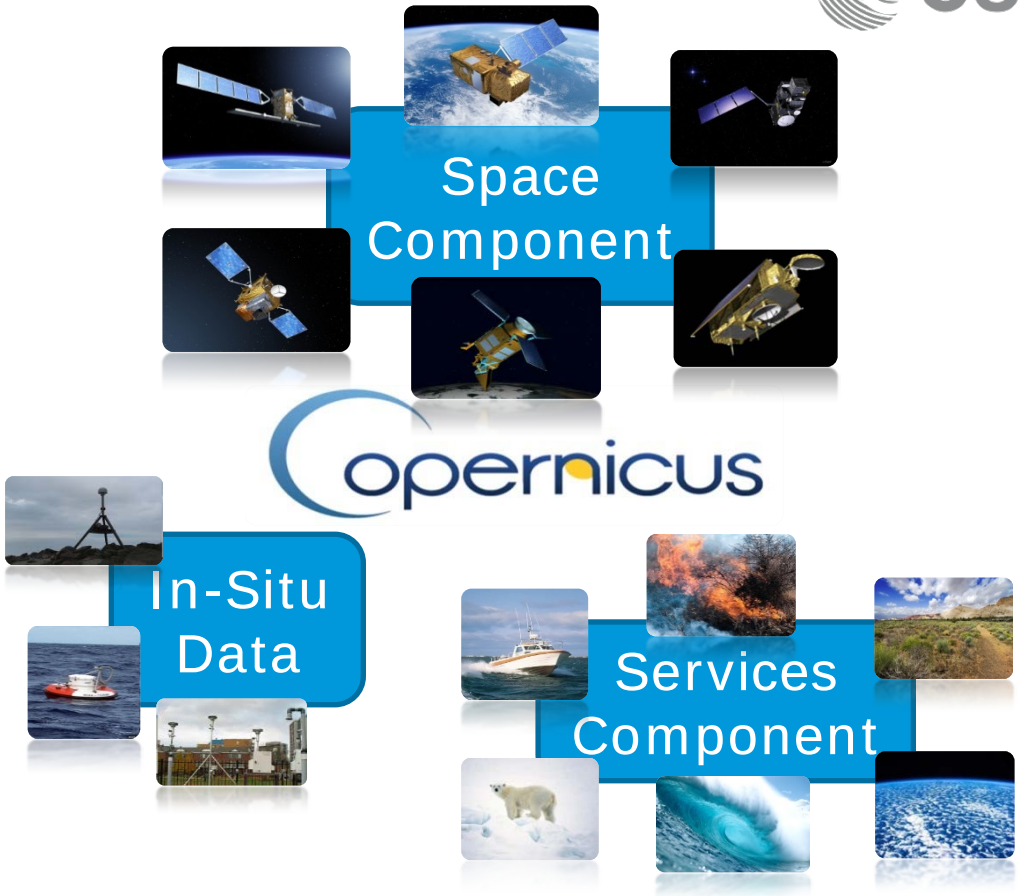
THE COPERNICUS PROGRAMME

ESA Copernicus Space Office

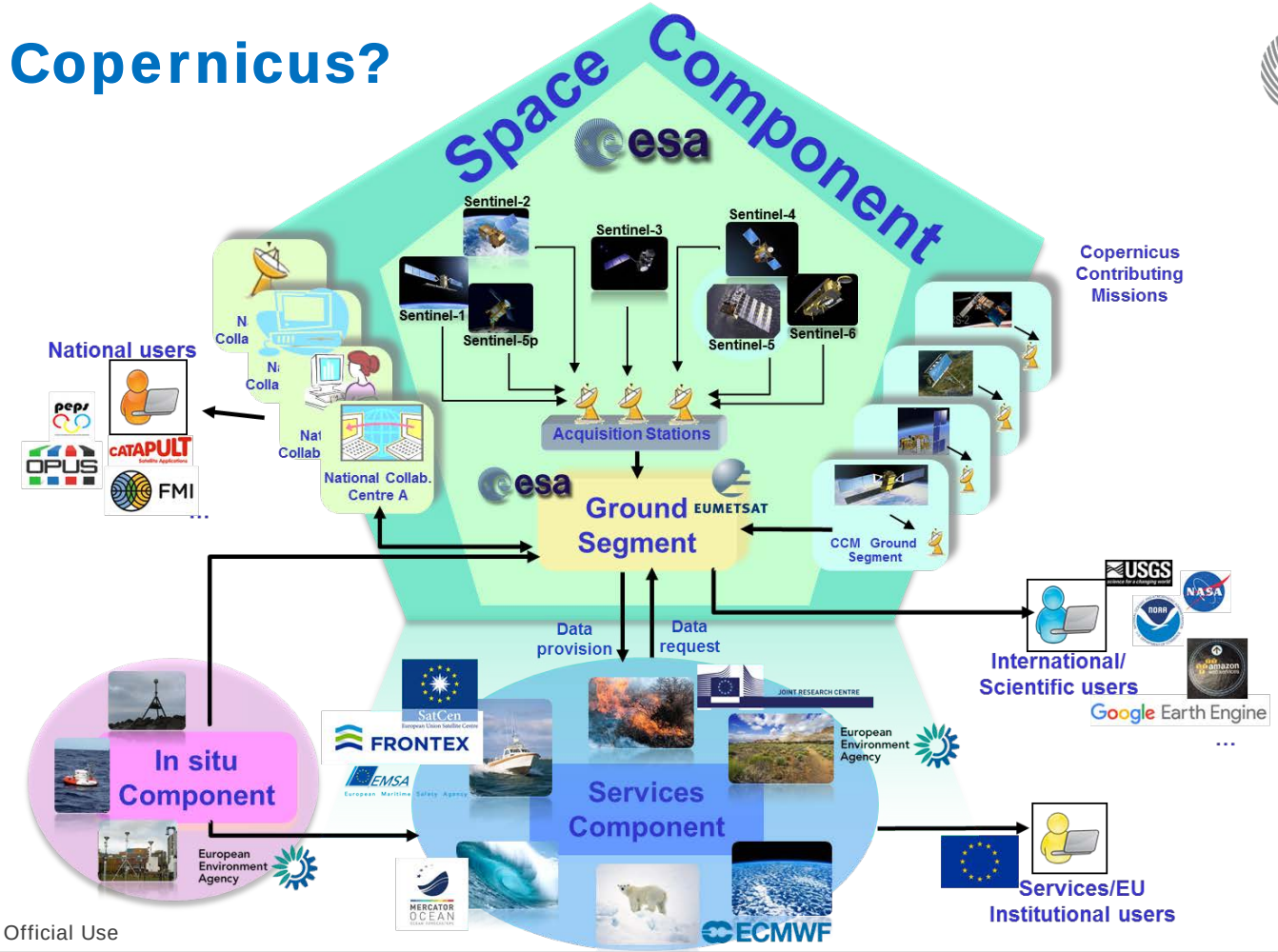
What is Copernicus?

European response to global needs:

- to manage the environment,
- to mitigate the effects of climate change and
- to ensure civil security



What is Copernicus?



GMES / Copernicus Key Milestones

2014+	First Sentinel satellites launched
2014	EU-ESA Copernicus Agreement for 2014-2020
2014	Revision of the ESA GSC Declaration
2014	EU Regulation of the Copernicus programme
2013	EU Delegated Regulation for Copernicus data access
2010	Commission proposal for a Regulation on GMES initial operations (2011-2013)
2008	ESA Ministerial Council in The Hague provided next major funding contribution by ESA Member States; Signature of EU-ESA Delegation Agreement on GMES
2005	ESA Ministerial Council in Berlin: first funds committed to the CSC
2001	ESA Ministerial Council in Edinburgh: first Copernicus services funded
1998	Initiation of Copernicus: ‘Baveno Manifesto’

Copernicus Components & Competences

Overall Programme Coordination:

European Commission

Space Component

Coordinators: esa

Partners:

- Industries
- Private companies
- National Space Agencies
- EUMETSAT

Services Component

European Commission

Service operators:

- EMCWF
- Mercator Océan
- EEA
- JRC
- SatCen
- EMSA and FRONTEX

In-situ data are supporting the Space and Services Components

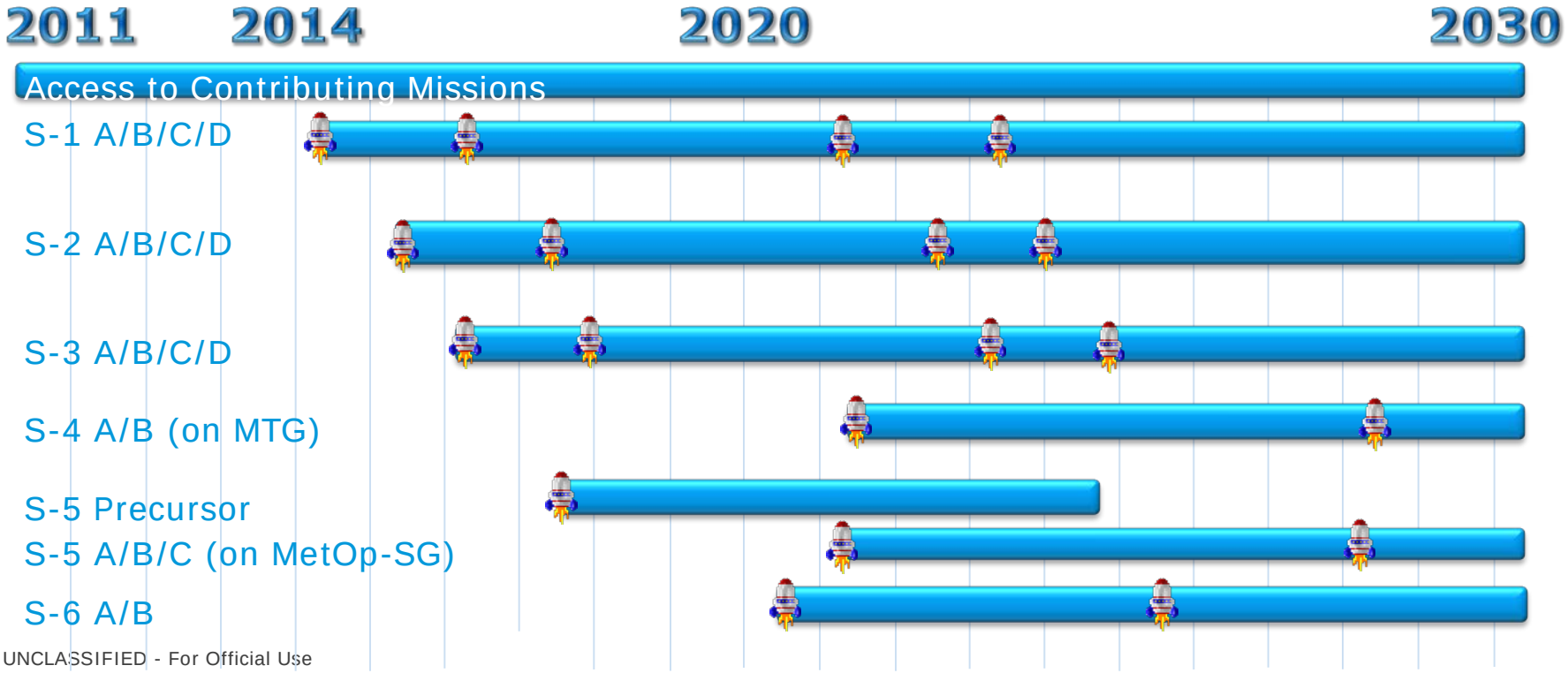
Copernicus Space Component: Role of ESA

- **Coordinator of overall Copernicus Space Component**
  - Definition of overall architecture and plan for future evolutions
  - Coordinating access to Copernicus missions from national, EUMETSAT and third party satellite owners
- **Development and procurement Agency for dedicated space infrastructure**
  - Development of first spacecraft and Ground Segment
  - Procurement of recurrent elements
- **Operator of Sentinel-1, Sentinel-2, Sentinel-3 (land) and Sentinel-5 precursor**
  - EUMETSAT is operator of Sentinel-3 (marine), Sentinel-4, Sentinel-5 and Sentinel-6

