Copernicus Sentinel Missions

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

Overview

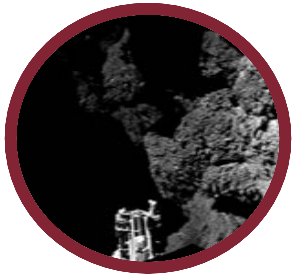
- Bit about ESA...
- Copernicus and Oceanography
- Sentinel-1
- Sentinel-2
- Sentinel-3
- Sentinel-6
- Summary and conclusions

ESA facts and figures

- 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

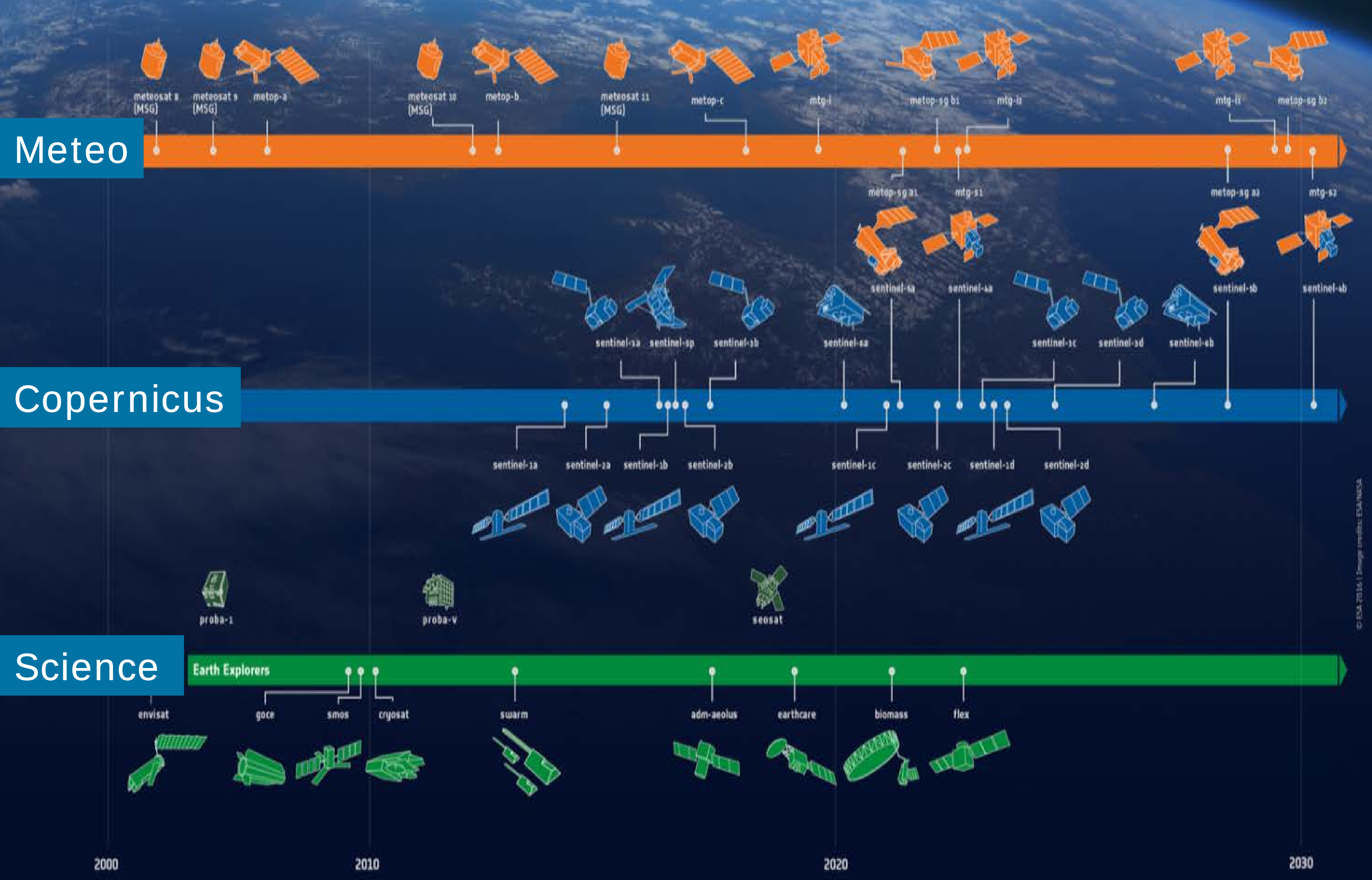
navigation

operations

technology

telecommunications


24

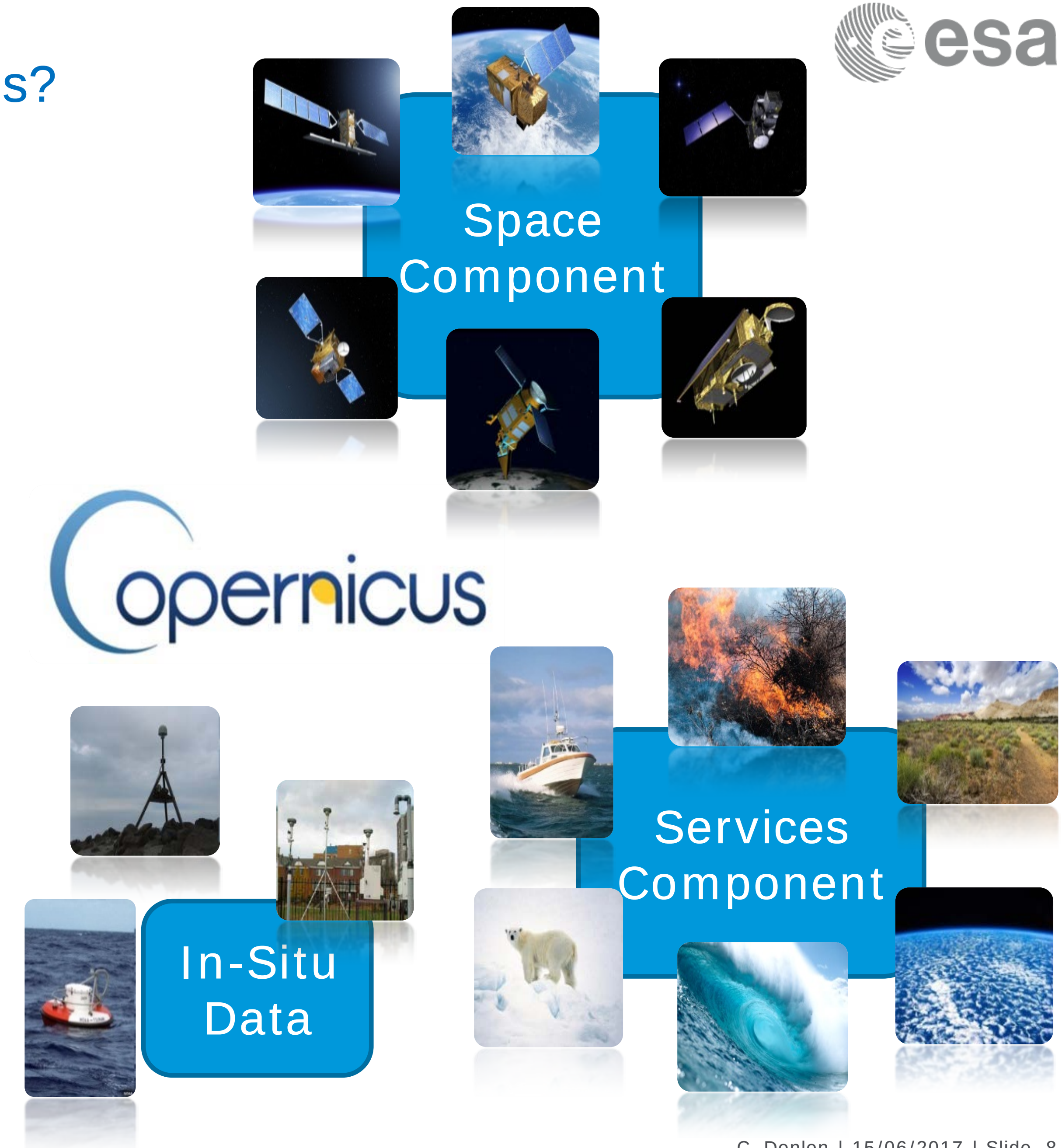


→ ESA-DEVELOPED EARTH OBSERVATION MISSIONS

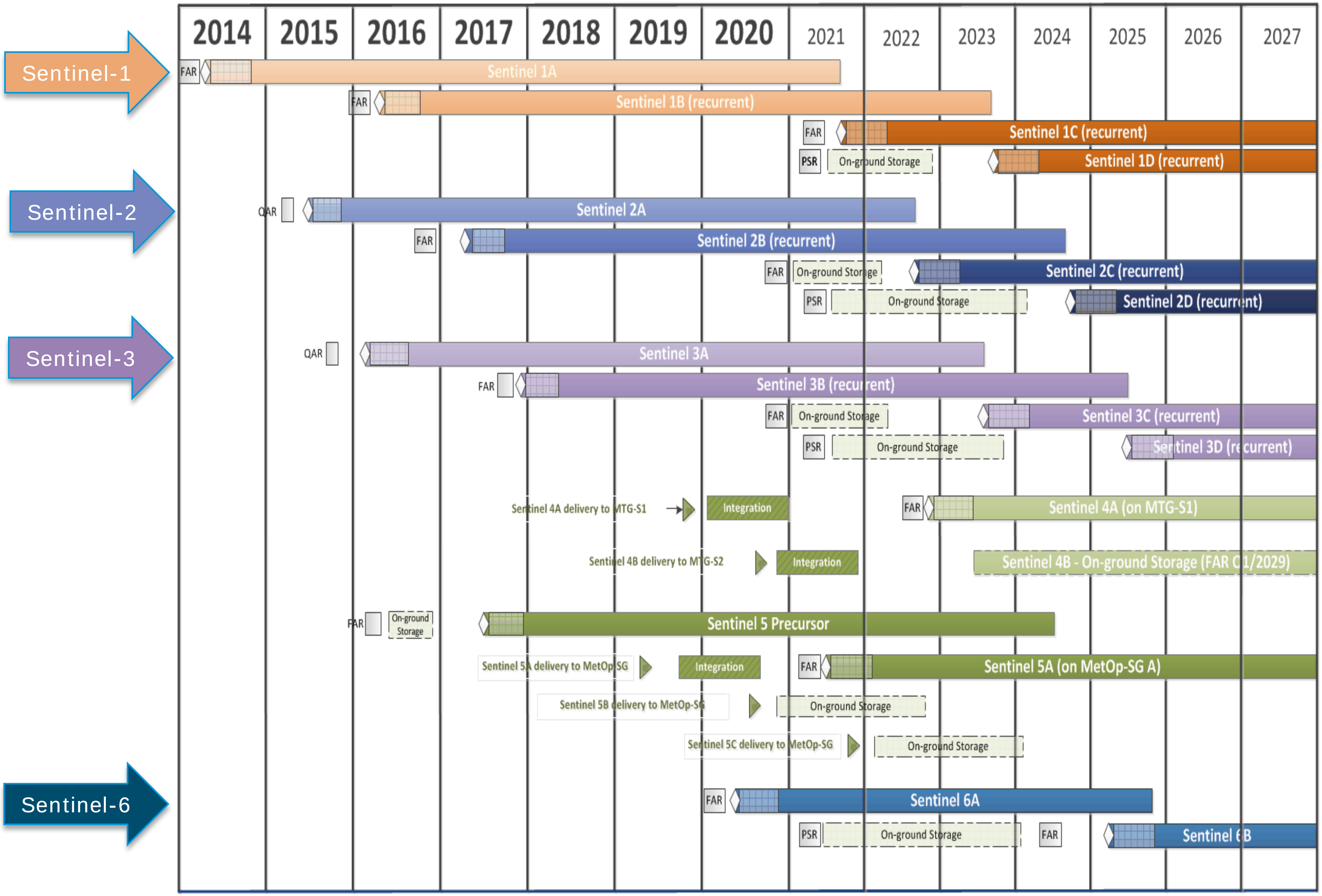
What is Copernicus?

European response to global needs:

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



Sentinel - Estimated Launch Schedule



Copernicus Components & Competences

Coordinators: Partners:

Overall Programme Coordination:

Space Component

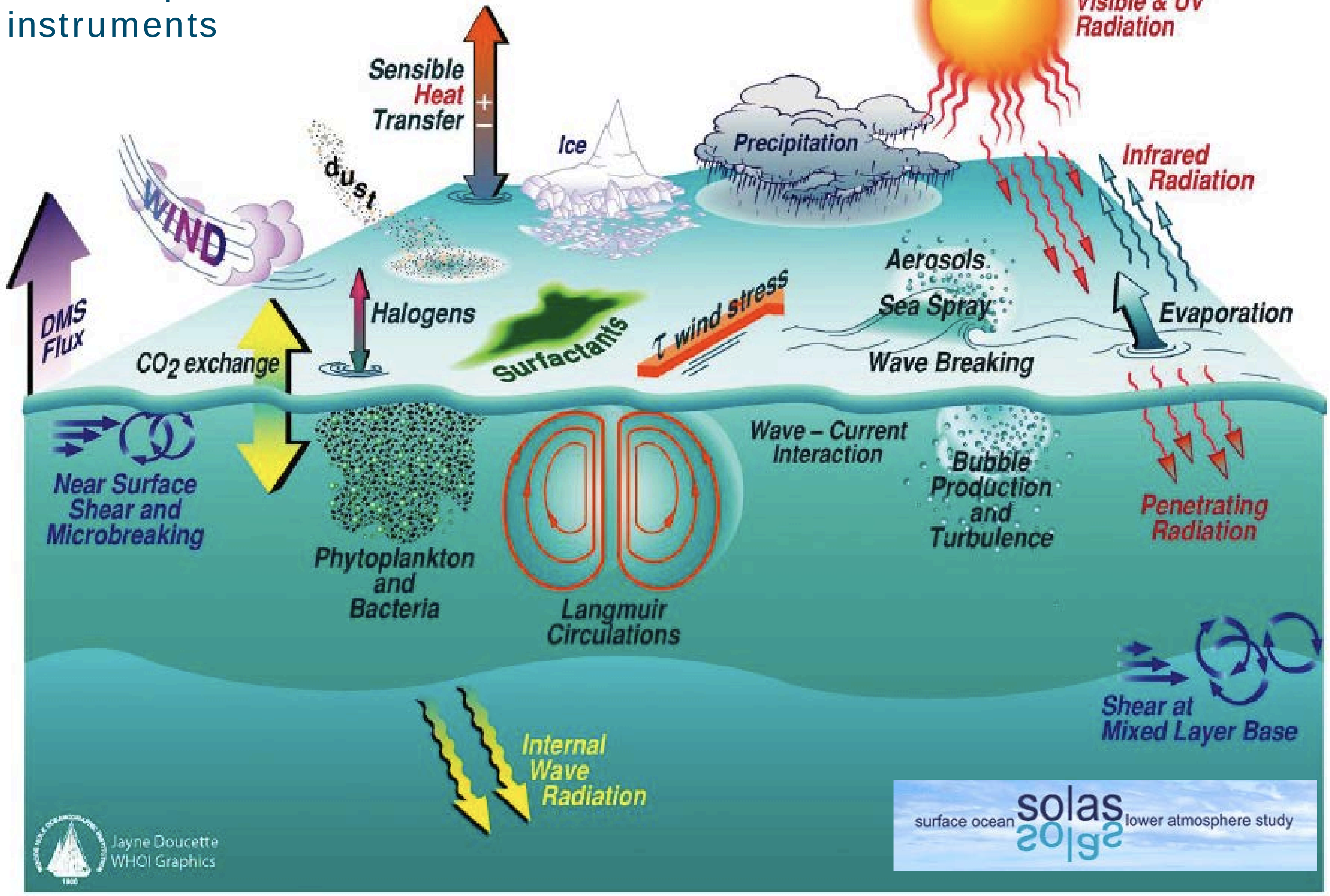
- Coordinator: esa
- Partners: Industries, Private companies, National Space Agencies, EUMETSAT

