

Copernicus Sentinel Missions

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ESA/ESTEC, Noordwijk, the Netherlands

AMT4SentinelFRM Workshop, Plymouth Marine Laboratory, UK, 20-21st June 2017

Overview

- Bit about ESA...
- Copernicus and Oceanography
- Sentinel-1
- Sentinel-2
- Sentinel-3
- Sentinel-6
- Summary and conclusions

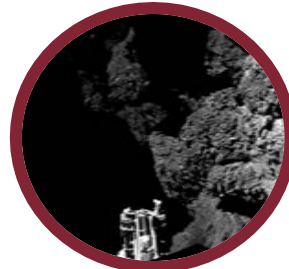


- Over 50 years of experience
- 22 Member States
- Eight sites/facilities in Europe, about 2200 staff
- 5.2 billion Euro budget (2016)
- Over 80 satellites designed, tested and operated in flight



ESA Activities

ESA is one of the few space agencies in the world to combine responsibility in nearly all areas of space activity.



space science



human spaceflight



exploration



earth observation



launchers



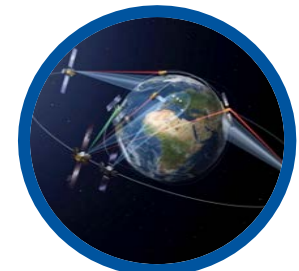
navigation



operations



technology



telecommunications

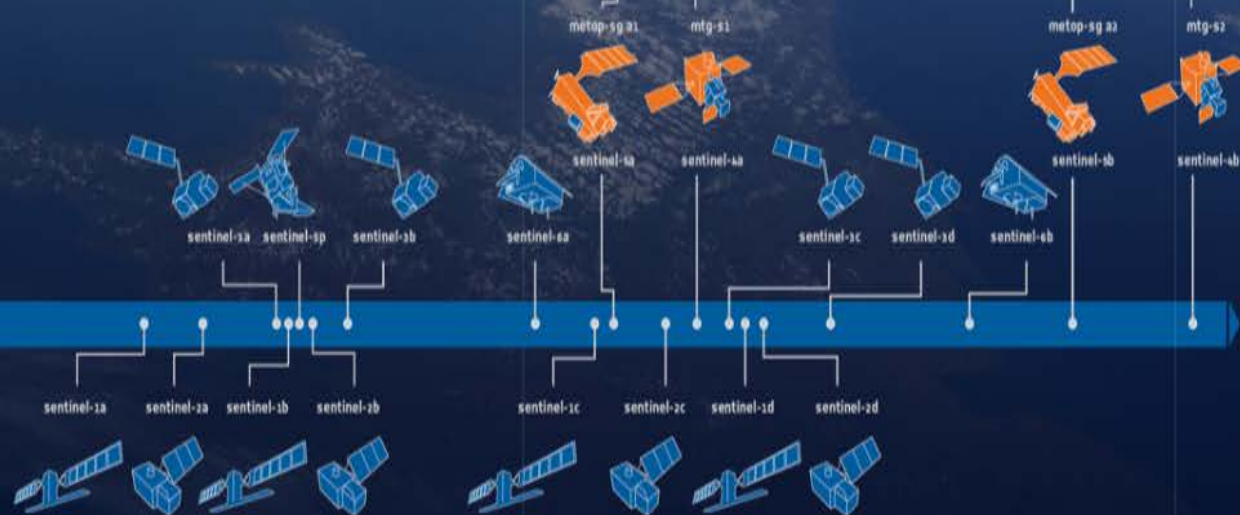




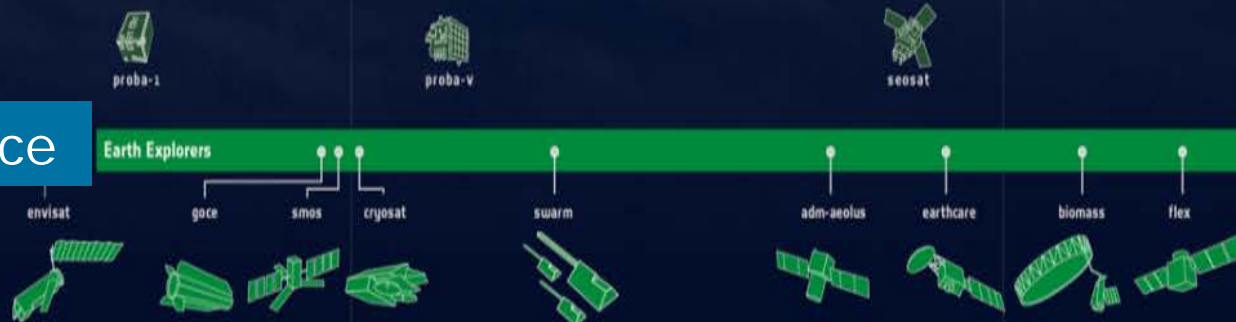
Meteo



Copernicus



Science



2000

2010

2020

2030

→ ESA-DEVELOPED EARTH OBSERVATION MISSIONS

What is Copernicus?

European response to global needs:

