esa space solutions

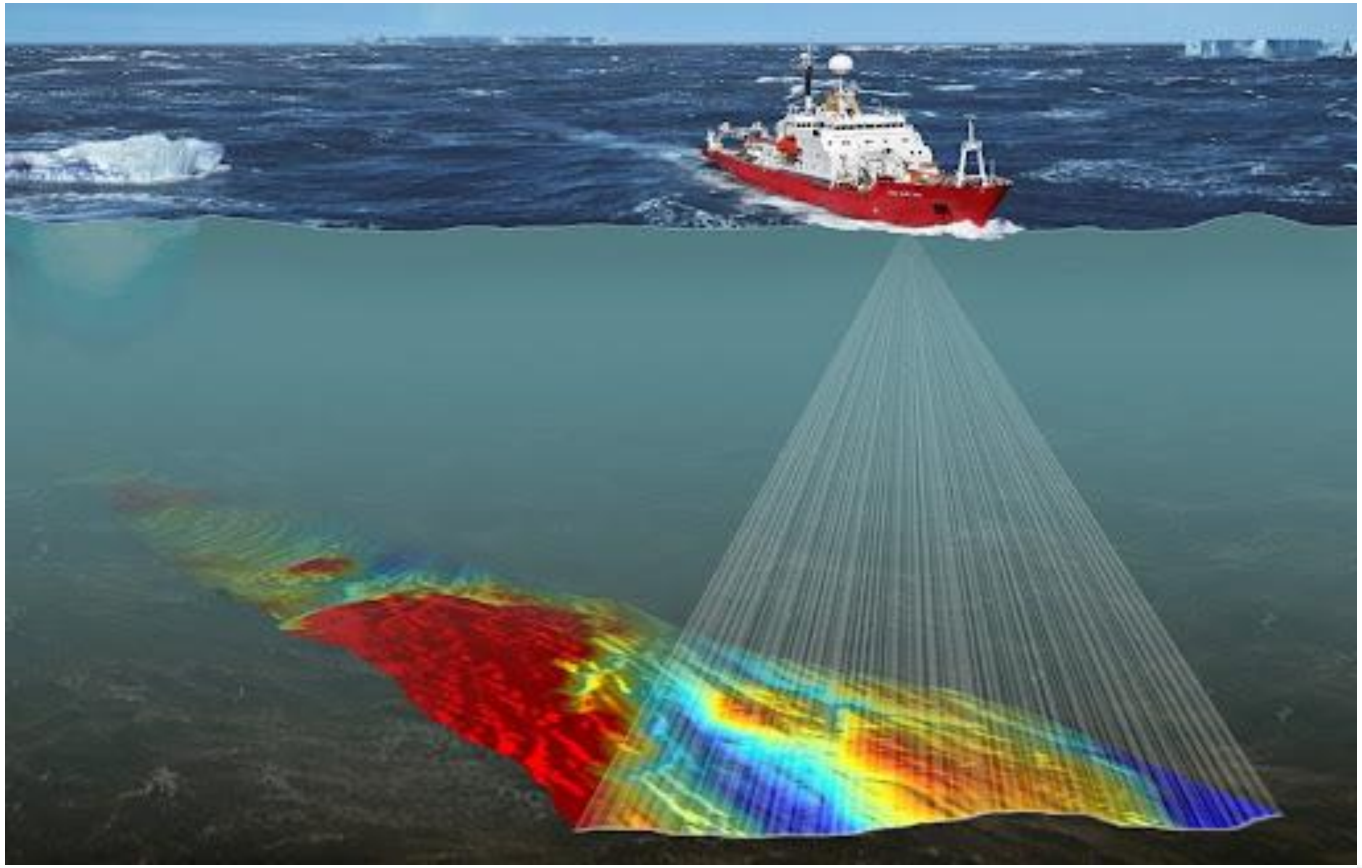
Copernicus Academy

ÚSTAV GEOGRAFIE
Prírodovedecká fakulta UPJŠ v Košiciach

13. Marine applications: nearshore bathymetry, sea surface monitoring

What is Bathymetry?

- Bathymetry is the study of underwater depth of the oceans and the topography of the sea/ocean floor
- It involves measuring and recording water depths to create maps, which provide valuable information about underwater features
- Bathymetric data is essential for various applications, including marine navigation, oceanographic research, coastal zone management, marine resource exploration, engineering work, port management, pipeline laying and fishing

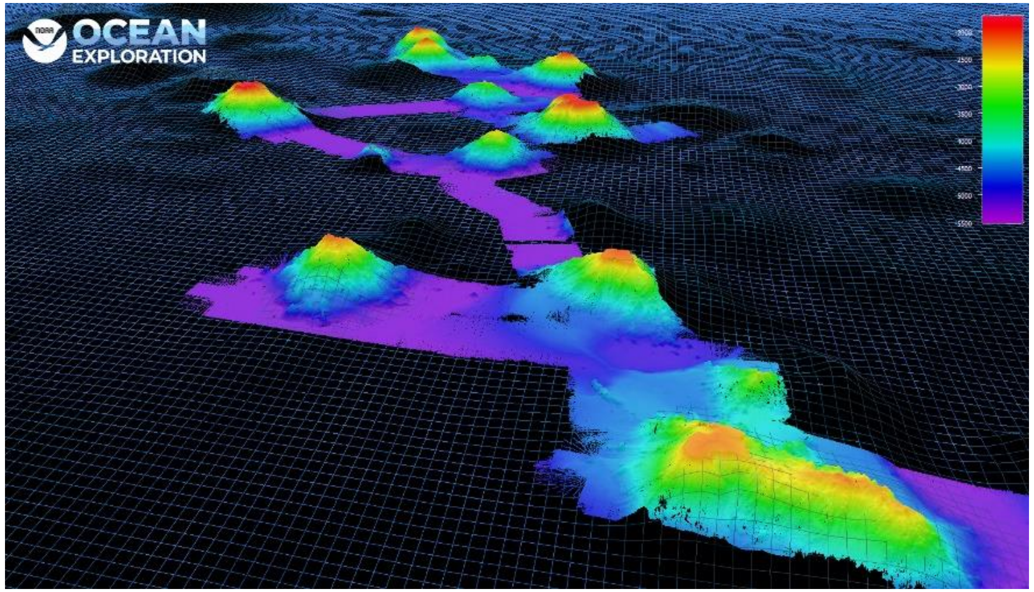


Source: http://digielitetechnologies.com/services/hydrographic-bathymetric-survey/

For more information, see the tutorial:
[13. Marine applications: deriving nearshore bathymetric model with Sentinel 2 data using SNAP software]

Evolution of Bathymetric mapping

- **Historically** - methods like premeasured ropes or cables to measure seabed depth - slow and inefficient approach
- **Acoustic echo-sounding** (single-beam and multi-beam) - faces limitations in turbid waters due to sound wave absorption
- **Airborne laser bathymetric (ALB) LiDAR systems** - effective but costly
- **Remote sensing -** has emerged as a promising tool for ocean bathymetry mapping due to its wide coverage, low cost, and repeatability
  - recent launches of satellites like Sentinel-1 or Ikonos, QuickBird, WorldView-2 provide high-resolution imagery