Services Component

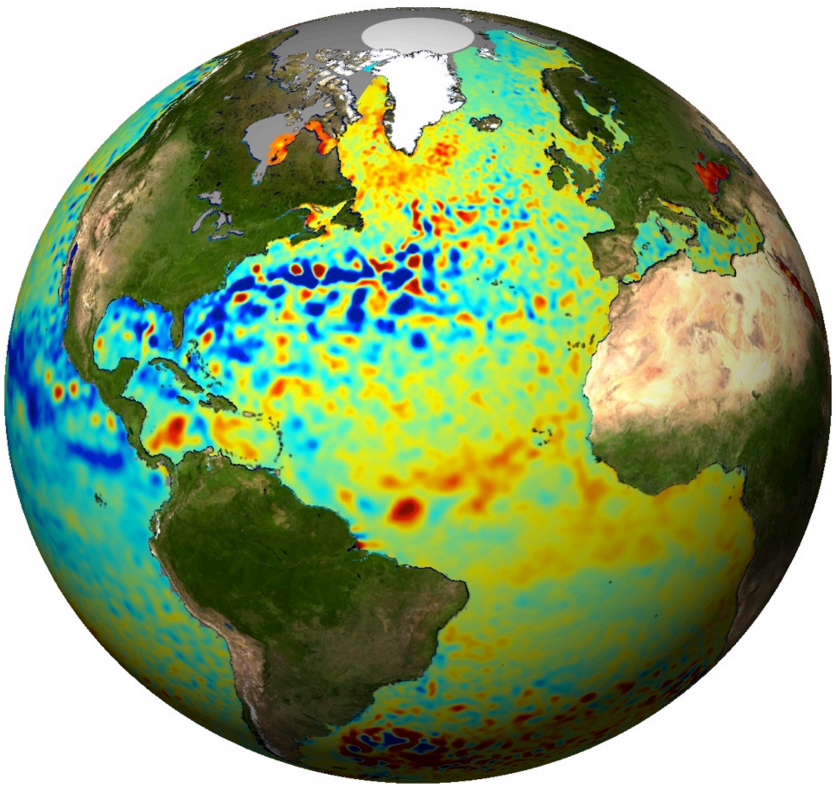
- Coordinator: European Commission
- Partners (Service operators): EMCWF, Mercator Océan, EEA, JRC, SatCen, EMSA and FRONTEX

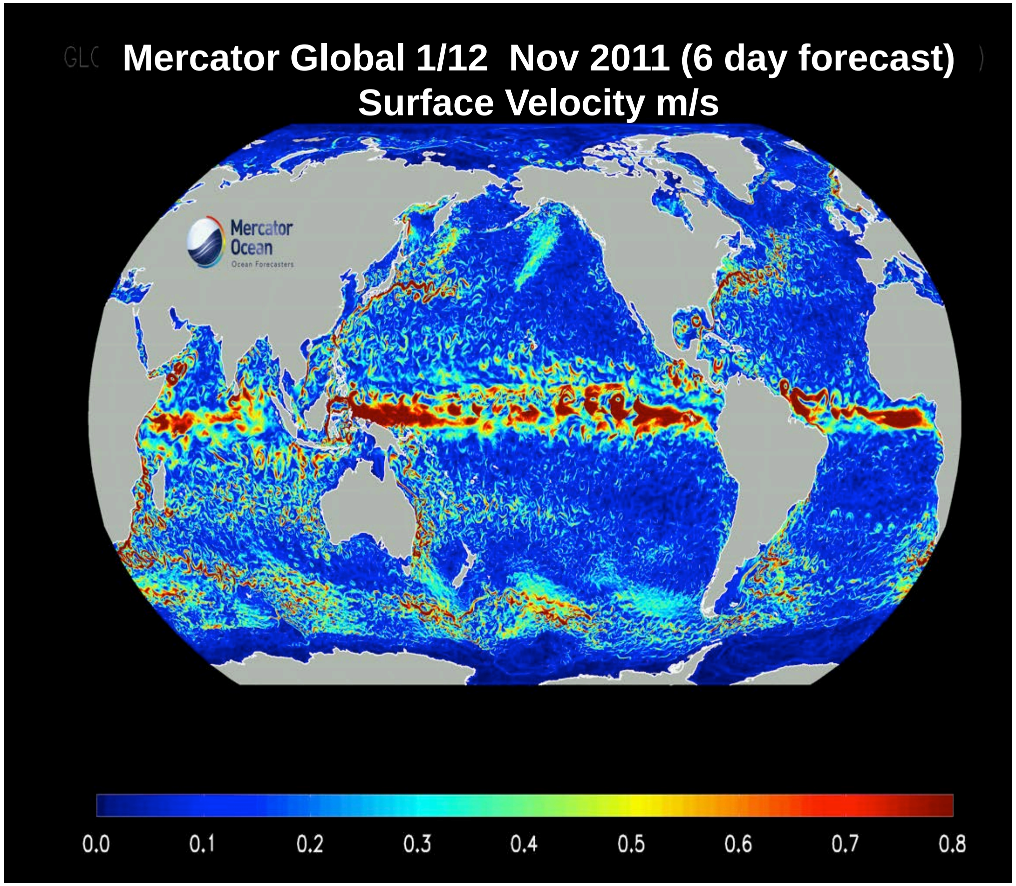
In-situ data are supporting the Space and Services Components

Copernicus provides information on many relevant parameters from its satellite instruments



The complexity of ocean circulation patterns…






European Commission
European Space Agency
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

Sentinel-1 C-band SAR mission

Mission profile:

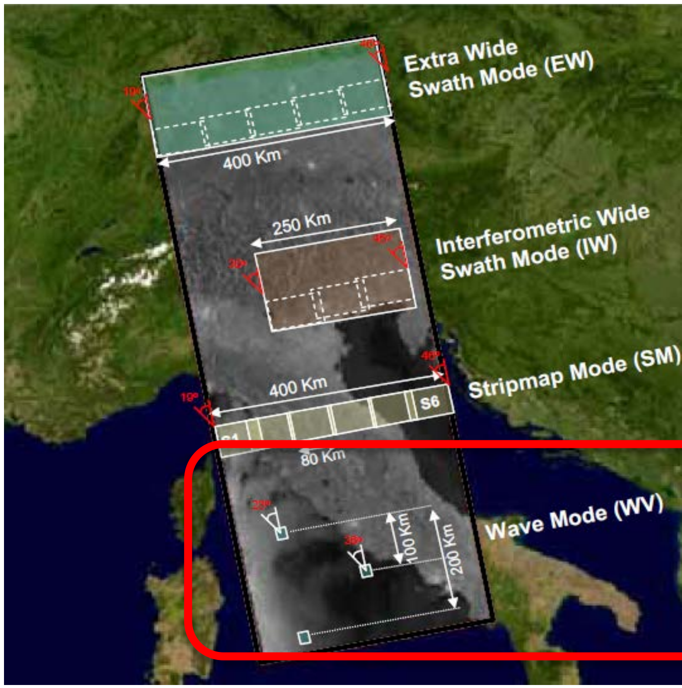
- **Two identical spacecraft in Dawn-Dusk orbit**
- **C-Band SAR** at 5.4 GHz, multi-polarisation
- Sun synchronous orbit at **693 km** mean altitude
- **250 km** swath width (Interferometric Wide-swath mode)
- **6 days** repeat cycle at Equator with 2 satellites
- **7 years** design life time, consumables 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

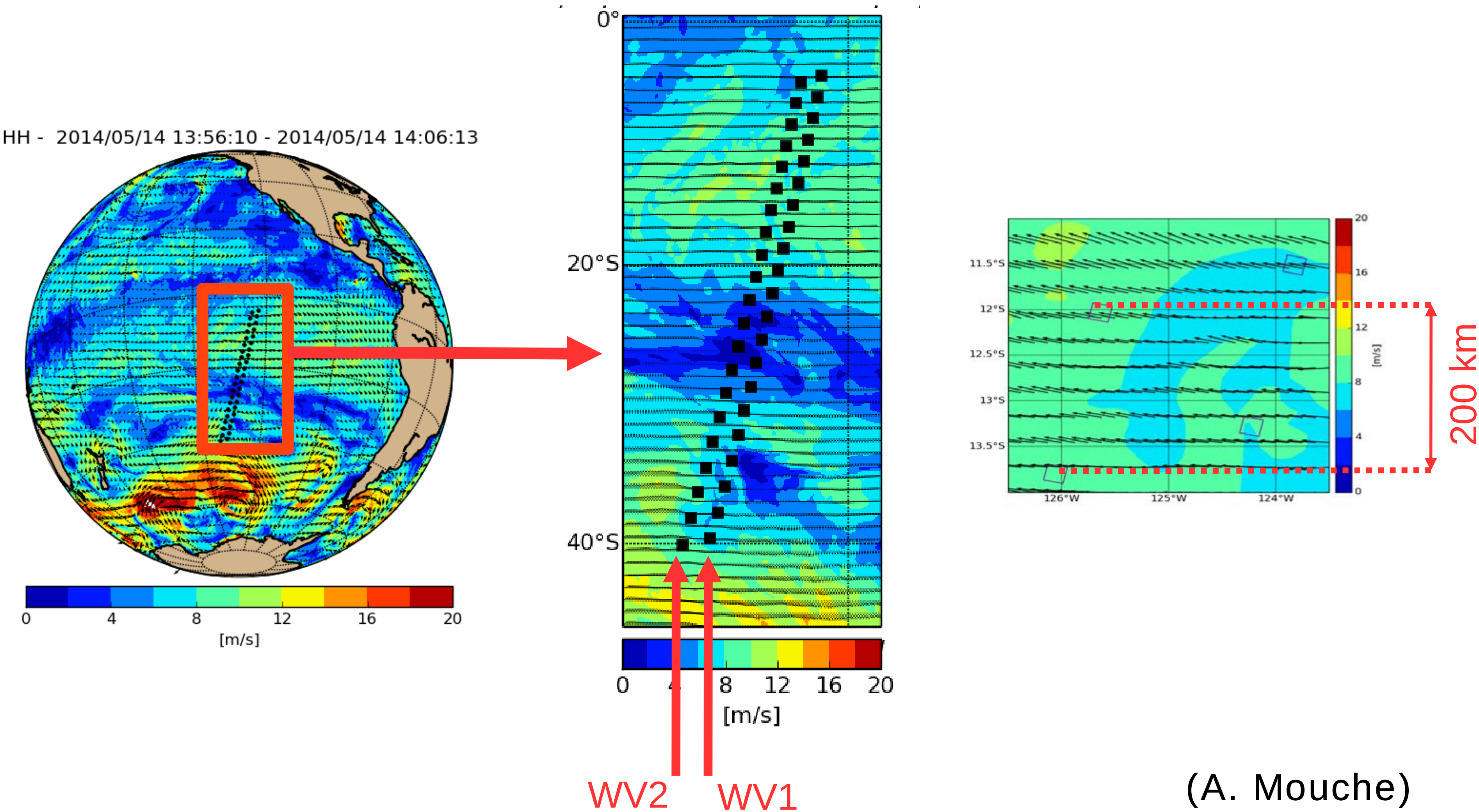
Operational Modes



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**

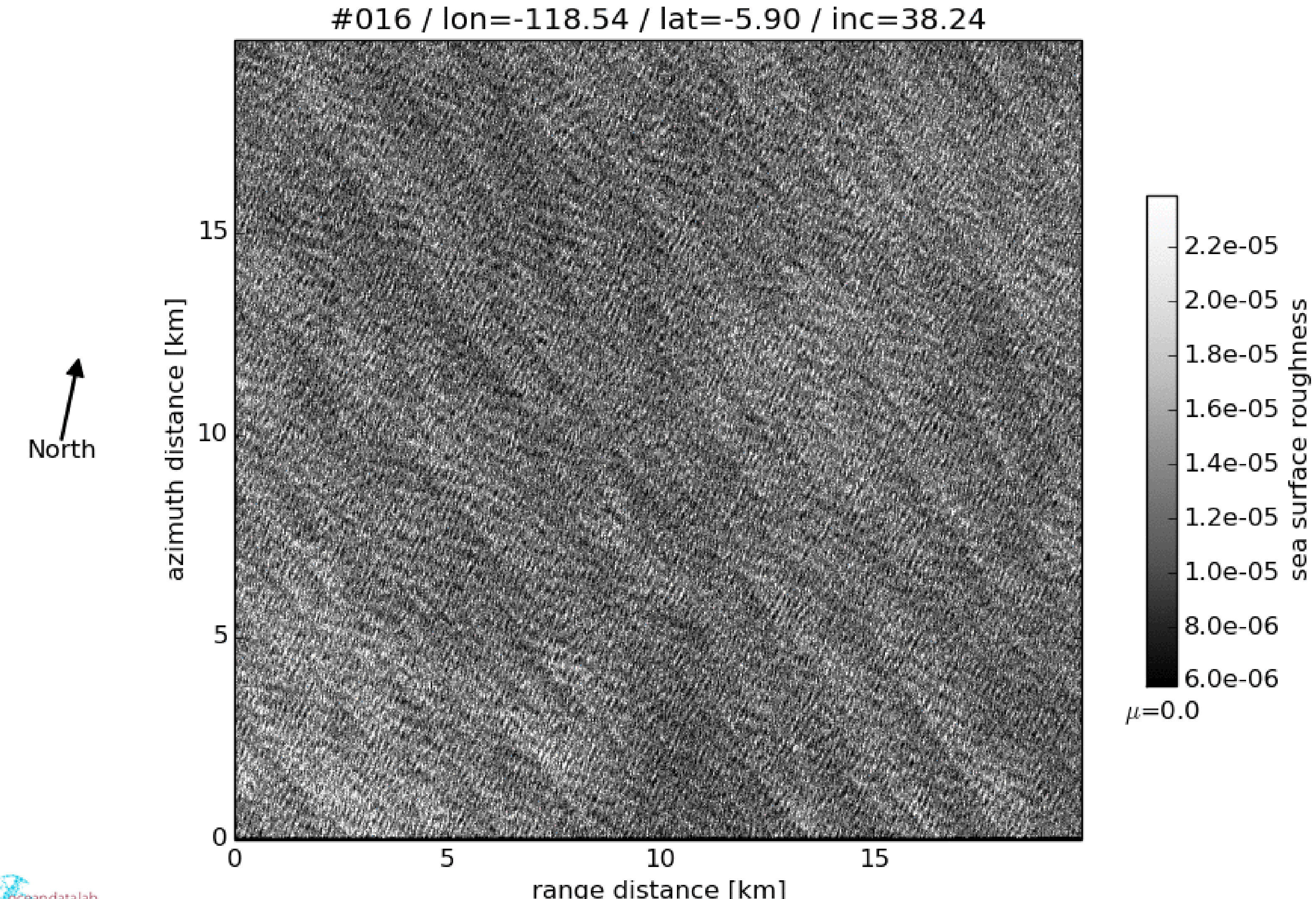
Sentinel-1 Wave-mode



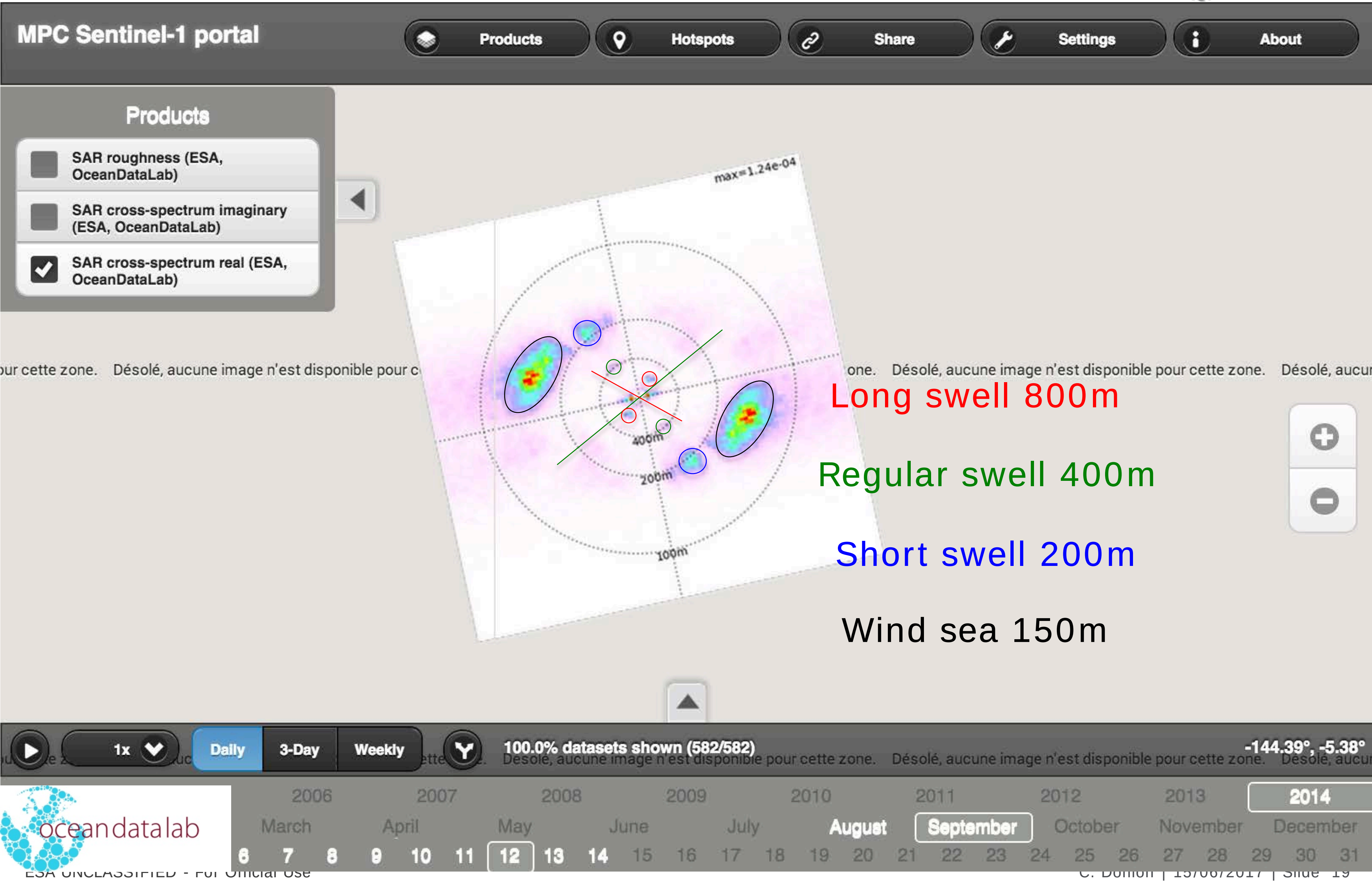
(A. Mouche)

