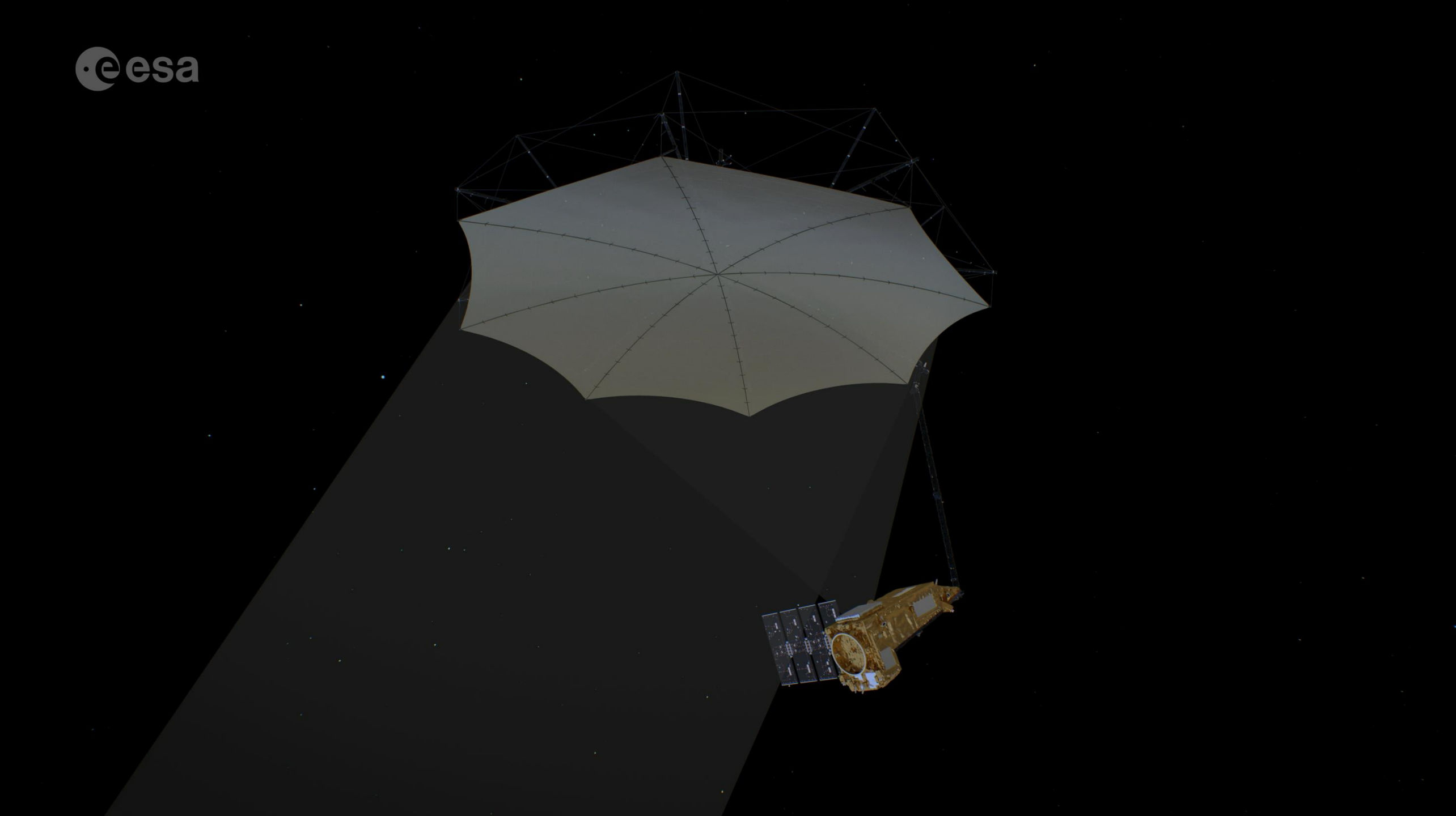

ESA BorealScat experiment. Median temporal coherence over temporal baselines of multiples of one day.
From Monteith and Ulander, TGRS, 2021

- P-band 'sees' the trunk and (big) branches, provide 'more direct' information on woody above ground biomass.
- P-band stays coherent for longer, enabling repeat pass interferometry.

# BIOMASS Mission



- Synthetic Aperture Radar
- Full polarimetric, P-band (at 435 MHz with 6 MHz bandwidth)
- Single satellite, operated in a polar sun-synchronous orbit
- Two mission phases: PolInSAR and TomoSAR (1 global acquisition at the beginning of the mission)
- Multi-repeat pass interferometry (3 passes in nominal operations) with a 3 days repeat cycle
- 5 years lifetime

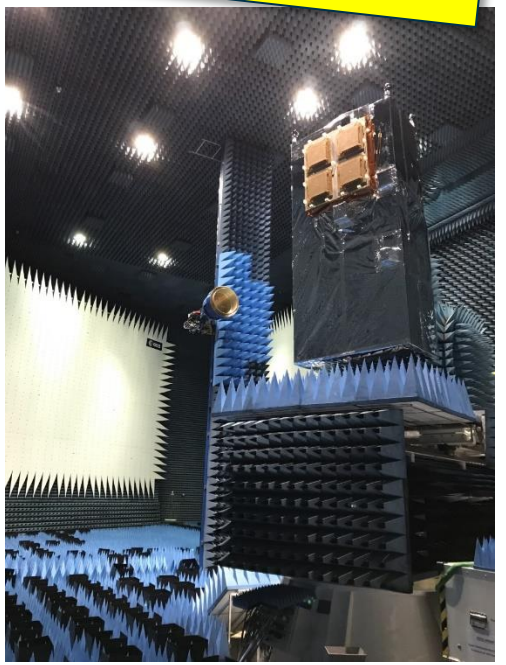


# The satellite is taking shape

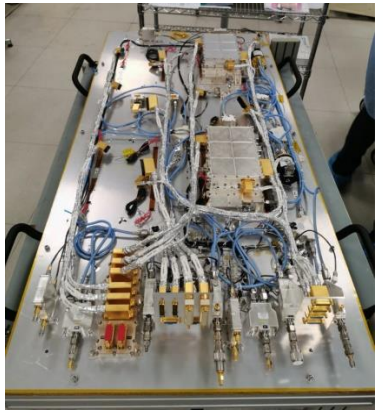
**Toward a launch in March-April 2025!**