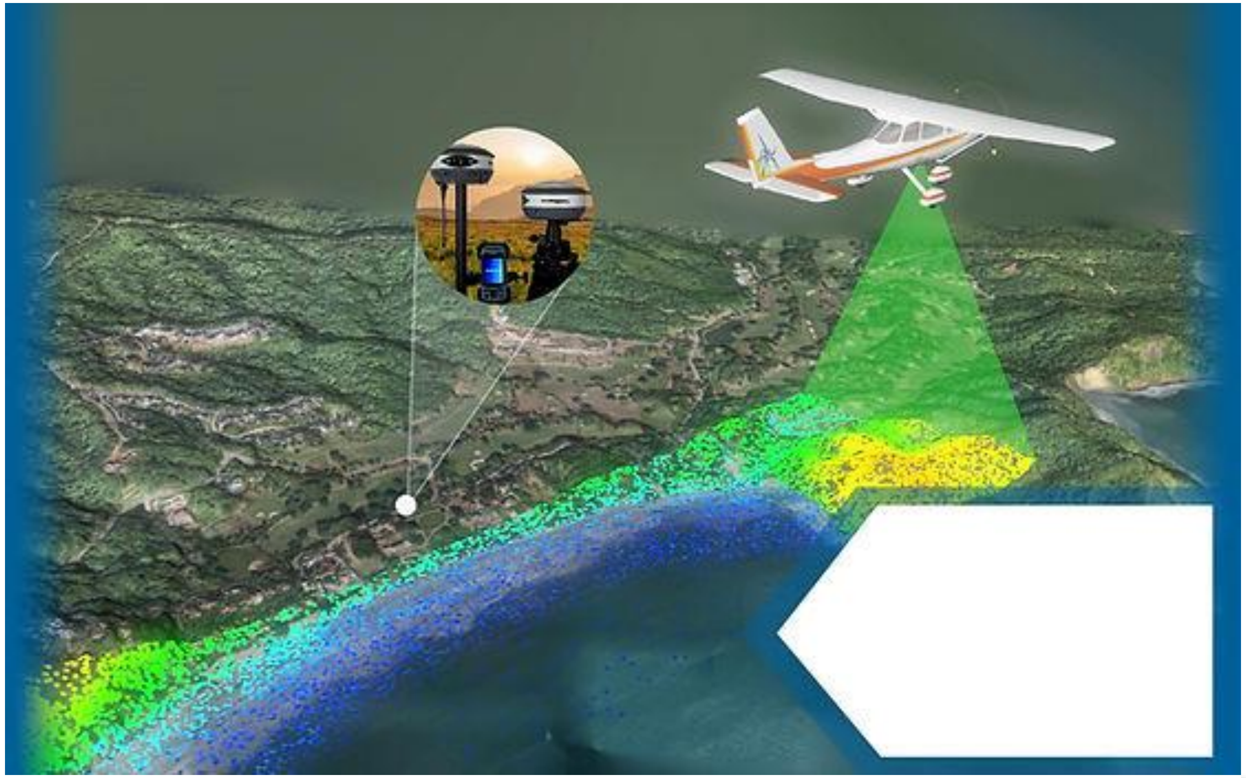


BATHYMETRIC METHODS				
Acoustic methods	Lidar	Remote sensing methods (EM spectrum)		
Pros: High quality data (IHO standard + high resolution)	Cons: Time and/or money consuming especially in shallow areas	SDB	Gravity	SAR radar
		Pros: Time and money efficient		
		Cons:		
		Depth limitation (up to 30 meters)	Resolution and accuracy	Depth limitation (10 m to 70 m)

Source:https://fig.net/resources/proceedings/fig_proceedings/fig2021/ppt/ts04.1/TS04.1_vrdoljak_kilic_10940_ppt.pdf

Approach for satellite imagery

- **Interactive/empirical methods**
  - Relative brightness to water depth
- **Photogrammetric/stereo approach**
  - Find matching points on seafloor
- **Multispectral, physics based approach**
  - Resolve light-transfer and retrieve optical properties



Source: https://www.lidar-america.com/aerial-bathymetry-lidar

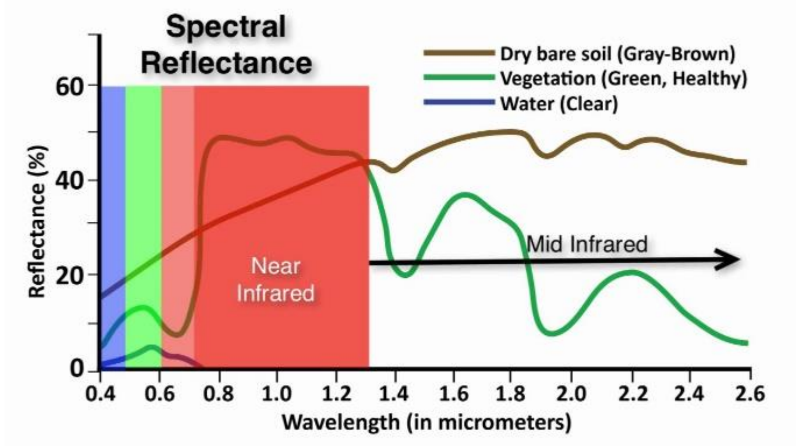
Common bands used in bathymetry

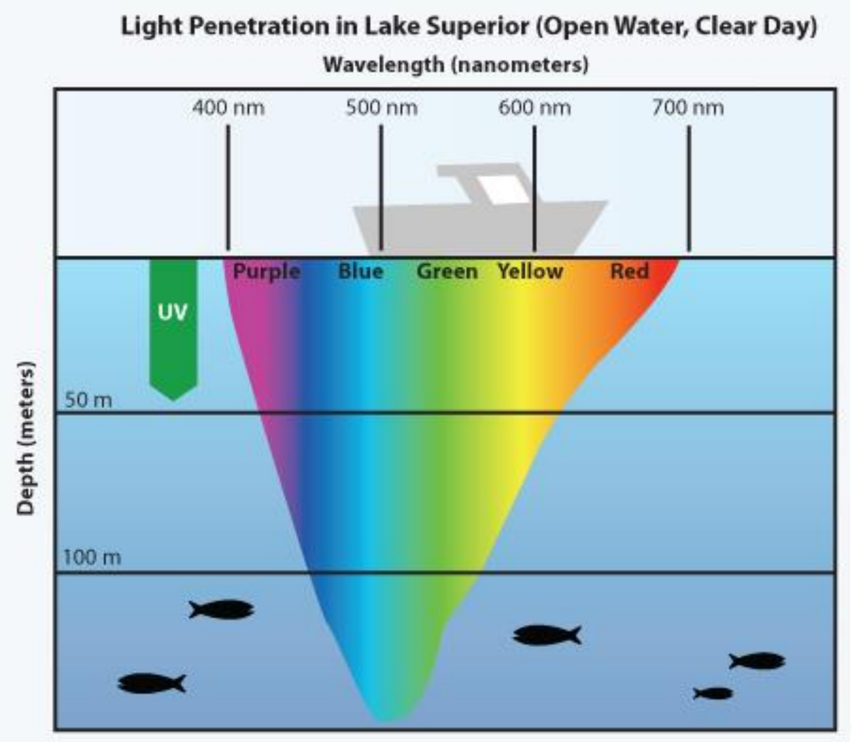
Bathymetry is typically conducted using sensors that operate within specific wavelength ranges:

- **Optical remote sensing:** blue (0.45–0.5 µm), green (0.5–0.57 µm), red (0.61–0.7 µm), NIR (0.7–1.3 µm) and SWIR (1.5–3 µm, sometimes also referred as middle infrared, MIR) bands have been commonly used in water-related applications

- **Bathymetric LiDAR systems:** typically operate in the near-infrared spectrum

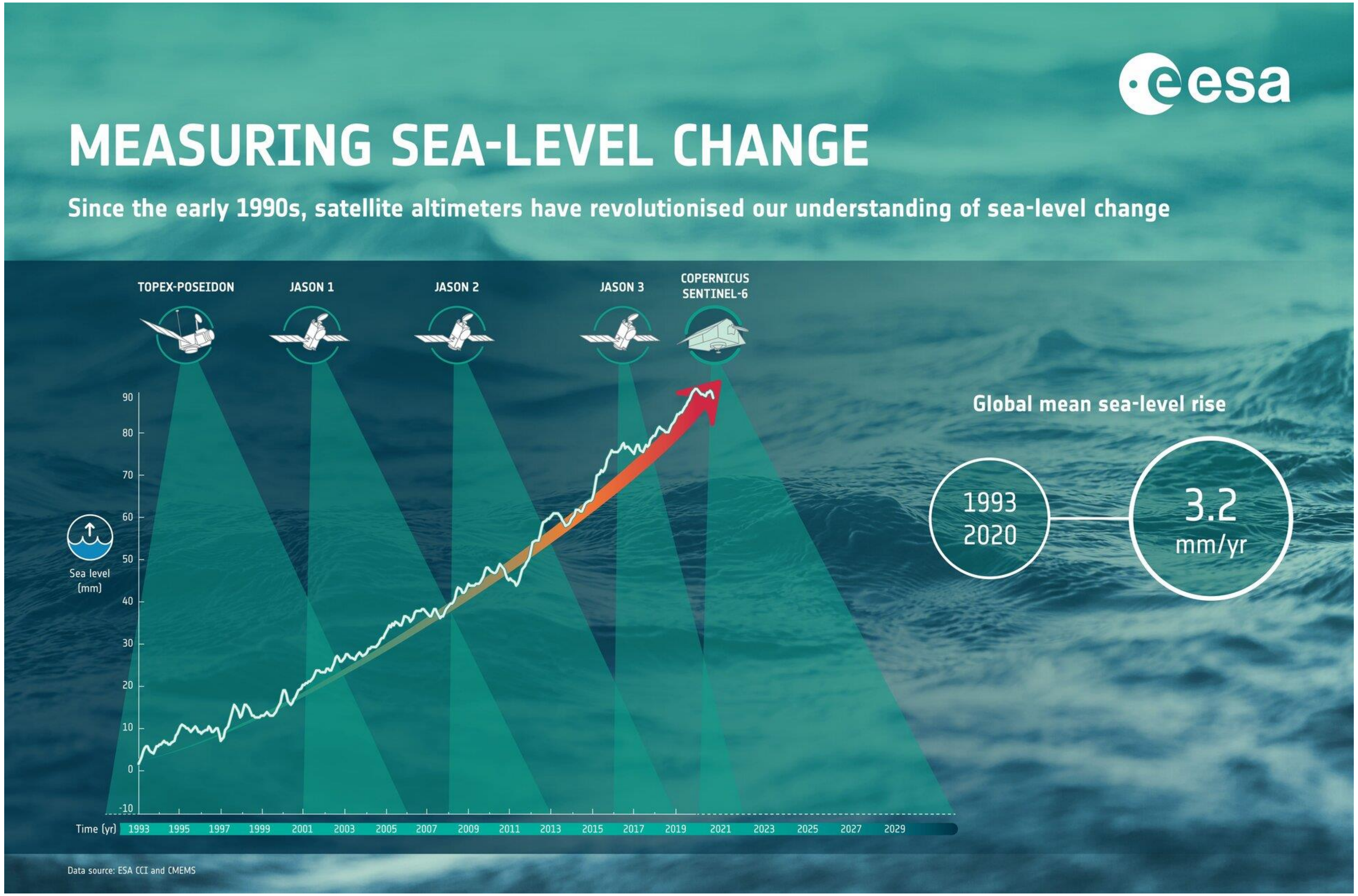
- **Synthetic Aperture Radar (SAR):** operating in the microwave spectrum. The C-band and X-band SAR sensors have been utilized for bathymetry studies