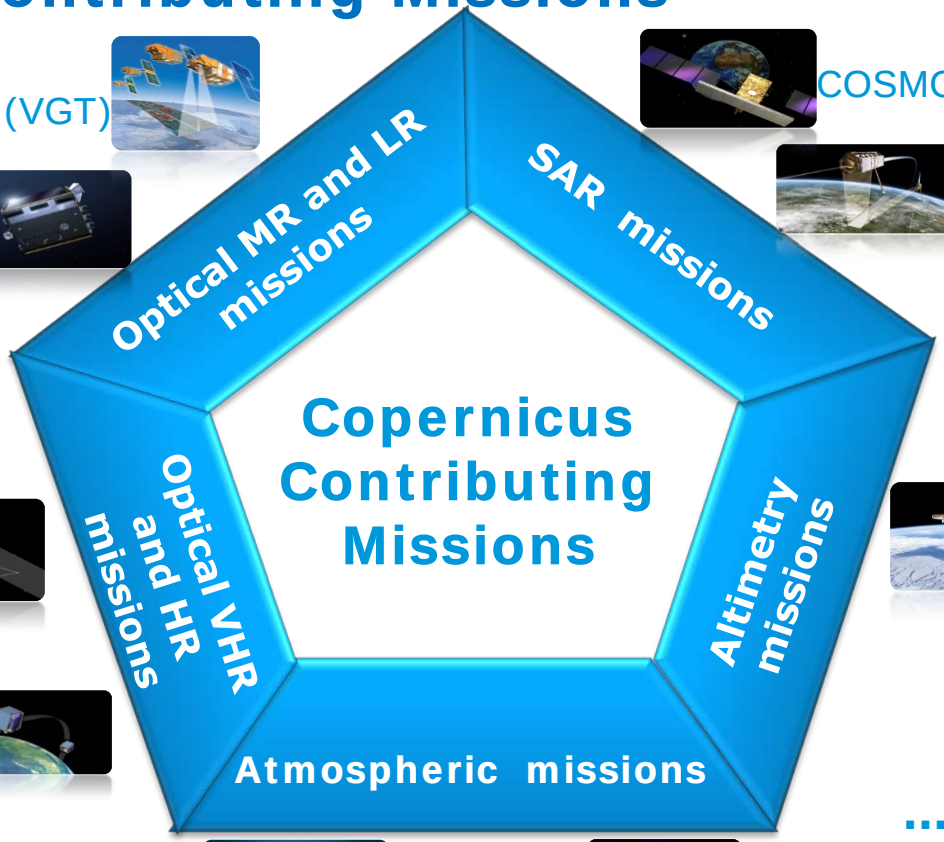
Copernicus Space Component: the dedicated Sentinels …

S1A/B: Radar Mission	3 Apr 2014/25 Apr 2016
S2A/B: High Resolution Optical Mission	23 June 2015/7 March 2017
S3A/B: Medium Resolution Imaging and Altimetry Mission	16 Feb 2016/2017
S4A/B: Geostationary Atmospheric Chemistry Mission	2021/2027
S5P: Low Earth Orbit Atmospheric Chemistry Mission	2017
S5A/B/C: Low Earth Orbit Atmospheric Chemistry Mission	2021/2027
S6A/B: Altimetry Mission	2020/2025

… with a long-term operational perspective



Copernicus Contributing Missions



SPOT (VGT)

PROBA-V

DMC

Pléiades

Deimos-2

RapidEye

SPOT (HRS)

COSMO-Skymed

TerraSAR–X

Tandem-X

Radarsat

Cryosat

Jason

MetOp

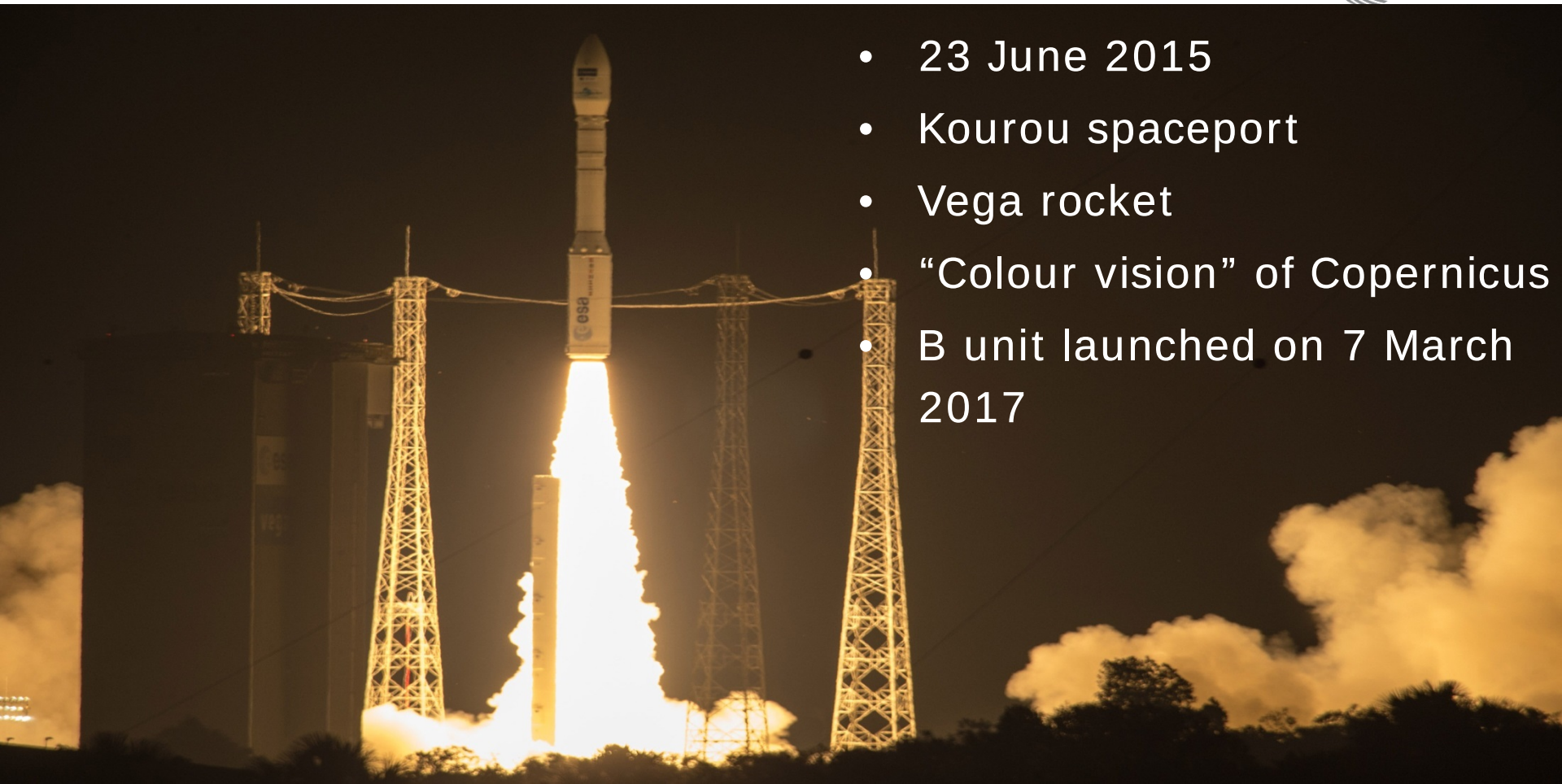
Meteosat 2nd Generation

... and many more!

Launch Sentinel-1A

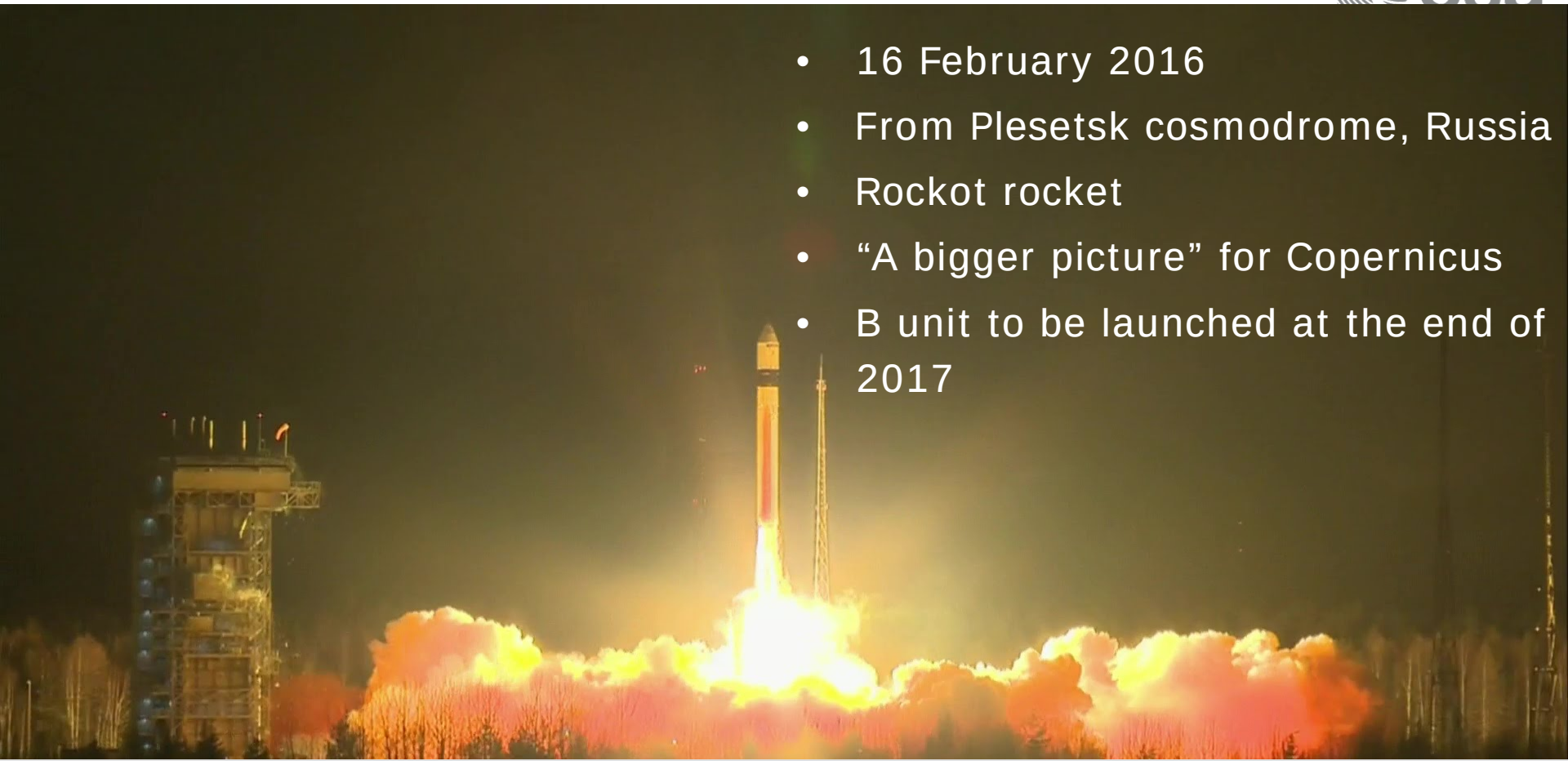
- 3 April 2014
- Kourou spaceport
- Soyuz-2 rocket
- New era of Earth observation
- B unit launched on 25 April 2016

Launch Sentinel-2 A



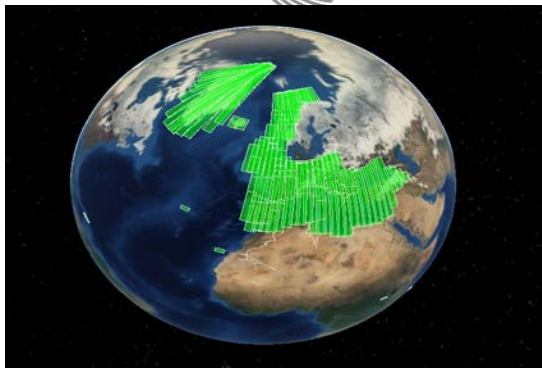
- 23 June 2015
- Kourou spaceport
- Vega rocket
- “Colour vision” of Copernicus
- B unit launched on 7 March 2017