Platform

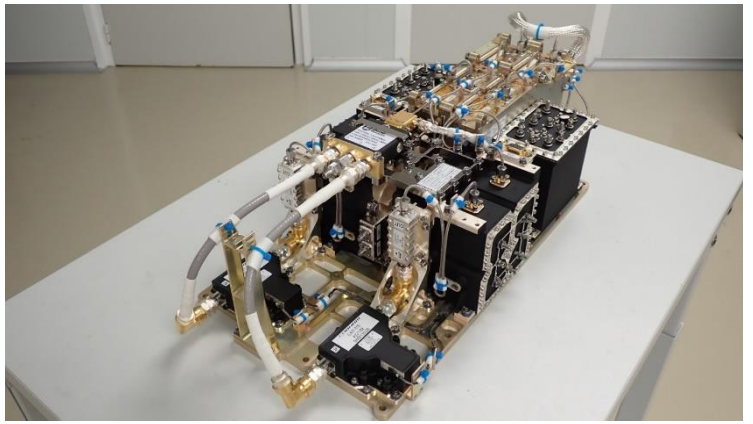
Large Deployable Antenna



Feed Array



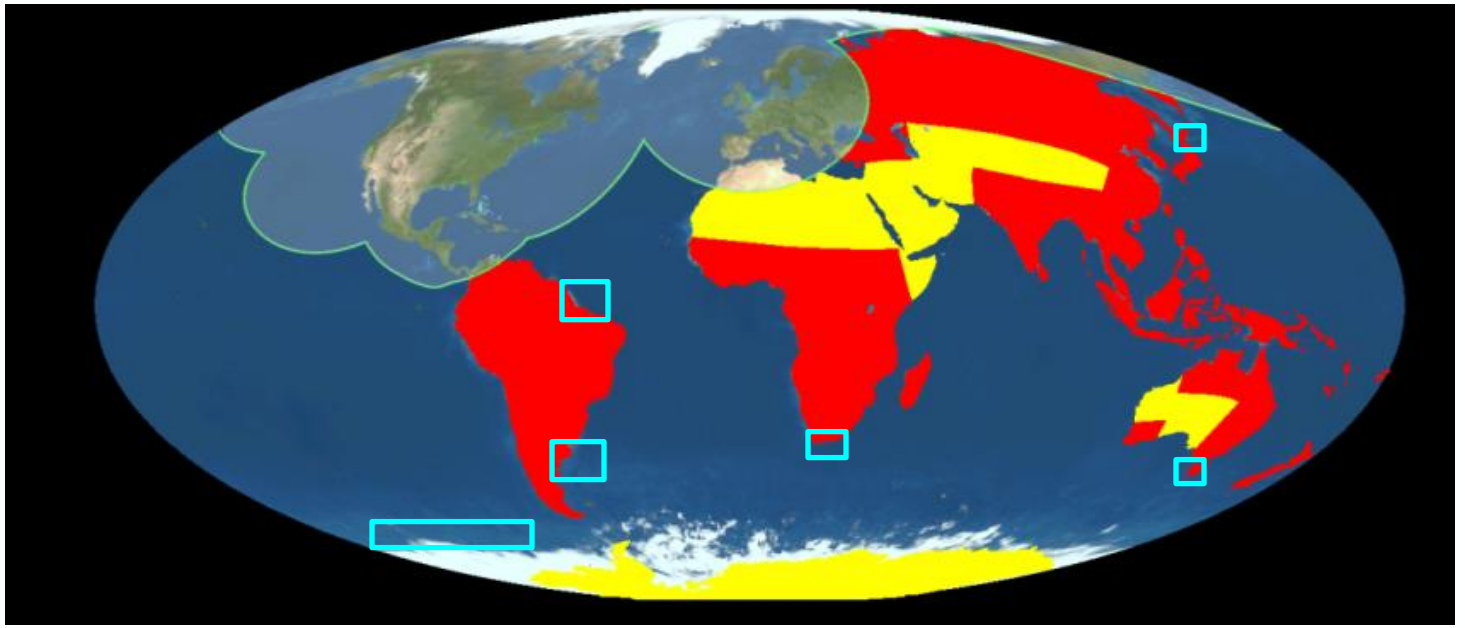
Power Amplifier



Receiver

# Coverage

1. Systematic Acquisitions for forested land (red area)
2. Global coverage in 9 months (INT phase) and 18 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)

# Biomass Products


**Above-ground biomass (tons/hectare)**

- 200 m resolution
- accuracy of 20%, or 10 t $ha^{-1}$ for biomass < 50 $t.ha^{-1}$

