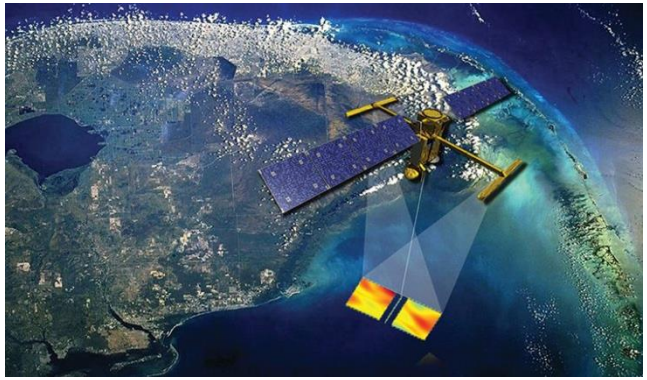
MALLORCA SCIENCE SCHOOL

Hands-on altimetry tutorial

Laura Gómez Navarro
IMEDEA (UIB-CSIC); Utrecht University
laura.gomez@uib.es

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

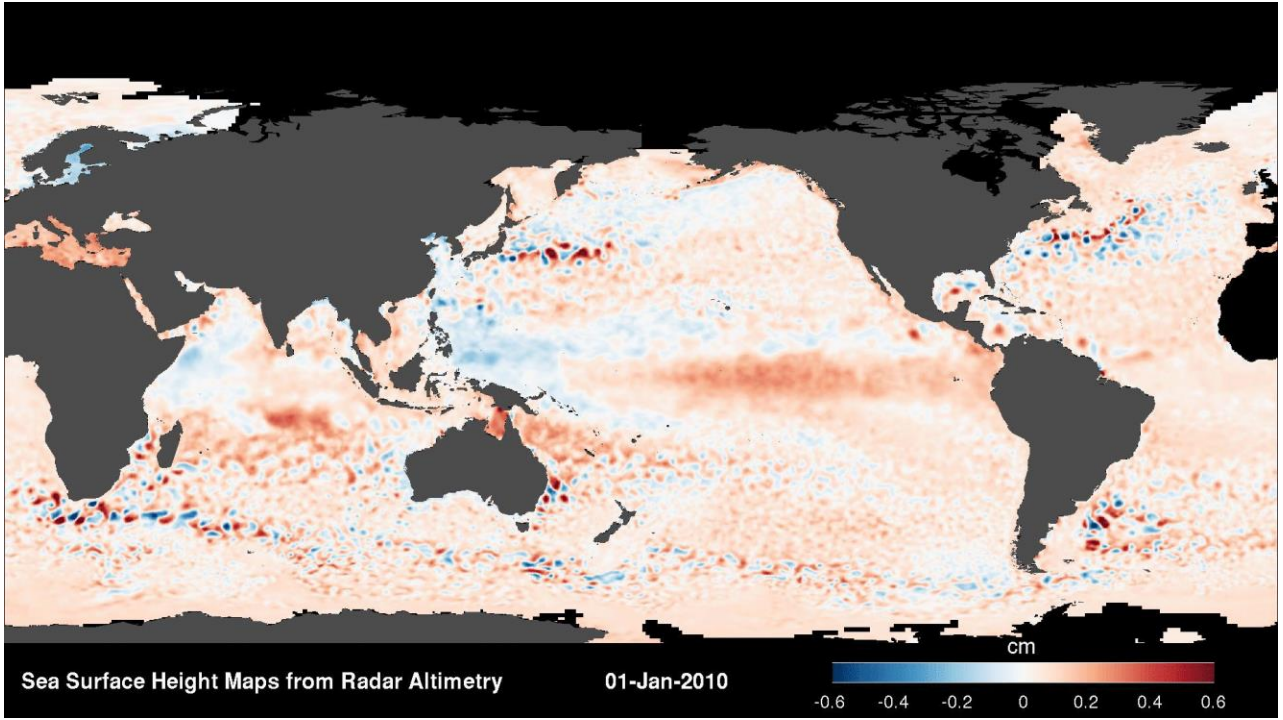


slides credits: Antonio Sánchez-Román and Ananda Pascual

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 …)

