EO FOR FORESTRY TRAINING 2024 (BELEM, BRAZIL)

Thanks to all ESA-EOP colleagues for their contributions

Thibault Taillade, Magdalena Fitrzyk

Summary

1. Introduction to ESA

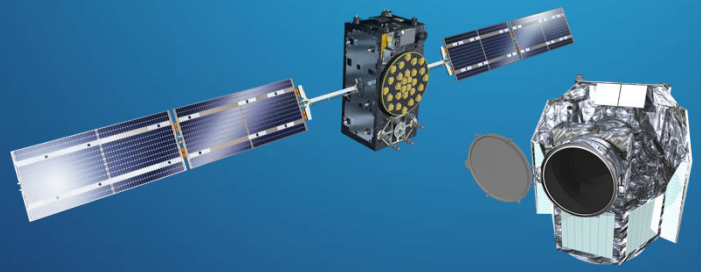
2. Earth Observation missions

ESA-EOP colleagues

Thibault Taillade, Magdalena Fitrzyk

What is the European Space Agency, ESA

Make Space for Europe



Pushing the limits of what is possible in space since 1975

5 500+

ESA Workforce

22 Member States

(+ associated & cooperating states)

2023-2025 Budget

16.9 billions €

ESA Activities and Achievements

All of this is possible thanks to the collaboration of ALL Member States

ESA, unlike many other agencies is active across **every area** of the **space sector**

World leader in **science** and **technology**

+80 programmes in parallel

Over 80 satellites developed, tested, and operated **since 1975**

More than 220 launches from Europe's Spaceport in Kourou

ESA Membership

22 Member States

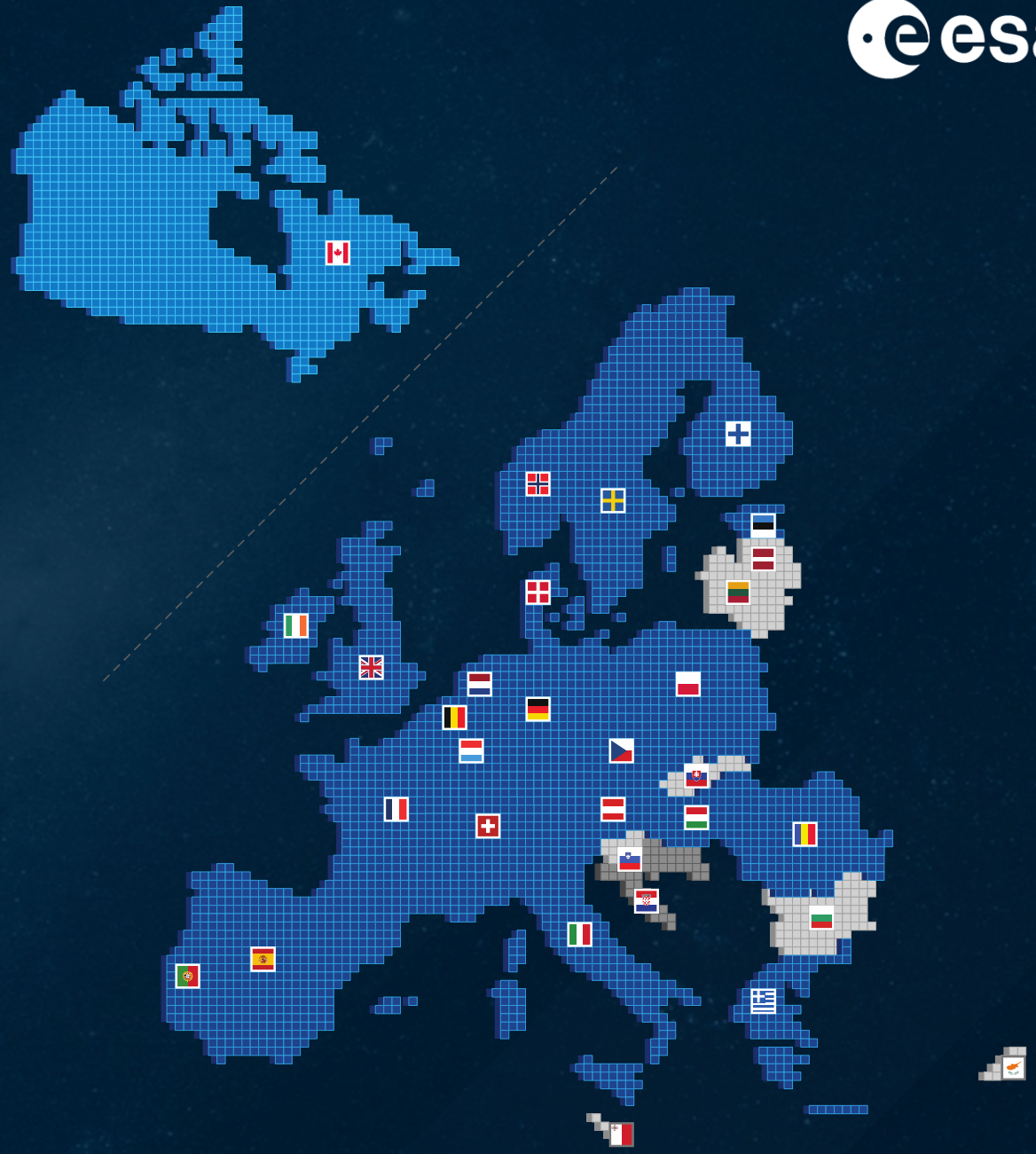
Austria
Belgium
Czech Republic
Denmark
Estonia
Finland
France
Germany
Greece
Hungary
Ireland
Italy
Luxembourg
Netherlands
Norway
Poland
Portugal
Romania
Spain
Sweden
Switzerland
United Kingdom

4 Associate Members

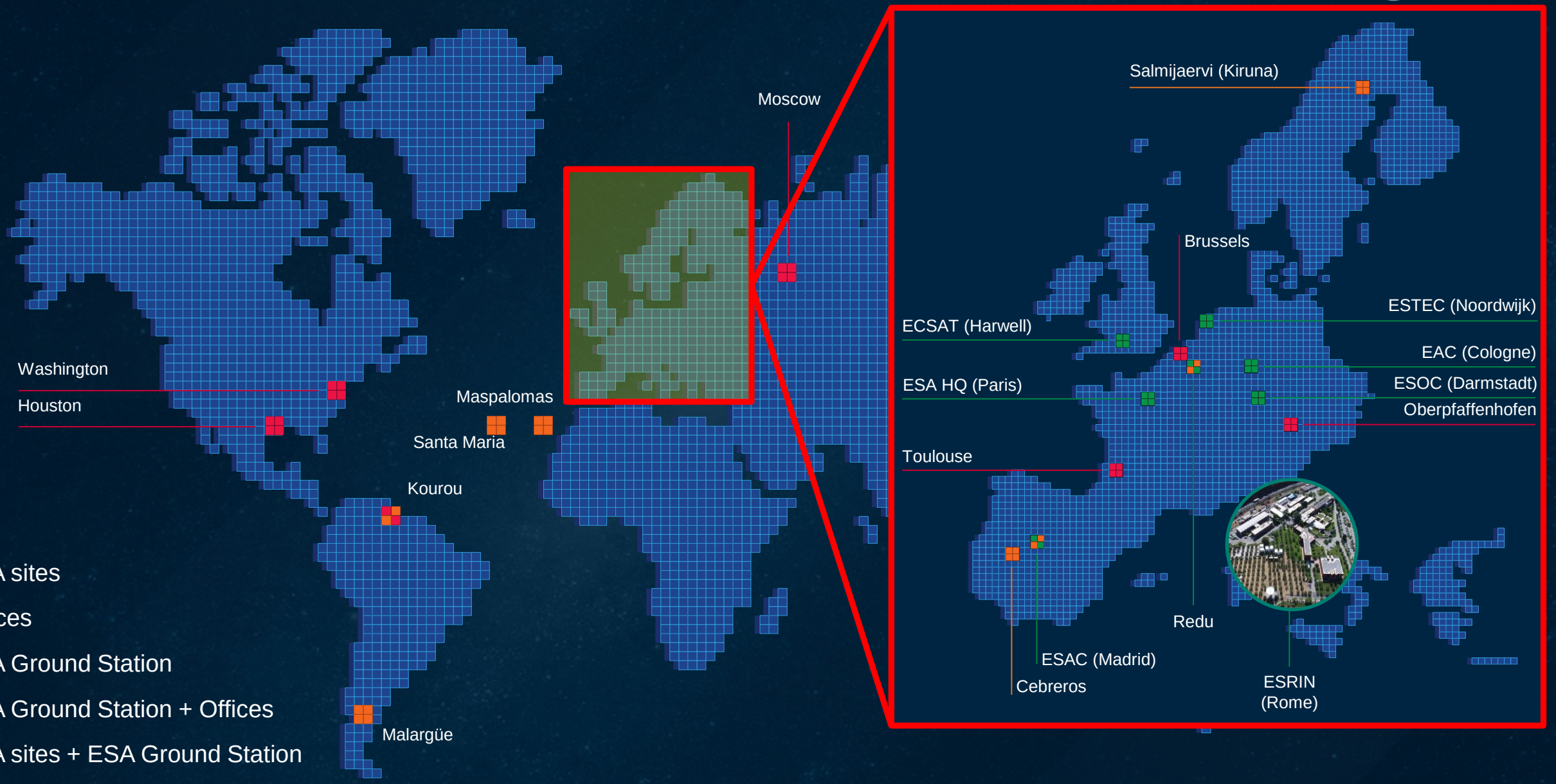
Slovenia, Slovakia, Latvia, Lithuania

Cooperation Agreements

4 other European States: Bulgaria, Croatia, Cyprus and Malta + Canada

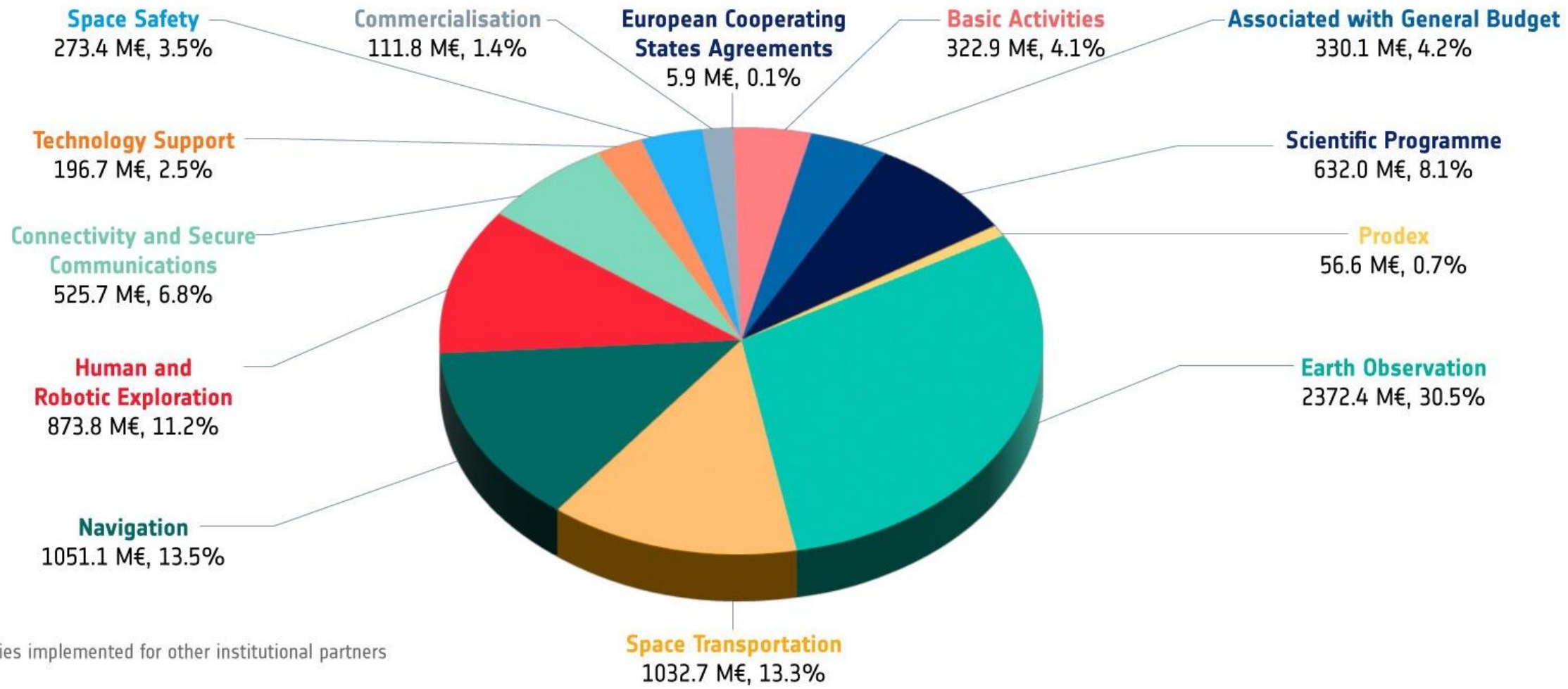


ESA Locations



- ESA sites
- Offices
- ESA Ground Station
- ESA Ground Station + Offices
- ESA sites + ESA Ground Station

ESA Budget by Domain for 2024: 7.79 B€*



*Includes activities implemented for other institutional partners

ESA EO Vision: “Building world class satellites”

Taking the Pulse of our Planet

ESA ESRIN Establishment

Activities

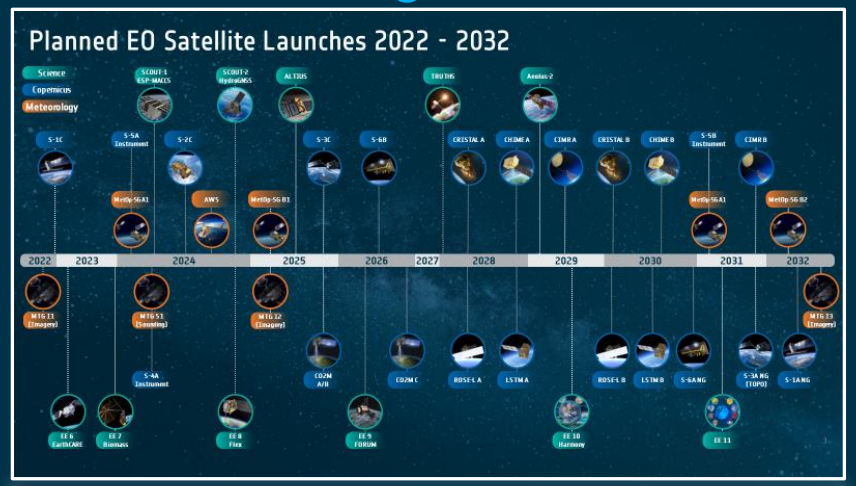
- Earth Observation
- Vega Launcher
- Corporate Informatics
- ESA Security Office
- Contracts, Personnel
- Site Management
- Communication

50.000 visitors per year

868 personnel on the site

ESA Activities: Earth Observation

Building satellites



Managing Missions

Cal/Val & Data Distribution

Applying the Data

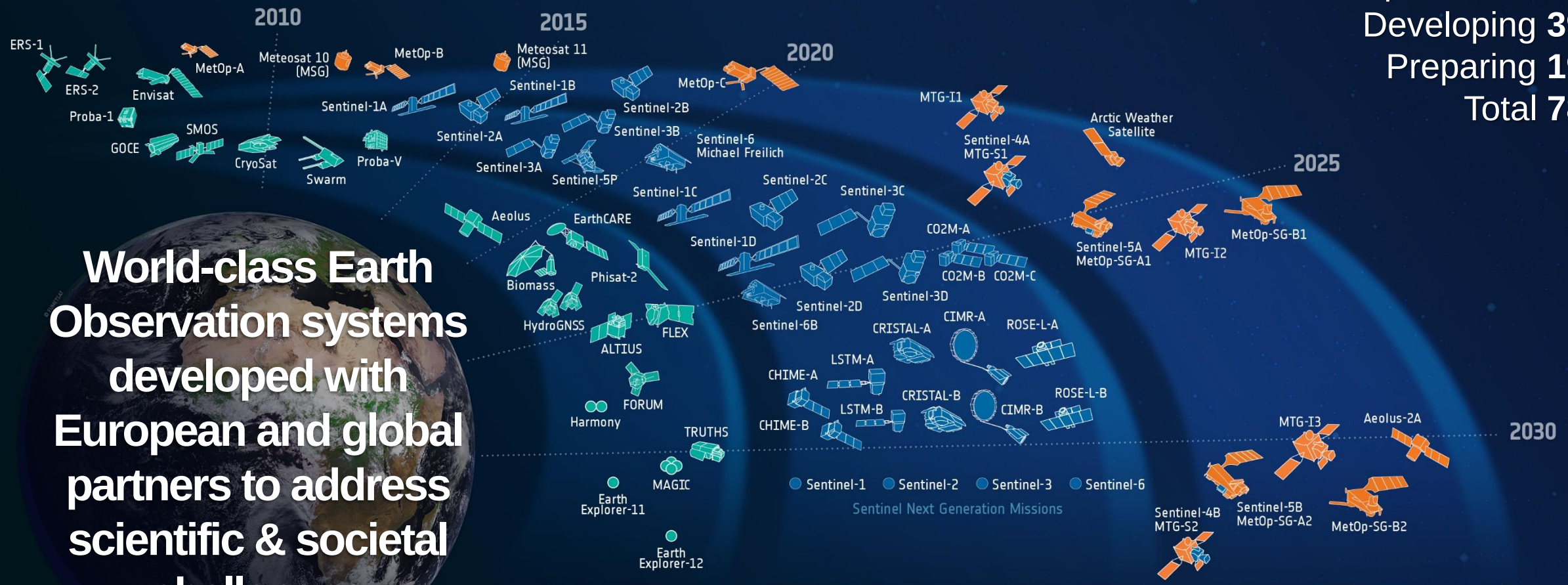
Innovation

Commercialisation

ESA's Earth Observation Missions

Satellites

Heritage **06**
Operational **14**
Developing **39**
Preparing **19**
Total **78**



World-class Earth Observation systems developed with European and global partners to address scientific & societal challenges

Science esa | Copernicus European Union | Meteorology EUMETSAT

Earth Explorers Putting together the puzzle Earth Since 2009

esa

EE-1 EE-2 EE-3 EE-4 EE-5 EE-6 EE-7 EE-8 EE-9

Goce
2009 - 2013

Smos
2009 - present

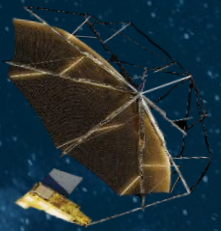
Cryosat
2010 - present

swarm
2013 - present

Aeolus
2018 - present

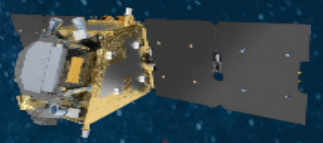
Clouds, aerosol & radiation

Earthcare
2024



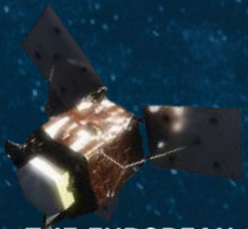
Forest mission

Biomass
Q1-2025



Photosyn-thesis

Flex
2025



Thermal radiation

Forum
2027

Geoid

Ocean Salinity & Soil Moisture

Thickness of ice

Magnetic Field

Wind mission

→ THE EUROPEAN SPACE AGENCY

Copernicus Global Monitoring with the Sentinels

PROGRAMME OF THE EUROPEAN UNION

esa

Copernicus is the largest producer of EO data in the world

All global landmass is observed every 5 days at 10m resolution

30 TB Daily Data Production by Sentinels

350 TB of Daily Sentinel Products Disseminated for Services to Society

> 750.000 Registered Users

Supporting 6 operational services

Land Atmosphere Ocean

Climate Disasters Security

Full, Free & Open Data Policy*

* ESA Sentinel Data Policy (Sep 2013) and
EU Delegated Act on Copernicus Data and Information Policy (Dec 2013)

PROGRAMME OF THE EUROPEAN UNION

Copernicus
Europe's eyes on Earth

co-funded with esa

CHIME

Copernicus Hyperspectral Imaging Mission for the Environment

soil properties
crop health
raw materials
biodiversity
water quality

ROSE-L

L-band Radar Observing System

geohazards
polar ice
forest management
food security
maritime surveillance

LSTM

Land Surface Temperature Monitoring

sustainable agriculture
water resources management
drought
urban heat islands

CIMR

Copernicus Imaging Microwave Radiometer

sea-ice concentration
sea-surface temperature
polar maritime security
global ocean and cryosphere
soil moisture and vegetation

CO2M

Copernicus Anthropogenic Carbon Dioxide Monitoring

carbon dioxide and methane from human activity

CRISTAL

Copernicus Polar Ice and Snow Topography Altimeter

sea-ice thickness
ice sheets and glaciers
snow
polar oceanography
coastal and inland waters