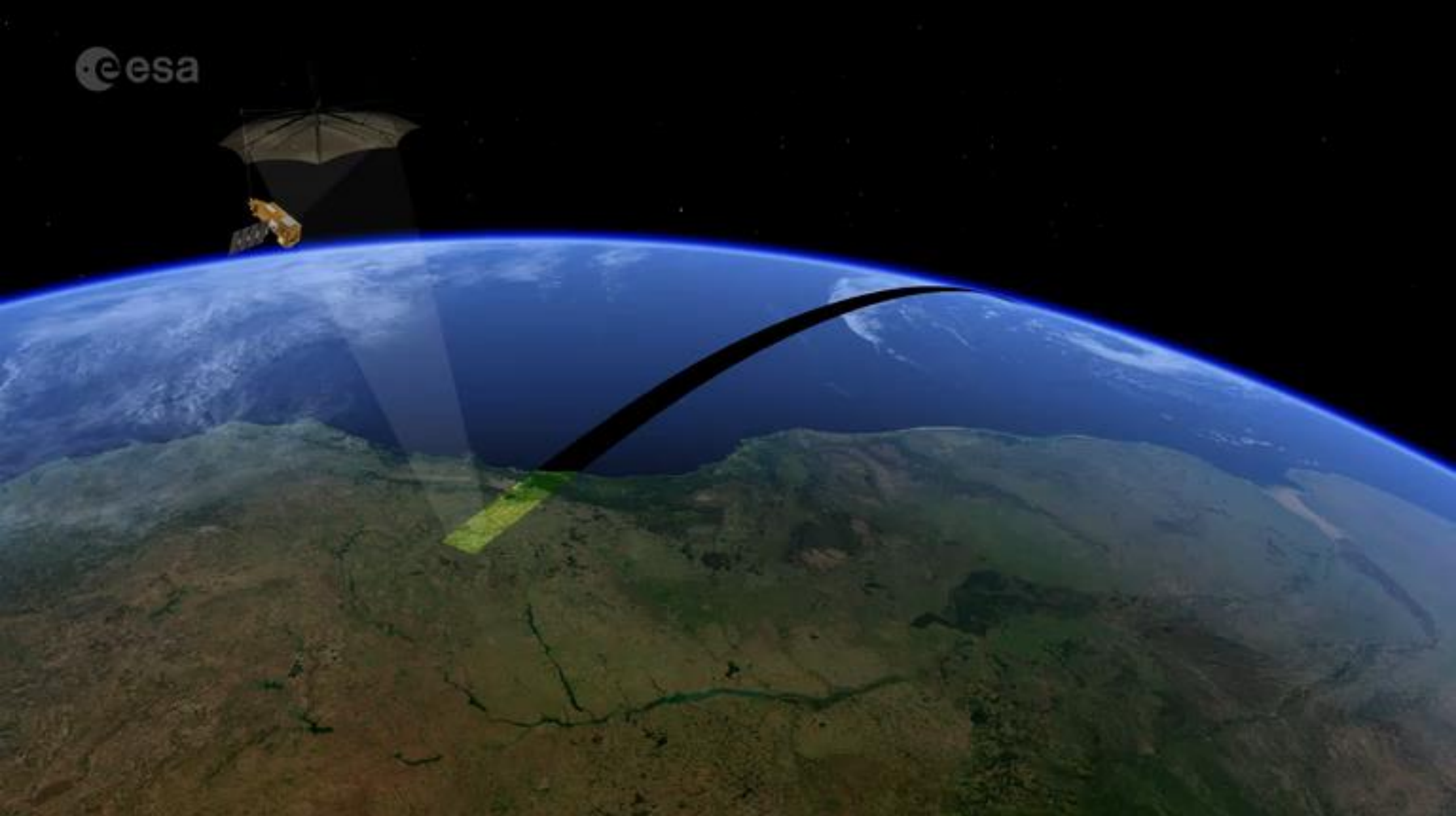

**Upper canopy height (meter)**

- 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)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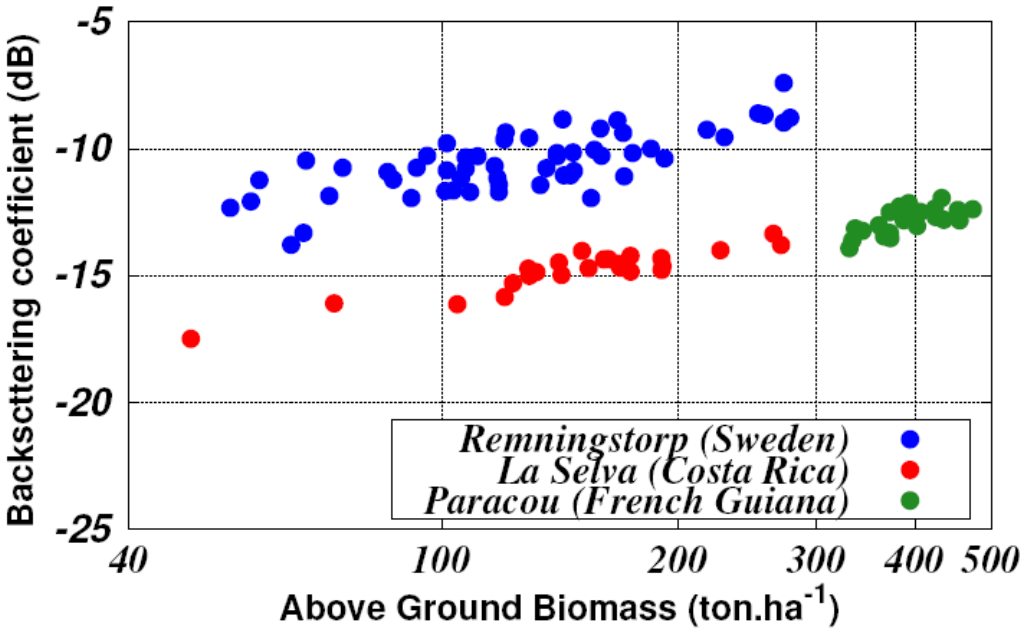
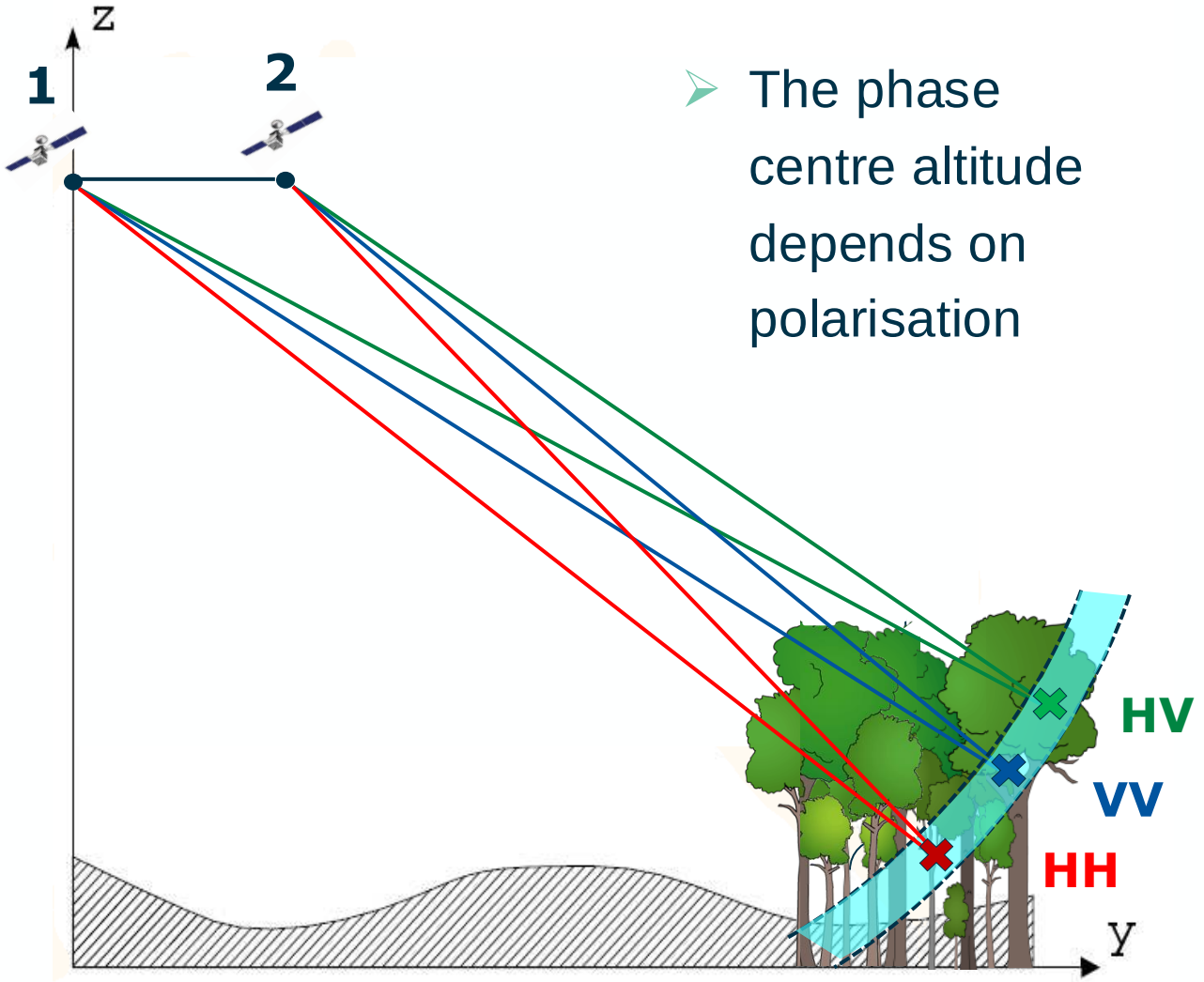
# a) Polarimetric SAR

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

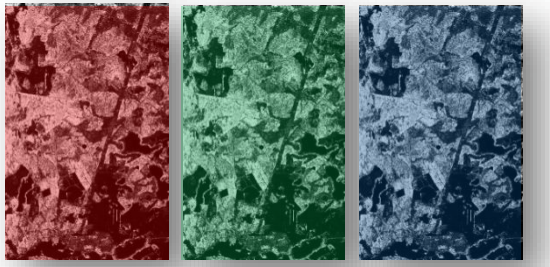
$$\log(AGB) = a + b \cdot \gamma^0{}_{HV}$$



