Collaborative and Open-Science approach for the BIOMASS and FLEX missions

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Jose Moreno - University of Valencia

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Panel

- Thuy Le Toan - CESBIO

  BIOMASS Mission Advisory Group

- Shaun Quegan - University of Sheffield

  BIOMASS Mission Advisory Group

- Jose Moreno - University of Valencia

  FLEX Mission Advisory Group

- Uwe Rascher - Forschungszentrum Jülich

  FLEX Mission Advisory Group

Agenda

A. The BIOMASS mission

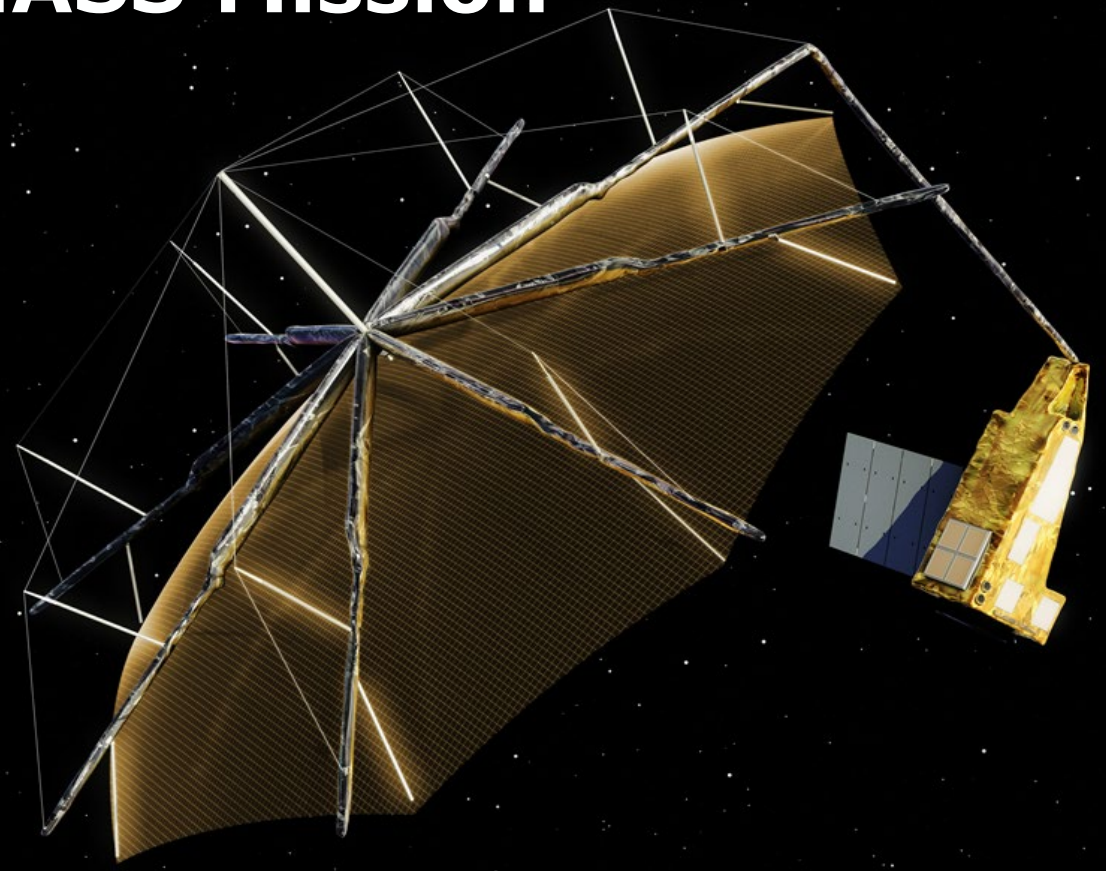
B. The FLEX mission

C. Concept of MAAP

D. Discussions

A. The BIOMASS mission

A. 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

A. What information do we need?

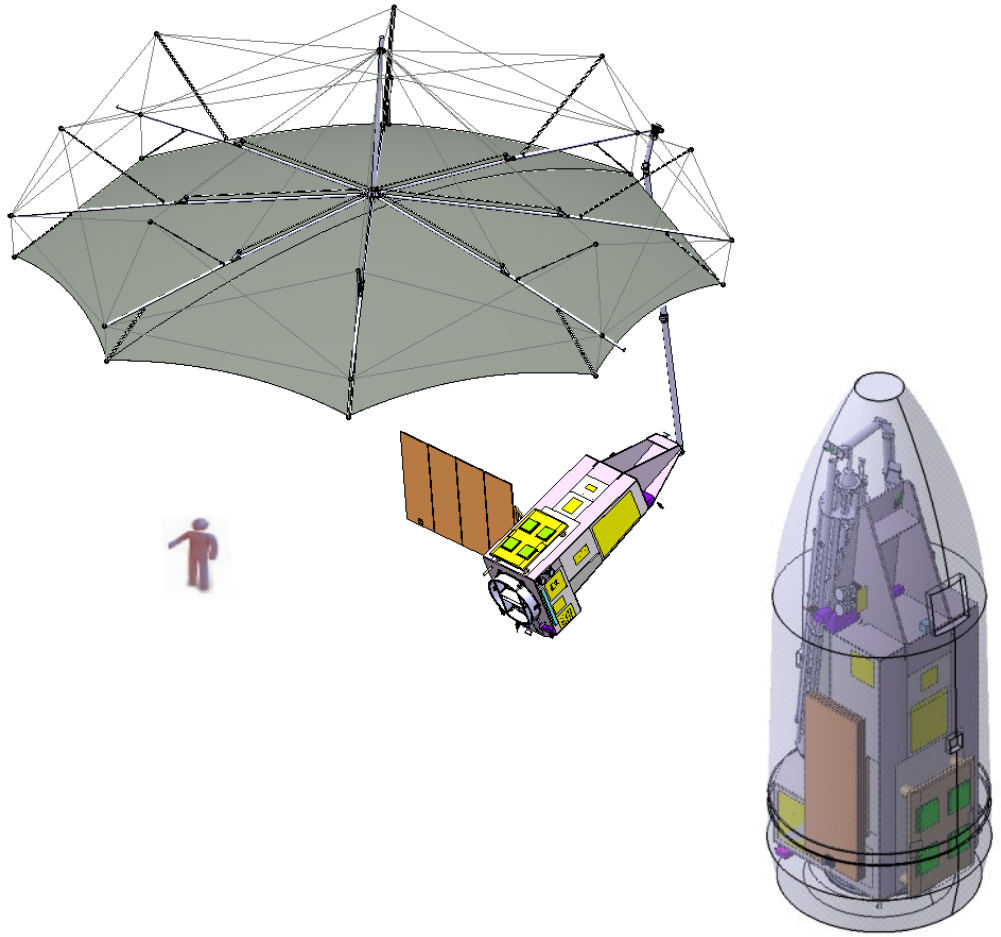
1. We need estimates of **forest biomass, height and disturbances**
2. The **crucial information need** is in the tropics:

