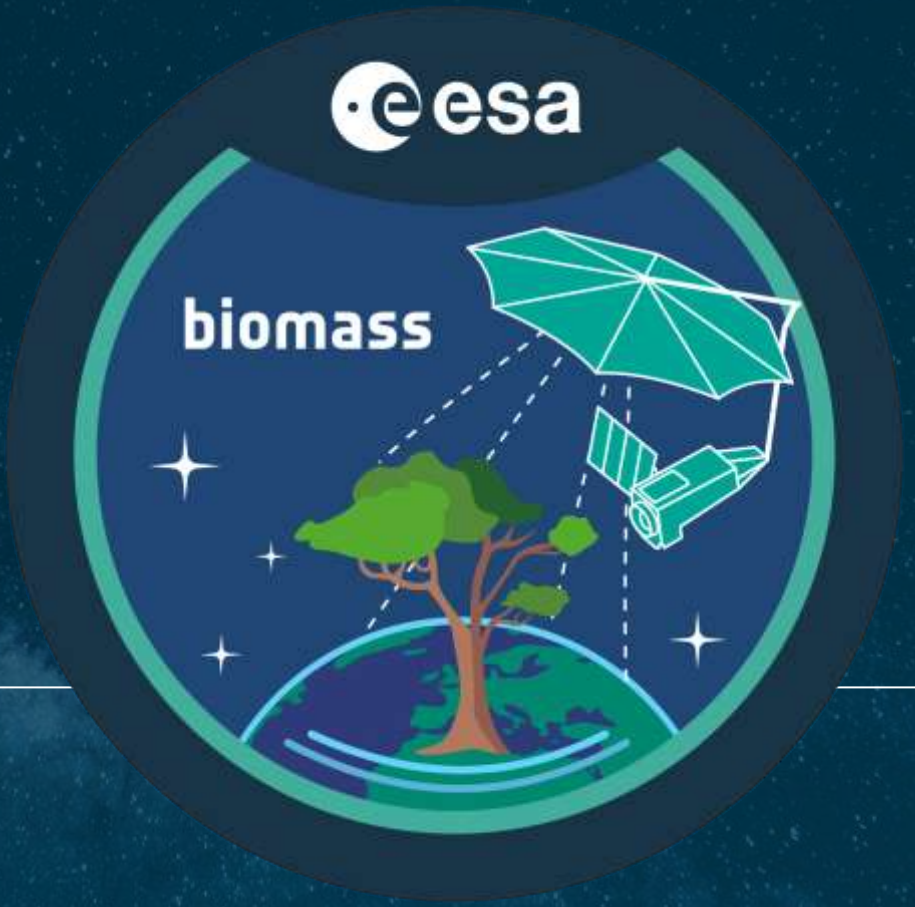
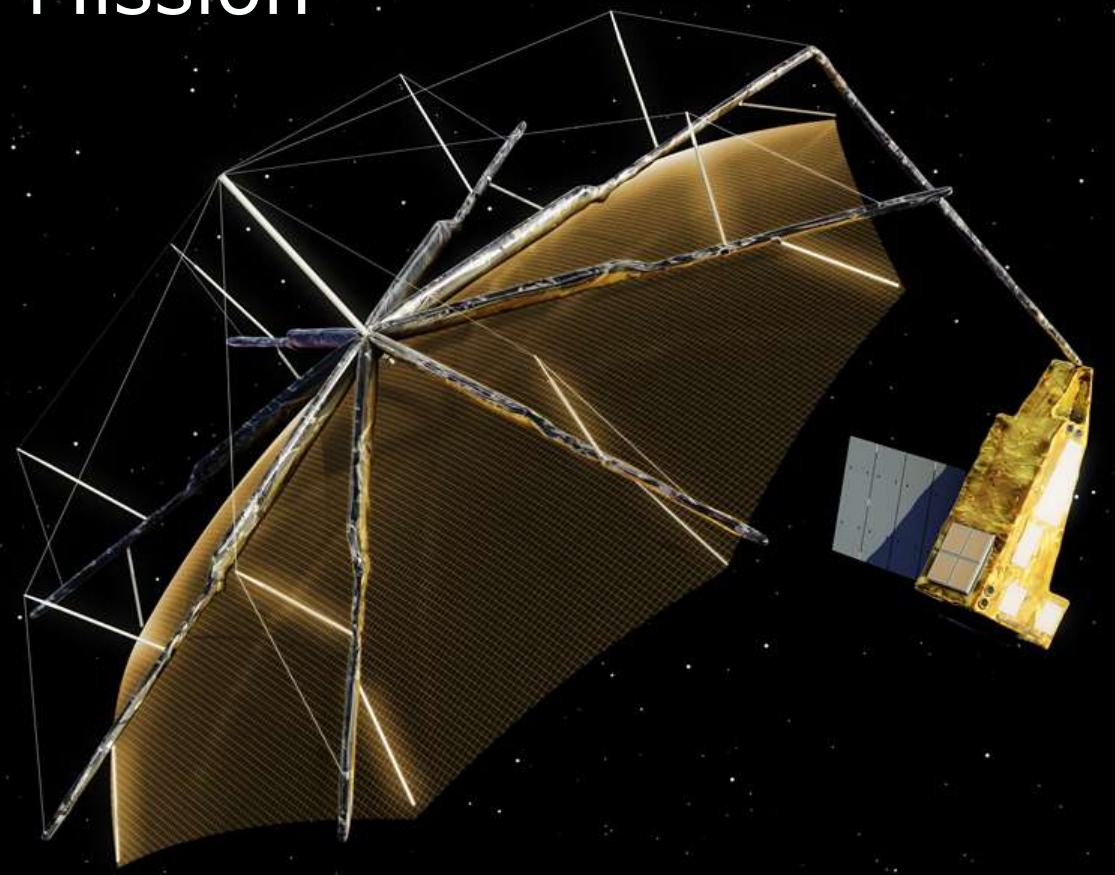
The Biomass Mission – ESA's PolInSAR mission