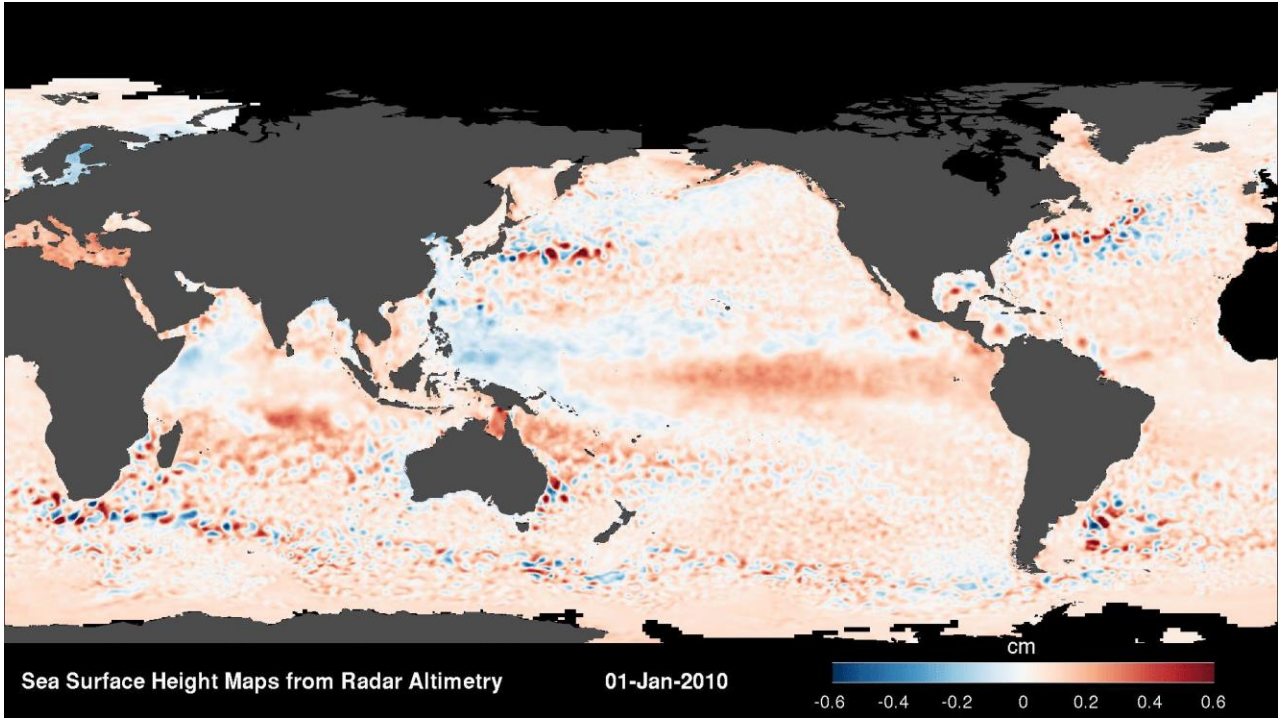


movie courtesy of R. Escudier

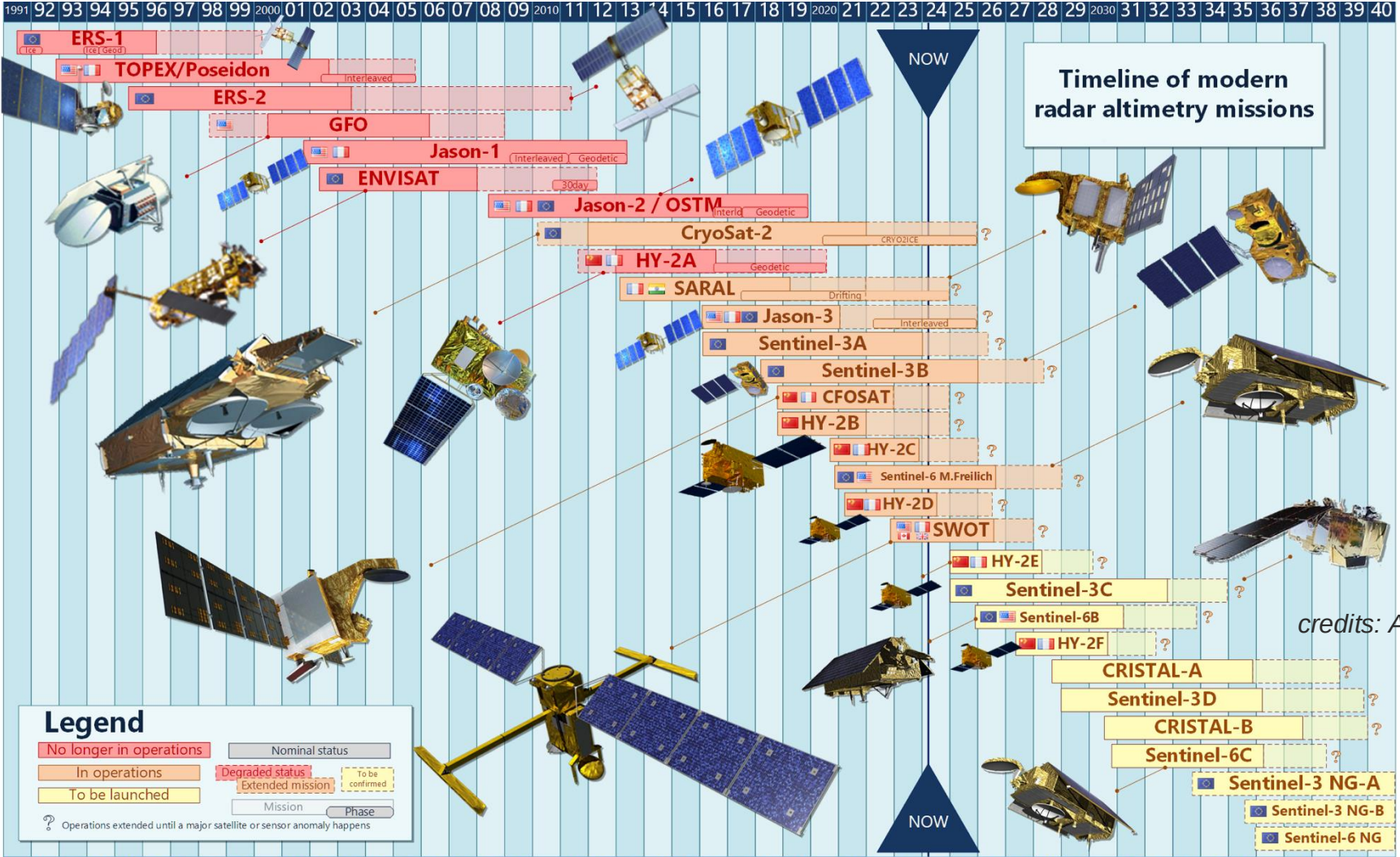
The role of satellites for the Global Ocean Observing System

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



credits: AVISO+ 2022

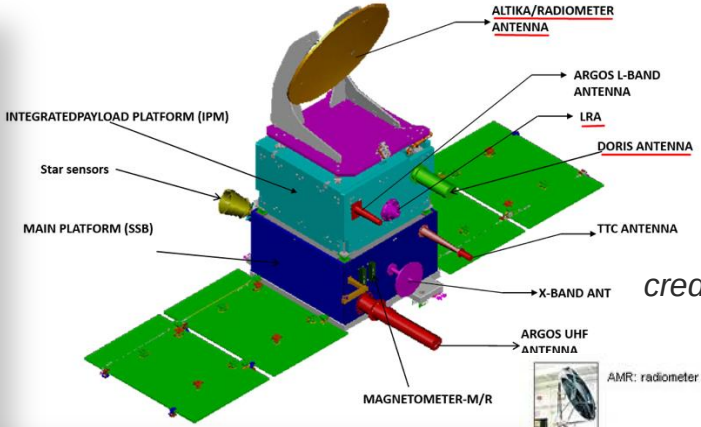
Altimeter mission characteristics and temporal evolution