   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

A. 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 ascending and descending passes
- ✓ 5 years lifetime

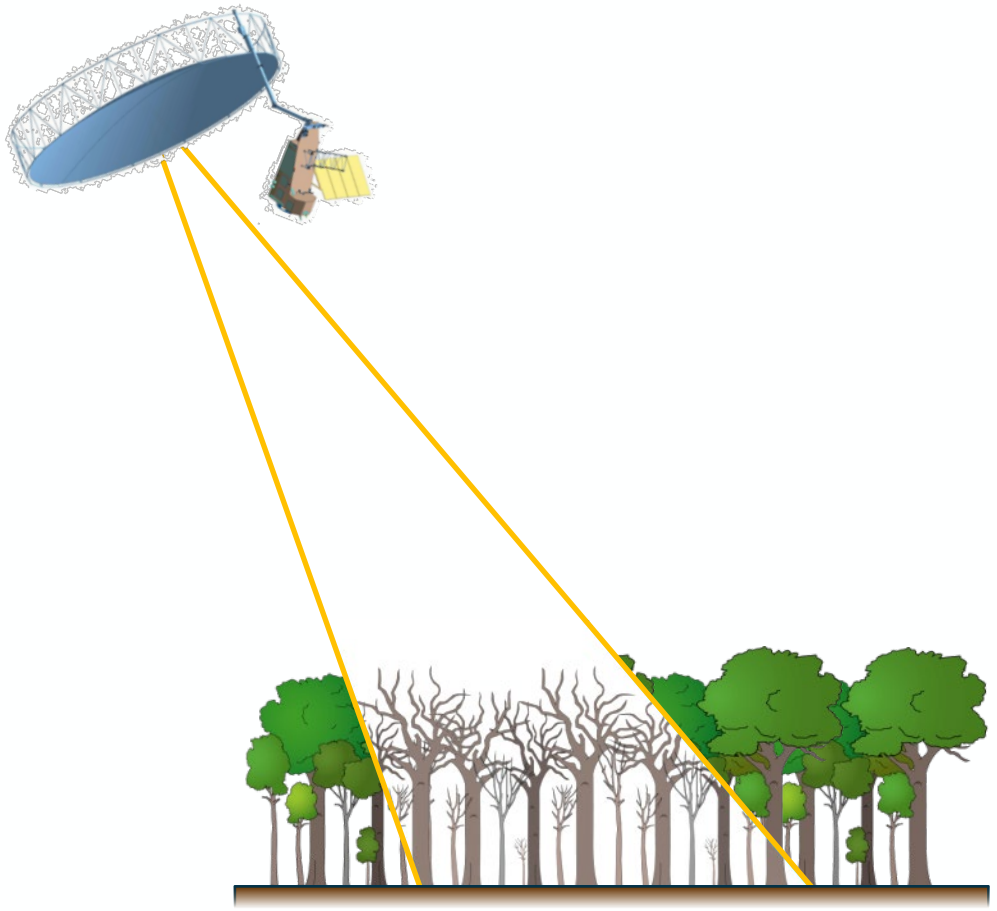


A. Why a P-band SAR to measure the world forest biomass ?

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



A. 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%

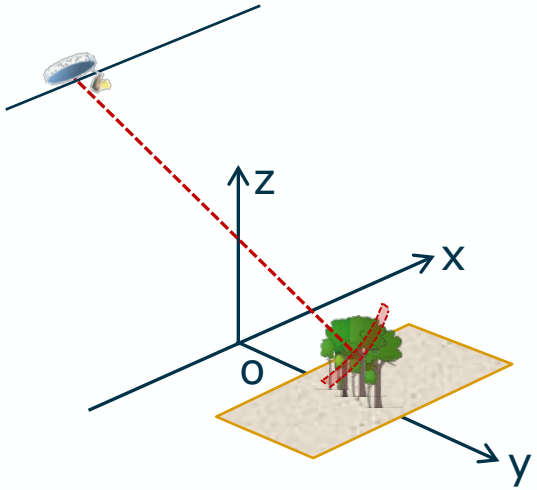
Areas of forest clearing (hectare)

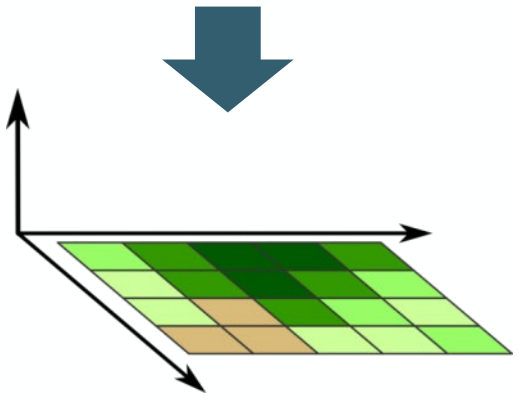
- 50 m resolution
- 1 map every 6 months
- global coverage of forested areas
- 90% classification accuracy

A. SAR can deliver 3 independent types of information related to biomass

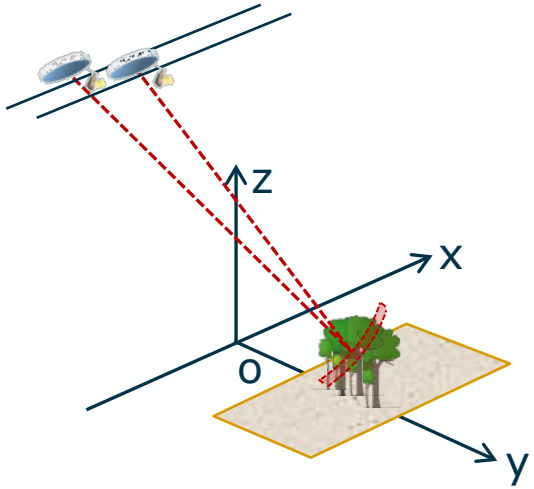
First 14th months only

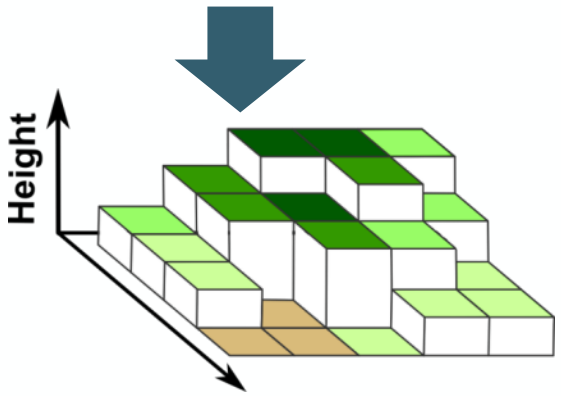
PolSAR
(SAR Polarimetry)