Source: https://www.youtube.com/watch?app=desktop&v=KF2j4sH7pkE, seagrant.umn.edu

Satellites for mapping seas and oceans



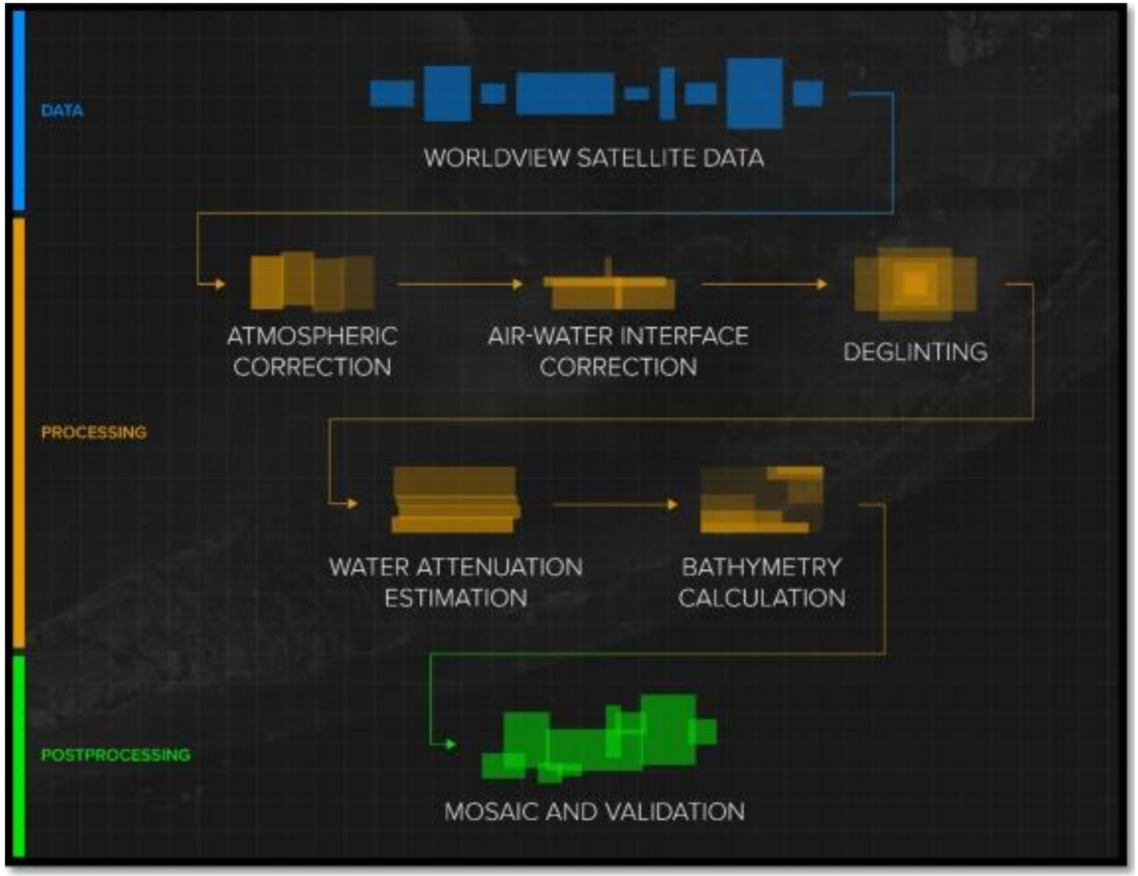
Since the early 1990s, **satellite altimeters** have revolutionised our understanding of sea-level change.

Satellites equipped with radar altimeters capture surface topography along their path over the Earth's surface. These instruments precisely determine the satellite's elevation above various features such as water, land, or ice by measuring the time taken for radar pulses to travel to the surface and back. This technology is crucial for monitoring changes in sea level globally.

Credit: ESA

Satellite-derived bathymetry (SDB)

- Satellite-derived bathymetry (SDB) has existed in practice since at least the 1970s to estimate water depth in clear, shallow water
- The process is based on the observation of water-leaving radiance, knowledge of light attenuation with depth in clear water, and a model calibrated using in-situ depth measurements
- More complex approaches use radiative transfer modeling of the water body’s inherent optical properties (IOPs)
- The remote sensing of aquatic properties includes many challenges, such as detecting and correcting for sun glint, wave action, high suspended sediment, or type of bottom

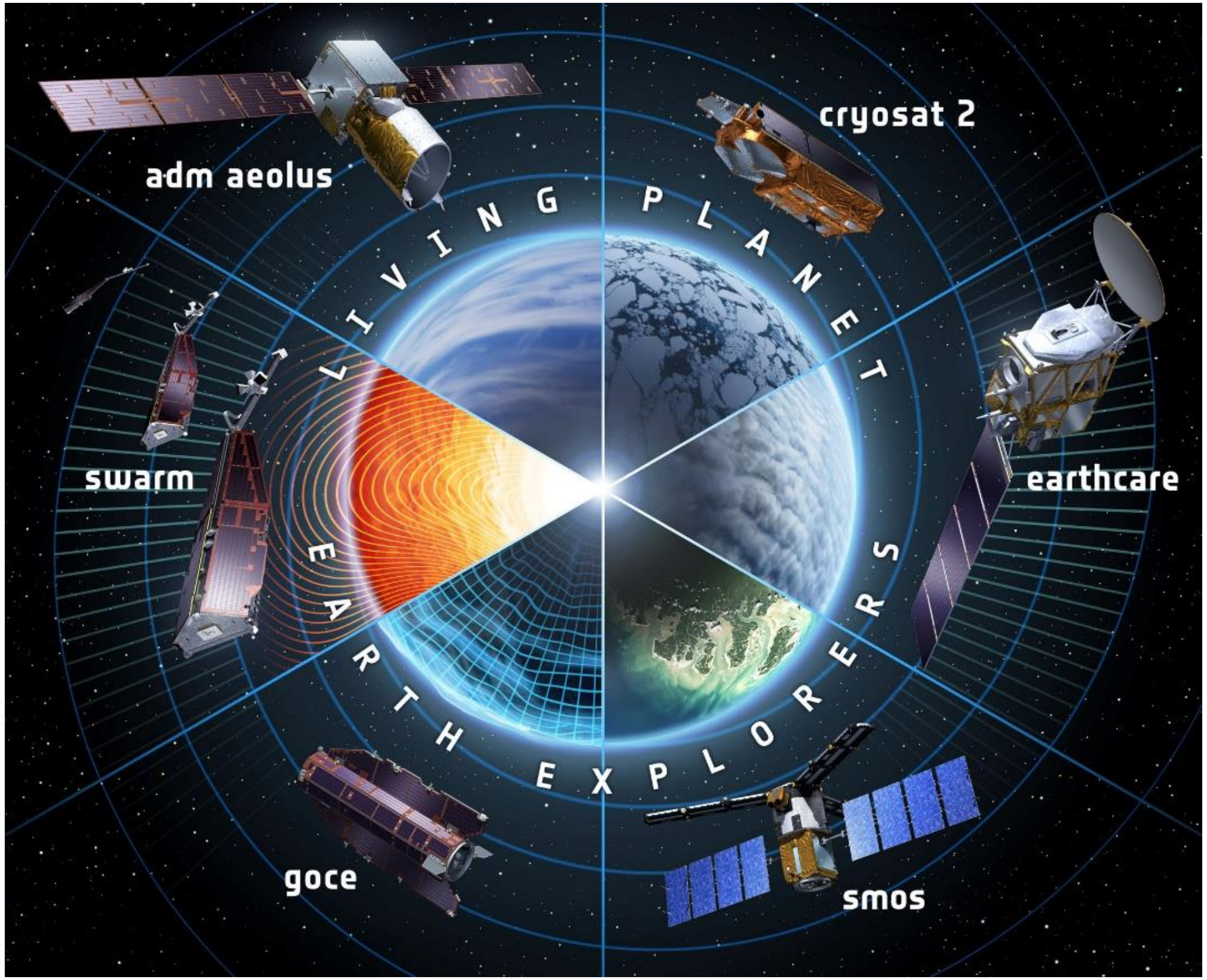


Source:https://www.sciencedirect.com/science/article/pii/S0303243422000198

ESA´s Earth Explorers for mapping sea and ocean

Several Earth Explorer missions launched by the European Space Agency (ESA) provide data that can be utilized for mapping seas and oceans:

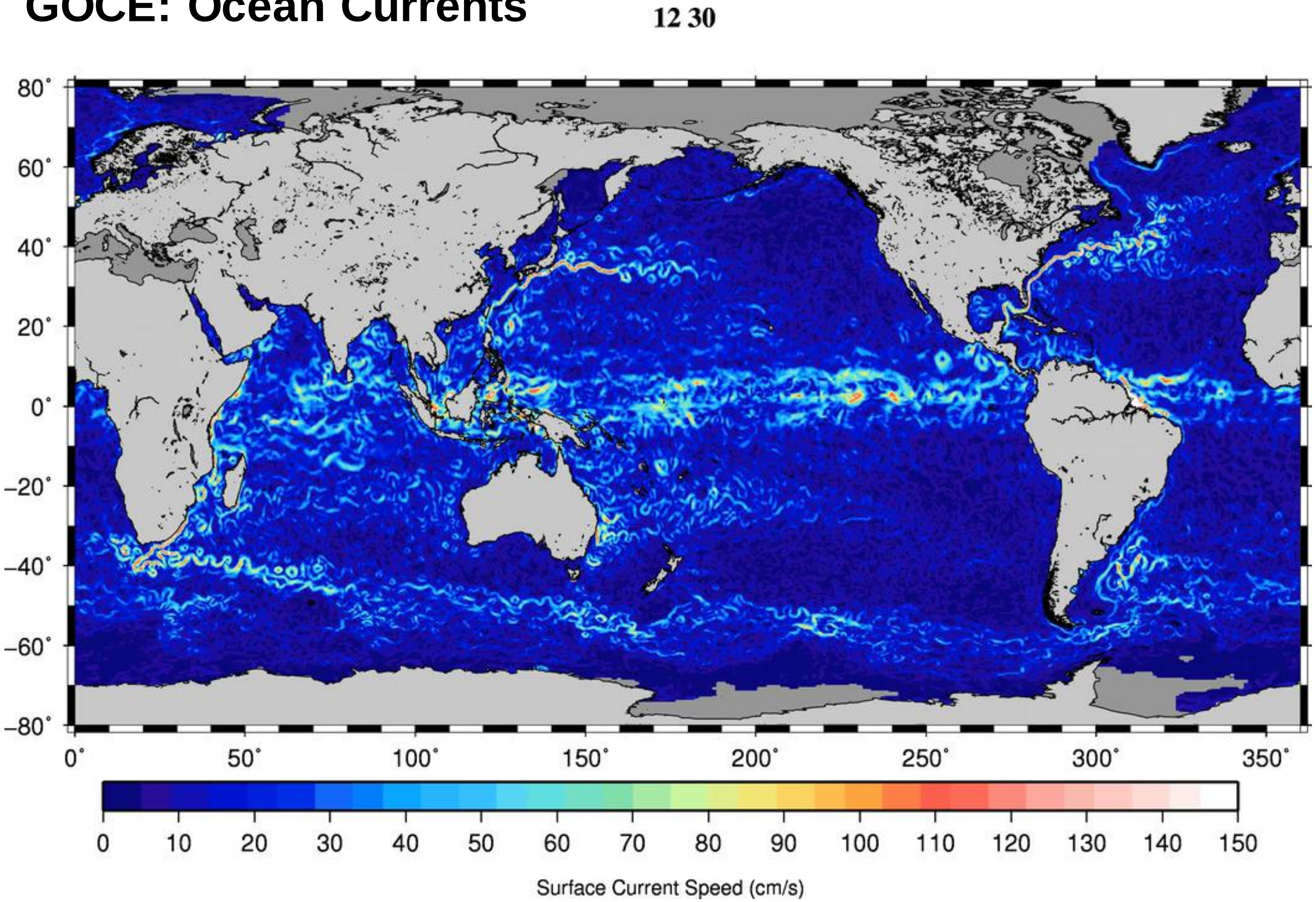
- **GOCE:** provides valuable data for studying ocean currents, sea level changes, and ocean circulation patterns
- **CryoSat:** provides valuable data on sea ice thickness and changes in sea level, which contribute to understanding ocean dynamics
- **Swarm:** provides data on ocean circulation and currents by measuring variations in the Earth's magnetic field caused by oceanic processes
- **SMOS:** can be used to study ocean dynamics and surface currents



Source:https://www.esa.int/ESA_Multimedia/Images/2012/11/ESA_s_Earth_Explorers_satellites

ESA´s Earth Explorers for mapping sea and ocean

GOCE: Ocean Currents



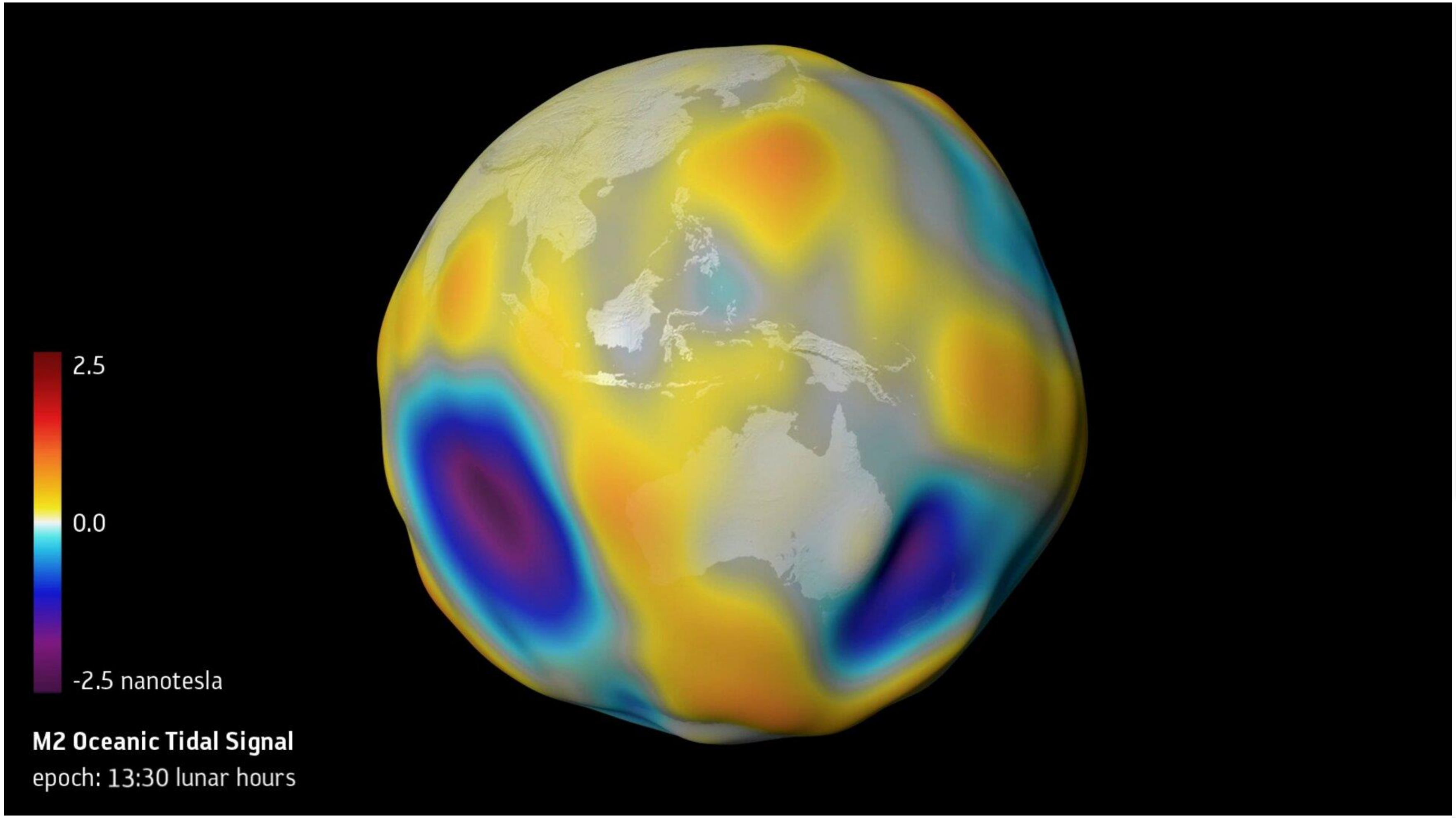
Weekly evolution of ocean surface currents from January 1993 to December 2011.