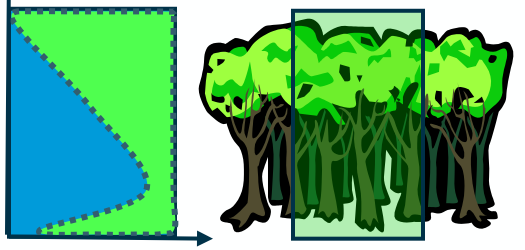
# b) PolInSAR

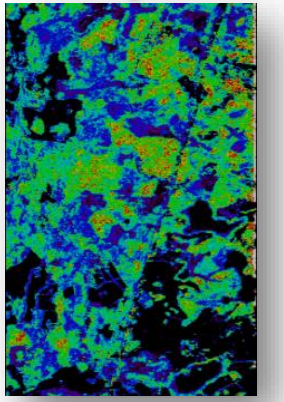



- The phase centre altitude depends on polarisation



Model inversion





***Vegetation height***

# c) SAR tomography, (= “3D SAR”) a new concept to explore 3D forest structure

First phase of the mission only

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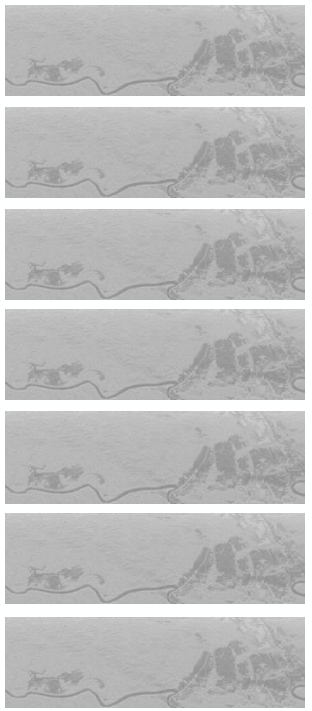
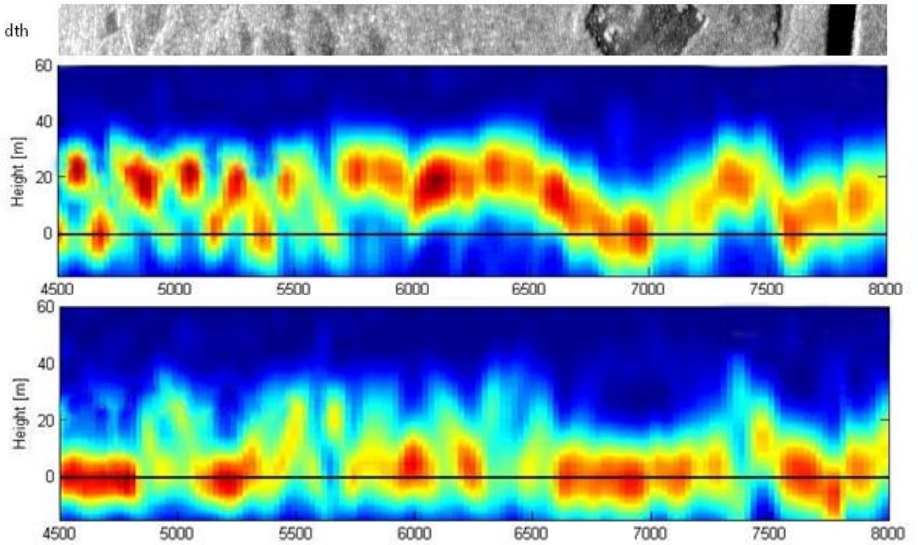
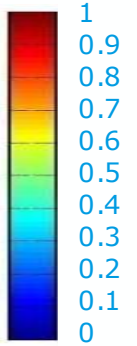
*Stack of 7 acquisitions*