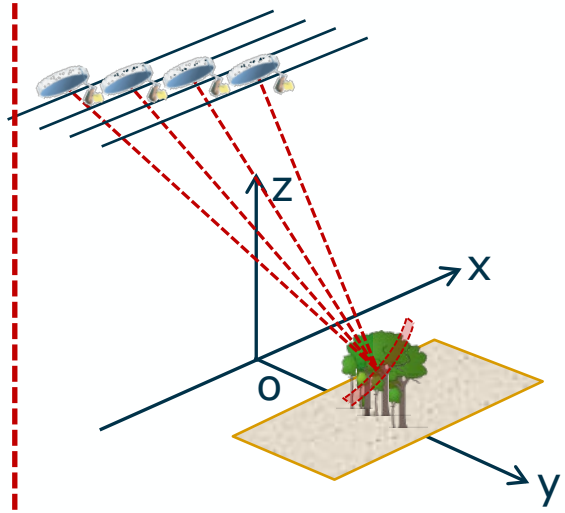


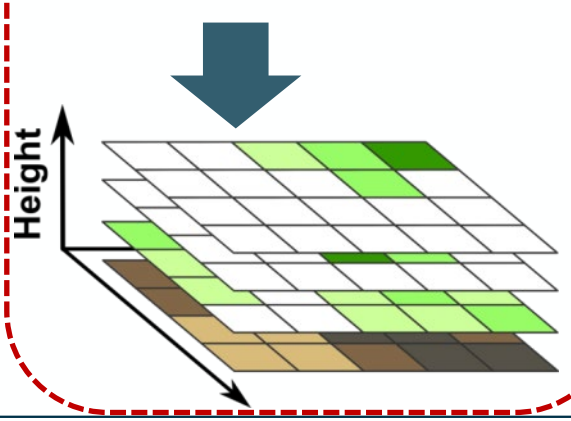
PolInSAR
(Polarimetric SAR Interferometry)



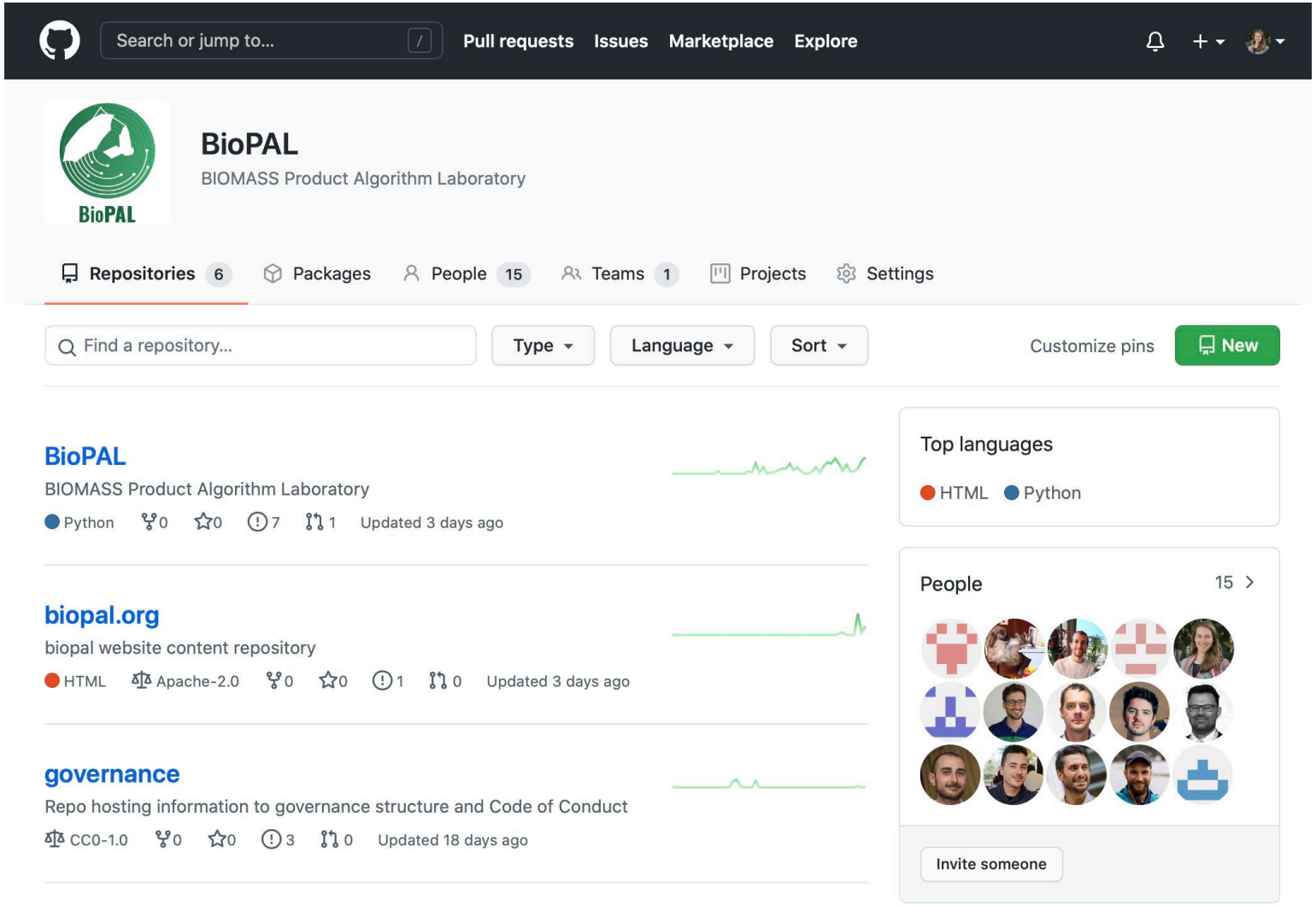


TomoSAR
(SAR Tomography)





BIOMASS Product Algorithm Laboratory



Open source

Today:
Level-2 prototype algorithms

Tomorrow:
Level-1 (as much as possible), Level-2 and Level-3 operational algorithms