Launch Sentinel-3 A



- 16 February 2016
- From Plesetsk cosmodrome, Russia
- Rockot rocket
- “A bigger picture” for Copernicus
- B unit to be launched at the end of 2017

Sentinels Operations Strategy



Main objectives of the Sentinels operations strategy:

- Reliable provision of data to Copernicus users
- Ensure systematic and routine operational activities

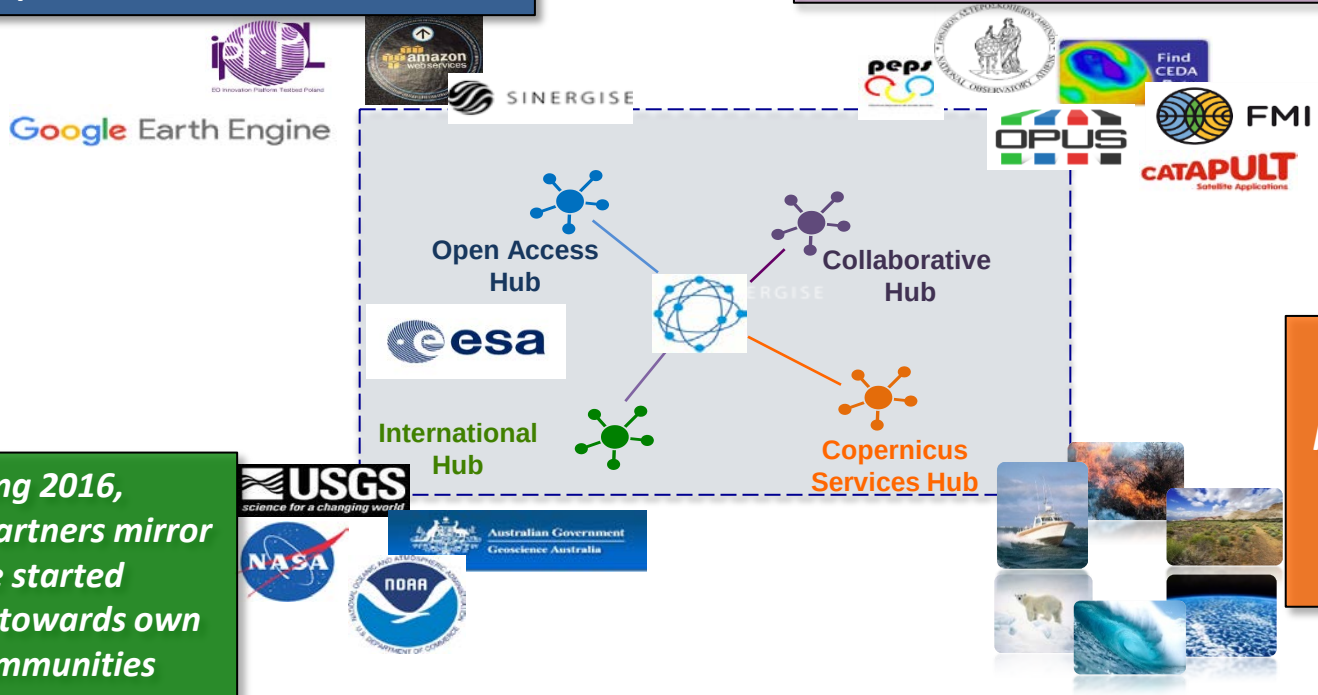
Sentinels operations approach:

- Sentinels are operated via a **pre-defined background** observation and downlink plan
  - Scenario is updated on a regular basis (e.g. 6 to 12 months) taking into account evolution of user needs
- All Sentinels acquired data is **systematically downlinked and processed** to generate a predefined list of **core products** within specific timeliness
  - Typically within 3h after sensing for Near-Real Time, and within 24h after sensing for Non-Time Critical

Sentinels Products dissemination: data hubs

Large and small private companies are re-distributing Sentinel products via free and pay-per-use schemes

Collaborative mirror sites directly serve more than 600 users (status end 2015)



As of spring 2016, international partners mirror sites have started disseminating towards own national communities

Copernicus Services are providing their higher level products to approx 10,000 users (status Q1-2016)

Sentinel Data Hubs – Latest Configuration (Feb 17)

Open Data Hub

Self Registration

> 63,000 Users

No Rolling Policy

Sentinel-1 NTC

Sentinel-2 L1C

Sentinel-3 (pre-Ops)

Max 2 Concurrent Downloads

ESA UNCLASSIFIED - For Official Use

Collaborative Data Hub

13 Collaborative GS

5 Data Hub Relays

Node 1: 30 days

Node 2: 9 days

Sentinel-1 NRT & NTC

Sentinel-2 L1C

Node 1: Max 10 downloads

Node 2: No limits

International Access Hub

4 Intl. Agreements

30 Days

Sentinel-1 NTC

Sentinel-2 L1C

Max 10 concurrent downloads

Copernicus Services Data Hub

copernicus space component data access

180 Users

No Rolling Policy

Sentinel-1 NTC

Sentine-2 L1C

Max 10 concurrent downloads

Copernicus Sentinel Data Policy

Sentinel Data Policy = FREE and OPEN access

- Joint COM/ESA **Sentinel Data Policy Principles** have been prepared in 2009 - adopted by ESA MSs in Sep 2009
- **EU Delegated Act** on Copernicus Data and Information Policy has been published on 12 July 2013 (C(2013)4311, final)
- ESA will table a **Sentinel Data Policy** for approval by PB-EO in Sep 2013. Main principles of Sentinel data policy:
- **Open** access to Sentinel data by anybody and for any use:
  - **Free** of charge data licenses
  - Restrictions possible due to technical limitations or security constraints

Sentinel-1 C-band SAR mission

Mission profile:

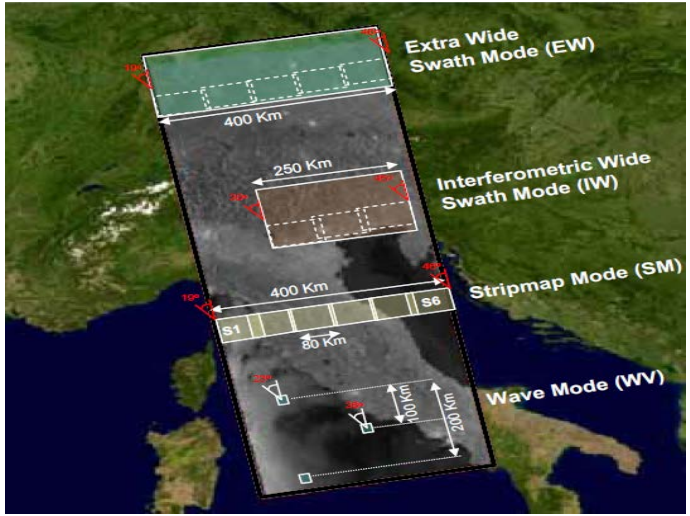
- **C-Band SAR** at 5.4 GHz, multi-polarisation
- Sun synchronous orbit at **693 km** mean altitude
- **250 km** swath width (Interferometric Wide-swath mode)
- **6 days** repeat cycle at Equator with 2 satellites
- **7 years** design life time, consumables for 12 years
- **4** nominal mutually exclusive operation modes

Mission objectives:

- Ice and marine, land monitoring
- Mapping for humanitarian aid and crisis management

Sentinel-1 Operational Modes

Operational Modes



Resolution	Swath Width	Polarisation
20 x 40 m²	> 400 km	HH+HV or VV+VH
5 x 20 m²	> 250 km	HH+HV or VV+VH
5 x 5 m²	> 80 km	HH+HV or VV+VH
5 x 5 m²	20 x 20 km² at 100 km spacing	HH or VV

- **Daily coverage of high priority areas, e.g. Europe, Canada, shipping routes**

Sentinel-2 Superspectral imaging mission

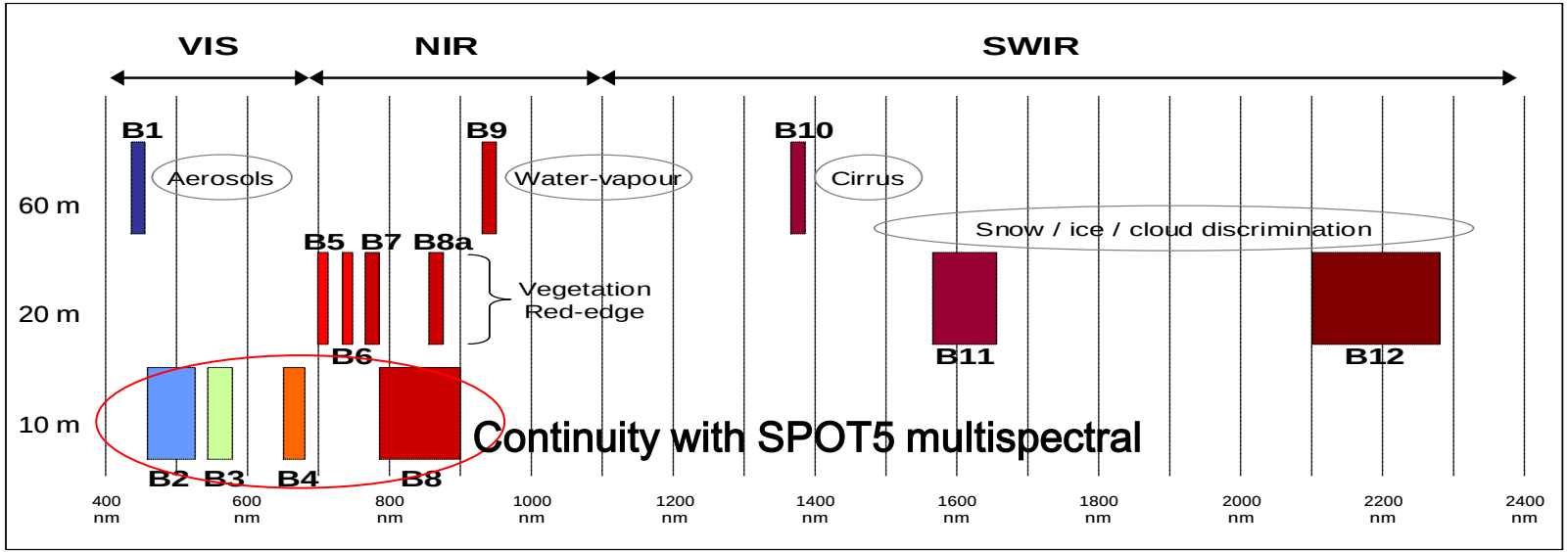
Mission profile

- Multispectral instrument with **13** spectral bands (VIS, NIR & SWIR)
- Sun synchronous orbit at **786 km** mean altitude
- **290 km** swath width
- **5 days** repeat cycle at Equator (cloud free) with 2 satellites
- **7 years** design life time, consumables for 12 years
- **10**, **20** and **60 m** spatial resolution

Mission objectives:

- Generic land cover maps
- Risk mapping and disaster relief

Sentinel-2: 13 Spectral Bands



Spectral bands versus spatial resolution

Sentinel-3 Ocean & Global Land Mission

Mission profile

- **3** main instrument sets: OLCI, SLSTR and RA
- Sun synchronous orbit at **814.5 km** mean altitude over geoid
- **1270 km** swath width for OLCI and **750 km** for SLSTR
- **< 1 day** repeat cycle for OLCI/SLSTR with 2 satellites, **27 days** for the topography package
- **7 years** design life time, consumables for 12 years

Mission objectives:

- Sea/land colour data
- Sea/land Surface temperature
- Sea surface and land ice topography