Klaus Scipal
7th Advanced Training Course on Radar Polarimetry, Toulouse, France

16/06/2023

The BIOMASS Mission

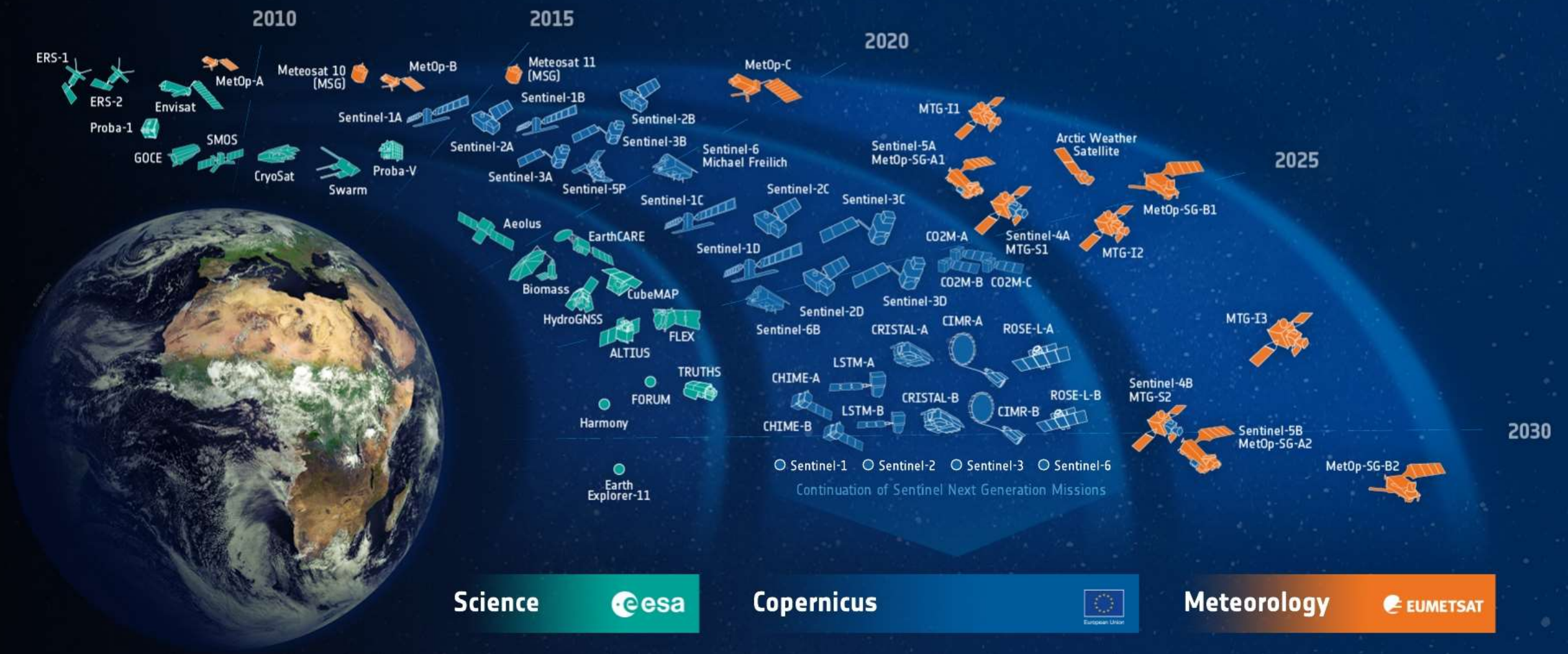


ESA’s 7th Earth Explorer to be deployed in 2023

An interferometric, polarimetric P-band SAR

Designed to observe forest height and biomass

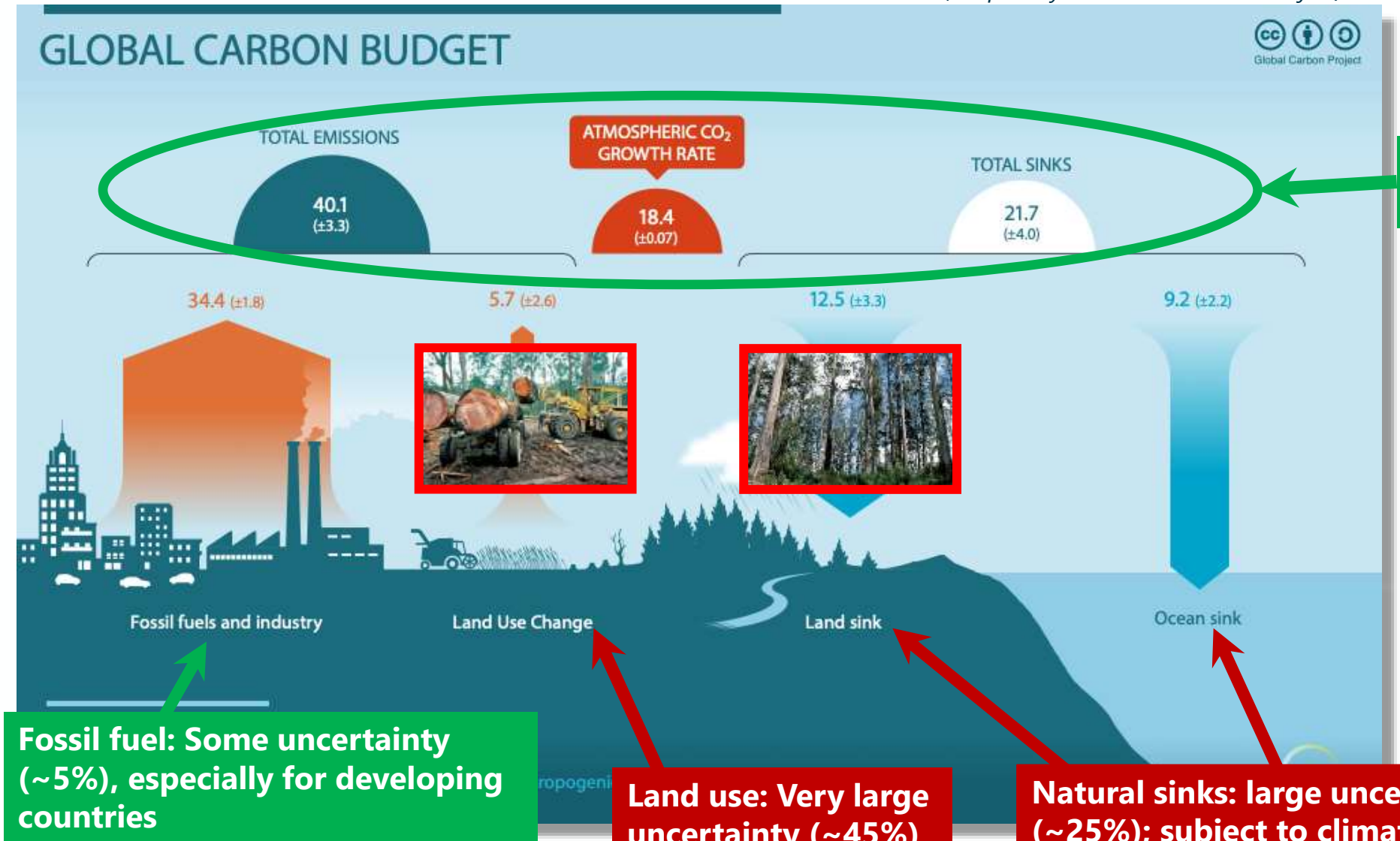
ESA-DEVELOPED EARTH OBSERVATION MISSIONS