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

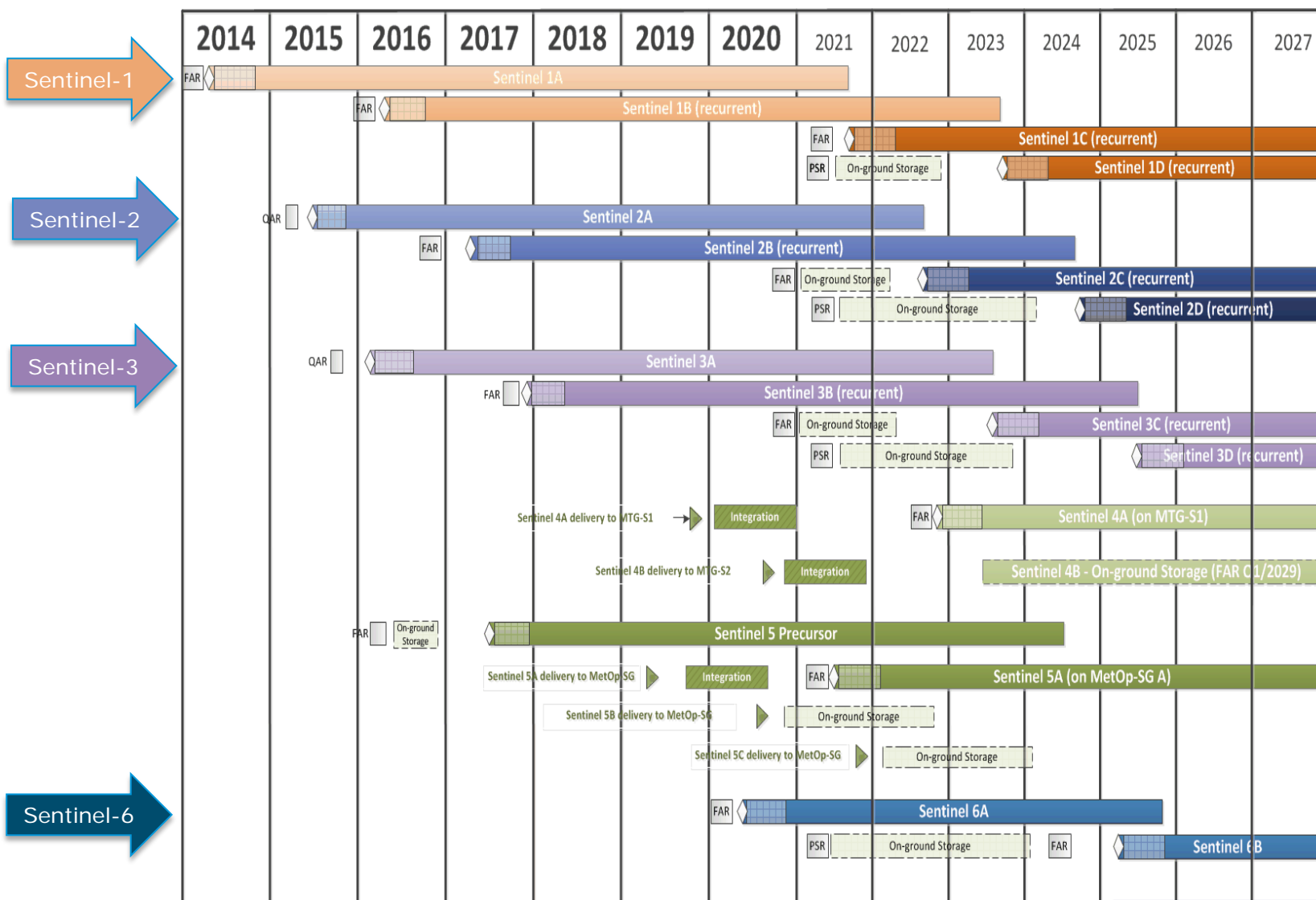
Copernicus

Space
Component

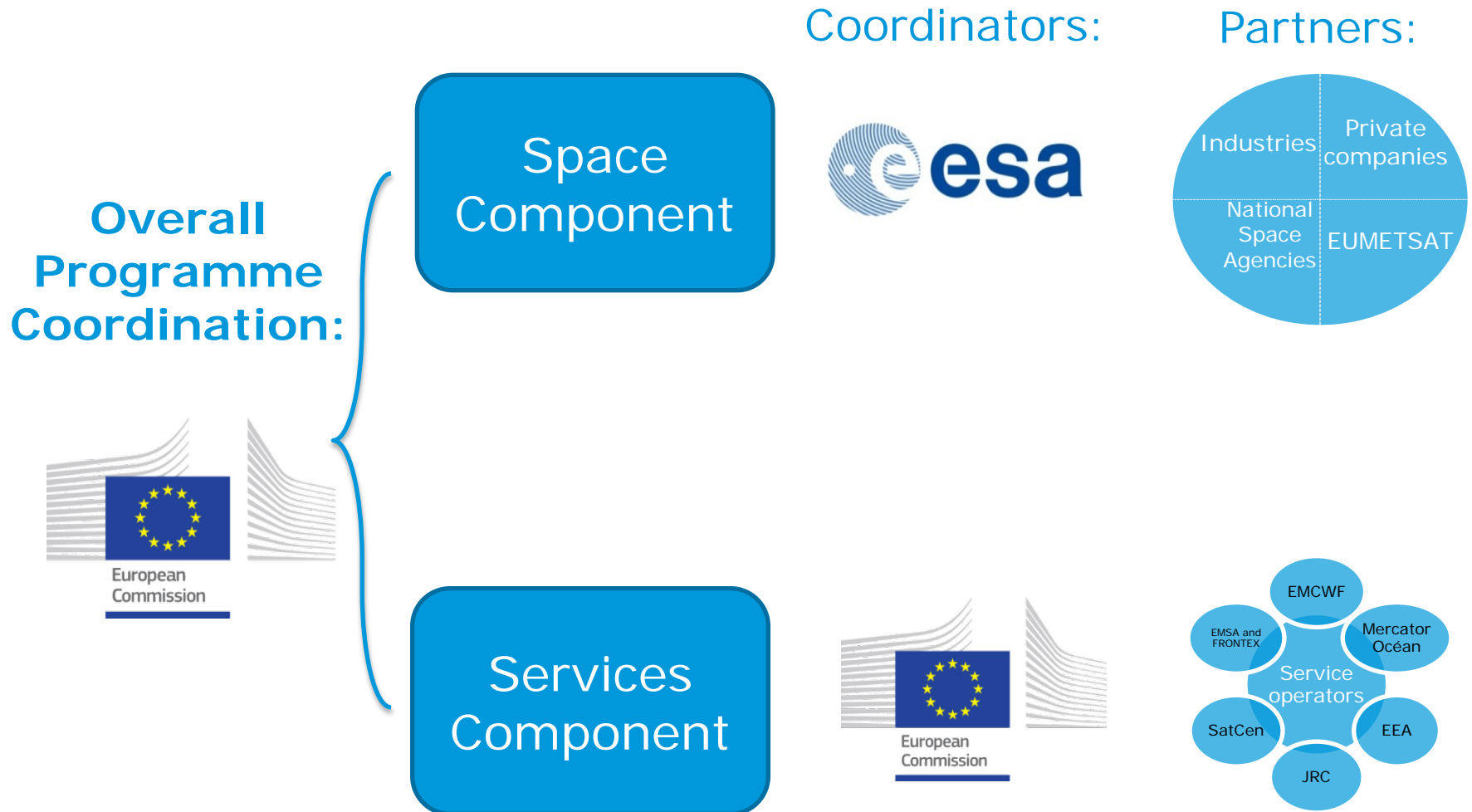
Services
Component

In-Situ
Data

Sentinel - Estimated Launch Schedule

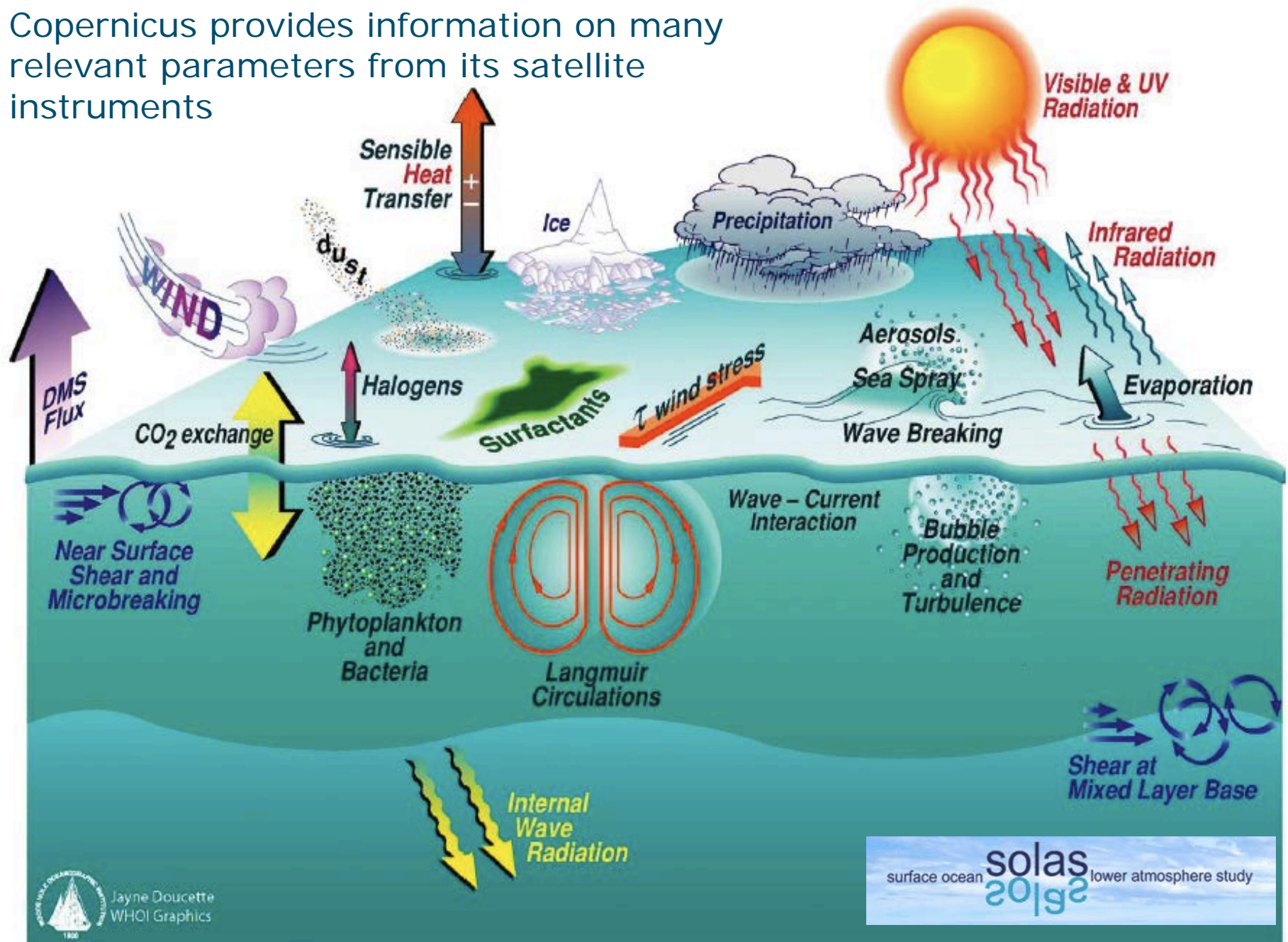


Copernicus Components & Competences

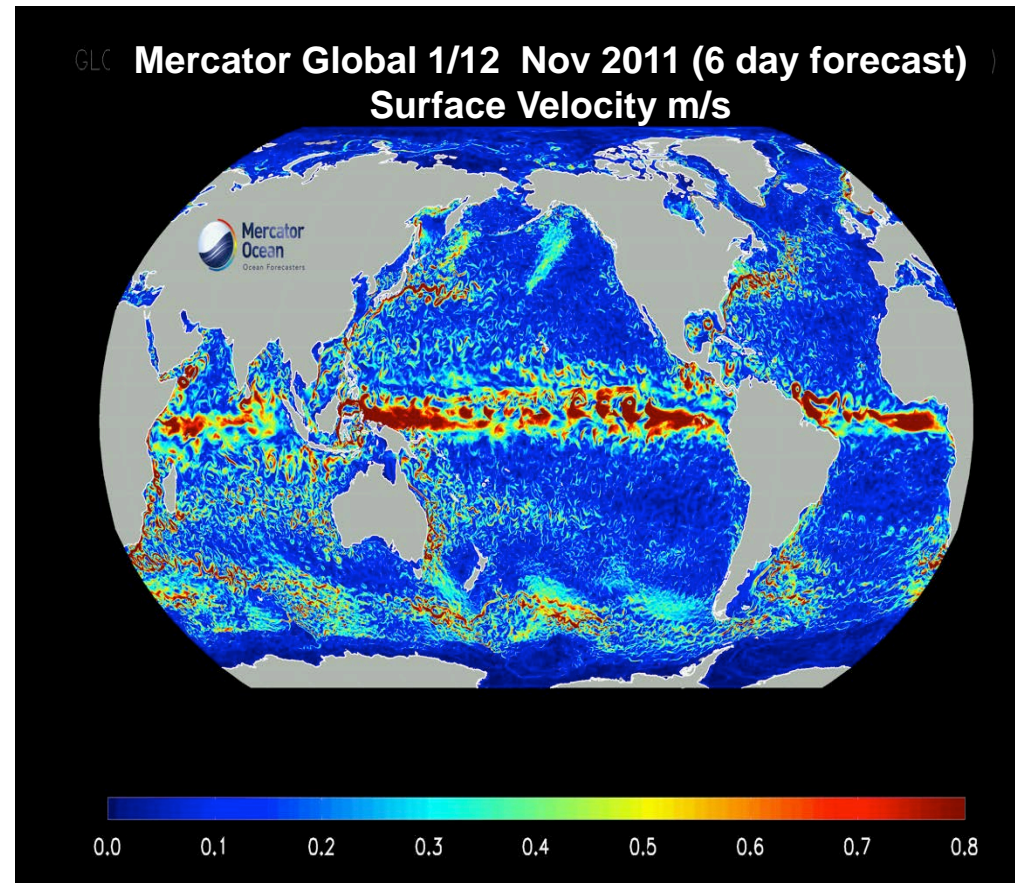
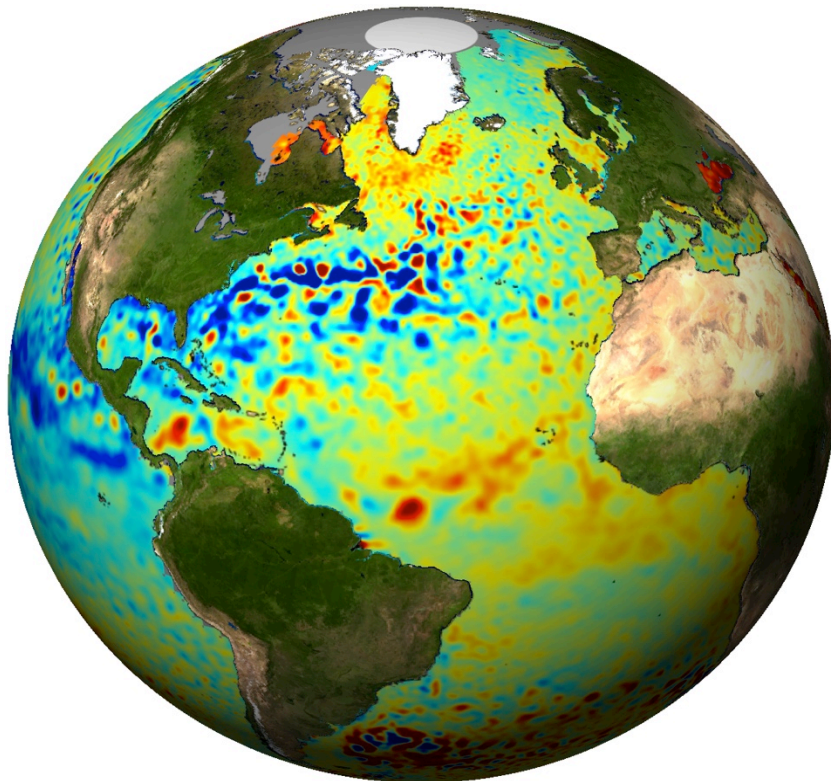


In-situ data are supporting the Space and Services Components

Copernicus provides information on many relevant parameters from its satellite instruments



The complexity of ocean circulation patterns...





Sentinel-1

→ RADAR VISION FOR COPERNICUS

Sentinel-1 (Soyuz-2, Kourou)

- Sentinel-1A launched on 3 April 2014
- Sentinel-1B launched on 25 April 2016



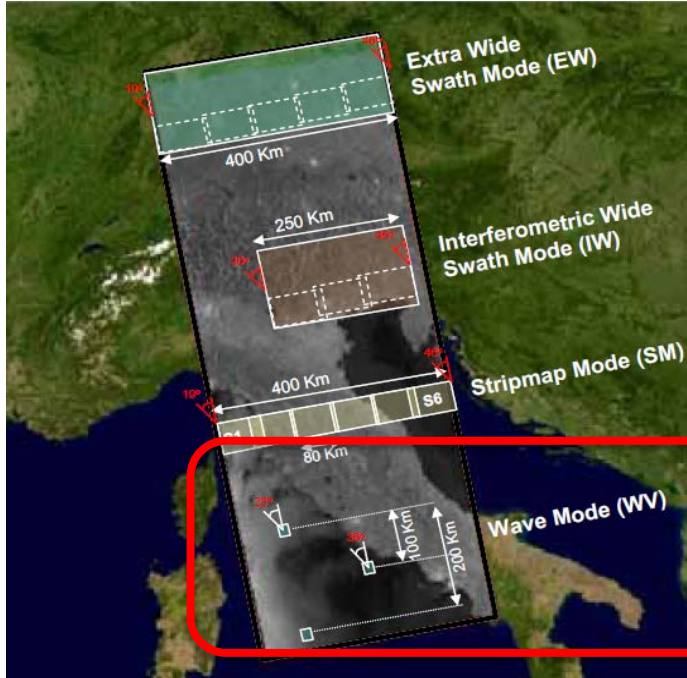
Mission profile:

- 
- Two identical spacecraft in Dawn-Dusk orbit
 - 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

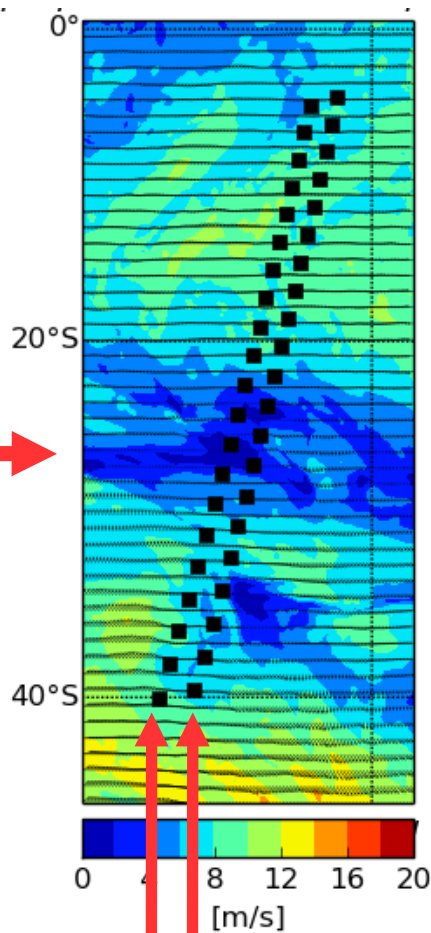
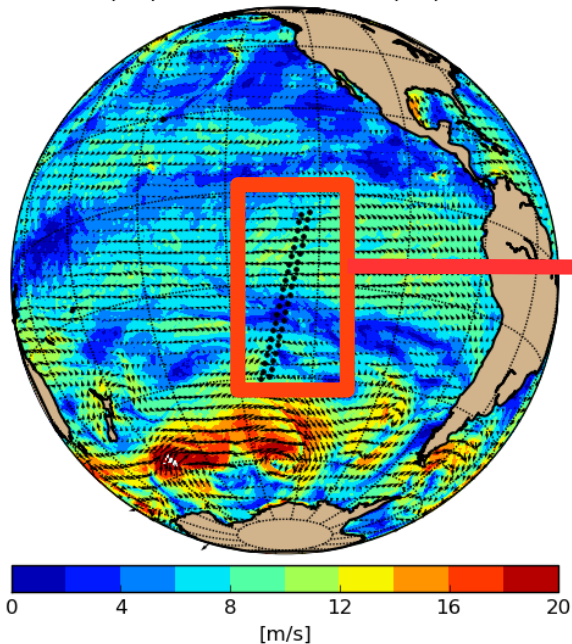
Sentinel-1 Operational Modes

Operational Modes		Resolution	Swath Width	Polarisation
	→	20 x 40 m ²	> 400 km	HH+HV or VV+VH
	→	5 x 20 m ²	> 250 km	HH+HV or VV+VH
	→	5 x 5 m ²	> 80 km	HH+HV or VV+VH
	→	5 x 5 m ²	20 x 20 km ² at 100 km spacing	HH or VV

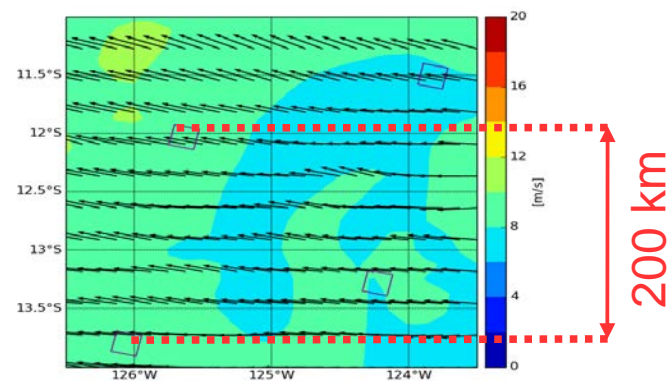
- Daily coverage of high priority areas, e.g. Europe, Canada, shipping routes

Sentinel-1 Wave-mode

HH - 2014/05/14 13:56:10 - 2014/05/14 14:06:13



WV2 WV1



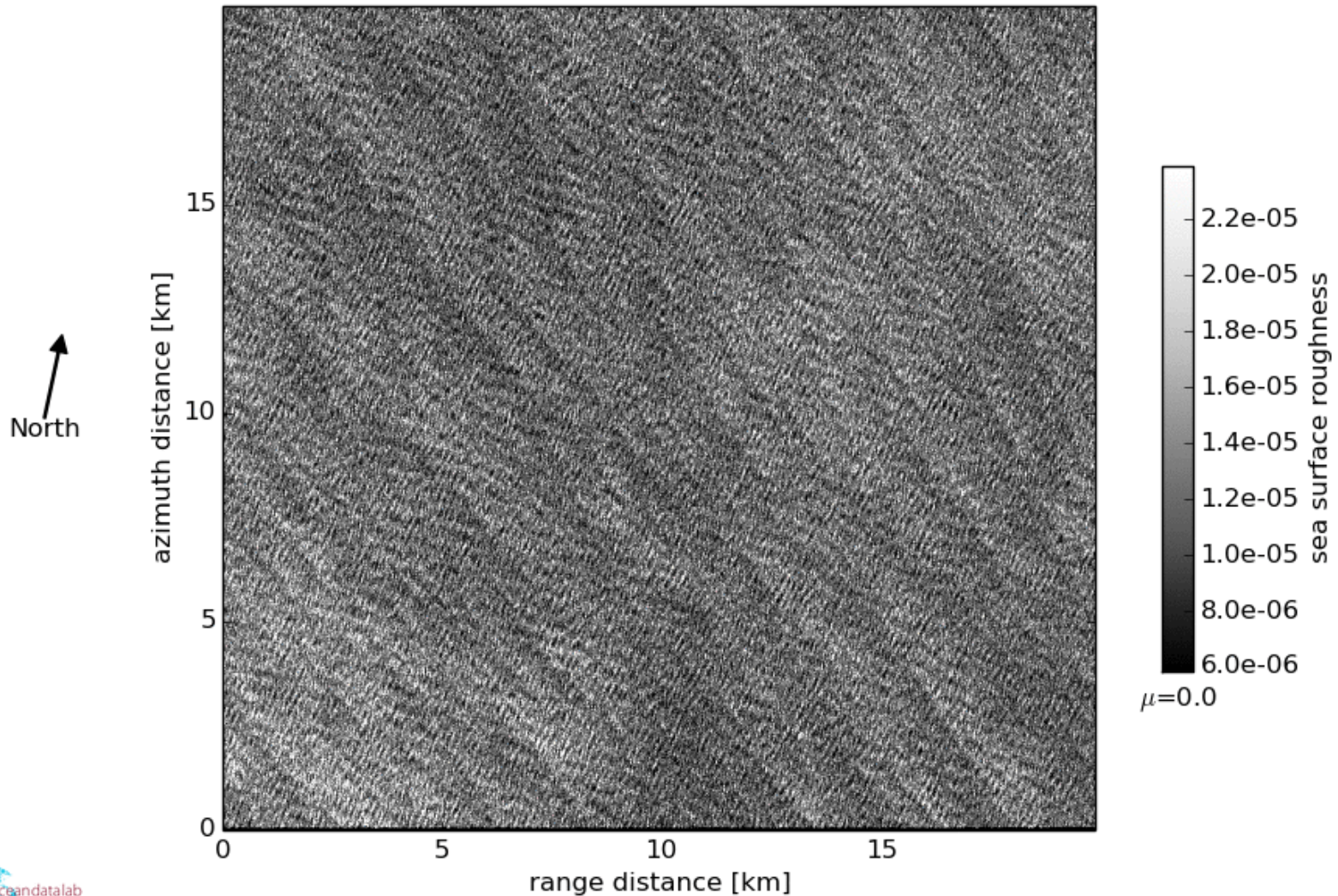
(A. Mouche)

Wave Mode : Imagette (20 x 20 km)



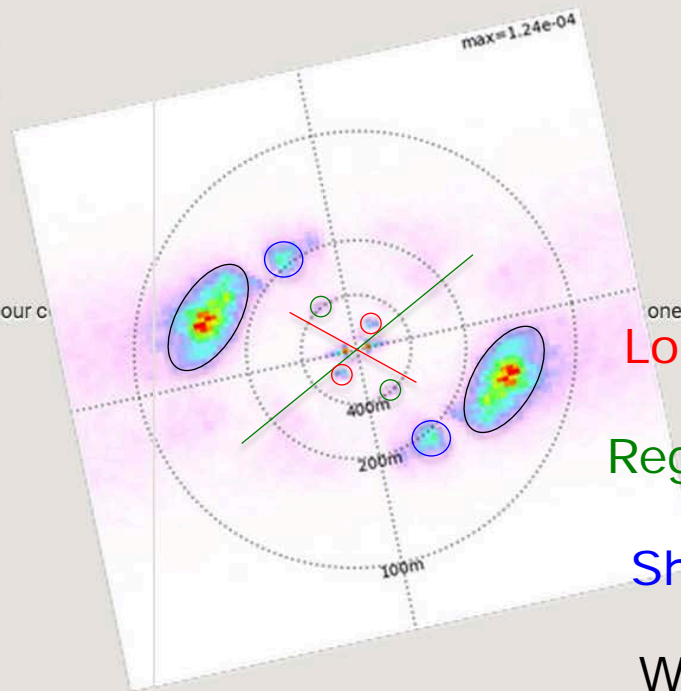
Imagette #016 from first track over Pacific

#016 / lon=-118.54 / lat=-5.90 / inc=38.24



Products

- ☐ SAR roughness (ESA, OceanDataLab)
- ☐ SAR cross-spectrum imaginary (ESA, OceanDataLab)
- ☒ SAR cross-spectrum real (ESA, OceanDataLab)