Gravity data from GOCE geoid & sea altimetry data

Source: https://www.esa.int/ESA_Multimedia/Images/2014/11/Ocean_currents_from_GOCE

ESA´s Earth Explorers for mapping sea and ocean

SWARM: Magnetic tides



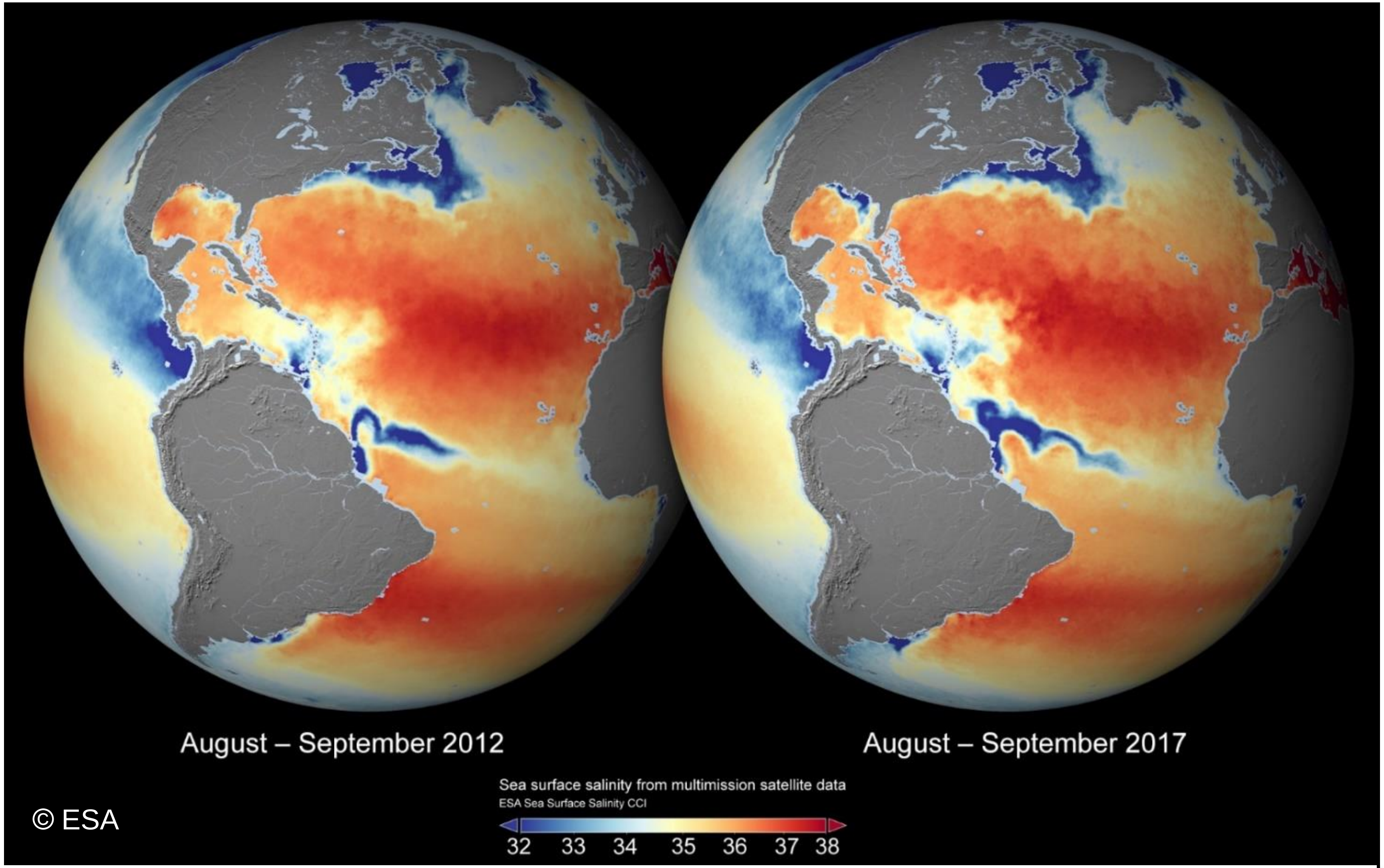
Source: https://www.esa.int/Applications/Observing_the_Earth/FutureEO/Swarm/Swarm_tracks_elusive_ocean_magnetism

The magnetic tidal signal measured by Swarm is important for ocean and climate modelling, and is used to determine the electrical properties of the Earth's lithosphere and upper mantle.

Source: ESA

ESA´s Earth Explorers for mapping sea and ocean

SMOS: Sea-ice change

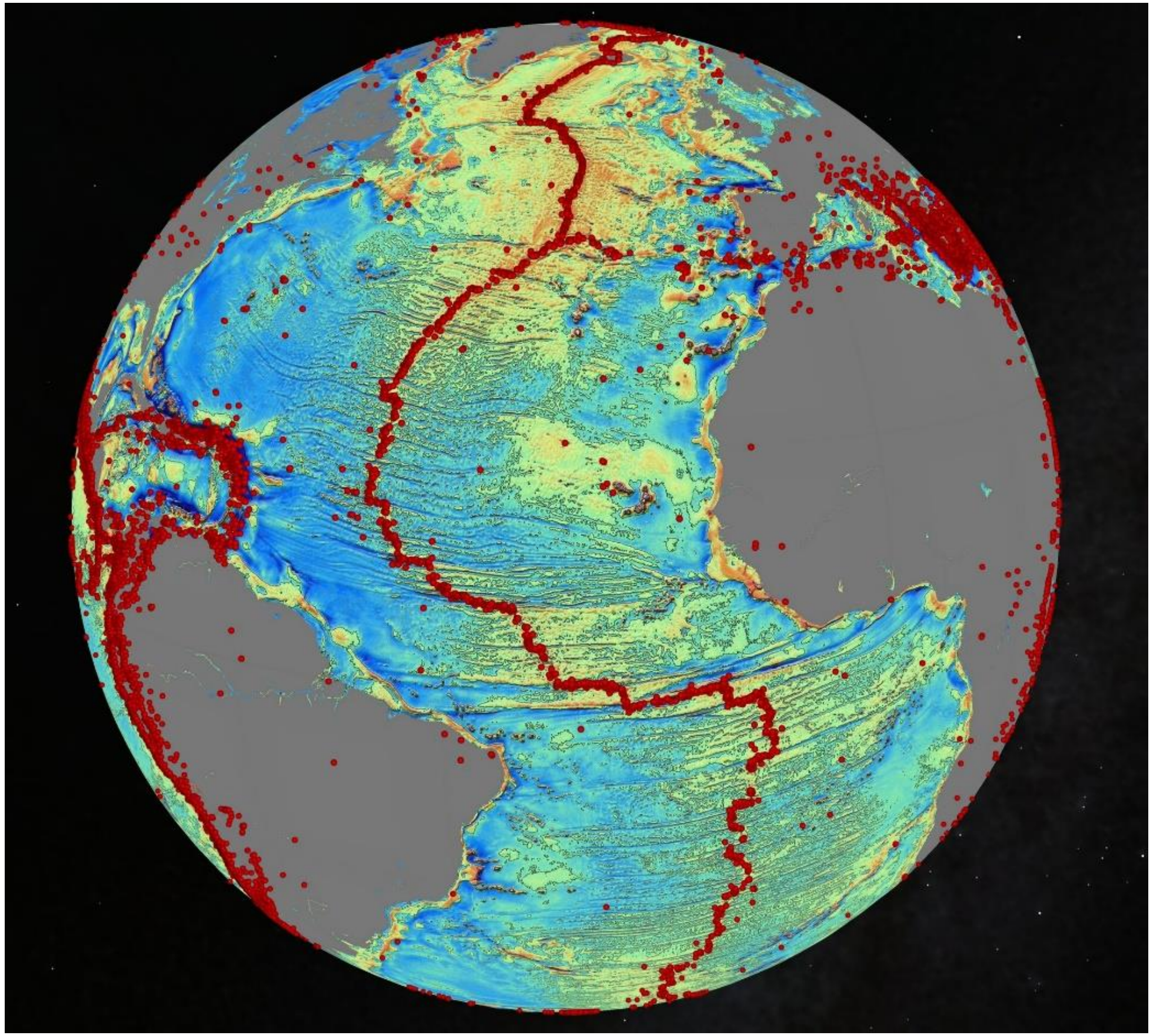


Global sea-surface salinity maps from ESA's Climate Change Initiative showing the difference for the same period in 2012 and in 2017. Note the differences in the spreading of the Amazon and Mississippi River plumes.