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

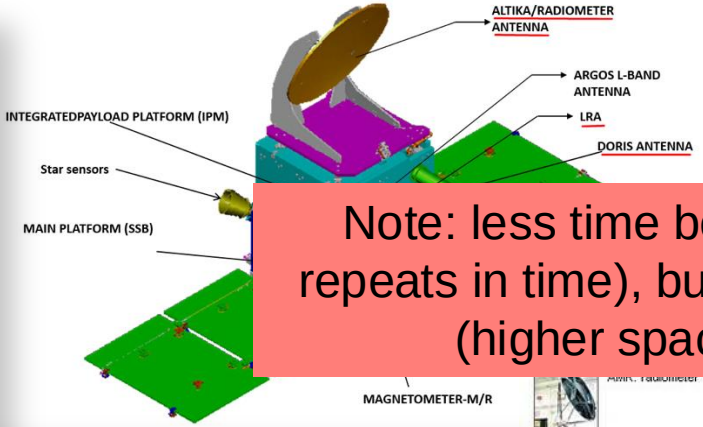
Altimeter mission characteristics and temporal evolution

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)

Jason-class

Agencies: CNES – NASA – NOAA – EUMETSAT

Orbit characteristics

Altitude: 1336 km
Repeat: 10 days
Inclination: 66 degrees
Track spacing: 315 km at Equator

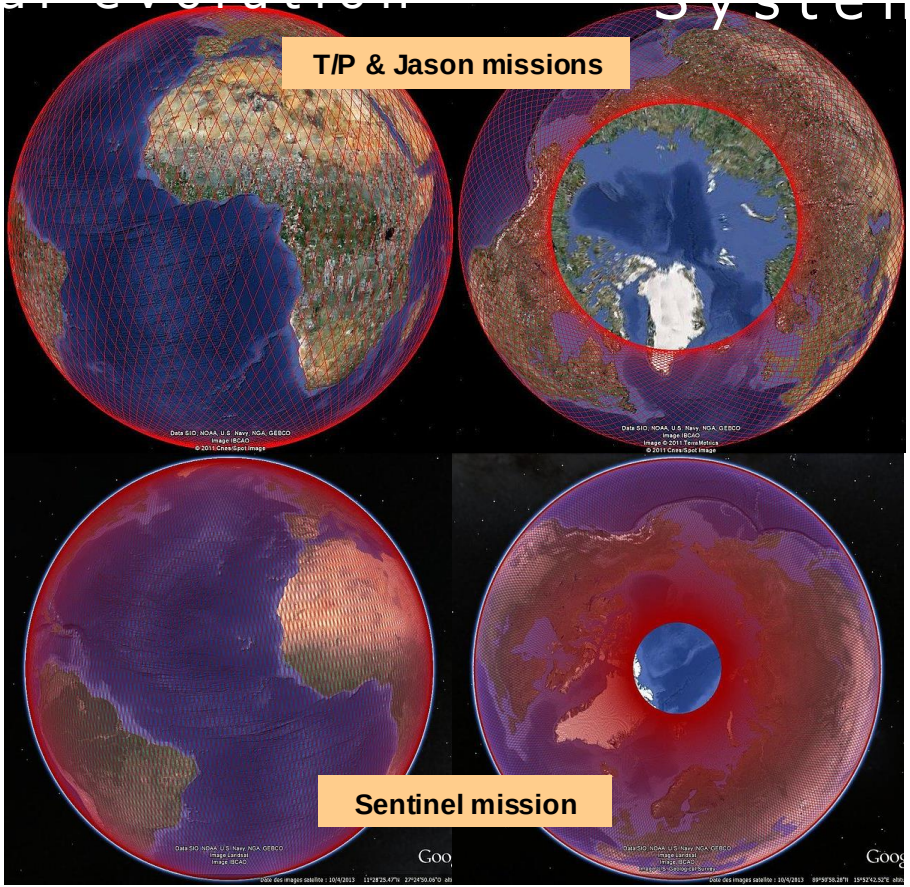
credits: CNES/AVISO

Altimeter mission characteristics and temporal evolution

Satellite altimetry coverage characteristics

Spatial coverage

- Global
- Homogeneous
- Nadir (not swath)