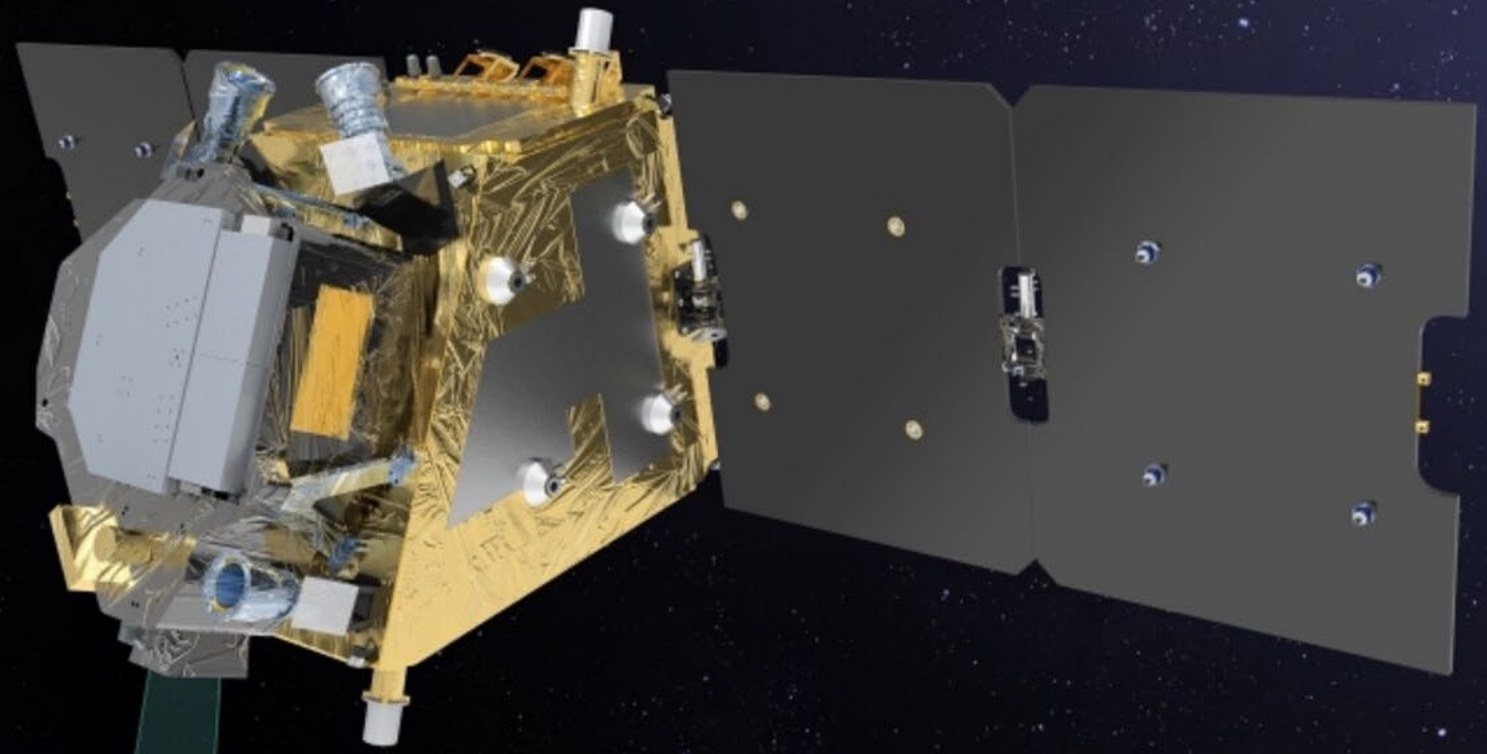
biopal@esa.int

biopal.org

github.com/BioPAL

B. The FLEX mission

B. The FLEX mission



ESA's 8th Earth Explorer (FLuorescense EXplorer – FLEX) will be deployed in 2025
A high-resolution imaging spectrometer
Designed to accurately measure the fluorescence signal emitted by plants to assess their functioning, health and stress

B. The FLEX mission

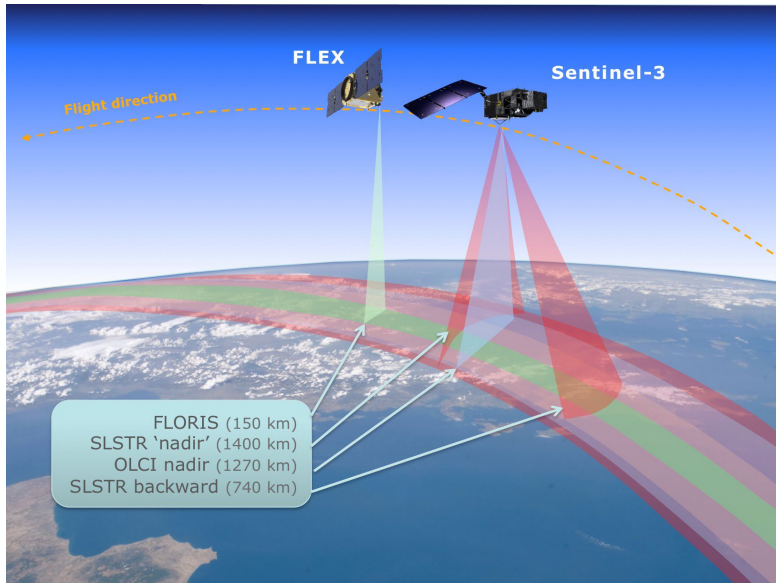
FLEX - ESA's photosynthesis mission will provide global measurements of vegetation fluorescence that will help to:

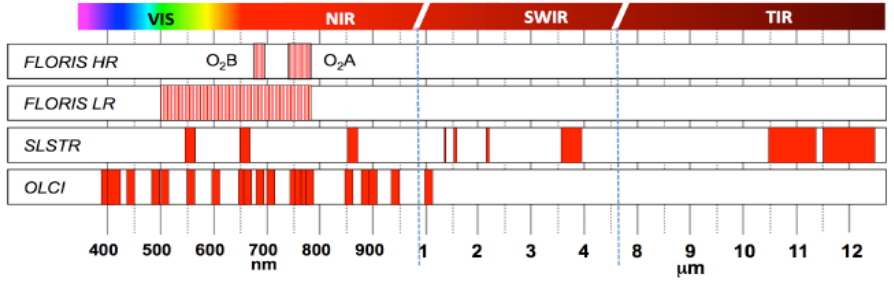
- quantify photosynthetic activity and plant stress by mapping vegetation fluorescence;
- advance our understanding of the photosynthetic machinery functioning and thus on the actual health and performance of terrestrial vegetation.

FLEX will **generate** monthly global maps with an on-ground **spatial resolution of 300 × 300 m²** and a **swath width of 150 km**.