Source: https://www.esa.int/ESA_Multimedia/Images/2019/11/Global_sea-surface_salinity_2012_and_2017

ESA´s Earth Explorers for mapping sea and ocean

CRYOSAT: Marine gravity map



- Scientists from Scripps Institute of Oceanography at University California San Diego used altimetry measurements from ESA's CryoSat mission and from the CNES–NASA Jason-1 satellite to create a new marine gravity map – twice as accurate as the previous version produced nearly 20 years ago.

- CryoSat's main task is to measure the elevation of the world's ice but its altimetry measurements acquired over oceans measure sea-surface height, and this can be used to create global marine gravity models and, from them, eventually derive maps of the seafloor.

Credits: ESA

ESA´s Sentinels for mapping sea and ocean

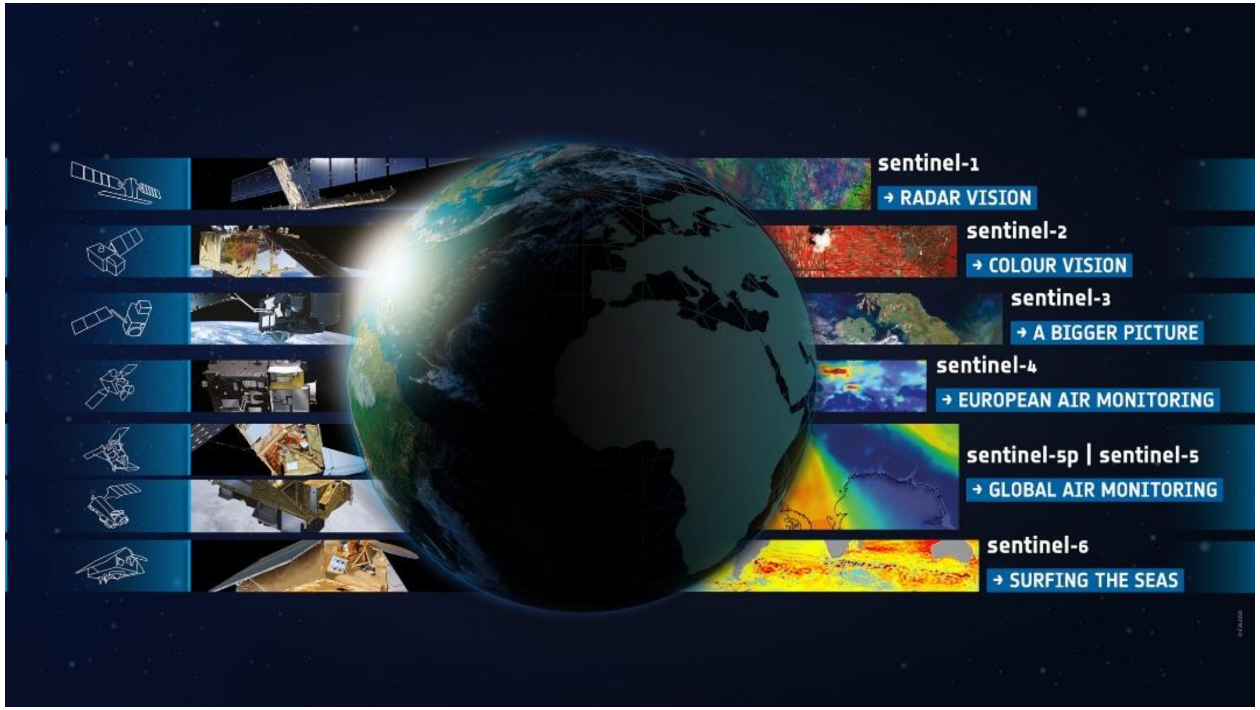
ESA's Sentinel satellite missions, including Sentinel-1, Sentinel-2, Sentinel-3, and Sentinel-6/Jason-CS, provide vital data for mapping and monitoring the Earth's seas and oceans:

Sentinel-1's Synthetic Aperture Radar (SAR) - tracks sea ice extent, ocean surface wind fields, and oil spills

Sentinel-2 offers insights into coastal erosion and coral reef health

Sentinel-3 is dedicated to oceanography, monitoring sea surface temperature, ocean color, and sea level rise

Sentinel-6/Jason-CS continues measuring sea surface height, aiding in understanding ocean circulation and climate change



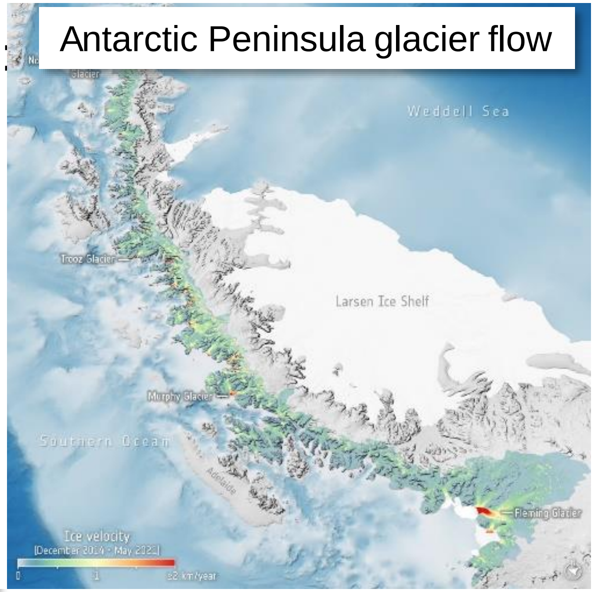
Source:ESA

ESA´s Sentinels for mapping sea and ocean

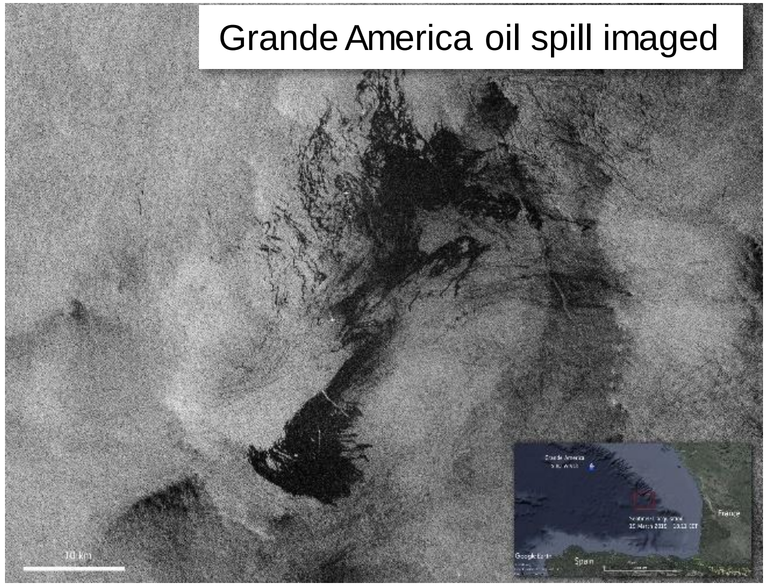
Sentinel-1 – Applications

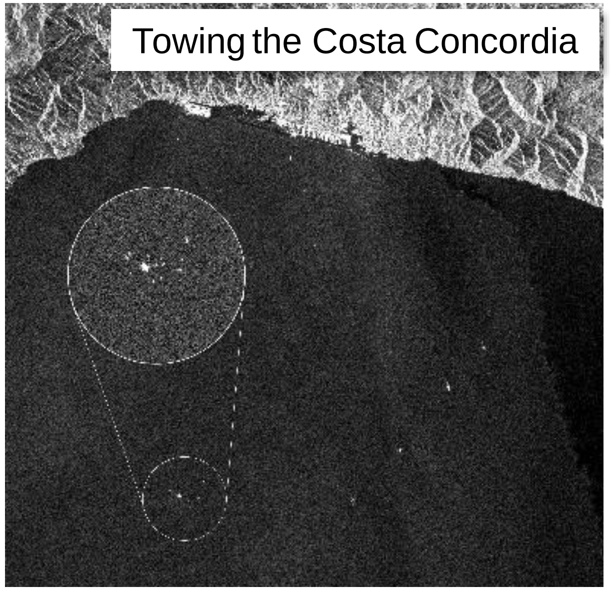
Maritime surveillance:

- Ice Monitoring
- Oil Spill Monitoring
- Ship Detection
- Marine Winds, Etc.