Altimeter mission characteristics and temporal evolution

Satellite altimetry coverage characteristics

Spatial coverage

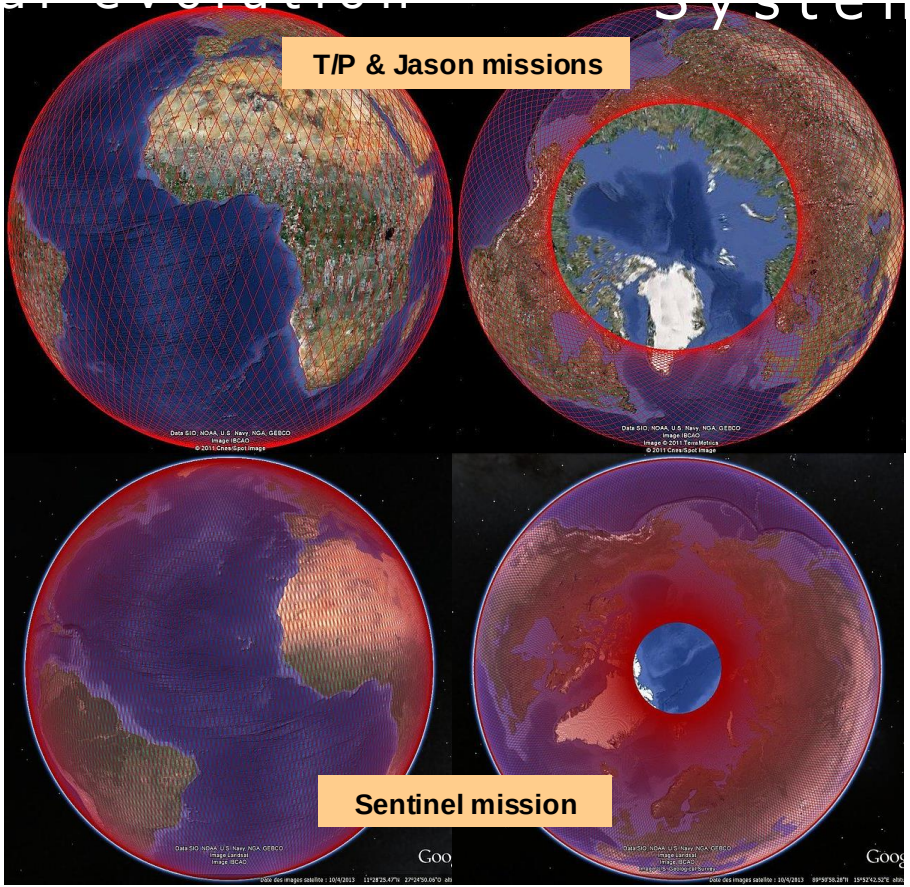
- Global
- Homogeneous
- Nadir (not swath)

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!!



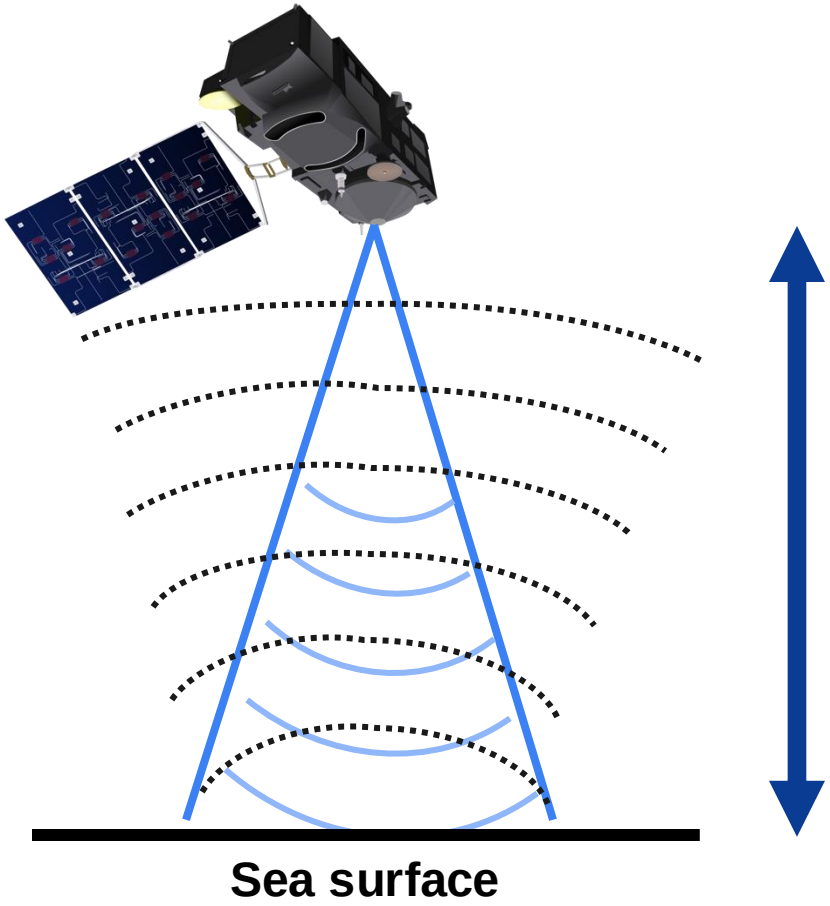
Principles of radar altimetry: sea surface height measurements

- Altimeters send microwave radar pluses vertically towards the ocean surface.

→ **Measure altimeter range**

- **Variables:**

- sea surface height,
- wind speed and direction,
- wave spectra,
- sea ice cover,
- surface roughness.