Wave Mode : Imagette (20 x 20 km)

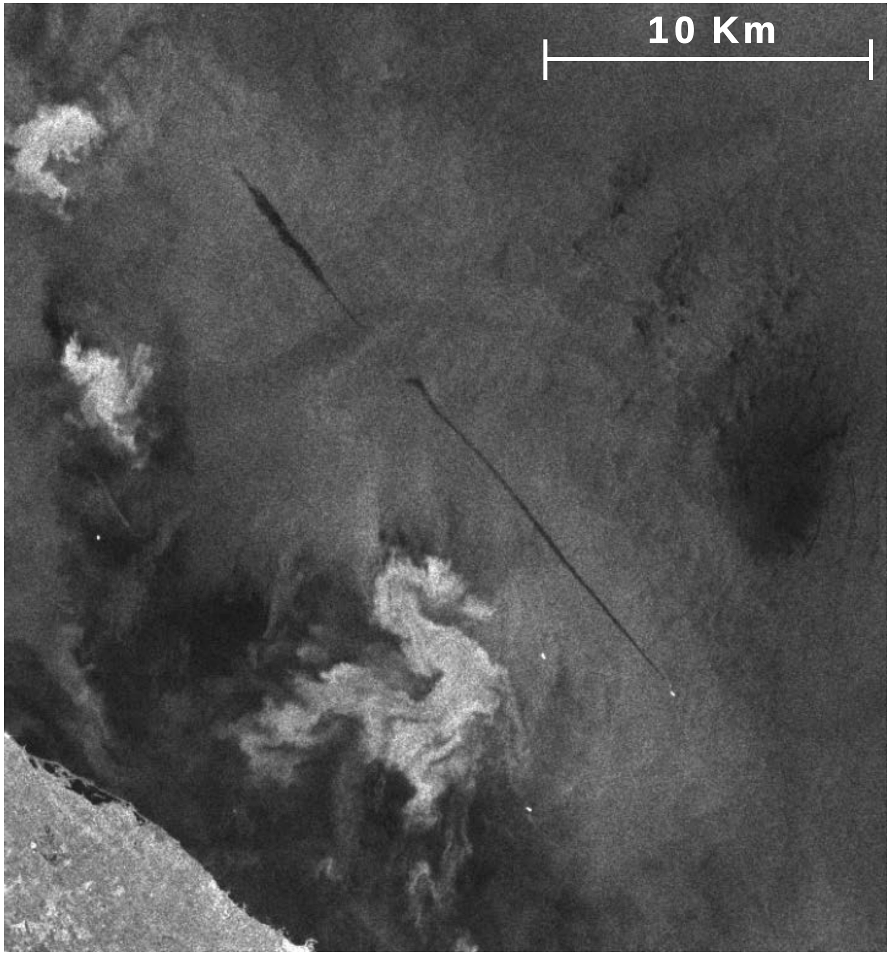
Imagette #016 from **first track over Pacific**



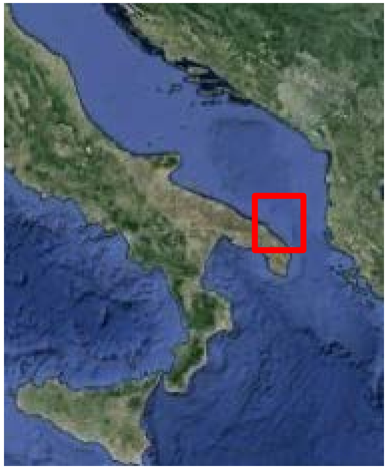
Forerunners Mid Pacific ocean : WV, VV pol, Sept 12



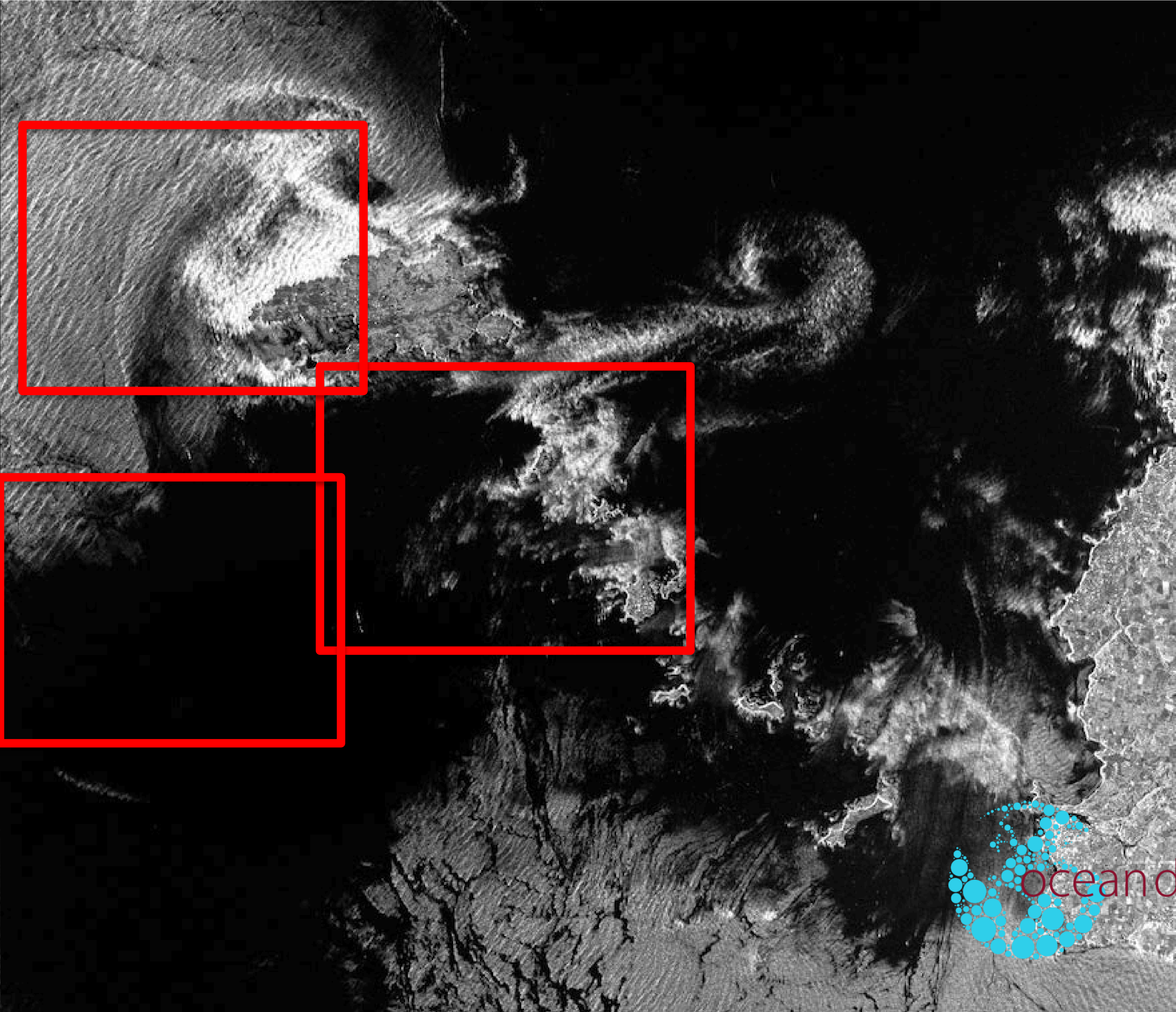
Oil discharge



S1A_IW_GRDH_1SDV_20140903T045517_20140903T045542_002223_002459_3497
Lat: 40.340 Lon : 18.554



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



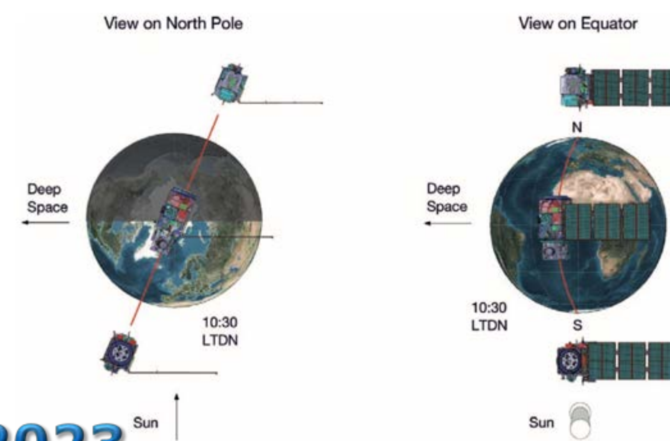

European Commission
esa
European Space Agency
Sentinel-2
→ COLOUR VISION FOR COPERNICUS

Launch Sentinel-2 (Vega, Kourou)

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

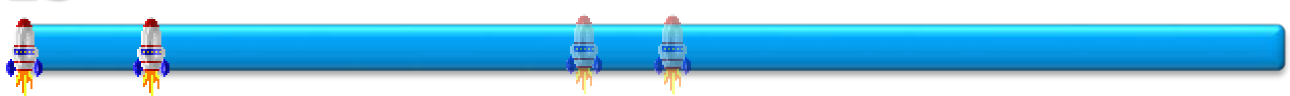
Sentinel-2 Mission Overview

- **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

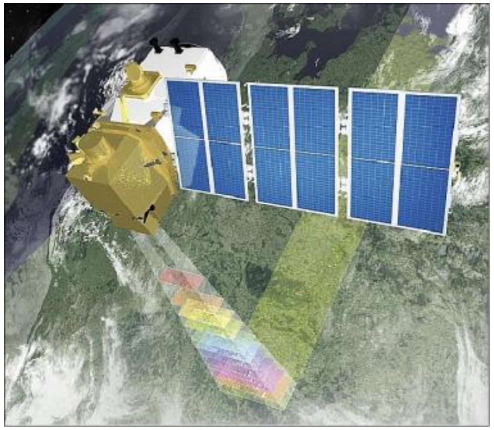


Jun 2015 | Mar 2017 | ~2023 | 2030

Sentinel-2 A/B/C/D



Sentinel-2: a big swath

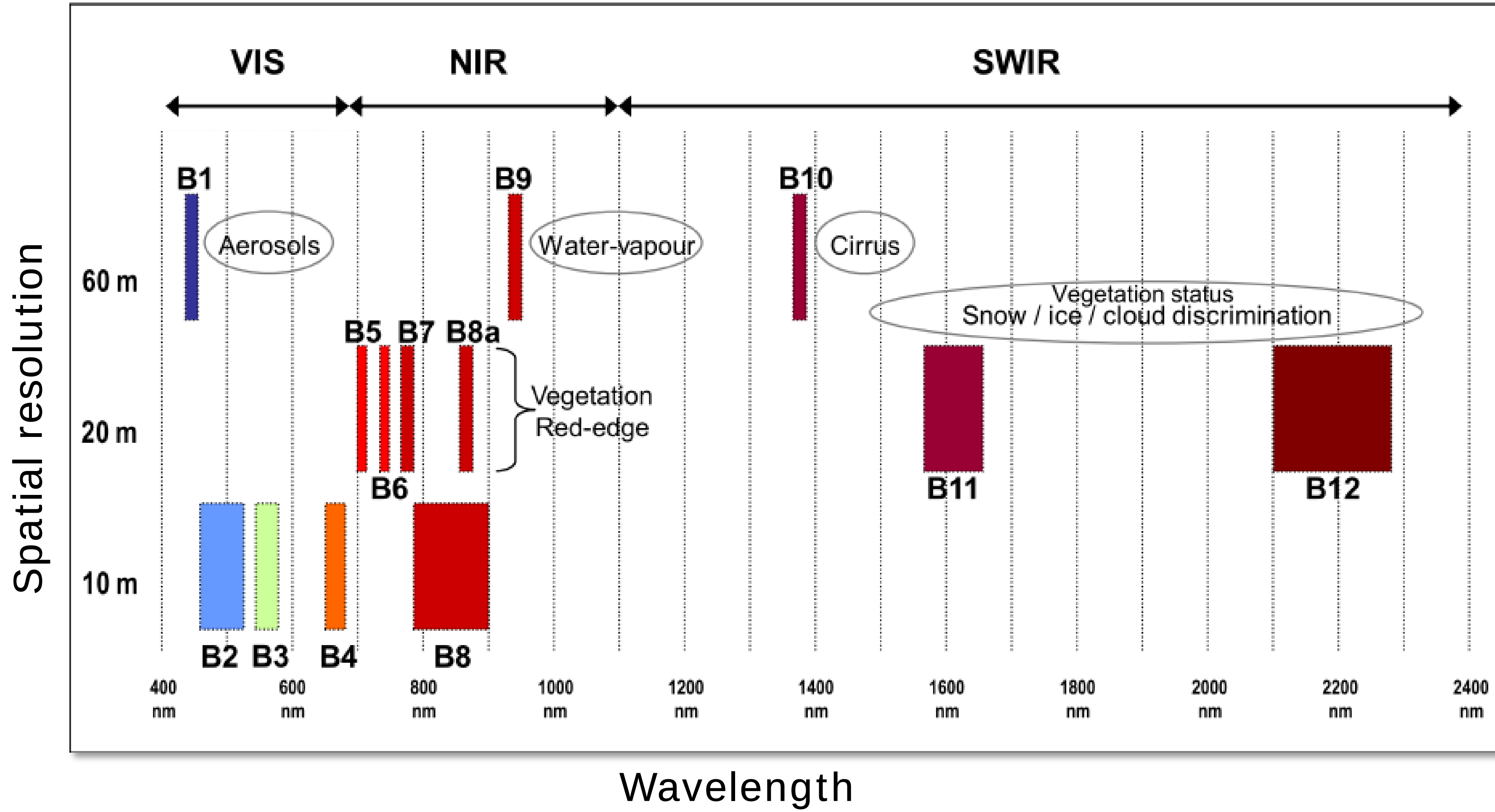


5 days revisit at equator (cloud free):