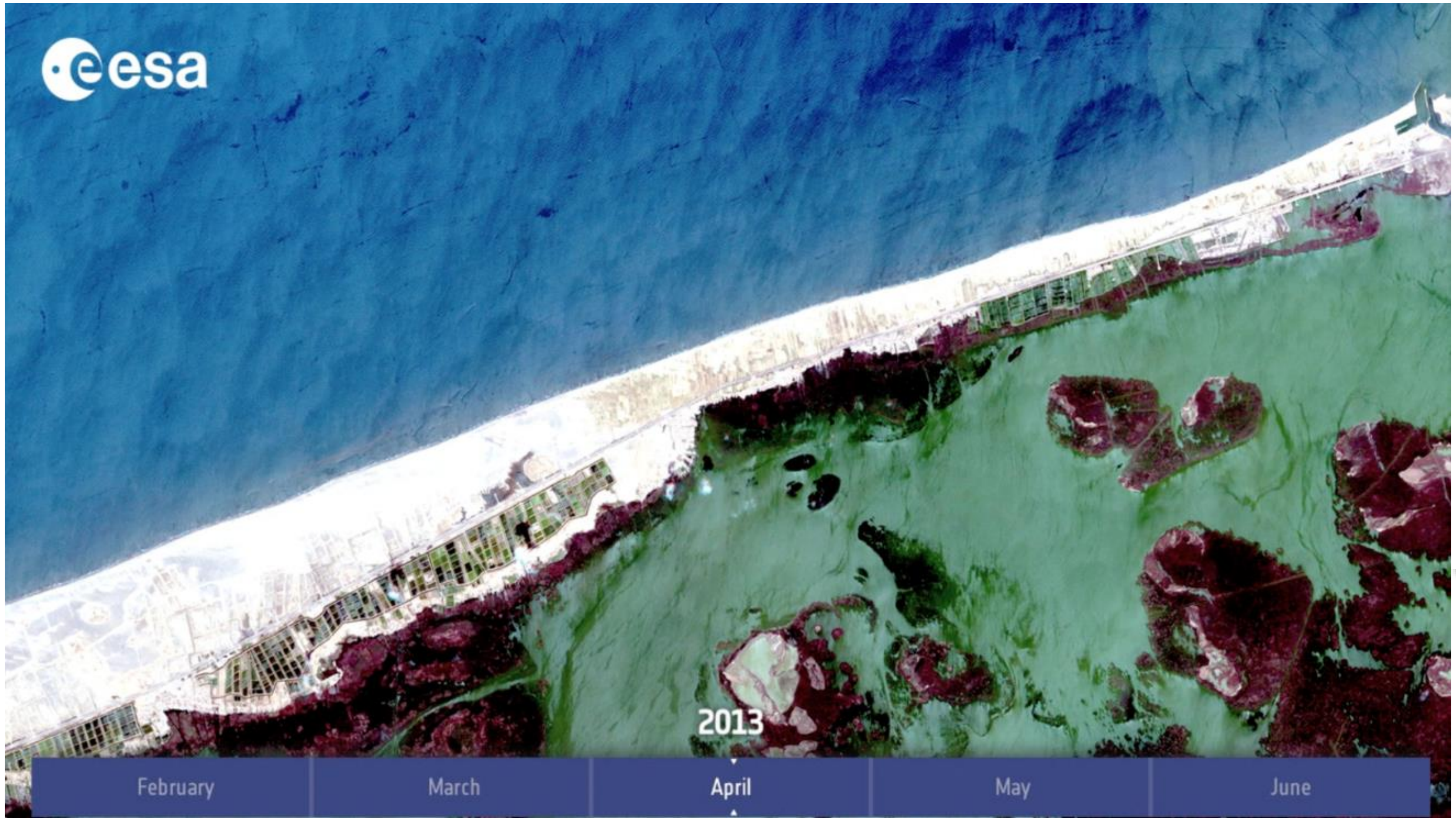
Antarctic Peninsula glacier flow


Grande America oil spill imaged


Towing the Costa Concordia

ESA´s Sentinels for mapping sea and ocean

Sentinel-2 – Applications

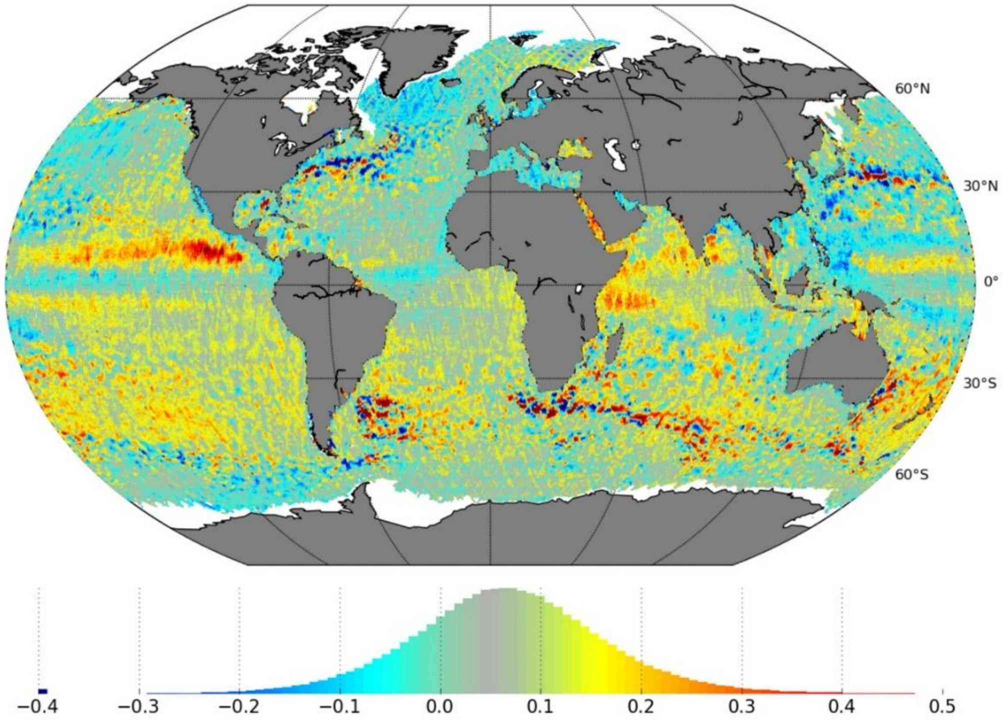


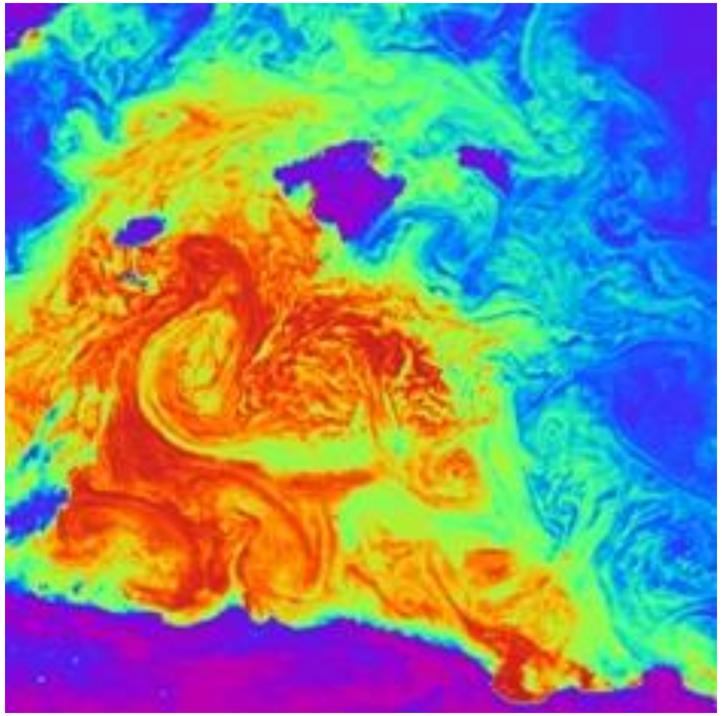
- This animation features imagery from the German RapidEye satellites to demonstrate how the future Sentinel-2 mission will be able to monitor land and coastal zones.