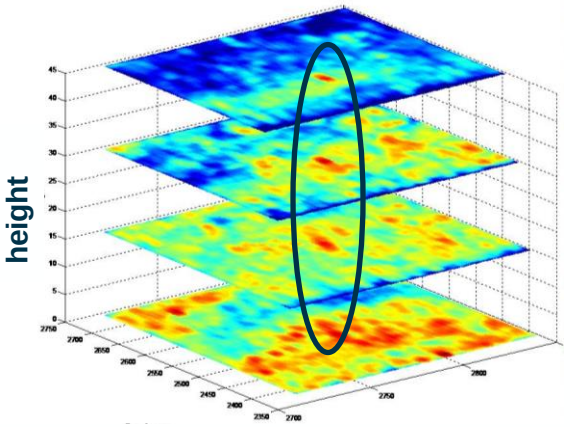
HV

HH

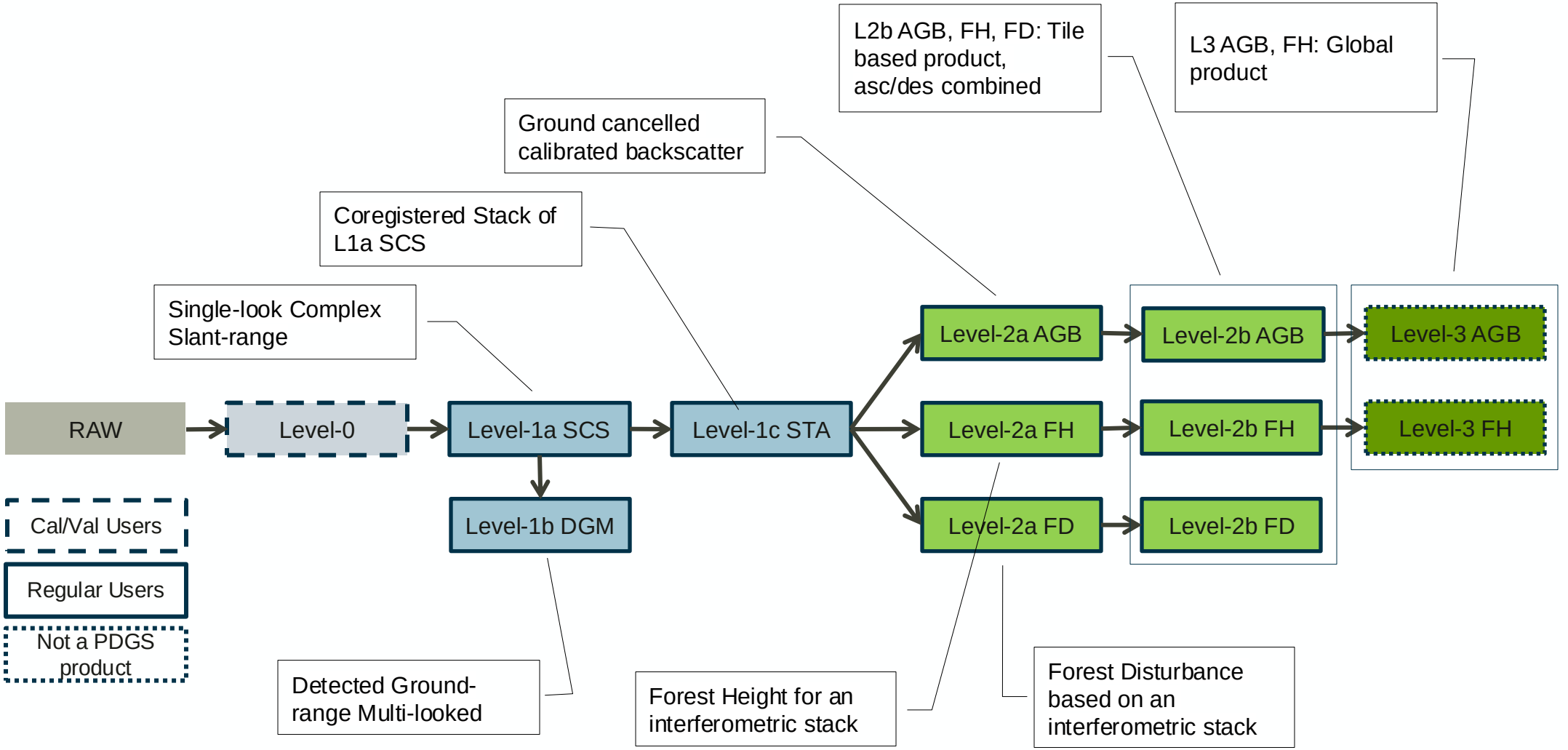


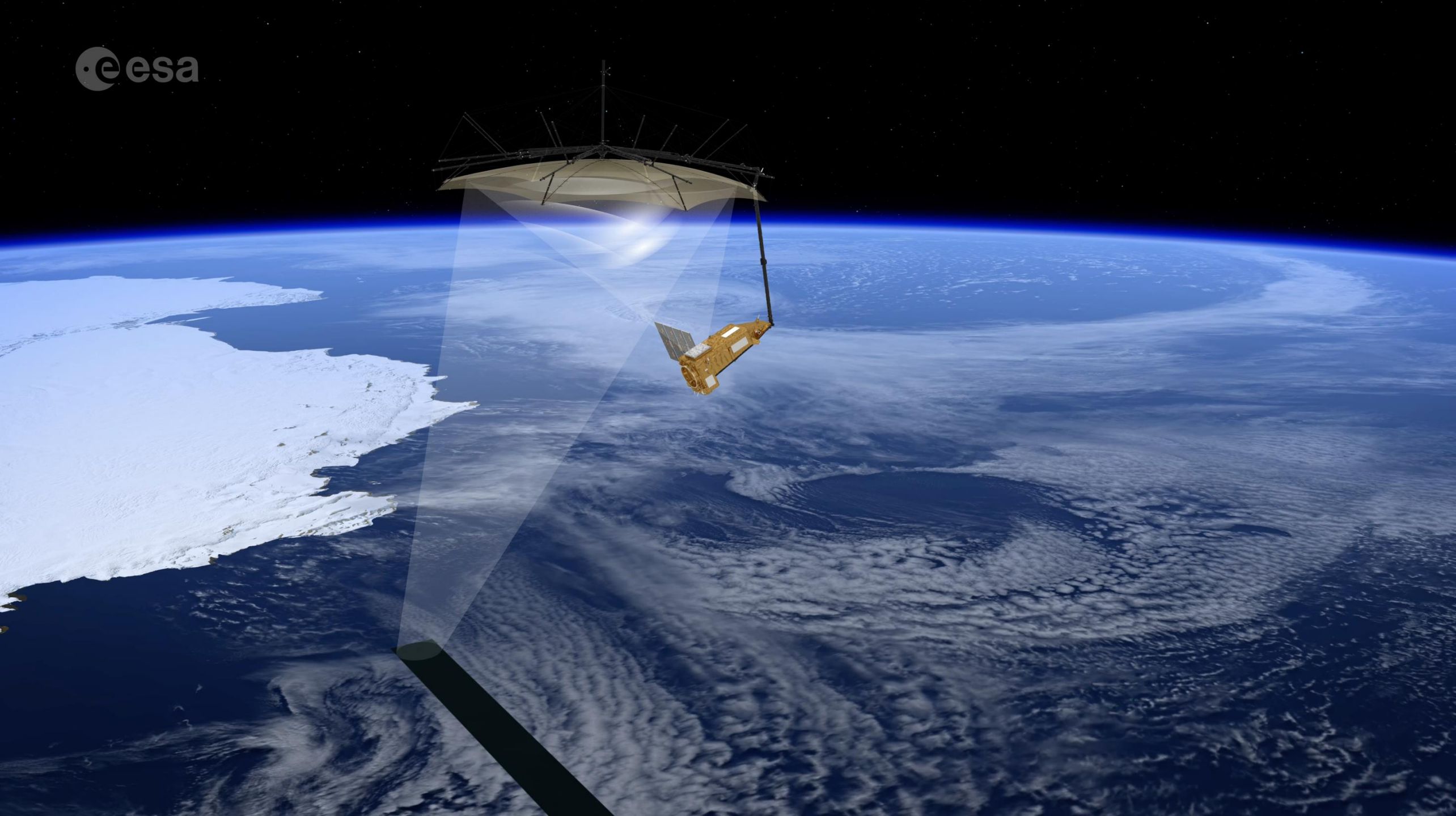




Normalised backscatter intensity




# Biomass Product Tree

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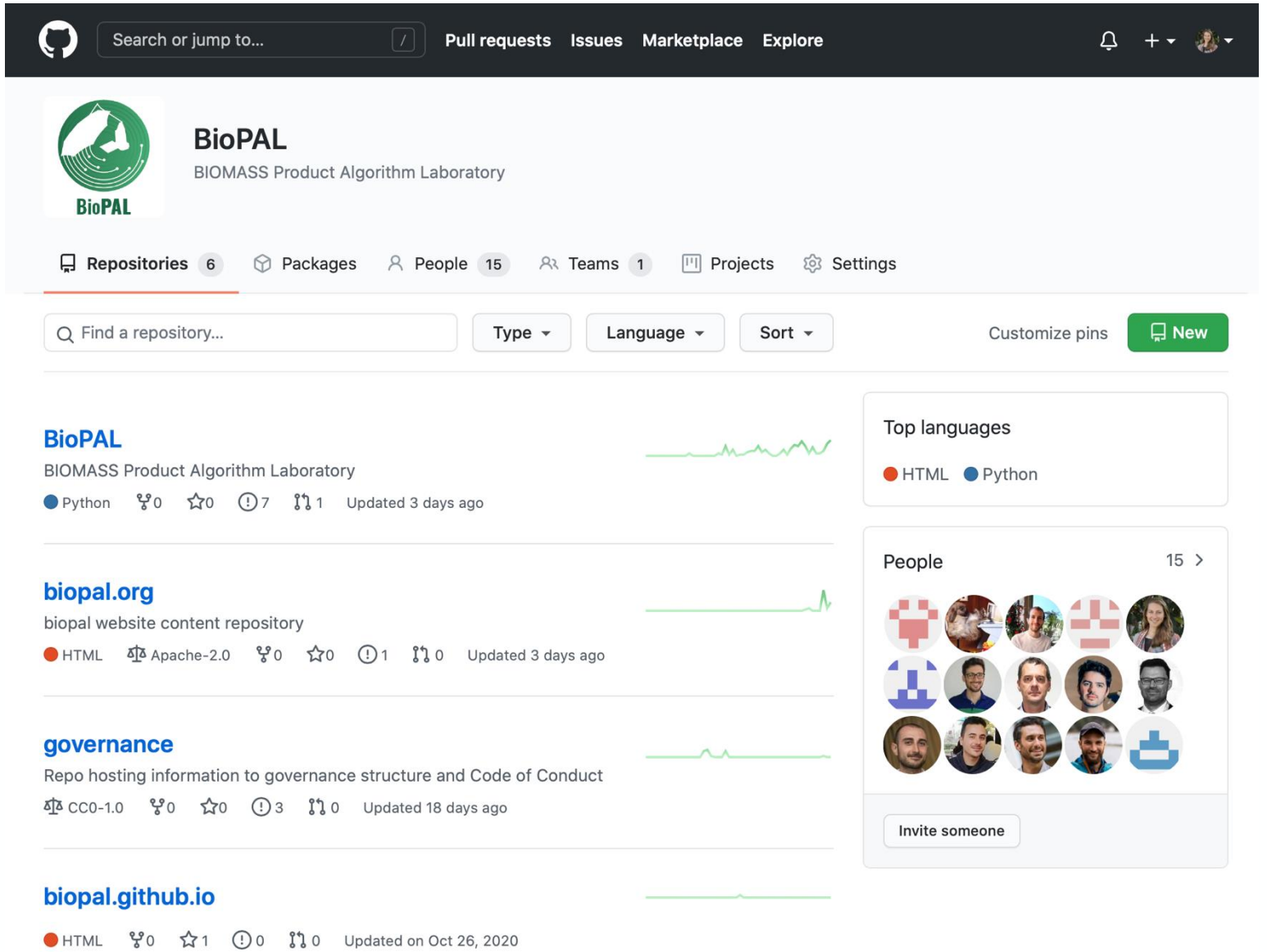
# Open-source Processors

New concept at ESA!




## Open source

Today:
Level-2 prototype algorithms

Tomorrow:
Level-1 (as much as possible), Level-2 and Level-3 operational algorithms, other open-source algorithms (Tomo, DTM, etc.)

biopal@esa.int

biopal.org

github.com/BioPAL