Science esa | Copernicus European Union | Meteorology EUMETSAT

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

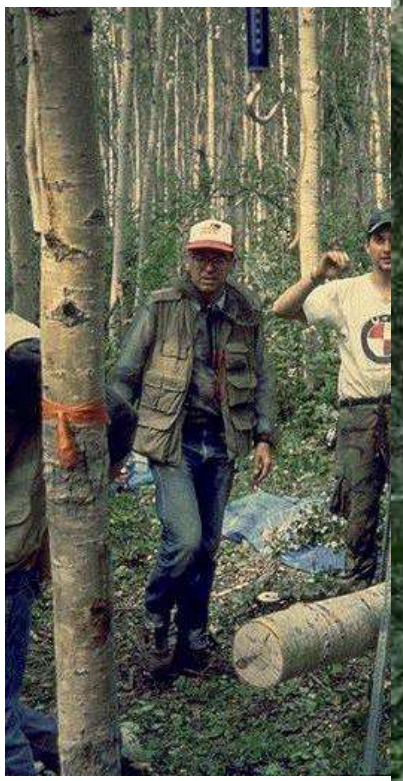
Beyond Carbon: Changes in forest affect the benefits we gain from forests

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)
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 biomass from space?



to

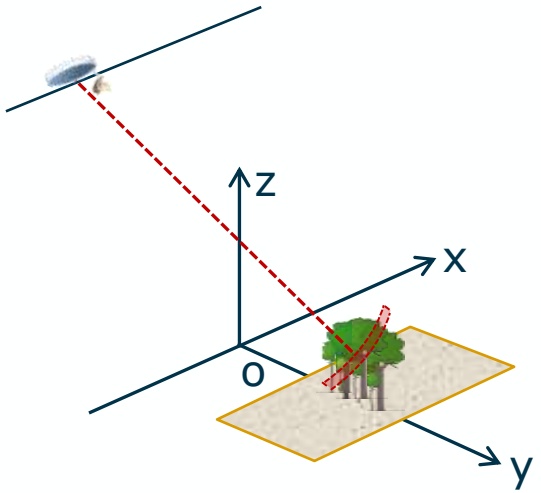
$\cdot H$

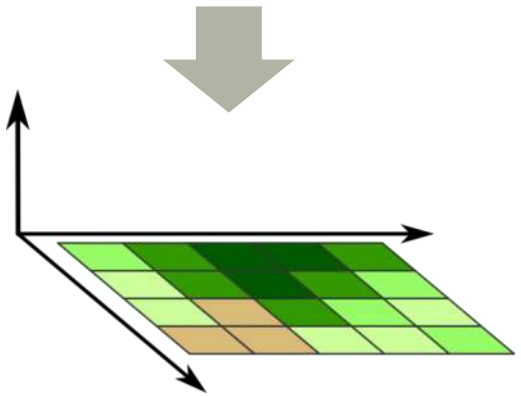
Height

er

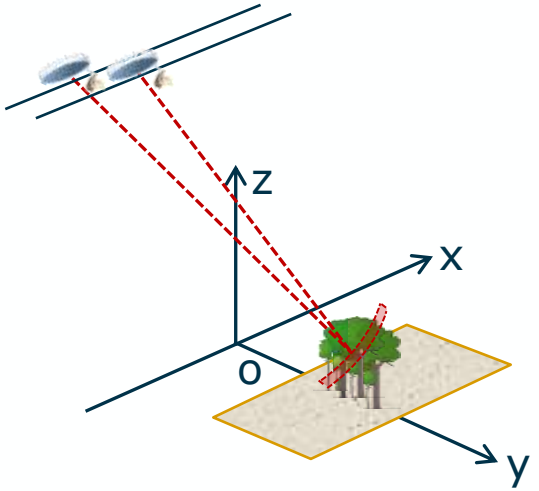
Synthetic Aperture Radar contains structure information

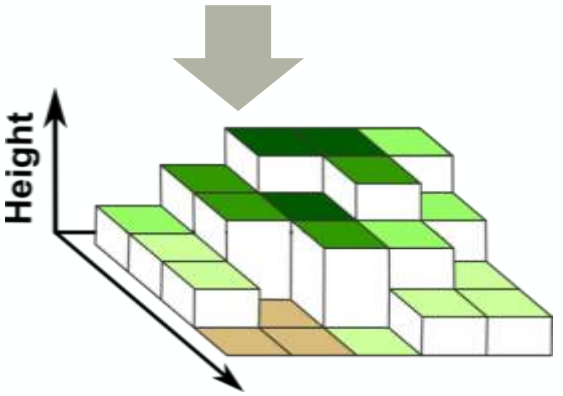
PolSAR
(SAR Polarimetry)



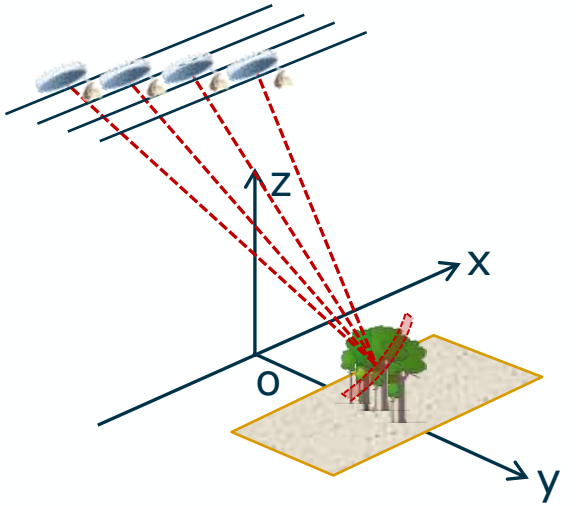


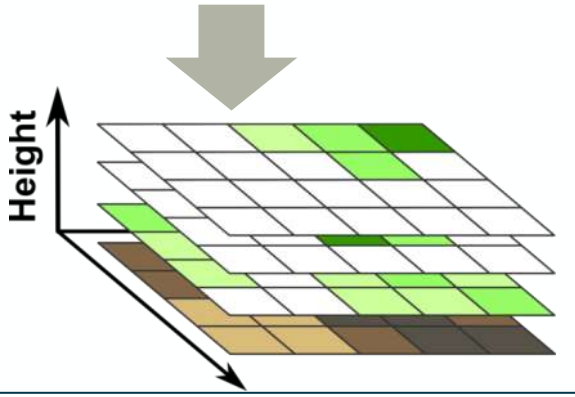
PolInSAR
(Polarimetric SAR Interferometry)





TomoSAR
(SAR Tomography)