concurrent observations of 2 satellites over a <u>very large swath</u>

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

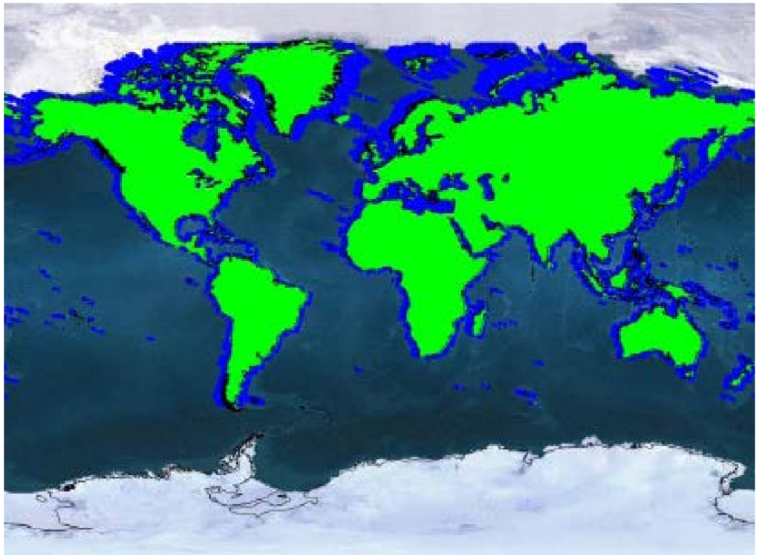


Sentinel-2 Acquisition Scenario

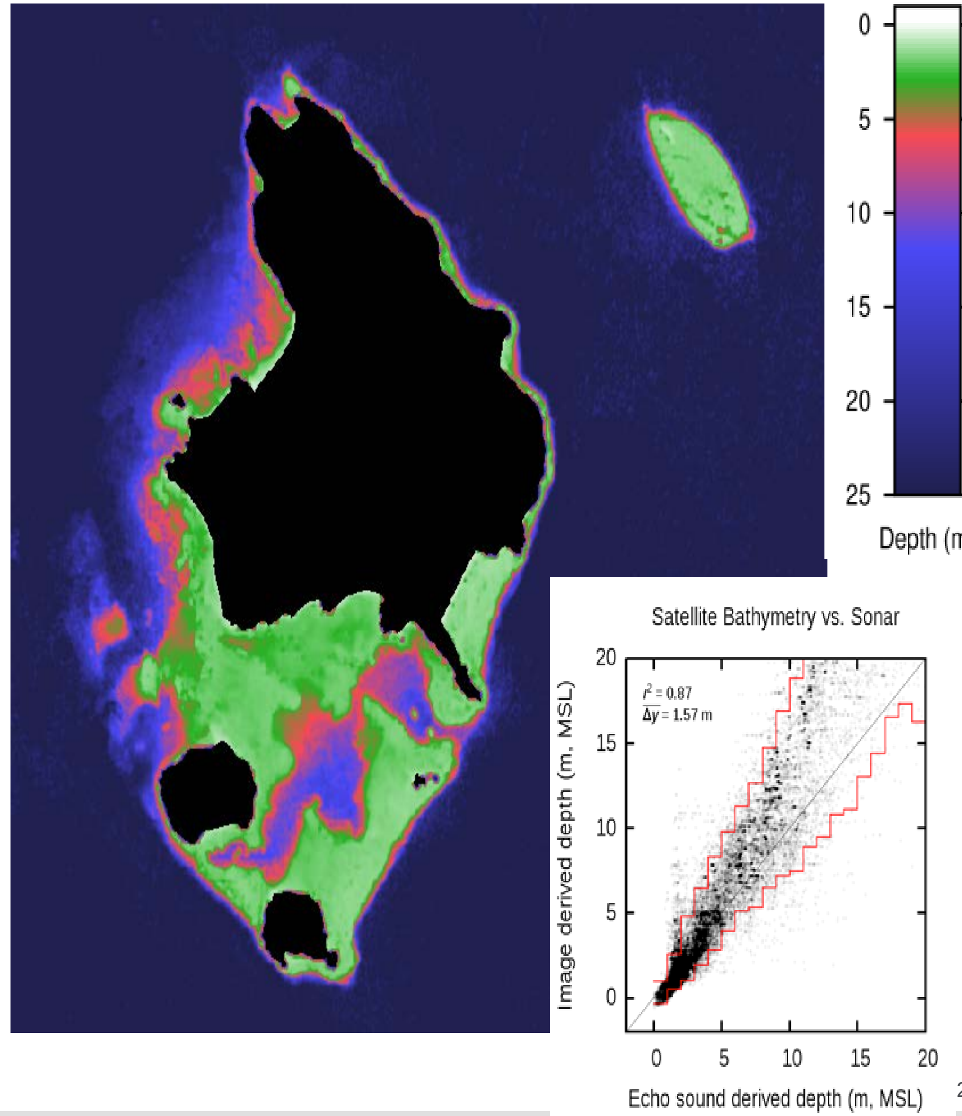
Systematic acquisition and systematic processing of Level-1B/1C data:

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**

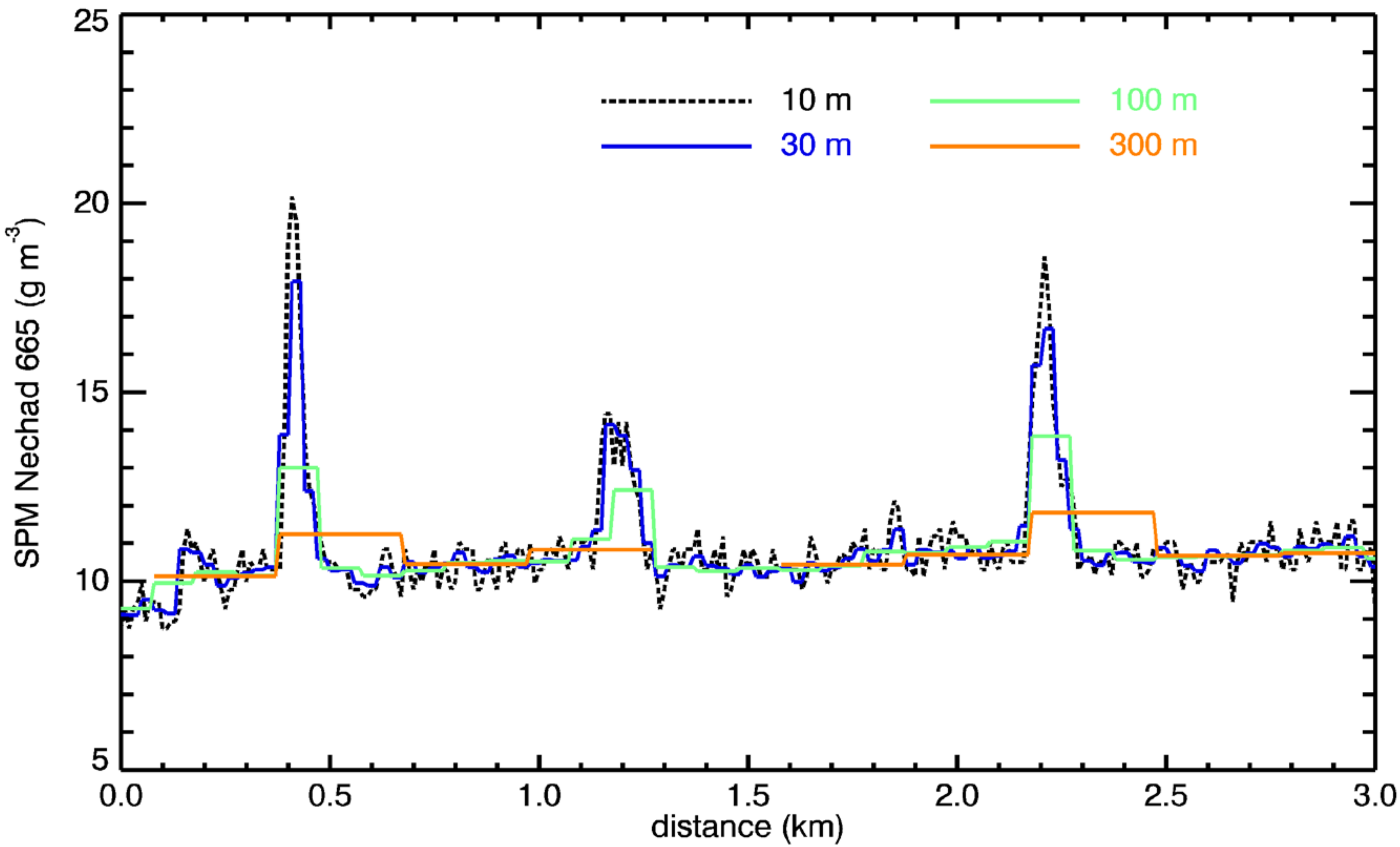


Coral Reef: Bathymetry
Lizard Island, Great Barrier Reef



Rio Verde Bay, West Falkland on 17/09/16 (image ~10 x 10 km!)

S2A resolution in E. Channel 28/08/15

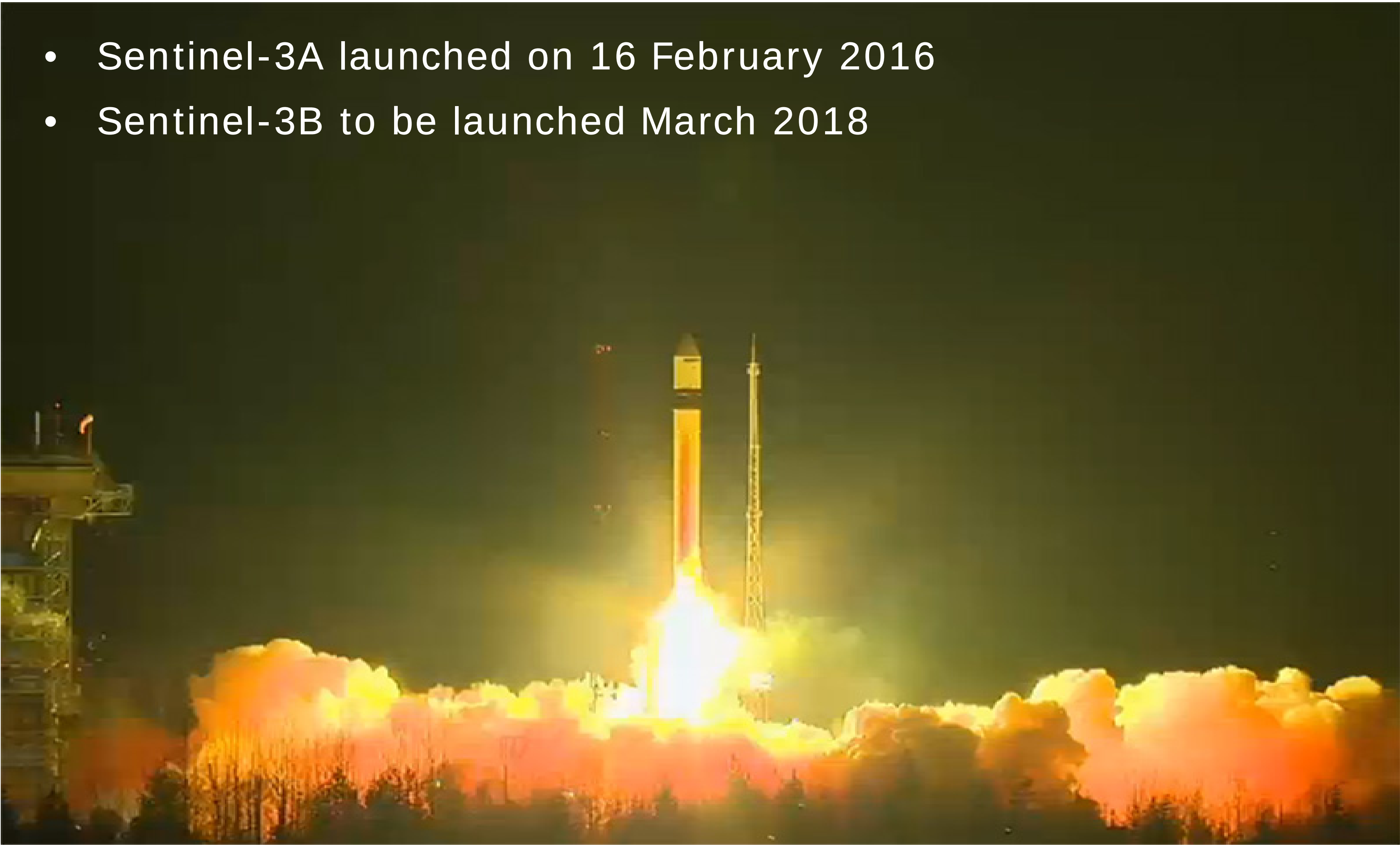


(Quinten Vanhellemont & Kevin Ruddick)

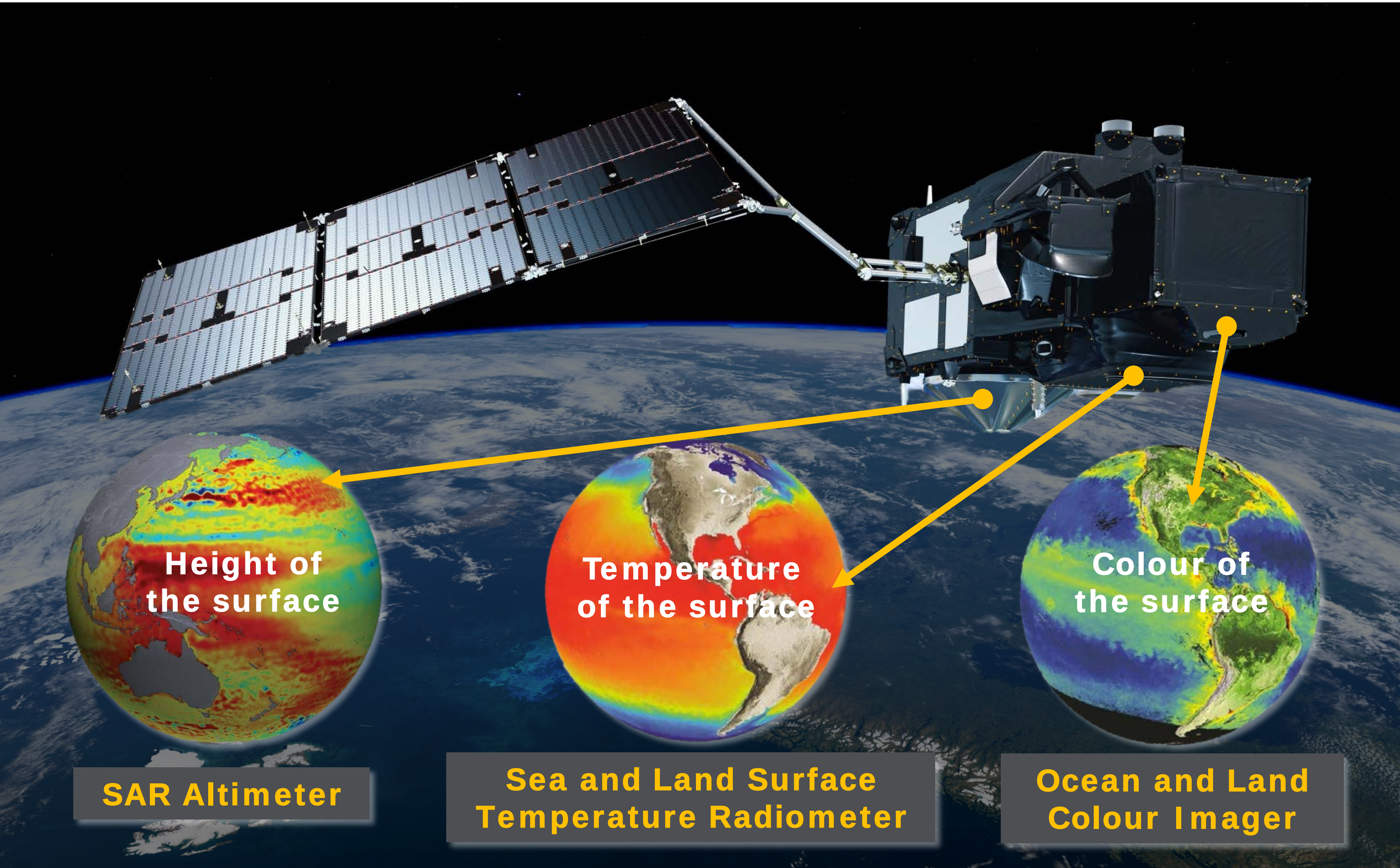

European Commission
esa
European Space Agency
Sentinel-3
→ A BIGGER PICTURE FOR COPERNICUS