Long swell 800m

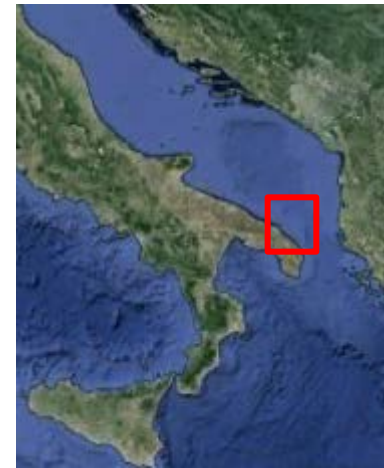
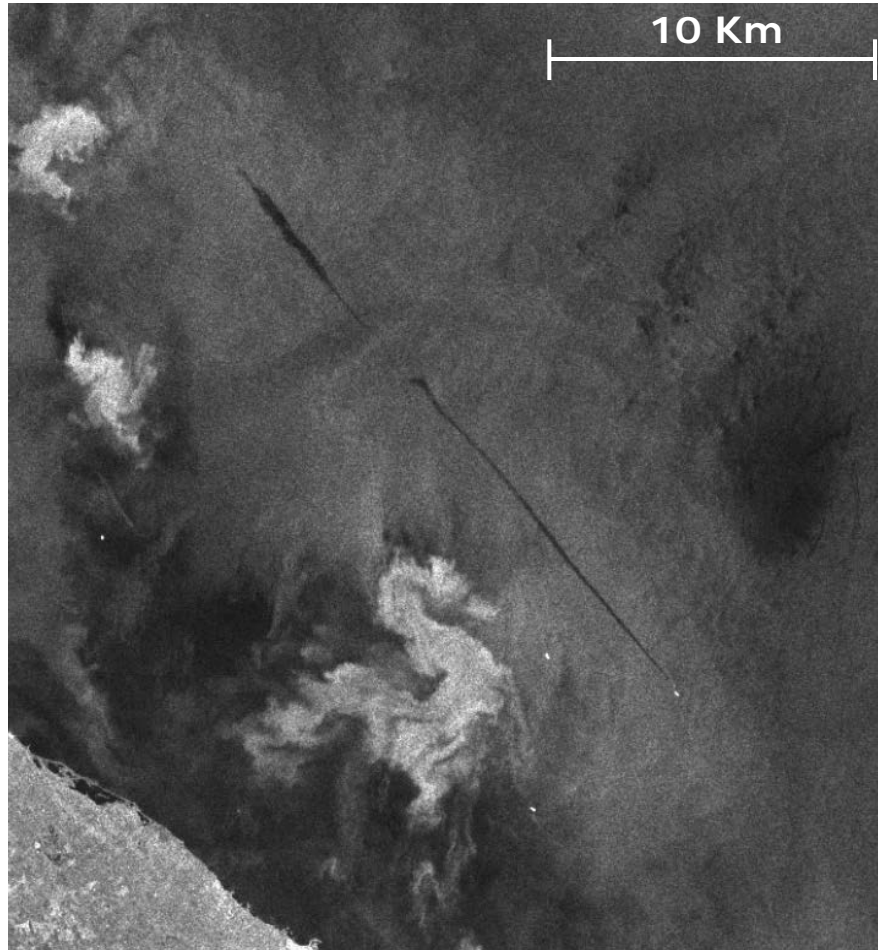
Regular swell 400m

Short swell 200m

Wind sea 150m

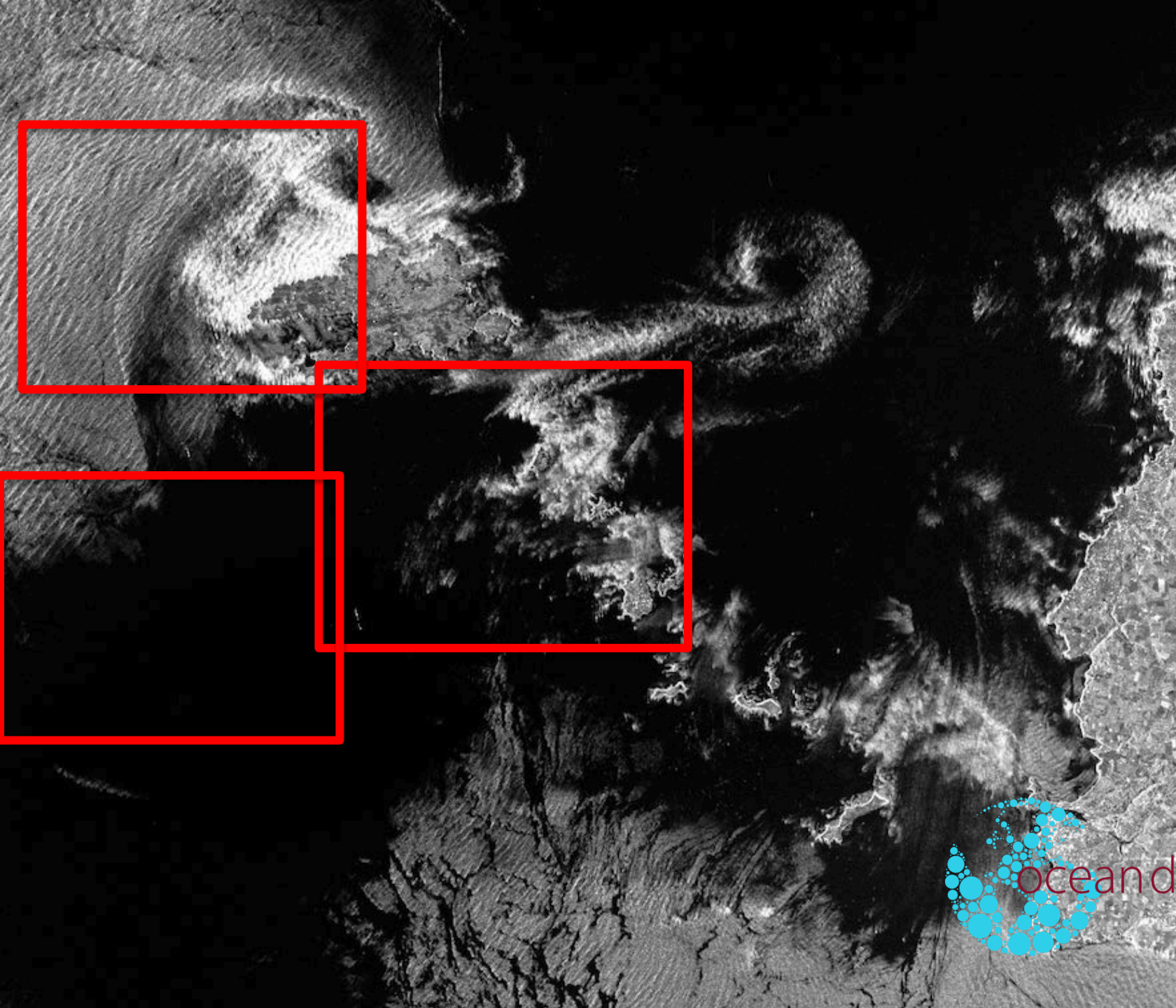


Oil discharge



(H. Greidanus and C. Santamaria, EC-JRC)

S1A_IW_GRDH_1SDV_20140903T045517_20140903T045542_002223_002459_3497
Lat: 40.340 Lon : 18.554





Sentinel-2

→ COLOUR VISION FOR COPERNICUS

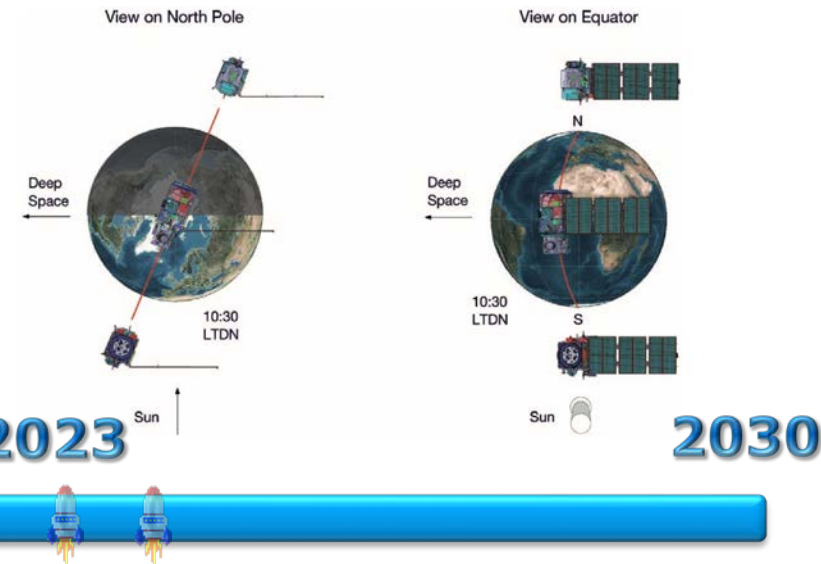
Launch Sentinel-2 (Vega, Kourou)

- Sentinel-2A launched on 23 June 2015
- Sentinel-2B launched on 7 March 2017



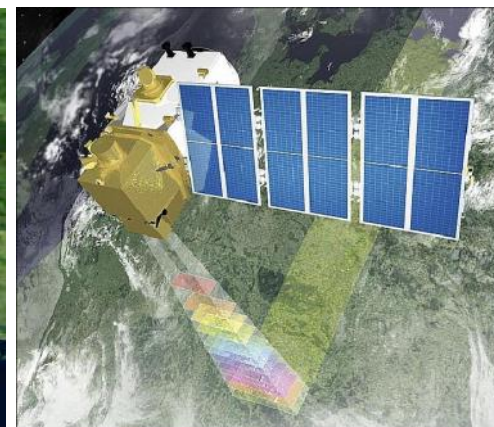
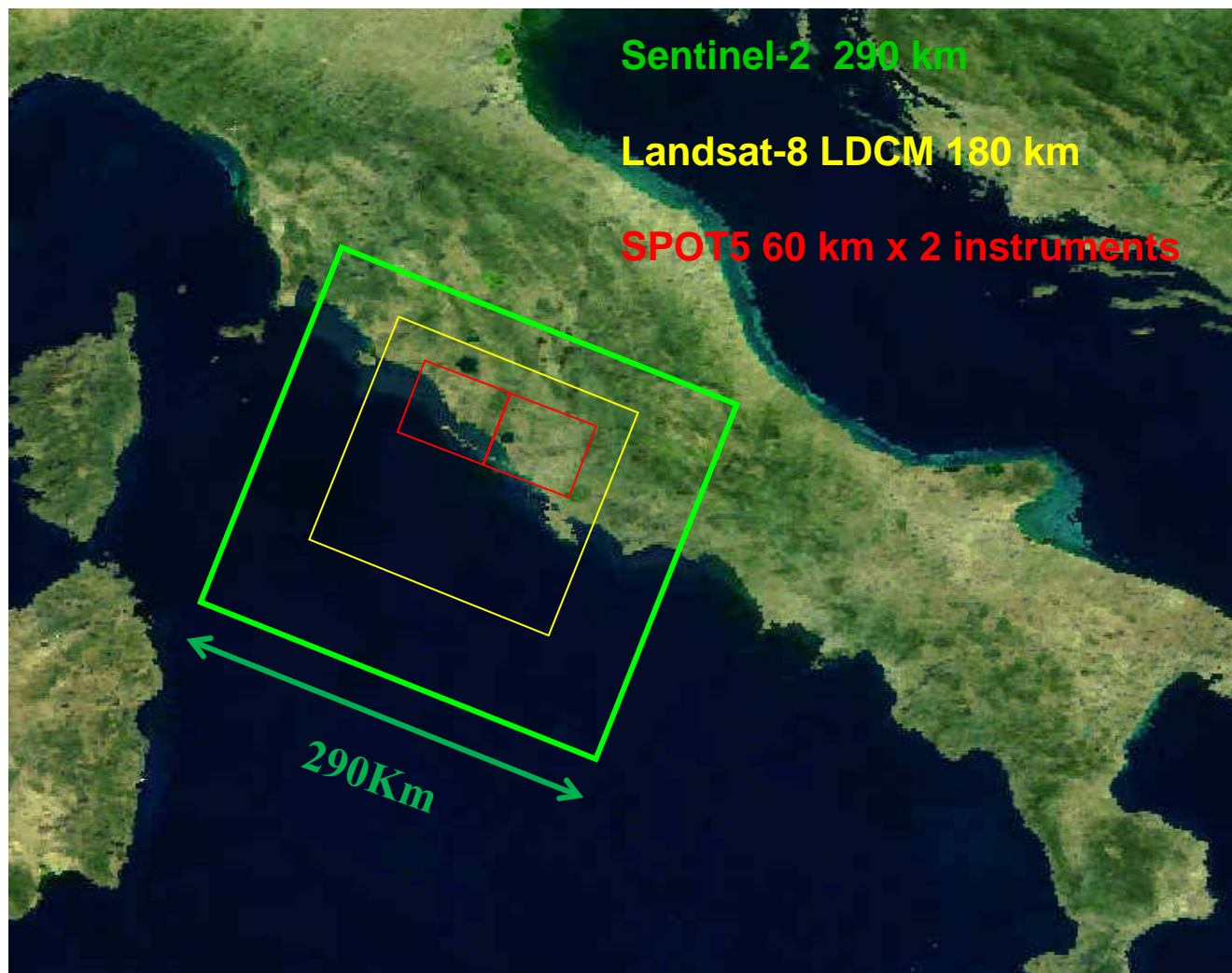
Sentinel-2 Mission Overview

- ❑ **Two** Identical Spacecraft operating in twin configuration
- ❑ Sun-synchronous orbit **786 km**, **LTDN** 10:30 AM
- ❑ **Multi-Spectral Instrument (MSI)** push-broom imager: filter-based, multi-spectral sampling, 295 km swath with **13** spectral bands (**VIS, NIR & SWIR**), at **10, 20** and **60 m** spatial resolution
- ❑ **5 day** revisit at Equator with 2 satellites
- ❑ **7 years** design life time for each satellite, consumables for 12 years



Sentinel-2 A/B/C/D

Sentinel-2: a big swath

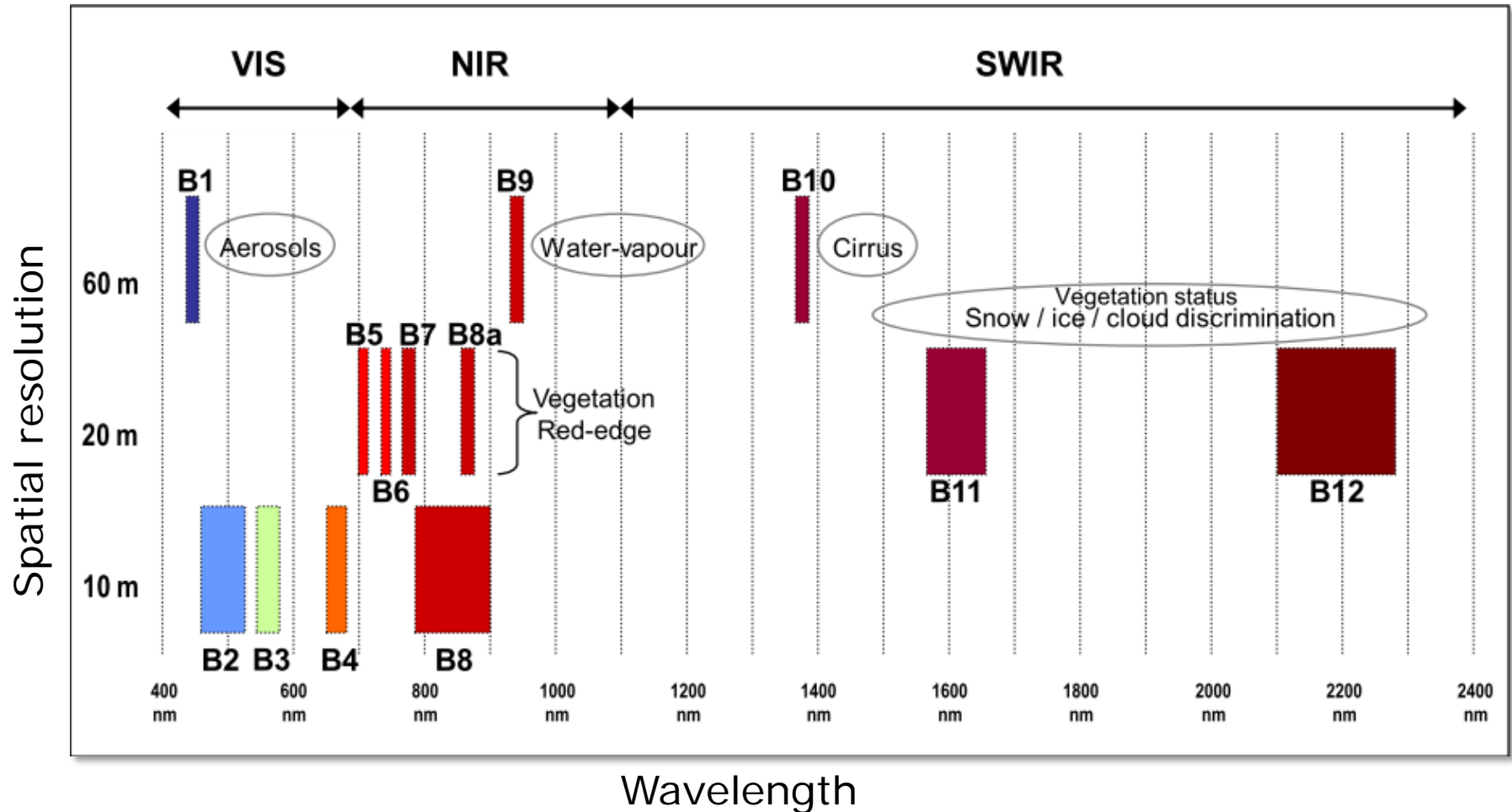


5 days revisit at
equator (cloud
free):

concurrent
observations of 2
satellites over a
very large swath

Multi-spectral Imager band settings

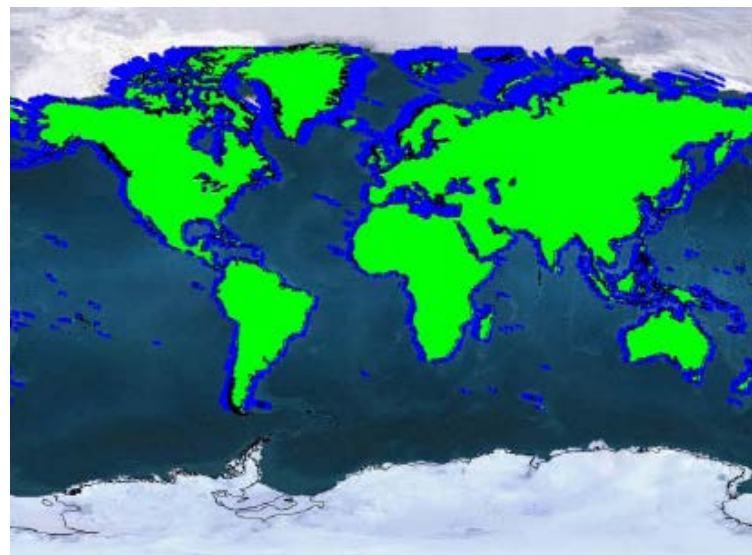
- 13 MSI bands are optimized for accurate atmospheric correction and vegetation monitoring
- But clearly have huge potential for marine applications