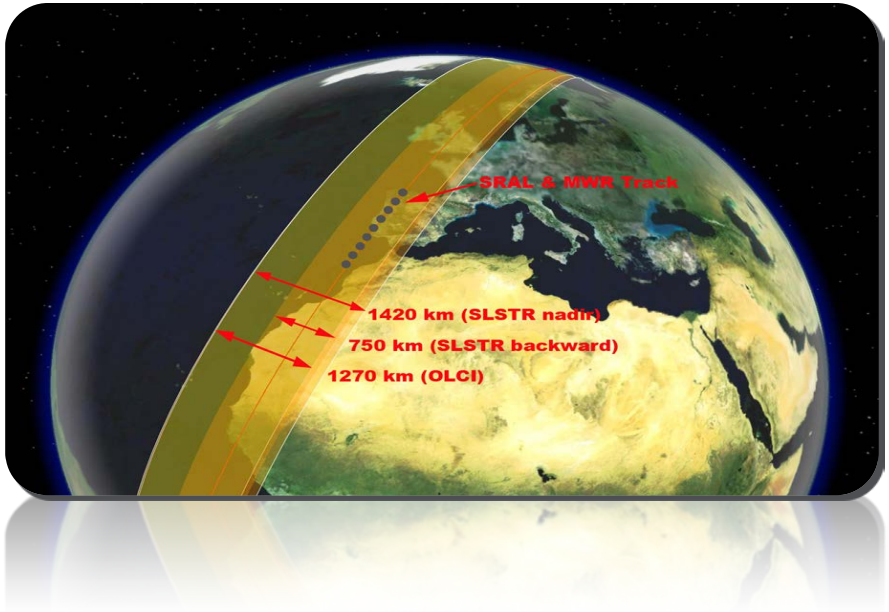
Sentinel-3 Payload

Optical Mission Payload

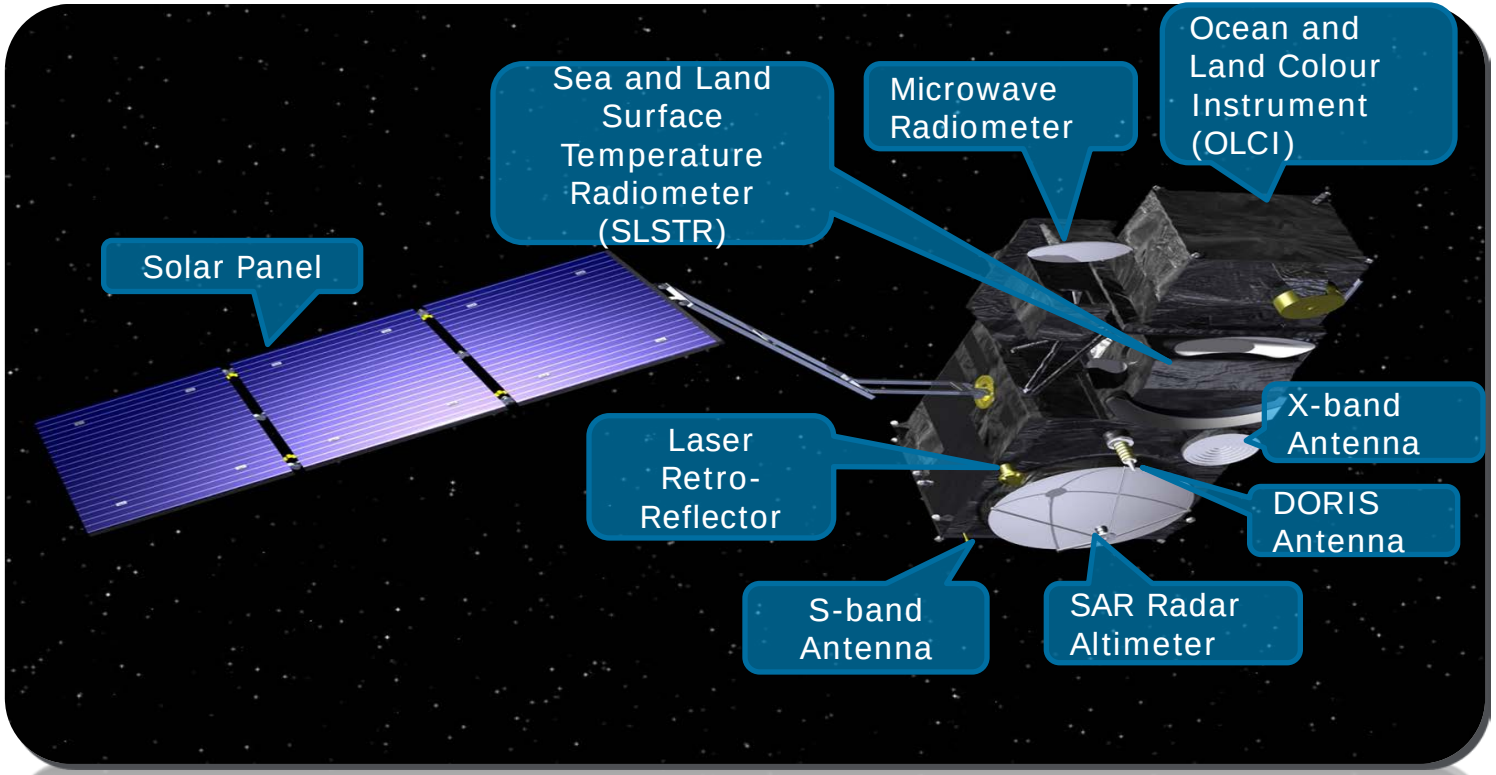
- Ocean and Land Colour Instrument (OLCI)
- Sea and Land Surface Temperature Radiometer (SLSTR)

Topography Mission Payload

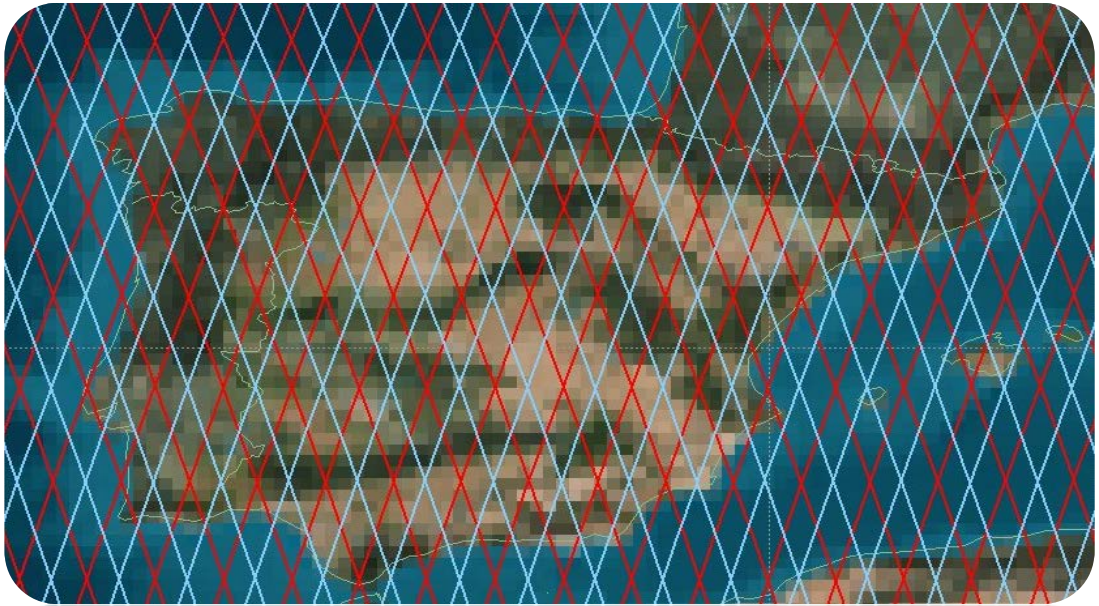
- Ku-/C-band Synthetic Aperture Radar Altimeter (SRAL)
- MicroWave Radiometer (Bi-frequency)
- Precise Orbit Determination (POD) including:
  - GNSS Receiver
  - DORIS
  - Laser Retro-Reflector



Sentinel-3 Main Components



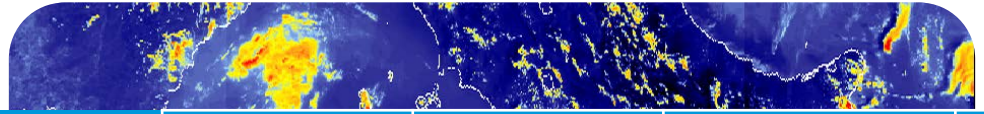
Sentinel-3 Revisit Time & Coverage: Topography Mission



Ground tracks after 1 complete cycle (27 days)

- Ground track repeatability
- Dense spatial sampling

Sentinel-3 Revisit Time & Coverage: Optical Mission



	Number of Satellites	Revisit at Equator	Revisit for latitude >30°	Spec.
Ocean Colour (Sun-glint free, day only)	2 Satellites	< 1.9 days	< 1.4 days	< 2 days
Land Colour (day only)	2 Satellites	< 1.1 day	< 0.9 day	< 2 days
SLSTR dual view (day and night)	2 Satellites	< 0.9 day	< 0.8 day	< 4 days

Simulated OLCI products

➢ **Short Revisit times for optical payload**

Sentinel-4 GEO atmospheric mission

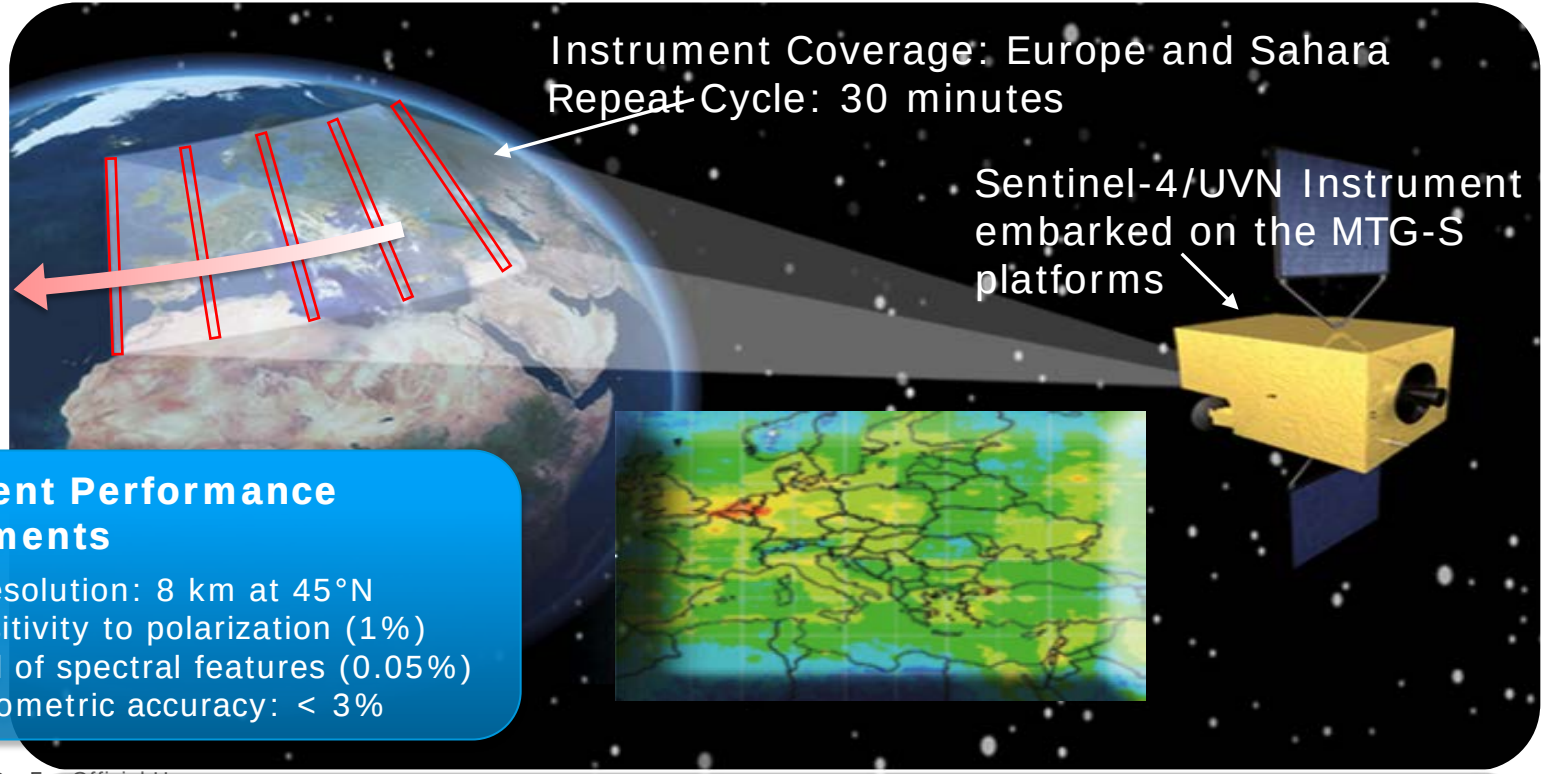
Mission profile

- **UV-VIS-NIR** spectrometer instrument
- Geostationary orbit at about **0º longitude**
- Spatial sampling of **8 X 8 km²** at **45º** north latitude
- **30 min** repeat cycle over Europe and North Africa