Launch Sentinel-3 (Rockot, Plesetsk)

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



Sentinel-3A: The Bigger Picture



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 Mission Payload providing

- ❑ **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**

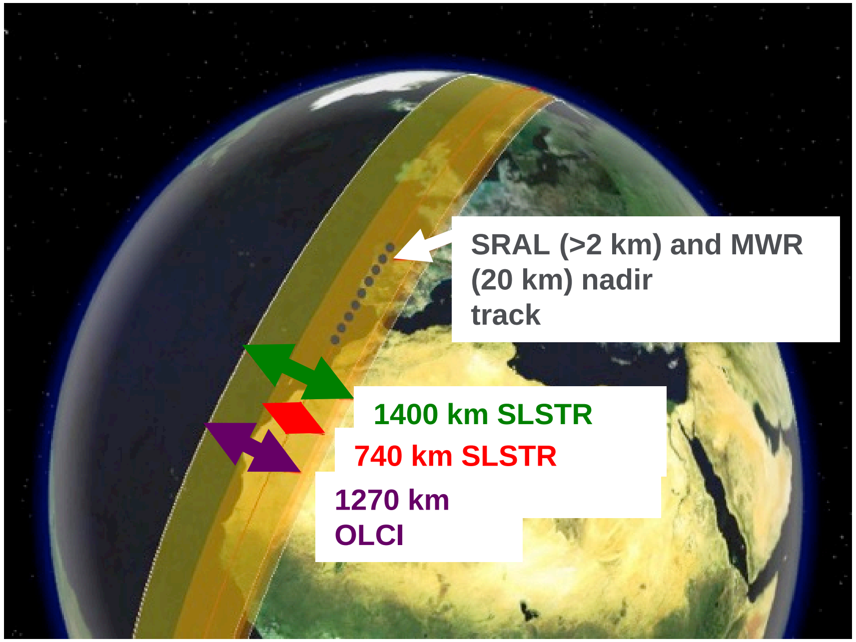
In addition, the payload design will allow

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

Optical Instruments

- **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

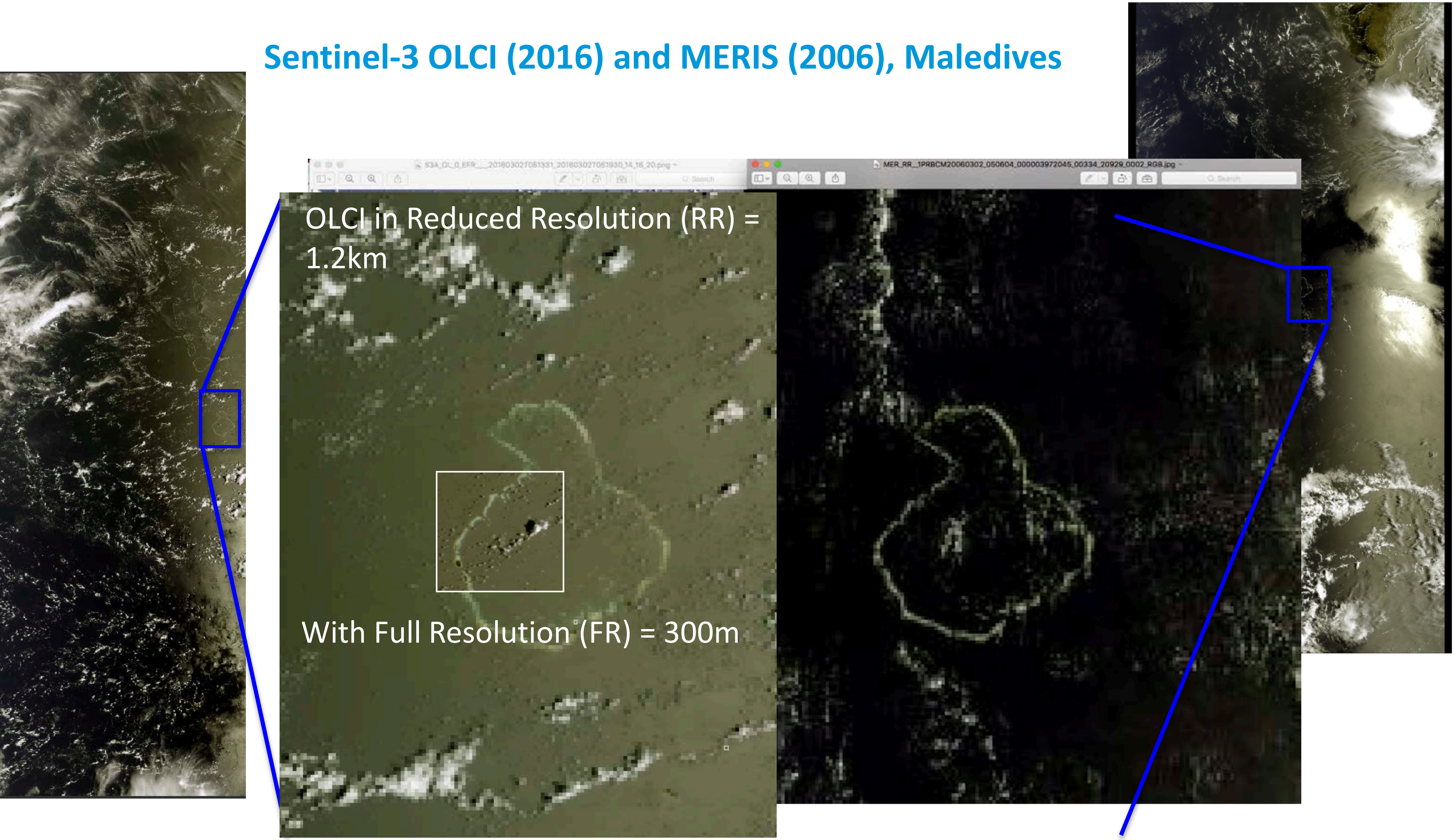
Instrument Swath Patterns



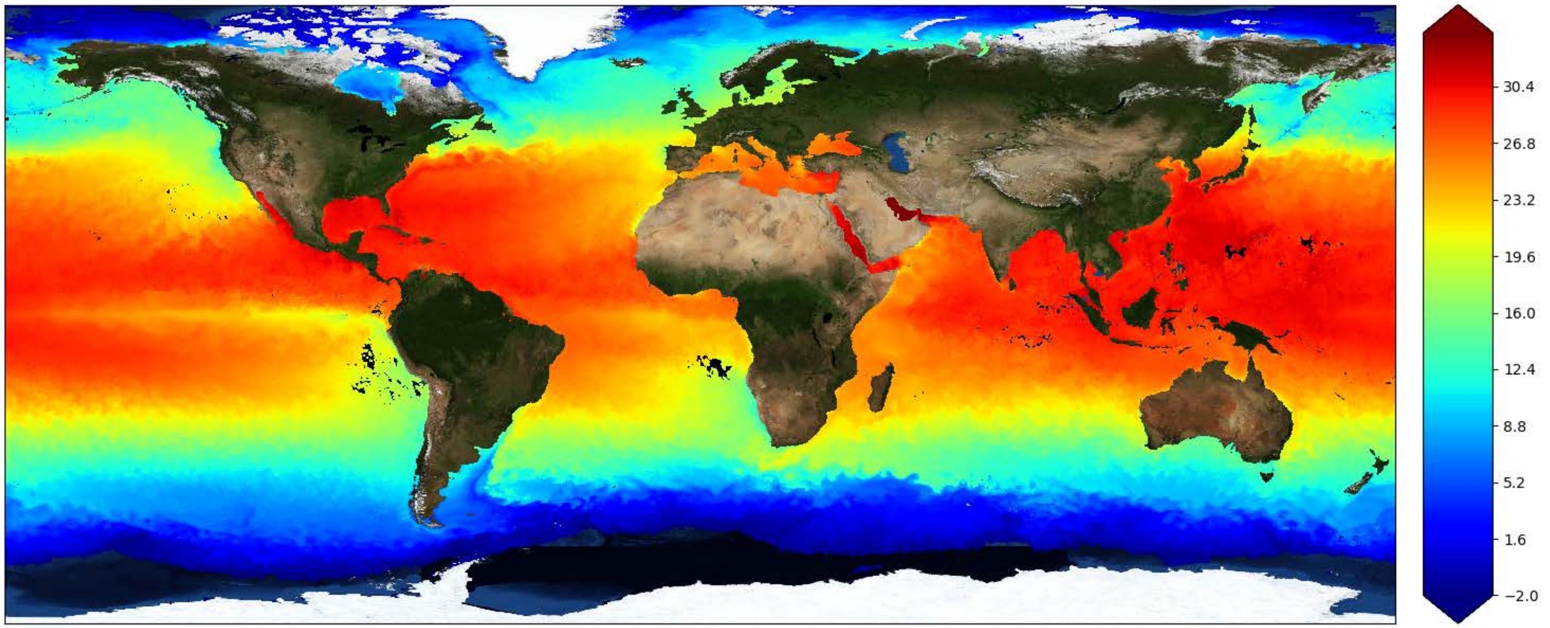
Orbit type	Repeating frozen SSO
Repeat cycle	27 days (14 + 7/27 orbits/day)
LTDN	10:00
Average altitude	815 km
Inclination	98.65 deg

OLCI versus MERIS: FR versus RR

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



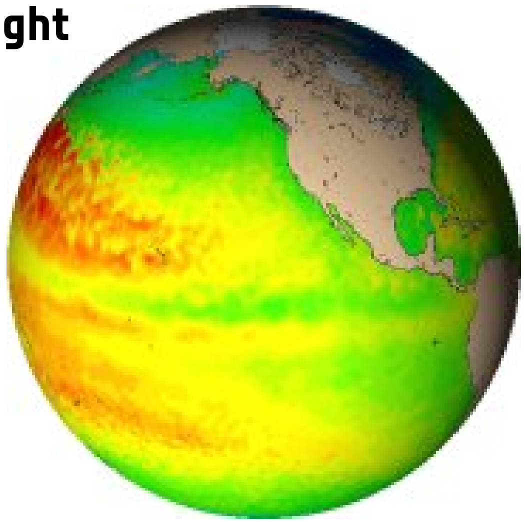
Sentinel-3: Example data



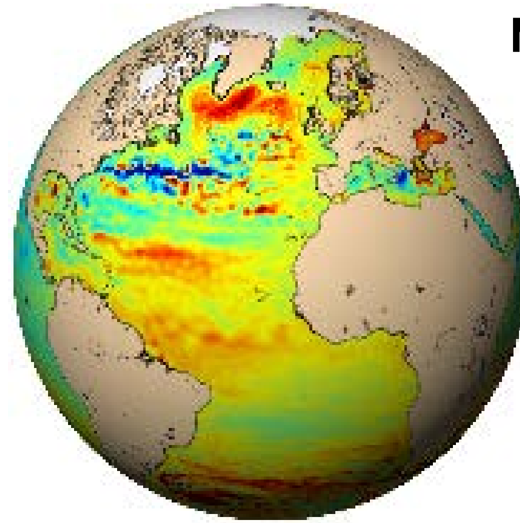
EUMETSAT Copernicus

Global SAR Sea Surface Altimetry

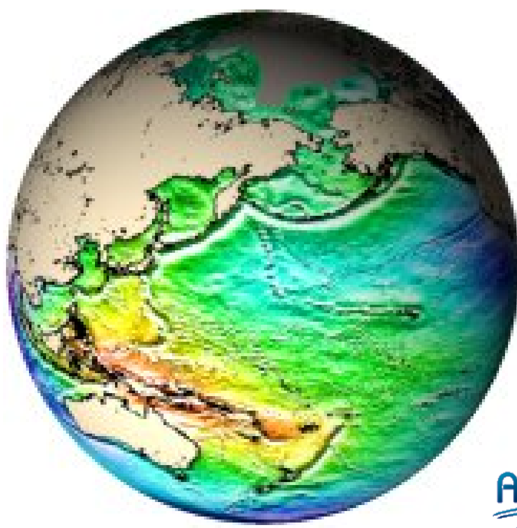
Sea Surface Height



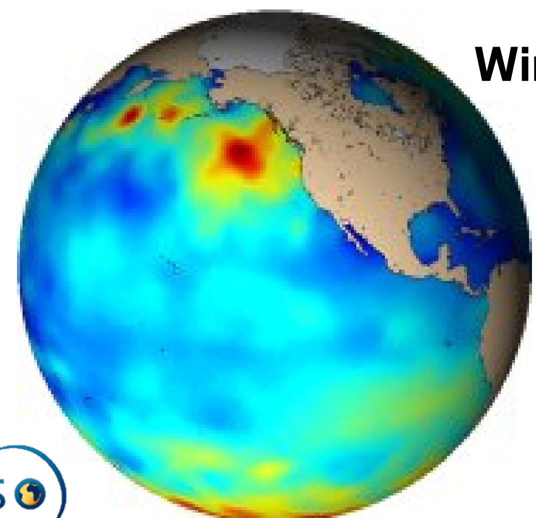
Mean Sea level

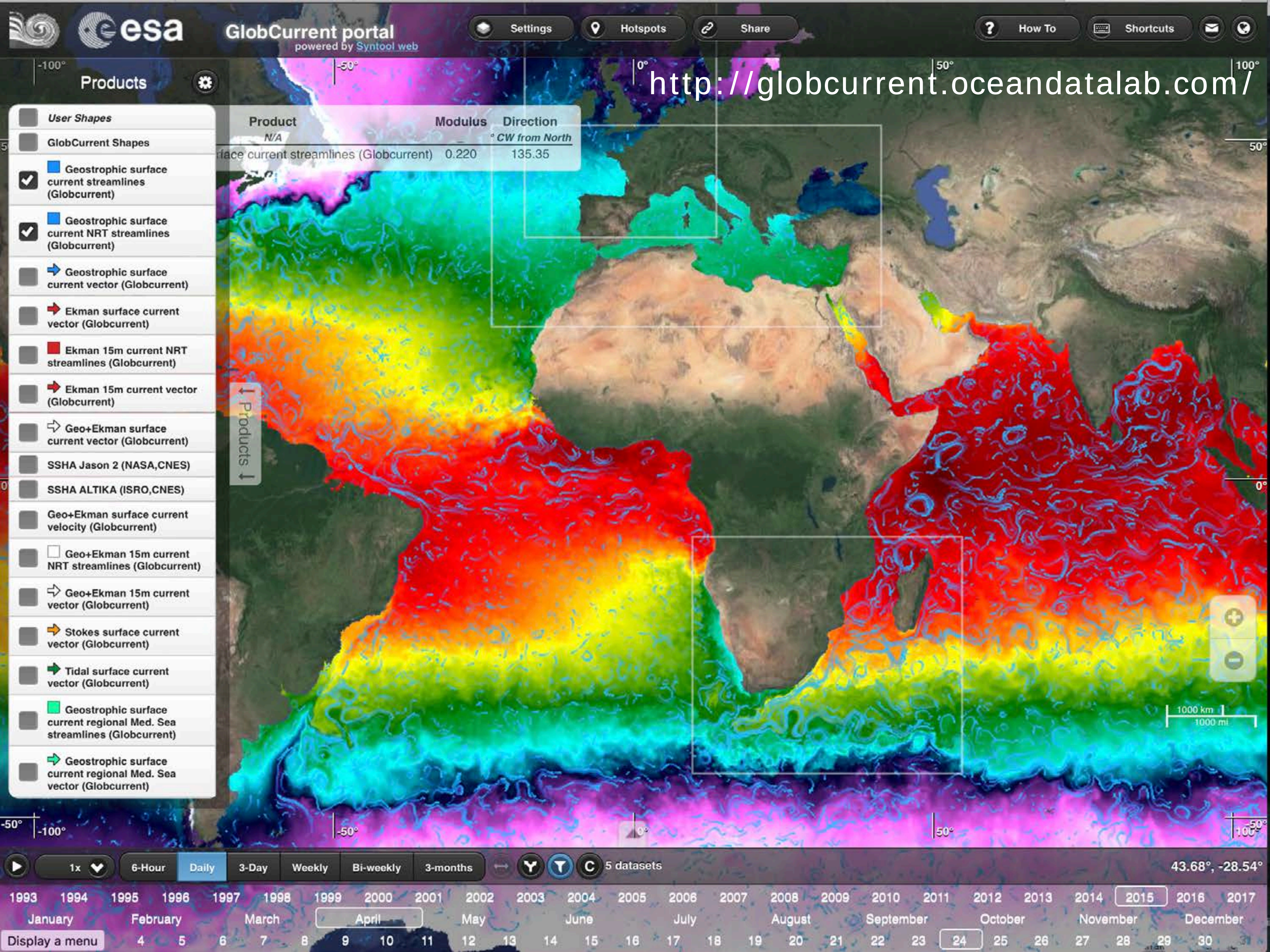


DEM, Tides, River and lake Heights, MSS ...