Sentinel-2 Acquisition Scenario

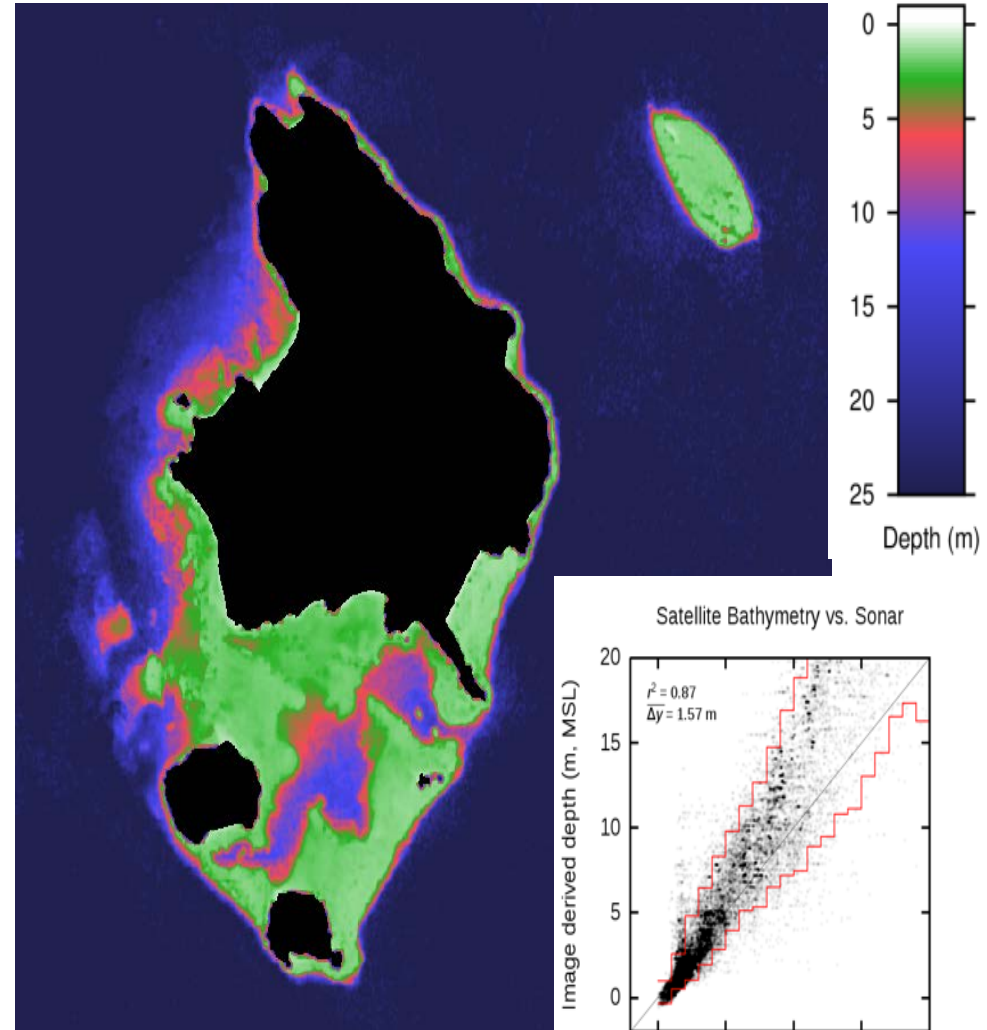
Systematic acquisition and systematic processing of Level-1B/1C data:

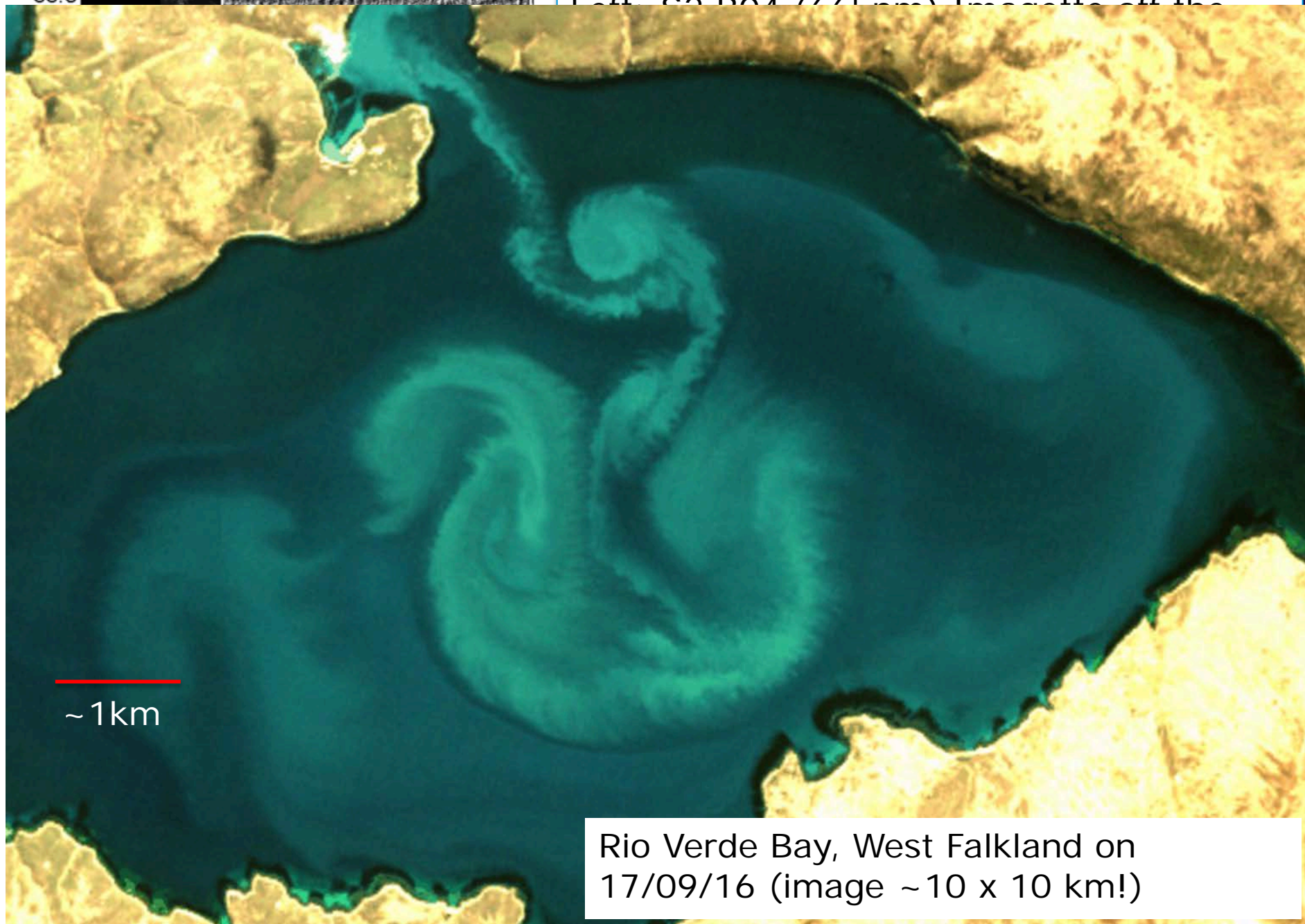
1. All land surfaces between 56deg South and 84deg North latitude
2. Major islands (greater than 100 km² size), EU islands and all the other small islands located at less than 20km from the coastline
3. Mediterranean Sea, all inland water bodies and all closed seas
4. Specific acquisition campaigns as required
5. 10-day revisit with 1 satellite
6. 5 day revisit with 2 satellites

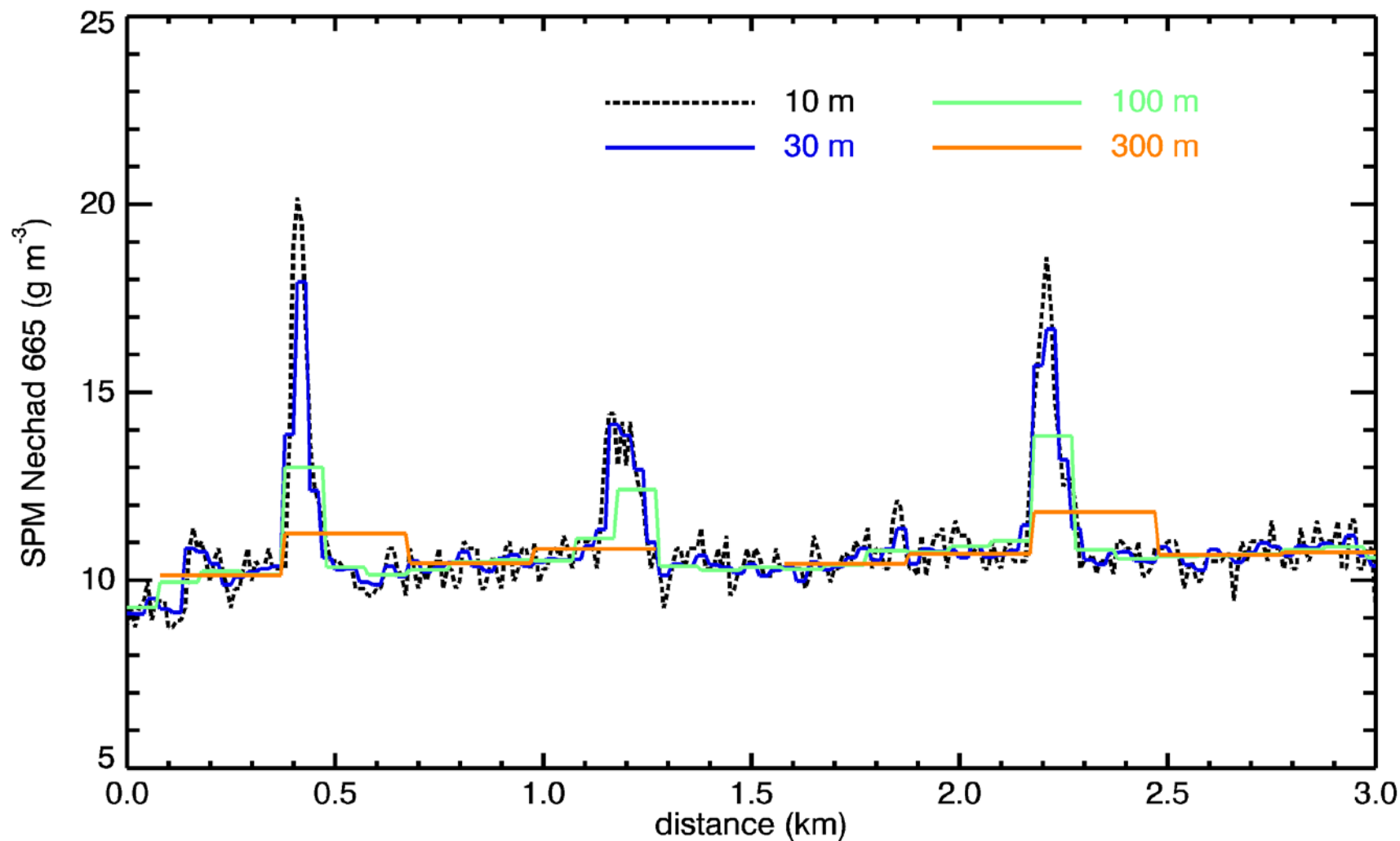


Coral Reef: Bathymetry

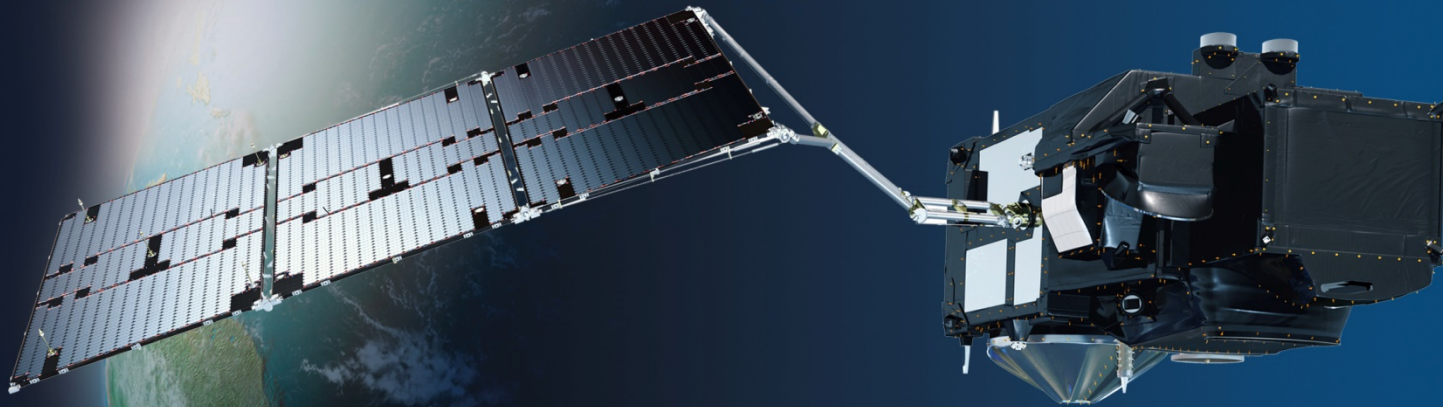
Lizard Island, Great Barrier Reef







(Quinten Vanhellemont & Kevin Ruddick)