Choice of frequency

Pinus Nigra

X-band
λ= 3 cm

L-band
λ= 27 cm

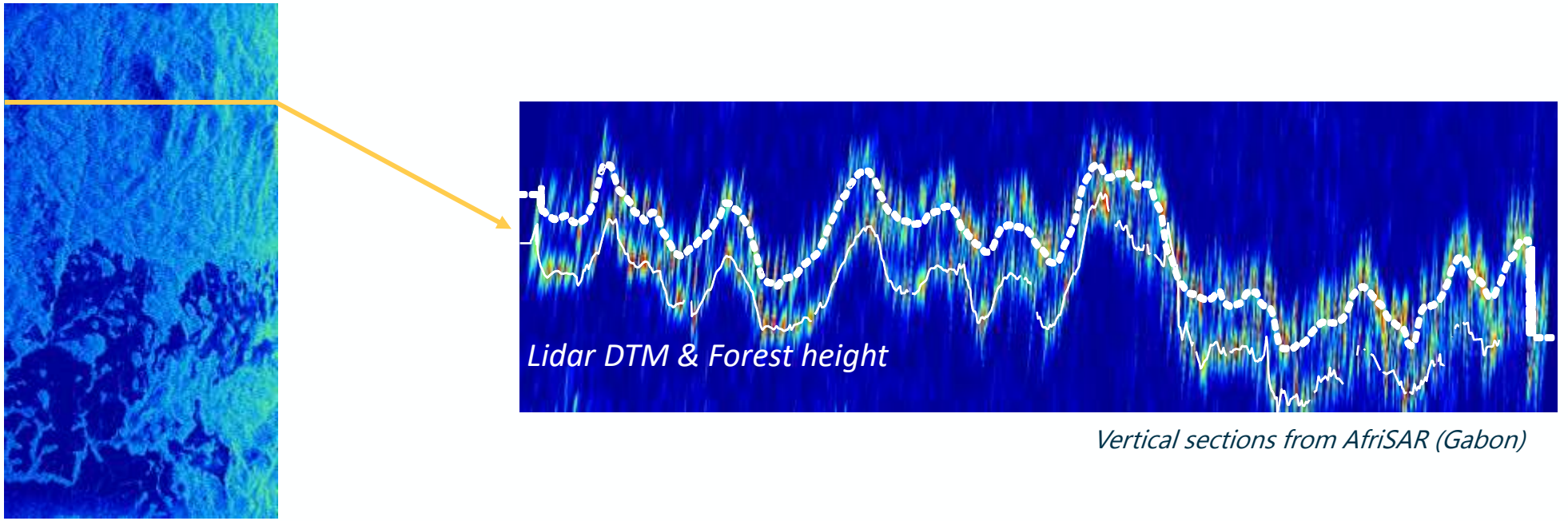
P-band
λ= 70 cm

P-band 'sees' the trunk and (big) branches, provide 'more direct' information on woody above ground biomass

Choice of Frequency

⇒ P-Band provides sensitivity to the whole forest vertical structure, as demonstrated by 3D tomographic analyses.

⇒ Enables interferometry with a repeat pass system



Vertical sections from AfriSAR (Gabon)

Biomass Mission Concept

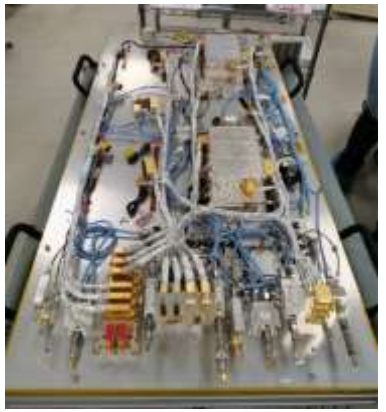
- ✓ Full polarimetric P-band (435 MHz) Synthetic Aperture Radar with 6 MHz bandwidth
- ✓ Single satellite, operated in a polar sun-synchronous orbit
- ✓ Two mission phases: Tomography (first 18 months), Interferometry (rest of the mission lifetime)
- ✓ Multi-repeat pass interferometry (3 passes in nominal operations) with a 3 days repeat cycle
- ✓ Global coverage in ~9 months on asc. and des. passes
- ✓ 5 years lifetime