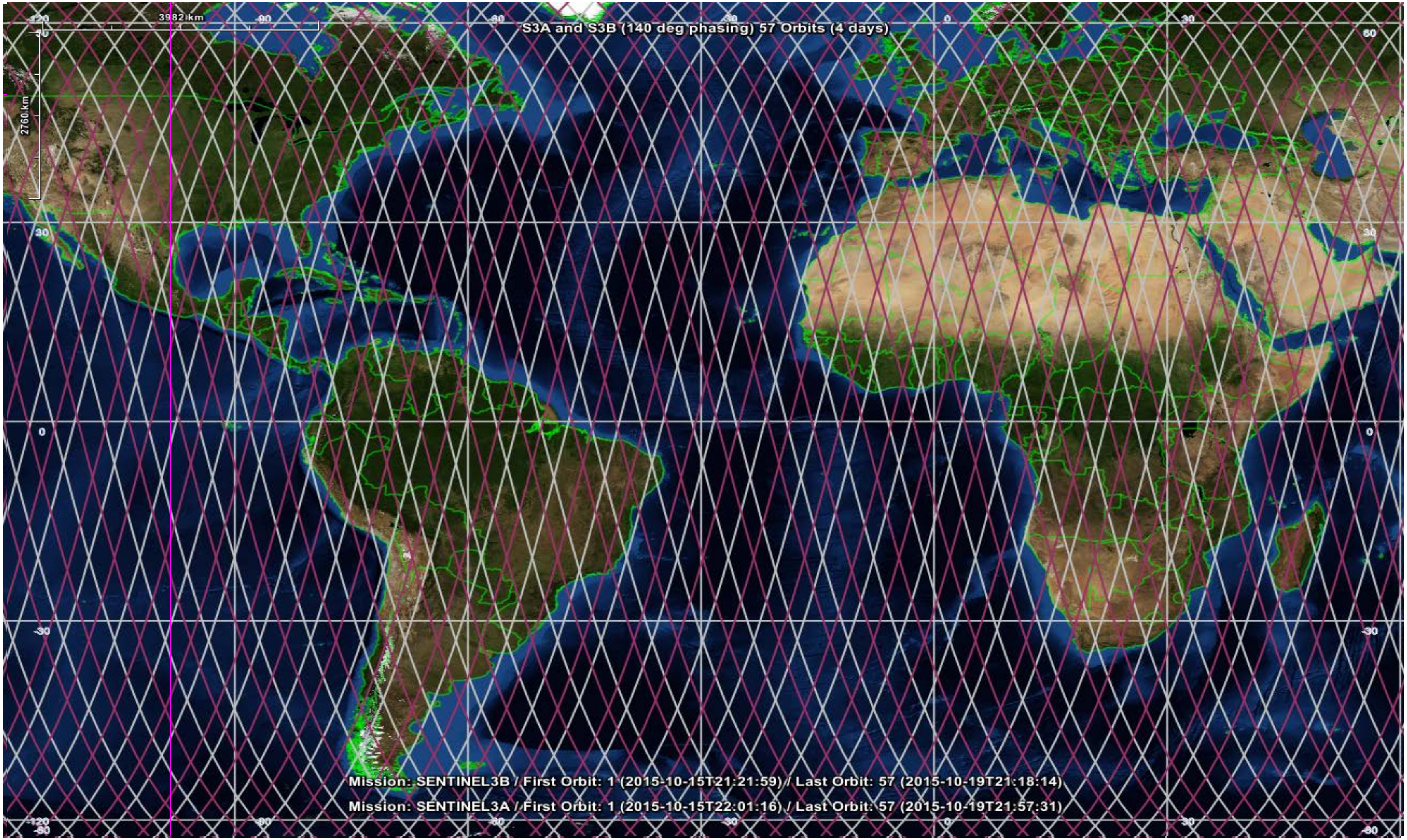
Wind and Waves





esa
GlobCurrent portal
powered by Syntool web
Settings
Hotspots
Share
How To
Shortcuts
http://globcurrent.oceandatalab.com/
Products
User Shapes
GlobCurrent Shapes
Geostrophic surface current streamlines (Globcurrent)
Geostrophic surface current NRT streamlines (Globcurrent)
Geostrophic surface current vector (Globcurrent)
Ekman surface current vector (Globcurrent)
Ekman 15m current NRT streamlines (Globcurrent)
Ekman 15m current vector (Globcurrent)
Geo+Ekman surface current vector (Globcurrent)
SSHA Jason 2 (NASA,CNES)
SSHA ALTIKA (ISRO,CNES)
Geo+Ekman surface current velocity (Globcurrent)
Geo+Ekman 15m current NRT streamlines (Globcurrent)
Geo+Ekman 15m current vector (Globcurrent)
Stokes surface current vector (Globcurrent)
Tidal surface current vector (Globcurrent)
Geostrophic surface current regional Med. Sea streamlines (Globcurrent)
Geostrophic surface current regional Med. Sea vector (Globcurrent)
Product
N/A
Modulus
Direction
° CW from North
rface current streamlines (Globcurrent) 0.220 135.35
1000 km
1000 mi
1x
6-Hour
Daily
3-Day
Weekly
Bi-weekly
3-months
5 datasets
43.68°, -28.54°
1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017
January February March April May June July August September October November December
Display a menu

Optimising the Constellation: Sentinel-3B phasing to 140° (instead of 180°) after 4 days



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

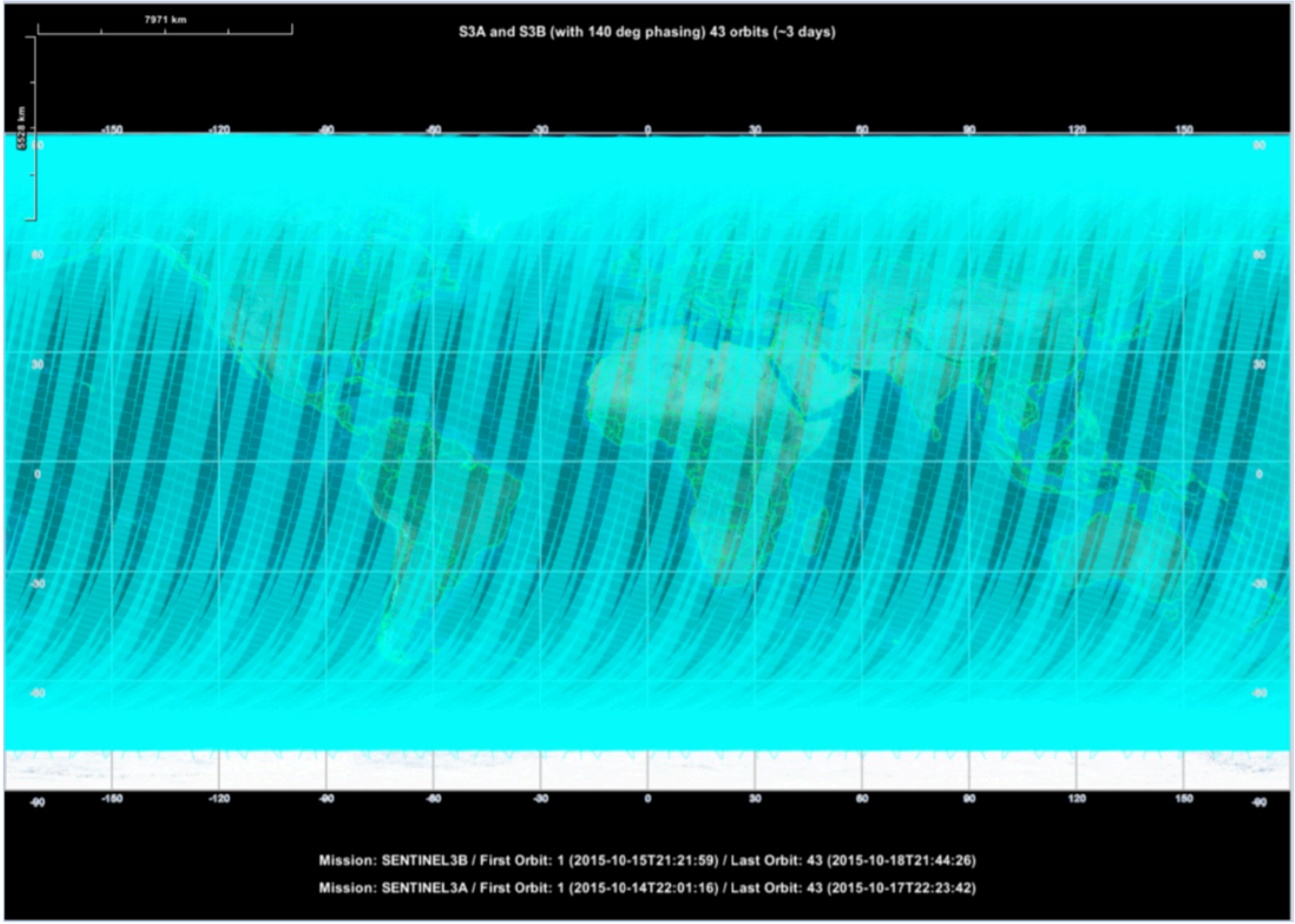
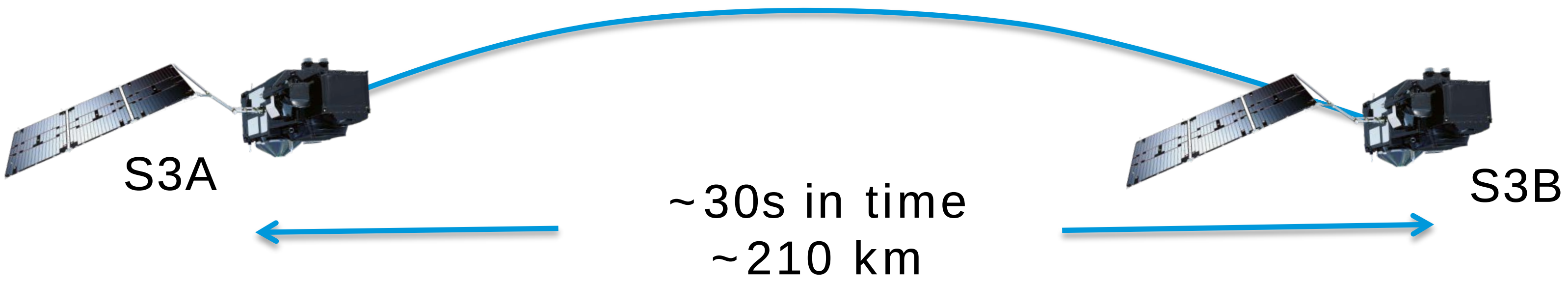


Figure 7. Complete coverage of OLCI after mitigation of sun-glint with S3B set in 140° phasing with S3A is reached after 3 day

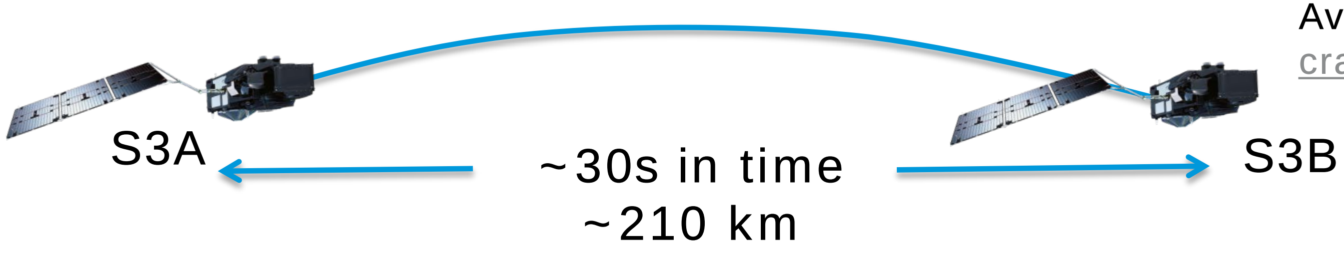
Sentinel-3 Tandem phas



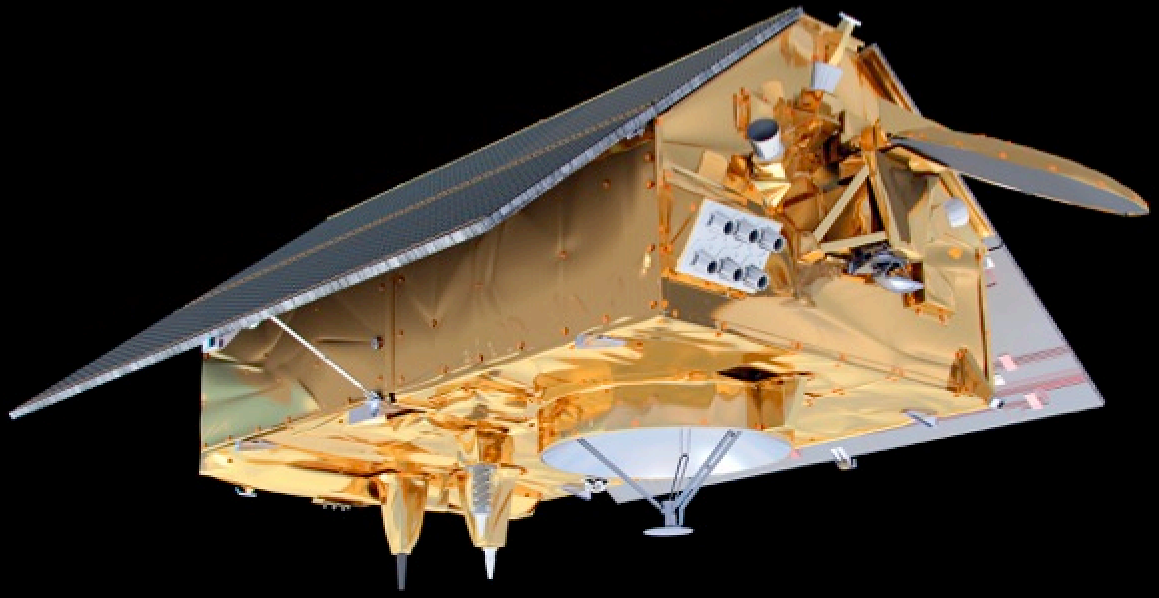
Tandem Rationale

- 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 ~30s, the atmospheric and oceanic variability will be reduced to negligible levels → reduced uncertainty when comparing data.
- At ~30s, 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.