# GEO-TREES: open forest biomass reference sites

**GEO-TREES** consists in a collection of permanent, well-studied, and locally supported sites to support the Cal/Val of the BIOMASS (but also GEDI and NISAR) missions

Sites for validation must be extensive, and cover a range of forest types: tropical, temperate and boreal.

Each site should have:

1. At least 10 1-ha permanent forest plots – established to the highest forest monitoring standards
2. At least 1000 ha of Airborne Lidar Scanning coverage
3. The capacity for Terrestrial Lidar Scanning
4. The capacity to remeasure plots
5. Ancillary data (weather)

- *Following the CEOS WGCV LPV Above Ground Biomass Validation Good Practices*

# “Mission Algorithm and Analysis Platform”

**Baseline for future ESA missions!**

→ ***It’s a Virtual open and collaborative environment that…***



Enables researchers to easily discover, process, visualize, and analyze large volumes of data.



Provides tools and infrastructures to bring data into the same coordinate reference frame to enable comparison, analysis, data evaluation, and data generation.



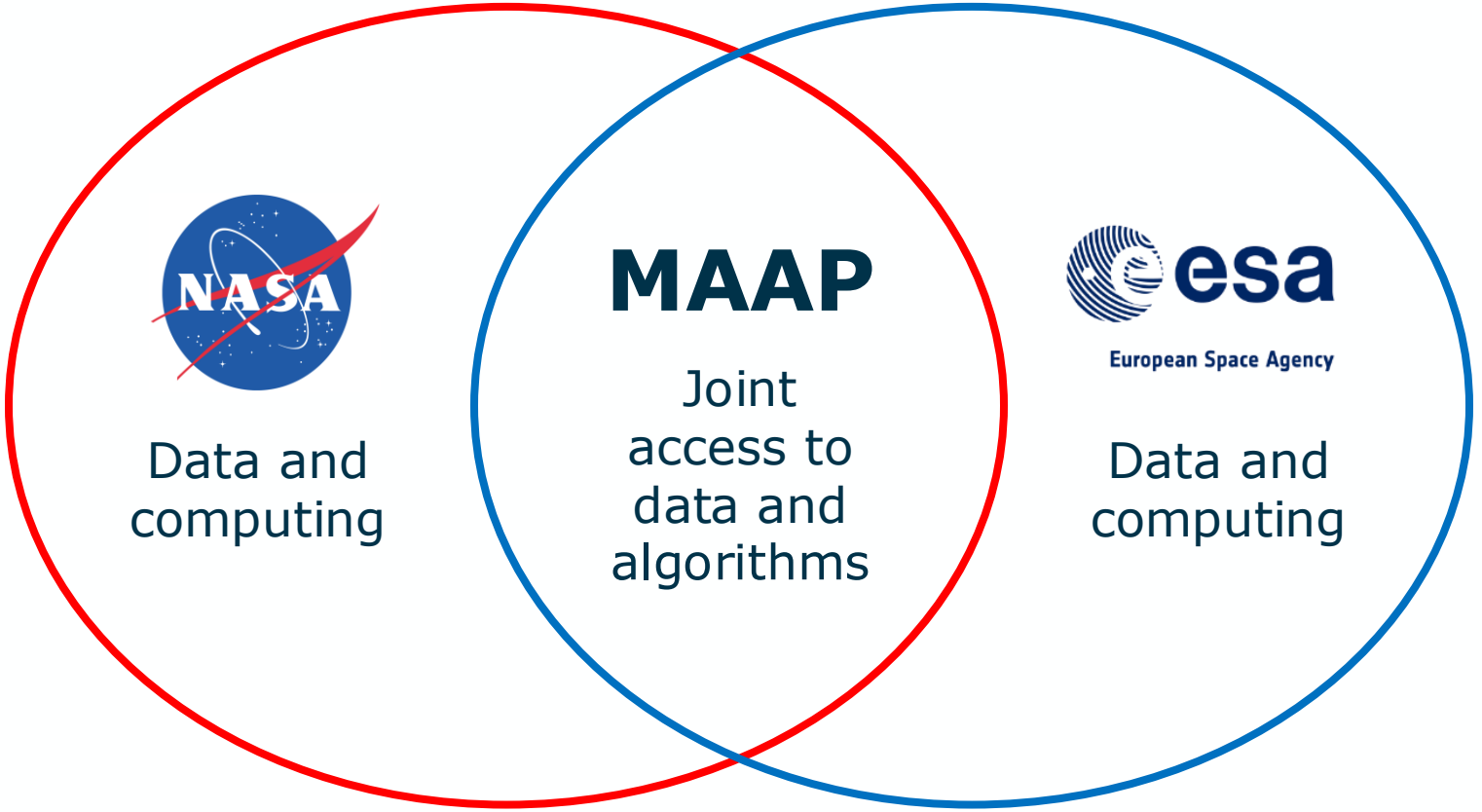
Provides a version-controlled science algorithm development environment that supports tools, co-located data, and processing resources.