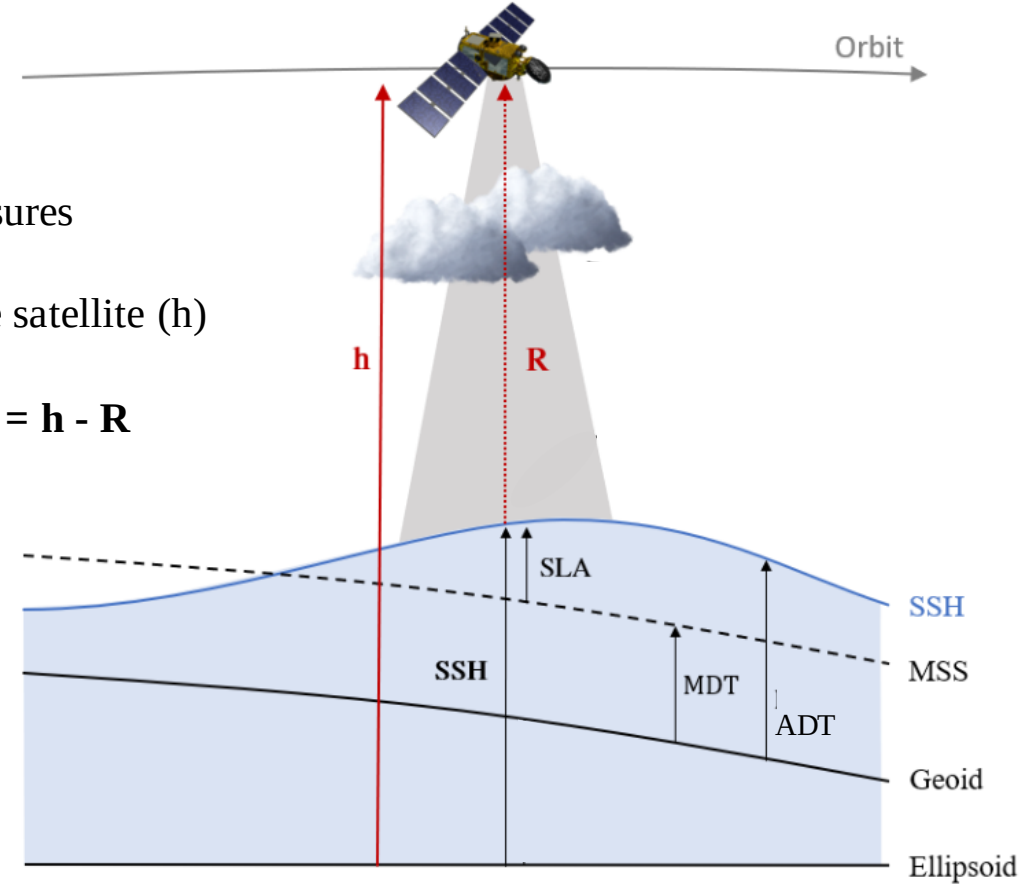
Altimetry data processing

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

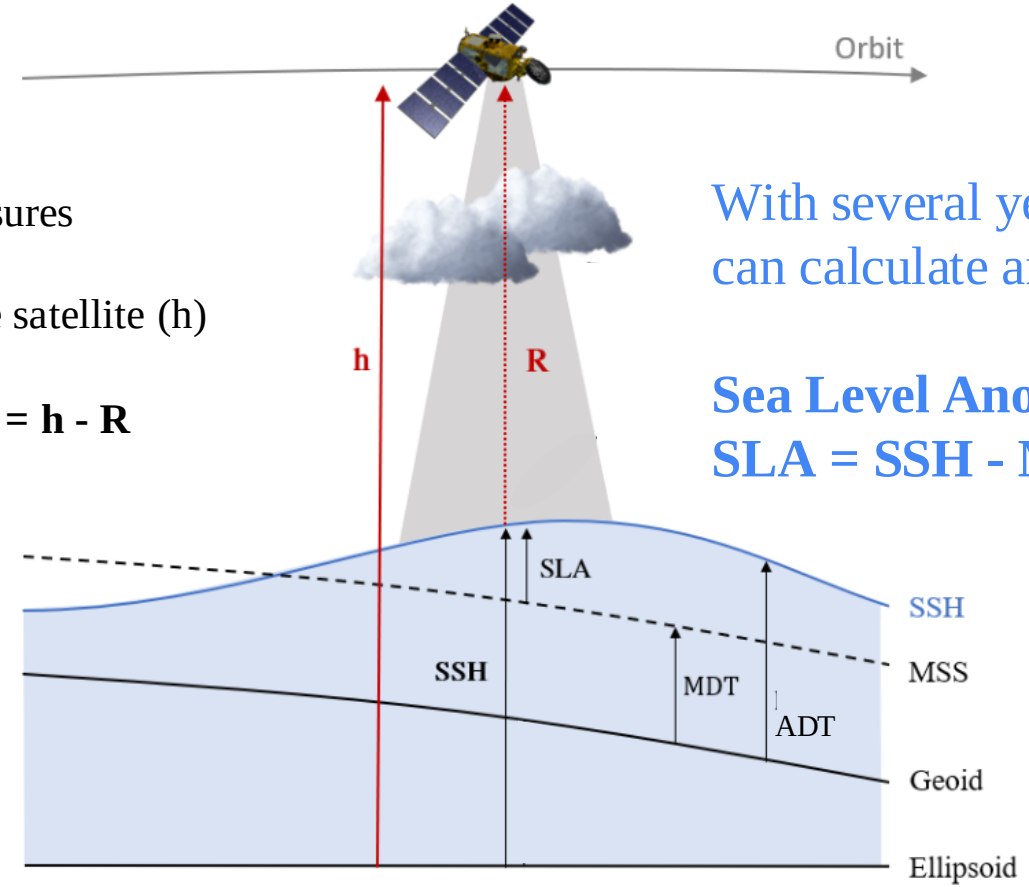
credits: Adapted from: Tranchant, (2022)

Altimetry data processing

R: Range
→ What the altimeter measures

We know the altitude of the satellite (h)

Sea Surface Height (SSH) = h - R



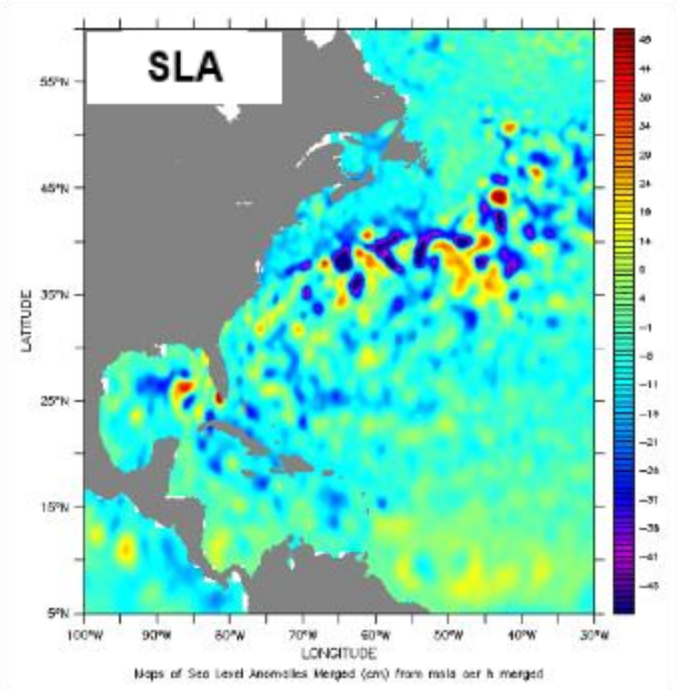
With several years of SSH we can calculate an average: MSS