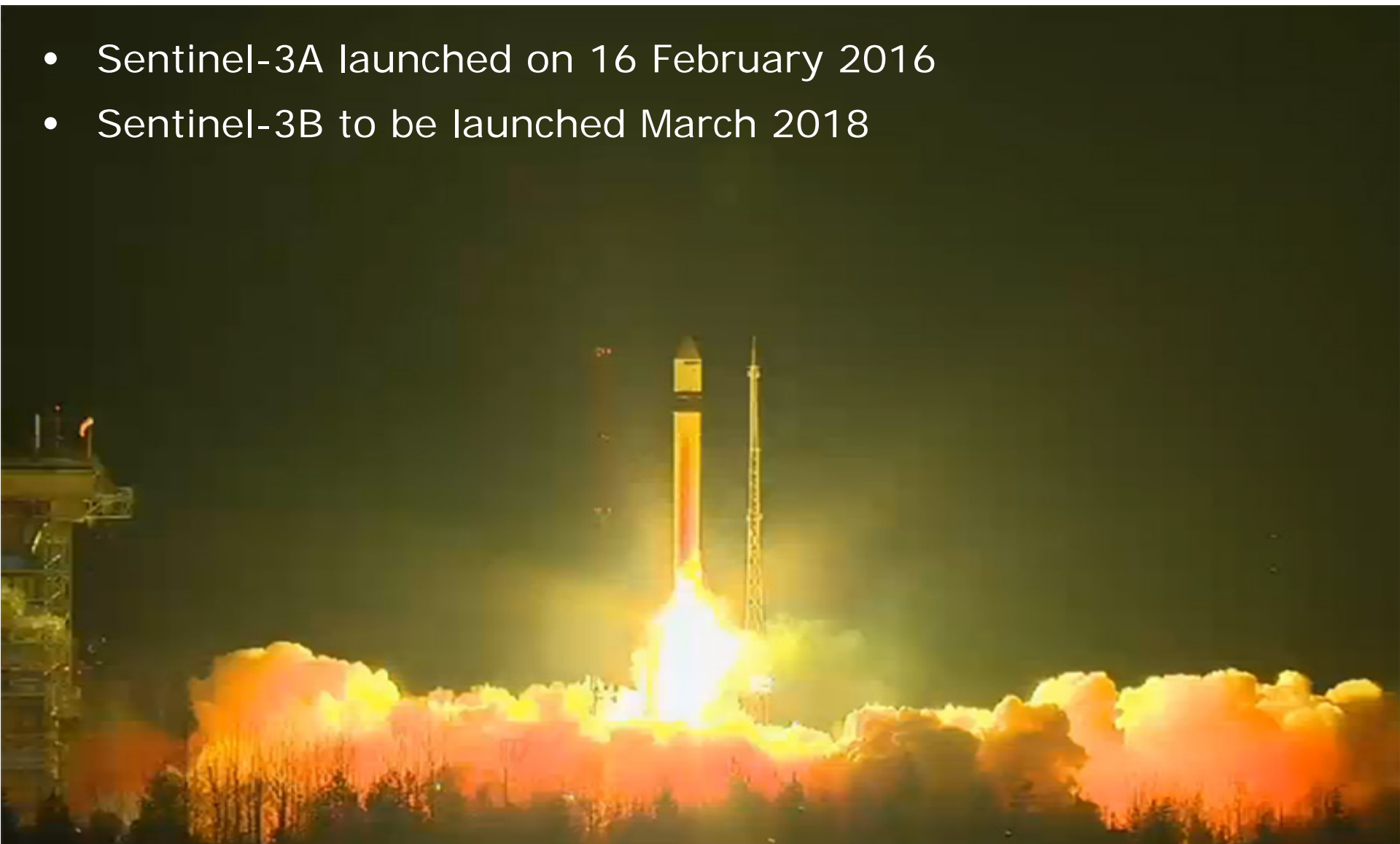


Sentinel-3

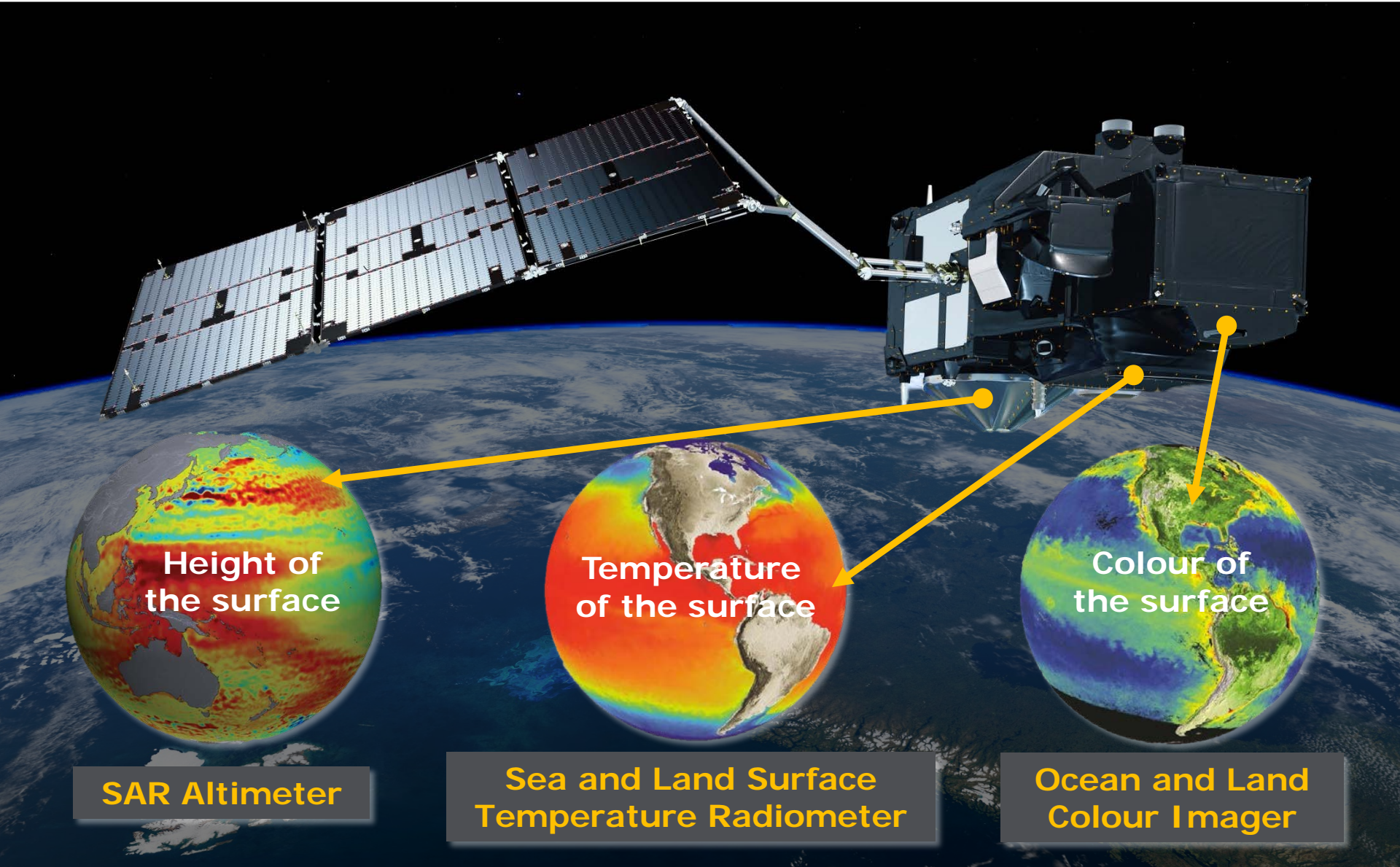
→ A BIGGER PICTURE FOR COPERNICUS

Launch Sentinel-3 (Rockot, Plesetsk)

- Sentinel-3A launched on 16 February 2016
- Sentinel-3B to be launched March 2018



Sentinel-3A: The Bigger Picture



Height of
the surface

SAR Altimeter

Temperature
of the surface

**Sea and Land Surface
Temperature Radiometer**

Colour of
the surface

**Ocean and Land
Colour Imager**

SENTINEL-3 MISSION OVERVIEW

- Operational mission in high-inclination, low Earth orbit
- Full performance achieved with 2 satellites in orbit (S-3A,-3B)

Optical Mission Payload providing

- ❑ Sea and land color data, through **OLCI (Ocean and Land Color Instrument)**
- ❑ Sea and land surface temperature, through the **SLSTR (Sea and Land Surface Temperature Radiometer)**

Topography providing

Mission

Payload

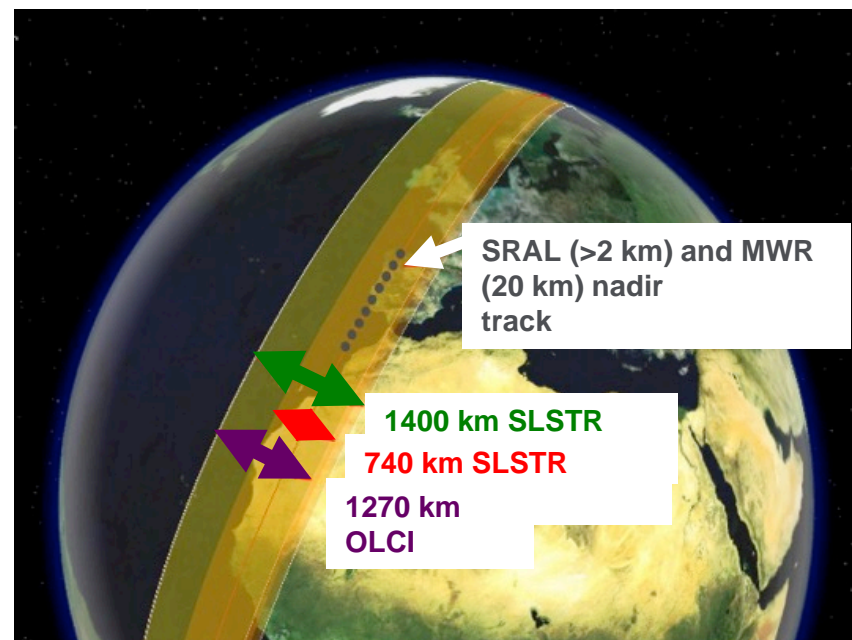
- ❑ Sea surface topography data, through a Topo P/L including a **Ku-/C-band Synthetic Aperture Radar Altimeter (SRAL)**, a bi-frequency **MicroWave Radiometer (MWR)**, and a **Precise Orbit Determination (POD)** including
 - **GNSS Receiver**
 - **DORIS**
 - **Laser Retro-Reflector**

In addition, the payload design will allow

- ❑ Data continuity of the Vegetation instrument (on SPOT4/5),
- ❑ Enhanced fire monitoring capabilities, river and lake height, atmospheric products

- ❑ **100% overlap** between SLSTR and OLCI
- ❑ **Increased number of bands** compared to both AATSR and MERIS allowing
 - ❑ Synergy between OLCI and SLSTR measurements
 - ❑ Enhanced fire monitoring capabilities
 - ❑ Enhanced ocean colour products
- ❑ **Broader swath**
 - ❑ OLCI: from 1150 km to 1270 km
 - ❑ SLSTR: Nadir view 500km → 1400km, Oblique view: 500km → 740km
- ❑ Optical payload **< 2 days global coverage** (with 2 Satellites) in view of the substantially increased swath
- ❑ **Increased spatial resolution:**
 - ❑ OLCI: 300m for land and ocean
 - ❑ SLSTR: 500m for VIS-SWIR, 1km for IR-Fire
- ❑ **Mitigation of sun glint** by tilting cameras 12.5 deg in westerly direction
- ❑ **Near-Real Time** (< 3 hr) availability of L1 and L2 core products

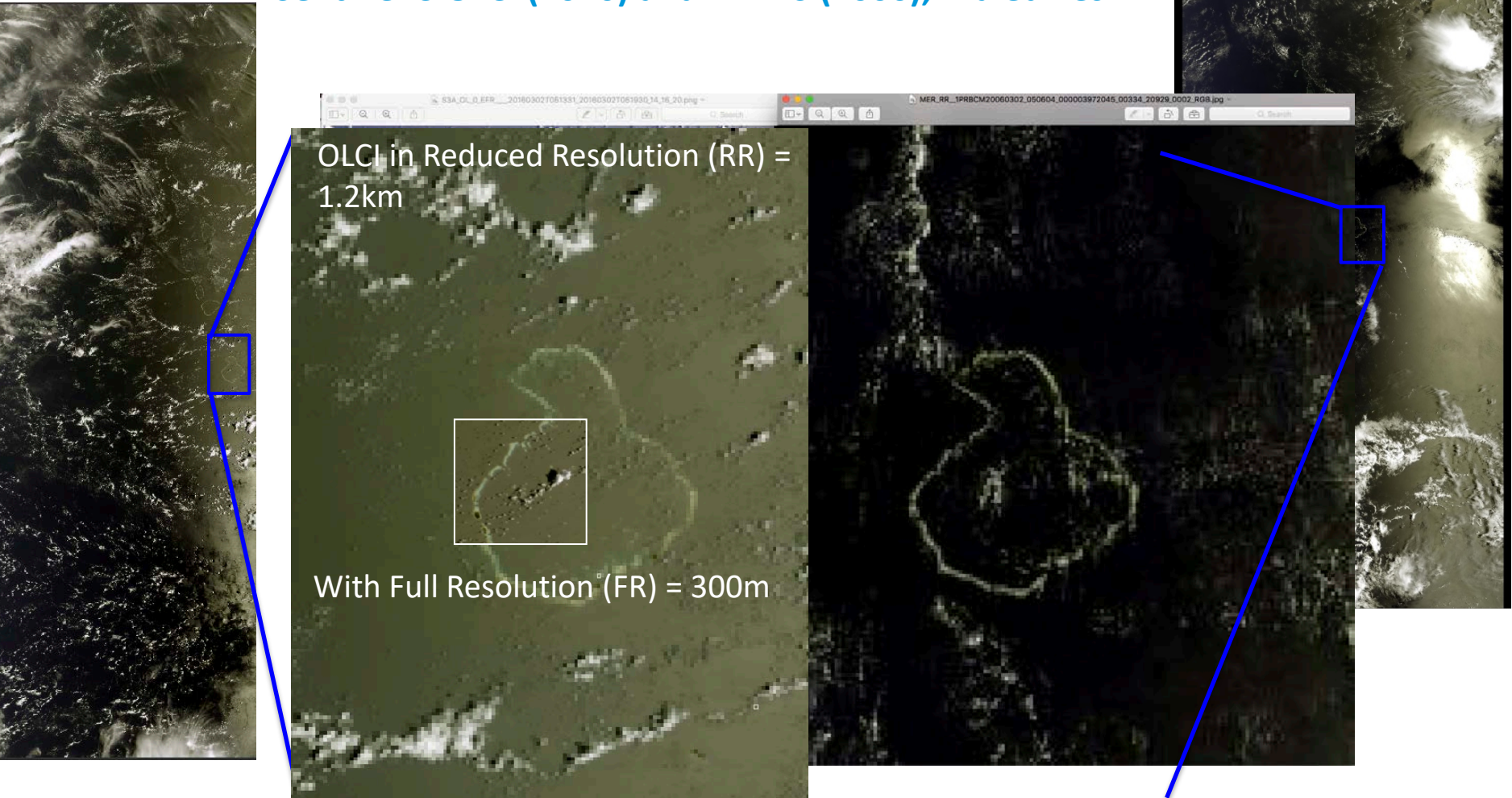
Instrument Swath Patterns



Orbit type	Repeating frozen SSO
Repeat cycle	27 days (14 + 7/27 orbits/day)
LTDN	10:00
Average altitude	815 km
Inclination	98.65 deg