Mission objectives:

- Air quality monitoring, climate forcing and tropospheric composition

Sentinel-4 UVN instrument



Instrument Performance Requirements

1. Spatial resolution: 8 km at 45°N
2. Low sensitivity to polarization (1%)
3. Low level of spectral features (0.05%)
4. High radiometric accuracy: < 3%

Sentinel-5 / 5P LEO atmospheric mission

Mission profile

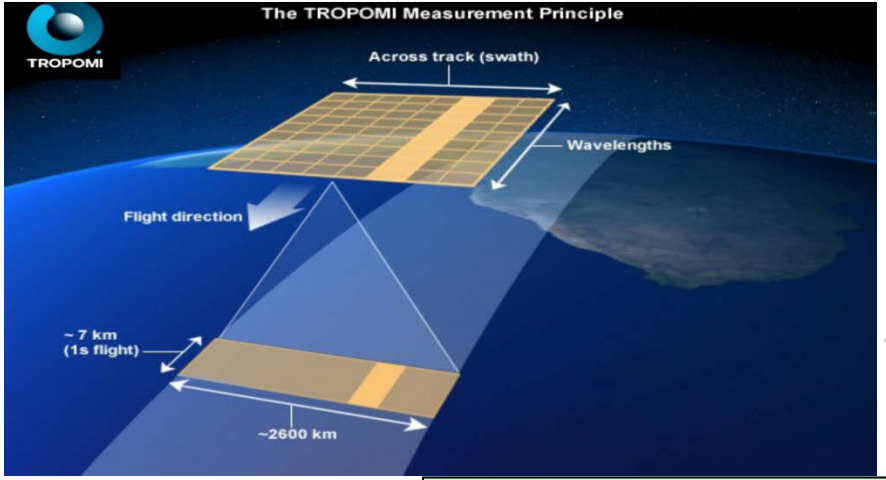
- **UV-VIS-NIR-SWIR** spectrometer instrument
- Sun-synchronous LEO platform at **824 km** mean altitude
- **7 years** design life time
- Global daily coverage with **7 x 7 km²** sampling

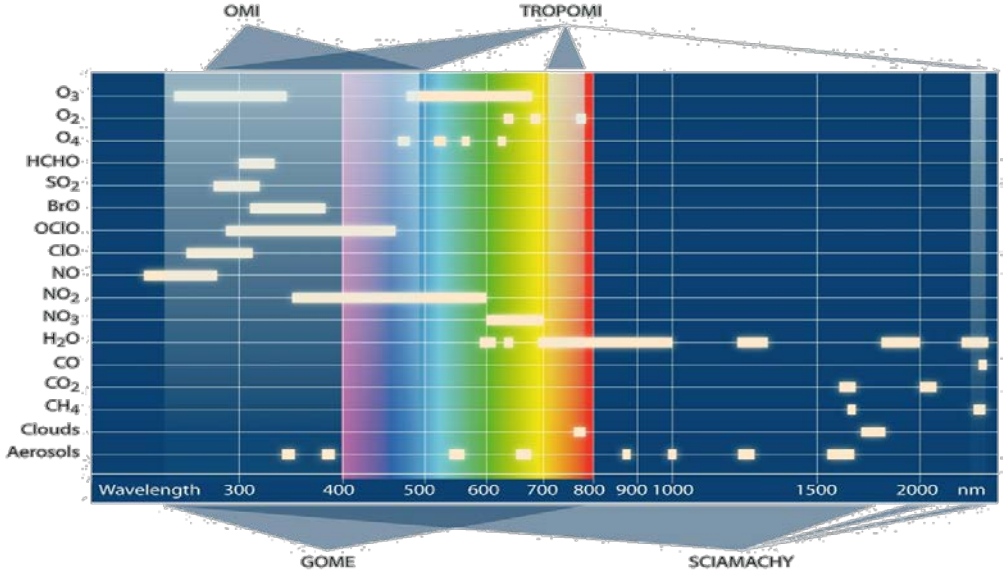
Mission objectives:

- Monitoring air quality, climate forcing and stratospheric ozone

Sentinel-5P Observation scenario

The Sentinel-5P instrument data is **acquired systematically** during the complete orbit according to a simple **baseline observation scenario**





The TROPOMI/SENTINEL-5P instrument has **a swath of 2600 km on the ground**

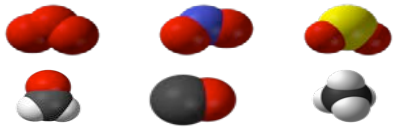
It provides a full daily surface coverage for latitudes >+7° and <-7° , and better than 95 % coverage for latitudes in the interval [-7,7]

Sentinel-5P: products overview

Sentinel-5 Precursor Data Products		
Product	**Description**	**Remarks**
Level 0	**Unprocessed instrument measurement, HK & engineering data**	**internal use only**
Level 1B	**Calibrated, geo-located Earth radiance & solar irradiance spectra in all bands**	**Systematic processing**
Level 2	***Column densities/profiles for S5P primary species:*** ***UVN channel products*** **O_3** total & tropospheric columns, profiles **NO_2** total & tropospheric columns **SO_2, HCHO** total columns **aerosols** aerosol index & aerosol layer height **clouds** cloud fraction, top height, optical thickness	**Non Time Critical:** **All products** **Near Real-Time:** **All species except CH_4 & tropospheric O_3**
	SWIR channel products **CO, CH_4** total columns	

Near real-time delivery: 3 hours after sensing

Non time critical: 14 days after sensing



Level 1b and Level 2 will be provided to all users by ESA

Sentinel-6 topography mission

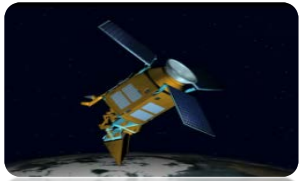
Mission profile

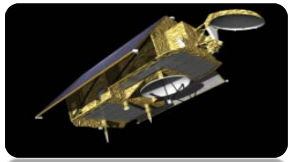
- SAR Radar altimeter, microwave radiometer and precise orbit determination instruments
- LEO non-sun-synchronous orbit, 1336 km mean altitude
- **10 days** repeat cycle with 66º inclination
- **5.5 y** lifetime

Mission objectives:

➢ To provide continuity of the reference, high-precision ocean topography service after Jason-3

Advantages of Sentinel Satellites





Fully operational system

Most comprehensive EO system in the world

Complementary to Contributing Missions

Free Sentinel data

Long-term observations

1st Generation Copernicus Space Component

- ✓ In 2005 ESA decided to invest in the build-up of the necessary space infrastructure, complementary to the capacity available in its MSs
- ✓ After iteration with thematic Implementation Groups a preliminary system architecture was consolidated:

GMES initial services	Sent-1	Sent-2	Sent-3	Sent-4	Sent-5
Marine & Coastal Environment	*	*	*		
Land Cover state & changes	*	*	*		
Global Change Issues	*	*	*	*	*
Atmos. Pollution Management			*	*	*
Risk Management	*	*	*		
Forest Monitoring	*	*	*		
Food Security	*	*	*	*	*
Marine Security	*	*			
Humanitarian Aid	*	*	*		

Sentinel-5p and 6 were added later to avoid data gaps for atmospheric composition and to continue Jason-1/2/3 reference altimetry

Copernicus Space Component: What is next?

✓ The evolution of the Copernicus Space Component is a joint EC-ESA endeavour that must be defined together. It is divided into two different sets of activities:

- The current Sentinel families need to be complemented to fill some gaps in environmental monitoring caused by emerging European policy priorities (first missions to be launched around 2024) ➔ **Sentinels expansion**
- Also, the current Sentinel generation will have to be replaced by a next generation of satellites before the end of the last units' lifetimes (first missions to be launched before 2030) ➔ **Next Gen Sentinels**

Copernicus Space Component expansion

The Mission Concepts and Thematic Areas proposed as high priority are:

- CO_2 Monitoring
- Polar ice/ocean interfer. altimetry
- Other polar (Arctic) observations
- Land thermal imaging
- Soil moisture, ocean salinity
- Hyperspectral land imaging

climate change

marine & polar envir. monitoring

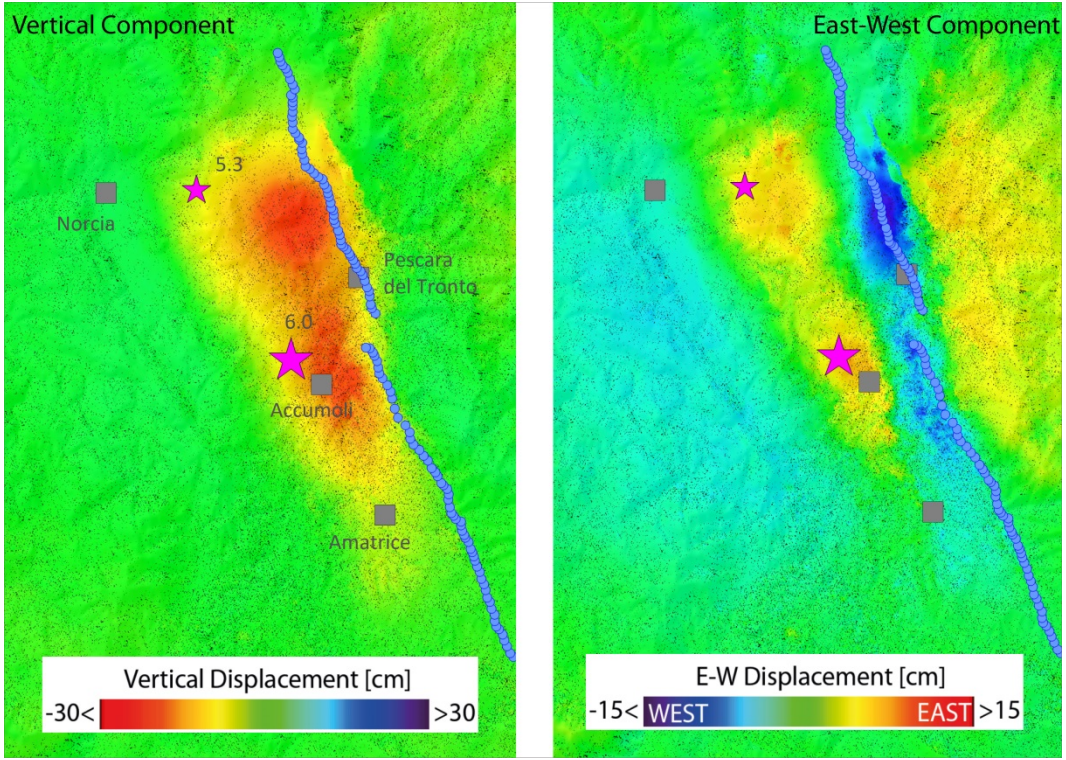
land monitoring *(agriculture, food security)*
emergency management *(geohazards)*
marine envir. monitoring