Food Security and Water Management

Monitoring Land and Natural Resources

Combatting Climate Change

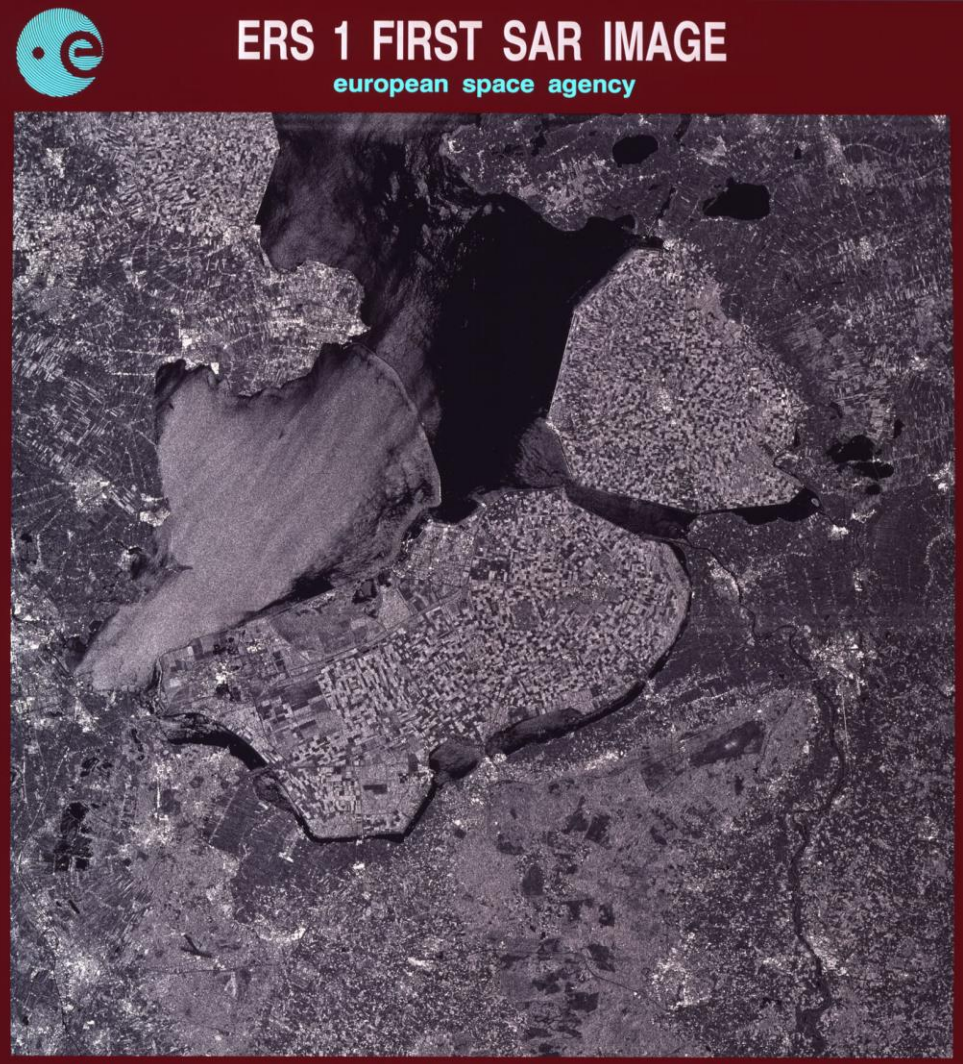
Copernicus Sentinel Expansion Missions

Safeguarding the Arctic

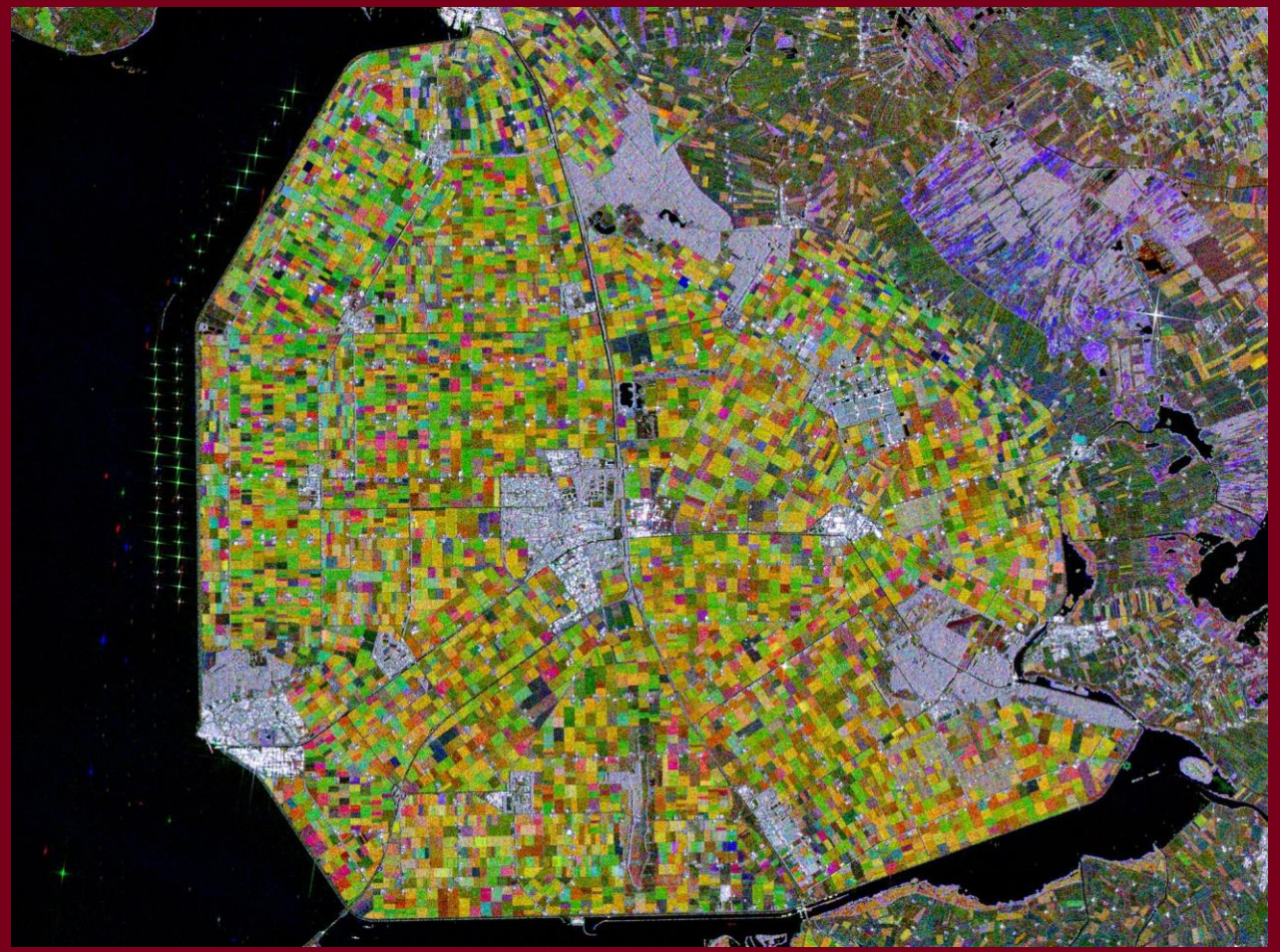
Current Missions

SENTINEL-1

33 years of SAR



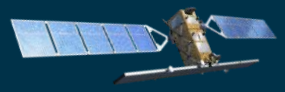
Sentinel-1



FLEVOLAND (NL), R: 8 May 2018, G: 7 July 2018, B: 5 Sept 2018

contains modified Copernicus Sentinel data (2018), processed by ESA

Sentinel-1 Mission in a nutshell



MISSION PROFILE

- Constellation of two identical SAR C-band satellites: (A & B → C units)
- Near-Polar, sun-synchronous (dawn-dusk) orbit at 698 km altitude
- 7.25 years lifetime (consumables for 12 years)
- 12-day repeat cycle (each satellite), 6 days for the constellation

PAYLOAD

- C-Band SAR
  - Centre frequency: 5.405 GHz
  - Polarizations: HH, VV, HH/HV, VV/VH
  - Incidence angle: 20º - 45º
  - Radiometric accuracy: 1 dB (3σ)
  - Radiometric stability: 0.55 dB (3σ), 0.45 (3σ) for S-1 C/D
  - NESZ: -22 dB
  - DTAR: -22 dB
- AIS Instrument marine surveillance (for S-1 C and D)

OPERATIONS

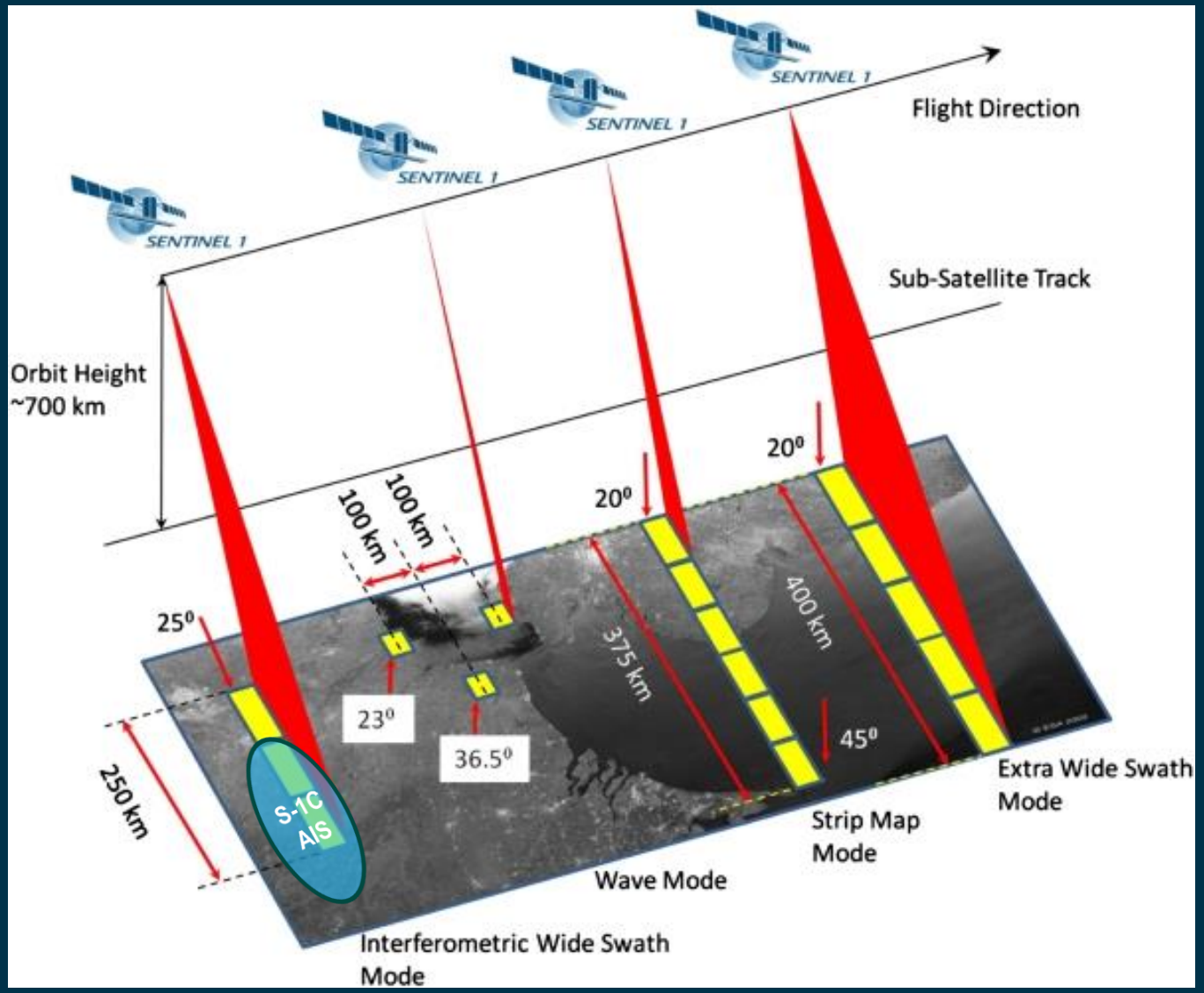
- Systematic SAR data acquisition using a predefined observation scenario
- Instrument duty cycle of max. 25 min/orbit in High Bit Rate modes (30 min outside eclipse) and 75 min/orbit in Low Bit Rate mode (Wave)

PROGRAMMATICS

- Sentinel-1C launch 2024
- Sentinel-1D currently in storage to be launched as soon as possible S-1C

Full, Free and Open Data

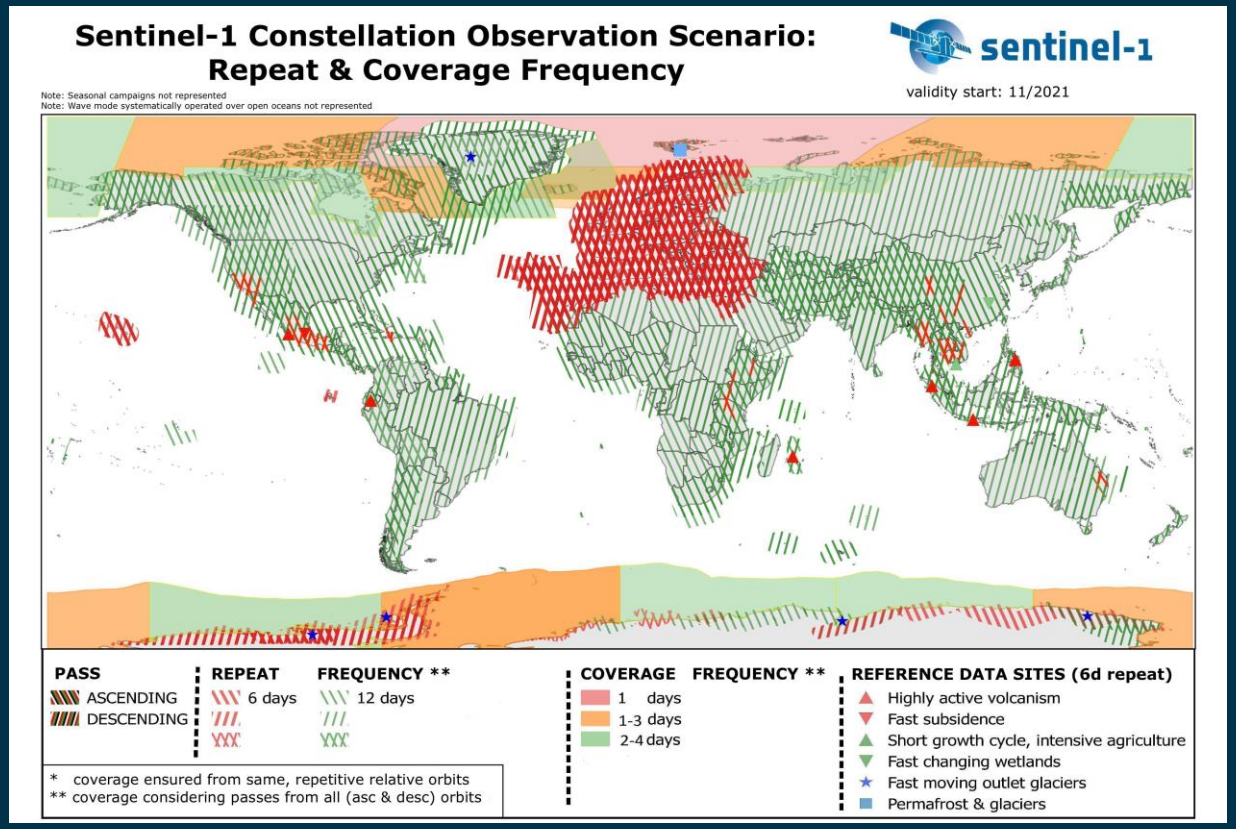
Sentinel-1 Imaging Modes



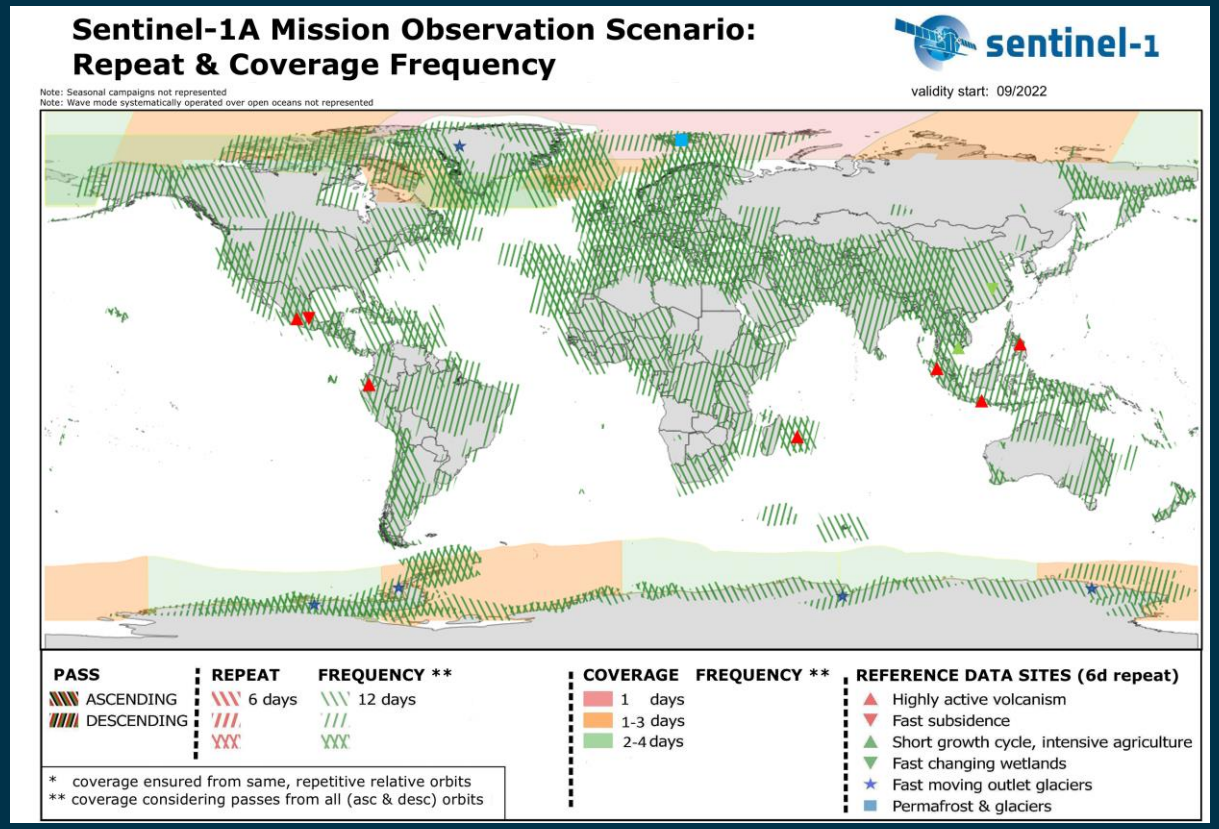
	TOPS	SM	TOPS
Parameter	**Interferometric Wide-swath mode (IW)**	**Wave mode (WV)**	**Strip Map mode (SM)**	**Extra Wide-swath mode (EW)**
Polarisation	Dual (HH+HV, VV+VH)	Single (HH, VV)	Dual (HH+HV, VV+VH)	Dual (HH+HV, VV+VH)
Access (incidence angles)	31°–46°	23°–37° (mid incidence angle)	20°–47°	20°–47°
Azimuth resolution	<20m	<5m	<5m	<40m
Ground range resolution	<5m	<5m	<5m	<20m
Azimuth and range looks	Single	Single	Single	Single
Swath	>250km	Vignette 20×20km	>80km	>410km
Maximum NESZ	−22dB	−22dB	−22dB	−22dB
Radiometric stability	0.5dB (3σ)	0.5dB (3σ)	0.5dB (3σ)	0.5dB (3σ)
Radiometric accuracy	1dB (3σ)	1dB (3σ)	1dB (3σ)	1dB (3σ)
Phase error	5°	5°	5°	5°

Sentinel-1 observation plan

The largest provider of SAR data worldwide



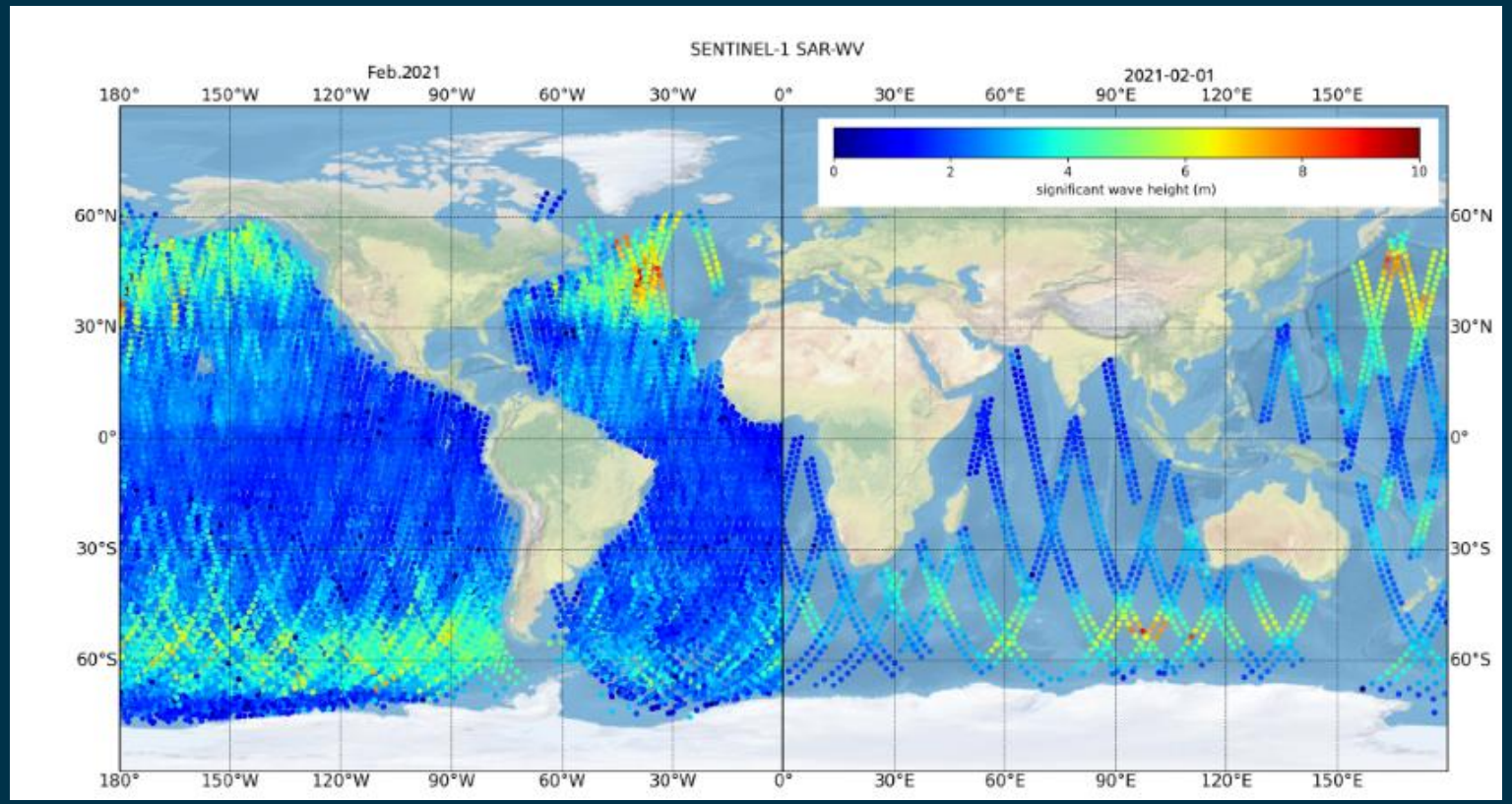
S-1A and B



S-1A only (>2021)

Observation plan details available at: https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-1/observation-scenario/