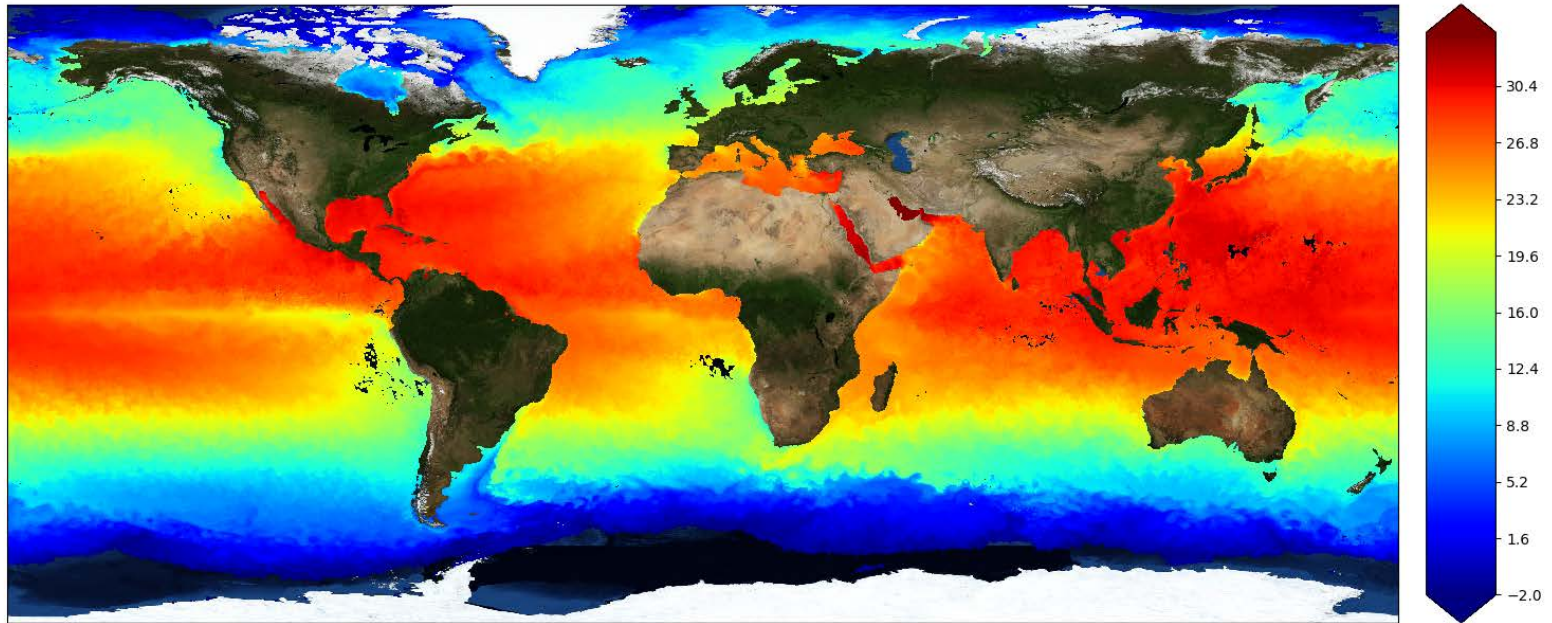
OLCI versus MERIS: FR versus RR

Sentinel-3 OLCI (2016) and MERIS (2006), Maldives



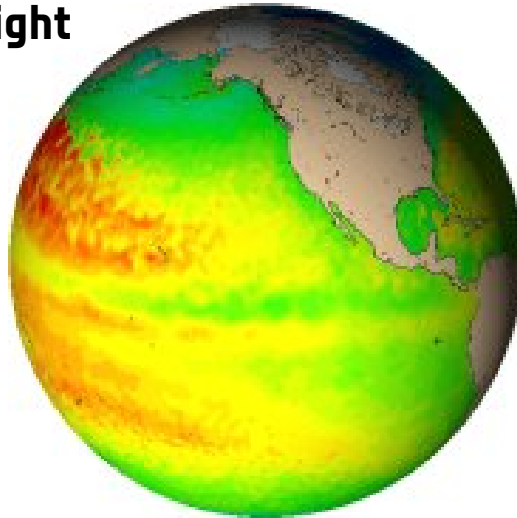
Sentinel-3: Example data

Sentinel 3A SLSTR sea surface temperature (S3A_SL_2_WST) - August 2016

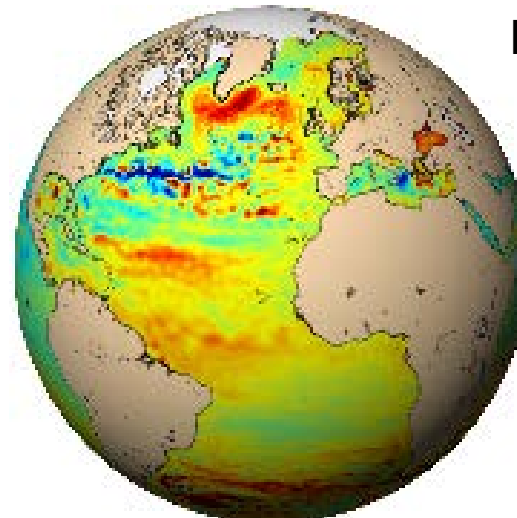


Global SAR Sea Surface Altimetry

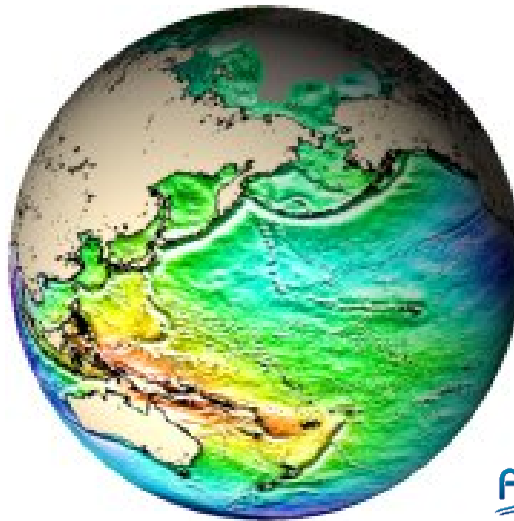
Sea Surface Height



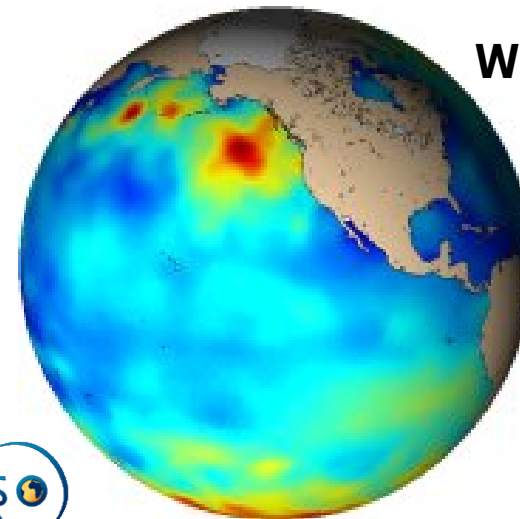
Mean Sea level

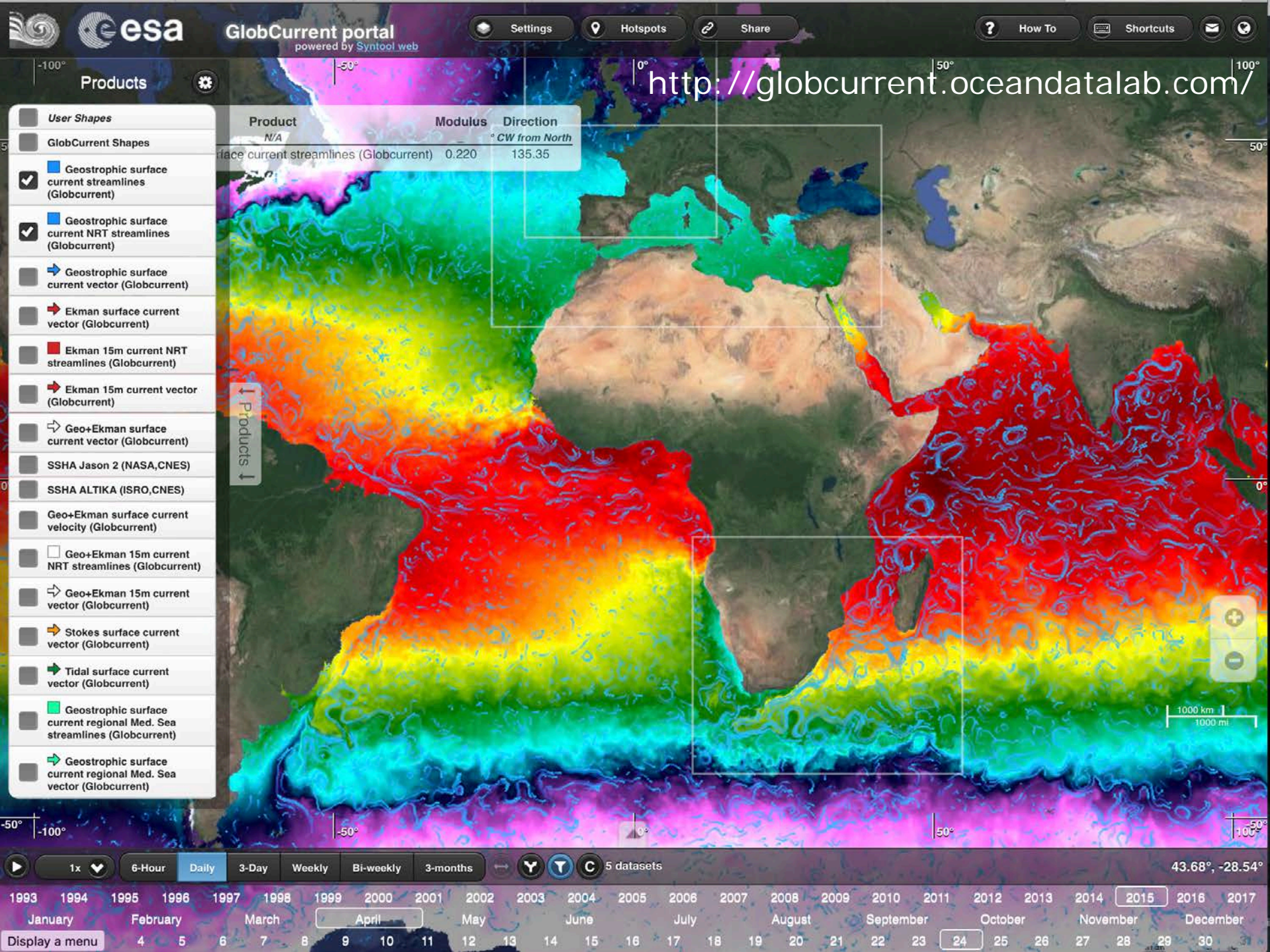


**DEM, Tides,
River and lake
Heights, MSS
...**



Wind and Waves





OLCI 2 day and 3 day coverage after mitigation of sun-glint

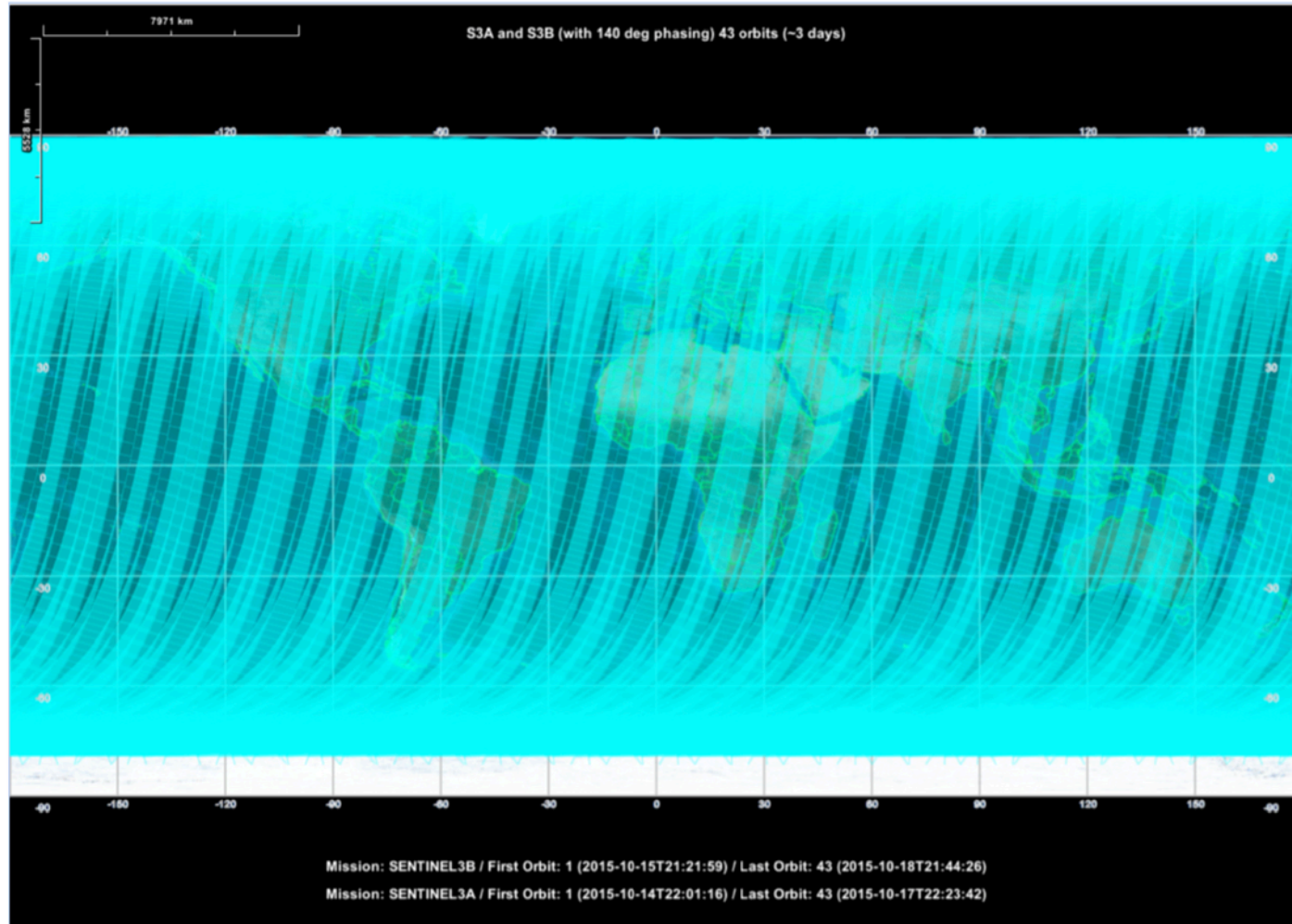
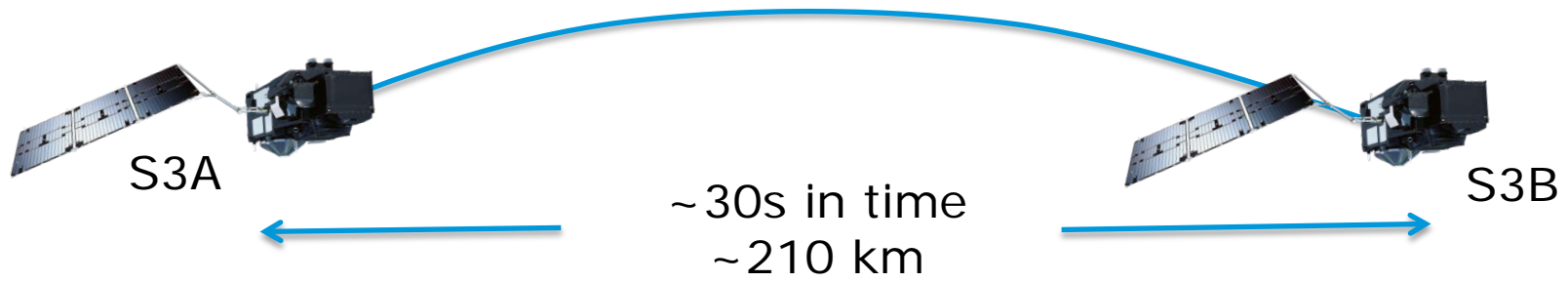


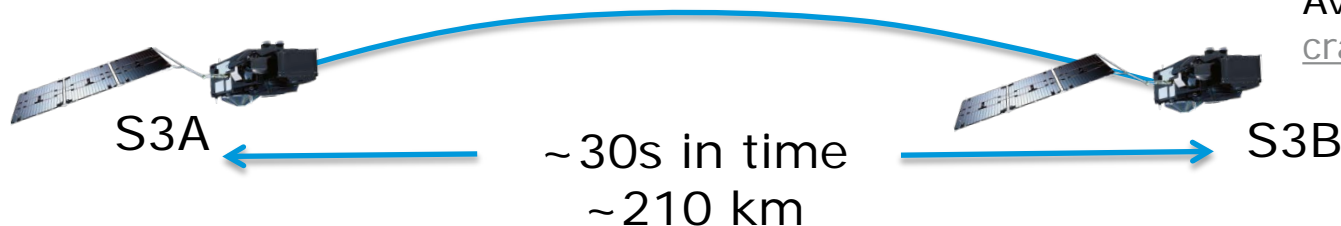
Figure 7. Complete coverage of OLCI after mitigation of sun-glint with S3B set in 140° phasing with S3A is reached after 3 day

Sentinel-3 Tandem phas



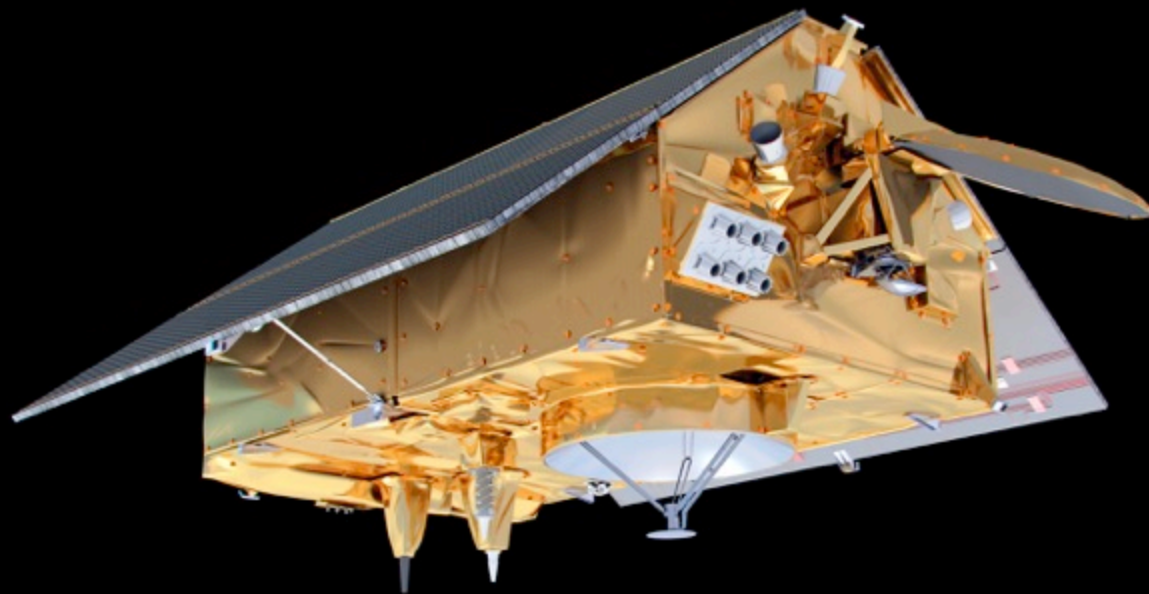
Tandem Rationale

- A tandem phase operation of the A/B pair with ~ 30 s separation in time between satellites on the same ground-track for ~ 4 -5 months will be flown during Phase E1.