Copernicus Services Component

Example of Land Monitoring

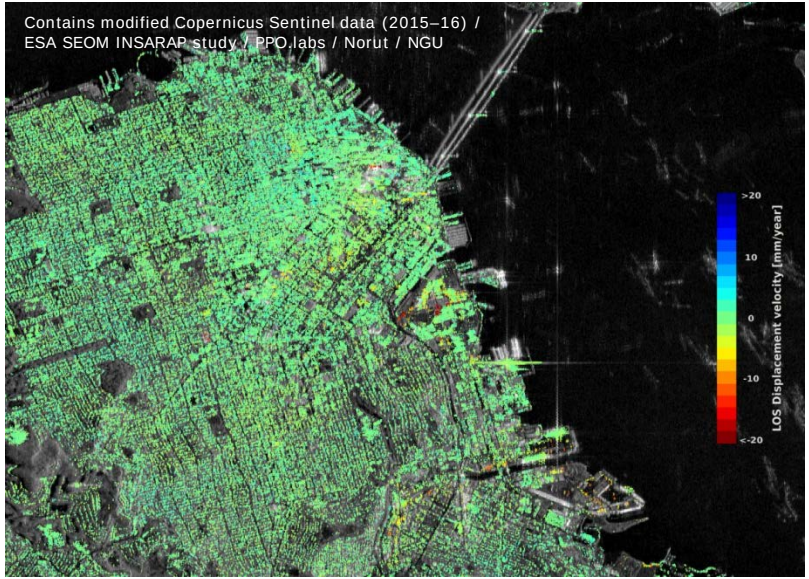
Devastating earthquake
in central Italy on 24th August 2016
(Magnitude: 6.2)

Credits: Panorama & AP Images

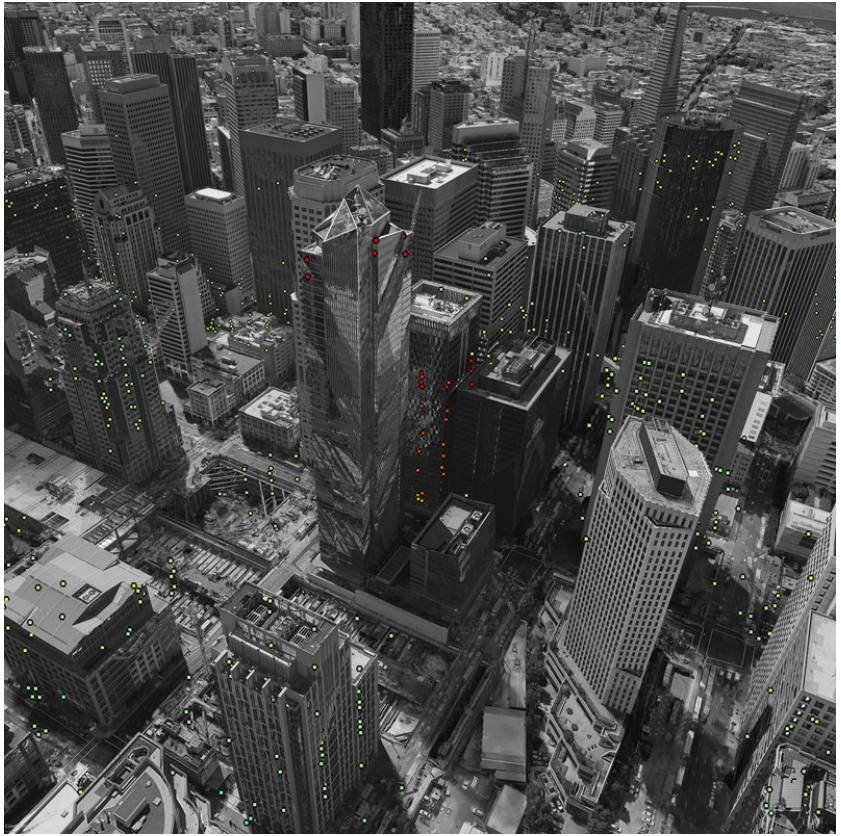


Vertical ground subsidence (~20 cm) and lateral movement (~16 cm) around Accumoli