Sentinel-1: An Ocean Mission



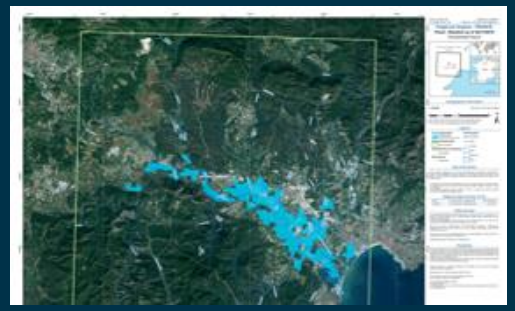
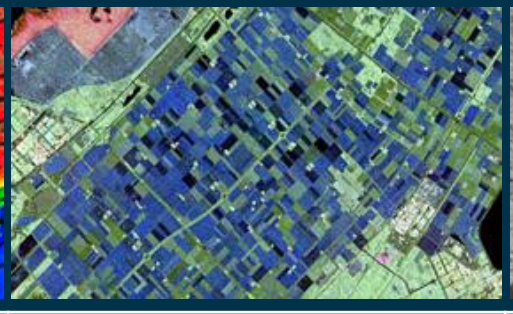
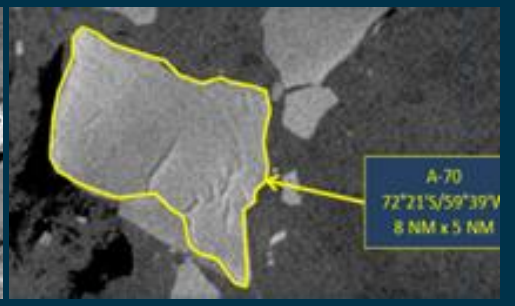
1 month

1 day

- Sentinel-1 continues the wave mission started by ERS.
- SAR Wave mode acquires “imagettes” every no other is used over ocean
- SAR Wave mode L2 products are operationally assimilated by met offices to improve wave model

- Sentinel-1 has collected millions of SLC imagettes

Sentinel-1 is used in most Copernicus Services

Emergency Management Service	Marine Environment Monitoring Service	Land Monitoring Service	Climate Change Service	Security Service
				
• Rapid mapping (flood mainly) • Risk recovery (e.g. ground deformation) • Validation (e.g. flood, landslide) • Automated global flood monitoring (in development)	• Describe and analyse the physical and sea ice state of the ocean at the surface, on global scale or for a specific zone	• Land Cover and Land Use Mapping (HRLs: Wetness and Water, Imperviousness, Tree cover & Forest, Grassland, Snow, River/Lake ice) • Biogeophysical parameters • European ground motion service	• Climate datasets and tools for science, policy and industry (e.g. for climate change impact assessment, risk assessment, sustainability)	• Oil spill detection and polluter identification (CleanSeaNet) • Maritime surveillance (detection, search and rescue, anti-piracy) • Border surveillance; • Support to EU External and Security Actions • R&D for EO Security
Flooded area **Ground movement** **Soil moisture** **Abrupt surface elevation changes**	**Sea ice type, concentration and motion** **Iceberg location, size and drift** **Ocean surface currents** **Ocean surface wind vectors** **Swell properties**	**Land use and land use change, including agriculture and forestry** **Ice sheets & glaciers velocity** **Wet snow extent** **Ground movement** **Global Soil moisture**	• **Sea ice type, concentration and motion** • **Ice sheets & glaciers velocity, Grounding line** • **Ground movement** • **Ice sheets margins and glacier surface height** • **Ice sheet melt/freeze extent**	• **Iceberg location, size and drift** • **Vessel location, size and velocity** • **Oil spill location and morphology** • **Feature identification** • **Change Detection**

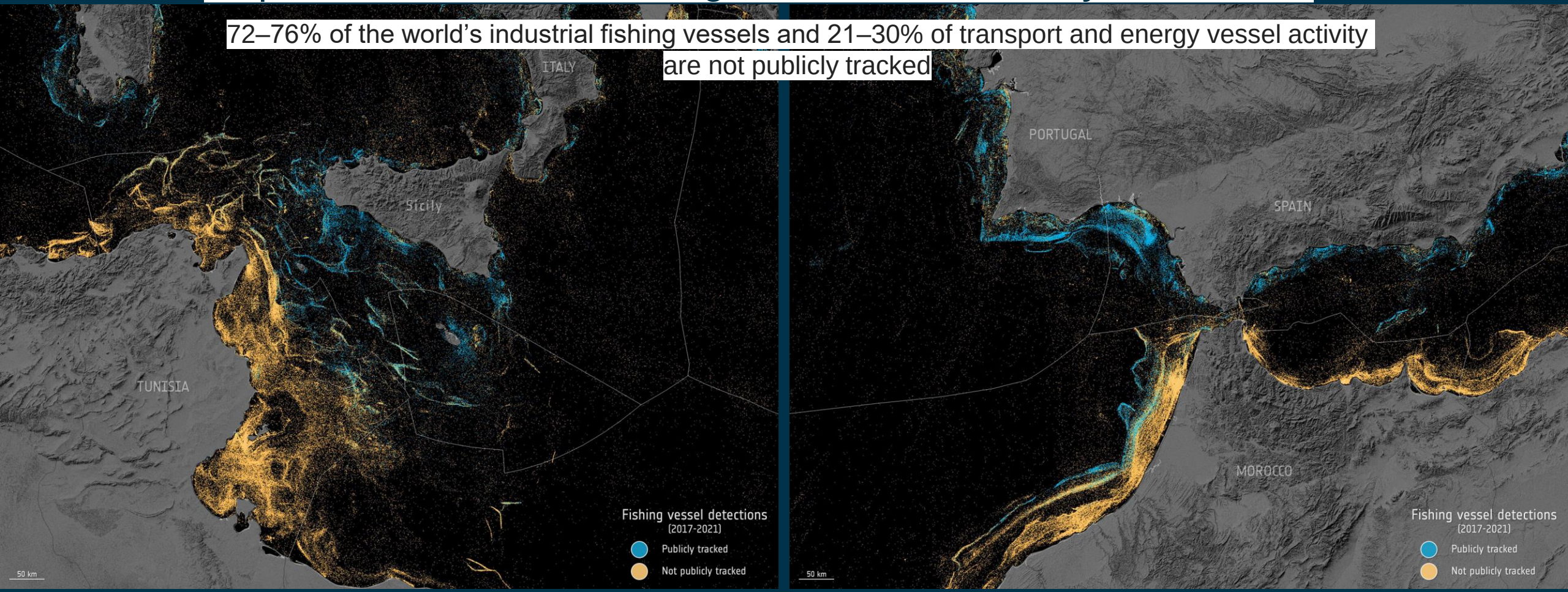
Enhanced continuity by Sentinel-1 Next Generation

Mapping untracked fishing vessels with AI

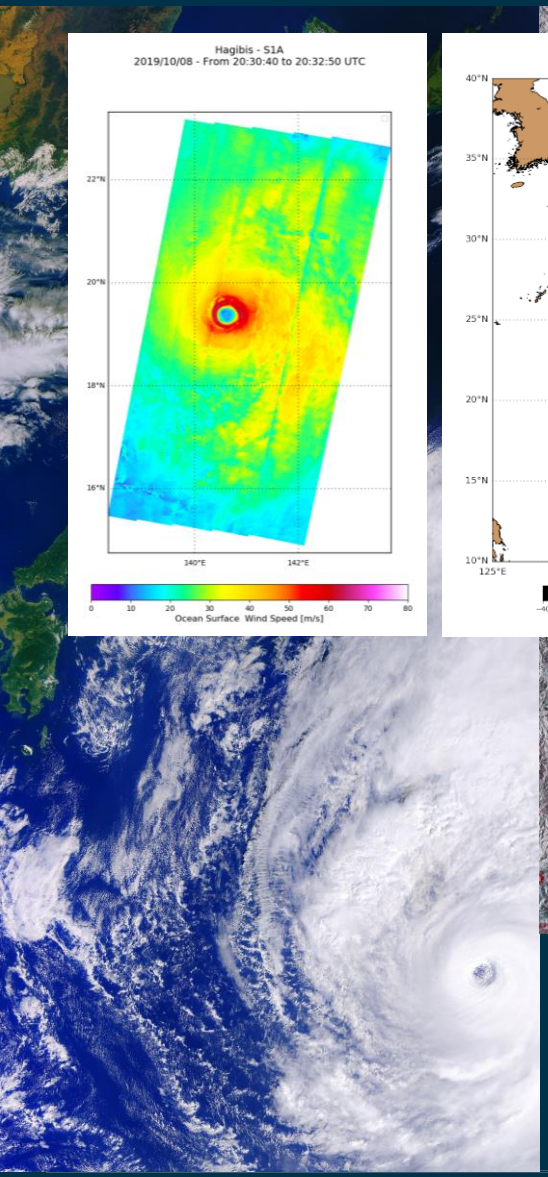
https://www.nature.com/articles/s41586-023-06825-8

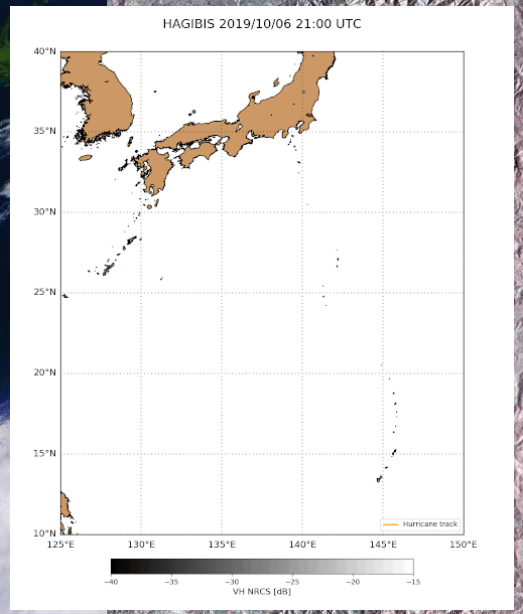
Map reveals untracked fishing vessels around Sicily and Tunisia

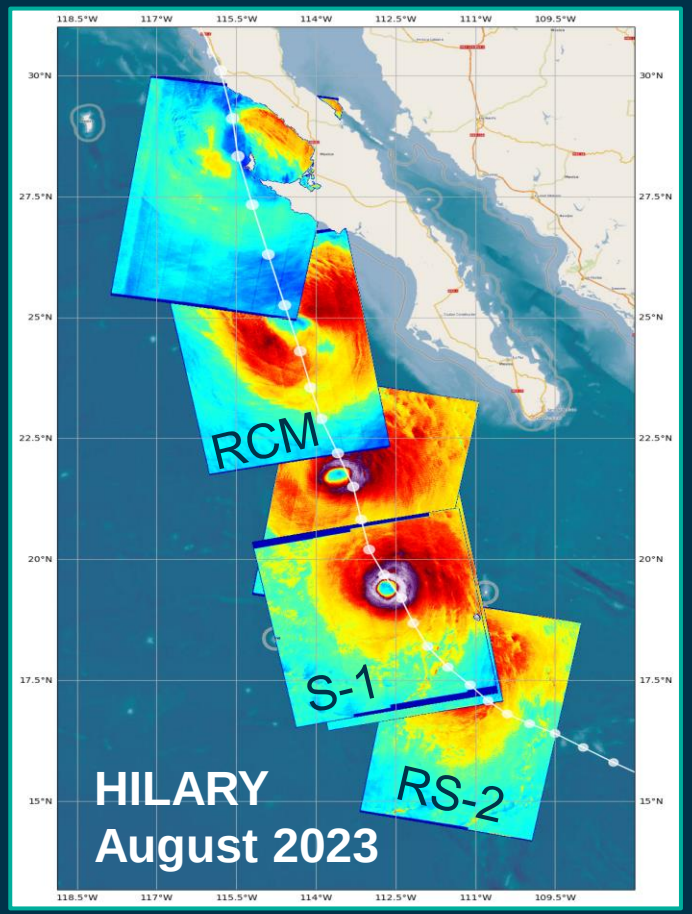
72–76% of the world's industrial fishing vessels and 21–30% of transport and energy vessel activity are not publicly tracked



Supporting rapid response to crisis



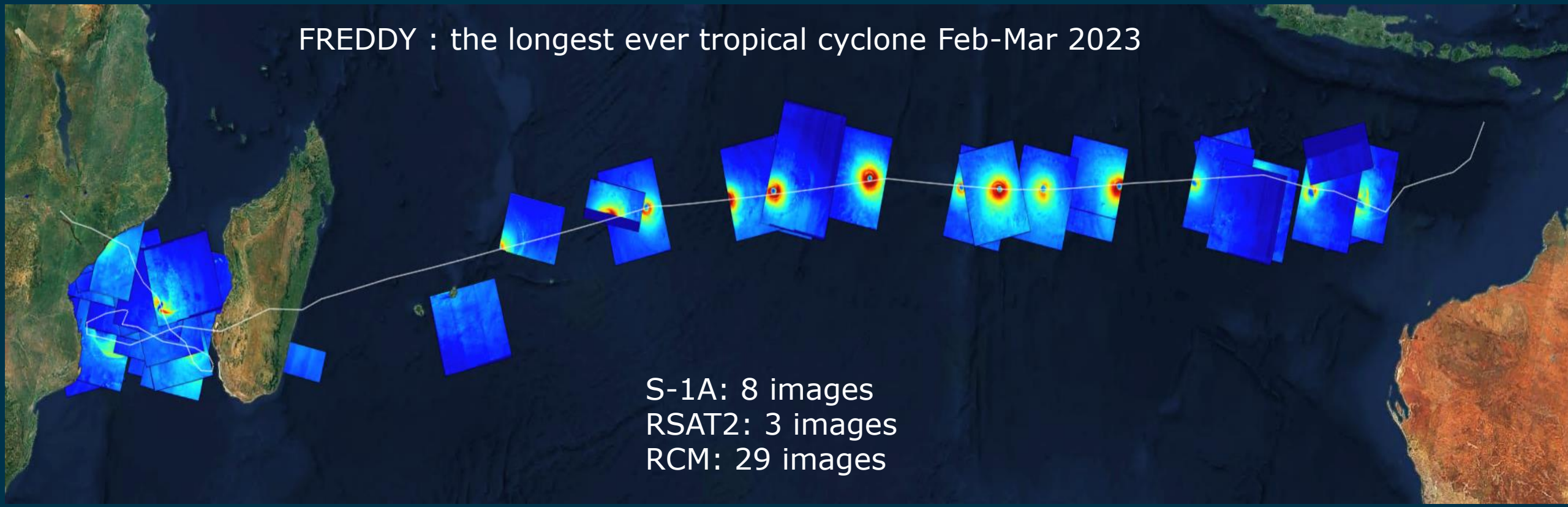




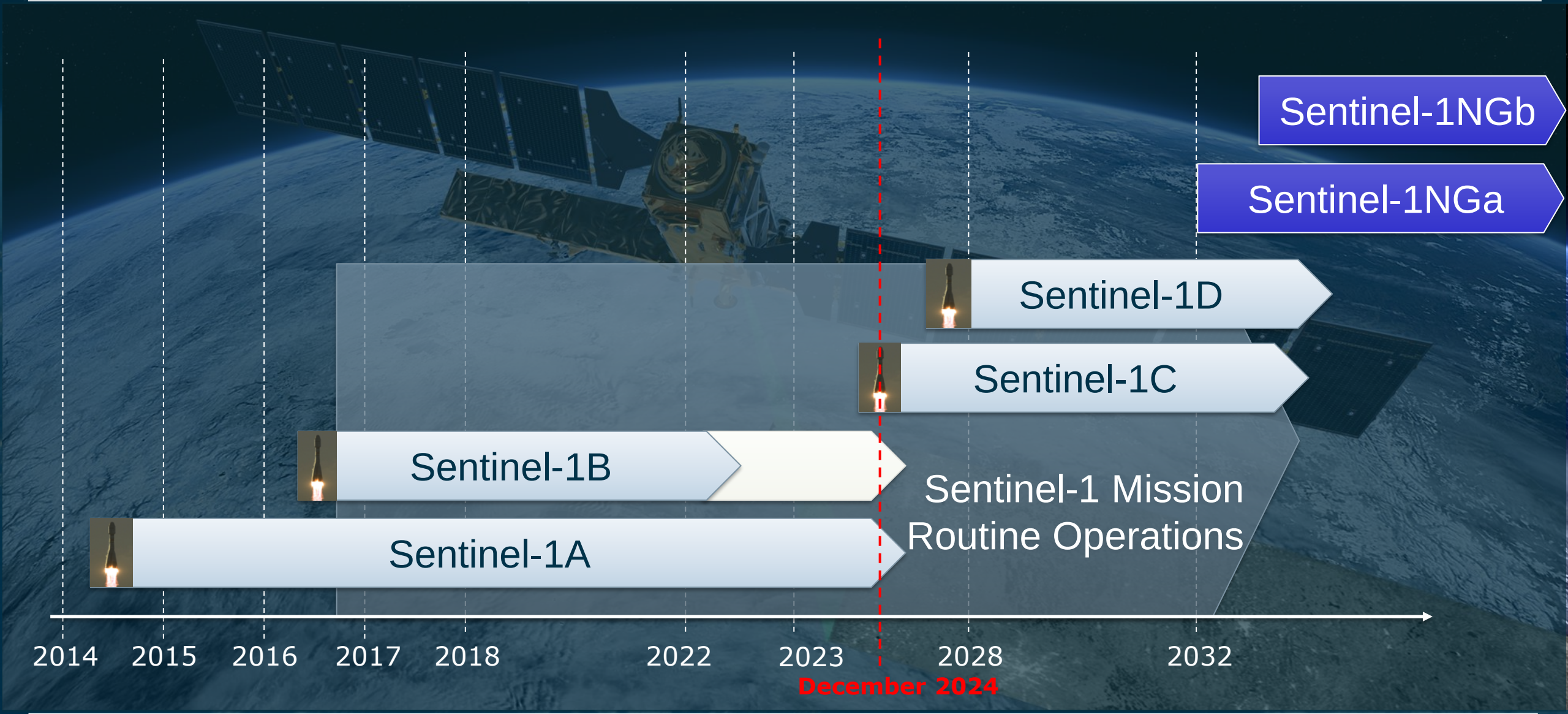
Copernicus Sentinel-3 view of Typhoon Hagibis
Ocean surface wind speed of Typhoon Hagibis derived from Copernicus Sentinel-1
Copernicus Sentinel-1 tracking of Typhoon Hagibis heading to Japan's main island of Honshu
extent of flooding on Japan's main island of Honshu. F
Foods around the cities of Sendai and Ishinomaki on 12 October.

Tropical Cyclone : An International Joint Effort

- SAR high resolution wind data over TC is key to improve the quality of cyclone and climate forecast
- Freddy is longest-lasting tropical cyclone ever recorded worldwide and it is a good example of the extreme events we will face in the future
- Freddy perfectly demonstrates the need for international coordination and the value of Virtual Constellations
- Further coordination is necessary amongst agencies to support and sustain this effort



Sentinel-1 C-Band SAR Evolution Context



Copernicus Sentinel-1C/D Status

Sentinel-1C/-1D to continue and augment Sentinel-1A/-1B services

- Fully compatible w.r.t. SAR mode characteristics, observation geometry, image resolution and burst synchronization (InSAR)

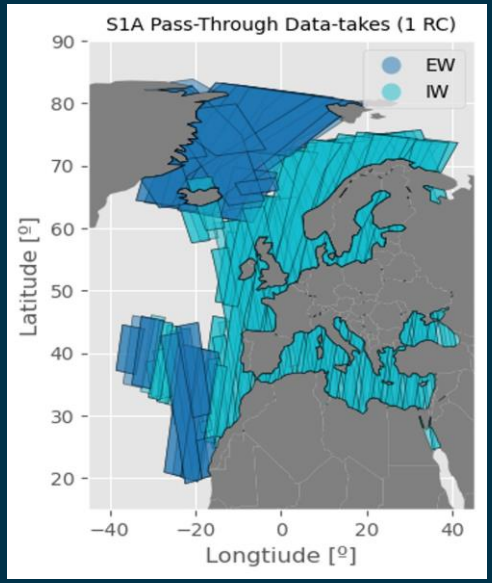
Sentinel-1C/D built on S-1A/-1B design with ***Evolution*** and ***Improvements***

- **AIS payload** to provide ship identification data for augmentation of SAR images
- S-1C/D design compatible with Space Debris Casualty Ratio less than 10-4
- GNSS receiver compatibility with Galileo
- Interleaved Calibration Noise Pulses for thermal noise correction
- Improved SAR Instrument Performance (radiometric accuracy)
- Satellite Manoeuvring (thruster performance)
- SMU Processing Capability (LEON3 processor)
- **Vega-C launcher qualification**

Sentinel-1C ready for **launch**

Sentinel-1D went into **storage** in Oct. 2021

S-1 Overpasses in direct downlink allowing for real time usage



AIS Instrument for augmentation of SAR maritime services

- Provides ship identification data simultaneously with SAR images
- AIS footprint matches IWS for maximising SNR and minimising message collisions
- AIS observation scenario is under definition (likely ‘real-time’ scenario over Europe allowing for direct usage at stations. Elsewhere to be defined)
- AIS Data policy is under discussion with European Commission

Take home messages about Sentinel-1:

- A fully operational mission
- Mapping land and ocean surfaces globally
- A long term commitment (decades)
- Other missions like ROSE-L, Harmony and S1NG will provide complementary capabilities