Tandem mission with Sentinel 3

The tandem flight with Sentinel-3 provides auxiliary measurements from OLCI and SLSTR on the atmospheric state and land-surface





B. FLEX characteristics

Mission duration

- Commissioning phase 3 months
- Lifetime 3.5 years

Mission Orbit and Satellite Attitude

Tandem Flight ca. S3	6-15s (ca100 km) ahead of
Orbit Type	LEO, sun-synchronous
Altitude	814 km
Repeat Cycle	27 days
Acquisition time	10:00
Inclination	98.645 degrees
Attitude Control	3-axis stabilized, nadir
Coverage	56° S to 75° N

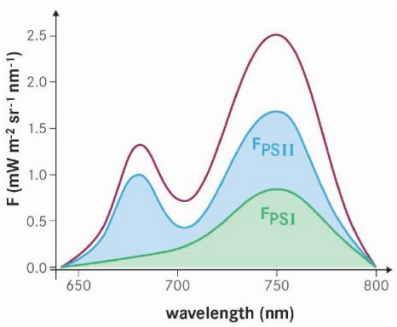
Flight Operations

ESOC via Kiruna

***Expected Launch* 2025**

Mass

- Instrument 140 kg
- Satellite Dry Mass 450
- Max Fuel Load 30 kg



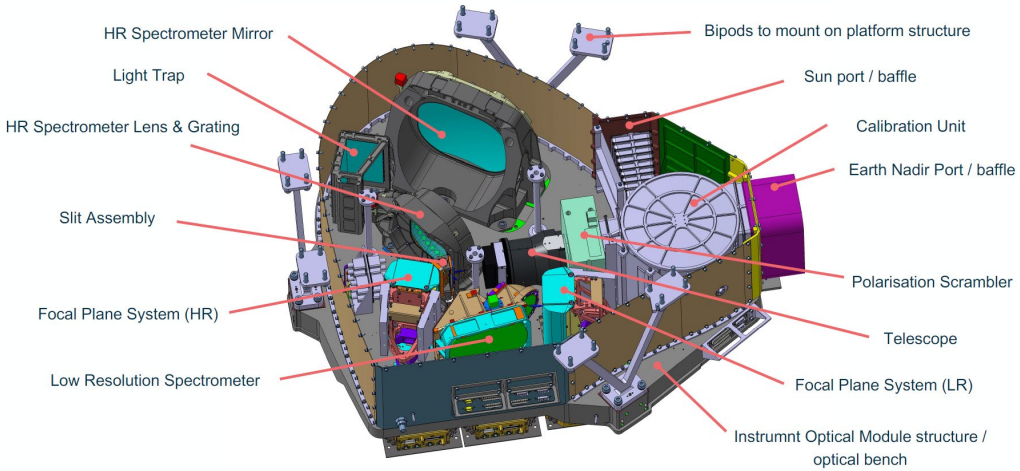
Payload: FLORIS

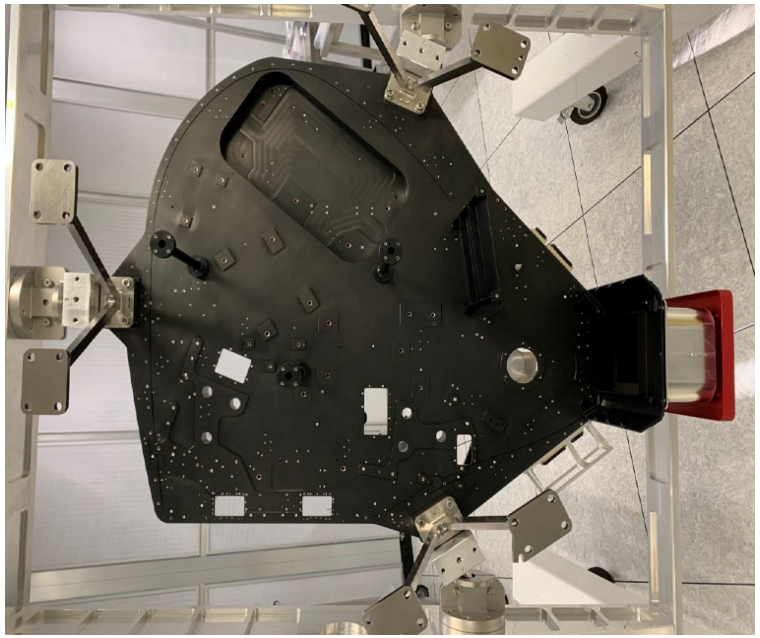
High-resolution imaging spectrometer that will acquire data over **land, inland waters and coastal areas** in the **500-780 nm** spectral range, with a sampling of:

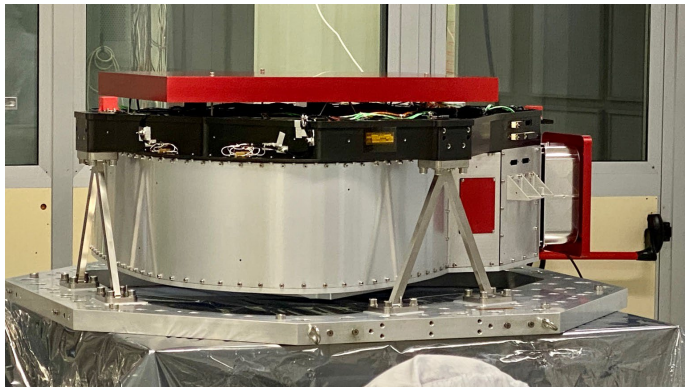
- **0.1 nm in the oxygen absorption bands** O2-A (759-769 nm) and O2- B (686-697 nm)
- 2.0 nm in the chlorophyll absorption band (600-677 nm) and Photochemical Reflectance Index band (500-

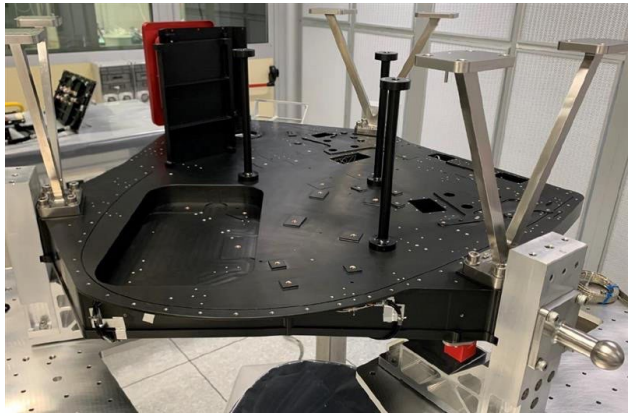
B. FLORIS Optical Bench and Housing

Instrument Optical Module flight model delivered
Optical bench ready for integration









SENER

B. What information we will get from FLEX

L1B – Top Of Atmosphere (TOA) radiances, from FLORIS instrument

L1C – FLEX and Sentinel3 synergy product (FLORIS+OLCI+SLSTR TOA radiances on a common grid)

L2A – data atmospherically characterized and corrected: Top of Canopy (TOC) surface apparent reflectance, at-surface solar irradiance, cloud mask and retrieved atmospheric parameters (eg aerosols, water vapour).