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: Adapted from: Tranchant, (2022)

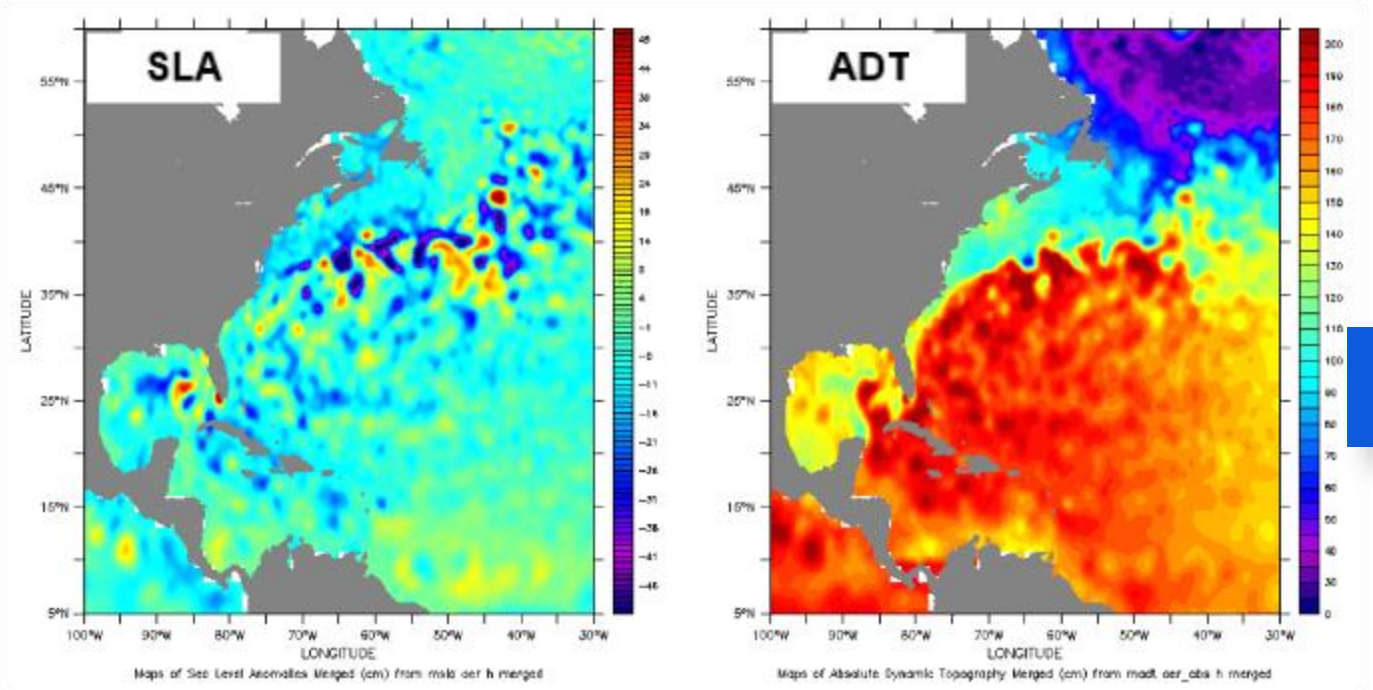
Altimetry data processing



credits: AVISO

SLA : Sea Level Anomaly

Altimetry data processing



ADT = SLA + MDT

credits: AVISO

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

Altimetry data processing

LEVEL 3 ⟷ SLA

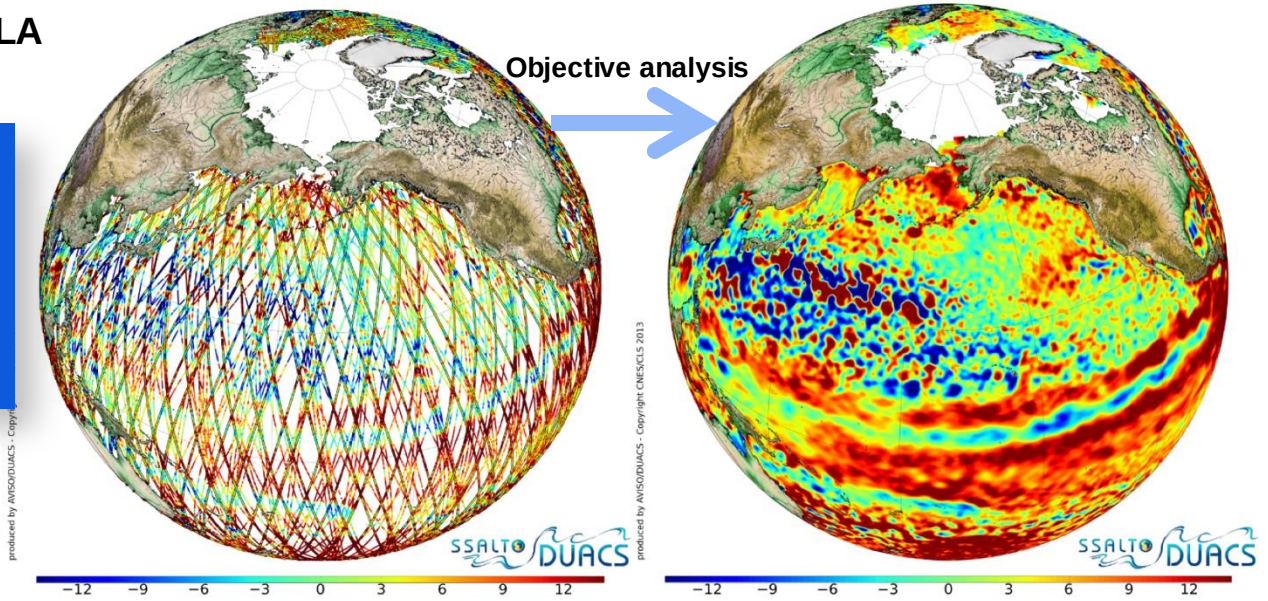
mapping (objective analysis)