Current Missions

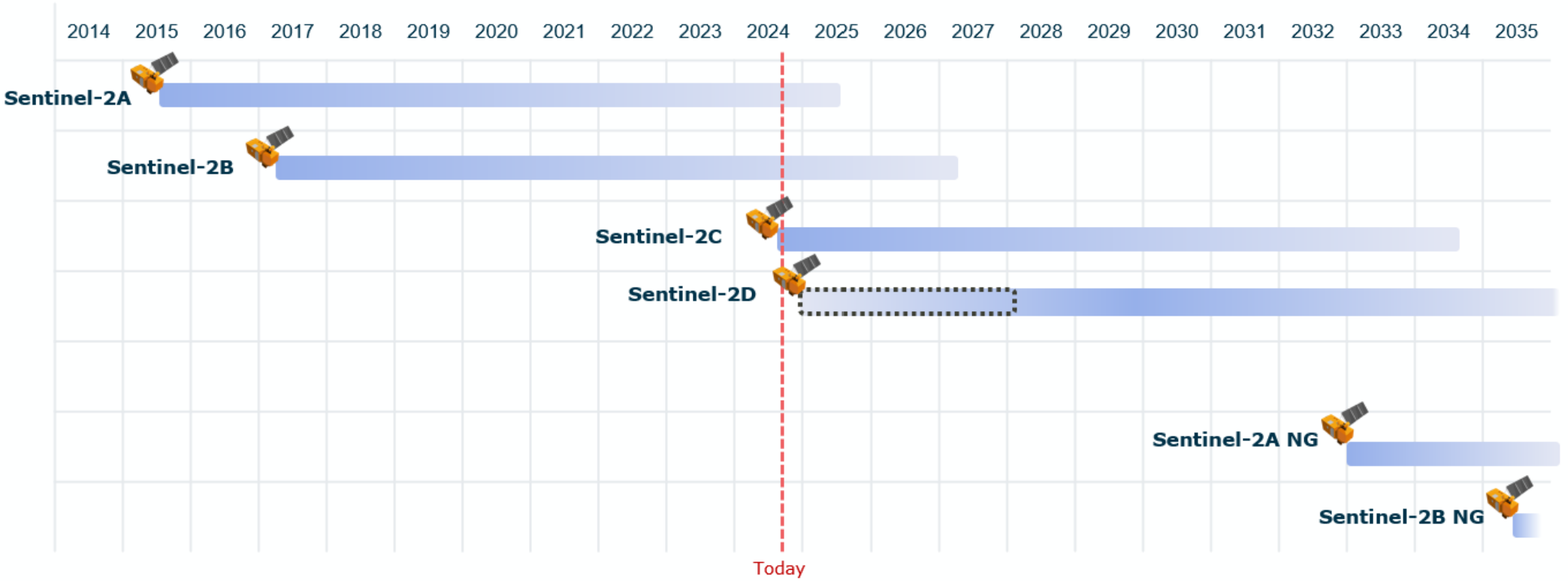
SENTINEL-2

Sentinel-2 : an Optical EO Mission

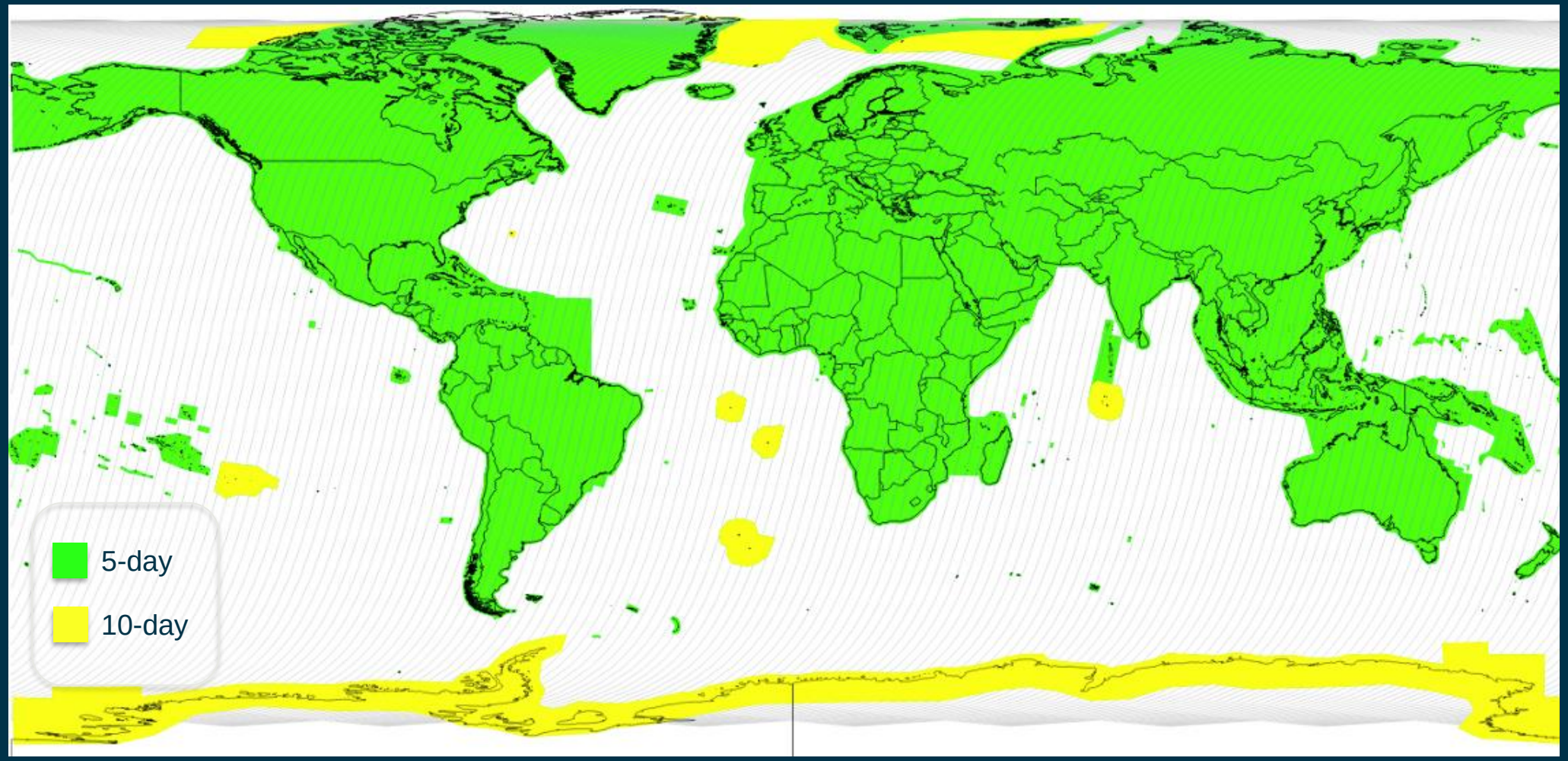
Optical multi-spectral sensor for monitoring land & coastal areas

- **Geometrical revisit**: 5 days (at the Equator) with 2 satellites
- **Local Time**: 10:30 a.m. descending node
- **Spectral Bands**: 13 spectral bands in the VNIR and SWIR
- **Spatial Resolution**: 10 m, 20 m, 60 m
- **Nominal swath**: 294 km, at 786 km altitude
- **Acquisition system**: Push-broom scanner
- **Data Access**: Free & open for a large range of applications

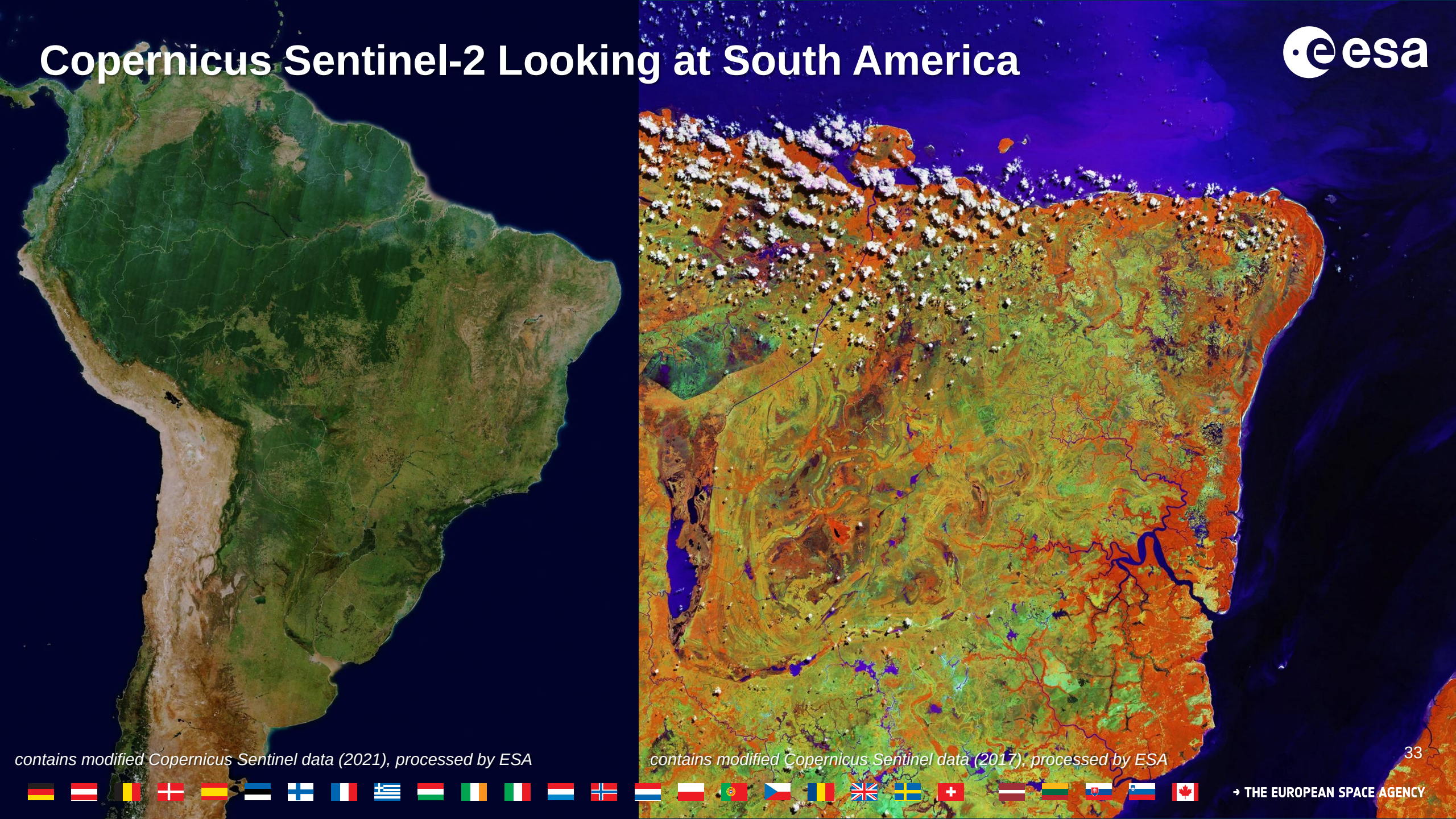
Sentinel-2 : an Optical EO Mission



Sentinel-2 : Observation Scenario



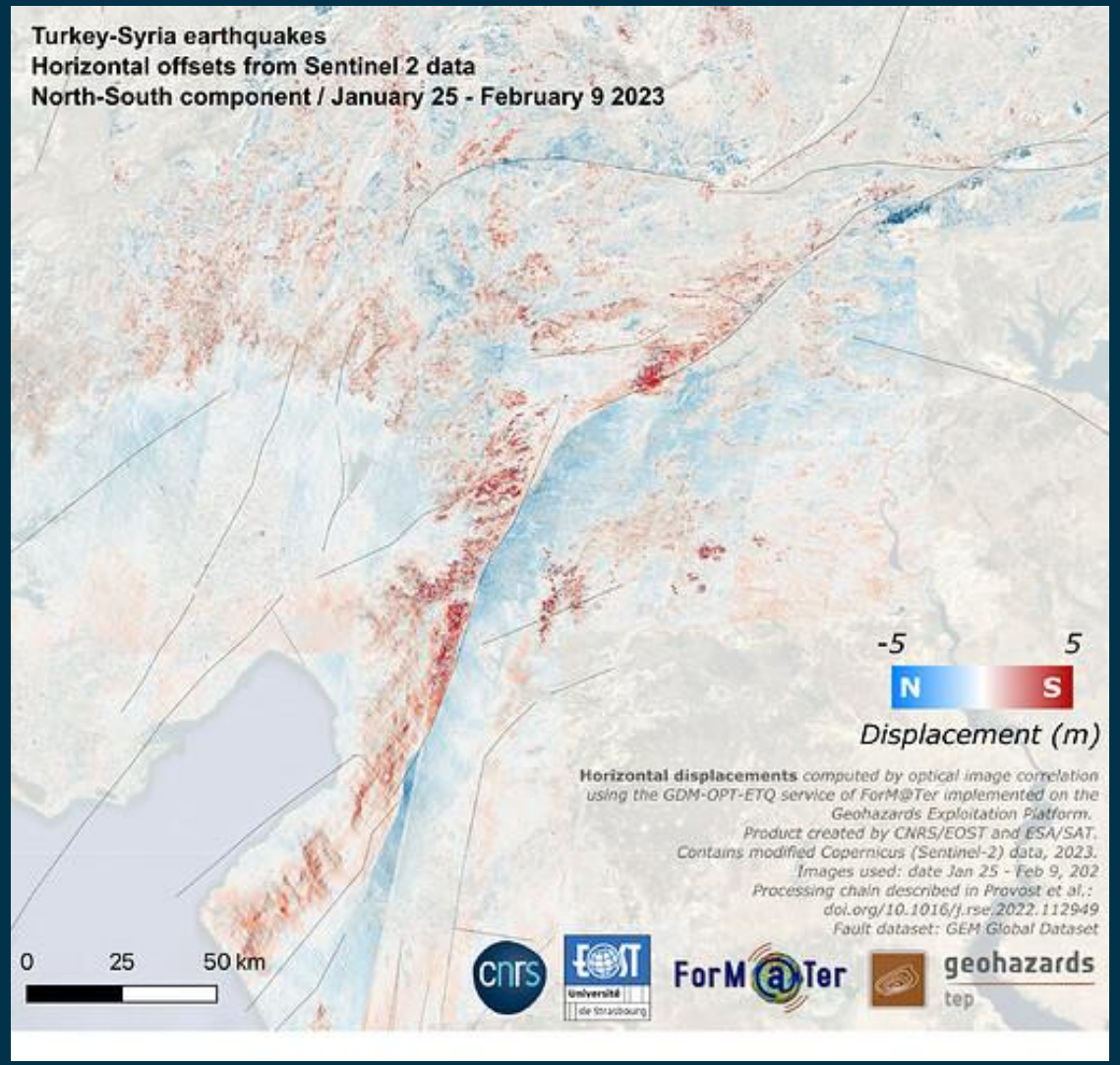
Copernicus Sentinel-2 Looking at South America



contains modified Copernicus Sentinel data (2021), processed by ESA

contains modified Copernicus Sentinel data (2017), processed by ESA

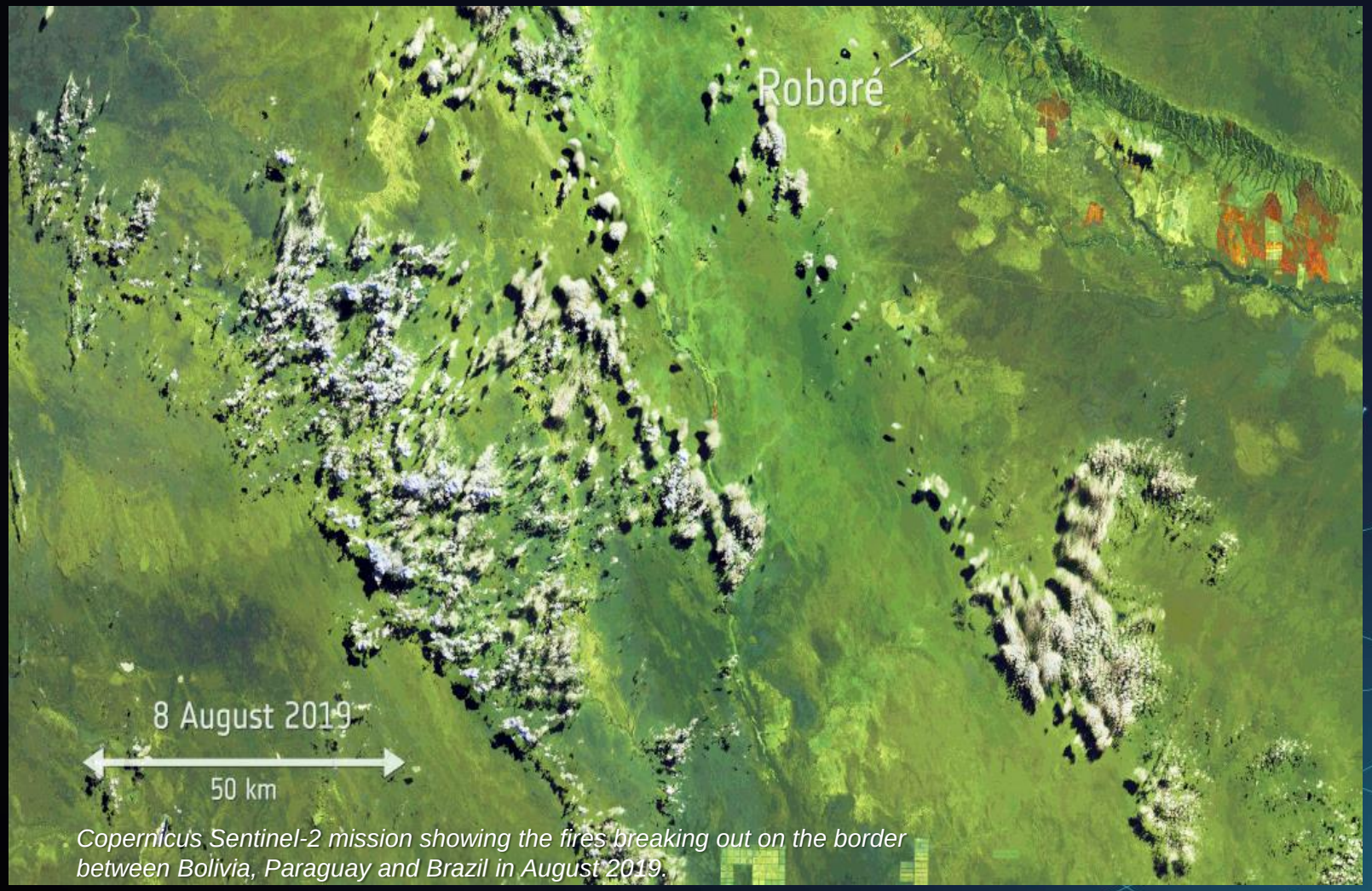
Impact assessment after Türkiye–Syria earthquakes



- ✓ North-South component of the deformation following the Türkiye and Syria 7.8 and 7.7 magnitude earthquakes of 6 February 2023 measured using Copernicus Sentinel-2 data.
- ✓ Sub-pixel optical correlation was applied on images of the acquired on 25 January 2023 (pre-event) and 9 February 2023 (post-event).

https://www.esa.int/Applications/Observing_the_Earth/Satellites_support_impact_assessment_after_Tuerkiye_Syria_earthquakes

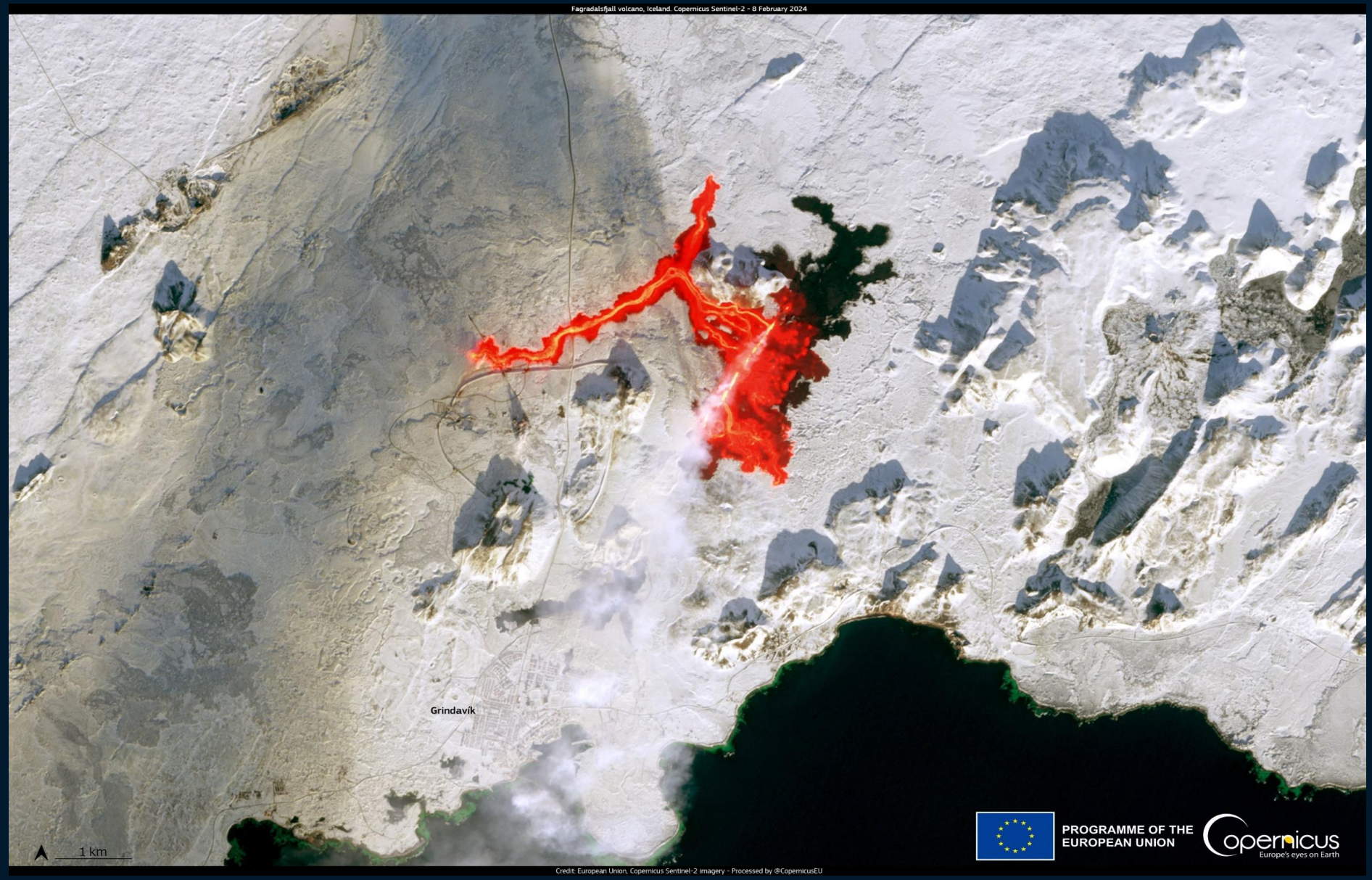
Systematic observations of wildfires:



Copernicus Sentinel-2 mission showing the fires breaking out on the border between Bolivia, Paraguay and Brazil in August 2019.

