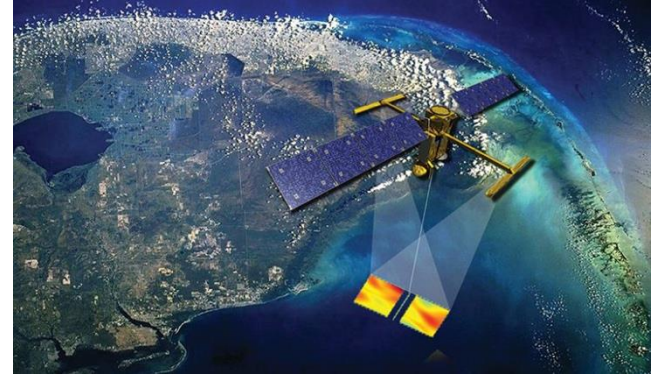


Hands-on altimetry tutorial

Laura Gómez Navarro
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laura.gomez@uib.es

Paul Hargous
IMEDEA (UIB-CSIC)
hargous@imedeia.uib-csic.es



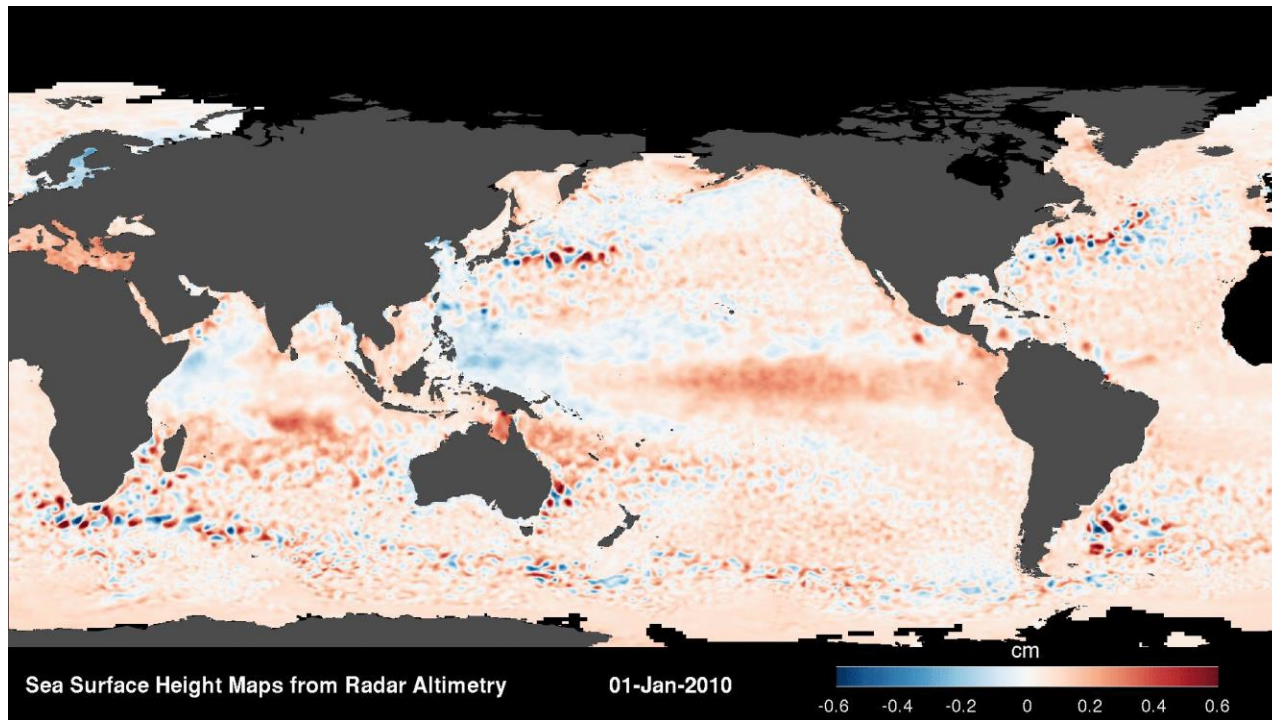
slides credits: Antonio Sánchez-Román and Ananda Pascual



The role of satellites for the Global Ocean Observing System

Contribution of satellites

- Provide long-term, continuous, global, high space and time resolution data
- Key ocean parameters: sea level and surface currents, ocean colour, sea ice, waves ..
- Assimilation and/or validation of ocean models
- Data can be directly used for applications (e.g. marine safety, water quality ...)