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



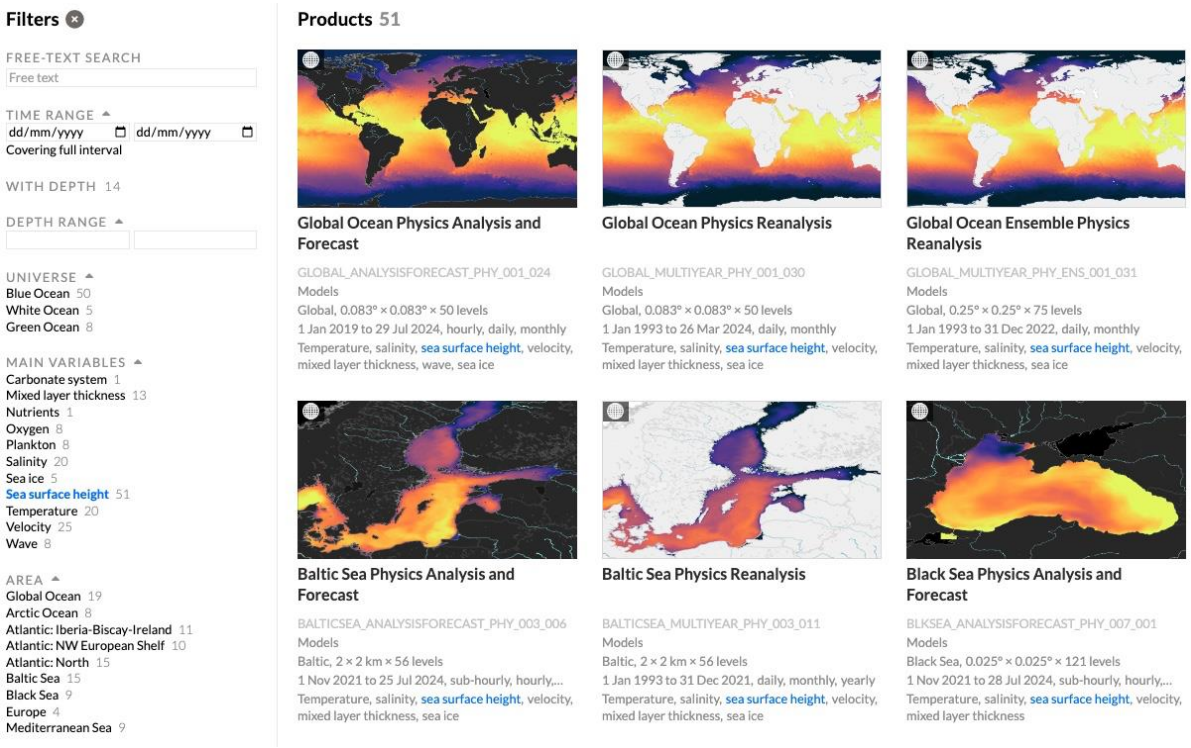
Sea Level Anomaly on May, 12-14th (cm) from Jason-2, SARAL-AltiKa, Cryosat2 and HY2A

credits: CNES/CLS

Altimetry products: the Copernicus Marine Service

https://marine.copernicus.eu

Altimetry products: the Copernicus Marine Service



- 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

Altimetry products: the Copernicus Marine Service

- 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

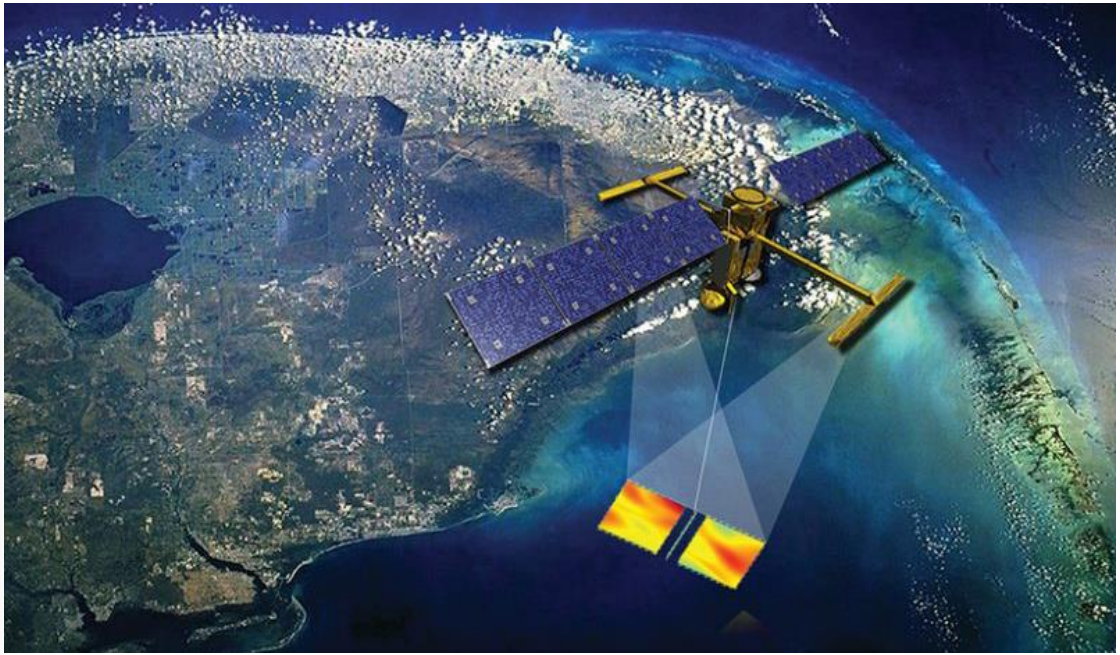
Altimetry products: the Copernicus Marine Service