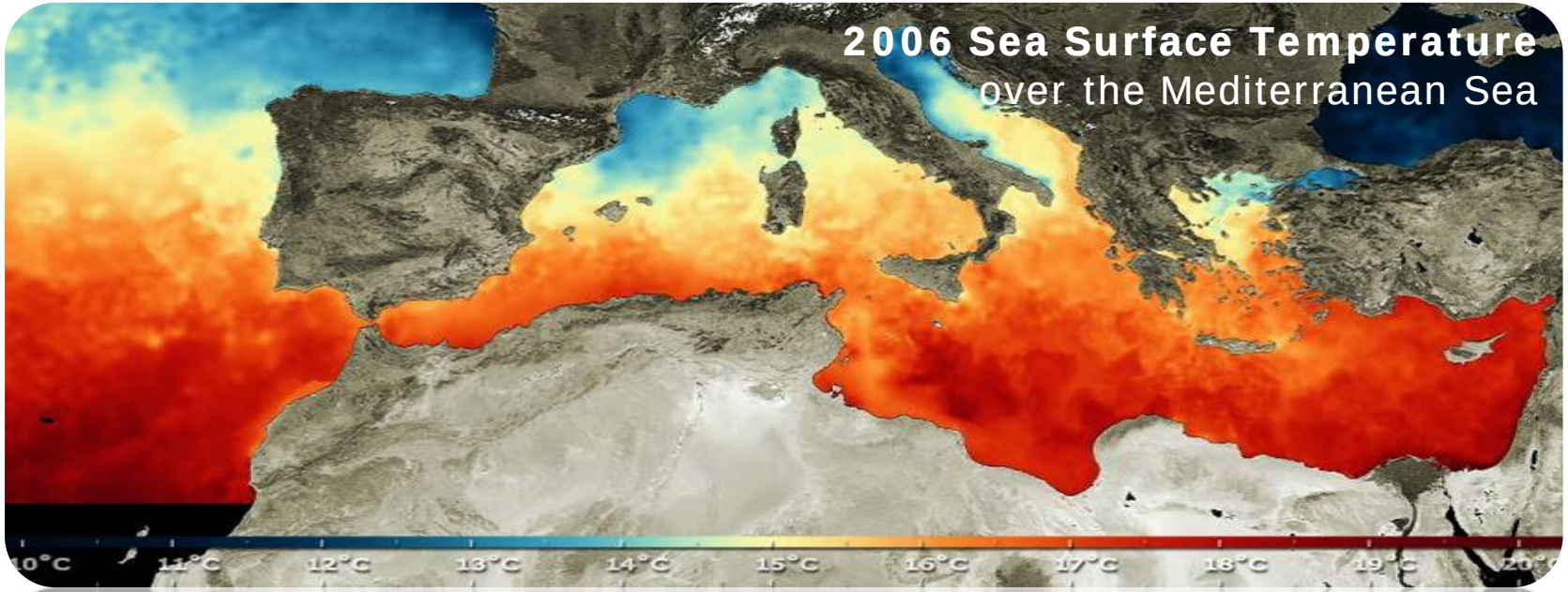
Example of Land monitoring



Sentinel-1 constellation study: INSARAP
San Francisco area InSAR Results

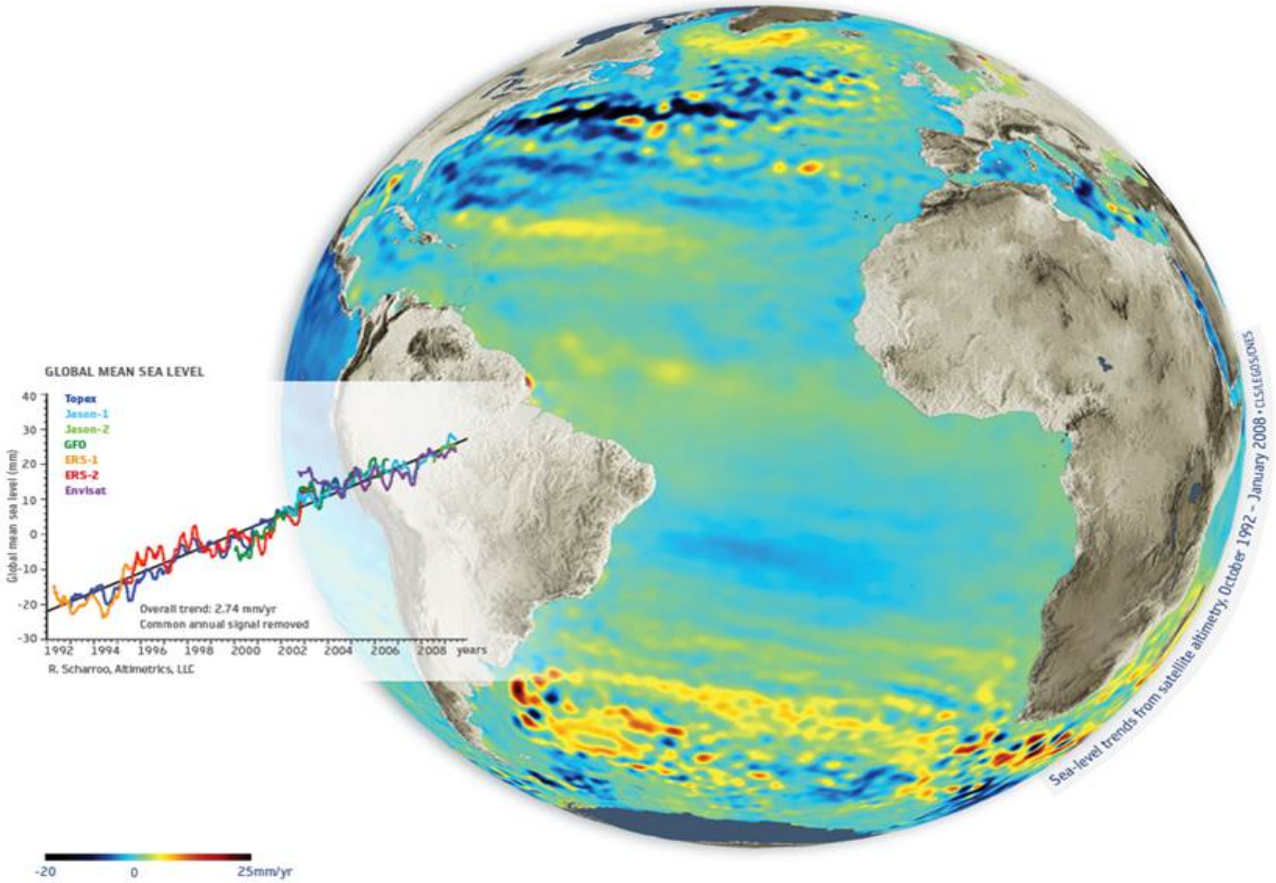


Example of Marine Monitoring



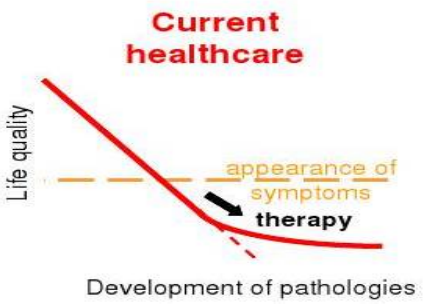
Credits: Medspiration

Example of Marine Monitoring

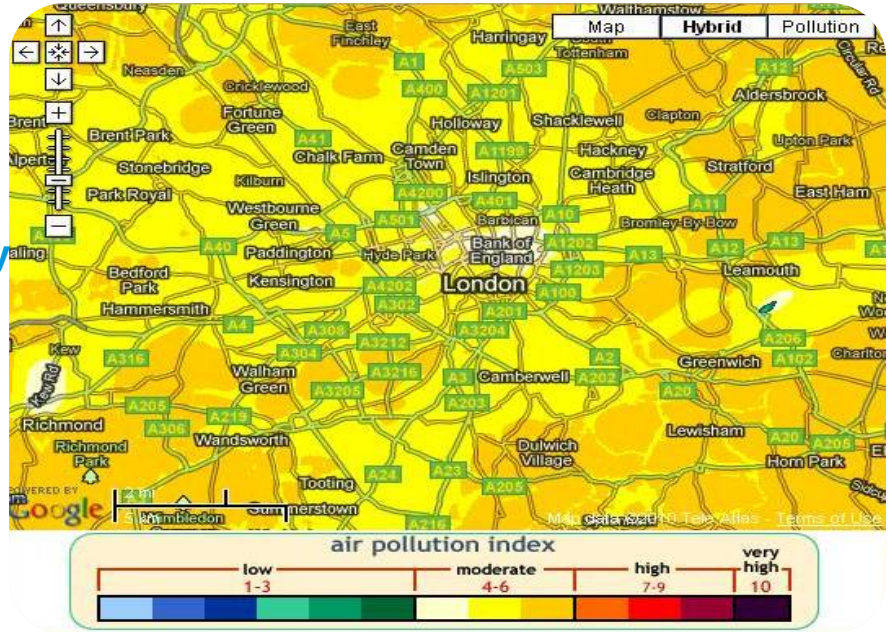


Global Sea Level Rise
from several satellite radar altimeters

Example of Atmospheric Monitoring

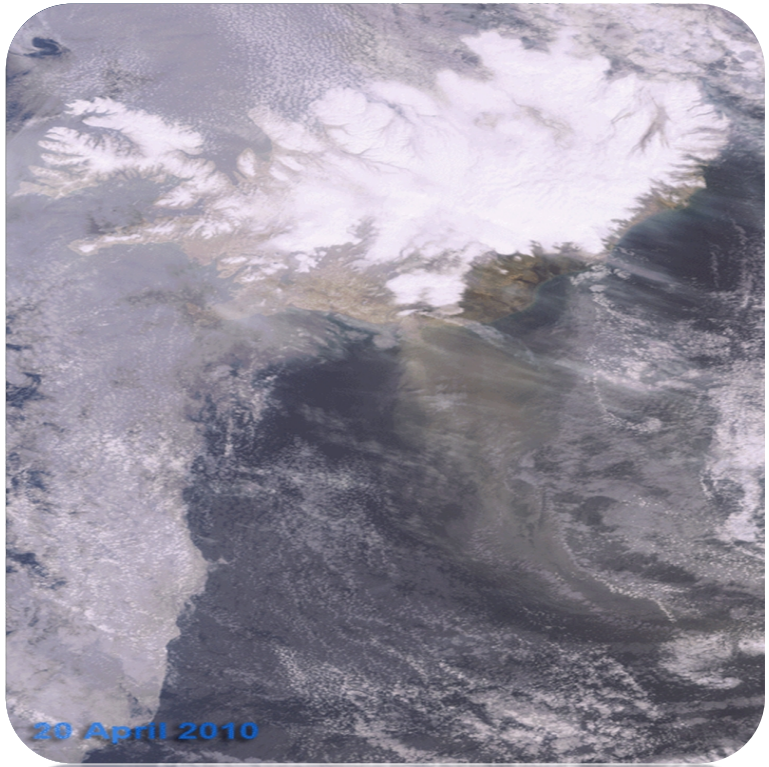


- **European Air Quality forecasts produced daily using models with EO and *in situ* data as input**
- **Local Air Quality forecasts use European-scale forecasts plus additional *in situ* input data**
- **City and street-level forecasts communicated to individuals**
  - physicians now exploring its use in predictive medicine

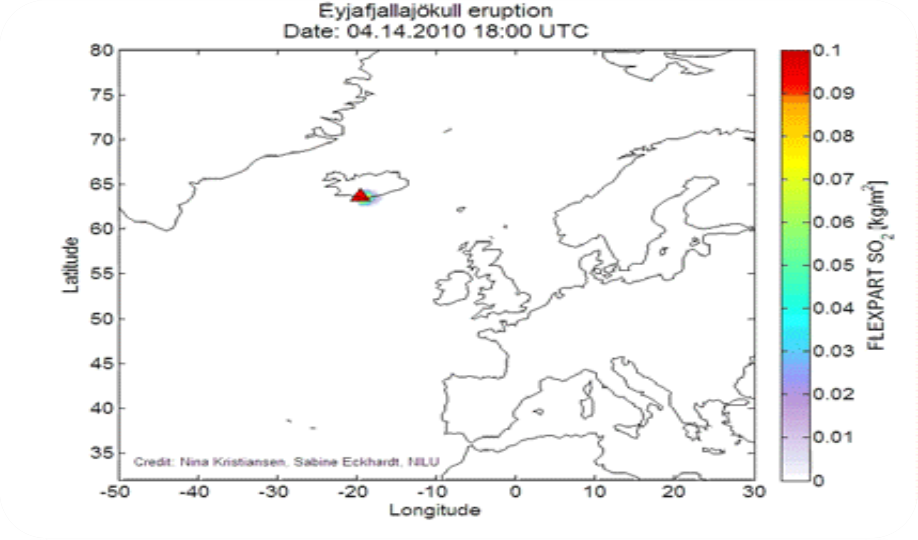


Credits: Airtext

Example of Atmospheric Monitoring



Ash Cloud Monitoring During Volcanic Eruption in Iceland, April 2010

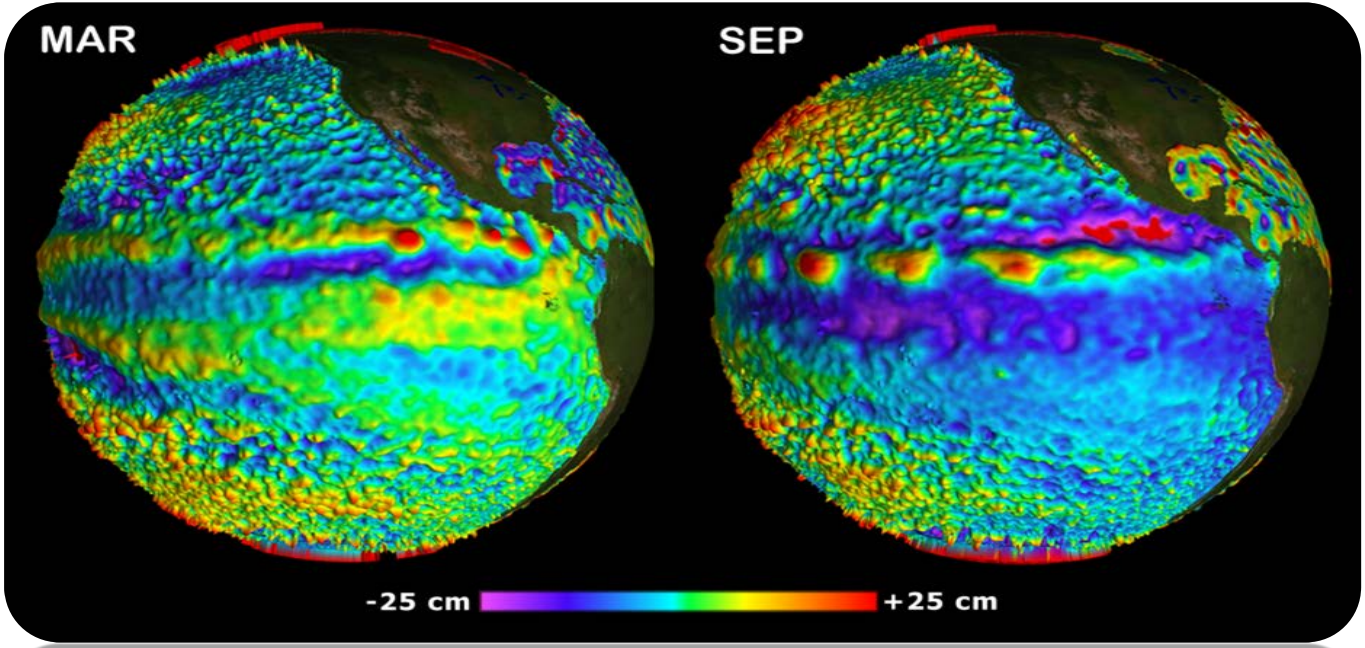


Credits: ESA, ENVISAT & Norwegian Institute for Air Research

Example of Climate Change Monitoring

Pacific Sea Surface Height between April and September 2010

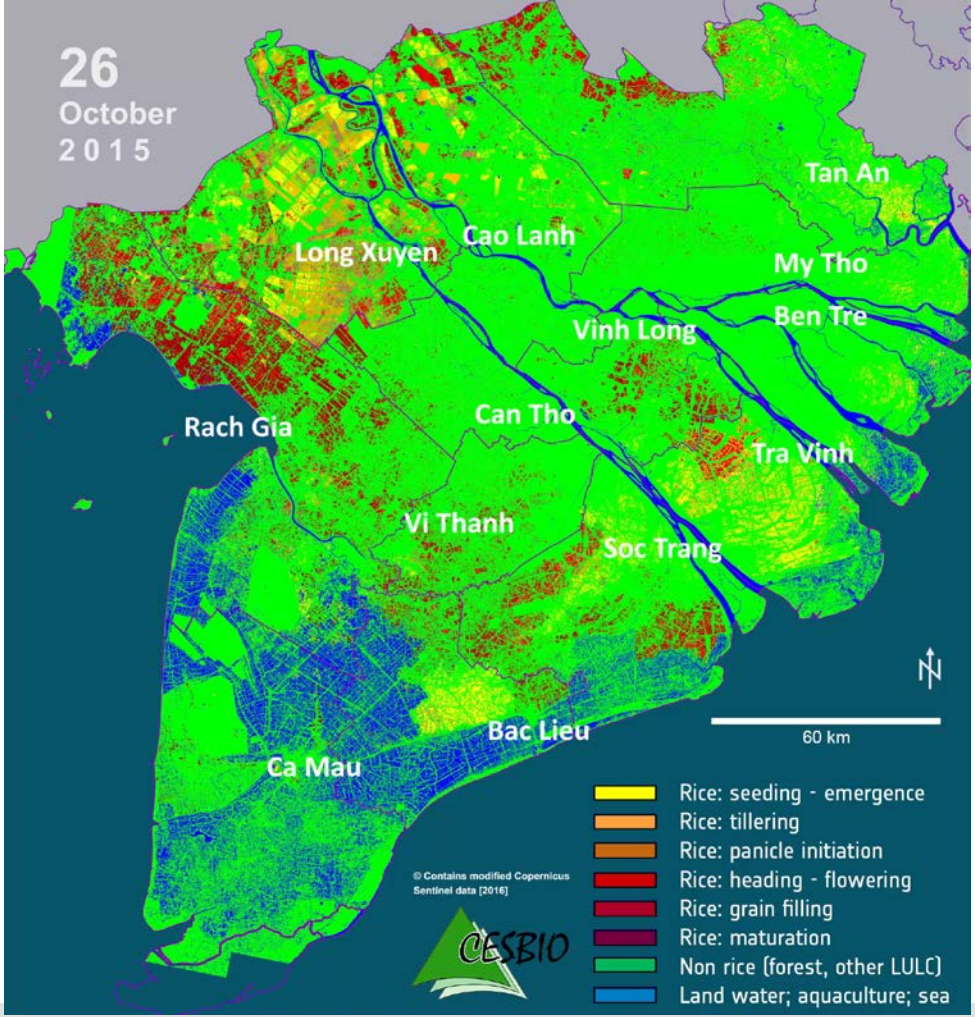
The sea surface is higher (warmer) than normal (yellow and red) in the West; and lower (cooler) than normal (blue and purple) in the East due to La Niña effects on Pacific coasts