Addresses intellectual property and sharing issues related to collaborative algorithm development and sharing of data and algorithms.

# ESA-NASA Multi-Mission Algorithm and Analysis Platform

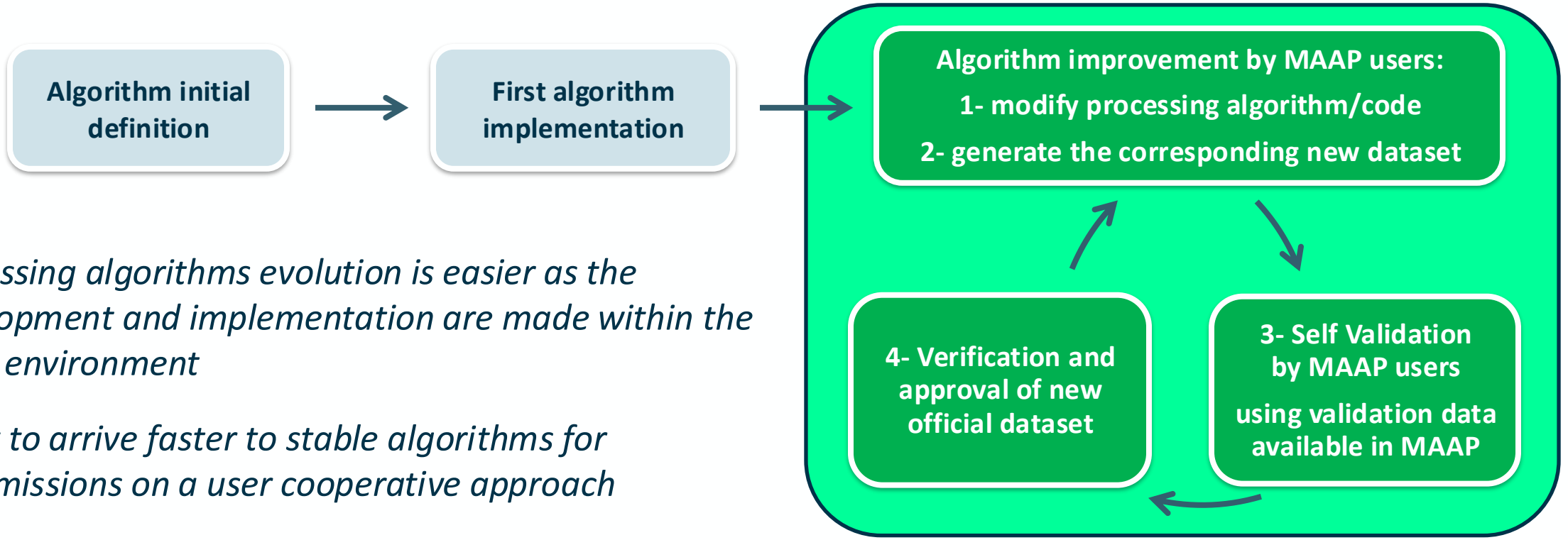
***Unified user access to the functions of joint ESA-NASA MAAP***




***Up to date data and algorithms + Collaborative community***

# ESA: Product Algorithm Laboratory

**New approach!**




- *Processing algorithms evolution is easier as the development and implementation are made within the same environment*
- *Allow to arrive faster to stable algorithms for R&D missions on a user cooperative approach*
- *People outside the core science team can contribute to the product improvement cycle*

***Mission Algorithm and Analysis Platform (MAAP)***

**Concepts of "Open Science" → *Well adapted to R&D EO missions***

# Summary – BIOMASS a true Earth Explorer

1. BIOMASS was proposed in 2005. Implementation started in Nov. 2015. The satellite is almost fully assembled and currently in the Test Facility. We are working towards a launch in March-April 2025.

2. BIOMASS is the first P-band SAR and first systematic 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...

4. It is the first Open-Source Earth Explorer with BioPAL (algorithms), GEOTREES (in-situ data) and MAAP (platform).