Sentinel-2 observation of lava flows

Janaury 2024, Iceland's Reykjanes Peninsula

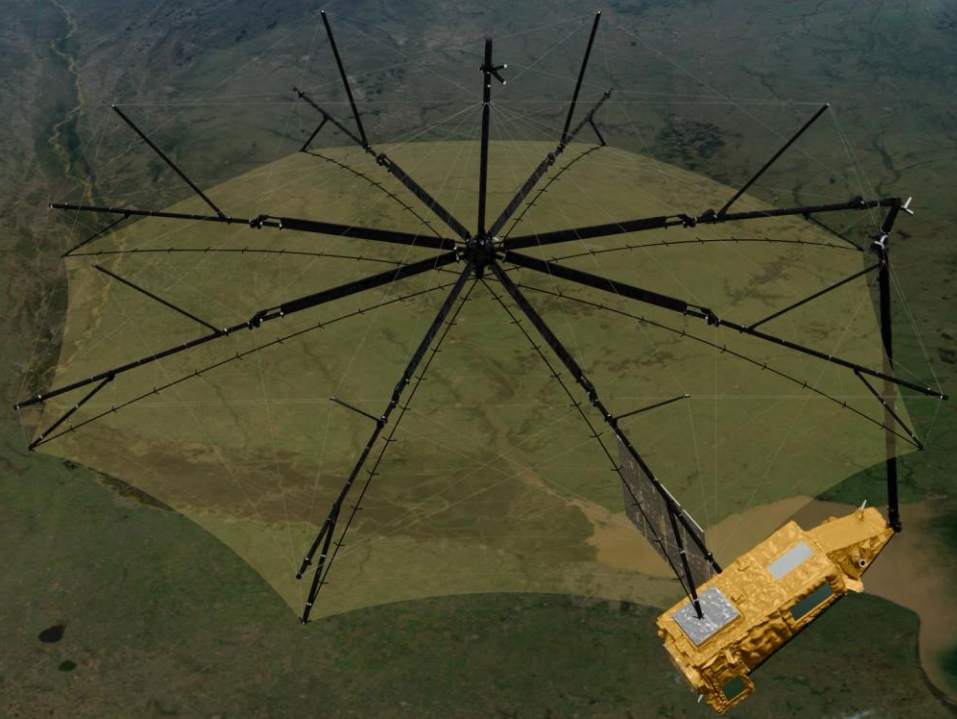


Take home messages about Sentinel-2:

- A fully operational mission
- Mapping land surfaces globally once every 5 days
- A long term commitment (decades)
- Other Copernicus missions like LSTM and CHIME will provide complementary capabilities

BIOMASS

The BIOMASS Mission



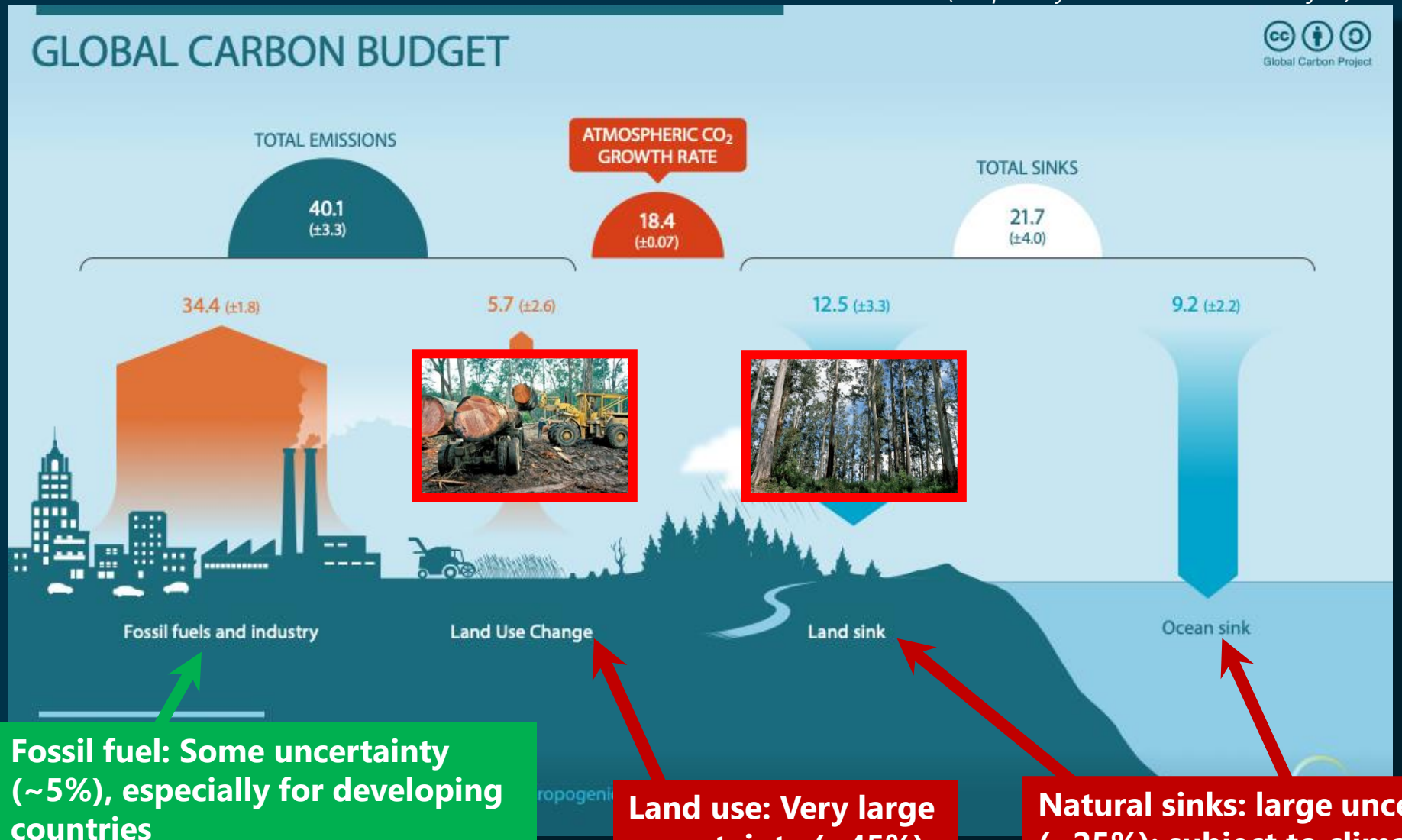
ESA's 7th Earth Explorer to be deployed in 2025

An interferometric, fully-polarimetric P-band SAR

Designed to observe forest height and biomass

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

(Graphic by the Global Carbon Project)



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

Land use: Very large uncertainty (~45%)

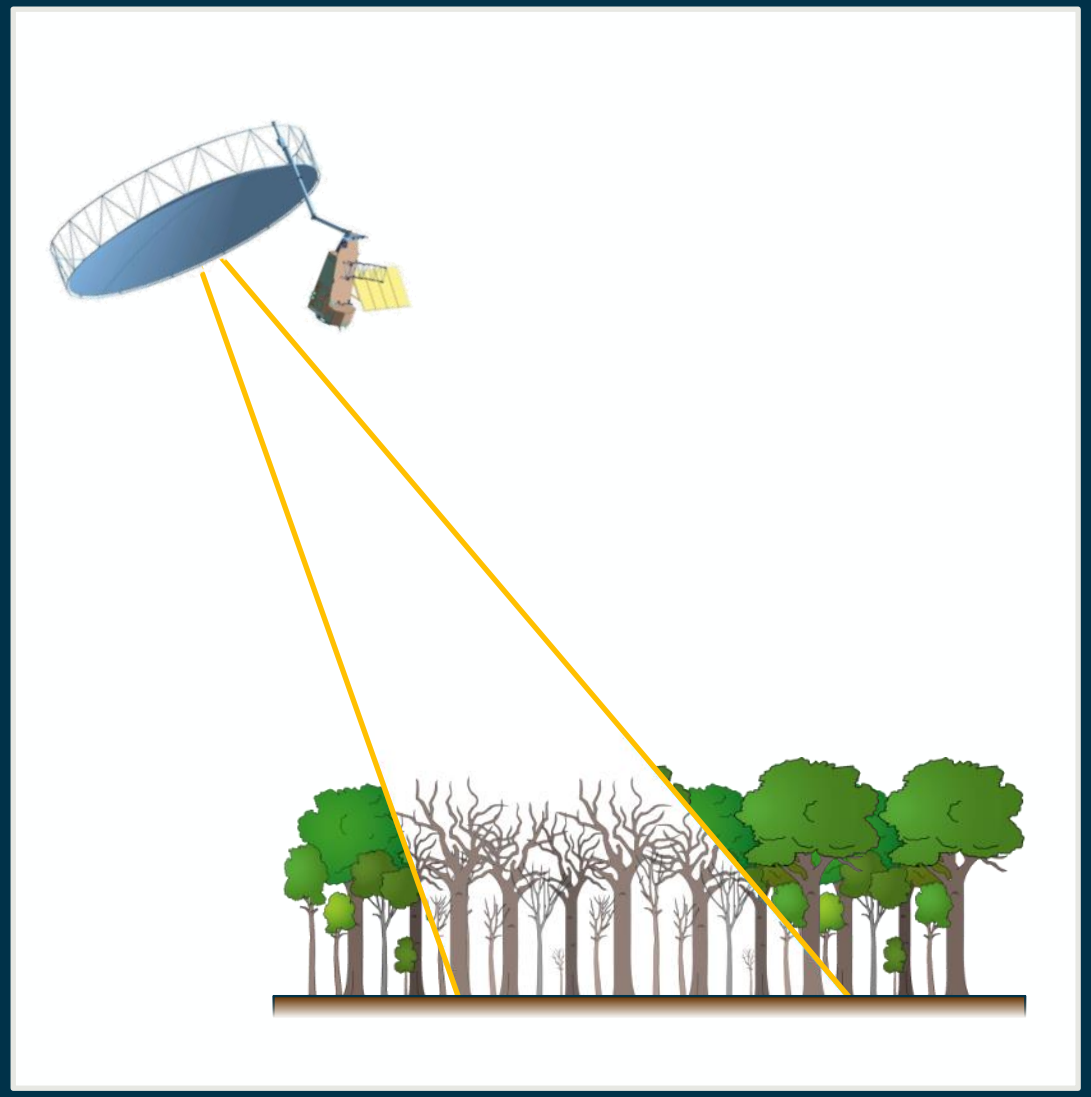
Natural sinks: large uncertainties (~25%); subject to climate feedbacks

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

Mapping forest biomass requires a radar sensor with long wavelength:

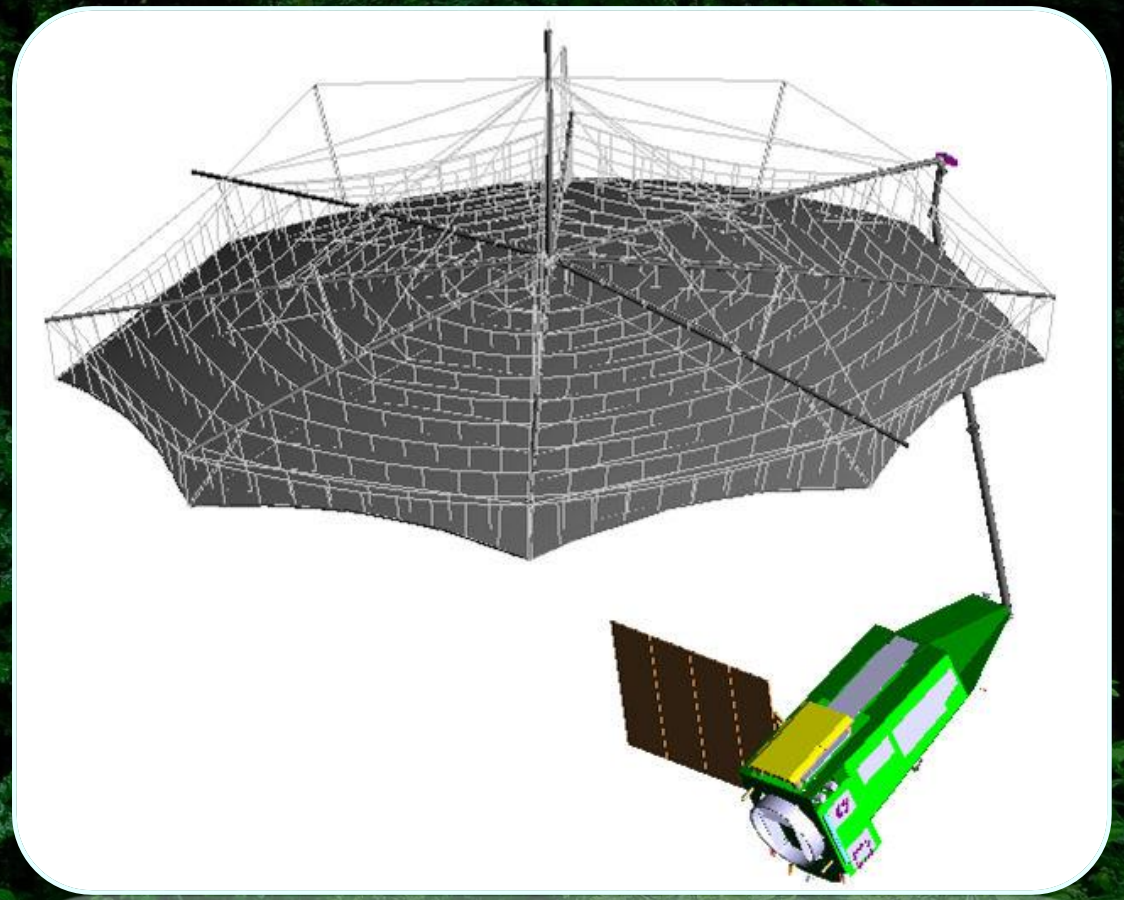
1. to penetrate the canopy in all forest biomes
2. to interact with woody vegetation elements
3. so that forest height can be estimated with a single satellite

This implies a radar at P-band, of wavelength ~70 cm, the longest possible from space



BIOMASS

Mission	Measure of forest biomass and height (200 m. pixel resolution)
Payload	P-Band radar
Orbit	SSO, alt: 666 km; LTAN: 6h00
Satellite	1250 Kg
Consortium	Prime: ADS-UK, Instrument: ADS-DE
Launch date	May 2025
Lifetime	5.5 years



BIOMASS Products

Forest biomass

Above-ground biomass (tons/hectare)

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

Forest height

Upper canopy height (meter)

- 200 m resolution
- accuracy of 20-30%

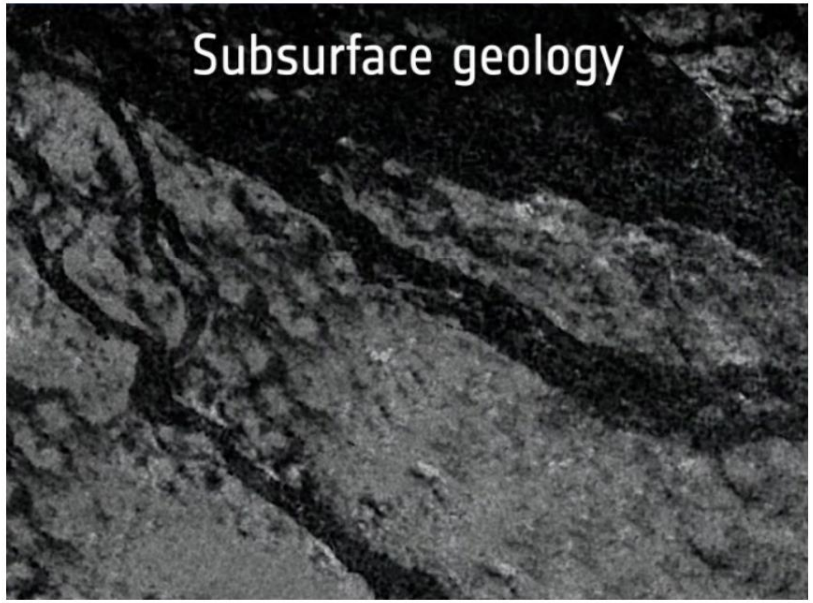
Disturbances

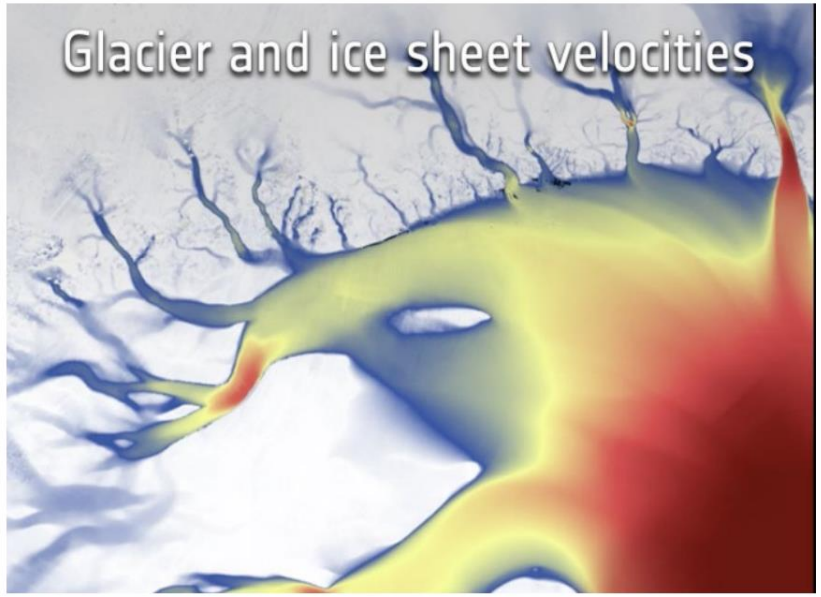
Areas of forest clearing (hectare)

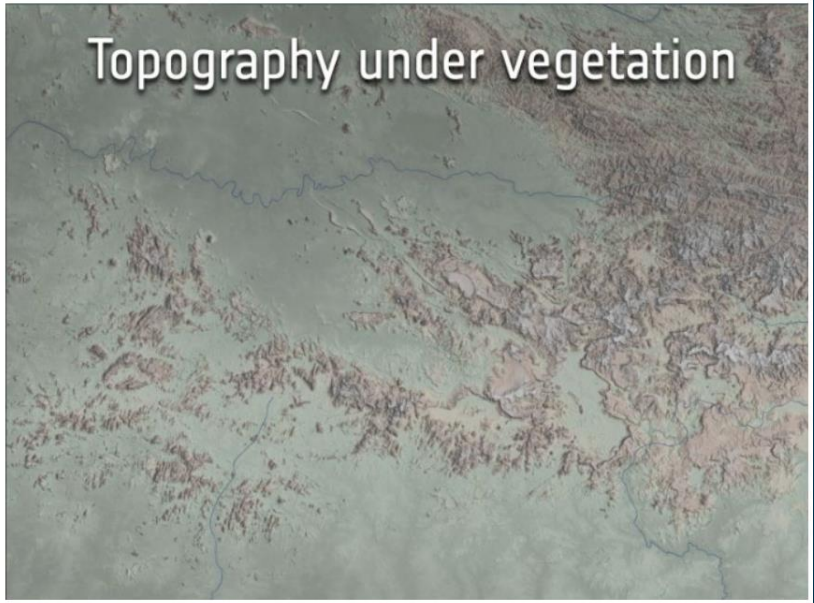
- 50 m resolution
- 90% classification accuracy

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

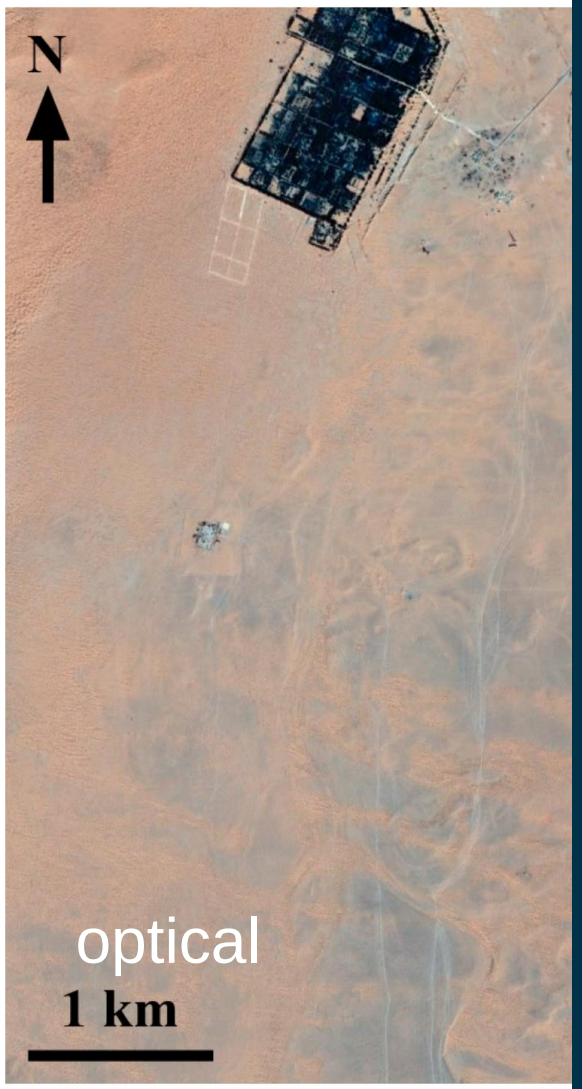
Secondary objectives

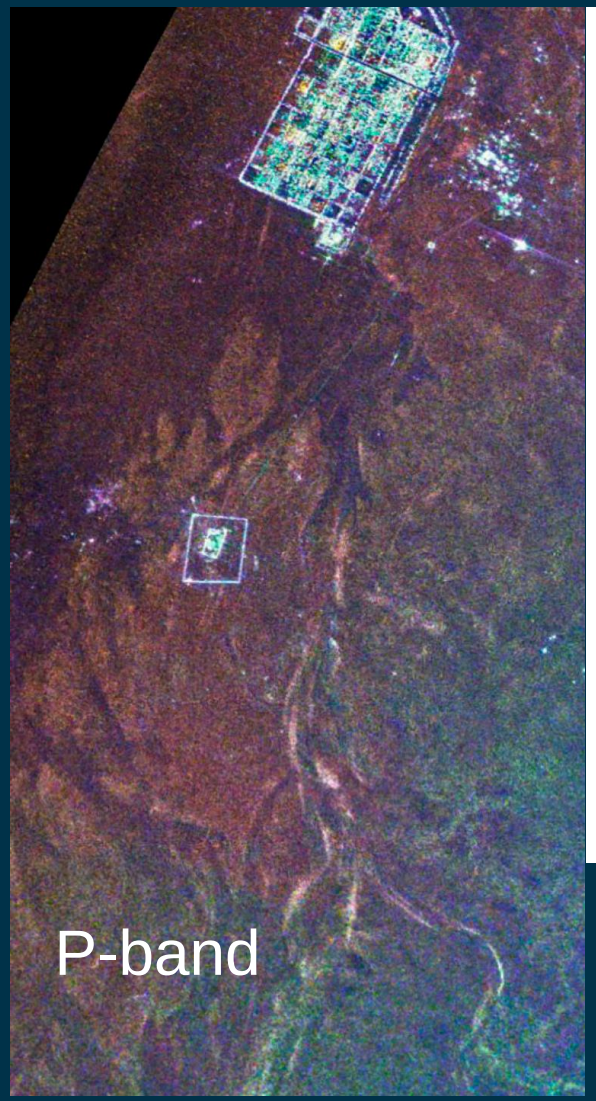






Some P-band interesting properties





Rémi Baqué, Philippe Dreuillet, Hélène Oriot. Sethi : Review Of 10 Years Of Development And Experimentation Of The Remote Sensing Platform. RADAR 2019, Sep 2019, TOULON, France.