Credits: ESA

ESA´s Sentinels for mapping sea and ocean

Sentinel-3 – Applications



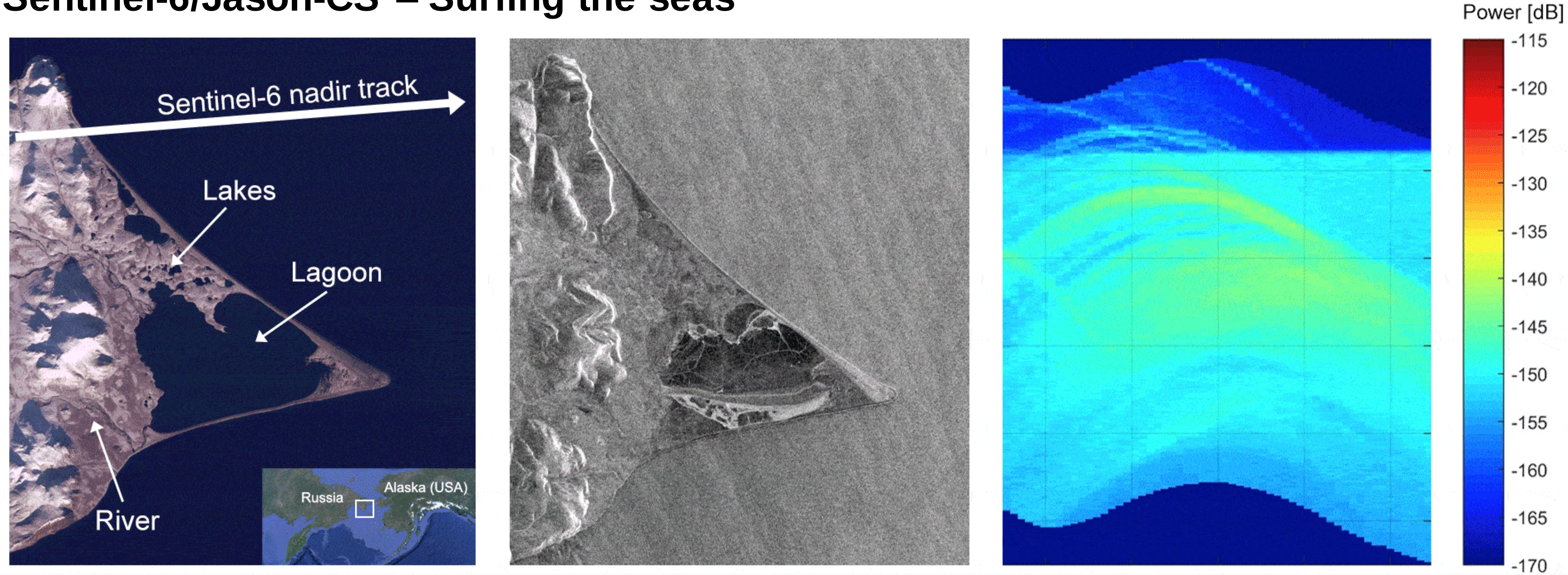


- This new map shows a month of ‘sea-level anomaly’ measurements from Sentinel-3A. The satellite has only been in orbit since 16 February 2016 and is therefore still being commissioned for service. Credits: ESA

- In this night-time image of SST from AATSR, the coldest areas - which include all the land - are shown in purple and blue, whilst yellow and orange are used to represent successively warmer temperatures over a total range of 280-295 K. Credit: RAL

ESA´s Sentinels for mapping sea and ocean

Sentinel-6/Jason-CS – Surfing the seas



The images of Russia’s Ozero Nayval Lagoon and surrounding rivers show multiple views from Copernicus satellites. The first is a 10-m resolution ‘camera-like’ image captured on 29 October 2020 by Copernicus Sentinel-2. The image is marked with the ground track of Copernicus Sentinel-6 as it crosses the region. The second is a radar image captured on 29 November 2020 by Copernicus Sentinel-1 in interferometric wide swath mode and processed to 10 m resolution. The lagoon has frozen over and numerous cracks are visible in the ice. Ocean swell and wind sea roughness are also seen in the ocean with some wave reflection and refraction on the southern coastal areas. The next image uses Copernicus Sentinel-6 pulse-limited low-resolution mode data for the same area. In this mode, similar to Jason-3, the strongest radar reflections appear as overlapping parabola features, but no discrimination of the ground can be made. Overlying the third image, the Copernicus Sentinel-6 Poseidon-4 fully-focused synthetic aperture radar image reveals features of the Ozero Nayvak Peninsular in fine detail. Credits: ESA

ESA's Third Party Missions

Many of ESA third party missions also provide datasets for monitoring Earth's water cycle, e.g.:

- **Pléiades Neo:** very high resolution data can be used for both hydrological and bathymetry applications, allowing deeper penetration in water bodies and a clearer understanding of underwater relief

- **Ocean-Sat:** data on ocean chlorophyll can help research into primary production and the monitoring of phytoplankton blooms

- **RADARSAT-2:** data provide valuable information about sea surface conditions, currents, and wave patterns, can be used for bathymetric mapping, particularly in shallow coastal areas or regions with limited optical visibility

Source:https://intelligence.airbus.com/newsroom/case-studies/pleiades-neo/dhi-water-management-from-space/

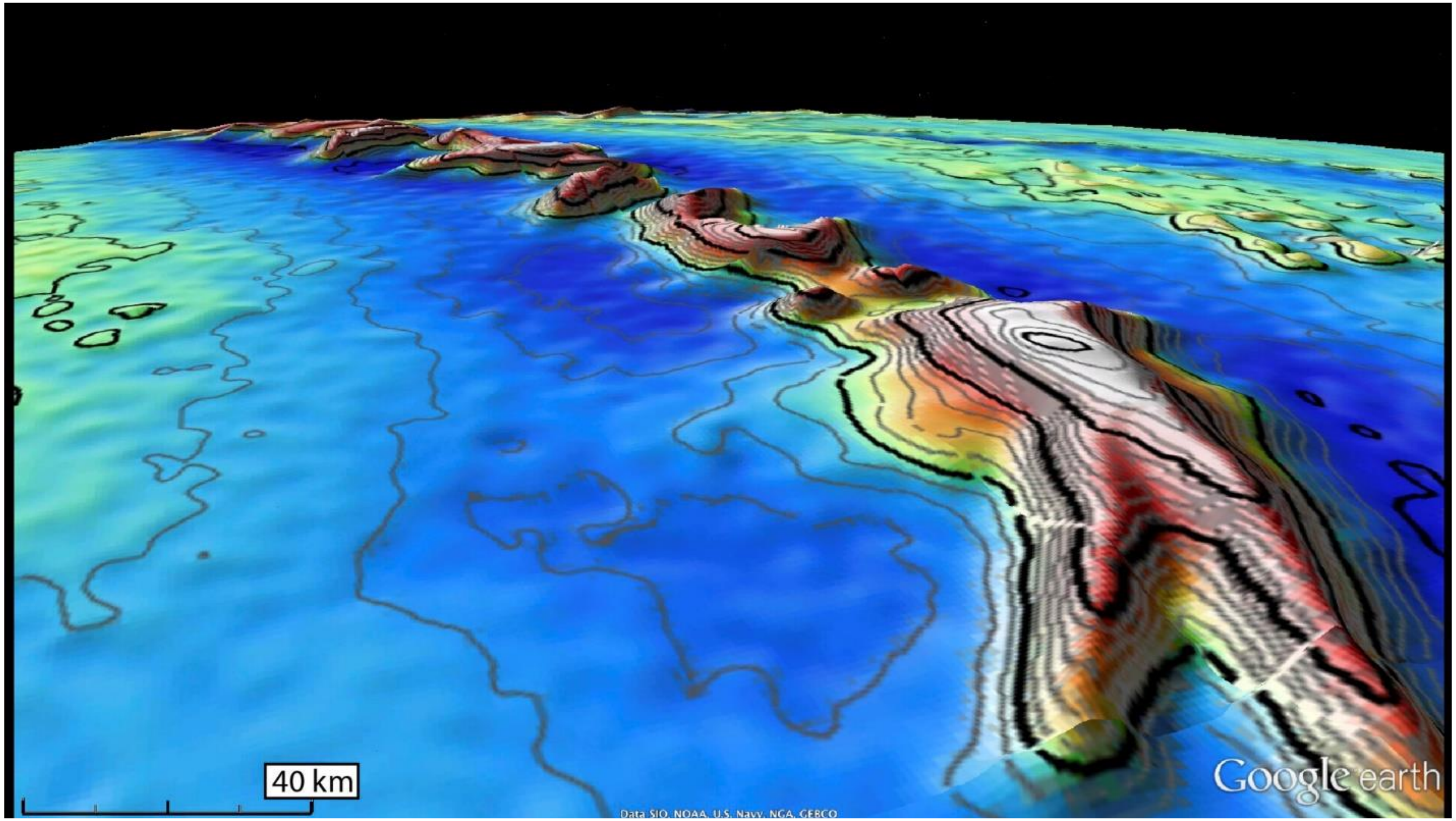
ESA's Heritage Missions

ERS-1 and -2

- data acquired for more than 20 years to track sea surface topography and winds, **moisture transfers**

Envisat

- data on water quality over long time periods



Gravity field over the Pacific Ocean's Emperor Seamounts based on CryoSat, ERS and Geosat satellite altimeter measurements of ocean-surface height.
Source: https://www.esa.int/ESA_Multimedia/Images/2012/05/Improving_bathymetry

Thank you for the attention