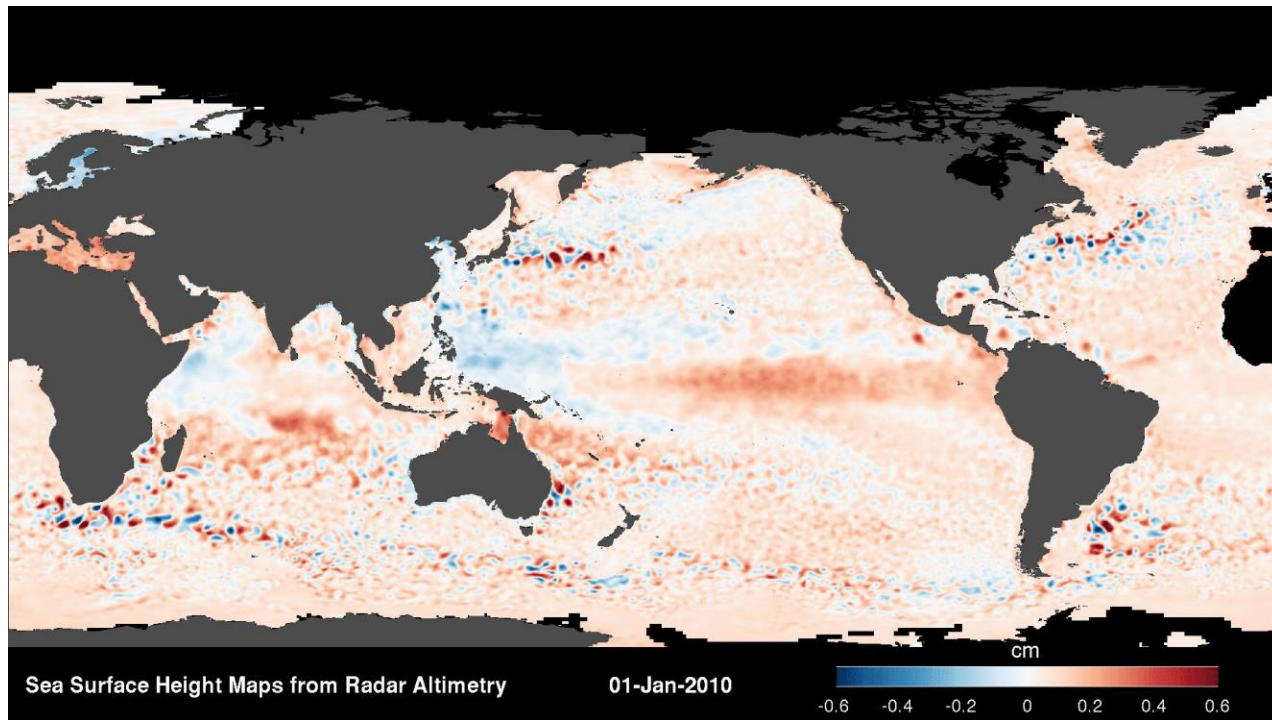


movie courtesy of R. Escudier

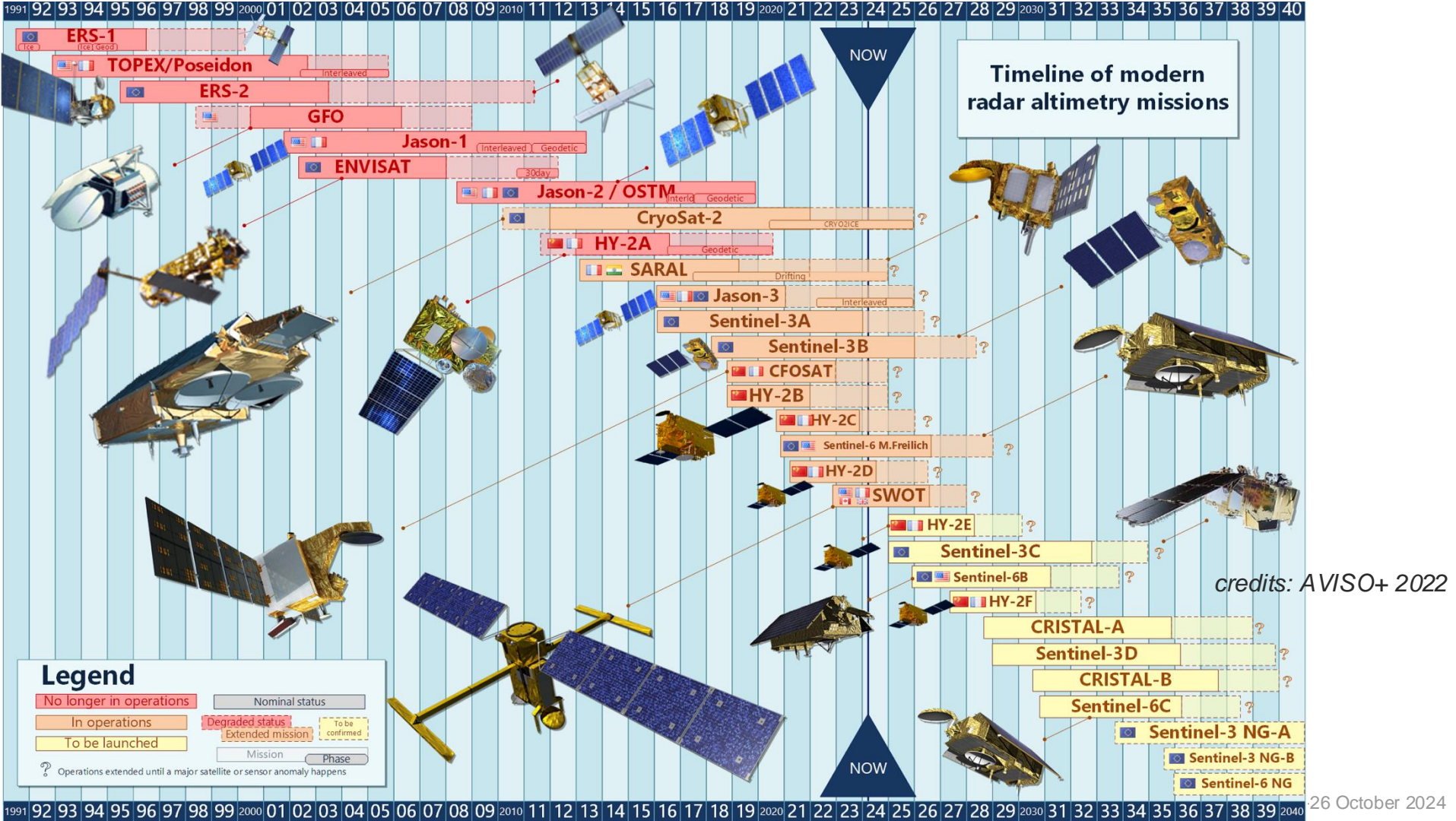
The role of satellites for the Global Ocean Observing System

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movie courtesy of R. Escudier



SARAL-AltiKa

Agencies: CNES – ISRO

Orbit characteristics

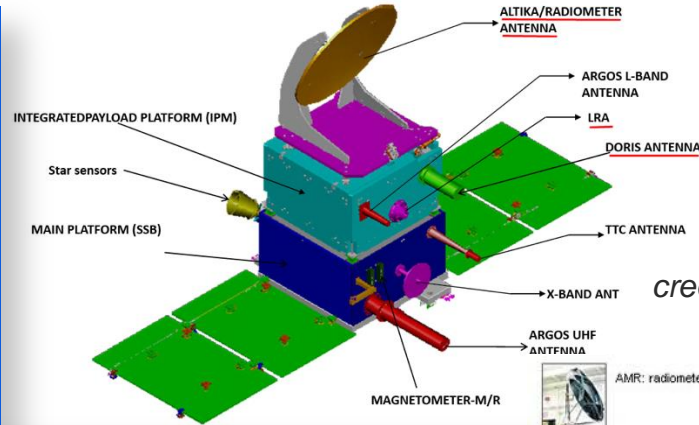
(Sun synchronous)