Some P-band interesting penetration properties

OPTICAL

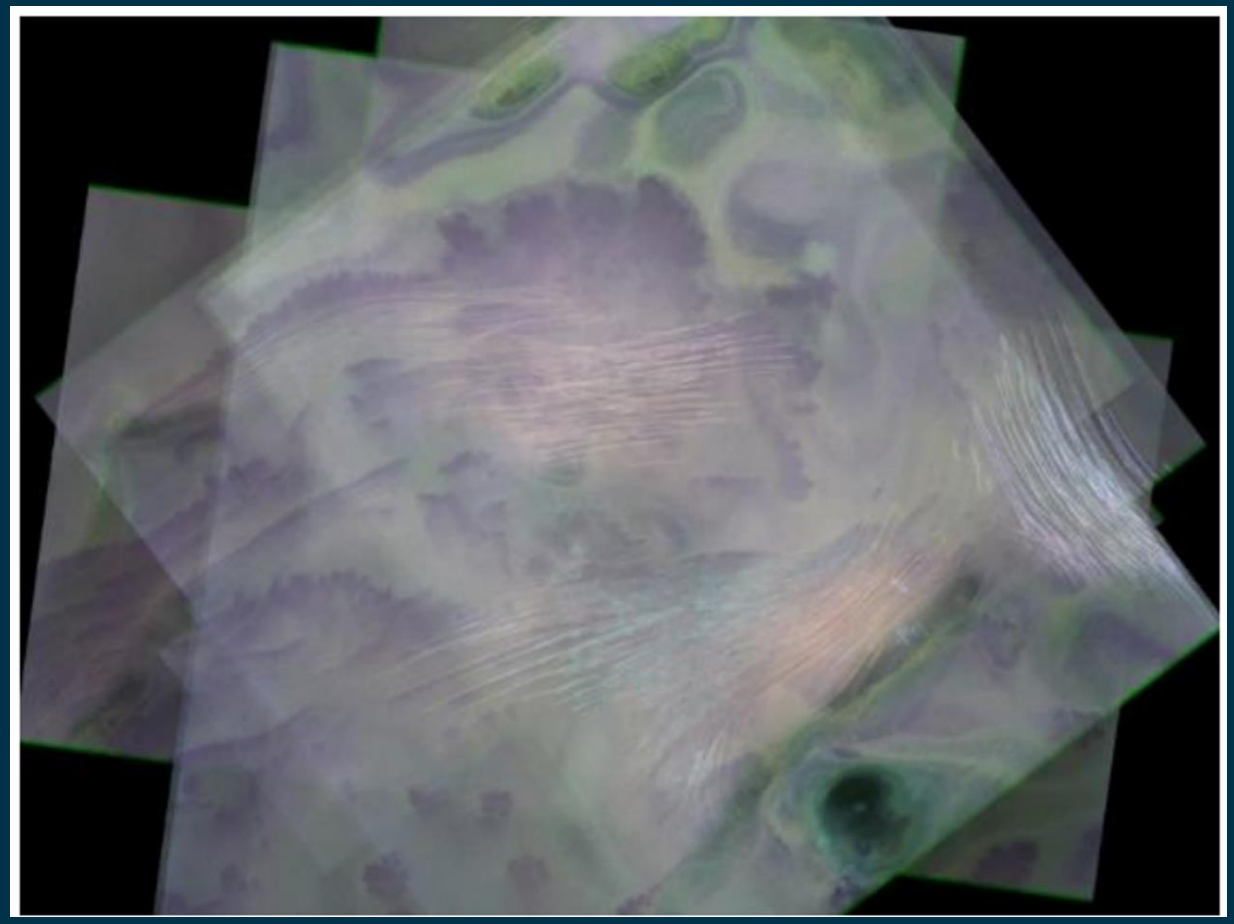
Cables hidden the sand below canopy (50 to 80 cm)

X-BAND wavelength ~ 3 cm

P-BAND wavelength ~ 70cm

R. Baqué, S. Angelliaume, P. Dubois-Femandez and O. R. du Plessis, "Ground penetrating capabilities of Airborne SAR System SETHI," *2021 18th European Radar Conference (EuRAD)*, 2022, pp. 9-12, doi: 10.23919/EuRAD50154.2022.9784476.

Some P-band interesting penetration properties



10k
m

At low radar frequencies, deep penetration in ice/snow → depends upon its state/properties

Take home messages about BIOMASS:

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...

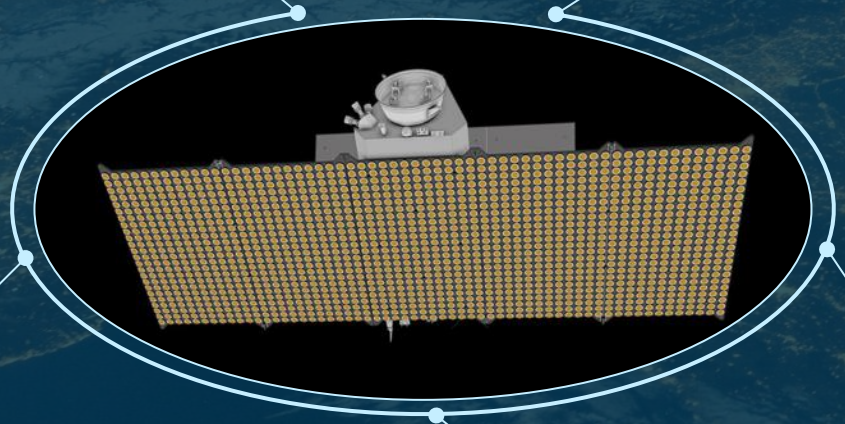
4. It is the **first Open-Source** Earth Explorer with BioPAL (algorithms), GEO-TREES (in-situ data) and MAAP (platform).

ROSE-L

ROSE-L Mission in Brief

GENERAL

- Constellation of 2 satellites (PFM & FM2) + options under study
- Consortium led by Thales Alenia Space Italy (TAS-I), involving 29 companies from 15 countries
- Service continuity with Sentinel-1 FG and NG



IMAGING

- L-Band – 85 MHz ITU allocated band (1.215-1.300 GHz)
- Dual-Pol and Quad-Pol modes
- Wave mode capability
- Resolution < 50 m2 (RIWS mode)
- NESZ < -28 dB
- DTAR < -23 dB
- Swath width > 250 km

COVERAGE

- Coverage of Global Land (excl. Antarctica) and Arctic
- Revisit with 2 satellites :
  - 6 days Global Land
  - 3 days Europe
  - 1 day Arctic
- Repeat cycle of 6 days over Global Land (2 satellites)

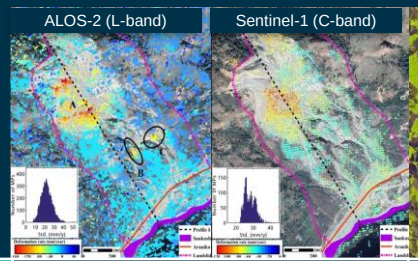
PROGRAMMATICS

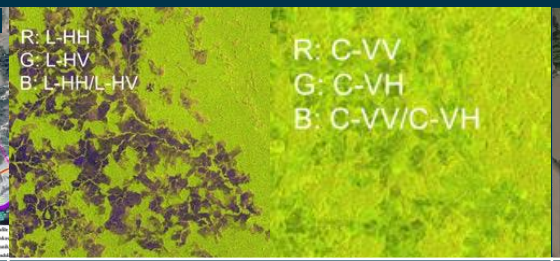
- Currently at the beginning of Phase C
- Science Plan activities start in 2023
- Launch of PFM expected in 2028
- FM2 delivery expected in 2030

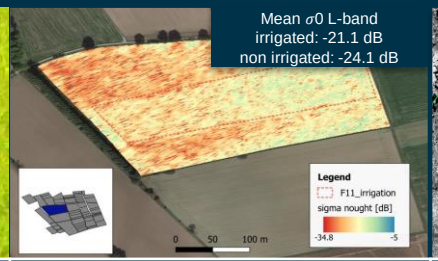
SYSTEM

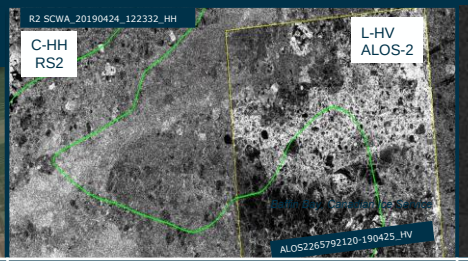
- Synergic acquisitions with Sentinel-1: co-located swaths and support to convoy configuration
- Low latency
  - 10 min Europe coastal waters
  - 200 min Global
- Companion friendliness for Single-Pass Interferometry

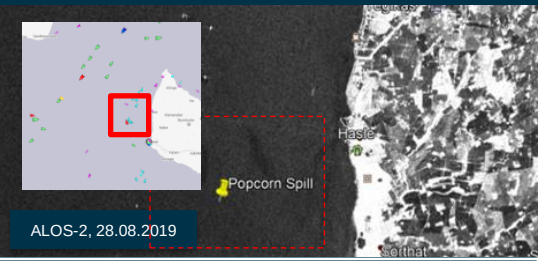
ROSE-L Applications









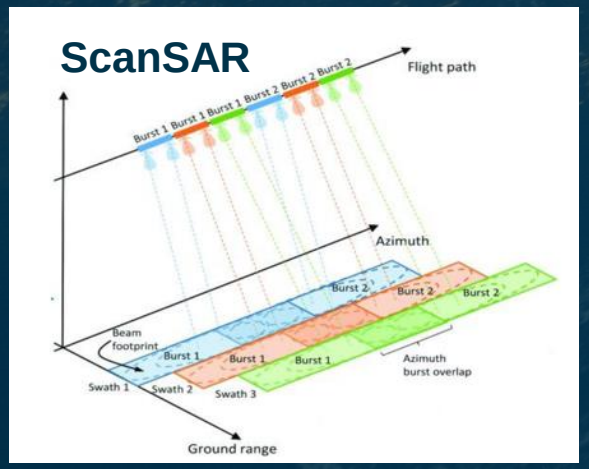


Application	Geohazards: Deformation, Landslides, Urban subsidence, Flooding	AFOLU: New timely information on AGB and biomes structure/type. L-band suitable to forests with AGB up to 100-150 Mg/ha, where it can sense the whole structure	Soil Moisture: High-resolution Soil Moisture tracking in a broad range of crops and vegetated land,	Cryosphere and the Arctic: Sea-ice, Ice sheets and Glacier velocity, Grounding Line, SWE, Permafrost thawing and extent	Marine and Maritime: Ocean surface wind vectors, Swell properties, Iceberg location, size and drift, Vessel location, size and velocity, Oil spill location and morphology
Complement to C-band	Improved coverage and motion information in vegetated and snow-covered areas, due the capability of sensing the ground Enhanced robustness to phase unwrapping in fast deformation scenarios due to longer wavelengths	Enhanced continuity on deforestation monitoring, including tropical forests due to sensitivity to changes/ losses (e.g. by logging) Improved LULC mapping in combination with Sentinel-1, complementary sensitivity	Soil Moisture up to ~5 cm depth complementing the Sentinel-1 SSM products (mainly suitable for bare soils and low vegetation areas, 1 cm depth)	Daily HR information on hazardous sea-ice and icebergs for navigation and weather/climate services Enhanced mapping of sea-ice type and concentration, due to L-band sensitivity to large ice structures (e.g. fractures and ridges) Improved mapping of sea-ice drift flying in close formation with S-1	Added value in vessel detection for maritime surveillance due to reduced sensitivity of sea backscatter at lower wind Improved detection of icebergs thanks to a better sensitivity of L-band to large ice structures Added value in extreme events (e.g. tropical cyclones) as high winds do not saturate the signal
Repeat pass	6 days repeat pass with two satellites	Revisit (6 days Global, 3 days Europe)	Revisit (6 days Global, 3 days Europe)	Revisit (1 day Arctic, 3 days Europe, 6 days Global)	Revisit (1 day Arctic, 3 days Europe, 6 days Global)
Resolution, NESZ	50 m2 Resolution for localized displacement	High resolution	High resolution Low noise level (NESZ, ambiguities)	High-resolution and wide swath Low noise level (NESZ, ambiguities)	High-resolution, wide swath Low latency for European waters (< 10 minutes) Low noise level (NESZ and ambiguities)
Acquisition scenario & latency	ASC and DESC acquisitions for EW motion Low latency for rapid mapping after event	Companion friendliness to support option for forest height retrieval	Integration (downscaling) with Scatterometers and L-band Radiometers for temporal revisit and accuracy	Simultaneous acquisitions with Sentinel-1 for sea ice mapping	Wave mode ATI capabilities (MAPS)

ROSE-L SAR Imaging and Systematic Acquisitions

As current baseline the instrument provides ***2 ScanSAR Wide Swath modes*** and a **Wave Mode** over open ocean

ROSE-L SAR Modes	**RIWS** ROSE-L Interferometric Wide Swath	**QWS** Quad-pol interferometric Wide Swath	**Wave Mode**
Polarization	Dual-Pol (HH-HV or VV-VH)	Quad-Pol (HH-HV-VH-VV)	Single-Pol
Incidence angle access	29 – 46 deg Full overlap with S1 IWS swath at all latitudes	Fixed swath within 20 – 45 deg (e.g. 25 – 42.3 deg)	Variable
Swath	260 km	260 km	20 x 20 km
Resolution	50 m^2	100 m^2	50 m^2
NESZ	< -28 dB	< -28 dB	< -28 dB
DTAR	< -23 dB	< -23 dB	< -23 dB



ROSE-L Sizing Requirements:

a) "Always on" over ***Europe***, ***Arctic***, ***coastal Antarctica*** and ***global Tectonic areas*** in dual or quad-pol SAR mode

b) Full coverage of ***remaining landmass*** (not included in a)) within *12-day* revisit time , i.e. *6-day* revisit time for entire *constellation* in dual or quad-pol SAR mode

c) Wave mode over ***Open Ocean***

ROSE-L ***continuous operations*** capability per sliding orbit time window:

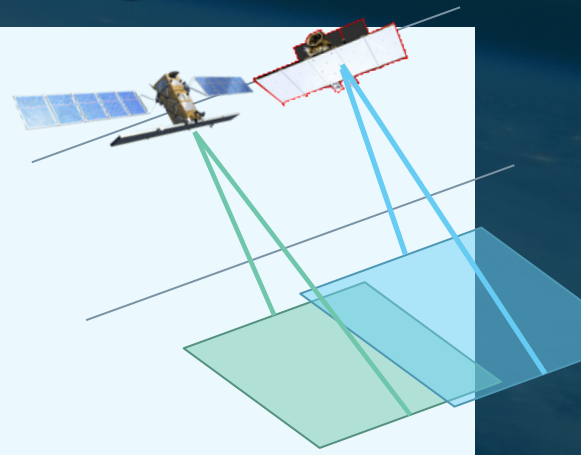
- 35 min in ***dual- pol SAR mode*** or
- 20 min in ***quad-pol SAR mode***, and
- for the remaining time in ***Wave Mode***

ROSE-L Mission Design Highlights and Constellation

ROSE-L will augment Sentinel-1 by means of a **synergic acquisition plan and mission design**

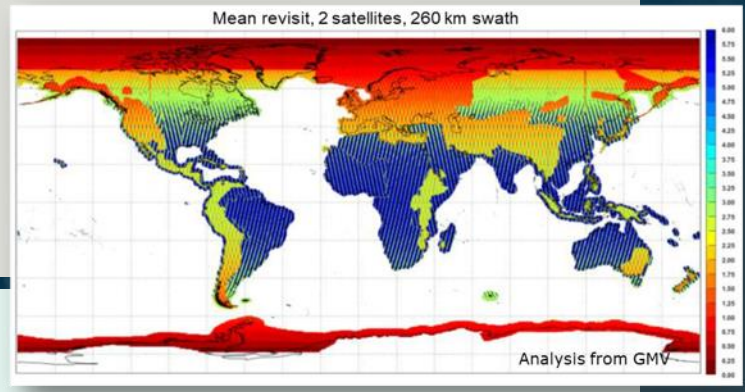
Collocation with Sentinel-1

- Same orbit configuration of Sentinel-1.
- Phasing of the orbital plane adjusted to follow the **same ground track of Sentinel-1**
- **RIWS mode guarantees full swath overlap with S1 IWS**
- Mission design supports options for: 1) different orbit phasing for optimized revisit
  2) convoy with Sentinel-1 (up to a minimum 1min baseline)



Extensive Global coverage and consistent long-term archive

- Coverage of Global land (except for South pole). **~ 38 min/orbit duty cycle**
- Consistent acquisitions through years for **long-term coherent data stacks**

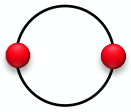


Free, full and open data policy

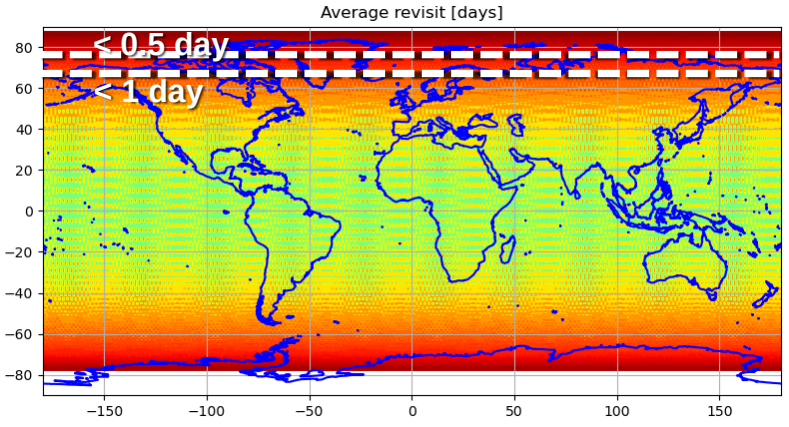
Moving towards a **System of Systems concept** and enhanced information products

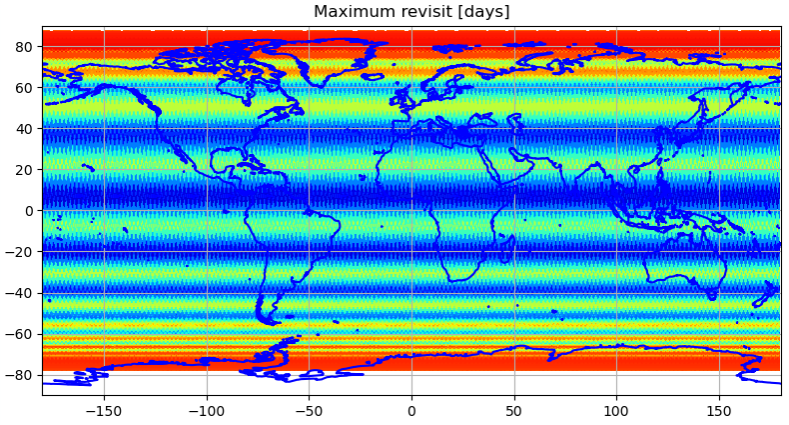
Joint Access Global (ROSE-L + S1FG/NG)

ROSE-L

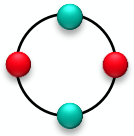


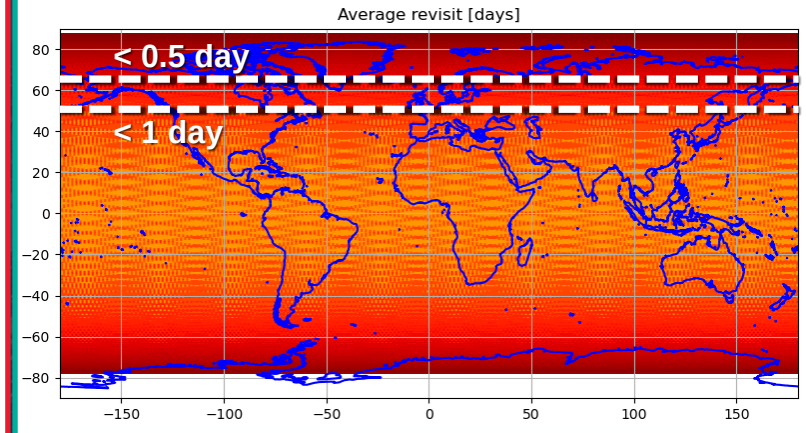
Phasing
3d - **9**d

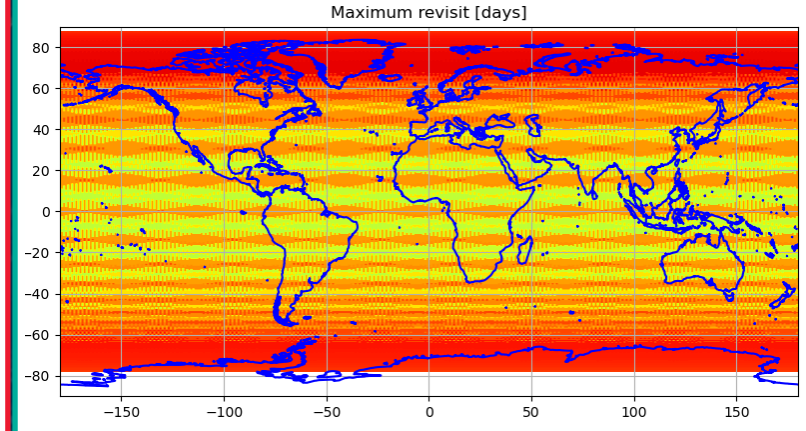




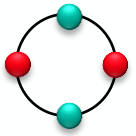
S1FG + ROSE-L

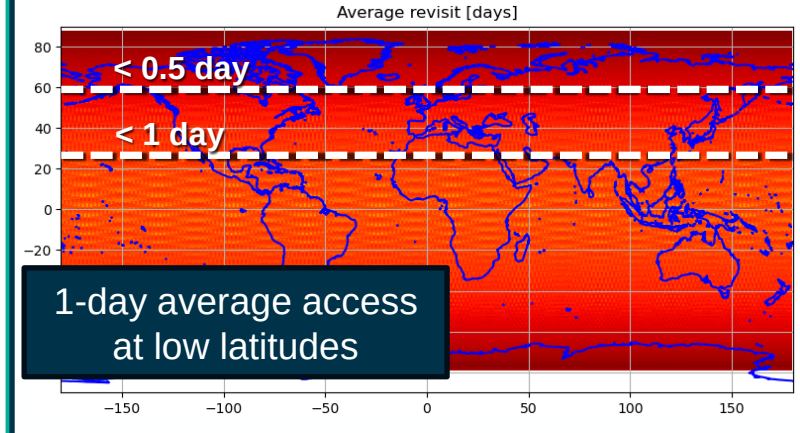


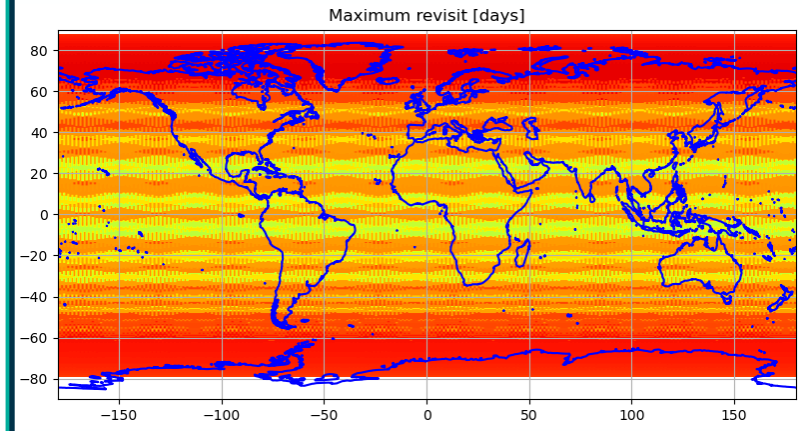




S1NG + ROSE-L







Take home messages about ROSE-L:

ESA with industry and together with EC preparing "expansion" of Copernicus SAR missions

- L-band SAR as a Copernicus Expansion mission *to address information gaps* and enhanced continuity

ROSE-L bring new and enhanced capabilities

- High resolution (50m2 for ROSE-L RIWS)
- Low NESZ and DTAR (-28 dB and -23 dB)
- Wide swath and frequent revisit capability

Sentinel-1, ROSE-L and Sentinel-1 NG shall be addressed as a system (not in isolation)

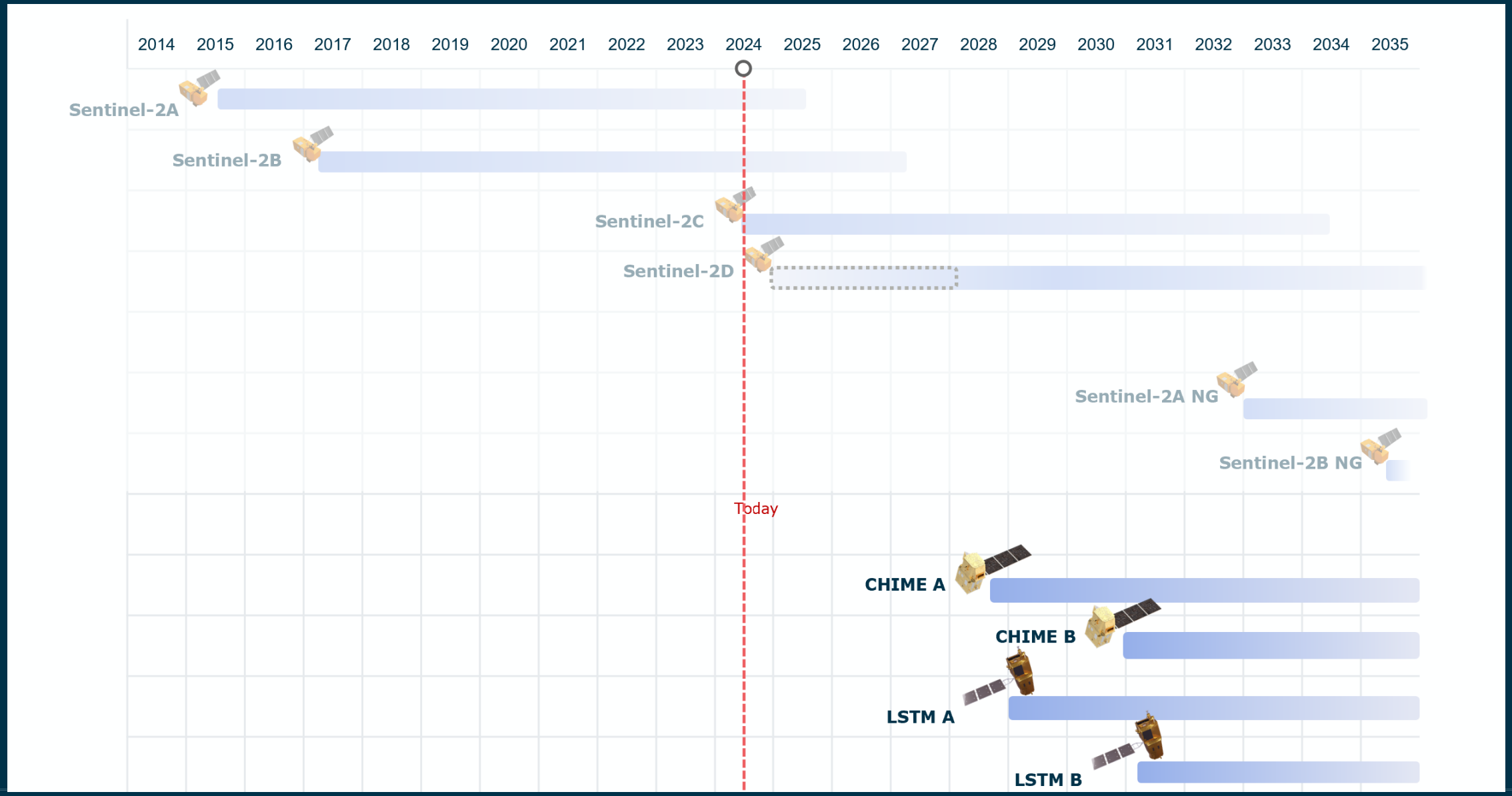
- ROSE-L same orbit, swath and acquisition geometry as Sentinel-1 (IWS) providing an operational dual-frequency system
- Synergies between C- and L-band expected to lead to enhanced and new information beyond what can be achieved for each mission taken in isolation
- Synergies with other missions such as Earth Explorer Biomass @P-band also need to be further investigated

Work still required to prepare for uptake of ROSE-L by user community (e.g. ionospheric and RFI correction, interferometric error budgets, C- and L-band synergies).

- Synergies and coordination with other space agencies (JAXA, NASA, CONAE) will be key.

LSTM : Land Surface Thermal Mission

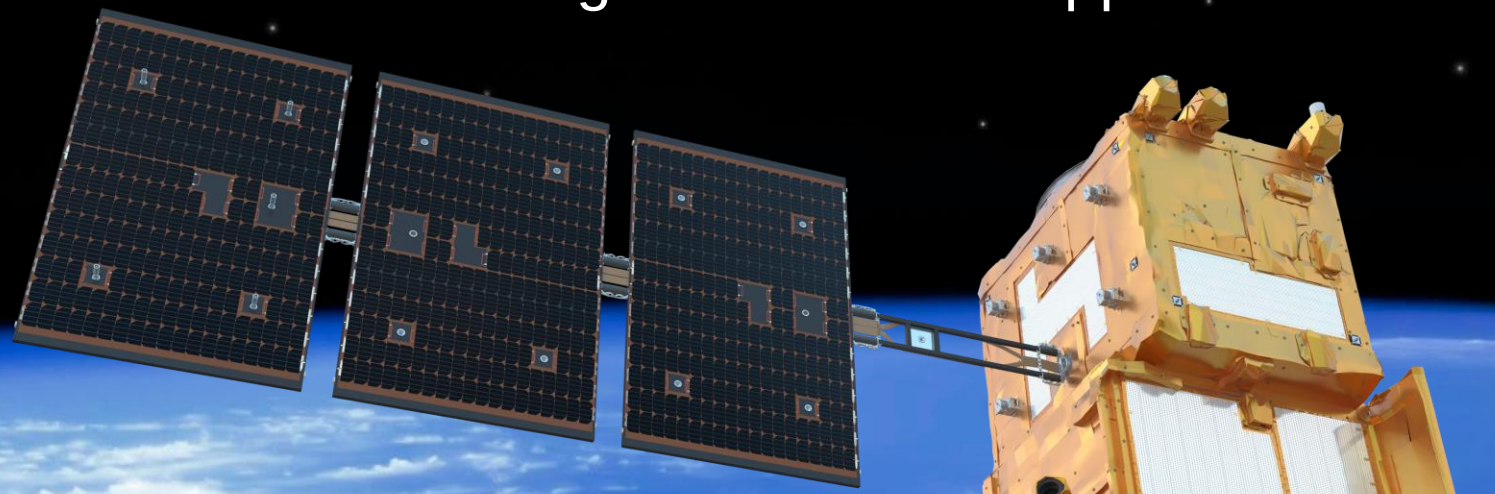
Schedule Overview



LSTM Mission Objective

LSTM Mission Objective:

Provide high spatio-temporal resolution Thermal Infra-Red observations over land and coastal regions ***in support of agriculture management services***,
and a range of additional applications



Copernicus
Europe's eyes on Earth

LSTM Mission Key Features & Requirements

Key requirement*	
Geometrical revisit	2 days/2 satellites
Local time	13:00 (Europe) & night observations
SSD	50 m (37m at nadir)
Spectral Bands	5 TIR, 4 VNIR, 2 SWIR
Nominal swath	687 km, at 651 km altitude
Acquisition system	Whiskbroom scanner
Geo-location L1c	0.5 SSD (GCP) / 1 SSD (without GCP)
MTF	0.2-0.3
Data latency (L2)	6-12 hours
NeDT	< 0.15 K
ARA	< 0.5 K

User requirement**
Evapotranspiration (goal)

- Accuracy 15% [mm/day]
- Precision 5%
- Field scale [0.5 ha]
- Daily observations

LST observations**

- 50 meters resolution
- 1-3 days revisit
- 1-1.5 K LST accuracy

* Copernicus LSTM Phase B2/C/D/E1 System Requirements Document
**Mission Requirement Document V3
https://www.esa.int/Applications/Observing_the_Earth/Copernicus/Copernicus_Sentinel_Expansion_missions

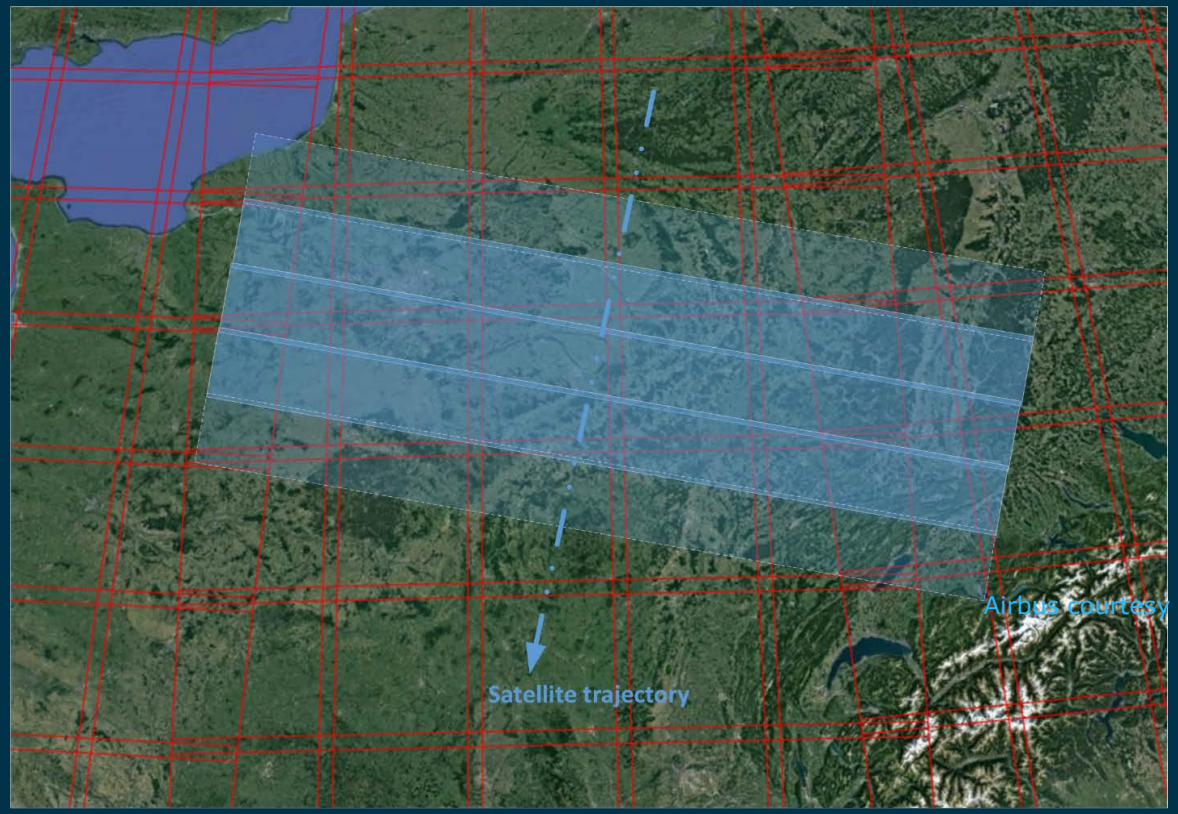
LSTM Data Products & Latency

The LSTM Level-1c products:

- Radiometrically & geometrically calibrated TOA radiance
- Top of atmosphere brightness temperature

The LSTM Level-2a products:

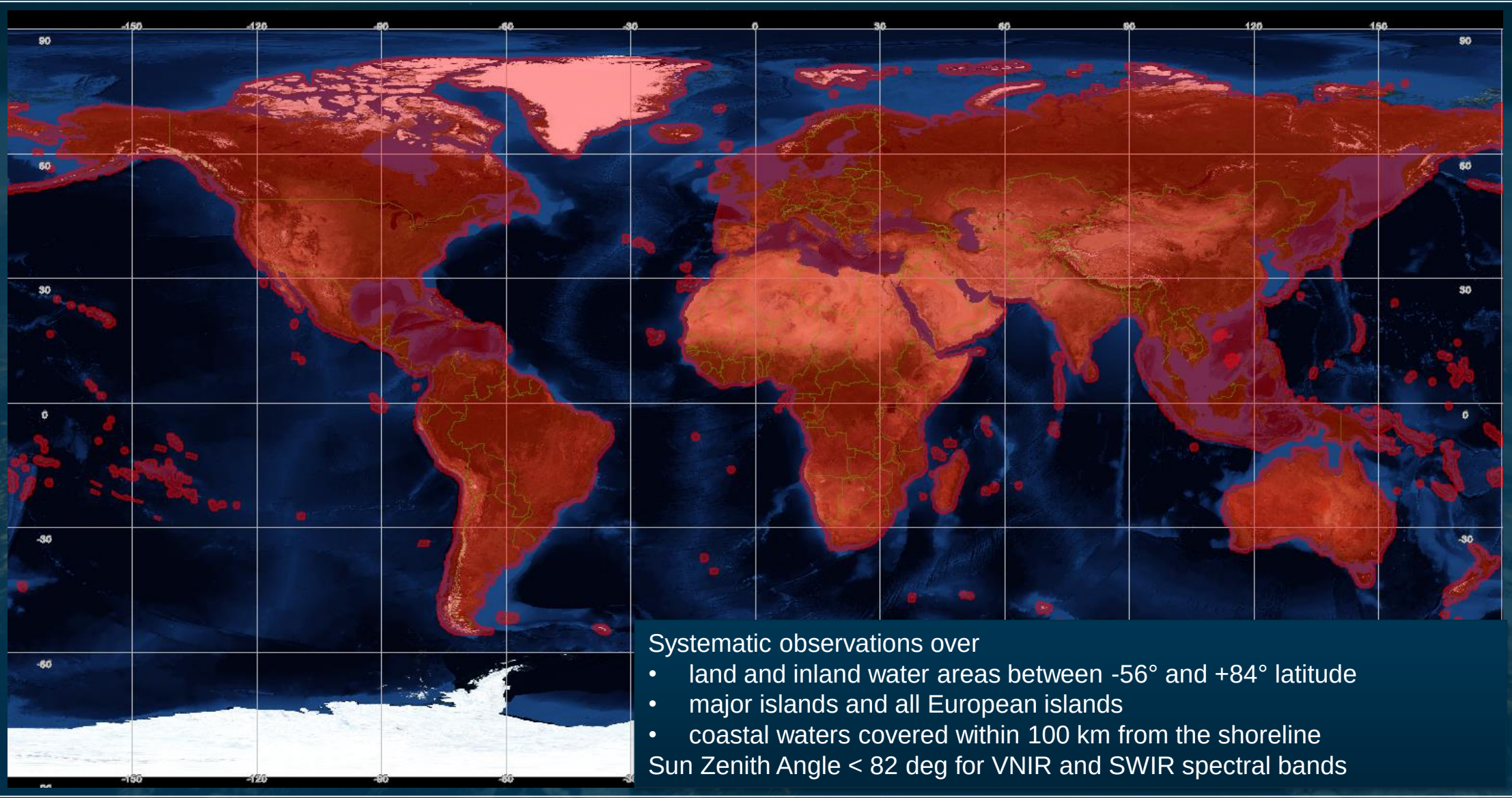
- Land Surface Temperature
- Land Surface Emissivity per TIR spectral band
- Bottom of atmosphere surface reflectance
- Total Column of Water Vapor (intermediate product required for LST retrieval)
- Cloud mask (intermediate product provided as a quality flag)



Maximum Data Latency

- Level-1c: 3 hours (goal) & 6 hours (threshold), highest priority over Europe and Africa.
- Level-2a (LST): 6 hours to 12 hours (TBC), highest priority over Europe and Africa.

LSTM Acquisition Mask



Systematic observations over

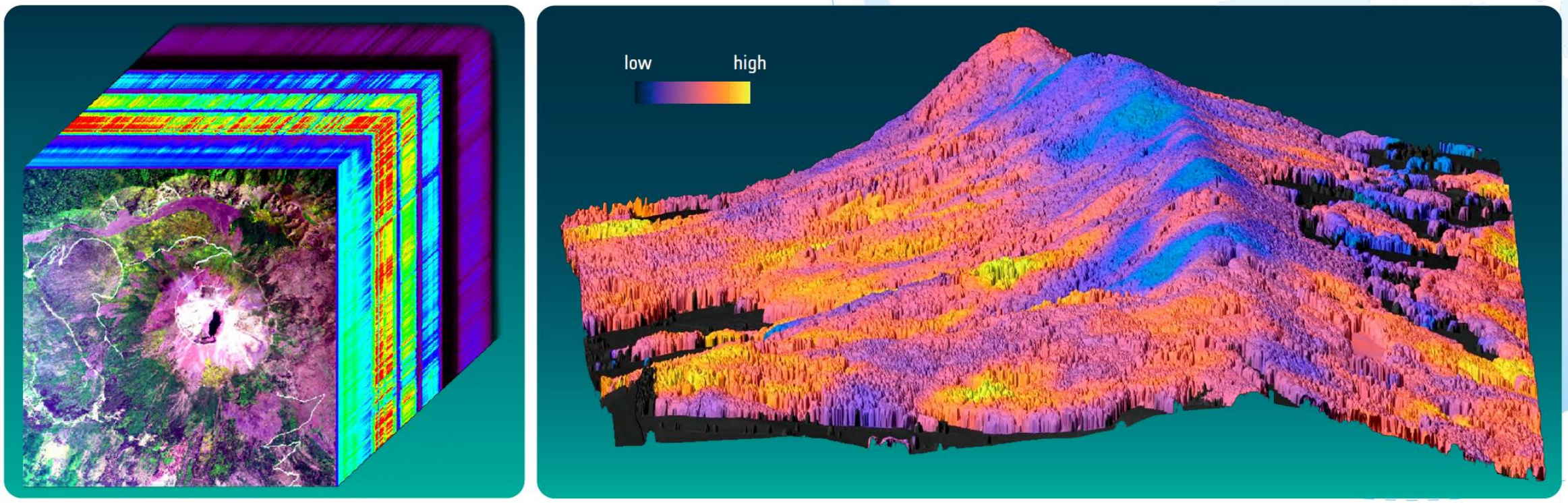
- land and inland water areas between -56° and +84° latitude
- major islands and all European islands
- coastal waters covered within 100 km from the shoreline

Sun Zenith Angle < 82 deg for VNIR and SWIR spectral bands

CHIME : Copernicus Hyperspectral Imaging Mission for the Environment

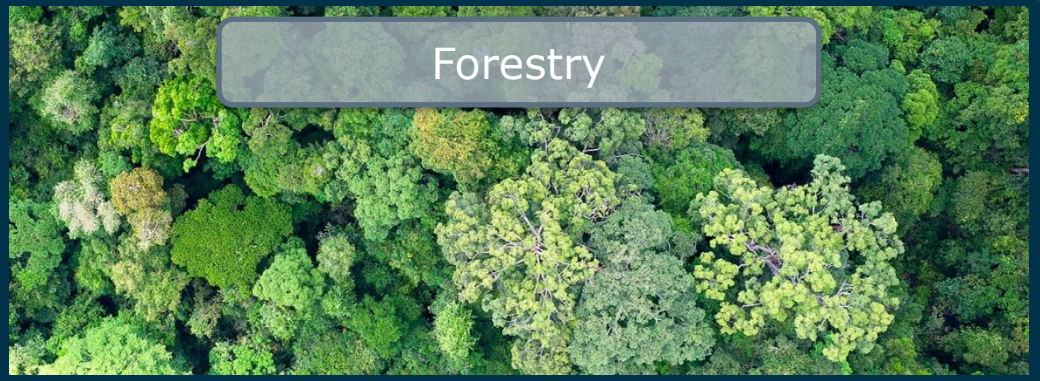
CHIME Mission Objectives

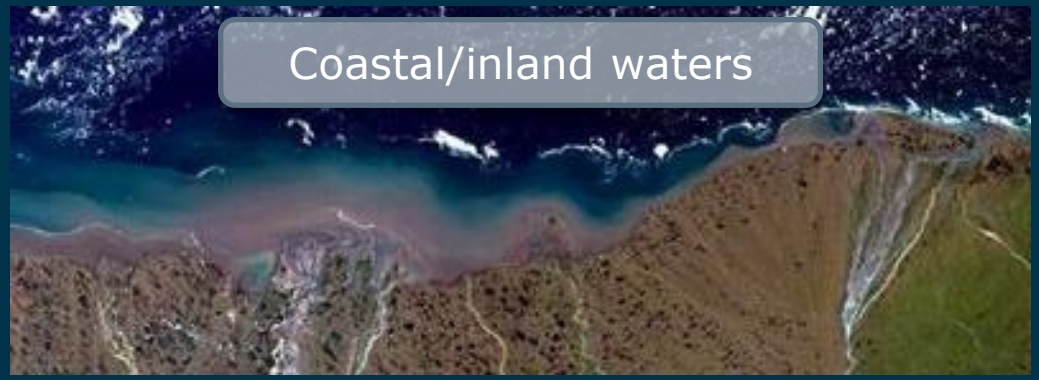
- Provide routine hyperspectral measurements in support of EU- and related policies for the management of natural resources & assets
- Support food security, agriculture and raw materials, soil properties
- Secondary Applications: biodiversity and ecosystem sustainability, forestry management, environmental degradation, lake/coastal ecosystems and water quality, snow grain size/albedo, snow impurities)

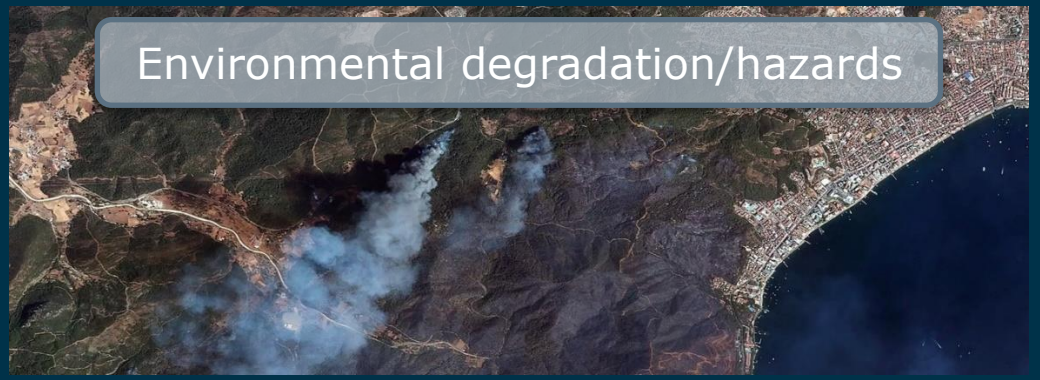


Physiological diversity of a temperate forest (Airborne imaging spectroscopy APEX data - Schaepman, Jehle et al. 2015)

Not forgotten: secondary applications!