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

The new SWOT mission

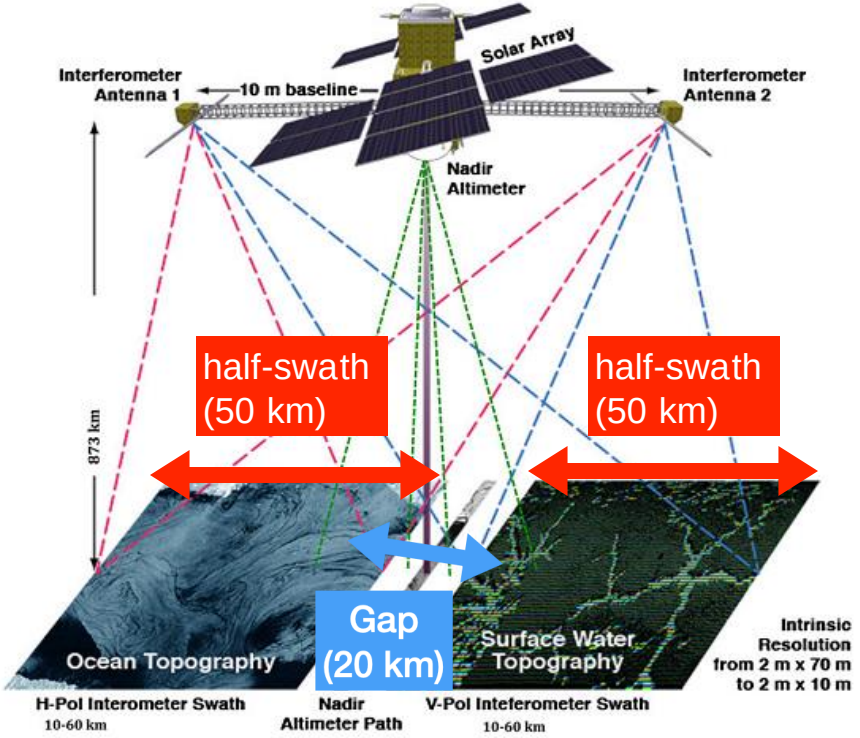
- Wide-swath altimeter
- Launch: November 2022
- SAR interferometry
- Provide water elevation maps
  - Oceanography
  - Hydrology



Morrow et al. EOS 2019

The new SWOT mission

- 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



References

- Brown, G. S. (1977) The Average Impulse Response of a rough surface and its applications, IEEE Trans. Antennas Propag., 25. https://10.1109/TAP.1977.1141536

- J. Aublanc, J., T. Moreau, P. Thibaut, F. Boy, F. Rémy, N. Picot, Evaluation of SAR altimetry over the antarctic ice sheet from CryoSat-2 acquisitions, Advances in Space Research, Volume 62, Issue 6, 2018, Pages 1307-1323, ISSN 0273-1177, https://doi.org/10.1016/j.asr.2018.06.043

- Ballarotta, M., Ubelmann, C., Pujol, M.-I., Taburet, G., Fournier, F., Legeais, J.-F., Faugère, Y., Delepoulle, A., Chelton, D., Dibarboure, G., and Picot, N.: On the resolutions of ocean altimetry maps, Ocean Sci., 15, 1091–1109, https://doi.org/10.5194/os-15-1091-2019

- Dufau, C., M. Orsztynowicz, G. Dibarboure, R. Morrow, and P.-Y. Le Traon (2016), Mesoscale resolution capability of altimetry: Present and future, J. Geophys. Res. Oceans, 121, 4910–4927, https://doi.org/10.1002/2015JC010904

- International Altimetry team, (2021). Altimetry for the future: Building on 25 years of progress. Advances in SpaceResearch, https://doi.org/10.1016/j.asr.2021.01.022

- Tonani, M., Sykes, P., King, R.R., McConnell, N., Pe´quignet, A.C.,O'Dea, E., Graham, J.A., Polton, J., Siddorn, J., 2019. The impact of anew high-resolution ocean model on the Met Office North-WestEuropean Shelf forecasting system. Ocean Sci. 15, 1133–1158 https://doi.org/10.5194/os-15-1133-2019

- Pascual, A., Boone, C., Larnicol, G., & Le Traon, P. Y. (2009). On the quality of real-time altimeter gridded fields: Comparison with in situ data. *Journal of Atmospheric and Oceanic Technology*, *26*(3), 556-569. https://doi.org/10.1175/2008JTECHO556.1

- Carret, A., Birol, F., Estournel, C., Zakardjian, B., and Testor, P. (2019) Synergy between in situ and altimetry data to observe and study Northern Current variations (NW Mediterranean Sea), Ocean Sci., 15, 269–290, https://doi.org/10.5194/os-15-269-2019.

- Gommenginger, C., Thibaut, P., Fenoglio-Marc, L., Quartly, G., Deng, X., Gómez-Enri, J., ... & Gao, Y. (2011). Retracking altimeter waveforms near the coasts: A review of retracking methods and some applications to coastal waveforms. *Coastal altimetry*, 61-101. https://doi.org/10.1007/978-3-642-12796-0_4

- 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

- Sánchez-Román, A.; Pascual, A.; Pujol, M.-I.; Taburet, G.; Marcos, M.; Faugère, Y. Assessment of DUACS Sentinel-3A Altimetry Data in the Coastal Band of the European Seas: Comparison with Tide Gauge Measurements. *Remote Sens.* 2020, *12*, 3970. https://doi.org/10.3390/rs12233970

- Bonaduce, A., Benkiran, M., Remy, E., Le Traon, P. Y., and Garric, G. (2018) Contribution of future wide-swath altimetry missions to ocean analysis and forecasting, Ocean Sci., 14, 1405–1421, https://doi.org/10.5194/os-14-1405-2018

- Gómez-Navarro, L., Fablet, R., Mason, E., Pascual, A., Mourre, B., Cosme, E., & Le Sommer, J. (2018). SWOT spatial scales in the western Mediterranean Sea derived from pseudo-observations and an ad hoc filtering. *Remote Sensing*, *10*(4), 599. https://doi.org/10.3390/rs10040599

- 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	Papadopoulo	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)