L2B – TOC real reflectances + Sun Induced Fluorescence emission spectrum

L2C – Biophysical products (e.g. Leaf Area Index, Non-Photochemical Quenching, Electron Transport Rate, …)

FLEX products to be made available via the FLEX MAAP.

C. The concept of MAAP

C. How to make the future of EO users better?

Innovative instrument

Innovative ground segment?

C. EO User's point of view

"Am I using the latest version of the dataset?"

"My computation takes too much time!"

"I don't like the official dataset but I have a good idea for improving it."

"I cannot do all what I want with the tool box."

"I don't have enough space to store all my TB data."

"How to share my results (few GB of data) with my peers?"

"Where do I find in-situ data to validate my results?"

C. “Mission Algorithm and Analysis Platform”

→ ***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.

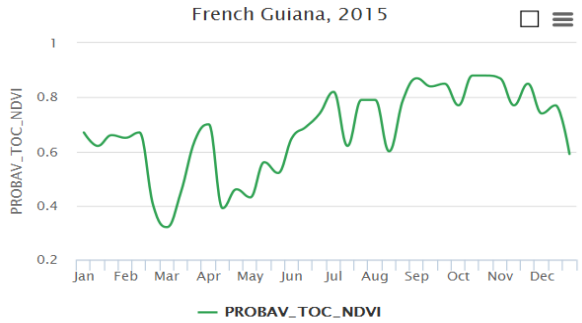
Addresses intellectual property and sharing issues related to collaborative algorithm development and sharing of data and algorithms.

C. → Data visualisation

2D data visualisation

- Search, discovery, overlay
- L1, L2, L3

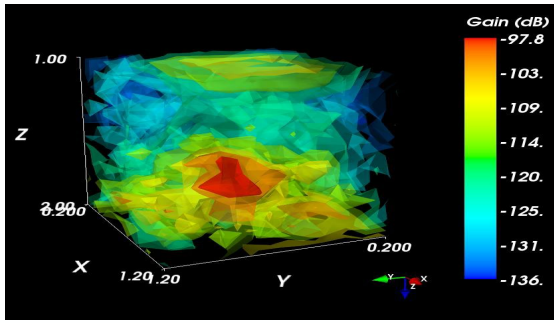
Time series visualisation



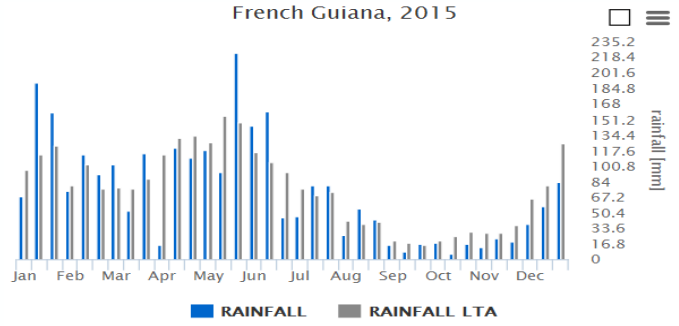
In-situ measurement (e.g. Forest Observation System)

3D data visualisation

- E.g., PolinSAR, TomoSAR



Meteorological data



C. → Data processing (product generation)

Select existing algorithms

Official L1, L2/3 algorithms

Research L1, L2/3 algorithms

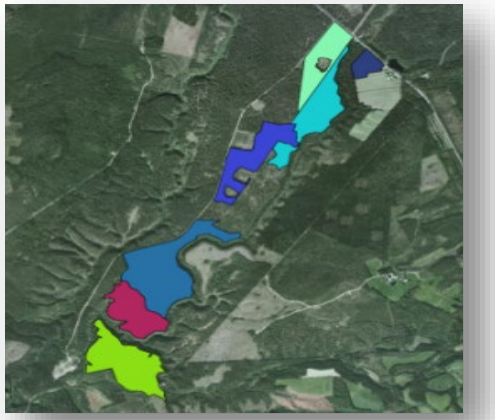
Generate products

- Systematic generation (every 6 months)
- On demand

Download data

Upload data

- raster, vector, table



Share computed data

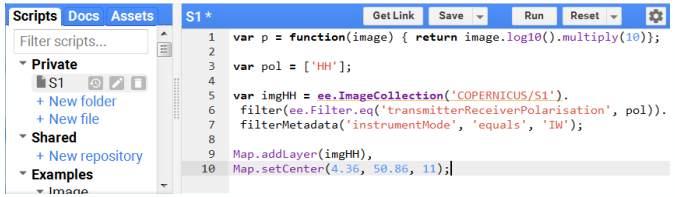
- Share link to give access to the data
- Export figure
- Embedded content in webpages, pdf…

C. → Product Algorithm Laboratory

New concept at ESA!

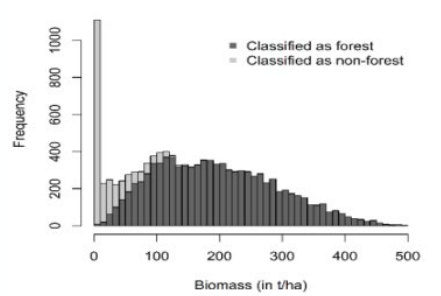
Modify/write processing algorithms

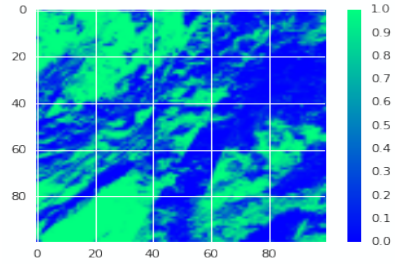
- Modify official L1, L2/3
- Compute own L1, L2/3
- Generate new products