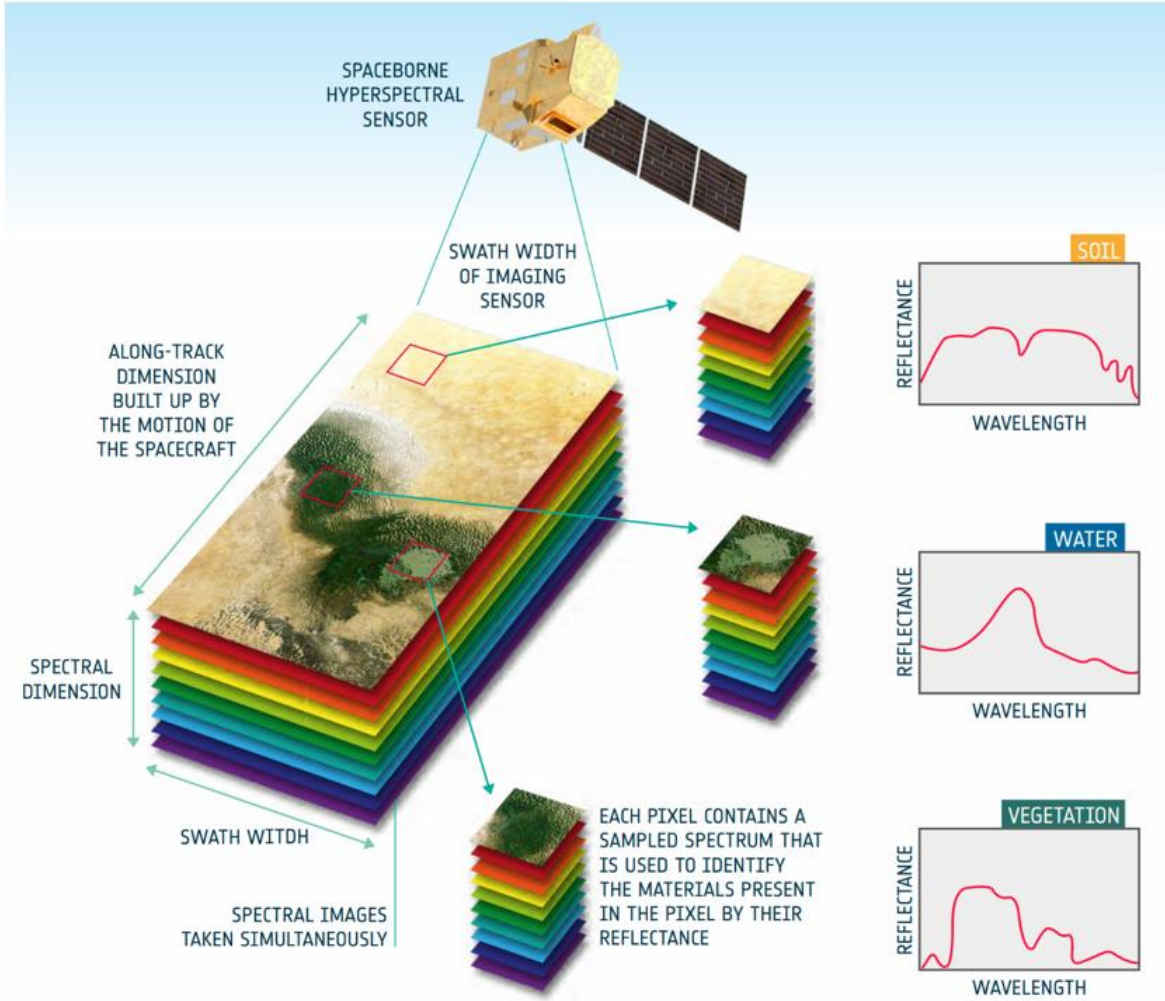




CHIME Overview

Operational hyperspectral observations of land and coastal areas

- **Spectral range**: 400 – 2500 nm
- **Spectral bandwidth** ≤ 10nm
- **SSD** (Spatial Sampling Distance): 30 m
- **Swath**: ~130 km
- **Revisit**: 12.5 days (2 satellites)
- High radiometric accuracy, low spectral/spatial mis-registration
- High SNR matching performance of similar missions (e.g. EnMAP, PRISMA, SBG)



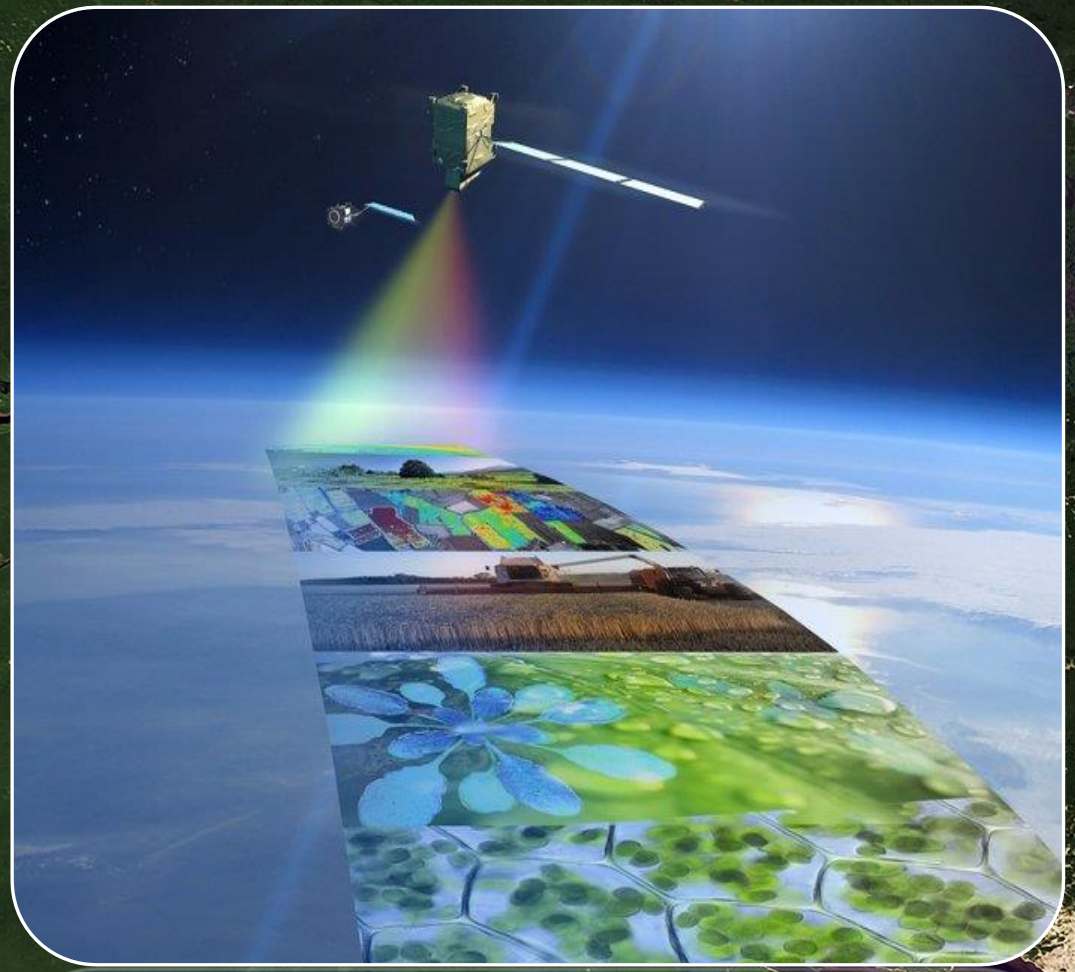
CHIME Overview

DOMAIN	THEMATIC AREA	VARIABLES CHPPP	CHIME Candidate Algorithms
AGRICULTURE / FOOD SECURITY	 Assessment of biophysical and biochemical variables related to the crops and of agronomic interest	Leaf/Canopy Pigment Content	Semi-empirical modelling based on narrow-band vegetation indices; Hybrid methods based on ANN/LUT or other machine learning algorithms applied to vegetation canopy radiative transfer models outputs (e.g. PROSAIL).
		Leaf/Canopy Nitrogen Content	Narrow-band vegetation indices; Hybrid methods based on ANN/LUT or other machine learning algorithms e.g. GPR methods applied to vegetation canopy reflectance models (e.g. PROSAIL).
		LAI	
		Canopy Water Content	
		Leaf/Canopy Pigment Content	
		Leaf Mass/Area	
	 Topsoil properties	Soil organic carbon content	Chemometrics modelling (e.g. PLSR); Spectral analysis; Spectral indices; Machine learning (e.g. Random Forest)
		Soil texture (clay, silt, sand)	
GEOLOGY & MINERALS	 Raw material detection	Mineral identification and abundances (Kaolinite, Smectite, Jarrosite, Dolomite)	Sub-pixel linear unmixing
		Hematite-goethite ratio	
		Ferric oxide contents	
		Kaolin Cristallinity	

FLEX

FLEX

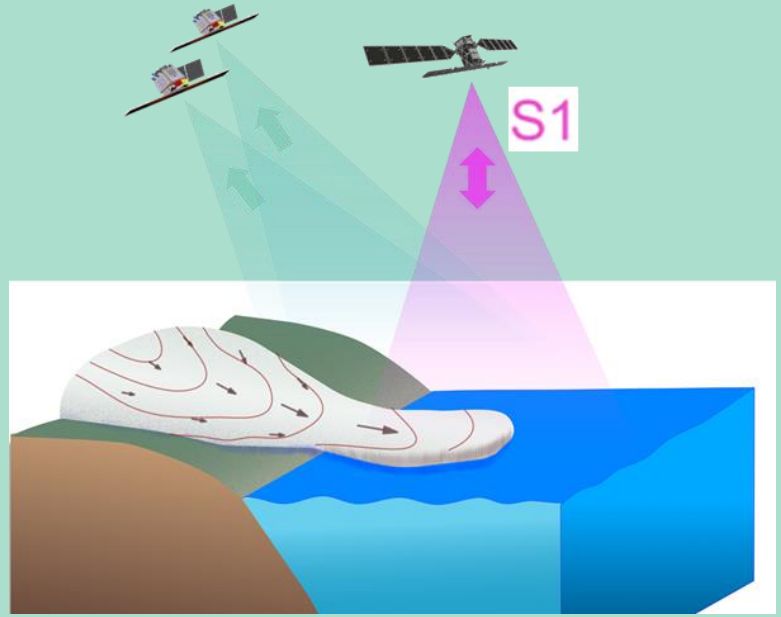
Mission	Study & monitoring of fluorescence signal linked to vegetation stress; pixel 300m.
Swath	150 km
Payload	FLORIS, 2 channels spectrometers (O_2 lines)
Orbit	SSO Alt: 814 km; LTDN: 10h00
Satellite	470 Kg
Consortium	Prime: TAS Instrument: Leonardo
Launch date	2025
Lifetime	3.5 years



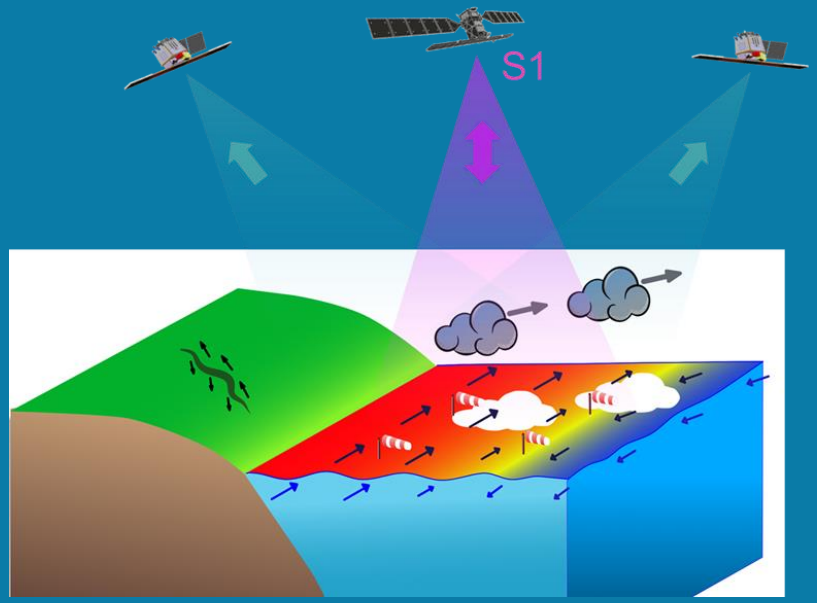

esa
harmony
TO RESOLVE STRESS
IN THE EARTH SYSTEM
ESA's dynamic surfaces mission

Harmony in a nutshell

Harmony is ESA's Earth Explorer 10 mission, comprised of two companion satellites in a loose convoy with Sentinel-1D (along-track separation ~350 km)
Its payload suite consists of a passive SAR and a multi-view TIR instrument



Cross-track Interferometric phase covering land applications like glaciers, permafrost, volcanoes.



Stereo phase covering 3-D surface deformation ocean applications: surface motion, surface winds, sea surface temperature, cloud motion.

Year 1 | Year 2 | Year 3 | Year 4 | Year 5

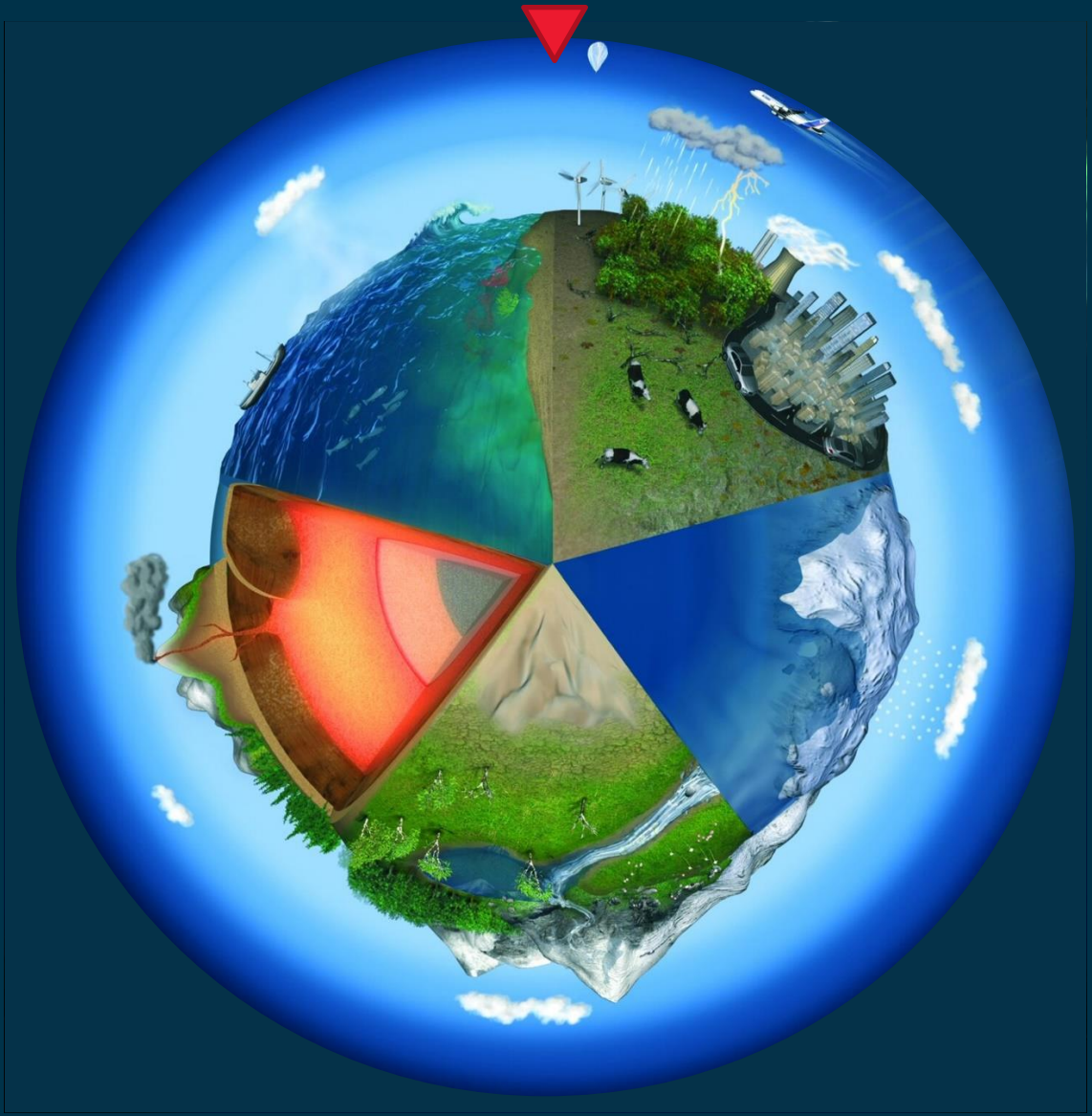
Harmony – a multi-domain “Earth System” mission

Upper oceans and ocean-atmosphere interactions

Land ice and sea ice

Tectonic strain and volcanic processes

Bringing Harmony to a dynamic world



Harmony will resolve (sub) kilometer scale motion vectors and topography changes associated to dynamic Earth System processes:

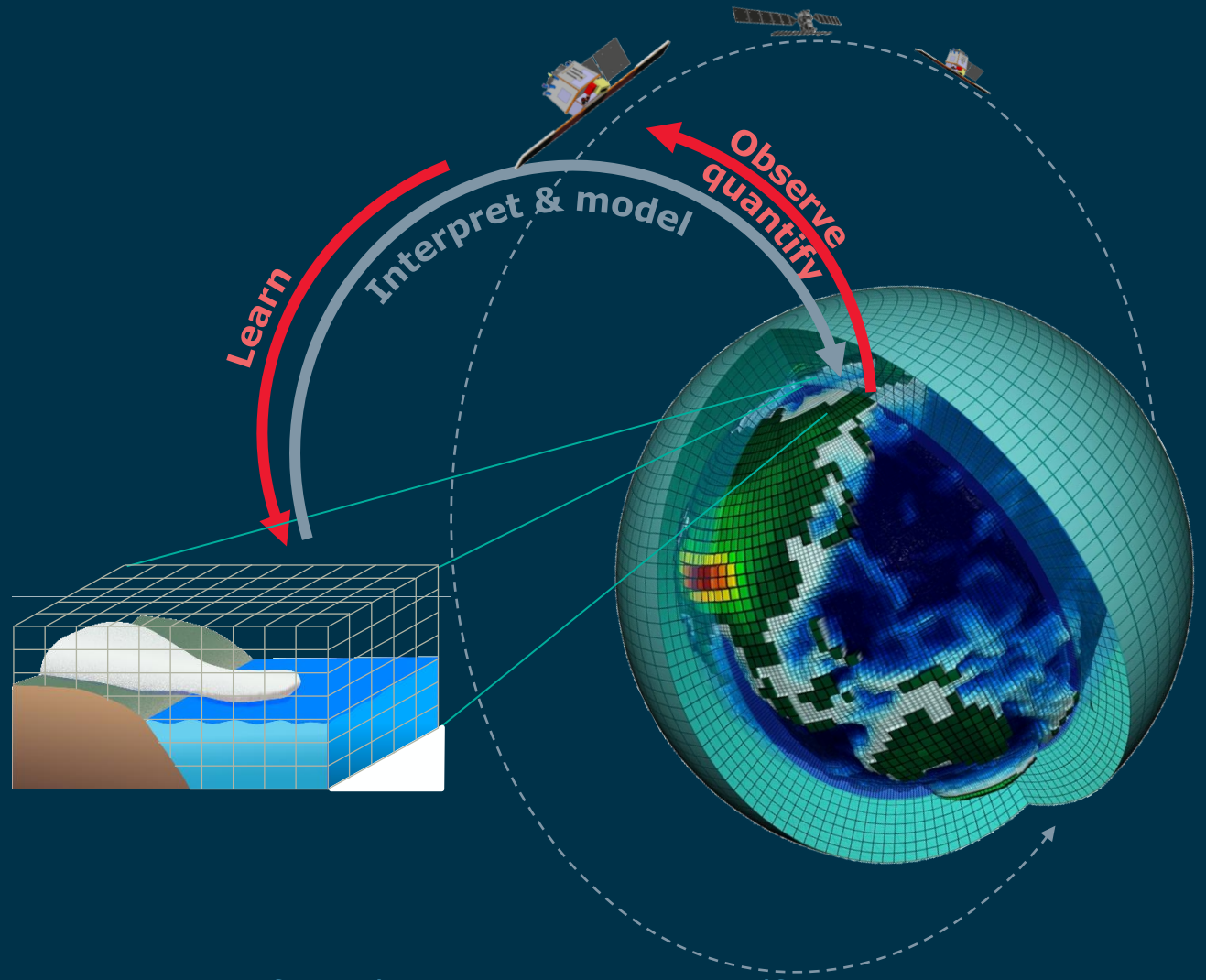
- heat, gas and momentum exchanges at the air-sea interface;
- the inner structure of ocean-atmosphere extremes;
- gradual and dynamic volume changes of global mountain and polar glaciers;
- instantaneous sea-ice motions to characterise sea-ice dynamics;
- 3-D deformation vectors associated to tectonic strain;
- topographic change at active volcanoes worldwide.

Contributing to data-driven Earth System Modeling

Earth System is highly non-linear → complex couplings and feedbacks between processes at different scales.

Unresolved O(≲ 1km) processes and couplings in Earth System Models represent major contribution to model uncertainties.

Harmony is set to provide observations needed to develop/train/validate next generations of fully coupled Earth System Models.



https://esamultimedia.esa.int/docs/EarthObservation/EE10_Harmony_Report-for-Selection_21June2022.pdf

GENERAL CONCLUSIONS ON ESA EO MISSIONS

- ESA's Earth Explorer and Copernicus missions play a crucial role in understanding and monitoring the Earth environment and climate

- **Unique contributions of each Mission type:**
  → **Earth Explorer Missions:** Pioneering scientific understanding of specific environmental processes
  → **Copernicus Program:** Ensuring continuous, large-scale monitoring for practical applications and policy support

- **The EO missions needs to be addressed also in Synergy to derive new applications and value added products (Forestry)**

Radar system of system			Optical/TIR system of system		
BIOMASS	S1	ROSE-L	S2	LSTM	CHIME