The satellite is taking shape

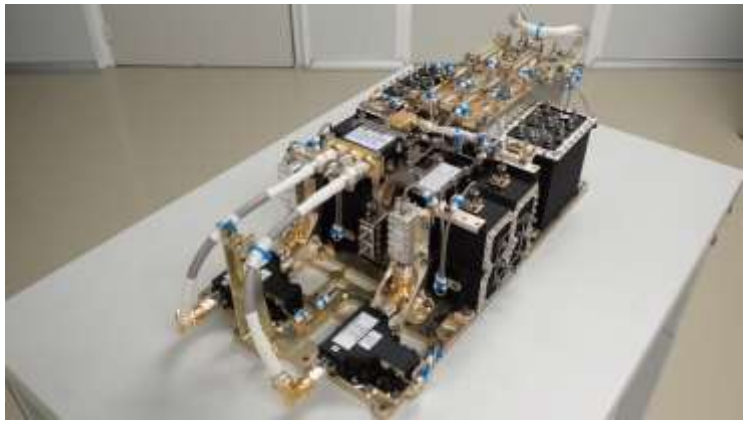
Platform

Large Deployable Antenna

Feed Array



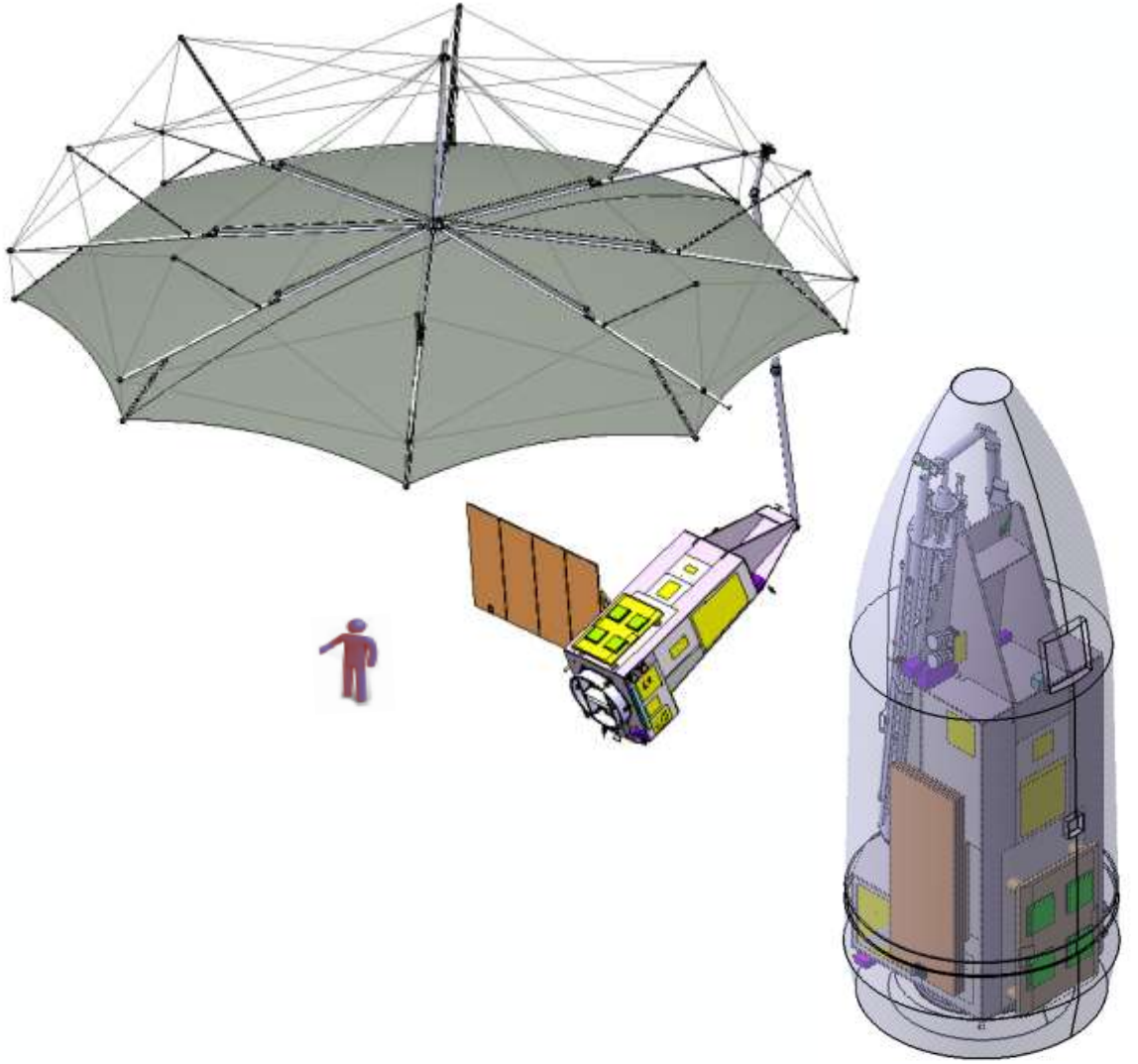
Power Amplifier

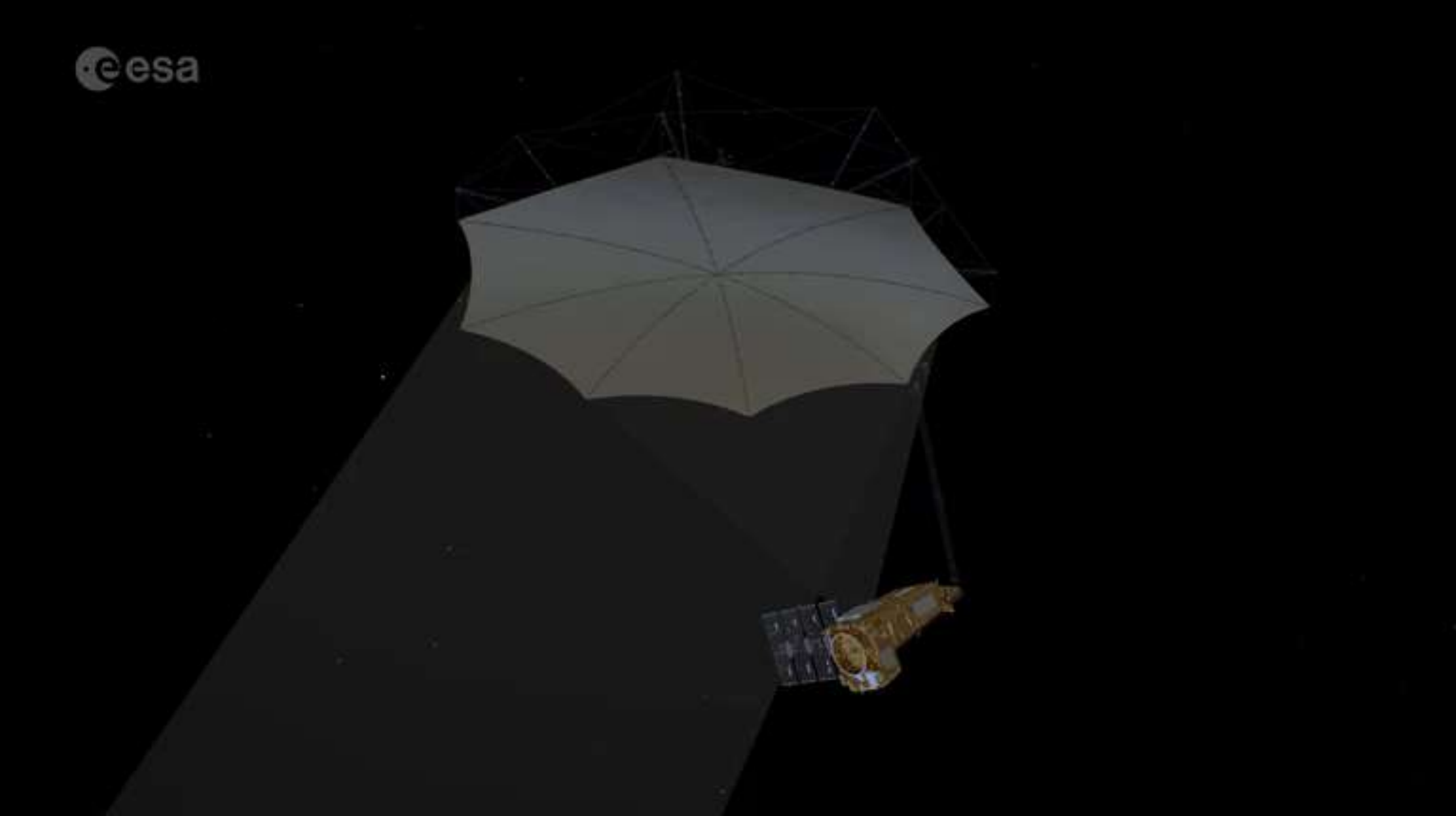


Receiver

Biomass Mission Specifications

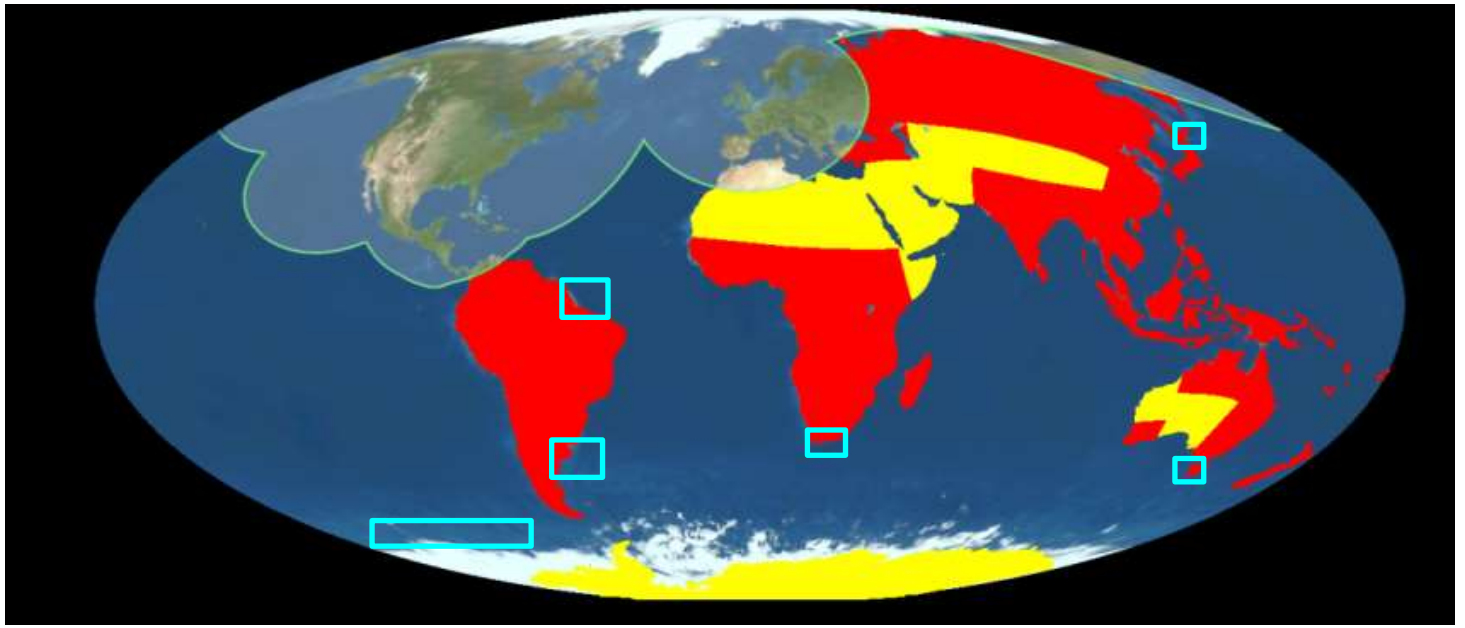
Key Parameters	