Altitude: 781 km

Repeat: 35 days

Inclination: 98.55 degrees

Track spacing: 75 km at Equator



credits: Indian Space Research Organization

Jason-class

Agencies: CNES – NASA – NOAA – EUMETSAT

Orbit characteristics

Altitude: 1336 km

Repeat: 10 days

Inclination: 66 degrees

Track spacing: 315 km at Equator



credits: CNES/AVISO



SARAL-AltiKa

Agencies: CNES – ISRO

Orbit characteristics

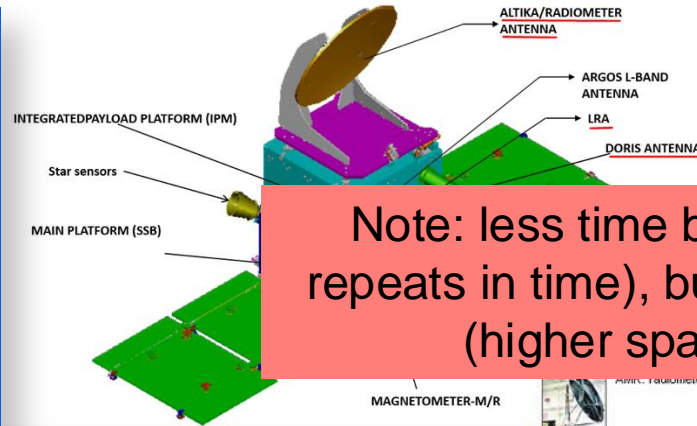
(Sun synchronous)

Altitude: 781 km

Repeat: 35 days

Inclination: 98.55 degrees

Track spacing: 75 km at Equator



Note: less time between cycles (more repeats in time), but less spatial coverage (higher spacing at equator)



credits: CNES/AVISO

Jason-class

Agencies: CNES – NASA – NOAA – EUMETSAT

Orbit characteristics

Altitude: 1336 km

Repeat: 10 days

Inclination: 66 degrees

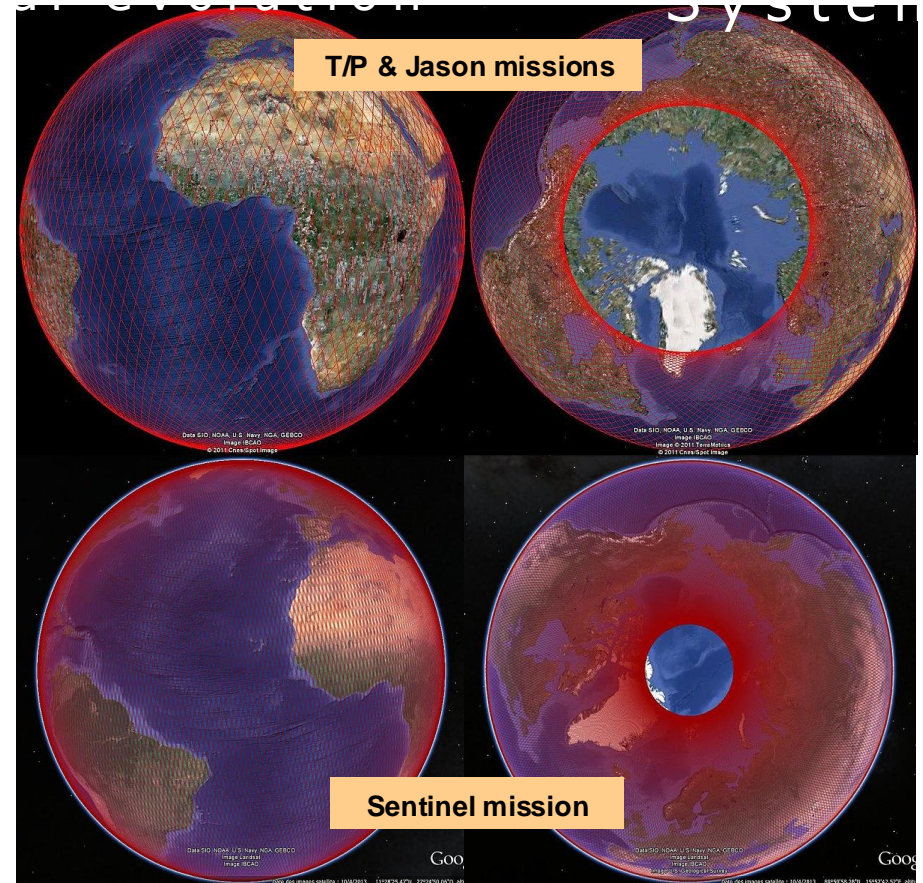
Track spacing: 315 km at Equator



Satellite altimetry coverage characteristics

Spatial coverage

- Global
- Homogeneous
- Nadir (not swath)



Satellite altimetry coverage characteristics

Spatial coverage

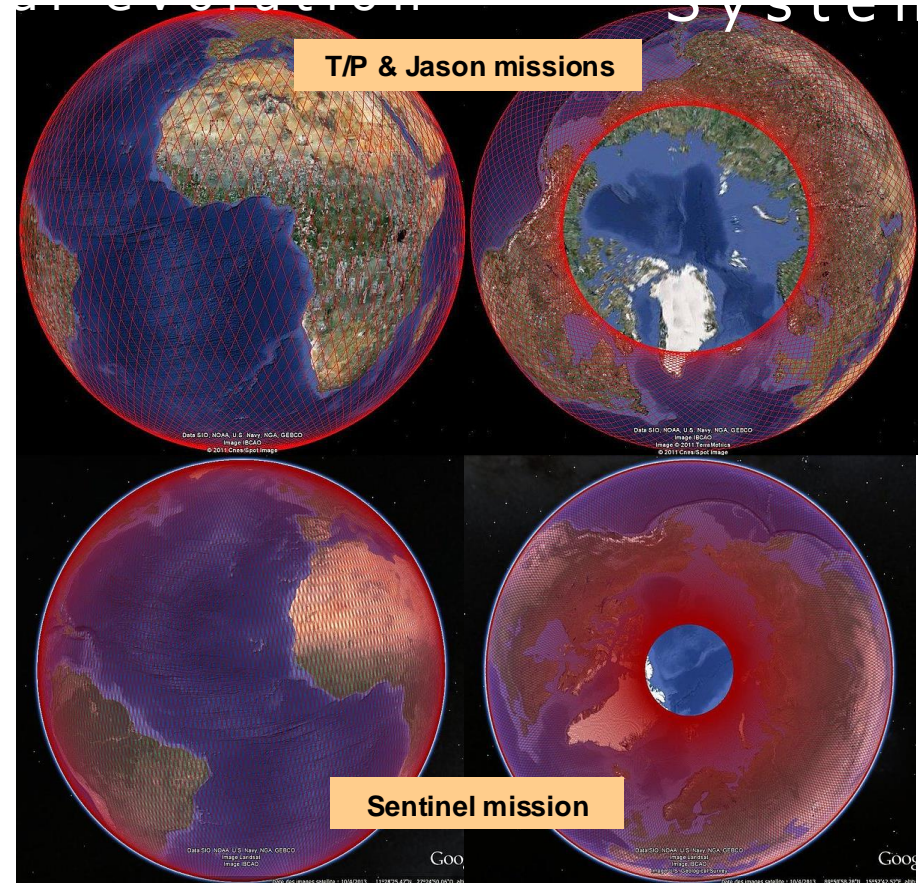
- Global
- Homogeneous
- Nadir (not swath)