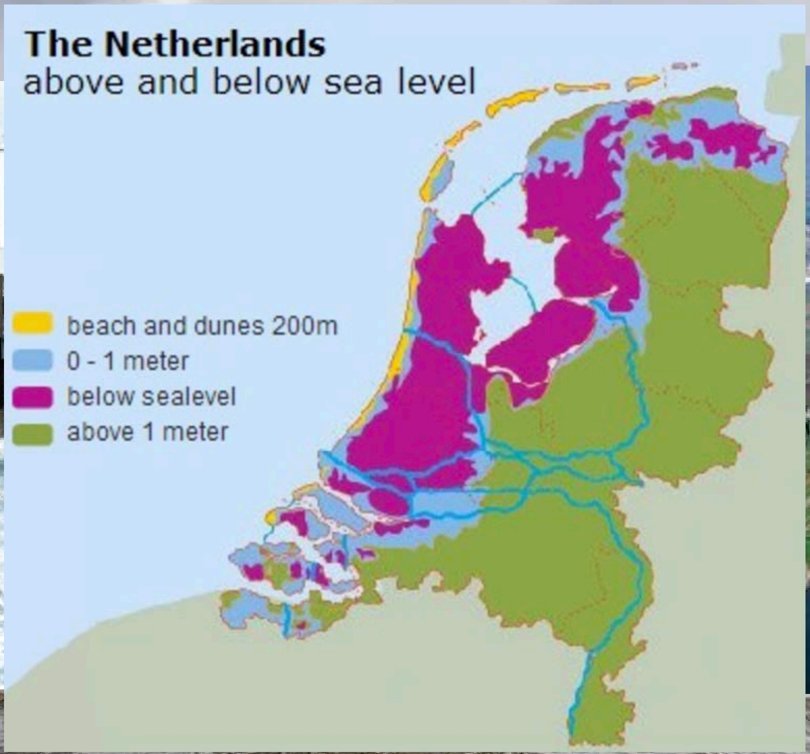
Sentinel-6/Jason-CS

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

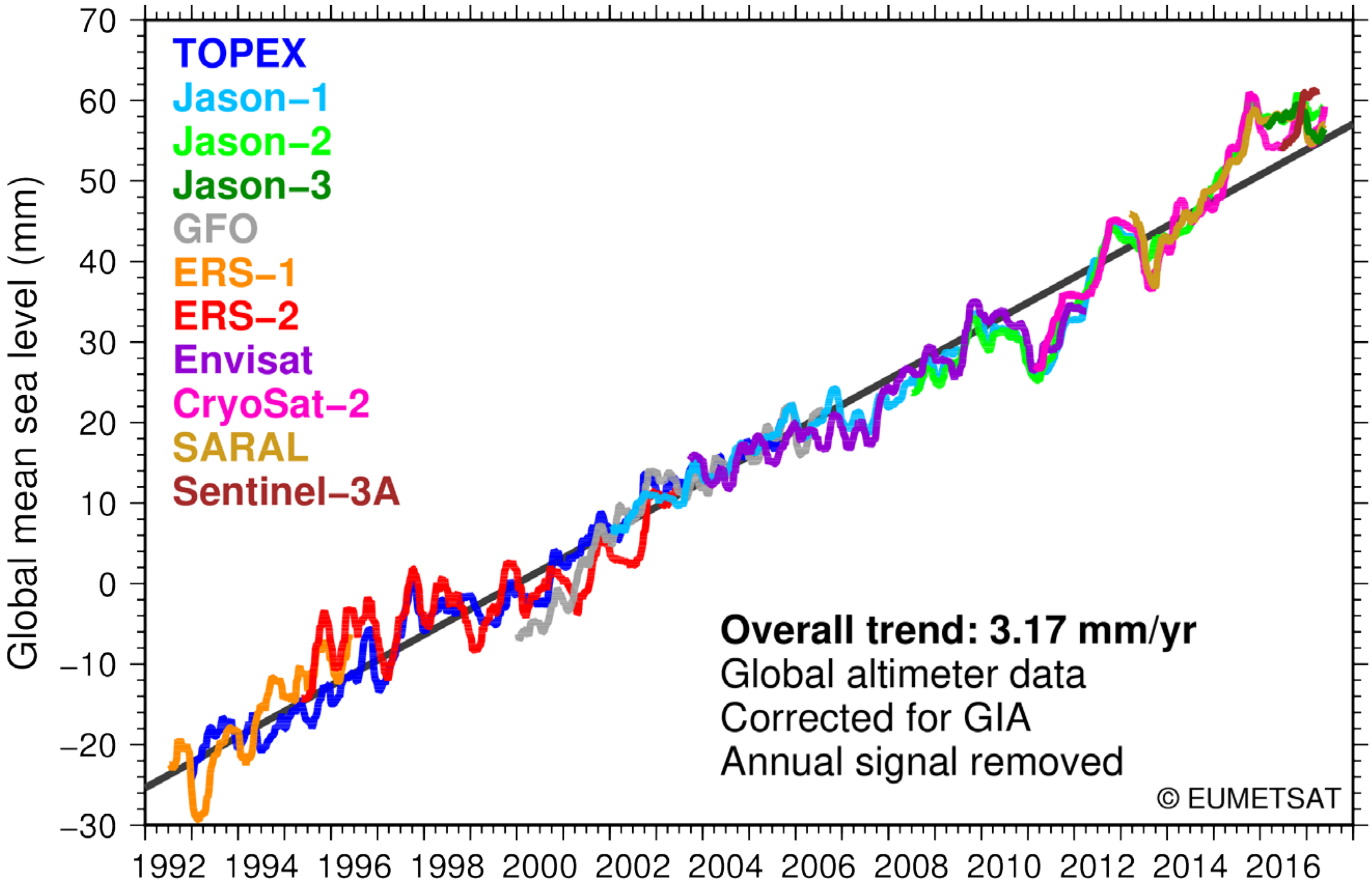
Sea level change: impacts

Oosterscheldekering
Storm Surge Barrier



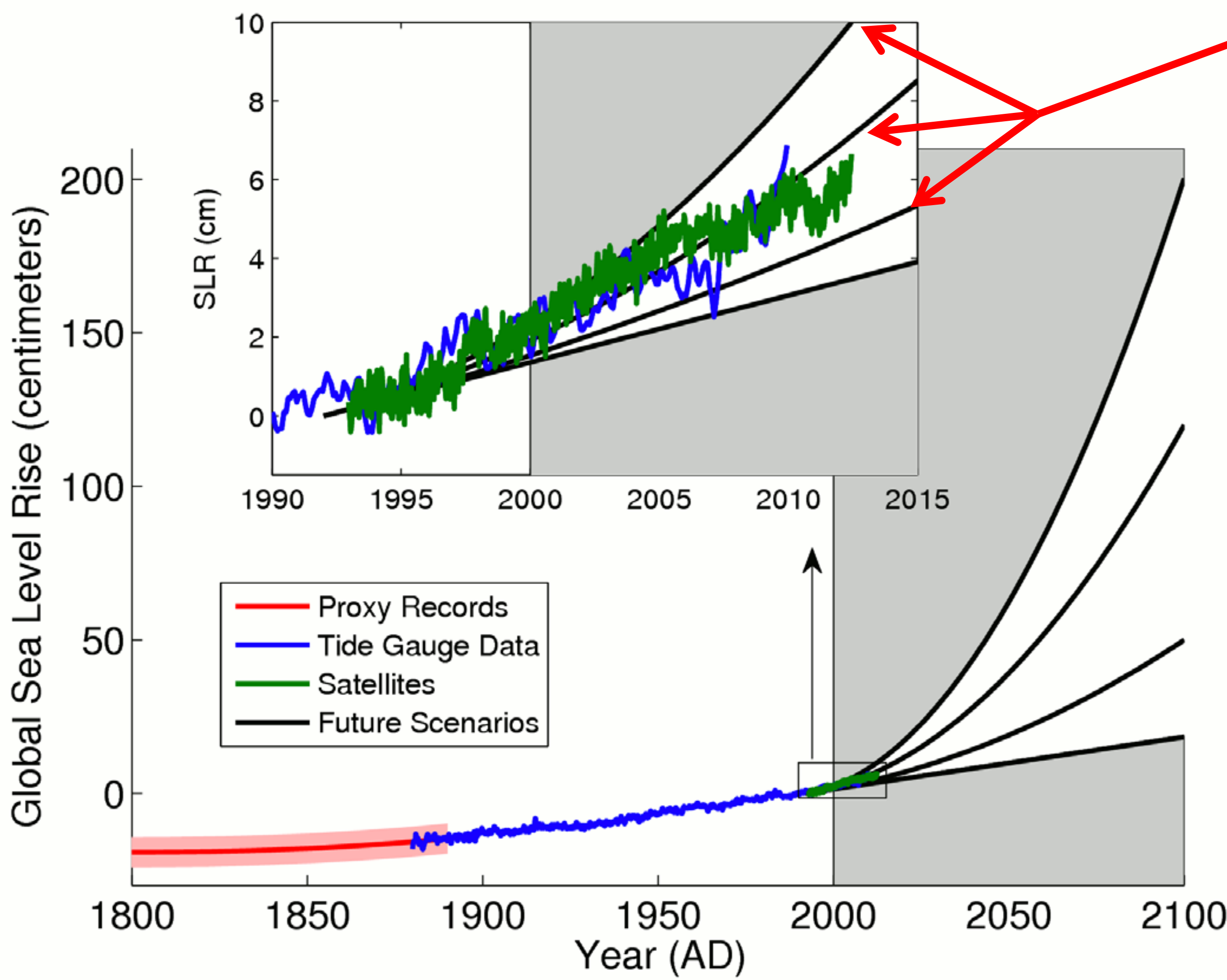
Maeslant Storm
Surge Barrier

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



Future Rise

Which path are we on?



(J. Willis)

EU/US Satellite Altimetry Instruments/Missions

Poseidon-1

1992
TOPEX/
Poseidon

Poseidon-2

2001
JASON-1

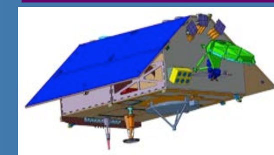
Poseidon-3

2008
JASON-2

Poseidon-3B

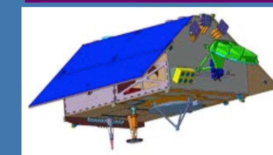
2015
JASON-3

Poseidon-4



2020
S6/J-CS A

Poseidon-4

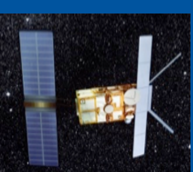


2026
S6/J-CS B

Copernicus

Polar Orbit Missions

RA



1992
ERS-1

RA

1995
ERS-2

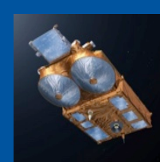
RA-2

2002
ENVISAT

SIRAL

2005
CS-1

SIRAL



2010
CS-2

SARAL

2012
AltiKa

SRAL

2016
S3-A

SRAL

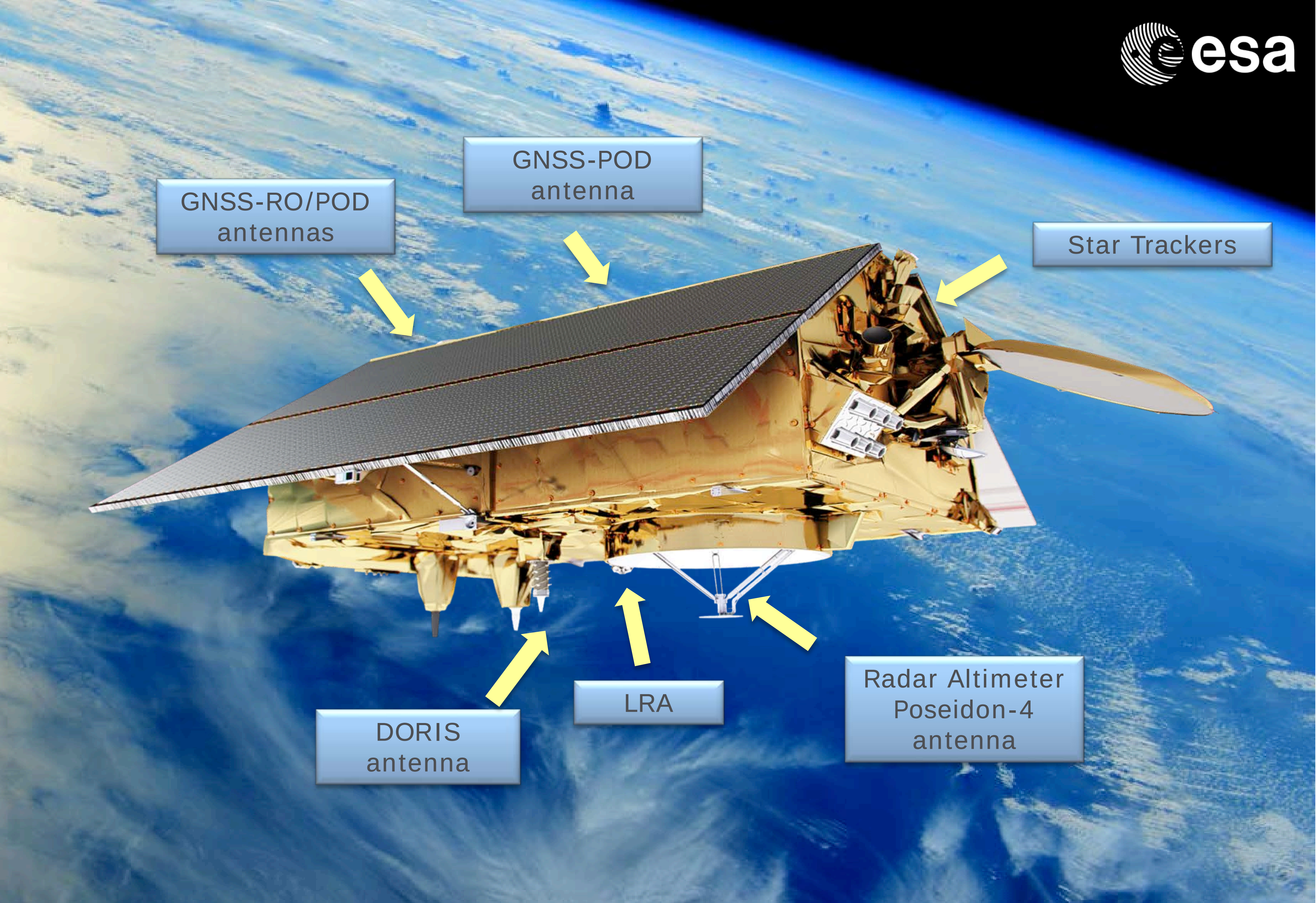
2018
S3-B

SRAL

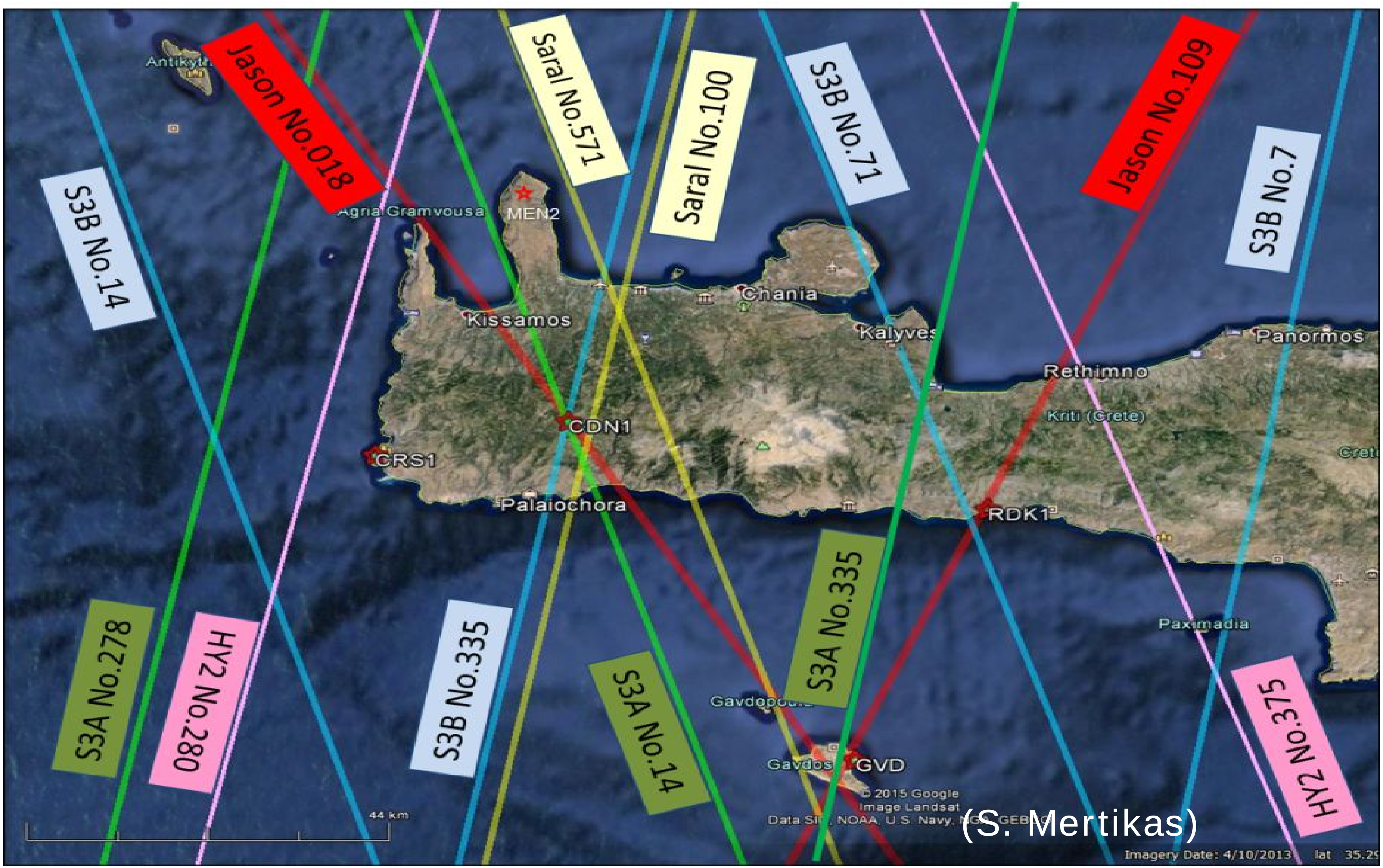
2023
S3-C

SRAL

2026
S3-D


GNSS-RO/POD antennas
GNSS-POD antenna
Star Trackers
DORIS antenna
LRA
Radar Altimeter Poseidon-4 antenna