Tandem rationale
Available on request from
craig.donlon@esa.int

- At ~ 30 s, the atmospheric and oceanic variability will be reduced to negligible levels \rightarrow reduced uncertainty when comparing data.
- At ~ 30 s, more dynamic targets such as convective cloud tops and hot deserts can be included in verification work.
- multiple coincidences extracted across a full range of atmospheric conditions at all latitudes will give the statistical power to characterise relative calibration to the precision required.
- We can run S3A and S3B instruments in different modes
- We are interested in new science aspects of the Tandem phase.



Sentinel-6/Jason-CS



ESA UNCLASSIFIED - For Official Use



European Space Agency

Mission aim and Objectives

The aim of the Sentinel-6 mission is to provide **continuity of satellite altimetry measurements** following TOPEX/Poseidon, Jason-1, Jason-2, and Jason-3 missions.

The mission will **extend this measurement time series to ~2030+ without degradation** in precision and accuracy.

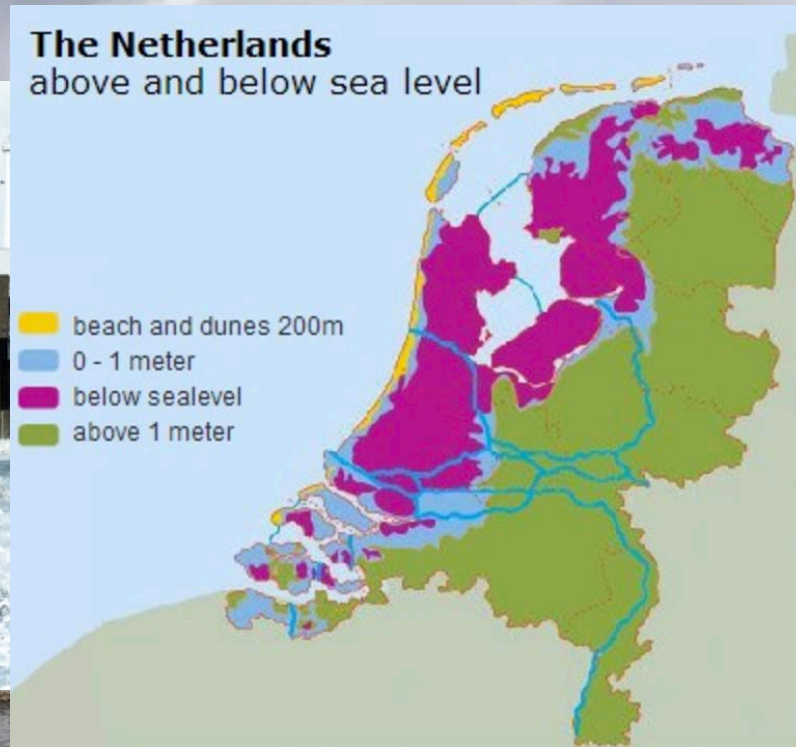
High Resolution altimetry based on **unfocused SAR (Synthetic Aperture Radar)** processing
combined with the **conventional Low Resolution Mode (LRM)** altimetry;

Sentinel-6 mission will take the **role of the reference mission** in the CEOS- coordinated virtual constellation of ocean surface topography missions

Sea level change: impacts

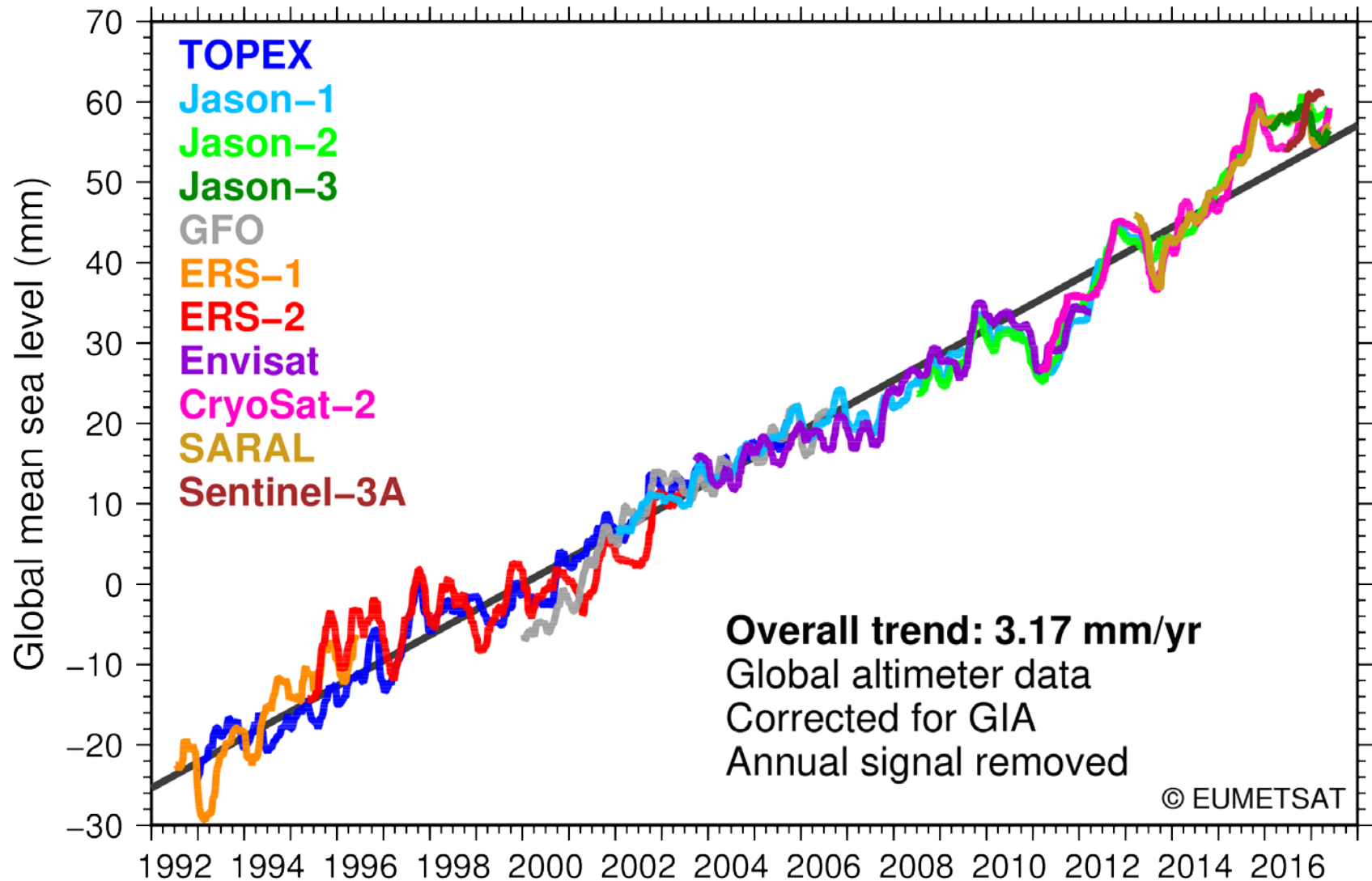


Oosterscheldekering
Storm Surge Barrier

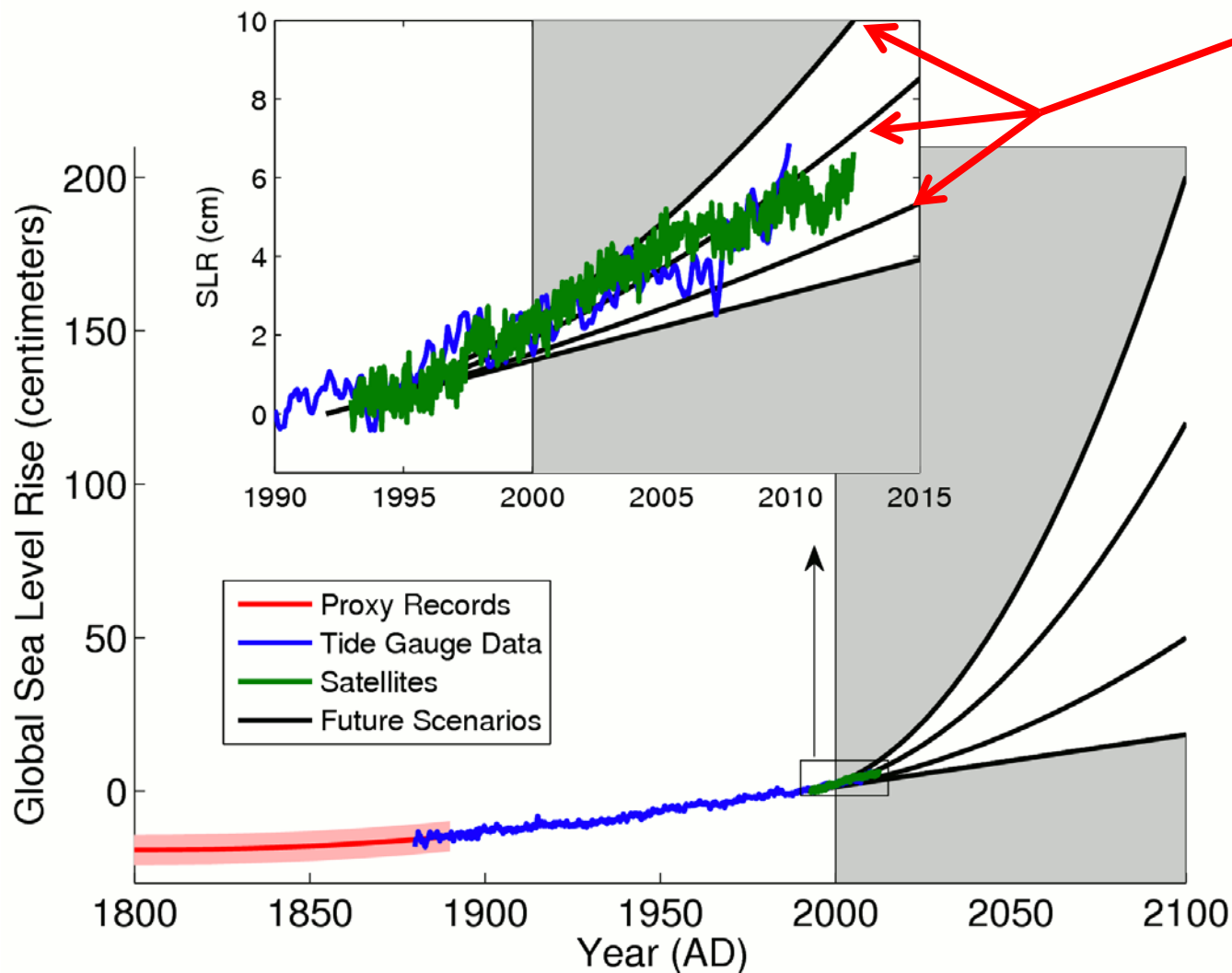


Maeslant Storm
Surge Barrier

Sentinel-3 will extend Multi-Mission altimetry sea level time series covering polar seas...



Future Rise



(J. Willis)