Tools for self validation

Create figures





Share algorithms

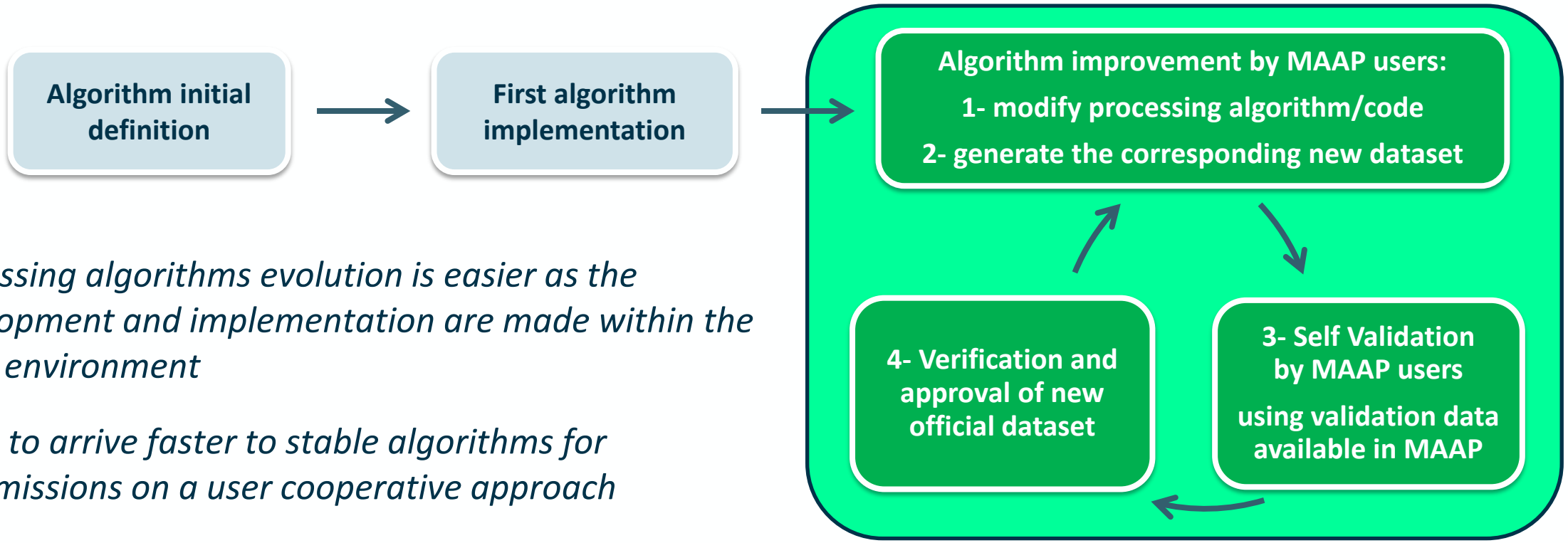
- Share link to give access to the algorithm and/or environment

"Free access to all the functionalities"

- With a limit of processing time and data storage
- Additional resources can be ordered or allowed for specific users

C. → Product Algorithm Laboratory

New approach!



Mission Algorithm and Analysis Platform (MAAP)

- *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*

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

C. → Information sharing

Forum

- FAQ
- Conversations between users, with the agency…

Link to social networks

- Blogs
- Facebook, Twitter, Research gate…

Wiki

- All the information related to the mission, instrument, data acquisition…

Link to online notebooks

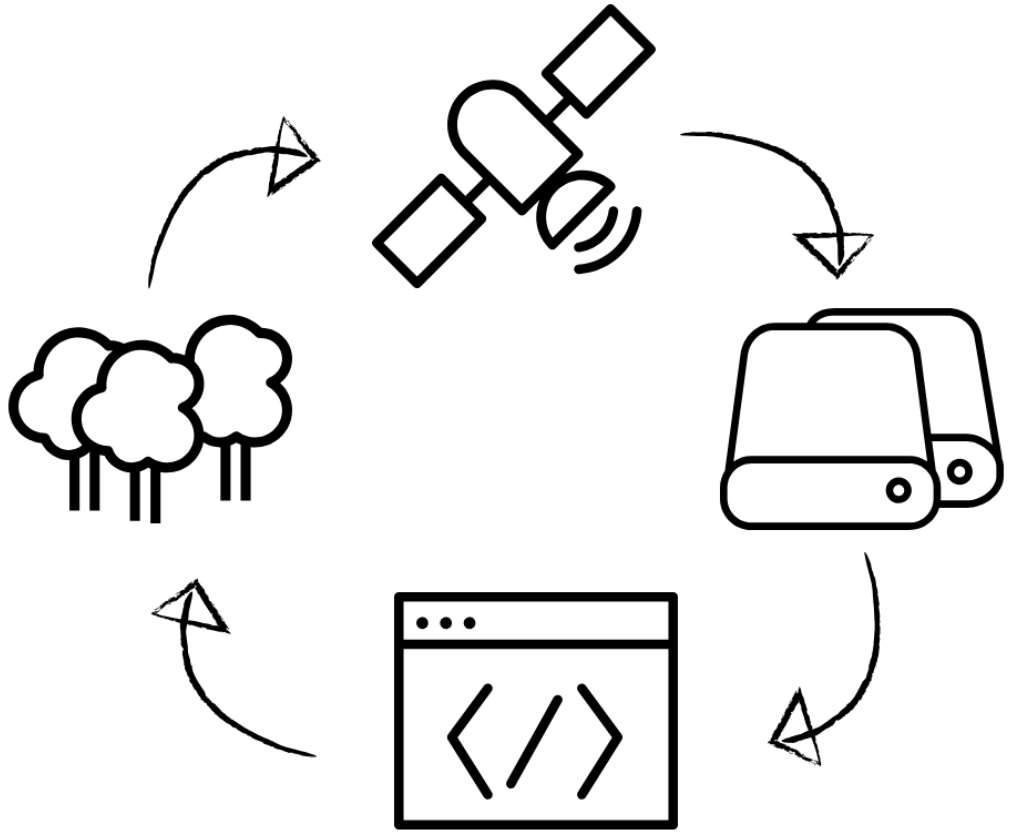
- Write and execute live code (e.g. Jupyter)

C. Importance of Open Science

- Open science allows collaboration that creates beneficial synergies
- Improves teamwork
- Encourages both higher quality work and community feedback on work
- Work has greater impact across the scientific community
- Open science creates new opportunities to leverage data, resources
- Encourages reuse of algorithms and computational workflows which lead to greater reproducibility

C. Summary

- The MAAP will make connections between data, algorithms, software and results.
- Concept of the Product Algorithm Laboratory make it easier to reproduce results and build from existing work.
- Encourage collaboration between data scientists.
- Bring together data from various spaceborne missions from various organizations to support development of global biomass maps.



OEF DEMO AREA - Today 05:45 pm - The BIOMASS Mission Algorithm and Analysis Platform and the Open Source Algorithm Environment BioPAL

Poll

https://forms.gle/V7eAqqa6U2Z6Y8L26

D. Discussions

Current Use / Habits

biomass

flex

esa

Google Earth Engine

Microsoft

SINERGISE

amazon.com

Poll questions 1-4

https://forms.gle/V7eAqqa6U2Z6Y8L26

tep
thematic exploitation platform

- geohazards tep
- coastal tep
- polar tep
- hydrology tep
- urban tep
- forestry tep

Etc.