Temporal coverage

Repeat period varying for the different missions:

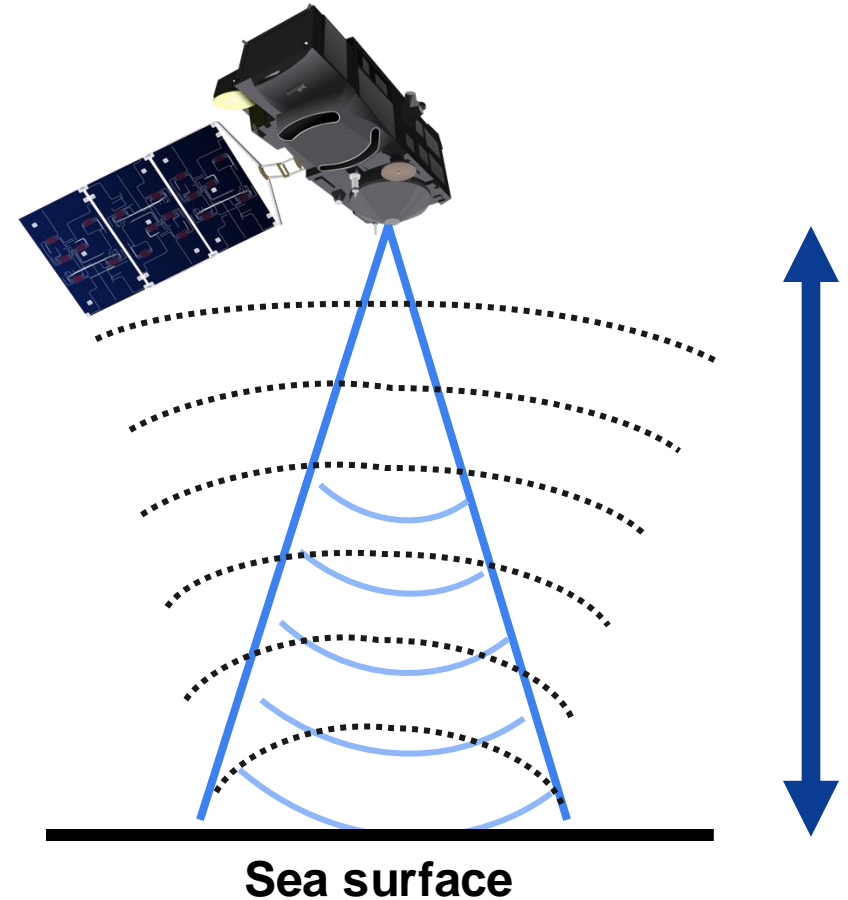
- 10 days: T/P, Jason
- 27 days: Sentinel
- 35 days: ERS, ENVISAT, SARAL-Altika

Providing accurate sea level data since 1993!!



Principles of radar altimetry: sea surface height measurements

- Altimeters send microwave radar pulses vertically towards the ocean surface.
- **Measure altimeter range**
- **Variables:**
 - sea surface height,
 - wind speed and direction,
 - wave spectra,
 - sea ice cover,
 - surface roughness.

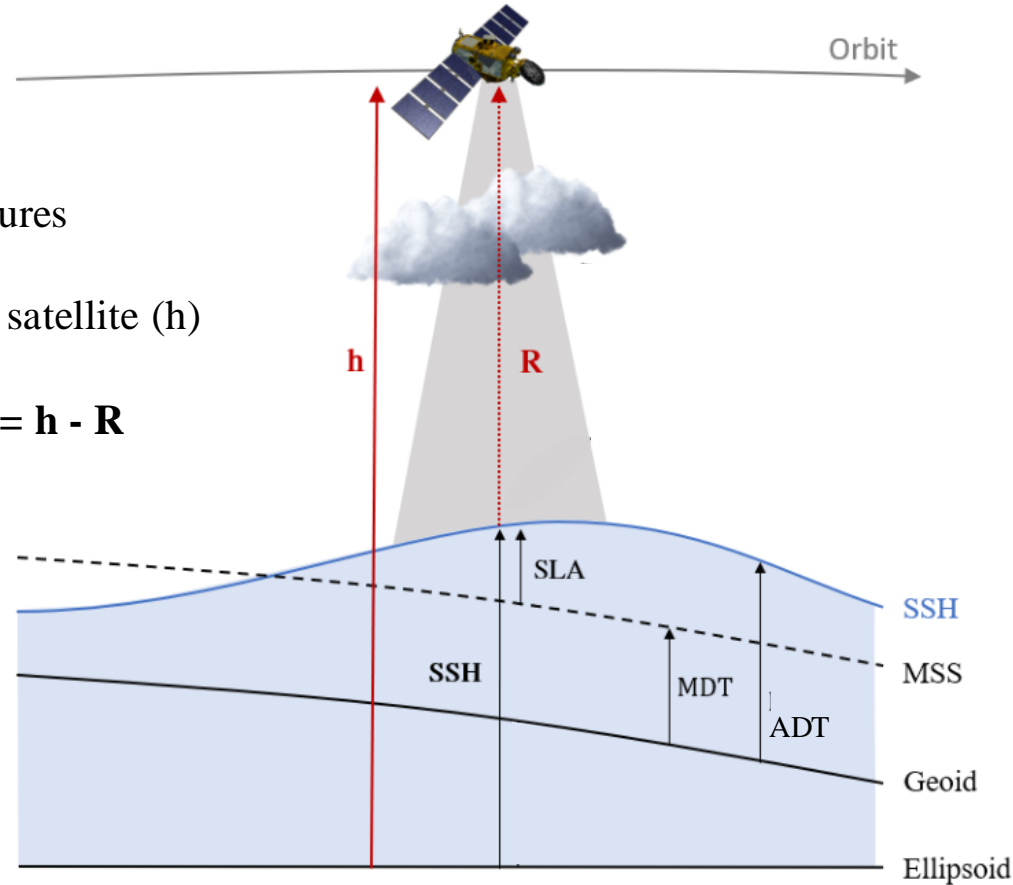


R: Range

→ What the altimeter measures

We know the altitude of the satellite (h)