Sensitivity (NESZ)	≤ -27 dB
Total Ambiguity Ratio	≤ -18 dB
SLC resolution	≤ 60m x 8m
Dynamic Range	35 dB
Radiometric Stability	≤ 0.5 dB
Radiometric Bias	≤ 0.3 dB
Crosstalk	≤ -30 dB
Swath Width	~ 50 km




esa

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

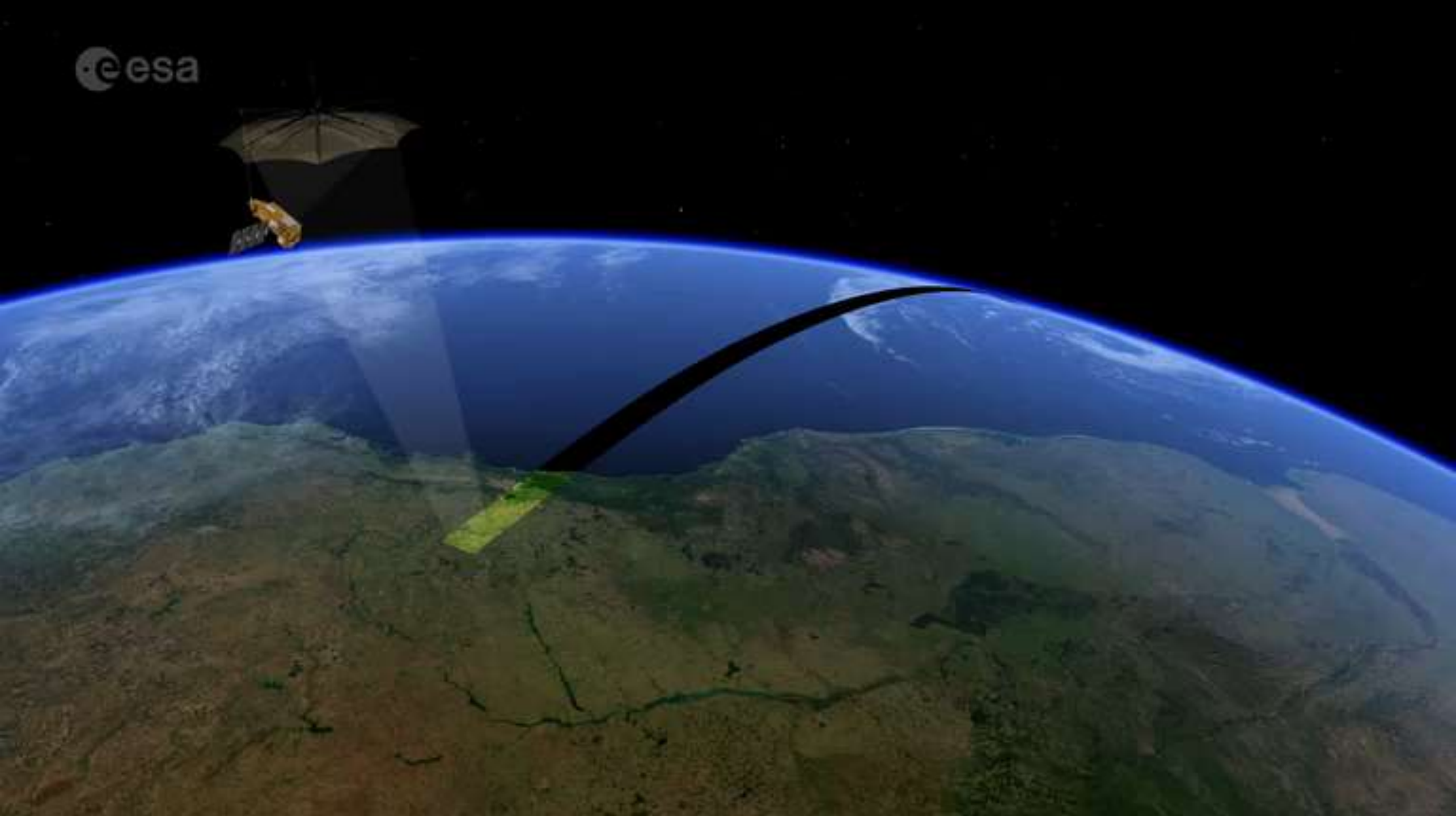
Upper canopy height (meter)