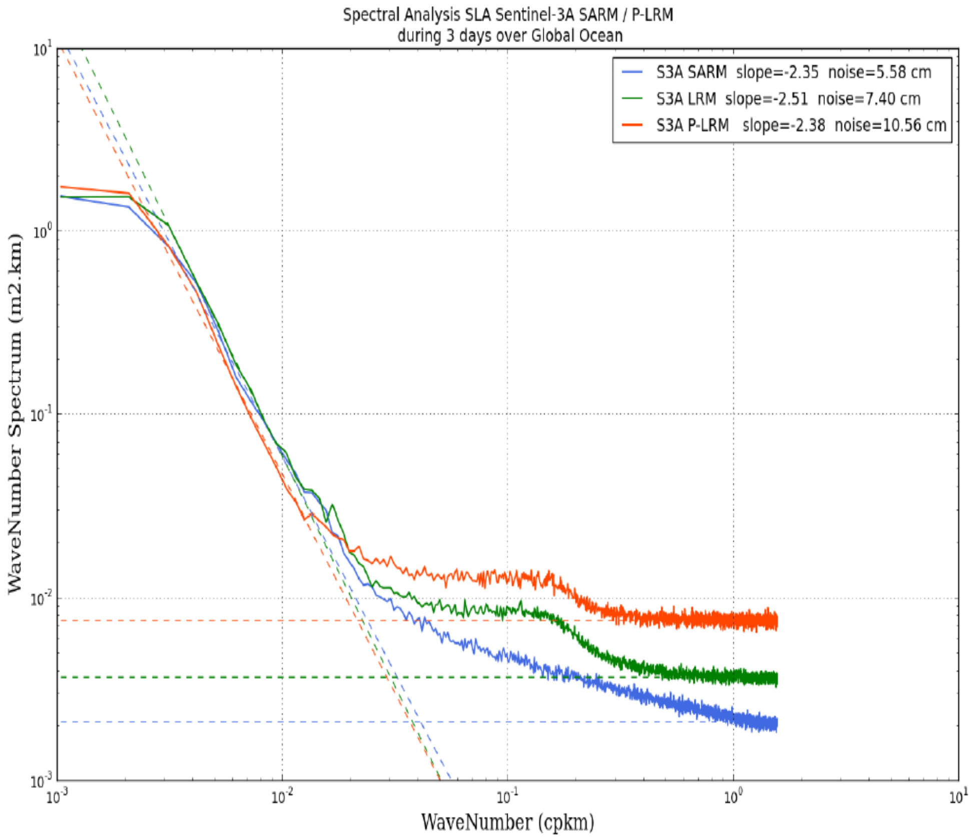
Multi-mission altimetry sampling

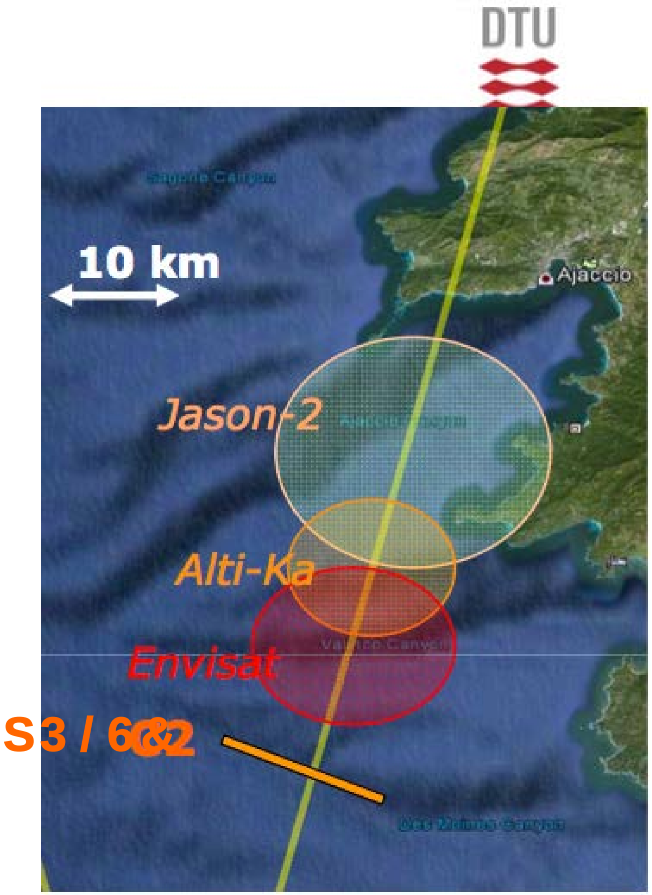


Sentinel-3A Spectral analysis

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

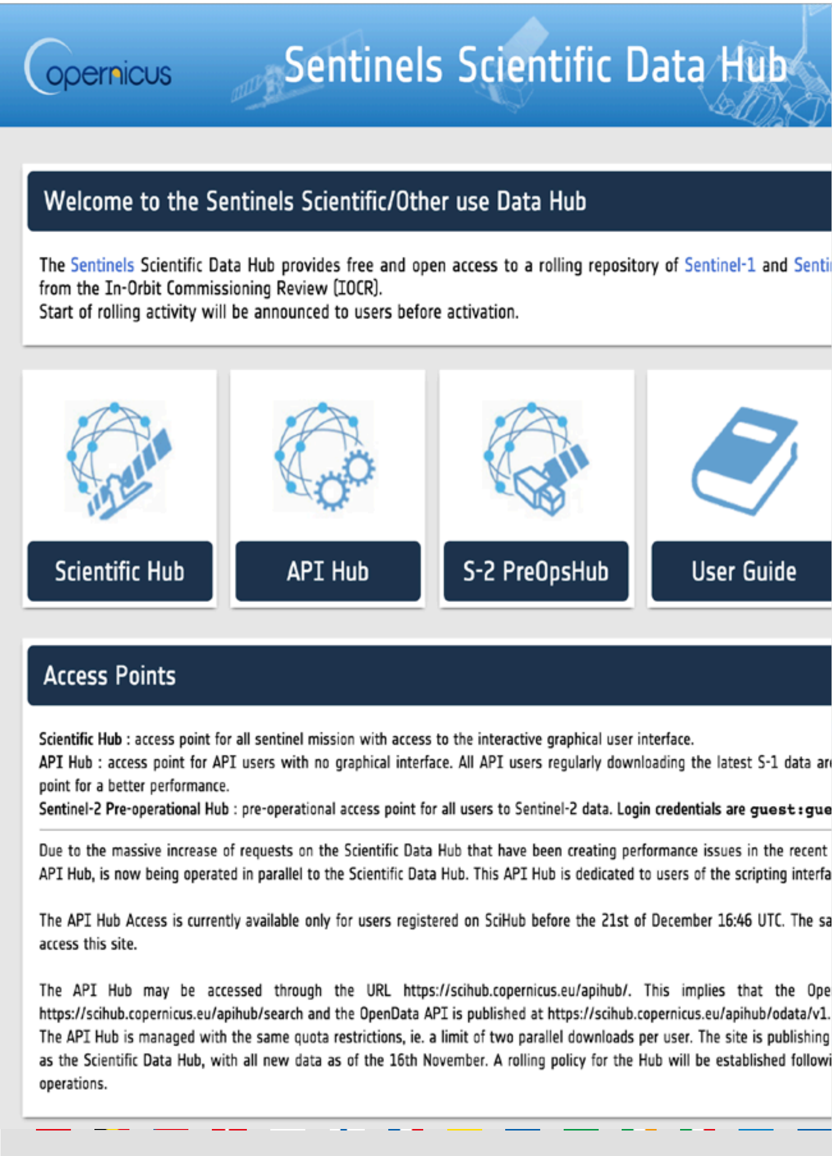


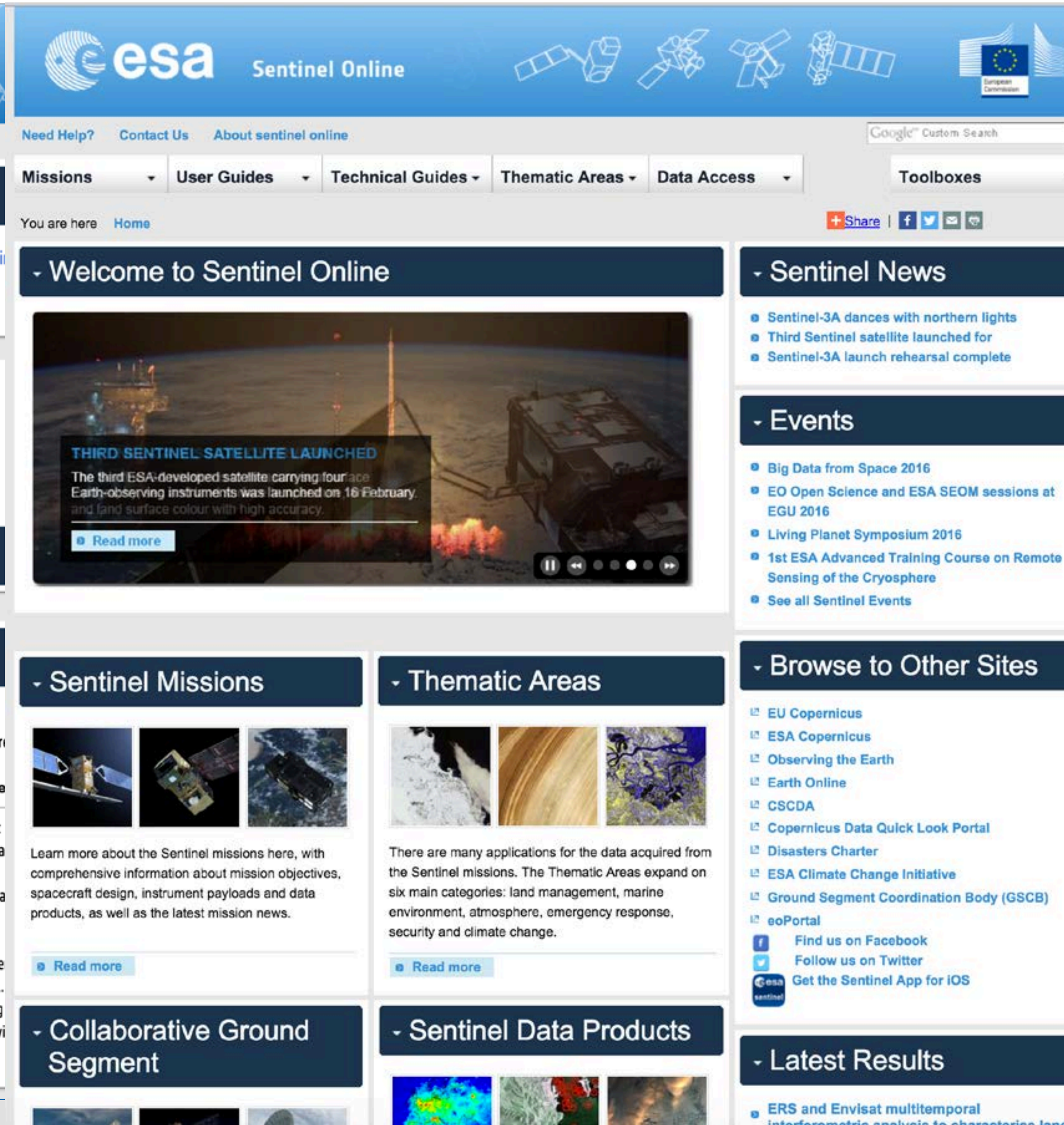


au)

Open and Free data access policy

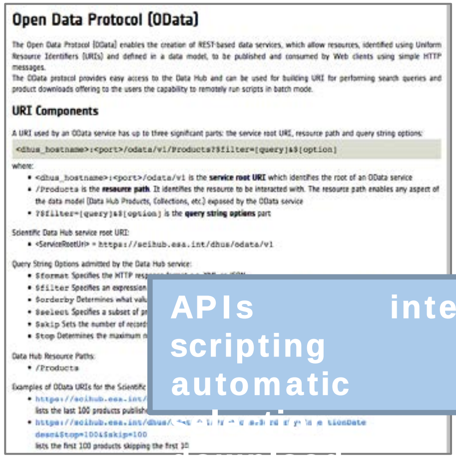
https://sentinels.copernicus.eu
https://scihub.copernicus.eu/





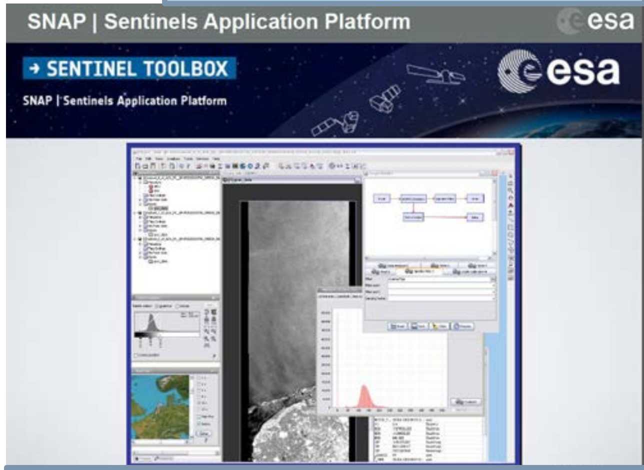
Sentinel data access tools @ ESA

Data Hub Web graphic Interface http://scihub.copernicus.eu



APIs interface: scripting for automatic data

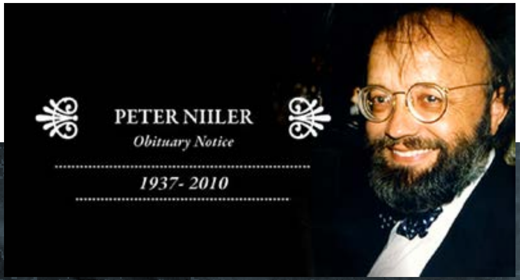
SNAP Sentinel toolbox



Data Hub Server available as open source software
https://github.com/SentinelDataHub/DataHubSystem

Sentinel Toolbox available as open source software
https://github.com/senbox-org

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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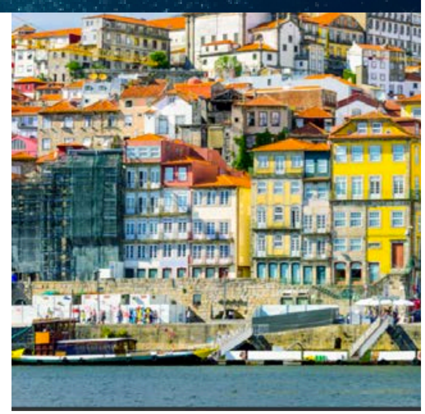

50 places available

Open to European and International PhD, Post grad and Post Doctorate scientists

	Monday	Tuesday	Wednesday	Thursday	Friday
Ocean Synergy Challenge [	Mesoscale and sub-mesoscale Structures ☐	Sea Level and Ocean Surface Transport ☐	Wind Waves and Wave/current interaction ☐	Salinity and Marine Inorganic Carbon ☐	Climate Change and Polar Oceans ☐
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					
12:15	Lecture-2: Ocean Biology from Space				
12:30					
12:45					
13:00	Lunch	Lunch	Lunch	Lunch	Lunch

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Thank You – any Questions

Contact: Craig.Donlon@esa.int