Sea Surface Height (SSH) = $h - R$



SLA: Sea Surface Height

SLA: Sea Level Anomaly

MDT: Mean Dynamic Topography

ADT: Absolute Dynamic Topography

MSS: Mean Sea Surface

R: Range

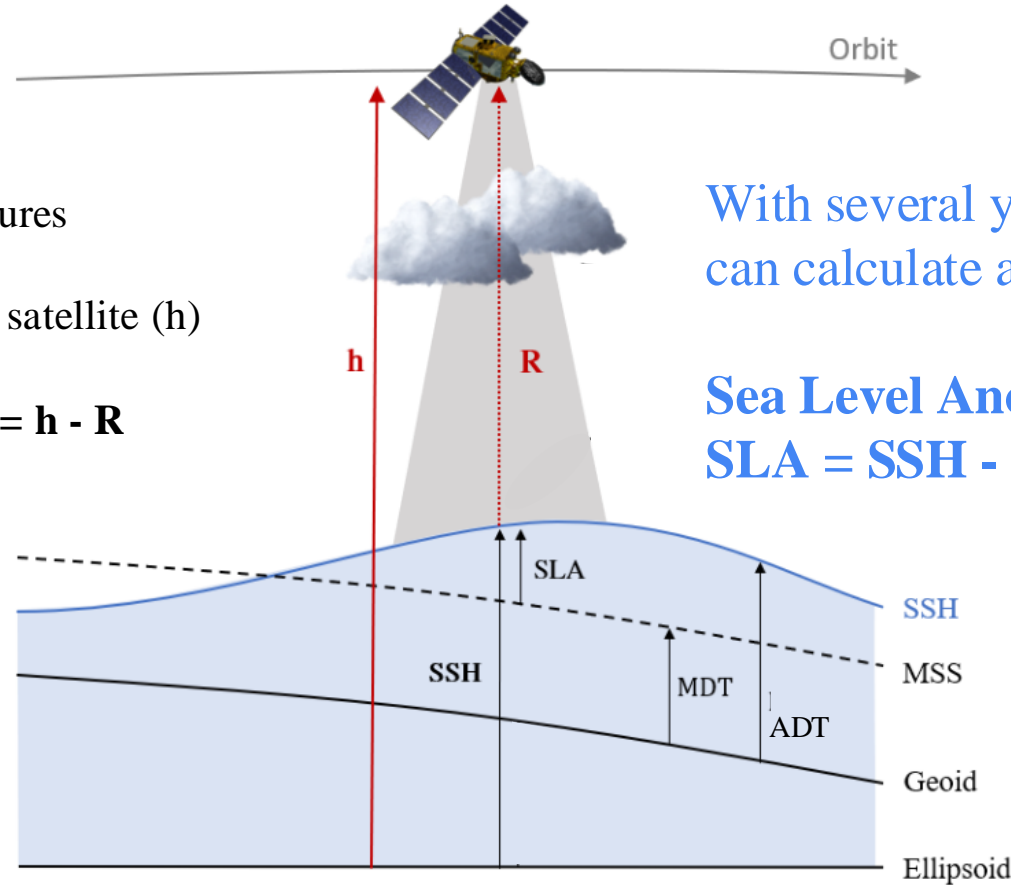
→ What the altimeter measures

We know the altitude of the satellite (h)