- 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)


esa

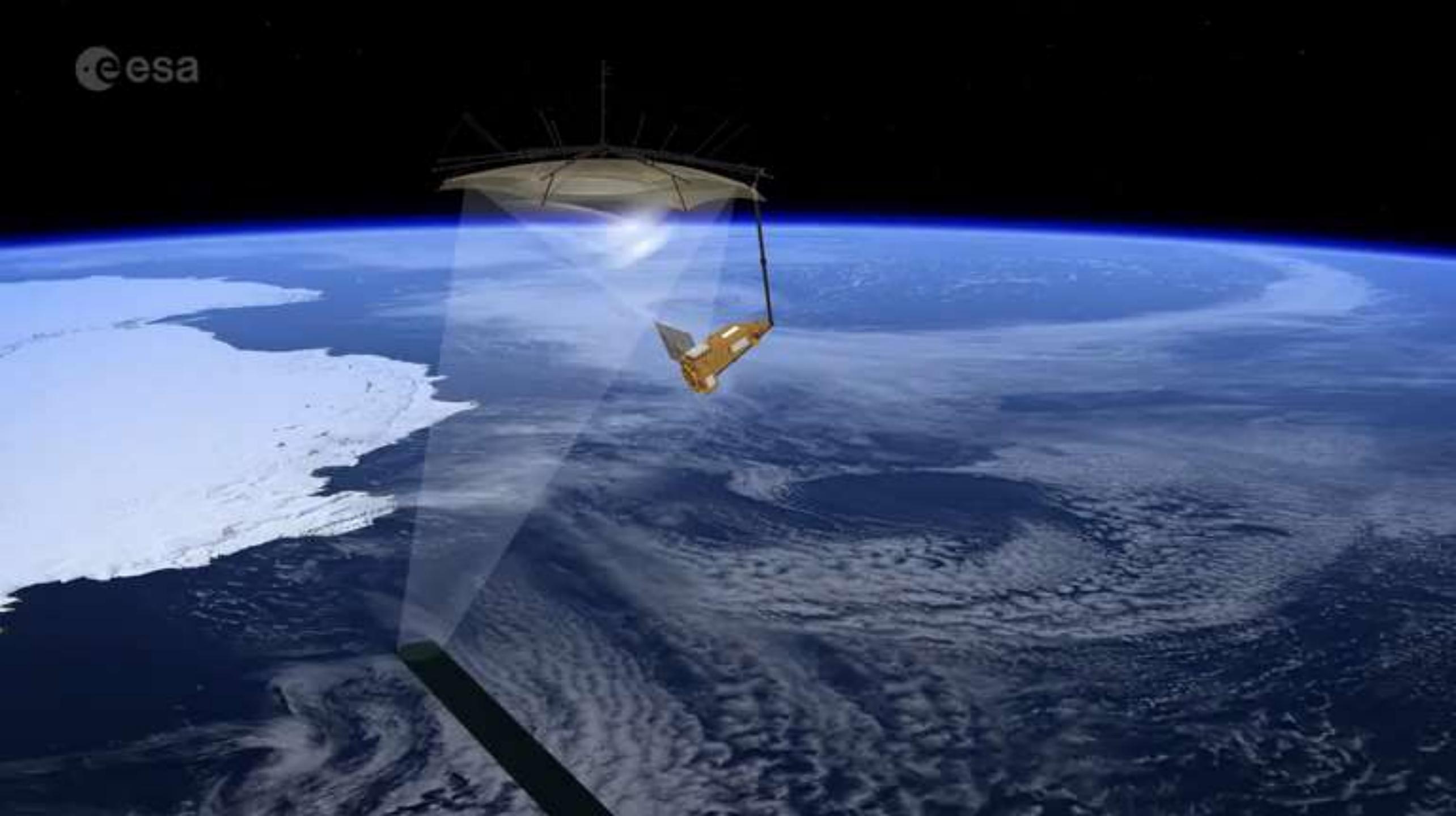
BioPAL

BIOMASS Product Algorithm Laboratory

biopal@esa.int
biopal.org
github.com/BioPAL

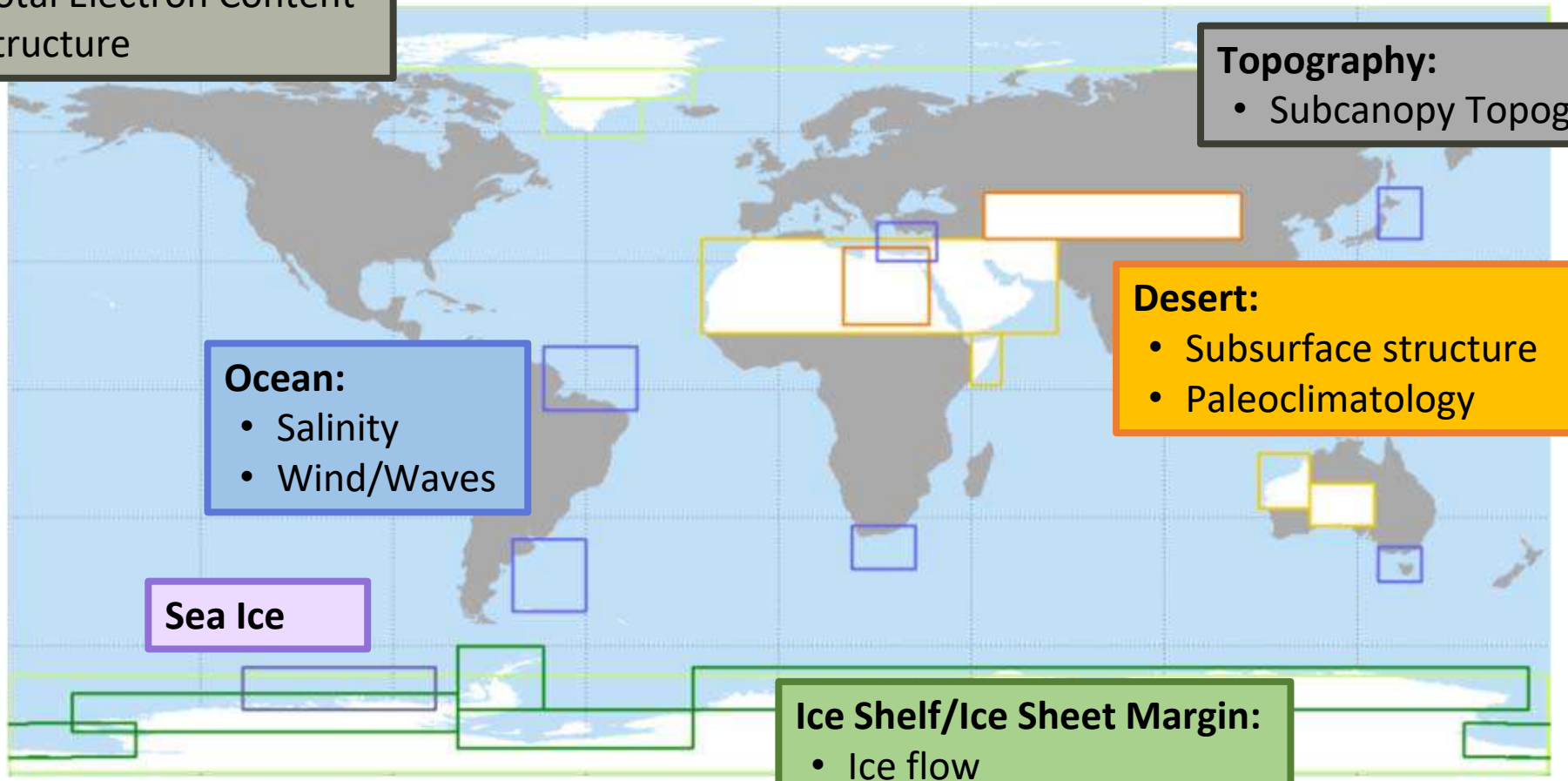
= Open Source Software Project
= official BIOMASS algorithms python
= first time that official algorithms are made publicly accessible