Credits: MyOcean

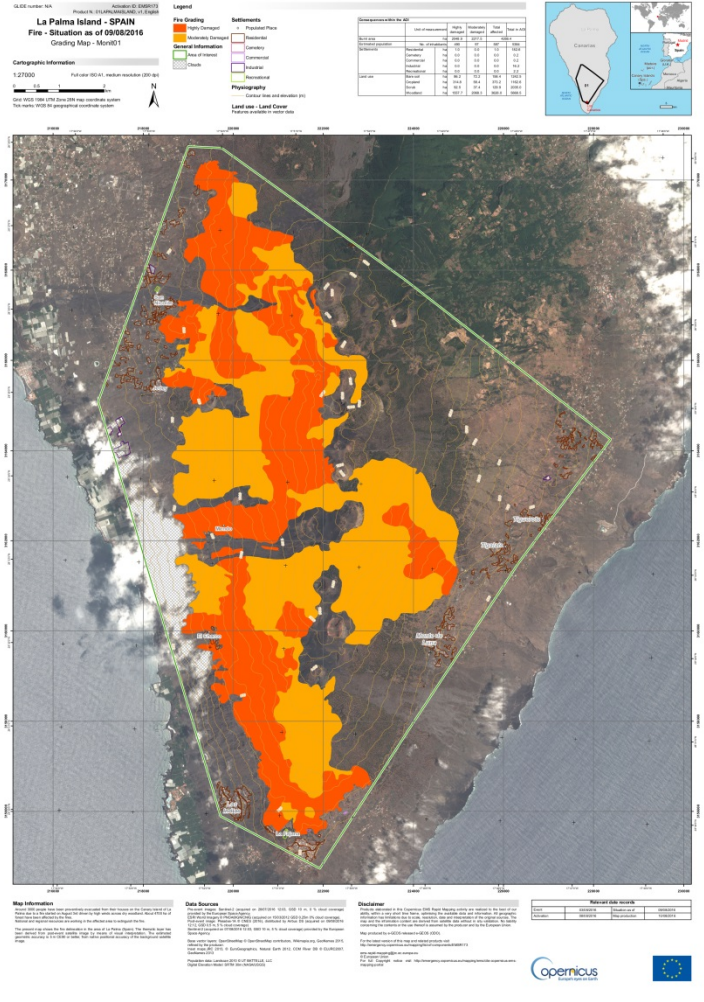
Example of Climate Change Monitoring

Rice crop evolution in the Mekong delta



Credits: contains modified Copernicus Sentinel data (2015–16)/CESBIO/ESA DUE GEO-Rice Innovator project

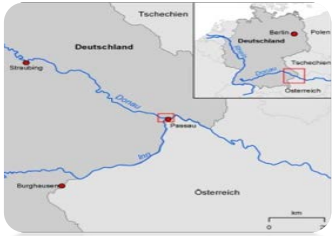
Example of Emergency Management



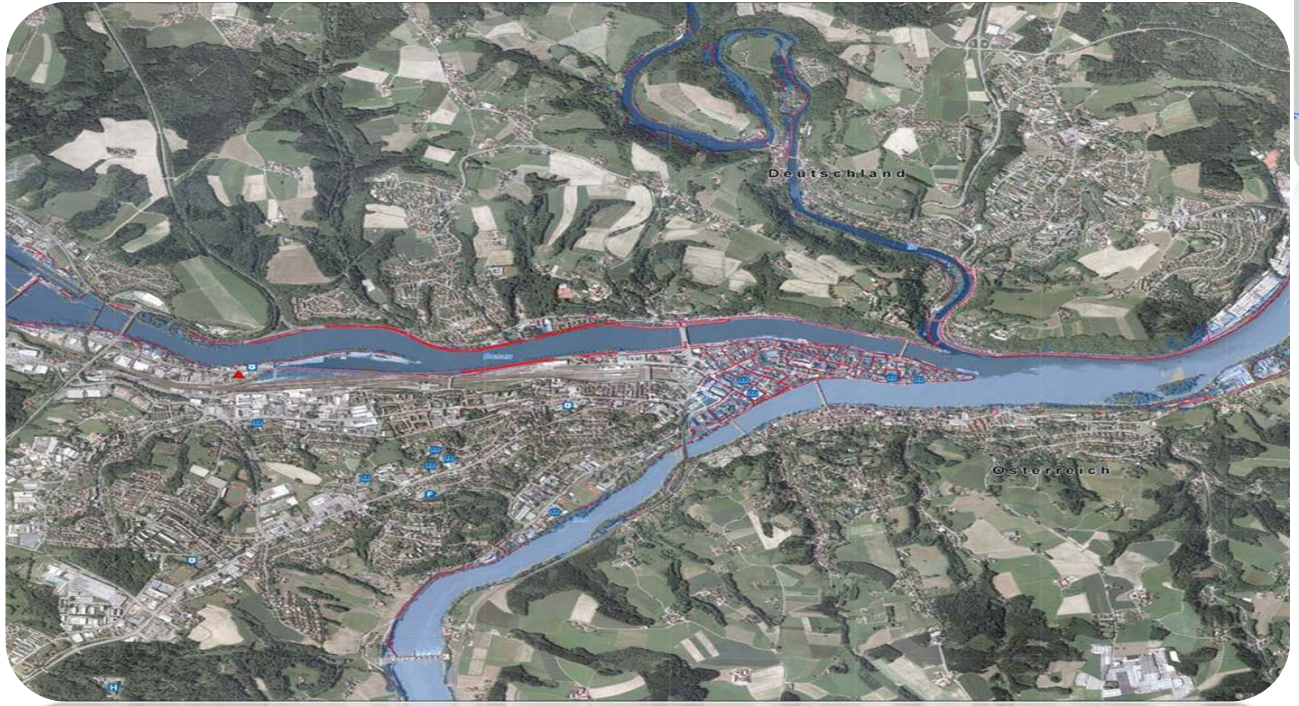
Fire map at La Palma, Canary Islands (Aug 2016)

Credits: Sentinel-2 and Pléaides-1A

Example of Emergency Management



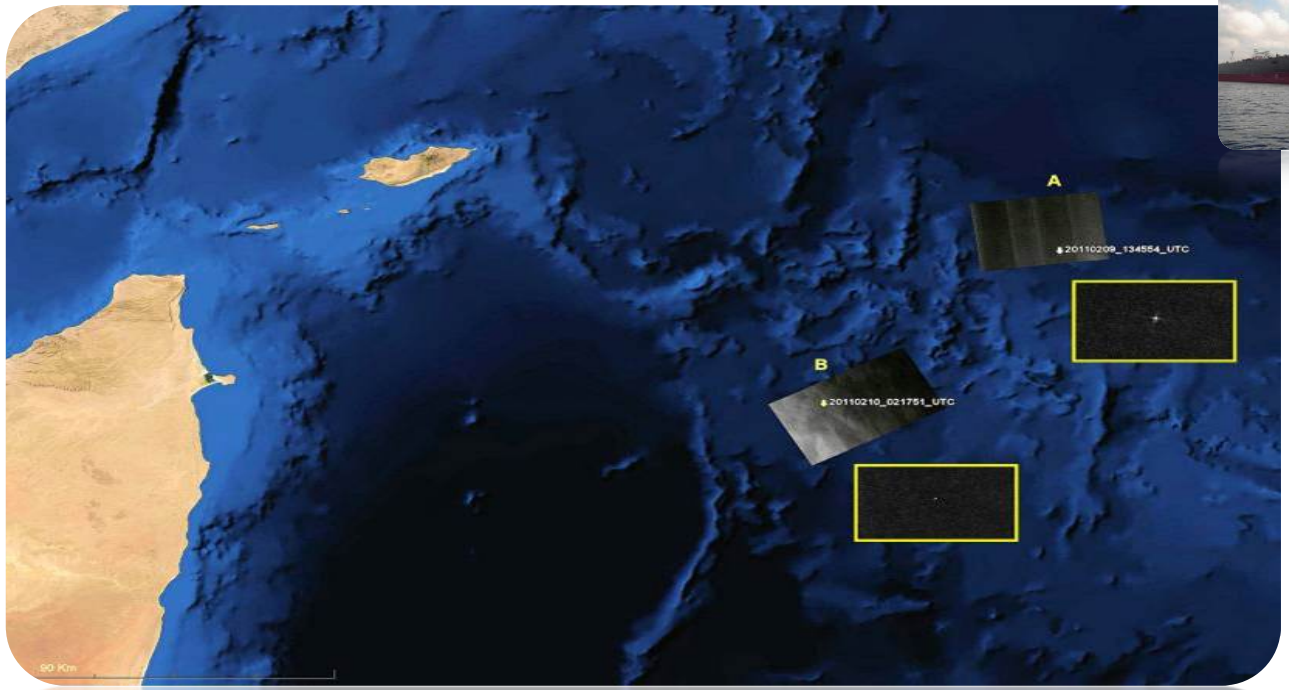
Flooding in Passau, Germany, June 2013



Credits: DLR

Example of Security Monitoring

Hijacked Italian 'Savina Caylyn' Oil Tanker monitored by COSMO-Skymed



Credits: e-GEOS

Example of Security Monitoring

WEBGIS Coastline

SAR Image L1B

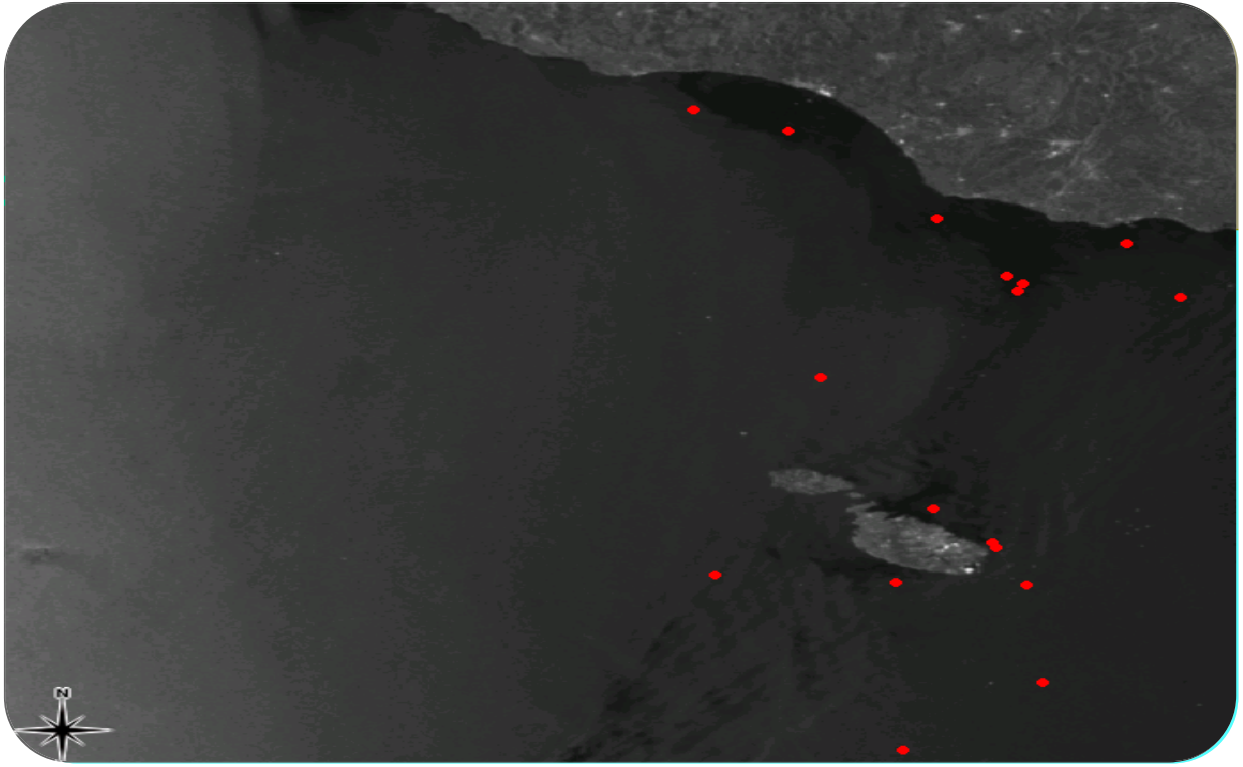
EO Plot

EO Plot and AIS Tracks

EO Plot Correlated with AIS Tracks

EO not Associated Plot

Service Timeline



Copernicus For Everyone: Socio-Economic Benefits

2026-2030 **potential Copernicus benefits =**

€ 130 B or around

€ 6.9 B / year =

0.2 % of the EU current annual GDP

- "Money where it matters – how the EU budget delivers value to you"
EC, MEMO/11/469, Brussels, 29 June 2011

1 € spent by European tax payer on Copernicus
→ **public return of 10€** can be expected

- "The Socio-Economic Benefits of GMES"
ESPI report 39, November 2011

Copernicus For Everyone: Educational Benefits & Development

www.copernicus-masters.com

www.app-camp.eu

ESA Copernicus website
http://www.esa.int/copernicus

Interested in more?

EC Copernicus website
http://copernicus.eu