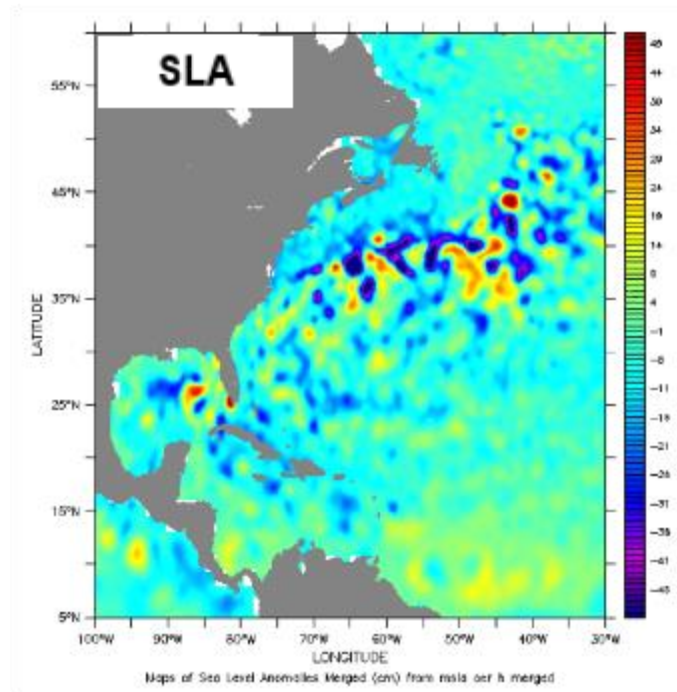
Sea Surface Height (SSH) = $h - R$

With several years of SSH we
can calculate an average: MSS

Sea Level Anomaly (SLA)
 $SLA = SSH - MSS$

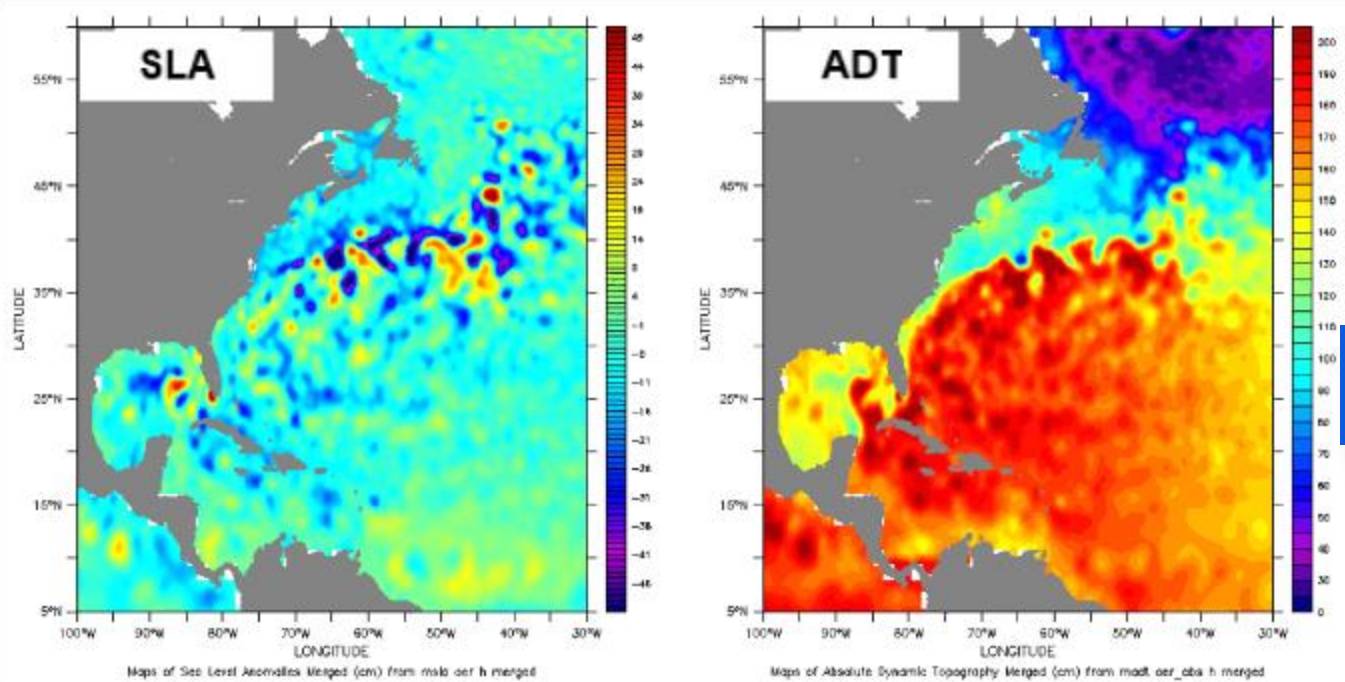


SLA: Sea Surface Height
SLA: Sea Level Anomaly
MDT: Mean Dynamic Topography
ADT: Absolute Dynamic Topography
MSS: Mean Sea Surface



credits: AVISO

SLA : Sea Level Anomaly



$$\text{ADT} = \text{SLA} + \text{MDT}$$

credits: AVISO

SLA : Sea Level Anomaly
ADT: Absolute Dynamic Topography
MDT: Mean Dynamic Topography

LEVEL 3



SLA

mapping (objective analysis)

LEVEL 4



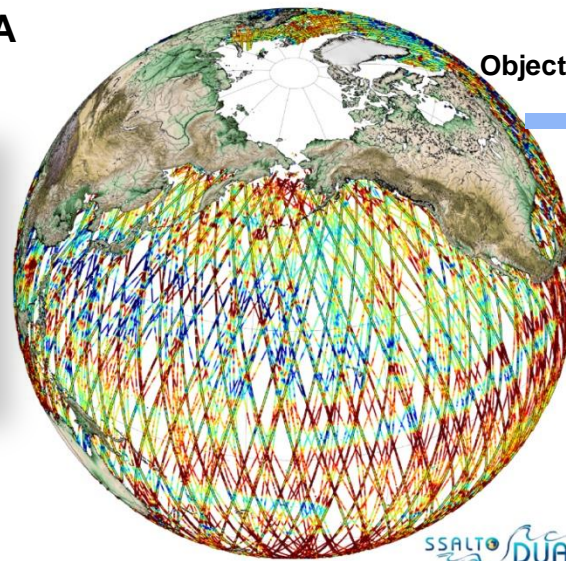
Maps of SLA

from along-track (level 3) to gridded multi-mission maps (level 4)

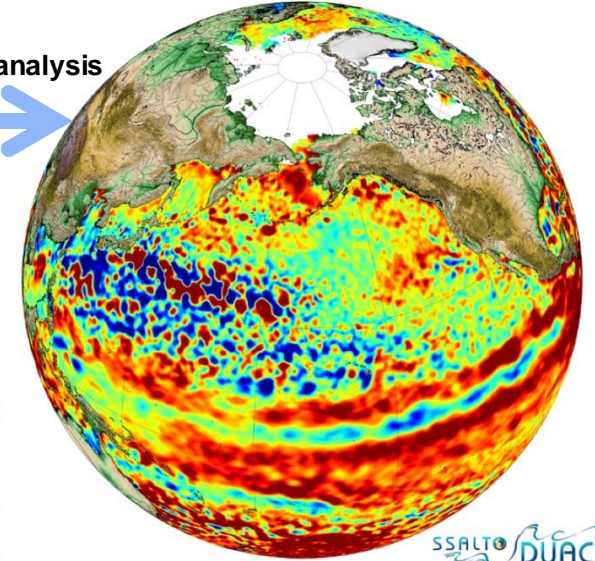
Purpose: construct regular gridded data merging along-track SLA from different missions

Method: objective analysis

Sea Level Anomaly on May, 12-14th
(cm) from Jason-2, SARAL-AltiKa,
Cryosat2 and HY2A



Objective analysis



produced by ANSO/DUACS - Copyright

produced by ANSO/DUACS - Copyright CNES/CLS 2013

SSALTO/DUACS

SSALTO/DUACS

-12 -9 -6 -3 0 3 6 9 12

-12 -9 -6 -3 0 3 6 9 12

credits:
CNES/CLS



The screenshot shows the Copernicus Marine Service website. At the top, there are logos for the European Union, Copernicus (Europe's eyes on Earth), and the Copernicus Marine Service. Below the logos are navigation links: Services, Opportunities, Access Data, Use Cases, User Corner, and About. The main header features the text "Copernicus Marine Service" and "Providing free and open marine data and services to enable marine policy implementation, support Blue growth and scientific innovation." Below this is a section titled "Access Data" with a right-pointing arrow. Under "Access Data", there are four columns: DATA, EXPERTISE, TRENDS, and EXPLORATION. Each column has a sub-header and a description:

- DATA: OCEAN PRODUCTS** - A robust ocean data catalogue, to download or visualise data including hindcasts, nowcasts and forecasts.
- EXPERTISE: OCEAN STATE REPORT** - Extensive annual analysis on the state of the ocean over nearly 20 years and severe/notable annual events.
- TRENDS: OCEAN MONITORING INDICATORS** - Essential variables monitoring the health of the ocean over the past quarter of a century.
- EXPLORATION: OCEAN VISUALISATION** - Dive into our 4D digital oceans through our visualisation tool in the past, present and future.