Banda, F.; Giudici, D.; Le Toan, T.; Mariotti d'Alessandro, M.; Papathanassiou, K.; Quegan, S.; Riembauer, G.; Scipal, K.; Soja, M.; Tebaldini, S.; Ulander, L.; Villard, L. "The BIOMASS Level 2 Prototype Processor: Design and Experimental Results of Above-Ground Biomass Estimation" Remote Sensing, 2020, 12, 985. doi.org/10.3390/rs12060985


esa

Beyond Forest Biomass

Ionosphere:
- Total Electron Content
- Structure



Topography:
- Subcanopy Topography

Desert:
- Subsurface structure
- Paleoclimatology

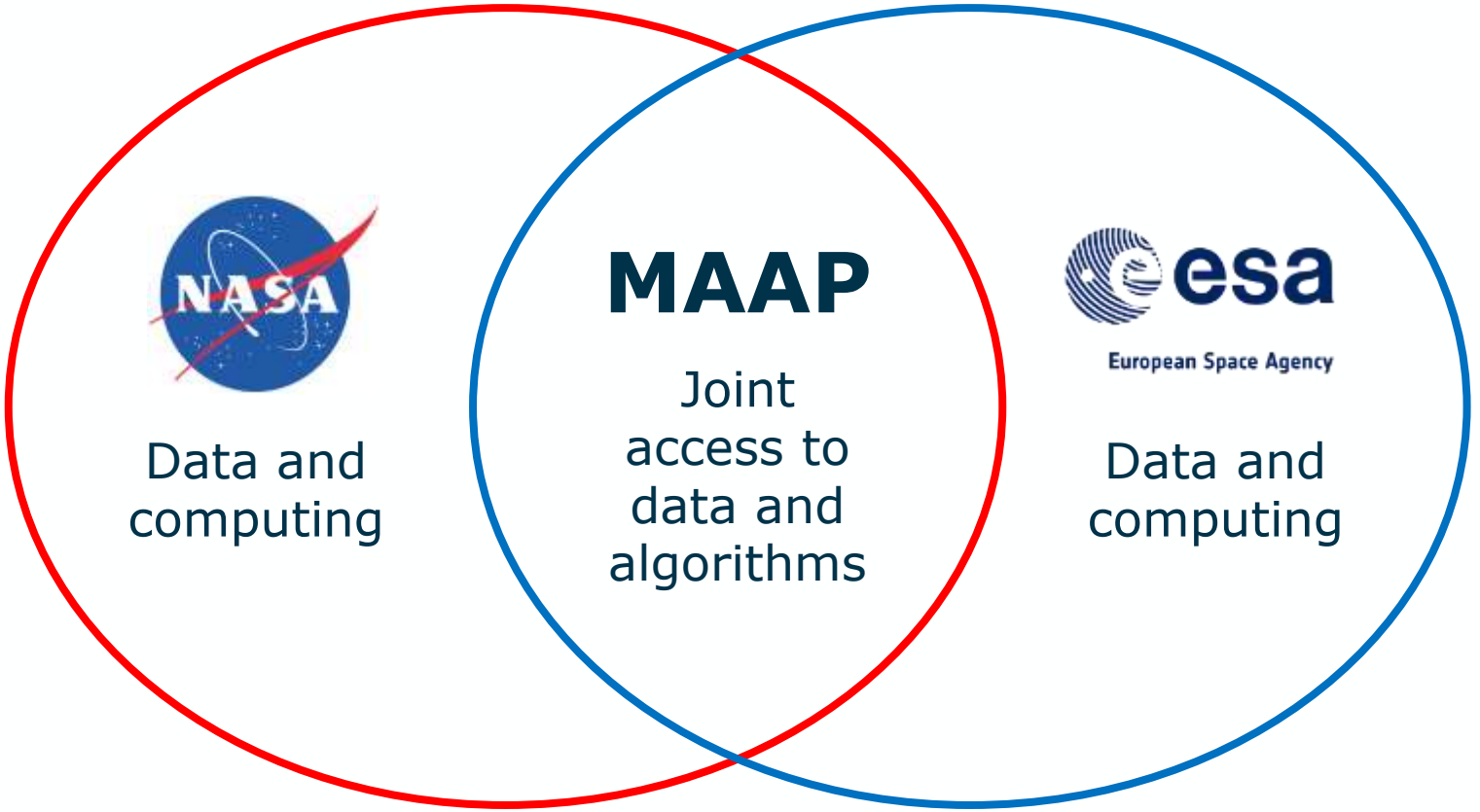
Ocean:
- Salinity
- Wind/Waves

Sea Ice

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

NASA-ESA Multi-Mission Algorithm and Analysis Platform

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



Up to date data and algorithms + Collaborative community

Summary – BIOMASS a true Earth Explorer

1. BIOMASS was proposed in 2005. Implementation started in Nov. 2013. The satellite is almost fully assembled and currently in the Test Facility. We are working towards a launch in 2024.

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. It is the first Open Source Earth Explorer.

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 ...