EU/US Satellite Altimetry Instruments/Missions

Poseidon-1



1992
TOPEX/
Poseidon

Poseidon-2



2001
JASON-1

Poseidon-3



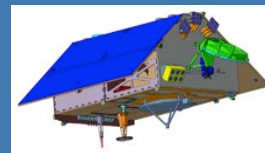
2008
JASON-2

Poseidon-3B



2015
JASON-3

Poseidon-4



2020
S6/J-CS A

Poseidon-4

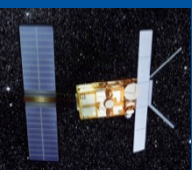


2026
S6/J-CS B



Polar Orbit Missions

RA



1992
ERS-1

RA



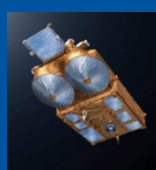
1995
ERS-2

RA-2



2002
ENVISAT

SIRAL



2005
CS-1

SIRAL



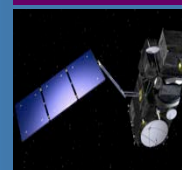
2010
CS-2

SARA



2012
Altika

SRAL



2016
S3-A

SRAL



2018
S3-B

SRAL

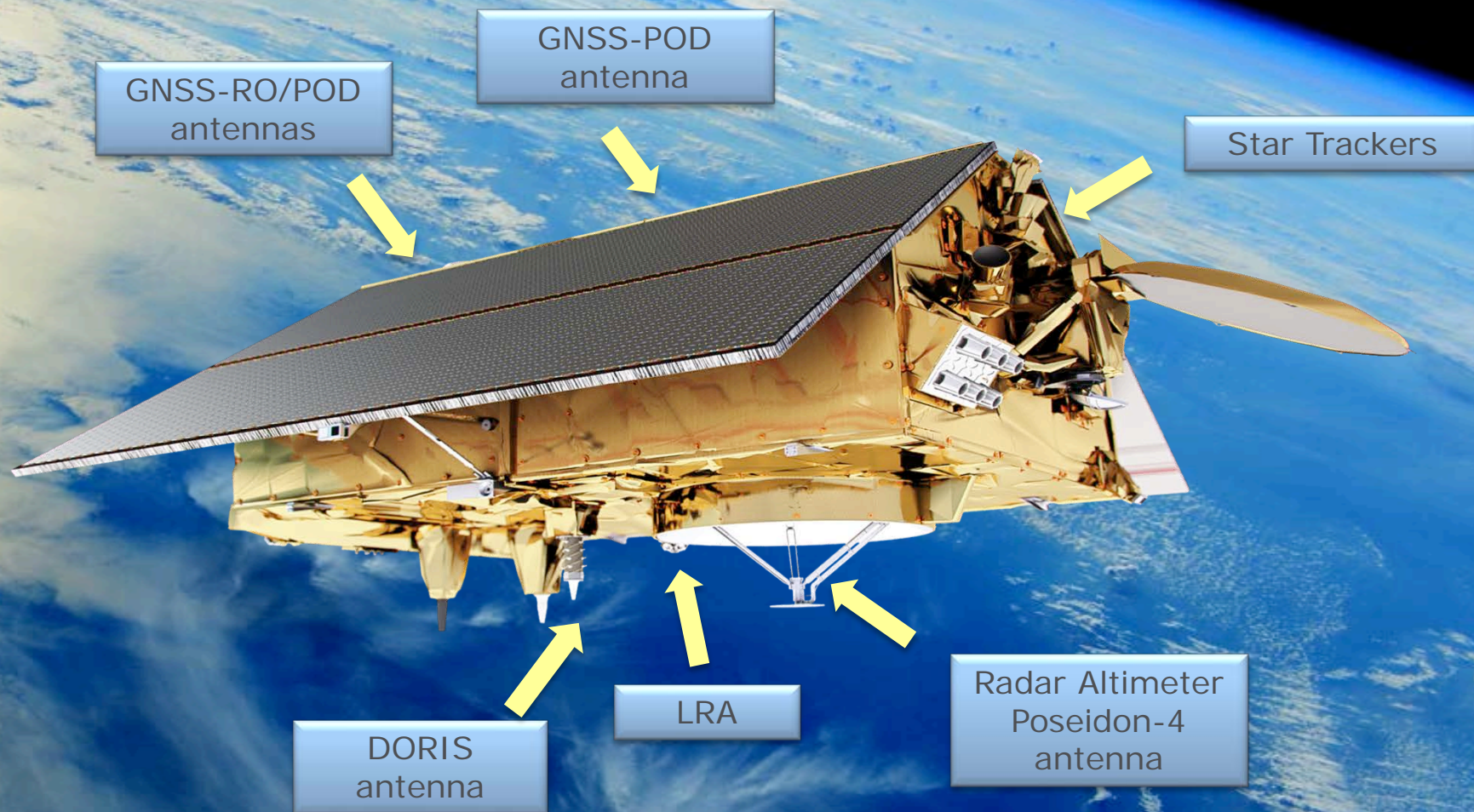


2023
S3-C

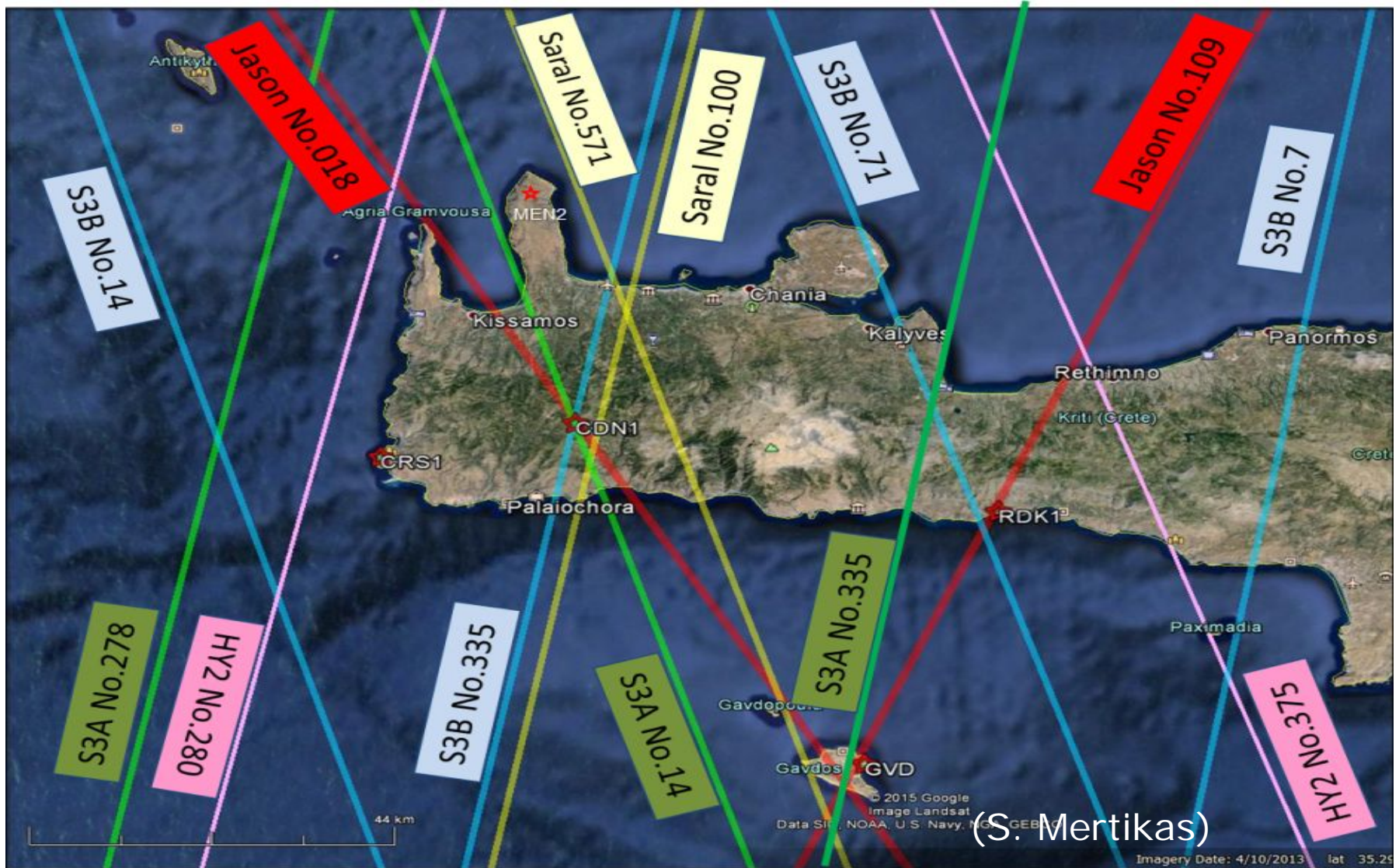
SRAL



2026
S3-D



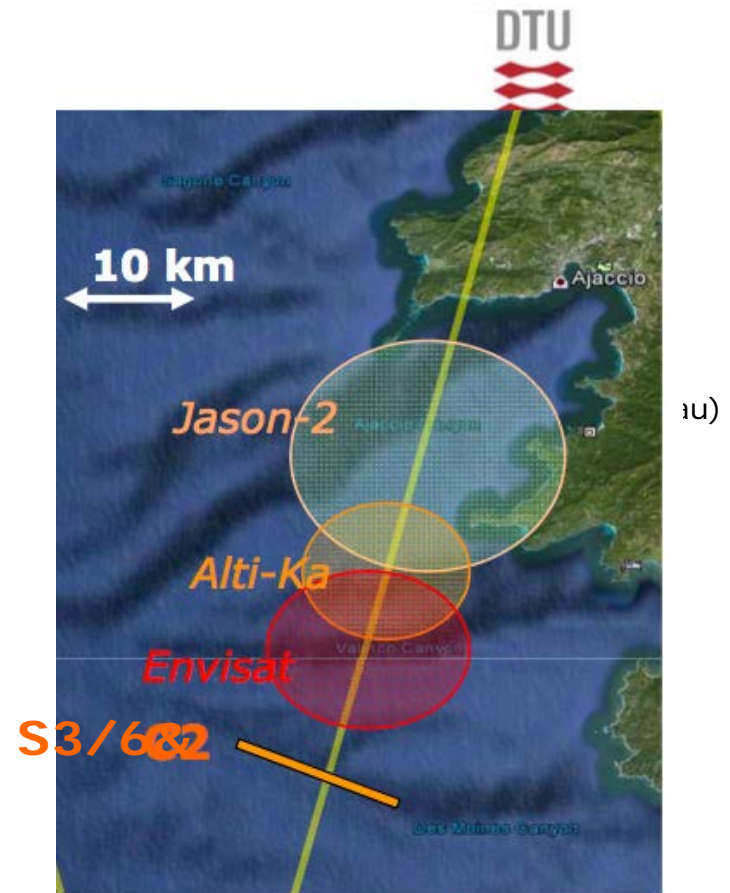
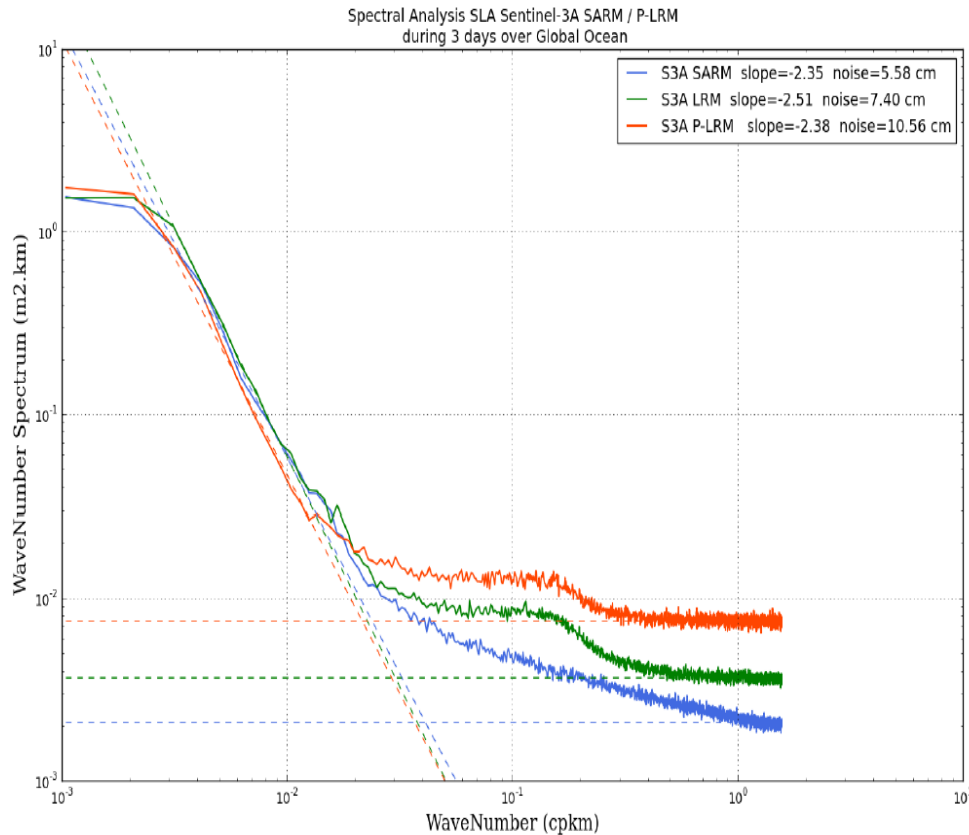
Multi-mission altimetry sampling



Sentinel-3A Spectral analysis

Expect Sentinel-6/Jason-CS to be slightly below Sentinel-3

SARM and P-LRM from 2016-04-06 to 2016-04-09
LRM from 2016-04-03 to 2016-04-06



Open and Free data access policy

<https://sentinels.copernicus.eu>

<https://scihub.copernicus.eu/>



Welcome to the Sentinels Scientific/Other use Data Hub

The [Sentinels](#) Scientific Data Hub provides free and open access to a rolling repository of [Sentinel-1](#) and [Sentinel-2](#) from the In-Orbit Commissioning Review (IOCR).
Start of rolling activity will be announced to users before activation.



Scientific Hub



API Hub



S-2 PreOpsHub



User Guide

Access Points

Scientific Hub : access point for all sentinel mission with access to the interactive graphical user interface.

API Hub : access point for API users with no graphical interface. All API users regularly downloading the latest S-1 data are point for a better performance.

Sentinel-2 Pre-operational Hub : pre-operational access point for all users to Sentinel-2 data. **Login credentials are guest:guest**

Due to the massive increase of requests on the Scientific Data Hub that have been creating performance issues in the recent API Hub, is now being operated in parallel to the Scientific Data Hub. This API Hub is dedicated to users of the scripting interface.

The API Hub Access is currently available only for users registered on SciHub before the 21st of December 16:46 UTC. The site access this site.

The API Hub may be accessed through the URL <https://scihub.copernicus.eu/apihub/>. This implies that the OpenData API is published at <https://scihub.copernicus.eu/apihub/odata/v1>. The API Hub is managed with the same quota restrictions, ie. a limit of two parallel downloads per user. The site is publishing as the Scientific Data Hub, with all new data as of the 16th November. A rolling policy for the Hub will be established following operations.



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Welcome to Sentinel Online

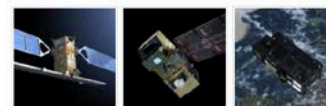


THIRD SENTINEL SATELLITE LAUNCHED

The third ESA-developed satellite carrying four advanced Earth-observing instruments was launched on 16 February, and land surface colour with high accuracy.

[Read more](#)

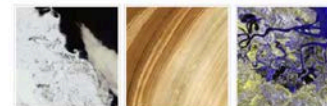
Sentinel Missions



Learn more about the Sentinel missions here, with comprehensive information about mission objectives, spacecraft design, instrument payloads and data products, as well as the latest mission news.

[Read more](#)

Thematic Areas



There are many applications for the data acquired from the Sentinel missions. The Thematic Areas expand on six main categories: land management, marine environment, atmosphere, emergency response, security and climate change.

[Read more](#)

Collaborative Ground Segment

Sentinel Data Products



Sentinel News

- [Sentinel-3A dances with northern lights](#)
- [Third Sentinel satellite launched for](#)
- [Sentinel-3A launch rehearsal complete](#)

Events

- [Big Data from Space 2016](#)
- [EO Open Science and ESA SEOM sessions at EGU 2016](#)
- [Living Planet Symposium 2016](#)
- [1st ESA Advanced Training Course on Remote Sensing of the Cryosphere](#)
- [See all Sentinel Events](#)

Browse to Other Sites

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- [Earth Online](#)
- [CSCDA](#)
- [Copernicus Data Quick Look Portal](#)
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- [ESA Climate Change Initiative](#)
- [Ground Segment Coordination Body \(GSCB\)](#)
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Sentinel data access tools @ ESA



Open Data Protocol (OData)

The Open Data Protocol (OData) enables the creation of REST-based data services, which allow resources, identified using Uniform Resource Identifiers (URIs) and defined in a data model, to be published and consumed by Web clients using simple HTTP messages.

The OData protocol provides easy access to the Data Hub and can be used for building URIs for performing search queries and product downloads offering to the users the capability to remotely run scripts in batch mode.

URI Components

A URI used by an OData service has up to three significant parts: the service root URI, resource path and query string options:

```
<idbua_hostname>:<port>/<odata/v1/><product>?<filter>=<query>[&[option]]
```

where:

- <idbua_hostname>=<port>/<odata/v1/> is the **service root URI** which identifies the root of an OData service
- <product> is the **resource path**. It identifies the resource to be interacted with. The resource path enables any aspect of the data model (Data Hub Products, Collections, etc.) exposed by the OData service
- ?<filter>=<query>[&[option]] is the **query string options part**

Scientific Data Hub service root URI:

- <ServiceRootURI> = <https://scihub.esa.int/odata/v1/>

Query String Options admitted by the Data Hub service:

- \$format Specifies the HTTP response format
- \$filter Specifies an expression
- \$orderby Determines what value
- \$select Specifies a subset of properties
- \$skip Sets the number of records to skip
- \$top Determines the maximum number of records to return

Data Hub Resource Paths:

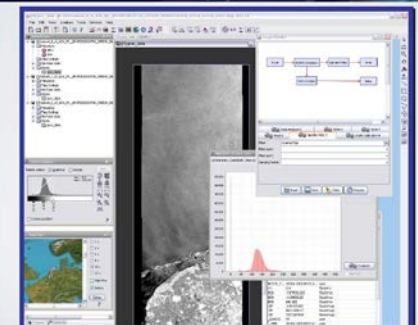
- /Products

Examples of OData URIs for the Scientific Data Hub:

- [https://scihub.esa.int/odata/v1/Products?filter=eq\('S2A_OPER_PRD_MSIL1C_PDMC_20160407T123928_R115_V...'\)](https://scihub.esa.int/odata/v1/Products?filter=eq('S2A_OPER_PRD_MSIL1C_PDMC_20160407T123928_R115_V...')) lists the last 100 products published
- [https://scihub.esa.int/odata/v1/Products?filter=eq\('S2A_OPER_PRD_MSIL1C_PDMC_20160407T123928_R115_V...'\)&\\$top=100&\\$skip=0](https://scihub.esa.int/odata/v1/Products?filter=eq('S2A_OPER_PRD_MSIL1C_PDMC_20160407T123928_R115_V...')&$top=100&$skip=0) lists the first 100 products skipping the first 0

APIs
scripting
automatic
interface:
for data

SNAP Sentinel toolbox



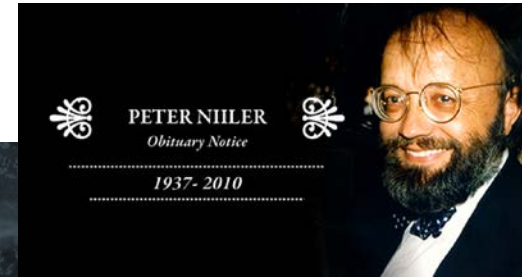
Sentinel Toolbox available as open source software

<https://github.com/senbox-org>

Data Hub Server available as open source software

<https://github.com/SentinelDataHub/DataHubSystem>

Oceanographic Priorities for 2025 (Peter Niiler 2009)



“The oceanography of 2025 will require observations and realistic modelling of the circulation patterns that contain the vertical motion of the upper 200m.

Models will be compared not by how well they assimilate or replicate the sea-level or reproduce the geostrophic velocity, but rather by how their internal vorticity, thermal energy and fresh water balances maintain ageostrophic velocity structures and the associated vertical circulations.

This task calls for development and implementation of new methods and instruments for direct velocity observations of the oceans”

ESA Ocean Training 2017, Porto Portugal

11-15th September 2017



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	Monday	Tuesday	Wednesday	Thursday	Friday				
<div>Ocean Synergy Challenge [1]</div>	<div>Mesoscale and sub-mesoscale Structures</div> <div>□</div>	<div>Sea Level and Ocean Surface Transport</div> <div>□</div>	<div>Wind Waves and Wave/current interaction</div> <div>□</div>	<div>Salinity and Marine Inorganic Carbon</div> <div>□</div>	<div>Climate Change and Polar Oceans</div> <div>□</div>				
08:30	Registration	Lecture 3: Sea Level and ocean heat content from space	Lecture 5: Wind waves and wave current interaction from space	Lecture 6: Measuring ocean surface salinity from space	Lecture 8: Polar oceans and Climate change from space				
09:00	Official Welcome								
09:15	Course introduction								
09:30	Lecture-1: Measuring the ocean using different satellite instruments in synergy	Interactive Lecture 4: What can an ocean altimeter do for me?	Interactive Lecture 8: How to measure ocean waves from space [1]	Interactive Lecture 12: Investigating sea surface salinity from space [1]	Interactive Lecture 16: Understanding the polar oceans from space				
09:45									
10:00									
10:15									
10:30	Coffee	Coffee	Coffee	Coffee	Coffee				
11:00	Interactive Lecture 1: Exploring the ocean mesoscale and sub-mesoscale using thermal and optical imagery	Interactive Lecture 5: Investigating sea level and ocean heat content using satellite altimeters	Interactive Lecture 9: How to measure ocean waves from space [2]	Interactive Lecture 13: Investigating sea surface salinity from space [1]	Interactive Lecture 17: Climate impact and the polar oceans				
11:15									
11:30									
11:45									
12:00	Lecture-2: Ocean Biology from Space								
12:15									
12:30									
12:45									
13:00	Lunch	Lunch	Lunch	Lunch	Lunch				