<https://marine.copernicus.eu>



Filters

FREE-TEXT SEARCH

TIME RANGE

dd/mm/yyyy

Covering full interval

WITH DEPTH 14

DEPTH RANGE

UNIVERSE

Blue Ocean 50

White Ocean 5

Green Ocean 8

MAIN VARIABLES

Carbonate system 1

Mixed layer thickness 13

Nutrients 1

Oxygen 8

Plankton 8

Salinity 20

Sea ice 5

Sea surface height 51

Temperature 20

Velocity 25

Wave 8

AREA

Global Ocean 19

Arctic Ocean 8

Atlantic: Iberia-Biscay-Ireland 11

Atlantic: NW European Shelf 10

Atlantic: North 15

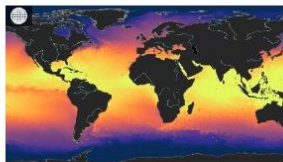
Baltic Sea 15

Black Sea 9

Europe 4

Mediterranean Sea 9

Products 51



Global Ocean Physics Analysis and Forecast

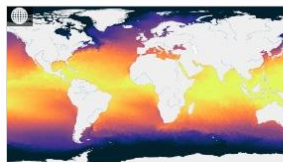
GLOBAL_ANALYSISFORECAST_PHY_001_024

Models

Global, $0.083^\circ \times 0.083^\circ \times 50$ levels

1 Jan 2019 to 29 Jul 2024, hourly, daily, monthly

Temperature, salinity, [sea surface height](#), velocity, mixed layer thickness, wave, sea ice



Global Ocean Physics Reanalysis

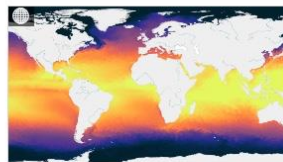
GLOBAL_MULTIYEAR_PHY_001_030

Models

Global, $0.083^\circ \times 0.083^\circ \times 50$ levels

1 Jan 1993 to 26 Mar 2024, daily, monthly

Temperature, salinity, [sea surface height](#), velocity, mixed layer thickness, sea ice



Global Ocean Ensemble Physics Reanalysis

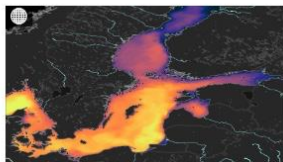
GLOBAL_MULTIYEAR_PHY_ENS_001_031

Models

Global, $0.25^\circ \times 0.25^\circ \times 75$ levels

1 Jan 1993 to 31 Dec 2022, daily, monthly

Temperature, salinity, [sea surface height](#), velocity, mixed layer thickness, sea ice



Baltic Sea Physics Analysis and Forecast

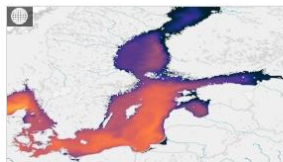
BALTICSEA_ANALYSISFORECAST_PHY_003_006

Models

Baltic, $2 \times 2 \text{ km} \times 56$ levels

1 Nov 2021 to 25 Jul 2024, sub-hourly, hourly,...

Temperature, salinity, [sea surface height](#), velocity, mixed layer thickness, sea ice



Baltic Sea Physics Reanalysis

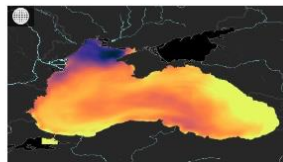
BALTICSEA_MULTIYEAR_PHY_003_011

Models

Baltic, $2 \times 2 \text{ km} \times 56$ levels

1 Jan 1993 to 31 Dec 2021, daily, monthly, yearly

Temperature, salinity, [sea surface height](#), velocity, mixed layer thickness, sea ice



Black Sea Physics Analysis and Forecast

BLKSEA_ANALYSISFORECAST_PHY_007_001

Models











Black Sea, $0.025^\circ \times 0.025^\circ \times 121$ levels

1 Nov 2021 to 28 Jul 2024, sub-hourly, hourly,...

Temperature, salinity, [sea surface height](#), velocity, mixed layer thickness


- SEALEVEL products
- Reprocessed (REP or DT) covering the whole altimetry period (1993 – present)
- Near real Time (NRT) covering the last two years (2022 – present)
- Level 3 (along-track) and Level 4 (gridded)
- Global & regional products
- Products based on models and *in situ* observations also available

<https://resources.marine.copernicus.eu>

 Description
 Notifications
 Data access
 Contact
DOCUMENTATION
 User Manual
 Quality Information Document
 Synthesis Quality Overview
 Licence
 How to cite
DOI
 10.48670/moi-00141

Data access and mapping services

There are multiple ways to download data from this product:

- If you prefer a graphical tool, click on the top-right button: .
- **Subset:** The most intuitive graphical approach for subsetting data in time, space and/or variables. For a programming approach (WCS-like), prefer the Copernicus Marine Toolbox: [CLI](#) or [Python API](#).
- **Files:** The fastest graphical approach to get original files (*FTP-like*). For a programming approach, prefer the Copernicus Marine Toolbox: [CLI](#) or [Python API](#).
- **Maps:** The standard mapping service for GIS approach (*QGIS* or similar tools).
- If you are looking for a lazy-loading data access (*xarray/OPeNDAP-like*), copy the dataset ID and use it with the Copernicus Marine Toolbox: [Python API](#).

Dataset ID

	Subset 	Files 	Maps 
cmems_obs-sl_eur_phy-ssh_my_allsat-l4-duacs-0.125deg_P1D	Form	Browse	WMTS
cmems_obs-sl_eur_phy-ssh_myint_allsat-l4-duacs-0.125deg_P1D	Form	Browse	WMTS

Metadata

Click here to fetch the most up-to-date raw metadata for this product from the [Catalogue Service for the Web \(CSW\)](#) service:

Download metadata

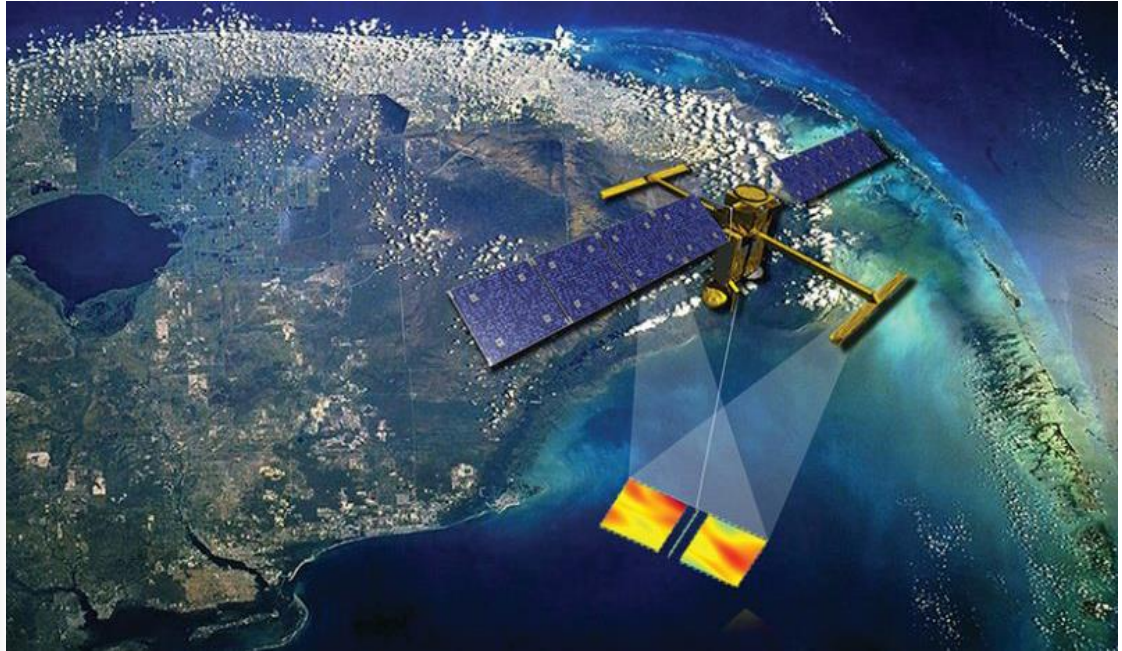
<https://resources.marine.copernicus.eu>

There are also other websites and platforms to obtain these dates like:

- Copernicus Climate: <https://cds.climate.copernicus.eu/cdsapp#!/search?type=dataset>
- PODAAC from NASA: <https://podaac.jpl.nasa.gov/>
- AVISO: <https://www.aviso.altimetry.fr/en/data.html>

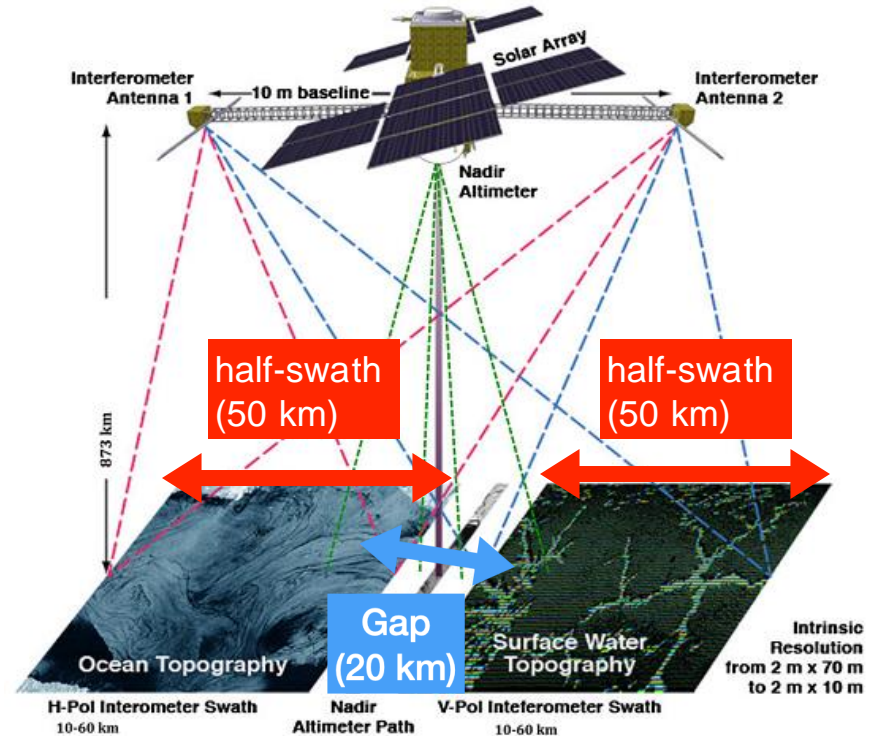


- Wide-swath altimeter
- Launch: November 2022
- SAR interferometry
- Provide water elevation maps
 - Oceanography
 - Hydrology



Morrow et al. EOS 2019

- Measure SSH in 2D at a high resolution
- Primary objective: observe the ocean mesoscale and sub-mesoscale circulation at spatial resolutions of 15 km and larger
- Observe coasts and high-latitudes



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- S. Vignudelli, *et al.* (Eds.), Coastal Altimetry, Springer, Berlin Heidelberg (2011), pp. 61-101, https://doi.org/10.1007/978-3-642-12796-0_4
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- Barceló-Llull, B., Pascual, A., Sánchez-Román, A., Cutolo, E., d'Ovidio, F., Fifani, G., ... & Muñoz, C. (2021). Fine-scale ocean currents derived from in situ observations in anticipation of the upcoming SWOT altimetric mission. *Frontiers in Marine Science*, 8, 679844. <https://doi.org/10.3389/fmars.2021.679844>
- Yann-Treden Tranchant. Vers une meilleure exploitation de l'altimétrie côtière : apports combinés de la modélisation hydrodynamique à haute-résolution et des nouvelles techniques de cartographie du niveau marin par GNSS. Sciences de la Terre. Université de La Rochelle, 2022. Français. NNT : 2022LAROS014. tel-03942913

Let's look at some data!

You Will work in groups: see [participants_groups.pdf](#)

Abel	Dechenne		África	Núñez García		Alejandro	Alegría Rodríguez		Alina	Hillinger
Ana	Amaral Wasielesky		Eliana	Ferretti		Irene	Gregori		Gloria	Mozzi
Constanze	Hammerl		Maria João	Lima		Marijana	Balić		Juan Manuel	Lopez Contreras
Mathilde	Couteyen Carpaye		Nicola	Wilson		Roman	Isaac		Marc	Gost
Veronica	Relano		Sophia Laura	Bergeler		valeria	hidalgo-ruz			
Andriana	Koutsandrea		Ariadna	Nocera		Barbara	Pizarro Cisternas		Buse	Uysaler
Diego	Vega		Elisabet	Verger Miralles		Diana Lorena	Rico-Velez		Davide	Bruno
Kenn	Papadopoulos		matteo	vergani		Erin	van Rheenen		Isobel	Stemp
Mariam	Tsetskhladze		Savannah	Hartman		Luis	Lizcano-Sandoval		Mar	Roca Mora
Silvia	Malagoli		Srilaxmi	Srilaxmi		Martina	Marianetti		Nakita	Daniel

List of tutorials:

- **1.Altimetric_data_visualization.ipynb**
- 2.Basic_análisis.ipynb
- 3.Calculation_of_derived_variables.ipynb
- **4.Plastics_simulation.ipynb**

(also in html format which will open in your browser even without jupyter installed)