Needs for Data and Tools

For BIOMASS:

6 ESA campaign
NASA campaign
GEDI L2 and L3/4
ALOS PALSAR L1 (Afriva)
Forest Observation System (FOS)
Copernicus DEM
NISAR L0 to L3/4
Sentinel 1 and 2

Global biomass datasets: ESA CCI (including Land Cover), Avitabile, Baccini, GlobBiomass, Hansen, Saatchi;

brat
BROADVIEW RADAR ALTIMETRY TOOLBOX

esa

POLSARPRO v. 4.0
The Polarimetric SAR Data Processing and Educational Tool

nest
next esa sar toolbox

proba-v Toolbox

SMOS-BOX

BASIC ENVISAT ATMOSPHERIC TOOLBOX

Python Radar Analysis Tools (PyRAT)

DLR

Sentinel toolboxes (SNAP)

s-1tbx s-2tbx s-3tbx

ORFEO ToolBox

cnes
CENTRE NATIONAL D'ÉTUDES SPATIALES

Poll questions 5-8

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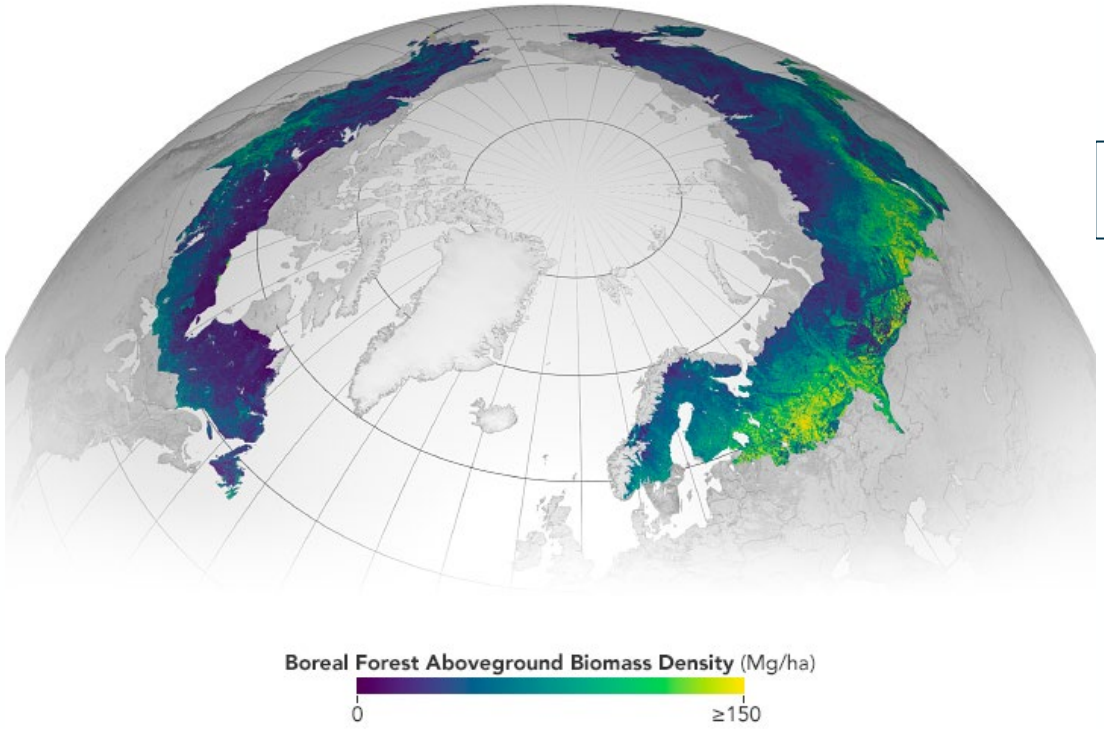
Expected Usage



NASA's ICESat-2 data fill GEDI's northern data gap for global lidar mapping (generated and available on the BIOMASS MAAP)

Poll questions 9-11

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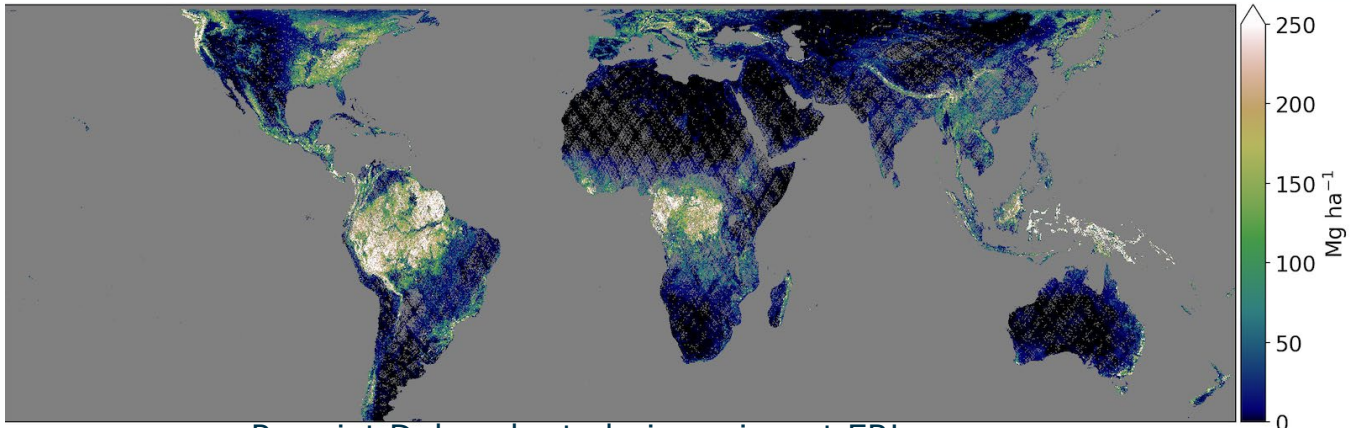
GEDI's biomass gridded map product recently published: ~*480 Pg* AGB in the GEDI domain



Preprint Dubayah et al., in review at ERL

Contribution to open projects

→ *The model of Open-Source development*

- ✓ An Open-Source software refers to a computer program in which the **source code is available** to the **general public** for **use and/or modification** from its original design.
- ✓ Open source gives the users the possibility to **benefit from other users work**, and to make other users **benefit from his work**.
- ✓ Every successful Open-Source software development is based on a **team** (or on a leader for small projects):
  - Define the contribution strategy
  - Check the code quality
- ✓ **All types of governance** can be successful!
- ✓ "Open" does not mean "Free" (for agencies): contributors work on what they want, however some developments/improvements may still require funding (and verification will also require funding).

Poll questions 12-16

https://forms.gle/V7eAqqa6U2Z6Y8L26

Open Science building blocks :

- **Open Notebooks** - documenting and sharing the experimental process of trial and error;
- **Open Data** - managing research data in a way that optimises access, discoverability and sharing for use and re-use;
- **Open Research Software** - documenting research code and routines, and making them freely accessible and available for collaboration;
- **Open Access** - making all published outputs freely accessible for maximum use and impact.

LPS2022 FLEX products user survey

URL:
https://forms.gle/2jDHoSGcRBrir2GW7

QR code: