ODYSSEA

UN environment programme

Mediterranean Action Plan Barcelona Convention

SPA / RAC

ΔΗΜΟΚΡΙΤΕΙΟ ΠΑΝΕΠΙΣΤΗΜΙΟ ΘΡΑΚΗΣ | DEMOCRITUS UNIVERSITY OF THRACE

VIRTUAL SCHOOL OF OCEANOGRAPHY FROM SPACE

3rd ODYSSEA "Summer" School

Satellite observations & data processing in operational oceanography

23-27 November 2020

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727277

PREFACE

Observing and collecting information on the ocean is mandatory to understand how life evolves on Earth, to forecast its future evolution, to manage and to protect natural resources and populations. Satellites are powerful tools for observing the Earth and especially the Big Blue Ocean, since it is not easy to perform in-situ measurements at sea, while emphasizing that field observation remains necessary.

Observation of sea surface temperature through Thermal Infrared on-board sensors provides knowledge on how changes influence the behavior of fishes, can cause the bleaching of corals or algal blooms, affect weather along the coast and the Earth Global Climate. Indeed, the ocean plays a major role in regulating the planet's weather and climate. Satellite images of sea surface temperature also show paths of currents, eddies evolution and upwelling areas characterized by cold and nutrients enriched waters that rise from the depths, often near the coasts.

Sensors operating in the visible spectrum provide information about the color of the ocean. Color data help to determine the impact of floods along the coast, detect river plumes, and locate blooms of harmful algae that can contaminate shellfish and kill other fish and marine mammals. Ocean color data from satellites allows us not only to identify where an algal bloom is forming, but also to predict where it might drift in the future. In another area of the spectrum, Synthetic Aperture Radar, which is very sensitive to the viscosity of the water surface, is appropriate to detecting oil spills and tracking illegal degassing at sea.

Everyone knows that the most significant impacts of climate change is sea level rise and storms intensification, which can cause inundations of coastal areas and islands, shoreline erosion, and destruction of important ecosystems such as wetlands and mangroves. Satellite altimeter radar measurements can be combined with numerical models and in-situ data to measure sea level and sea surface waves, both on a global and regional basis with unprecedented accuracy. The measurement of long-term changes in global mean sea level provides a way to test climate models' predictions of global warming.

However, powerful data systems and platforms are essential to store, easily access and analyze the huge volume of data offered and then transform it in actionable insight for a sustainable Blue Growth. This is one of the aims of the ODYSSEA project with its Marinomica service. As partner leading the capacity building work package of ODYSSEA, SPA/RAC, the UNEP/MAP center of specially protected area and marine biodiversity conservation, took the initiative to organize this Virtual School of "Oceanography from Space", with the support and kind collaboration of partners, scientists and professionals from specialized European organizations, among then EUMETSAT, LEGOS, DUTH, FORTH, CLS, DELTARES, ORBITAL-EOS, BLUE-LOBSTER IT.

Slim GANA, Ph.D., HDR, Physical Oceanography
On behalf of Spa/Rac and Odyssea Consortium

GMT+1 time	10:00-11:00	11:00 - 11:15	11:15 - 12:15	12:15 - 14:30	14:30-15:30	15:30-16:30
Monday 23/11/2020	1- Welcome to the Virtual School by UNEP/MAP-SPA/RAC 2- Introduction to the Webinar and Odyssea (Georgios Sylaios (ODYSSEA Coordinator, DUTH University) 3 - Introduction to Oceanography from Space (Hayley Evers-King, EUMETSAT)	SHORT BREAK	Satellite Data Retrieval from Copernicus (Hayley Evers-King)	LUNCH BREAK	Overview of ODYSSEA project activities and outcomes Georgios Sylaios (ODYSSEA Coordinator)	
Tuesday 24/11/2020	1- Measuring Sea Surface Temperature from Space 2- Working with SST data from Satellites (Hayley Evers-King)	SHORT BREAK	1 - Measuring Ocean Color from Space 2 - Working with ocean color data from satellites (Hayley Evers-King)	LUNCH BREAK	Introduction to Marinomica Services and Products (Simon Keeble, BLIT)	
Wednesday 25/11/2020	- Measurement of Sea Surface Level using altimeter sensors in the open ocean - Retrieval of Tides, currents, waves and winds (Florence Birol, LEGOS)	SHORT BREAK	Satellite altimetry in the coastal zone (Florence Birol, LEGOS)	LUNCH BREAK	Meso-scale eddies and their dynamics using Marinomica (Cori Pegliasco, CLS)	
Thursday 26/11/2020	Exercises on satellite altimetry data - Session 1 (Florence Birol, LEGOS)	SHORT BREAK	Exercises on satellite altimetry data – Session2 (Fernando Nino and Fabien Léger)	LUNCH BREAK	Forecasting tools for wind and waves in Marinomica (Katerina Spanoudaki, FORTH)	Automatic detection of Offshore Oil Spill using Satellite data. (Juan Peña Ibanez, EOS-Orbital)
Friday 27/11/2020	Monitoring coastal erosion patterns from space: Coastal erosion 'hotspots' and trend analysis –(Konstantinos Zachopoulos, DUTH)	SHORT BREAK	Freshwater fluxes and SPM data products in river plumes - Nikolaos Kokkos (DUTH)	LUNCH BREAK	Eutrophication indices in Marinomica (Lorinc Meszaros, Deltares)	

INTRODUCTION TO THE WEBINAR
and to
ODYSSEA CONCEPT

Prof. Georgios SYLAIOS
Democritus University of Thrace
gsylaios@env.duth.gr

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727277

What is ODYSSEA

ODYSSEA is a Mediterranean-focused research project funded by EU Research and Innovation Program Horizon 2020

- 28 partners from 14 countries (6 non-EU)
- 8.398 Millions euros budget
- 54 months duration
- Starting date 1st June 2017
- Ending date 30th November 2021
- 932 PMs in total
- 118 researchers involved
- 7 Advisory Board Members

Horizon 2020

ODYSSEA

Horizon 2020 is the biggest EU Research and Innovation program ever with nearly €80 billion of funding available over 7 years (2014 to 2020) – in addition to the private investment that this money will attract.

Achievements: scientific breakthroughs, discoveries and world-firsts by taking great ideas **from the lab to the market**.

The EU Blue Growth Strategy

ODYSSEA

- Long term strategy to support sustainable growth in the **MARINE** and **MARITIME** sectors as a whole.
- Leads to achieving the Europe 2020 Strategy for Smart, Inclusive and Sustainable Growth.
- Recognizes that seas and oceans have great potential for innovation and growth.
- Considers the blue economy as a driver for Europe's welfare and prosperity.
- **KEY ISSUES: Jobs and Sustainability**

Horizon 2020

ODYSSEA

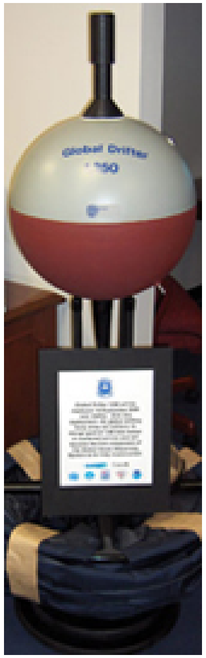
Four “key-elements” driving EU research on Blue Growth:

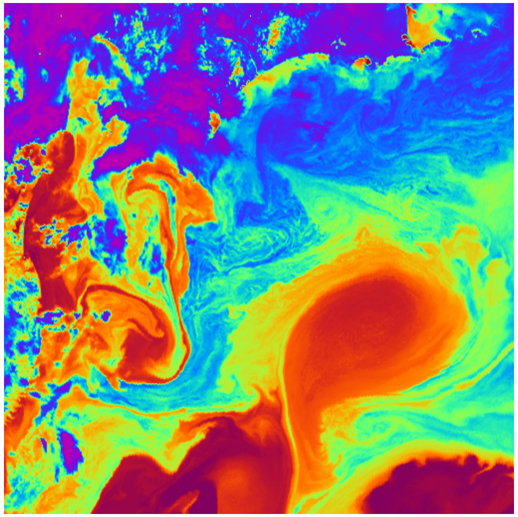
a) Cost-effectiveness
b) Interoperability
c) Open and freely available data
d) Sustainability

Cost-effectiveness

ODYSSEA

Get more with less





Interoperability

Measure once use it for multiple purposes

- From observations (sparse and non-consistent) to models (continuous in space and time)
- Fish – Mussel Farms
- Fisheries, Marine mammals, Invasive species
- Benthic biodiversity
- Anoxia
- Ocean energy
- Submarine outfalls (Wastewater, Heat)

Sustainability

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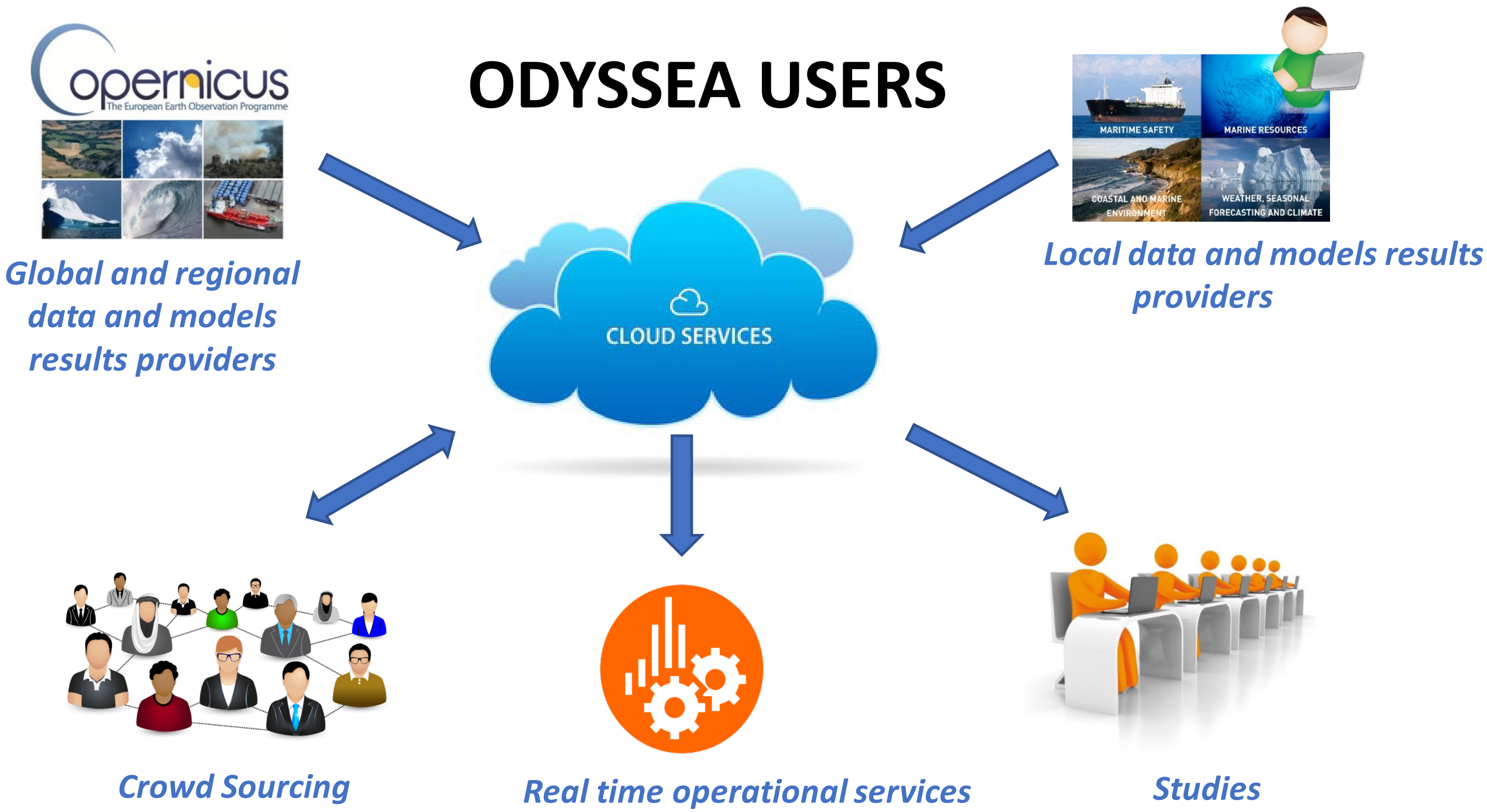
Business strategy to provide end-user services and ensure long-term sustainability



Marine Open Data

ODYSSEA

EGO

OneGeology

Data to Information

Data

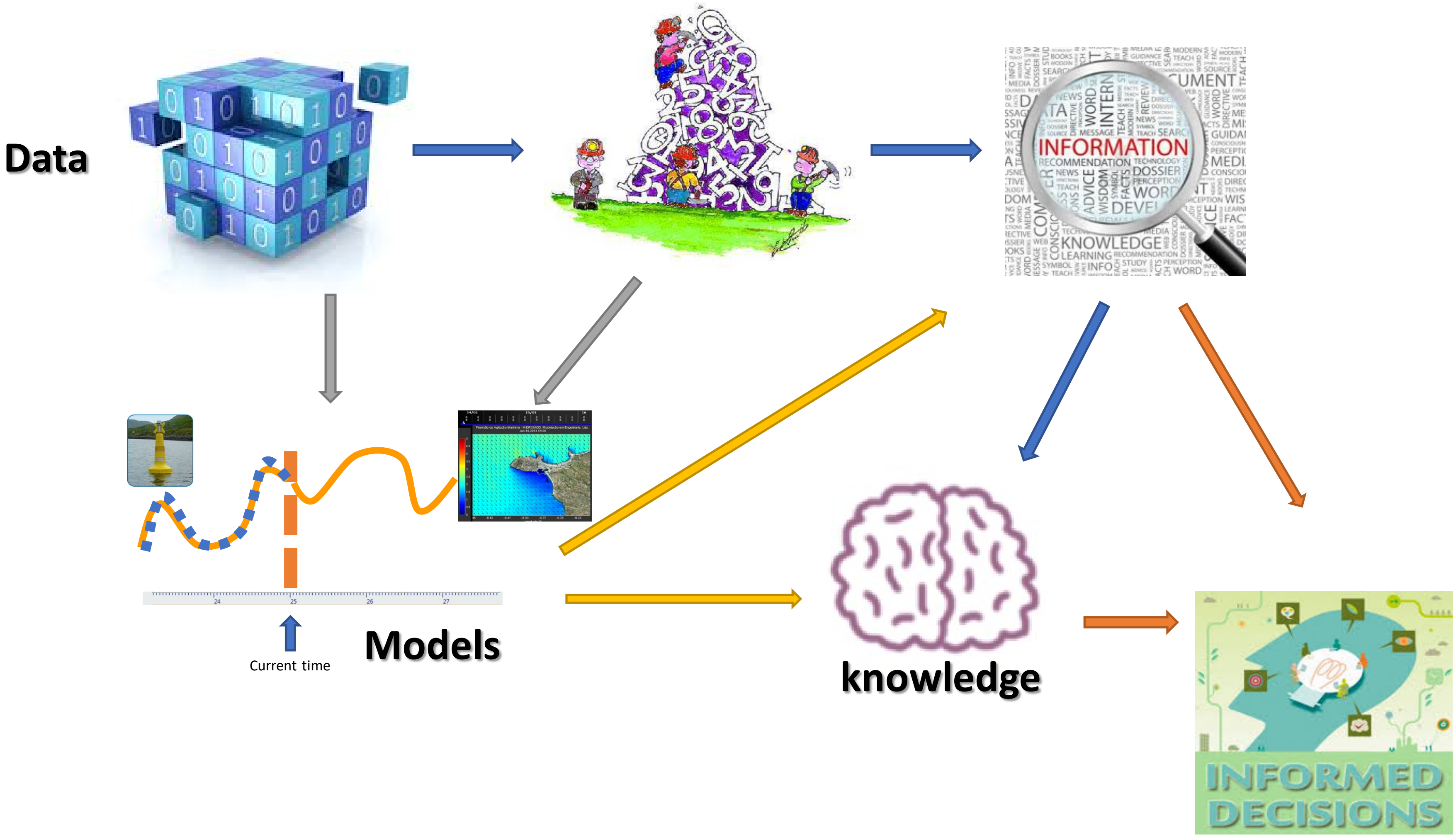
Water Temperature is 28^{o}C

If Water Temperature is higher than 26^{o}C for more than 5 days then 'HEAT STRESS"

High probability of fish mortality

Data to Information

ODYSSEA



Build one Platform for all

ODYSSEA

Marinomica

Marinomics

ODYSSEA

Noun /məˈriːn’nɒmɪks/

1. The science of decision making in the marine environment.
2. The branch of knowledge concerned with the production, consumption, and transfer of wealth in the marine environment.

Marinomics could be a new interdisciplinary scientific topic involving the provision of digital marine data services from sensors development, models implementation, integrative platforms, Big Data collection and processing, product development, cost analysis, marketing, testing user satisfaction, etc. Therefore, Marinomics is a multidisciplinary scientific topic adopting the novel approaches of Earth Big Data to provide Services within the concept of Blue Economy and Growth. Marinomics aims to improve decision-making and operations in the multitude of users operating at sea, protect the marine environment and support marine and maritime sustainable development.

ODYSSEA Central Objective

ODYSSEA is a user-centred project aiming to make Mediterranean marine data easily accessible and operational to multiple end-users, by

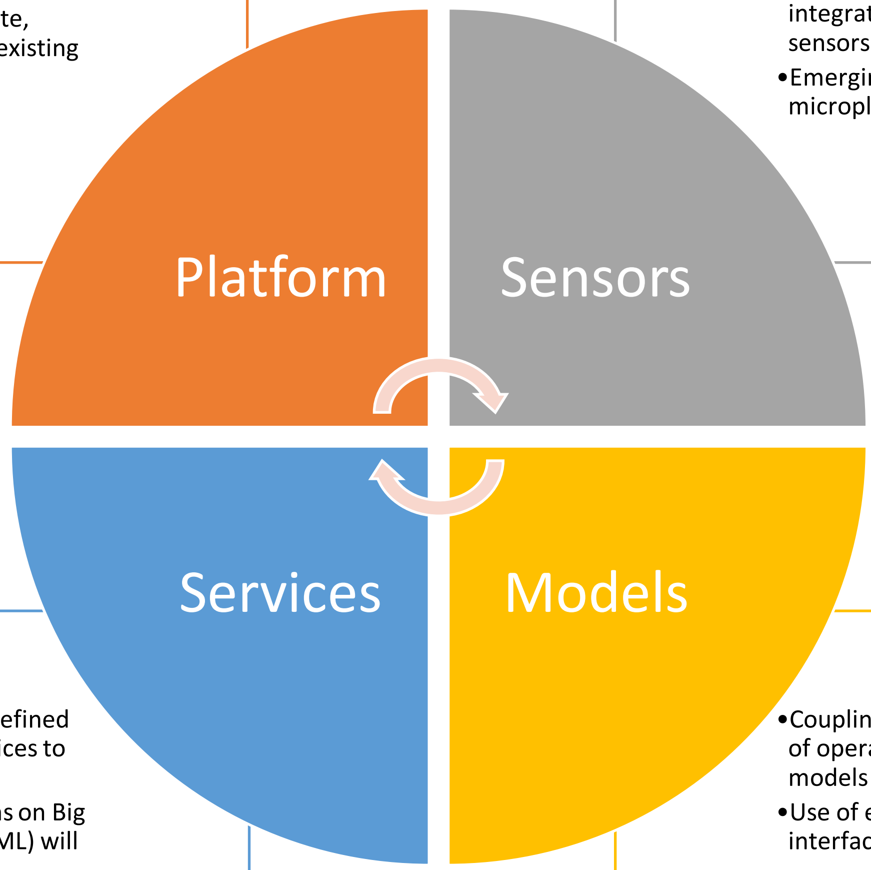
- harmonizing existing Earth Observing systems,
- upgrading operational oceanographic capacities,
- supporting EU policy implementation,
- improving interoperability in monitoring,
- fostering blue growth jobs creation, and
- opening participation to non-EU member states.

ODYSSEA Pillars

ODYSSEA

- Novel, easy to use
- Integrate, aggregate, expose data from existing systems

- Development and integration of novel sensors
- Emerging pollutants as microplastics



- Develop of well-defined products and services to end-users
- Modern algorithms on Big Data analysis (AI, ML) will be used

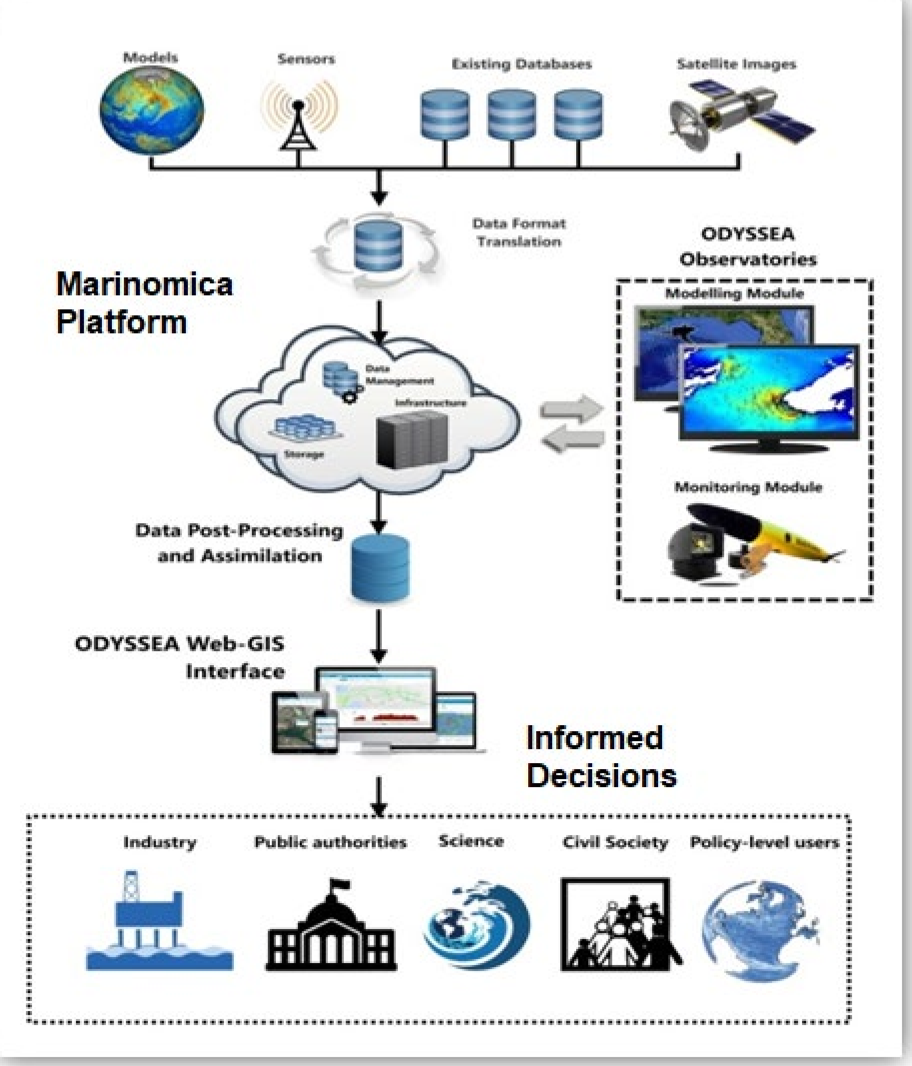
- Coupling and linking a set of operational numerical models
- Use of existing tools and interfaces

ODYSSEA's Concept

ODYSSEA

ODYSSEA is a system bridging the gap between operational oceanography capacities and the need for information on marine conditions from the community of end-users.

ODYSSEA's ambition is to develop an **interoperable, fully-integrated and cost-effective multiplatform network of observing and forecasting systems** across the Mediterranean basin, addressing both the open sea and the coastal zone.



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INTRODUCTION TO OCEANOGRAPHY FROM SPACE

Dr Hayley Evers-King

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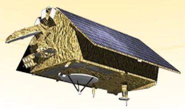
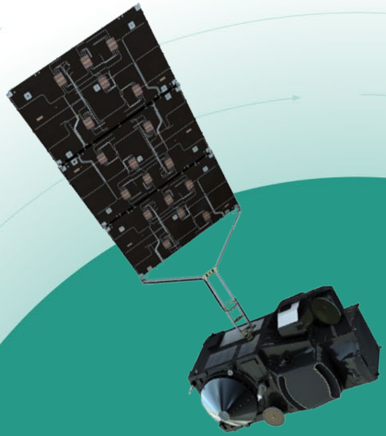


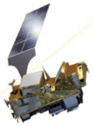
Introduction to Oceanography from Space

Dr Hayley Evers-King, EUMETSAT

ODYSSEA virtual school – Oceanography from Space



Hayley.EversKing@eumetsat.int, @HayleyEversKing



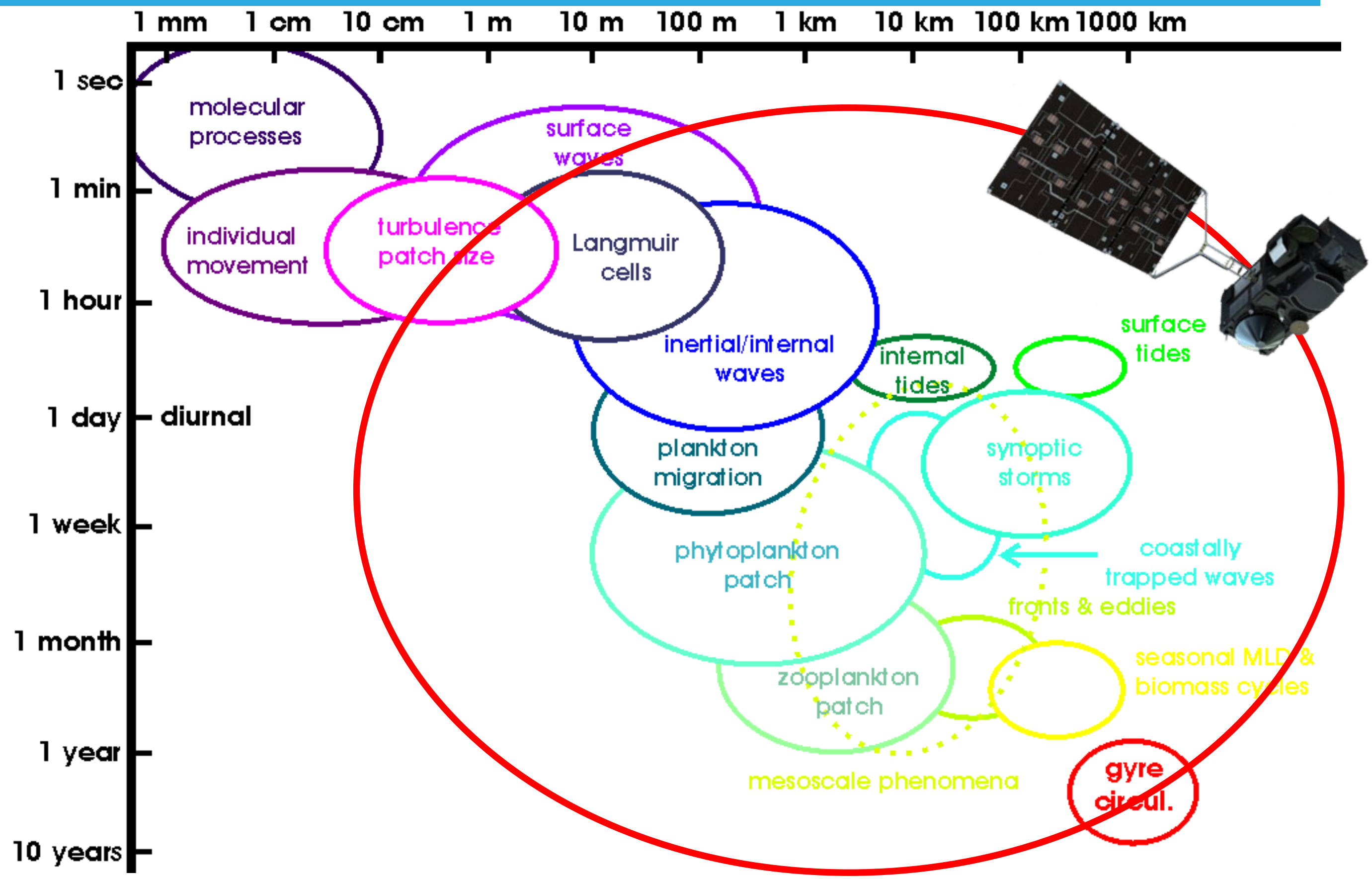
Why would we want to observe the oceans from space?

ODYSSEA

System drivers
e.g. Wind – Scatterometry, Altimetry, SAR

Physical response
e.g. Temperature - Radiometry

Biological response
e.g. Phytoplankton - Ocean colour

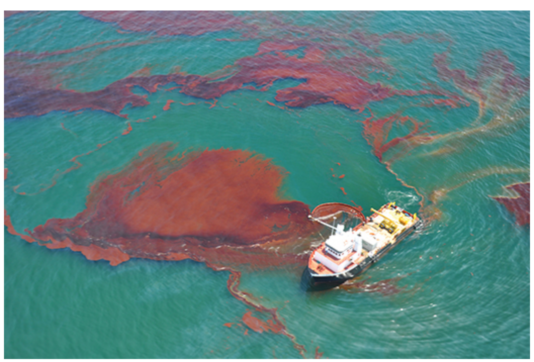


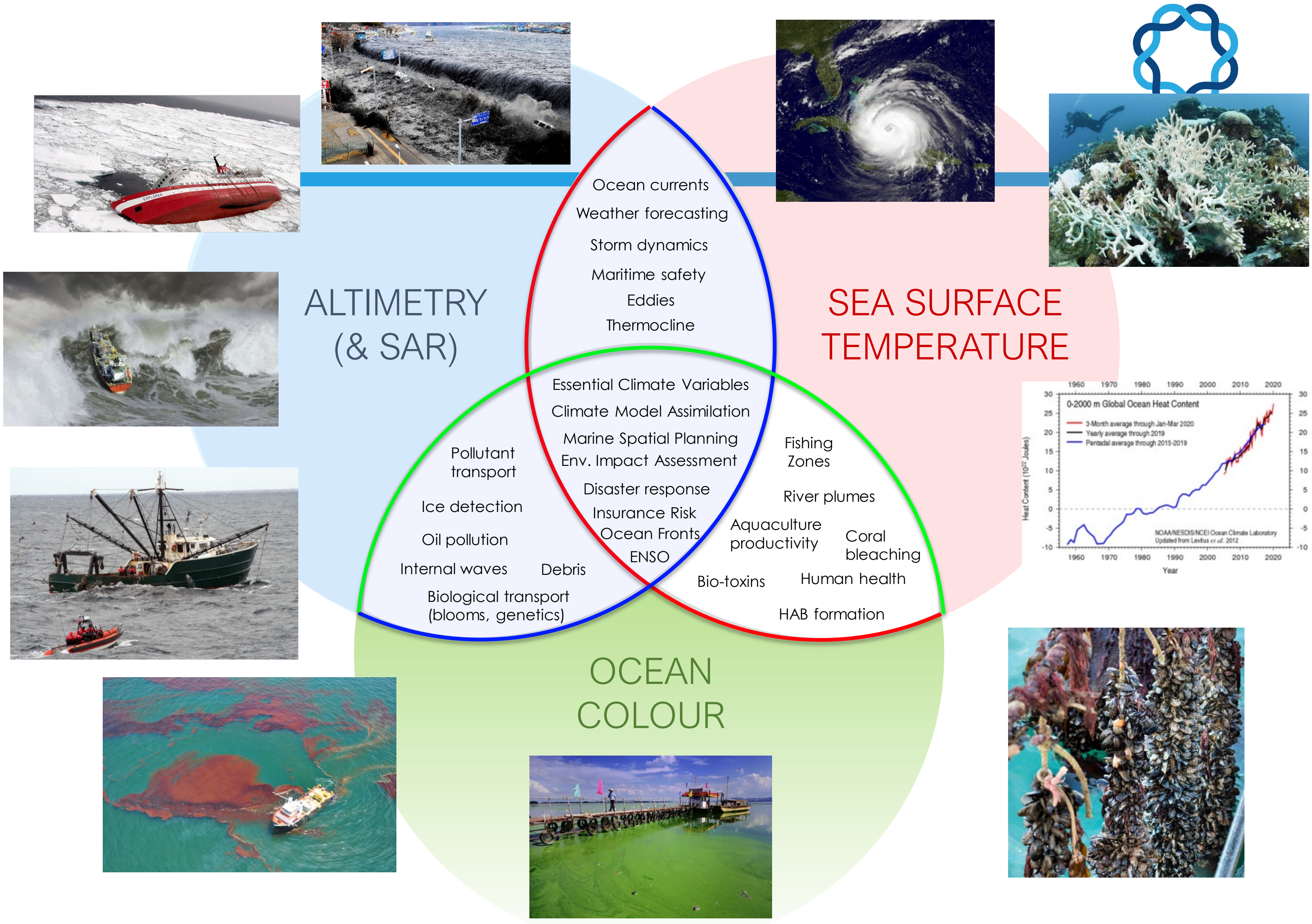
Why would we want to observe the oceans from space?











ALTIMETRY (& SAR)
SEA SURFACE TEMPERATURE
OCEAN COLOUR
Ocean currents
Weather forecasting
Storm dynamics
Maritime safety
Eddies
Thermocline
Essential Climate Variables
Climate Model Assimilation
Marine Spatial Planning
Env. Impact Assessment
Disaster response
Insurance Risk
Ocean Fronts
ENSO
Pollutant transport
Ice detection
Oil pollution
Internal waves
Debris
Biological transport (blooms, genetics)
Fishing Zones
River plumes
Aquaculture productivity
Coral bleaching
Bio-toxins
Human health
HAB formation
0-2000 m Global Ocean Heat Content
3-Month average through Jan-Mar 2020
Yearly average through 2019
Pentadal average through 2015-2019
NOAA/NESDIS/NCEI Ocean Climate Laboratory
Updated from Levitus et al. 2012
Year
Heat Content (10^{22} Joules)

ODYSSEA

Satellites – a way to measure processes that matter!

Who's who?

ODYSSEA

copernicus
Europe's eyes on Earth

EUMETSAT

esa
European Space Agency

NASA

NOAA

USGS

s3vt
Sentinel-3 Validation Team

IOCCG
International
Ocean Colour
Coordinating Group

CASC
China Academy of Space Technology

Copernicus
Marine Service

MERCATOR
OCEAN
INTERNATIONAL

WEkEO
by COPERNICUS

JAXA

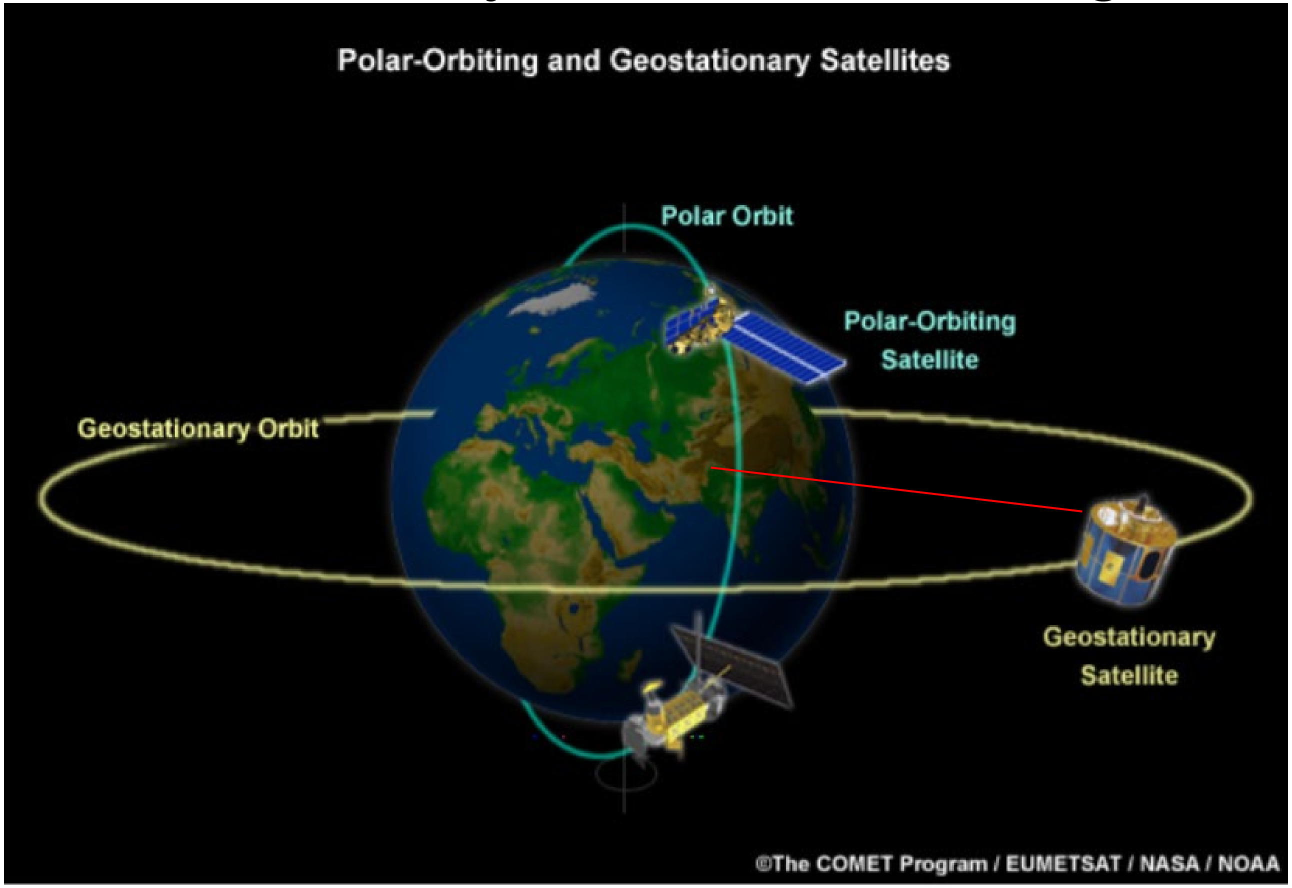
KARI
한국항공우주연구원
Korea Aerospace Research Institute

GHRSST
GROUP FOR HIGH RESOLUTION
SEA SURFACE TEMPERATURE

Completely non-exhaustive!.... Lots of organisation – agencies (development, launch, operations, data processing and provision), downstream providers, scientific organisations, data services…

Some basic concepts about satellite oceanography

- Orbits: Geostationary and Polar orbiting



Some basic concepts about satellite oceanography

- Orbits: *Geostationary* and Polar orbiting

Some basic concepts about satellite oceanography

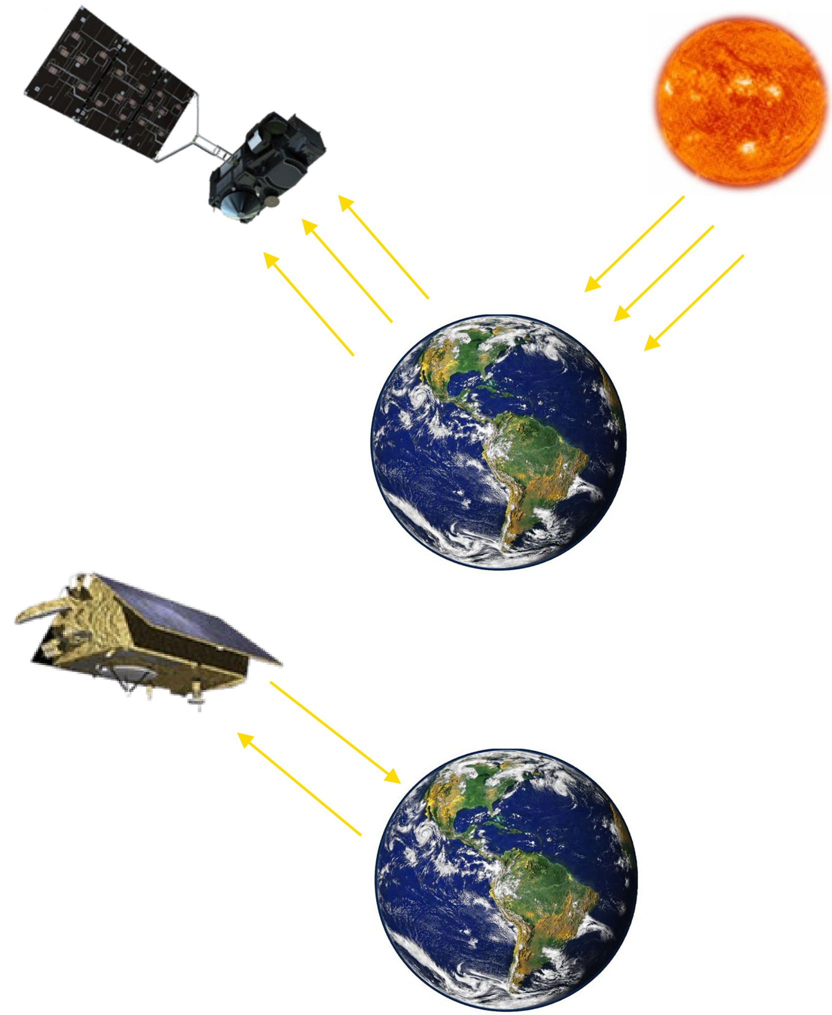
ODYSSEA

- Orbits: Geostationary and *Polar orbiting*

Some basic concepts about satellite oceanography

ODYSSEA

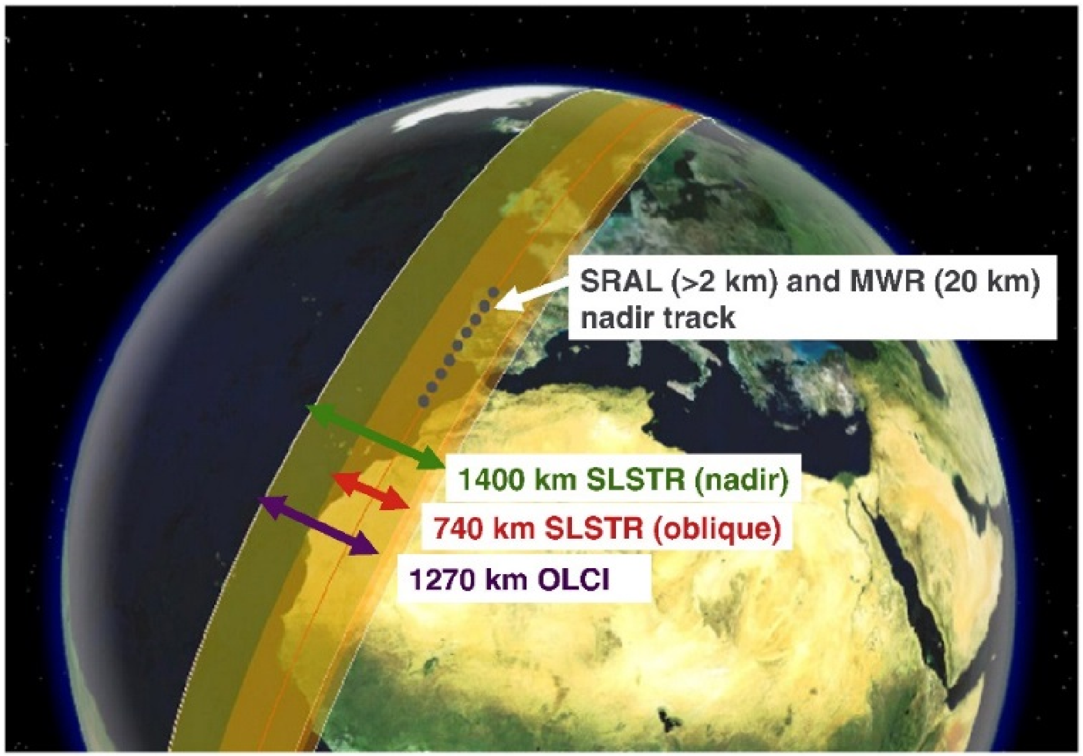
- Types of instrument
  - Passive
    - Detects signals emitted by the Earth
      - E.g. visible/infrared light – ocean colour, SST
  - Active
    - Sends a signal and detects a return signal
      - E.g. Radar – SAR, altimetry, scatterometry



Some basic concepts about satellite oceanography

ODYSSEA

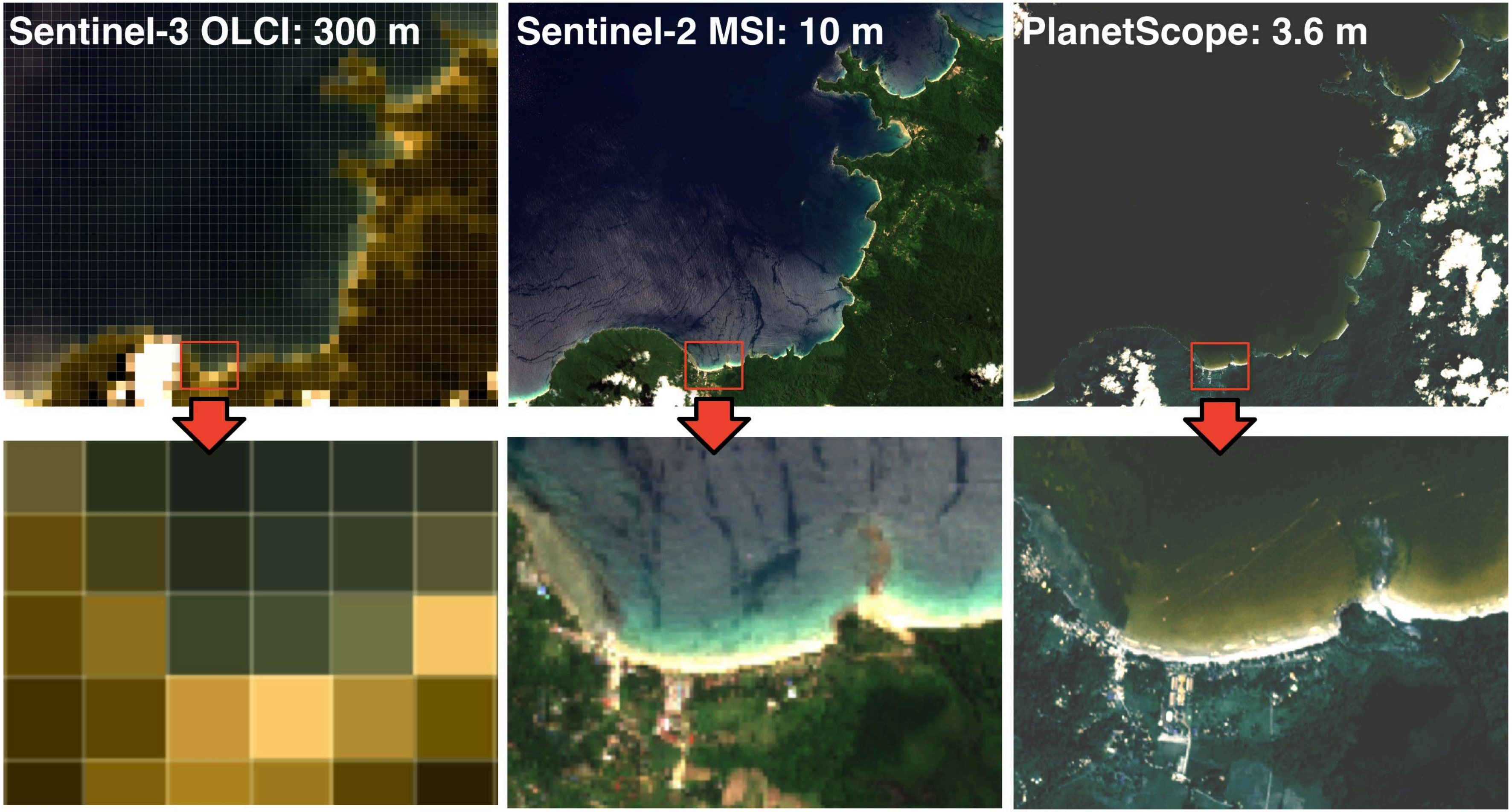
- **Resolution and revisit:** Spatial resolution



- High resolution: 10-60m (S-2, L8)
- Medium resolution: 300m – kms
- Along-track: 300m
- Downstream products: 1km – degrees (see later slides)

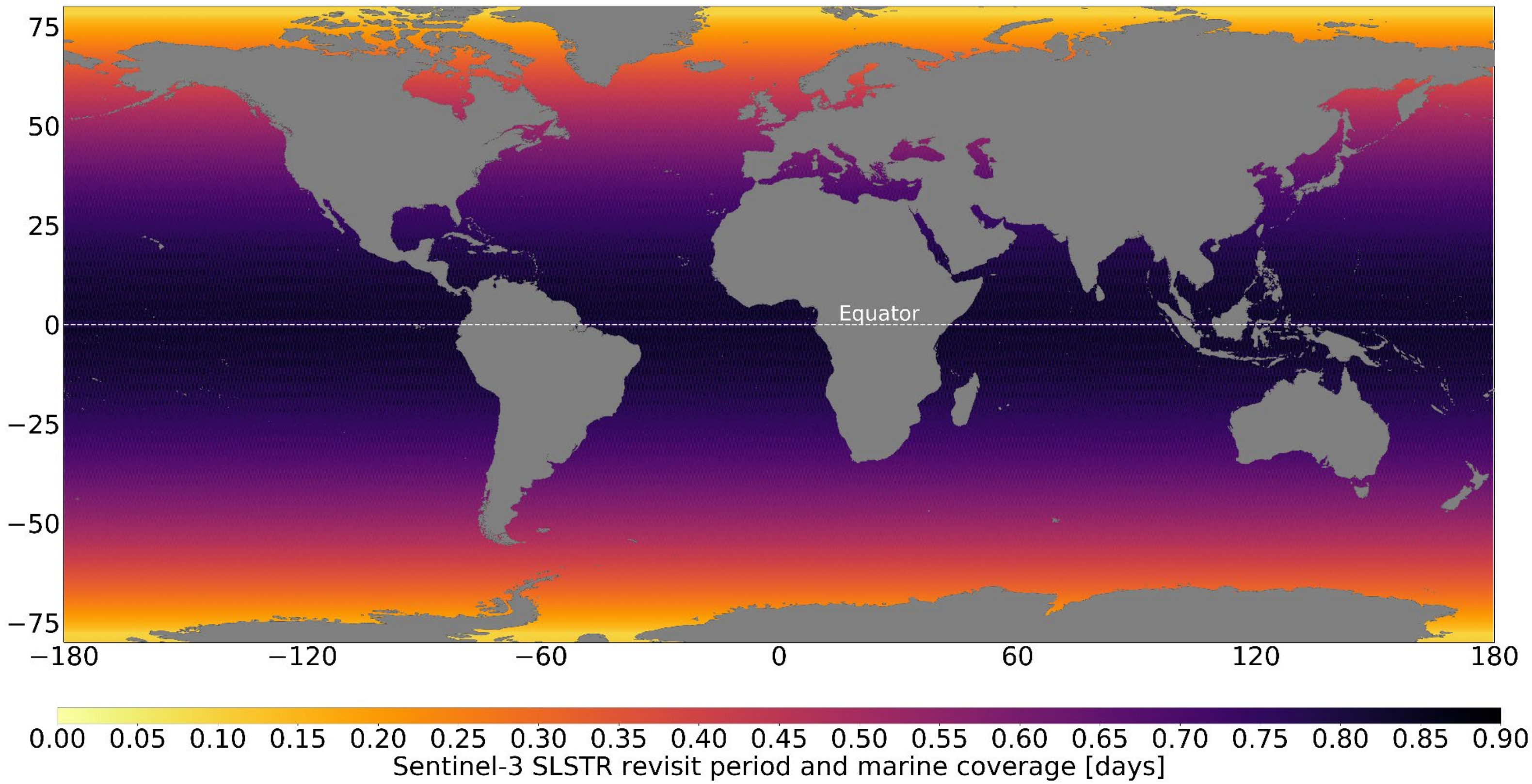
- **Resolution and revisit:** Spatial resolution

ODYSSEA



Some basic concepts about satellite oceanography

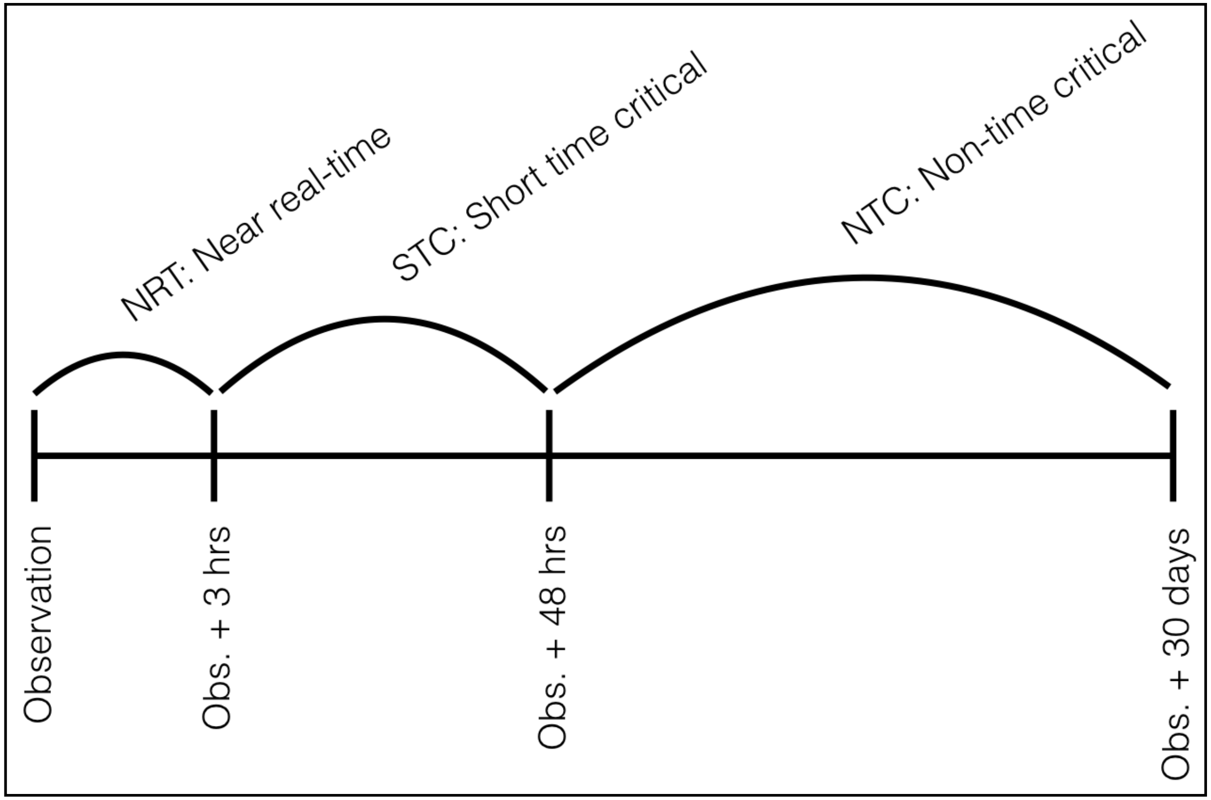
ODYSSEA



Some basic concepts about satellite oceanography

ODYSSEA

- **Resolution and revisit: Temporal**

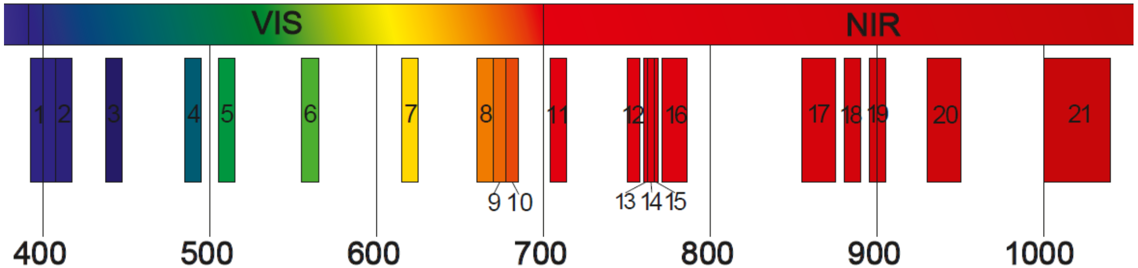


- Refers to level-1 and level-2.
- Downstream products mixed:
  - NRTish
  - Reprocessed, ICDRs and CDRs

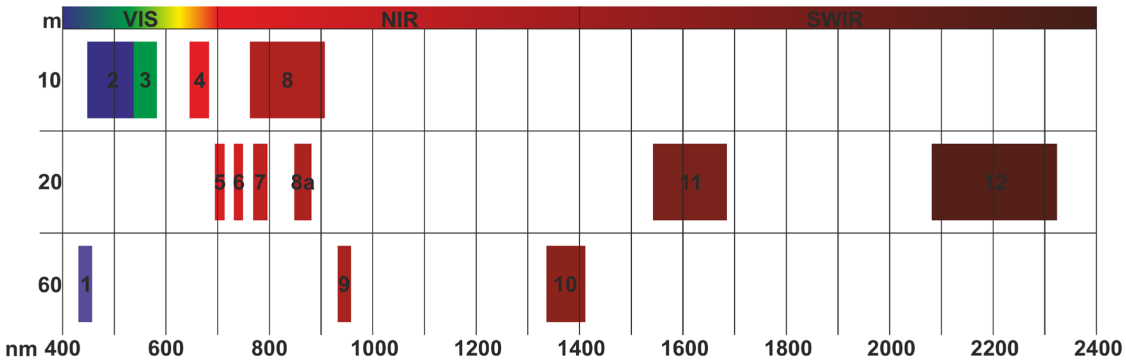
Some basic concepts about satellite oceanography

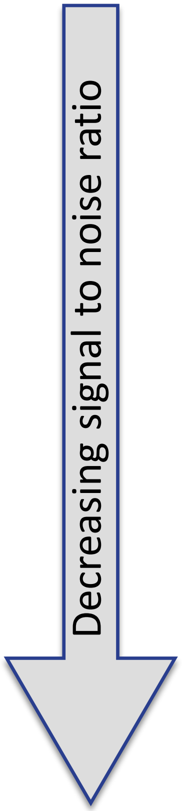
ODYSSEA

- Sentinel-3 OLCI:



Sentinel-2 MSI:





PlanetScope: Red, Green, Blue, (1 x NIR)

Typical data processing

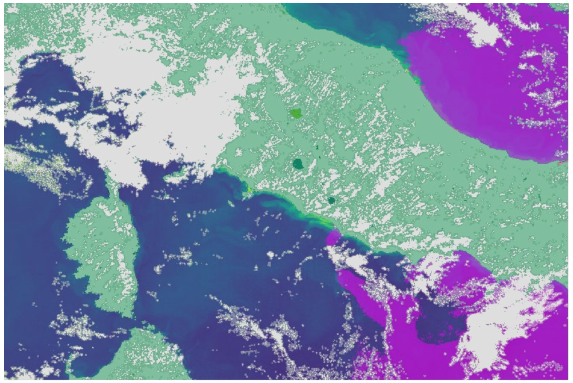
ODYSSEA

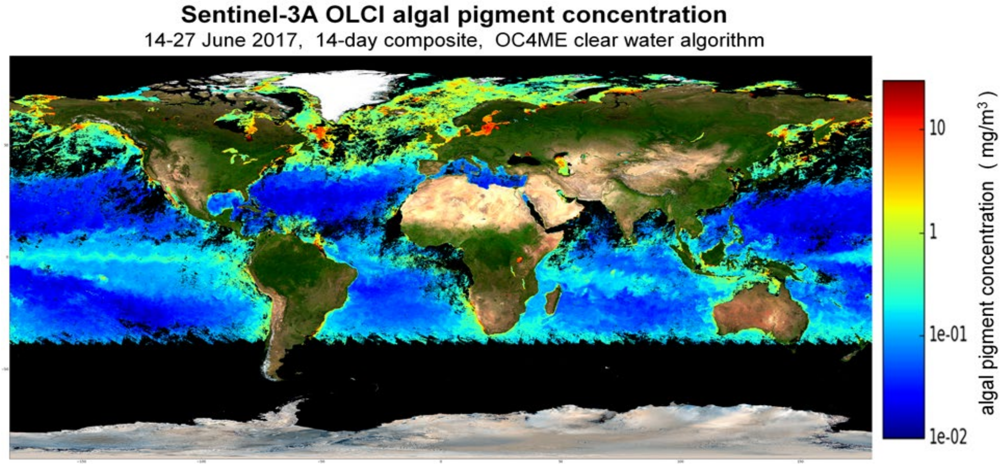
Processing Level	Description
Level 0	Reconstructed, unprocessed instrument and payload data at full resolution, with communications artefacts removed.
Level 1 (a+b)	Reconstructed, unprocessed instrument data at full resolution, time-referenced, and annotated with ancillary information.
Level 2 (+p)	Derived geophysical variables at the same resolution and location as Level 1 source data. Often involves atmospheric correction.
Level 3	Variables mapped on uniform space-time grid scales, usually with some completeness and consistency. Except topography (L4)
Level 4	Model output or results from analyses of lower-level data (e.g., variables derived from multiple measurements).

NOTE: There are differences in how parts of the remote sensing community define processing levels. And different instruments will include different methods at each level. Look at individual handbooks, product guides, ATBDs etc for more information.

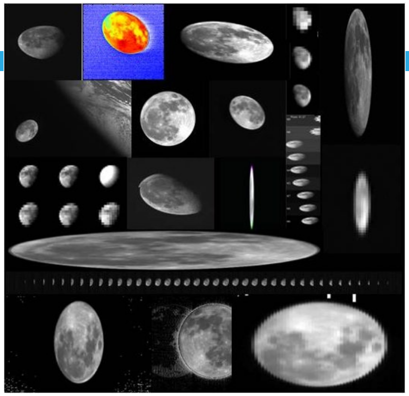
Typical data processing

- **Common processes:**
  - Atmospheric correction
  - Geophysical algorithms
  - Flagging
  - Regridding
  - Merging
  - Reanalysis

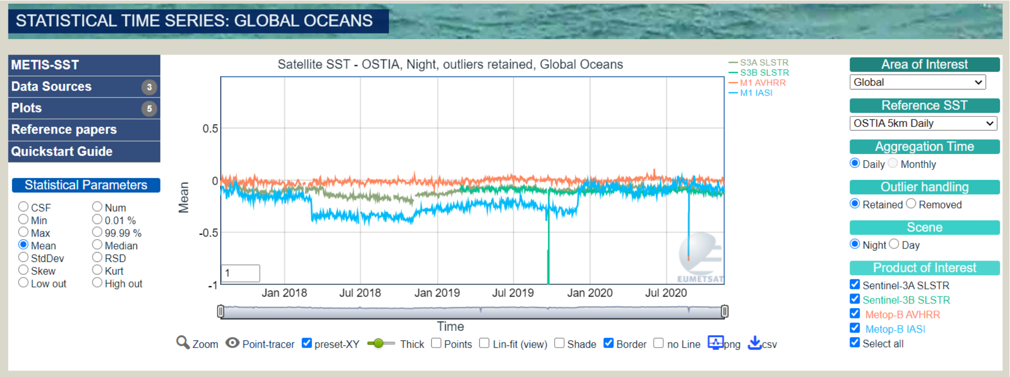




Calibration and validation



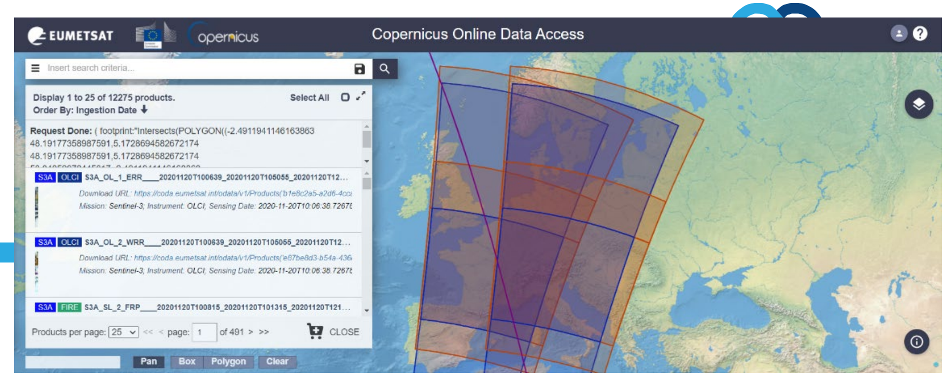
- Satellite measurement accuracy over time
- Algorithm development
- Using in situ measurements from a wide variety of sources.

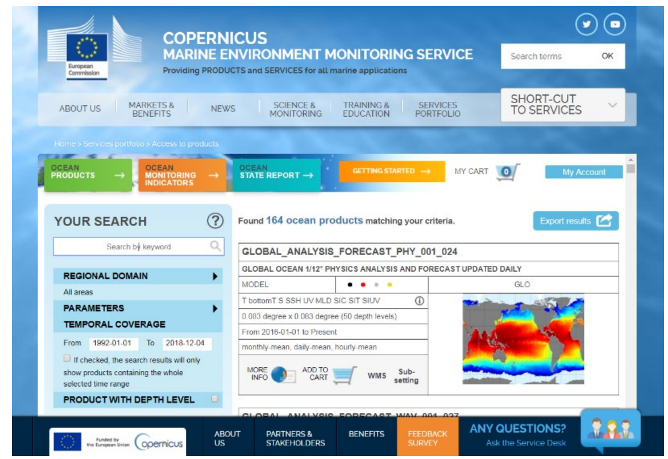


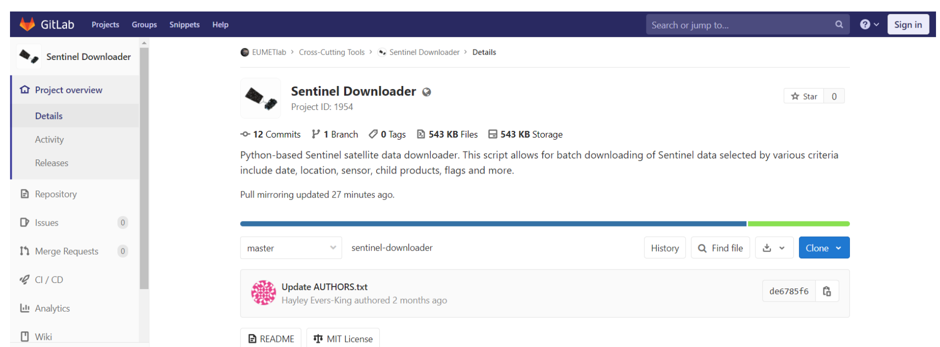
Data Sources

- Europe:
  - Copernicus EU
  - ESA
  - EUMETSAT
  - DIAS
- USA:
  - NOAA
  - NASA
  - USGS
- Downstream providers
  - Individual projects and initiatives
- Private companies

Access via GUIs, FTP, satellite push services, and - more commonly now - APIs







How do I choose which data to use?!

ODYSSEA

- Questions to ask:
  - What variable do I need to analyse?
  - Is standard processing sufficient?
    - Can I process my own data?
  - What spatial/temporal scale do I need?
  - How will merging/averaging/interpolation/processing assumptions affect the phenomena I wish to investigate?

Software and tools

ODYSSEA

- Data portals
  - Varying functionality: Download, view, basic analysis
- Software with GUI:
  - GIS: ArcGIS, QGIS etc
  - SNAP, BRAT, SeaDAS, DeDop, Acolite….
- Programming approaches:
  - Open source: Python, R associated libraries
  - Proprietary

Getting help and support

ODYSSEA

- Agency and service help desks
- Software forums
- Growing array of training offers (often financially supported!)
- Community organisations:
  - IOCCG, GHRSST, OSTST etc etc

Questions?

- Will cover in upcoming sessions:
  - Data access in Copernicus
  - Specifics of Ocean Colour and SST
  - Some examples of downloading data
  - Some examples of working with tools

OCEAN SATELLITE DATA RETRIEVAL FROM COPERNICUS

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Ocean satellite data retrieval from Copernicus

Dr Hayley Evers-King, EUMETSAT

ODYSSEA virtual school – Oceanography from Space

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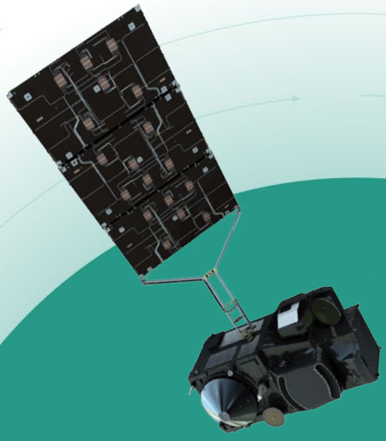
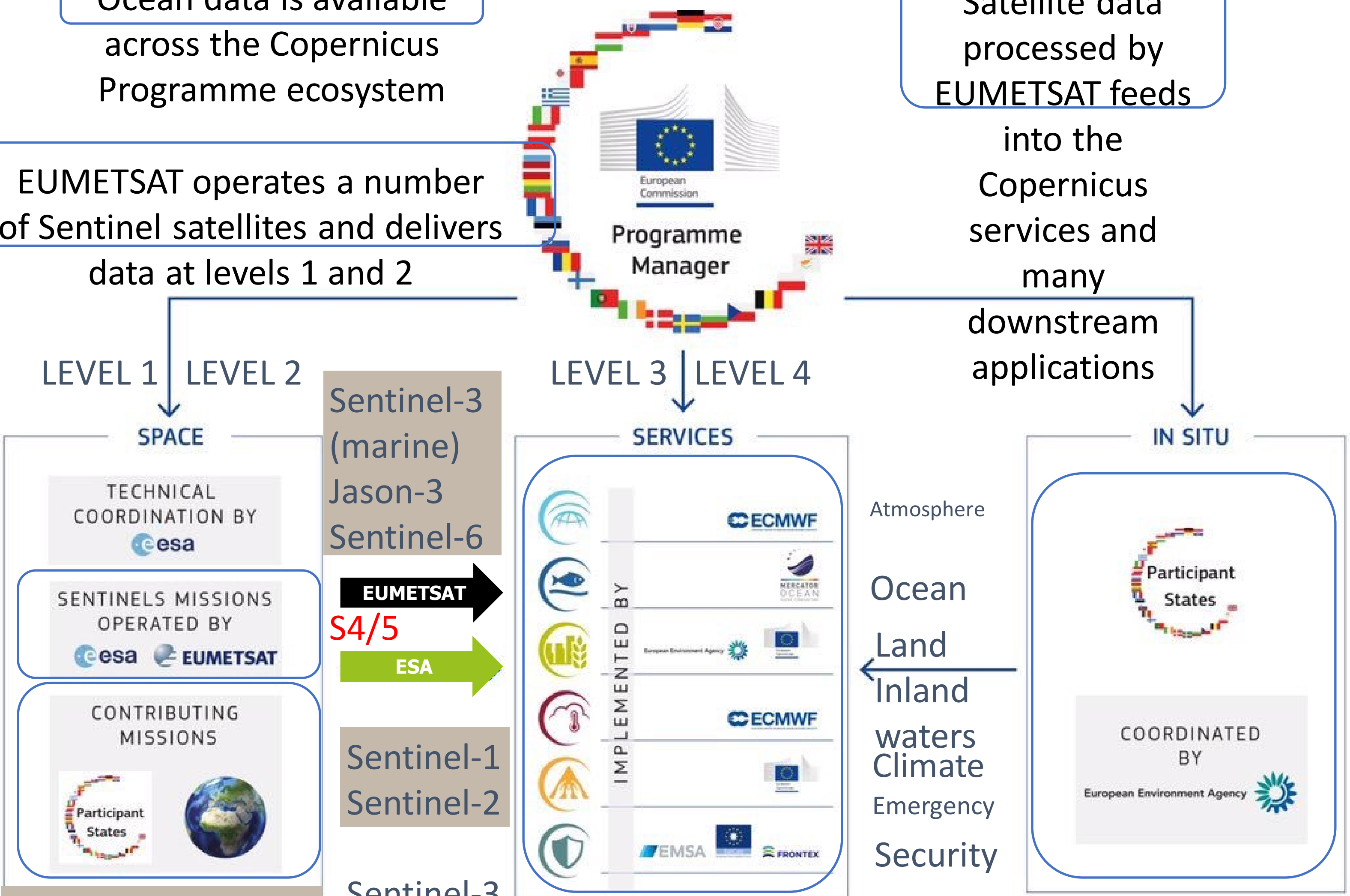


Ocean(+) data in Copernicus

Ocean data is available across the Copernicus Programme ecosystem

EUMETSAT operates a number of Sentinel satellites and delivers data at levels 1 and 2

Satellite data processed by EUMETSAT feeds into the Copernicus services and many downstream applications



Sentinel-3 (marine)
Jason-3
Sentinel-6

S4/5

Sentinel-1
Sentinel-2

Sentinel-3 (land)

MODELS

Contributing missions:
OceanSat2 (3)

DYSSEA

GMES AND AFRICA

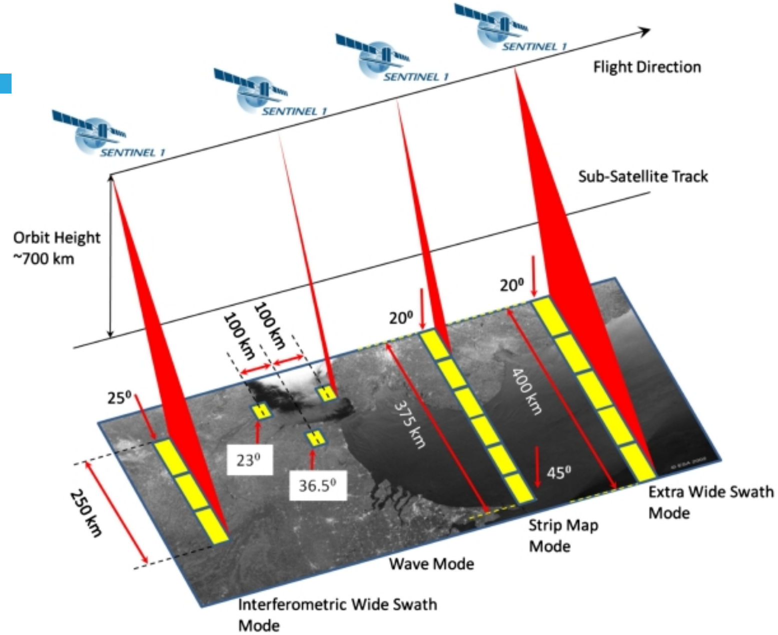
4 marine consortia (nominally N, E, S, W)

User driven data delivery and services for the marine environment

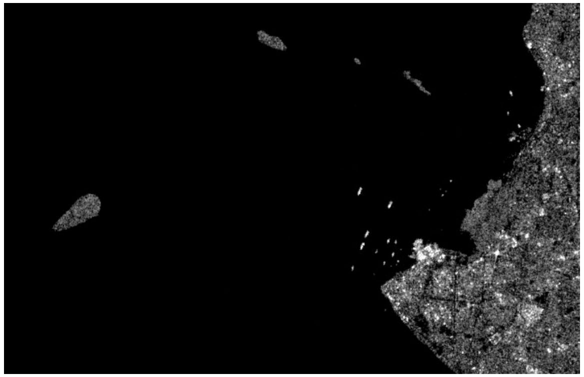
Partnerships with government and industry

Sentinel-1

- Operated and data delivered by ESA.
- Synthetic Aperture Radar – active method, information comes from surface roughness.
- Ocean applications:
  - Oil spill detection and pollution identification
  - sea-ice and iceberg monitoring
  - Wind / wave information
  - Ship and infrastructure detection

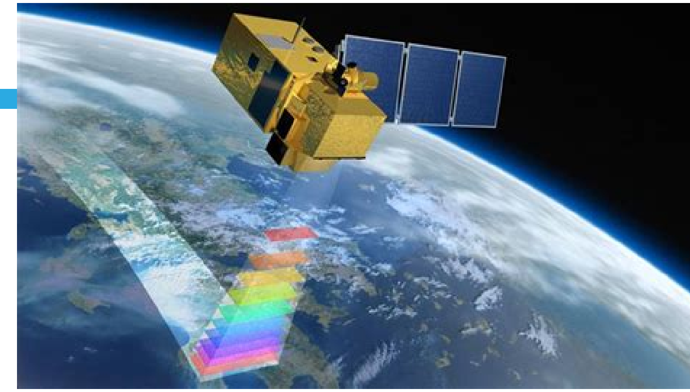


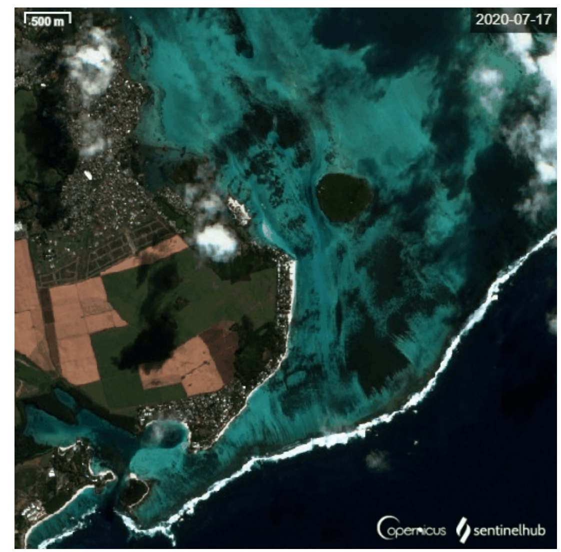
- Lots of detail available from ESA
  - https://sentinel.esa.int/web/sentinel/user-guides/sentinel-1-sar;jsessionid=570C985C6EC09E4046D2B912D9CA089B.jvm1
- Great course if you want detail on this https://eo-college.org/courses/echoes-in-space/ Also check out @SistersofSAR for various training initiatives.



Data from https://scihub.copernicus.eu/

Sentinel-2



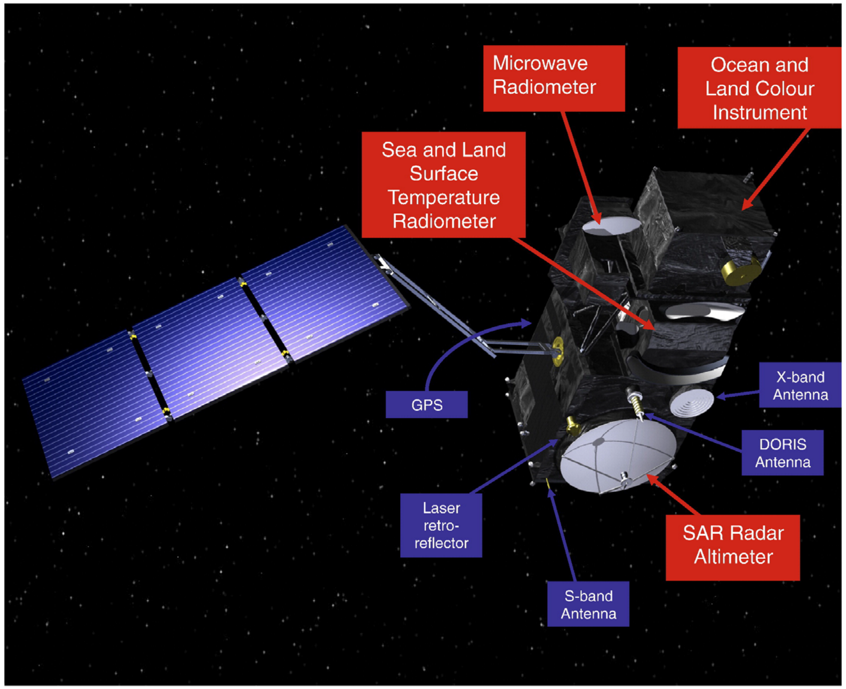


- Operated and data delivered by ESA. Not technically a marine mission, but growing applications in the coastal zone.
- Optical imager – high spatial resolution but low SNR and # of wavebands.
- Detailed information: https://sentinel.esa.int/web/sentinel/user-guides/sentinel-2-msi
- Open source processing options for the ocean.
- Ocean Applications:
    - Coastal maritime infrastructure
    - Sediment dynamics
    - Dredging
    - Debris
    - Water quality

Data from https://scihub.copernicus.eu

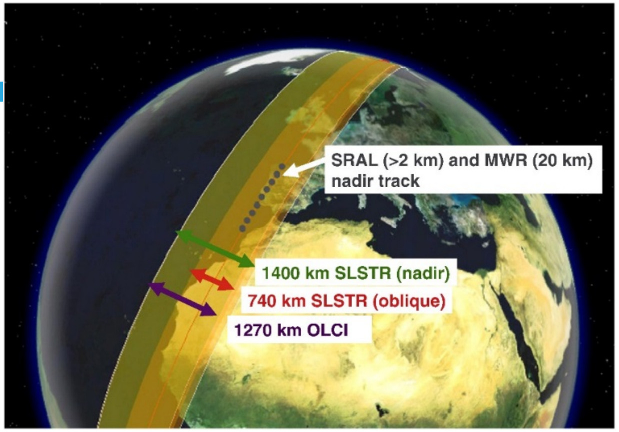
Sentinel-3

- The ‘blue Sentinel’
  - SLSTR (SST)
  - OLCI (Ocean Colour)
  - SRAL/MWR/POD (Surface topography/altimetry)
- S3A (launched 16th Feb 2016), S3B (launched 25th April 2018)
- Spacecraft Operations (routine phase) and marine data processing/performance/ dissemination by EUMETSAT
- Ocean applications: Long list covering nearly all aspects of oceanography.



Sentinel-3A and -3B

- Two satellites working together to optimize coverage.
  - 27 day repeat cycle
  - 140º phasing between A and B
  - Full global coverage in <3 days (OLCI) and <2 days (SLSTR) at the equator.
- Secondary benefit: opportunities for inter-calibration.
  - Tandem phase
  - Data available to S3VT from EUMETSAT



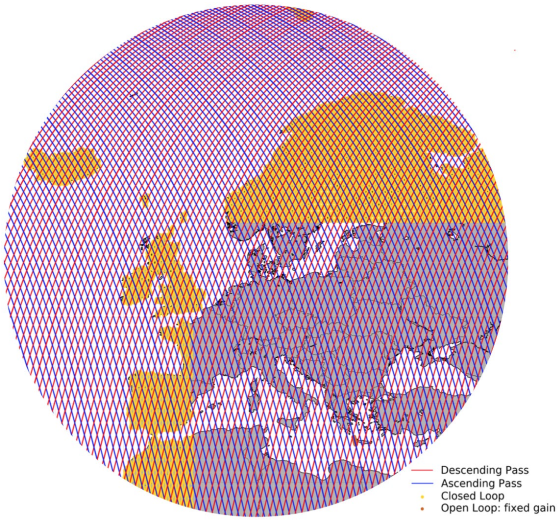


Figure 1: S3A SRAL track spacing and operating modes

EUMETSAT Copernicus Marine Data Stream

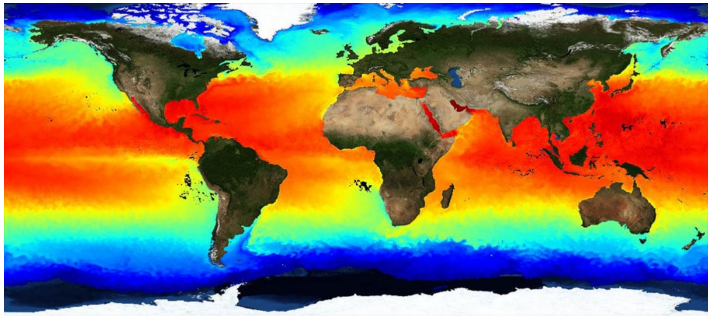
ODYSSEA

- **Sentinel-3A and 3B**
  - Operation of satellite
  - Ground segment
    - Data processing
    - Data to services

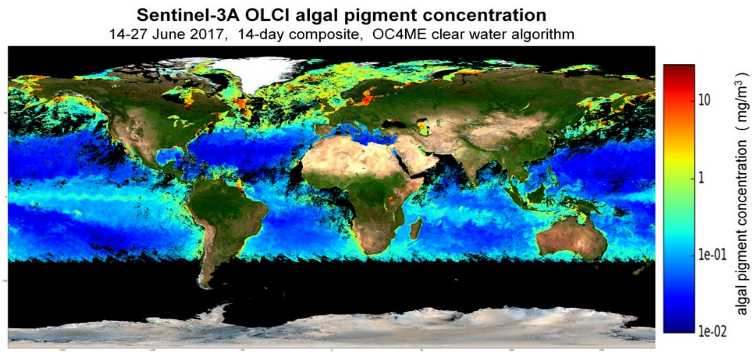
- **Global Level 1 and Marine Level 2 data**
  - Daily, highest resolution (sensor specific, native)
  - NRT/STC/NTC
  - Level 1 allows for the user to implement custom processing
  - Level 2 - geophysical products provided as standard

Primary oceanographic variables available through CMDS

- SLSTR (optical radiometry) L2 products:
  - Sea Surface Temperature (SST) (GHRSST L2P)

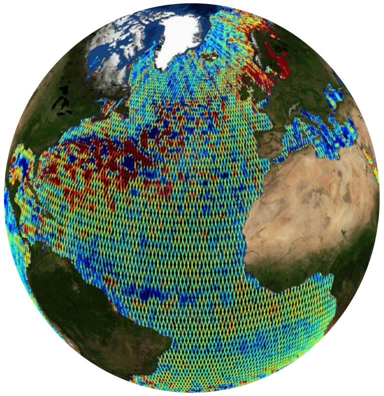


- OLCI (optical radiometry) L2 products
  - Water leaving radiance
  - Chlorophyll (CHL)
  - Total Suspended Matter (TSM)
  - Absorption of gelbstoff and detritus (a_dg)
  - Diffuse attenuation coefficient (Kd_490)
  - Photosynthetically active radiation (PAR)



- SRAL* (SAR altimetry) L2 products:
  - Sea surface height (SSH)
  - Significant wave height (SWH)
  - Wind speed (WS)
  - Sea Level Anomaly (SSHA) (at L2)
  - Sea ice products

*plus MWR and POD



Data Access for Sentinel-3 (and some other data)

ODYSSEA

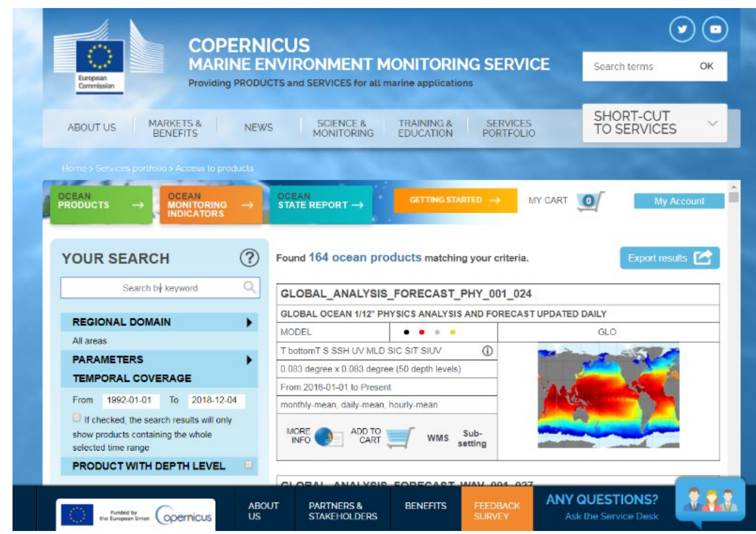
EUMETSAT offers a range of data discovery and delivery mechanisms

Single sign on registration for online services at https://eoportal.eumetsat.int

	EUMETCast	EUMETCast is a multi-service push dissemination system based on multicast technology. The multicast stream is transported to the user via satellite (EUMETCast Satellite) or terrestrial (EUMETCast Terrestrial) networks.
	Copernicus Online Data Access (CODA)*	CODA offers all Sentinel-3 marine products through a rolling buffer spanning the last 12 months of data. It can be accessed through its API and web-based GUI. CODAREP also available for reprocessed data.
	Data Centre Long-Term Archive	An ordering application enables users to browse and select from the long-term archive of products including those from Sentinel-3 marine service.
	EUMETView	EUMETView is a visualisation service that allows users to view EUMETSAT's data and Copernicus Sentinel-3 marine data in an interactive way using an online map viewer.
WEkEO by COPERNICUS	WEkEO	WEkEO is one of the Copernicus Data Information and Access Services (DIAS), and is coordinated by EUMETSAT, ECMWF and Mercator Ocean. Cloud and harmonized API.

Copernicus marine service

- http://marine.copernicus.eu
- Lead by Mercator Ocean International with many contributing organisations in Thematic Application Centres.
- Products from in situ, satellites, reanalysis and models.
- Includes: sea level, wind, waves, currents, temperature, chlorophyll, nutrients, and other biological parameters, sea ice.



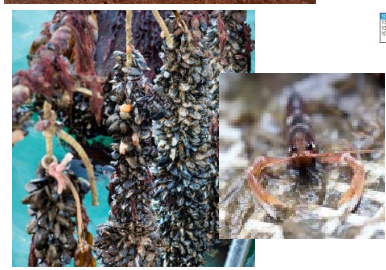
Demonstrations

ODYSSEA

- ESA Copernicus SciHub
- Getting Sentinel-3 data from CODA
  - GUI
  - API
- Searching the marine service catalogue

A note on the Copernicus value chain!

End User → Service Delivery → Service Content → Tailored Service → Product Analysis → Product → Data processing → Data ID and specification

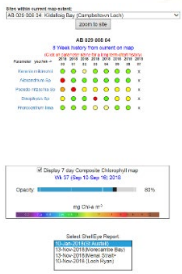


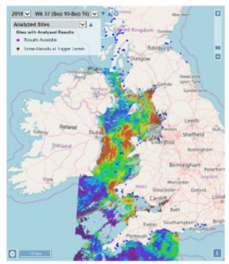

Chile's salmon farms losing up to $800 million from algal bloom

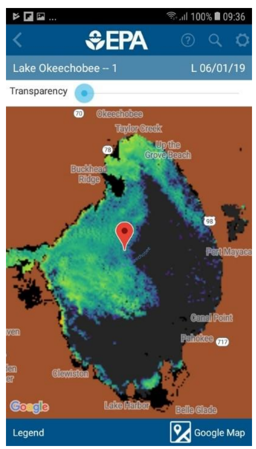
By Anthony Esposito

SANTIAGO (Reuters) - A deadly algal bloom has hit the world's second biggest salmon exporter, Chile, where nearly 23 million fish have already died and the economic impact from lost production is seen soaring to $800 million, industry and government sources told Reuters.

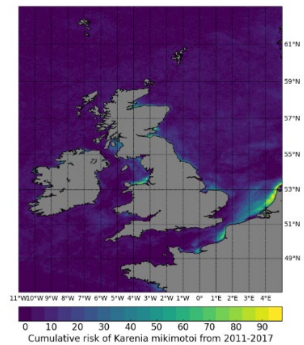
Sector Stakeholders

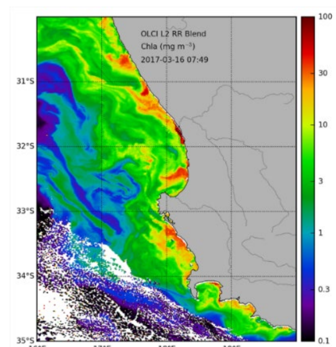






Thematic subject experts





ODYSSEA

Thematic subject experts

Expert EO users e.g. Universities, Research organisations

Agencies e.g. EUMETSAT, ESA, EC

Finding out more about Copernicus data

ODYSSEA

- ESA Copernicus helpdesk:
- eosupport@copernicus.esa.int

- EUMETSAT helpdesk: ops@eumetsat.int
- Training: https://training.eumetsat.int
- YouTube: https://www.youtube.com/watch?v=z9GGmvJzDx0&list=PLOQg9n6Apif1ODObv39j43j8IAvJDOAVY
- MOOC: https://oceansfromspace.org

- Marine service: http://marine.copernicus.eu

- Copernicus relays, academies, BICs etc

Questions?

- Will cover in upcoming sessions:
  - More on data access for OC and SST
  - Example applications
  - Demonstration of some tools and links to further learning resources

Creating products and knowledge for the Mediterranean

ODYSSEA

OVERVIEW, PROJECT ACTIVITIES AND OUTCOMES

“Oceanography from Space” Virtual School, 23-27/11/2020

Prof. Georgios SYLAIOS

Democritus University of Thrace

gsylaios@env.duth.gr

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 727277

Objective

ODYSSEA

ODYSSEA is a complex, data-driven, user-centred project aiming to:

- make Mediterranean marine data easily accessible to multiple end-users,
- transform data into valuable information,
- aggregate data to explore hidden ecological patterns, behaviours and trends,
- support EU & Barcelona Convention policy implementation,
- foster blue growth jobs creation, and
- welcome the participation of non-EU Med countries into an integrated, operational, Blue Growth entity

Specific Objectives

ODYSSEA

1. Develop a platform to discover, integrate and process datasets obtained from an expanded range of existing observation platforms
2. Fill-in data gaps & increase spatial and temporal resolution by establishing ODYSSEA Observatories
3. Develop a prototype ‘chain’ of models providing data never previously reported
4. Expand existing operational monitoring systems capacity
5. Emphasize on biological datasets
6. Combine data to extract secondary indicators
7. Link indicators to EU policies
8. Involve end-users on platform design, data collection and day-to-day operations
9. Train and educate policy-makers and end-users on platform usage
10. Improve professional skills and competences - focus on Northern Africa capacity building

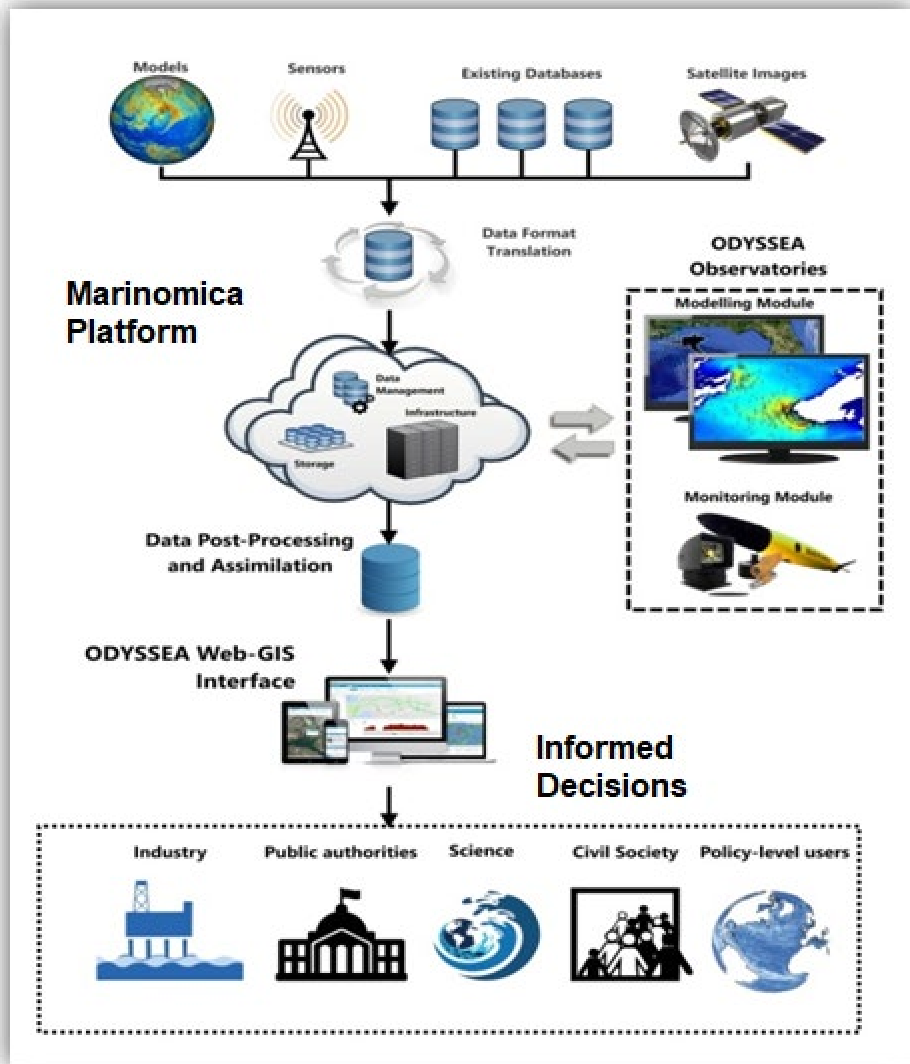
SO1

Develop a platform to discover, integrate and process datasets obtained from an expanded range of existing observation platforms

ODYSSEA as a platform

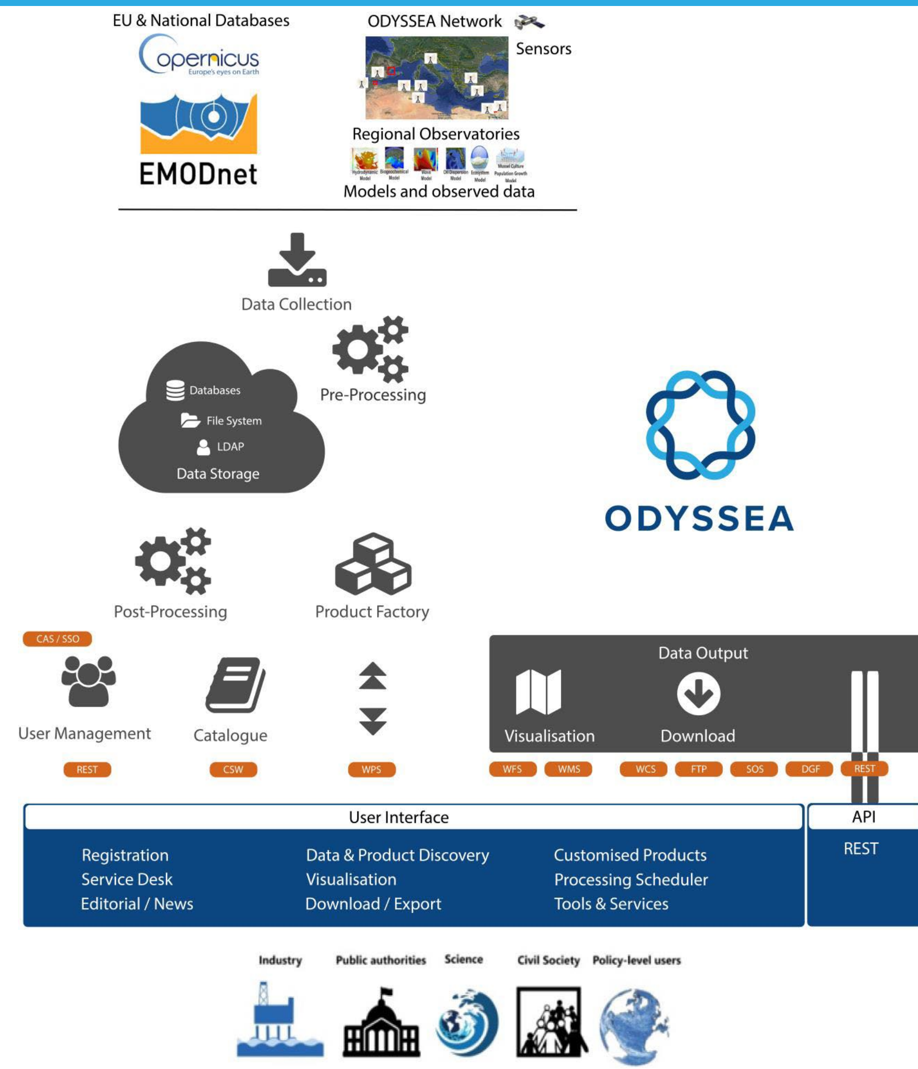
ODYSSEA is a system bridging the gap between operational oceanography capacities and the need for information on marine conditions from the community of end-users.

ODYSSEA's ambition is to develop an **interoperable, fully-integrated and cost-effective multiplatform network of observing and forecasting systems** across the Mediterranean basin, addressing both the open sea and the coastal zone.



The Platform

1. Integrate marine data from existing databases maintained by Earth Observing facilities,
2. Receive and process novel newly produced datasets (through models, remote sensing and on-line sensors) from nine prototype Observatories,
3. Transform marine data into meaningful information, ultimately developing, testing, validating and disseminating marine data products and services to end-users,
4. Stimulate Blue Growth throughout the Mediterranean basin, creating businesses, advancing science and supporting the societal use of digital information



The Marinomica platform

ODYSSEA

MARINOMICA LOGO

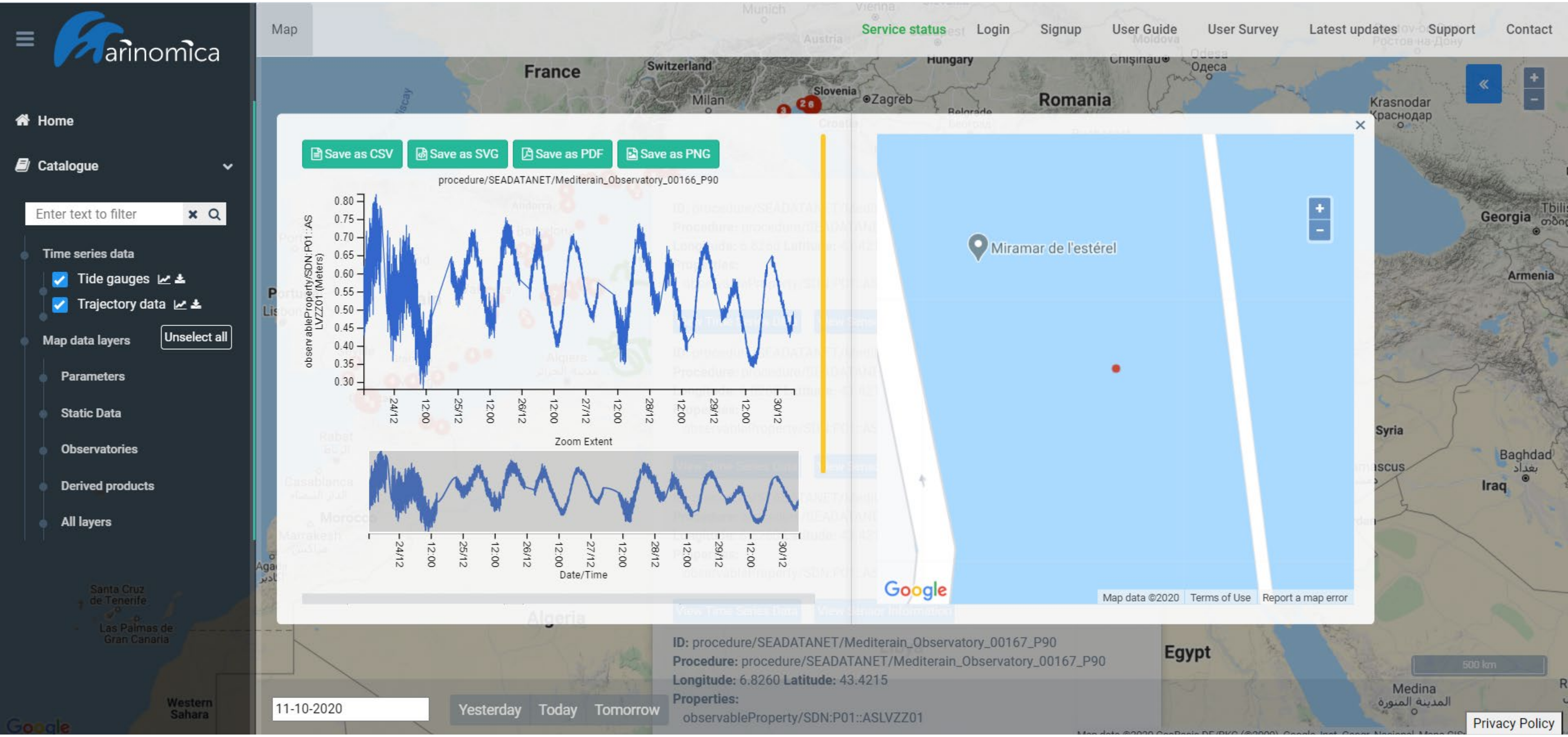
The following domain have been registered:

- marinomica.com

The Marinomica platform

odysseaplatform.eu |@odysseaplatform

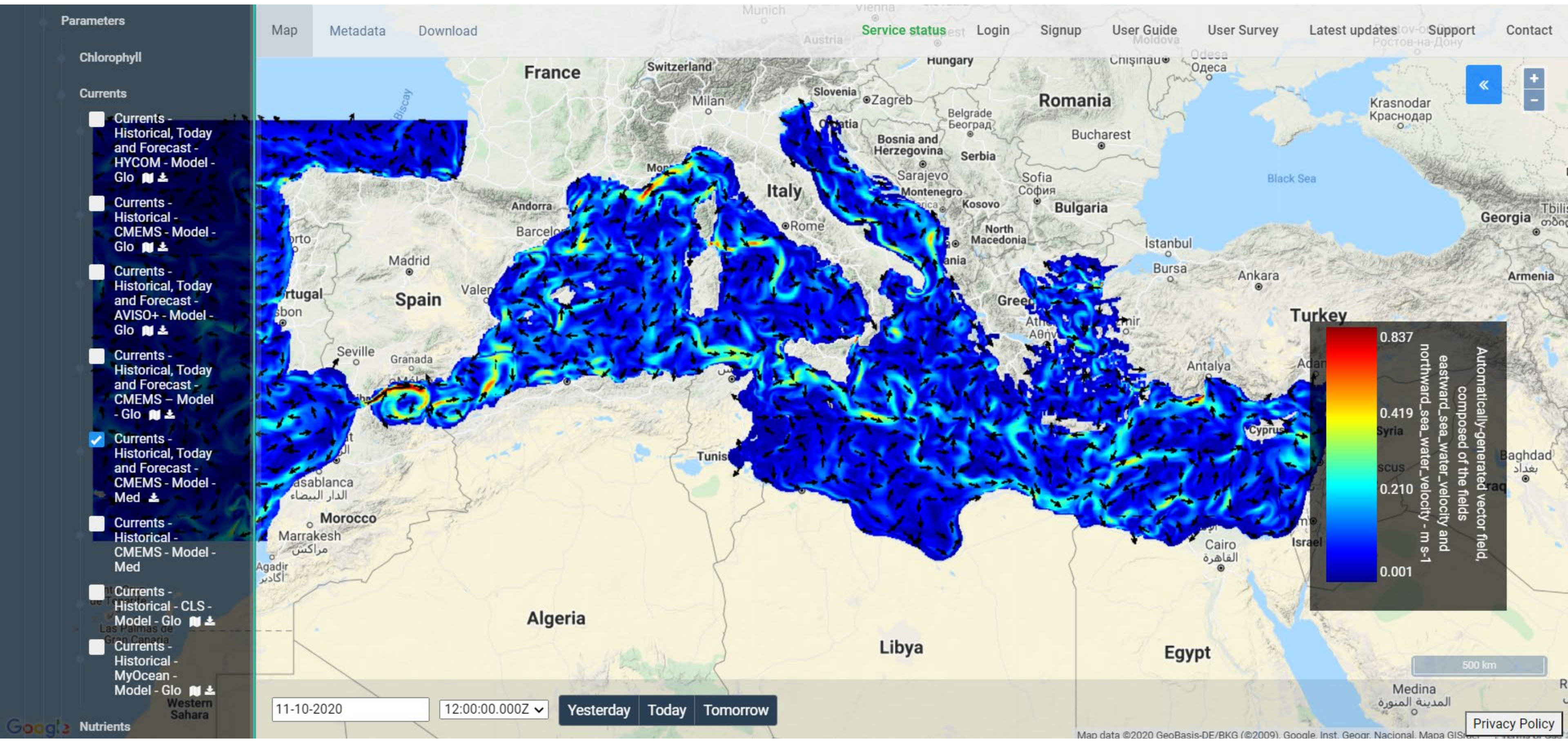
The Marinomica platform



The Marinomica platform

ODYSSEA

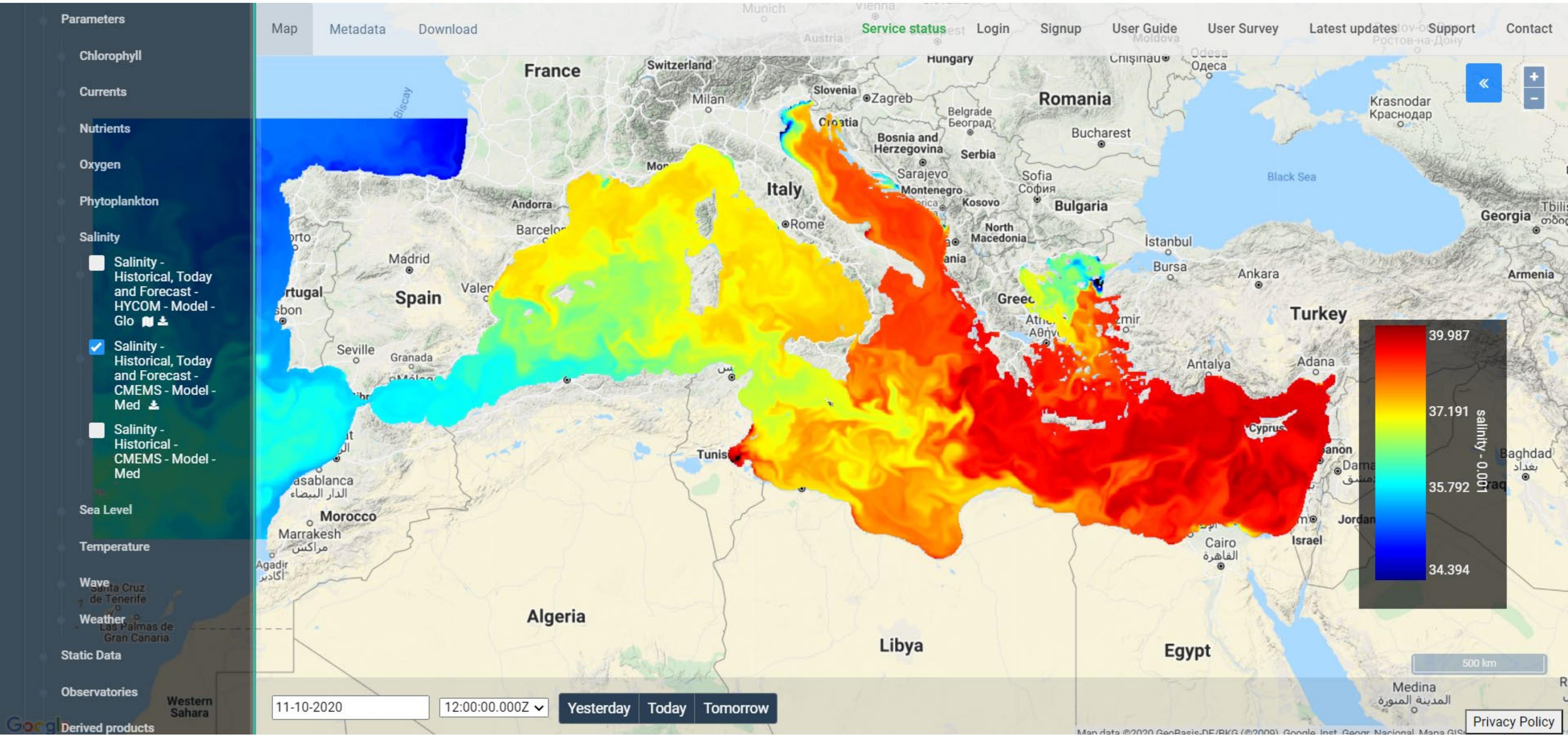
Surface Currents



The Marinomica platform

ODYSSEA

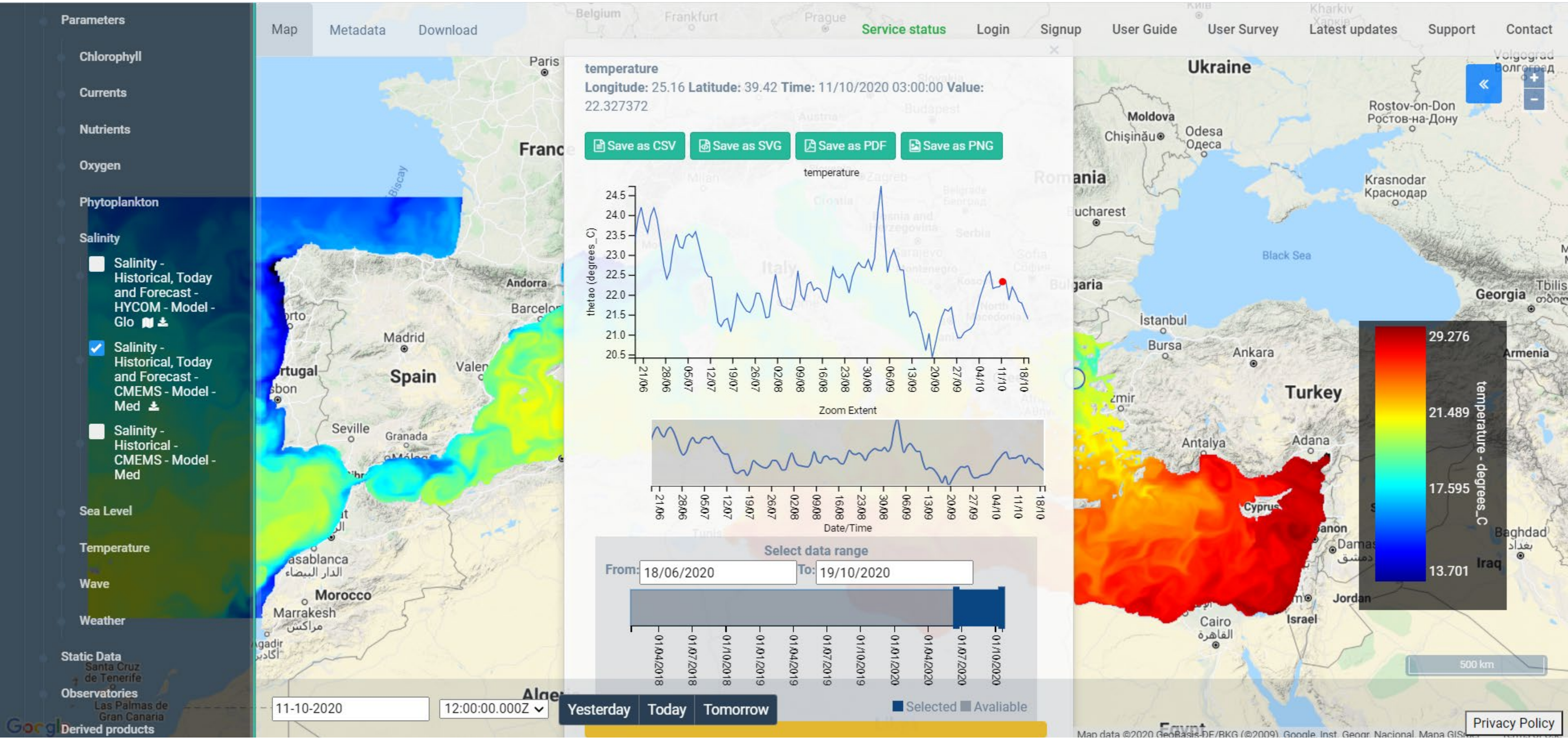
Surface Salinity



odysseaplatform.eu |@odysseaplatform

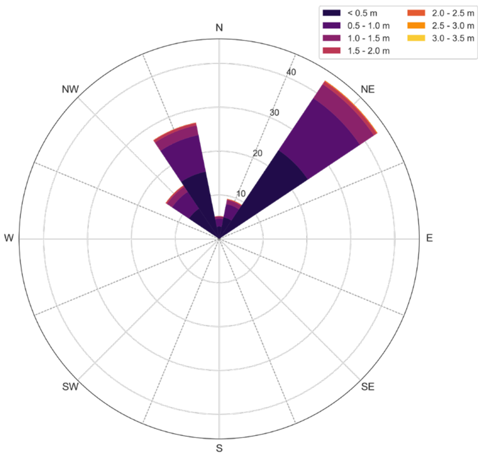
The Marinomica platform

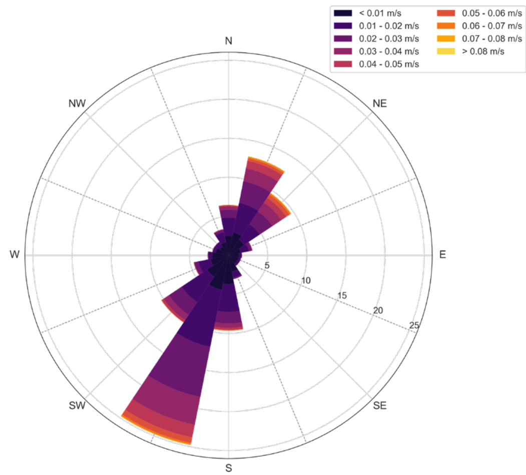
Surface Temperature

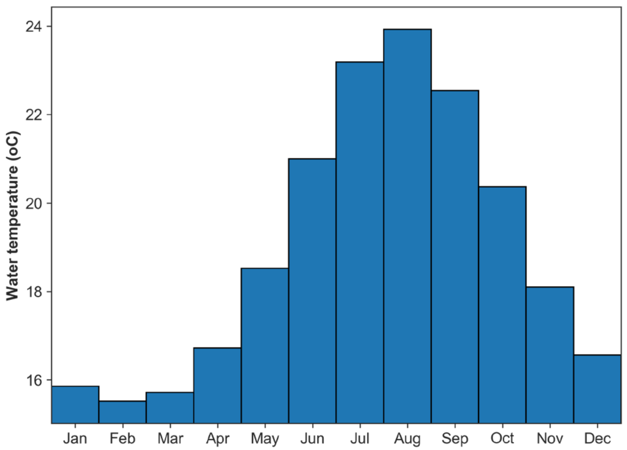


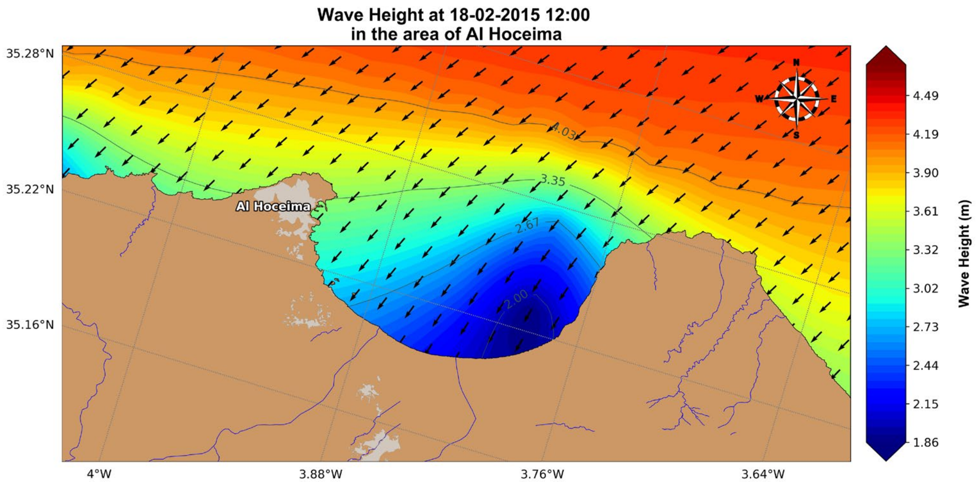
The Marinomica dashboard

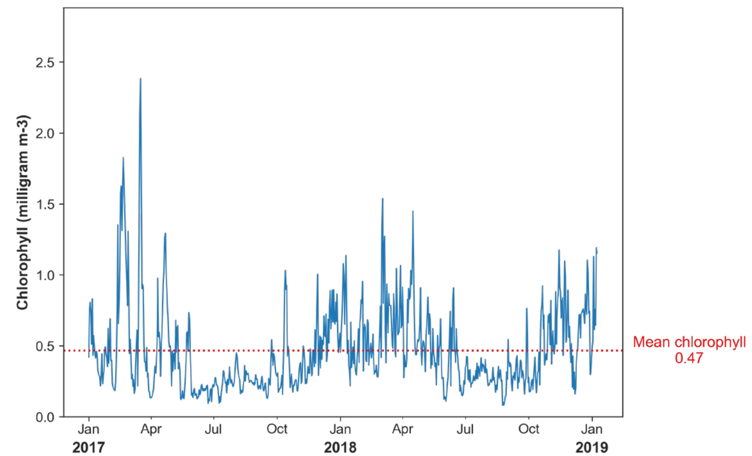
ODYSSEA











Marinomica Data Center

The Marinomica platform

Present Datasets: CMEMS, HYCOM, AVISO+, CLS models, Sentinels, ECMWF, NOAA

Upcoming Datasets: EMODnet habitats, OneGeology, Fishbase, UNEP-WCMC, CORDEX CC, e-Hype

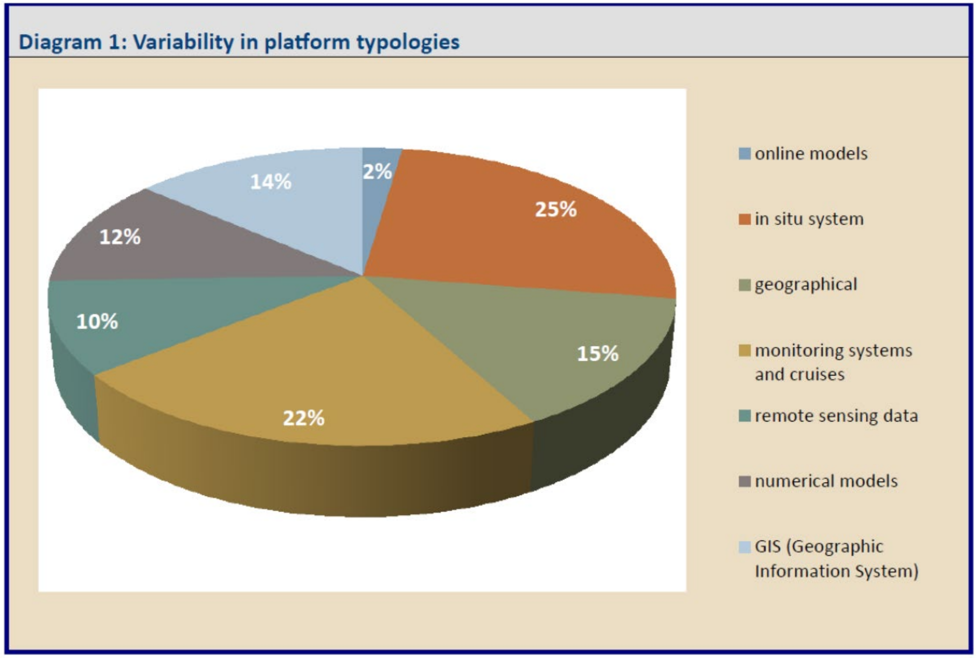
SO2

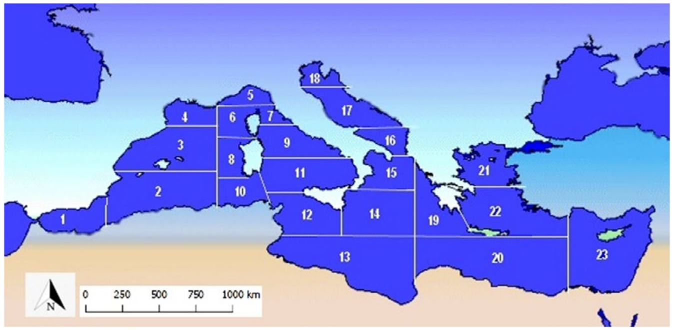
ODYSSEA

Fill-in data gaps & increase spatial and temporal resolution by establishing ODYSSEA Observatories

Existing Datasets Analysis

ODYSSEA





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ELSEVIER

An identification and a prioritisation of geographic and temporal data gaps of Mediterranean marine databases

Davide Astiaso Garcia [a,*], Marina Amori [b], Franco Giovanardi [b], Giuseppe Piras [c], Daniele Groppi [c], Fabrizio Cumo [c], Livio de Santoli [a]

[a] Department of Astronautics, Electrical and Energy Engineering (DIAEE), Sapienza University of Rome, Via Eudossiana, 18, 00184 Rome, Italy
[b] ISPRA, Italy
[c] Interdepartmental Centre for Landscape, Building, Conservation, Environment (CITERA), Sapienza University of Rome, Via A. Gramsci, 53, 00197 Rome, Italy

Data Typology	Data Typology code	Data Typology	Data Typology code
Meteorology	M010	Rock and sediment sedimentology	GSED
Biota abundance biomass and diversity	B070	Terrestrial including bathymetry and under-sea features	T001
Birds mammals and reptiles	B015	Positioning references and data management	Z005
Fish	B020	Habitat	B050
Anthropogenic contamination	H001	Macroalgae and seagrass	B055
Construction and structures	H002	Pigments	B035
Fisheries	H004	Dissolved gases	C015
Human activity	H005	Carbon nitrogen and phosphorus	C005
Currents	D030	Sedimentation and erosion processes	G060
Sea level	D032	Rock and sediment physical properties	G040
Water column temperature and salinity	D025	Optical properties	D015
Waves	D034	Suspended particulate material	G015
Rock and sediment lithology and mineralogy	G045	Earth science oceans marine volcanism	VOLC

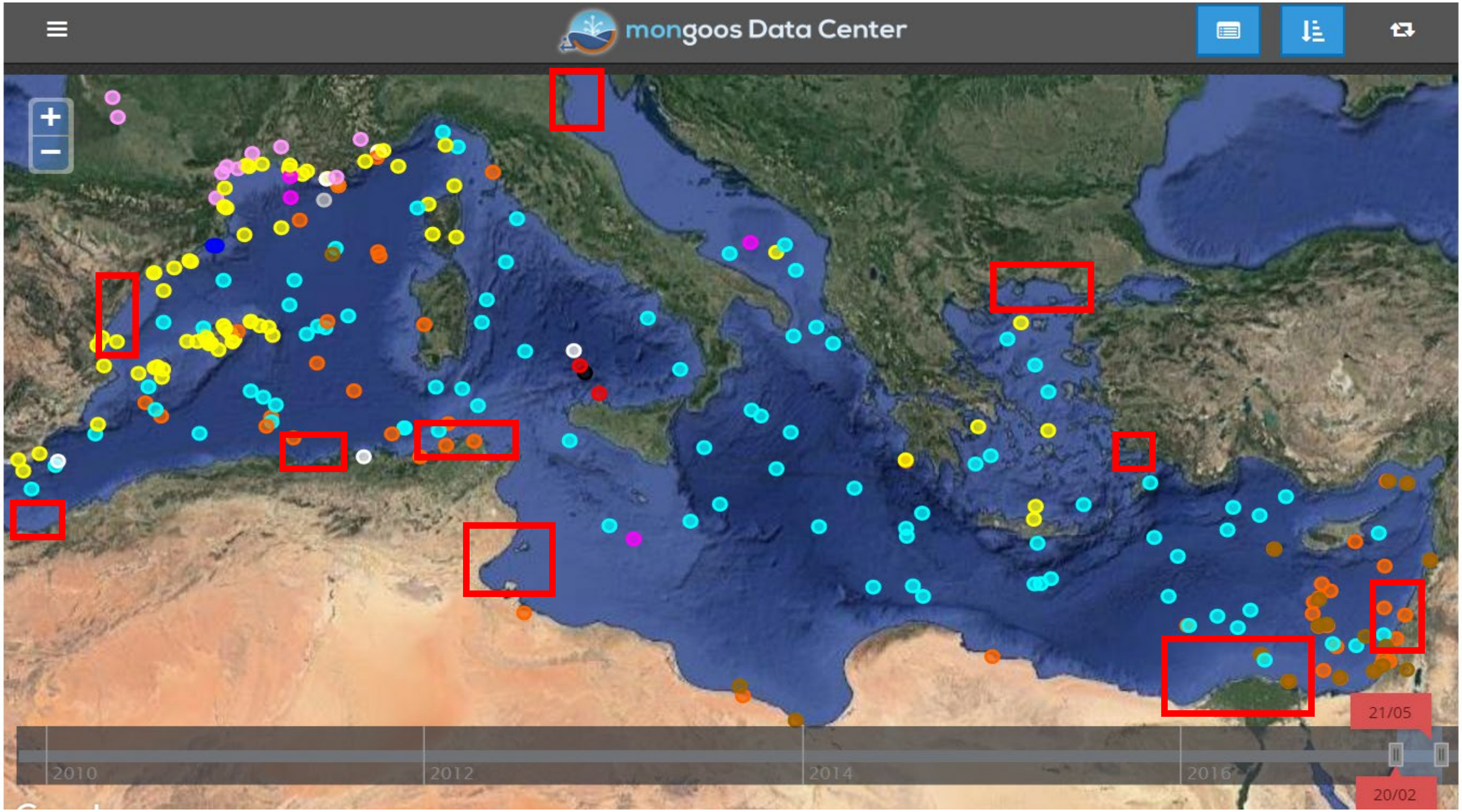
9 ODYSSEA Observatories

ODYSSEA

Establish ODYSSEA Observatories to fill-in data gaps & increase spatial and temporal resolution

A. North Aegean/Thracian Sea (Greece/Turkey),
B. Gulf of Gökova (Turkey),
C. Valencia's regional coastline (Spain),
D. Northern Adriatic Sea basin,
E. Arzew Bay/Stora Gulf (Algeria)
F. Gulf of Gabes and Monastir-Kuriat Islands (Tunisia),
G. MPA National Park Al-Hoceima (Morocco),
H. Israel's coastline and
I. Nile River of Freshwater Influence (Egypt).

The Observatories



What is an ODYSSEA Observatory ?

ODYSSEA

They are pilot facilities referring to an **ODYSSEA local partner** with the aim to:

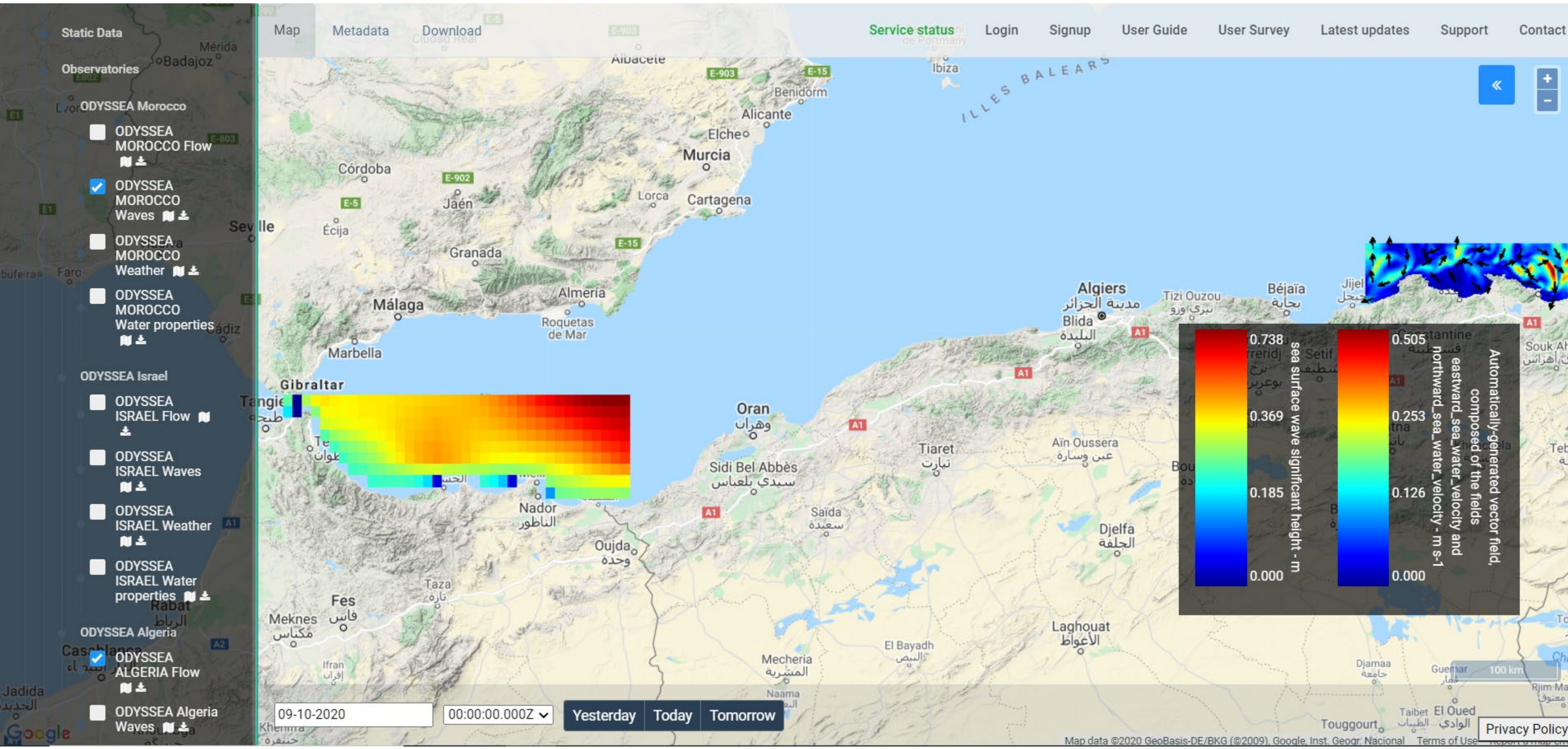
- Identify, contact and inform potential users and stakeholders needing marine data;
- Promote and train scientists and users on Marinomica Platform
- Customize the dashboard of Marinomica Platform according to users' needs
- Have trained staff to operate numerical models for local forecasts on sea conditions
- Have trained staff to operate and maintain at least a sensor at sea located at the facility of an end-user
- Have special interest to 'sale' services and products to marine and maritime users through Marinomica platform

The Observatories

ODYSSEA

- ✓ Comprise a network of 9 observing and forecasting systems,
- ✓ Decentralized entities
- ✓ Cover coastal and shelf zone environments,
- ✓ Cover Ecologically-vulnerable systems (MPAs) / systems with increased human pressure,
- ✓ Combine monitoring and modeling activities,
- ✓ Produce new datasets, store, manipulate, make accessible through the ODYSSEA platform,

Marinomica Platform and ODYSSEA Observatories



odysseaplatform.eu |@odysseaplatform

SO3

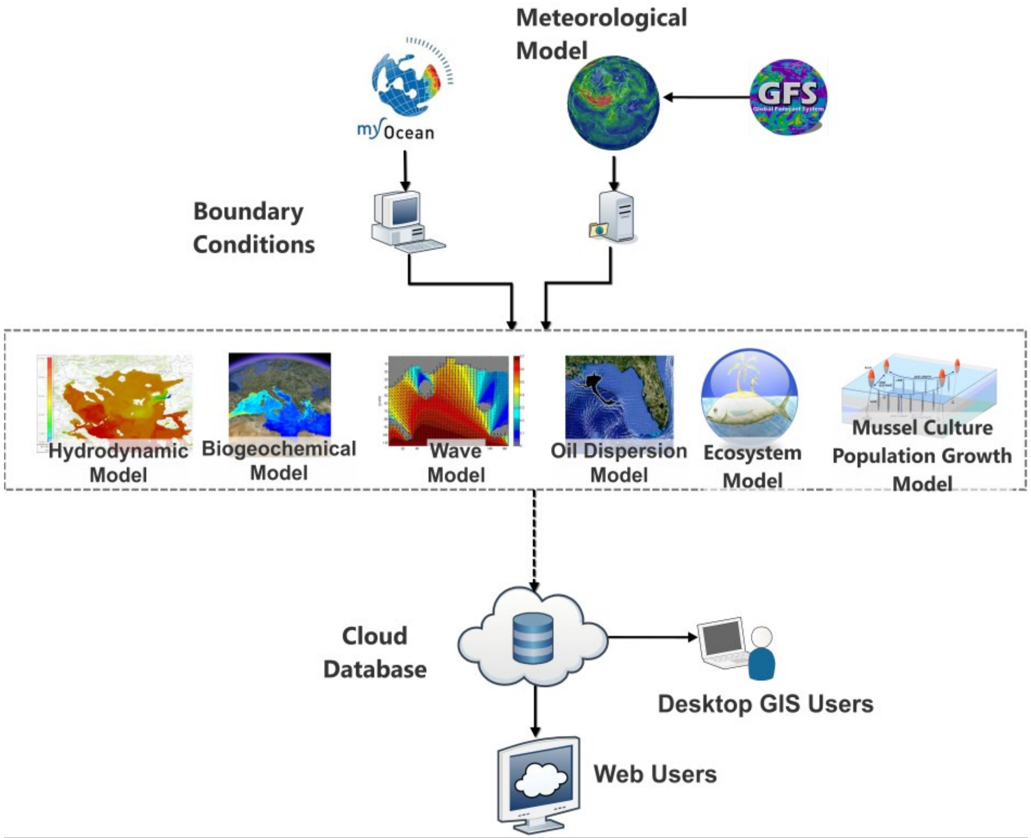
ODYSSEA

Develop a prototype ‘chain’ of models providing data never previously reported

The Models

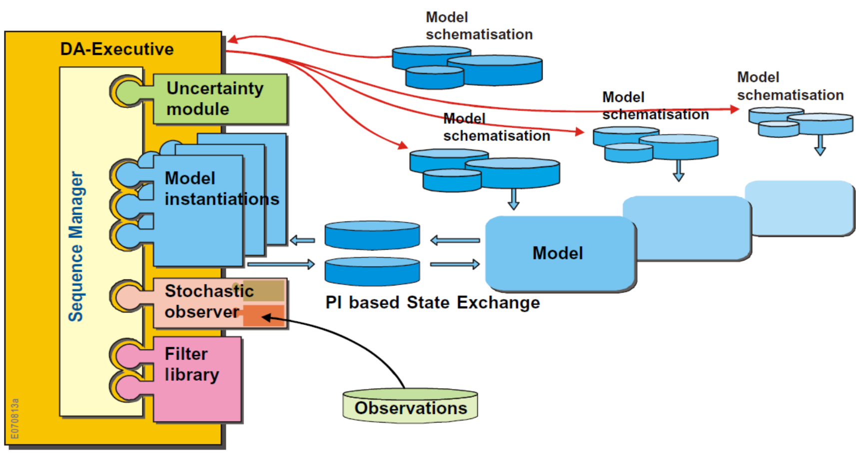
- ✓ A prototype 'chain' of operational models will be developed,
- ✓ Link models to existing databases,
- ✓ Provide short- and long-term prognostic results,
- ✓ Manage risks and emergencies in coastal and offshore areas,
- ✓ Meet the requirements of various end-user groups,
- ✓ Report on parameters never previously reported,

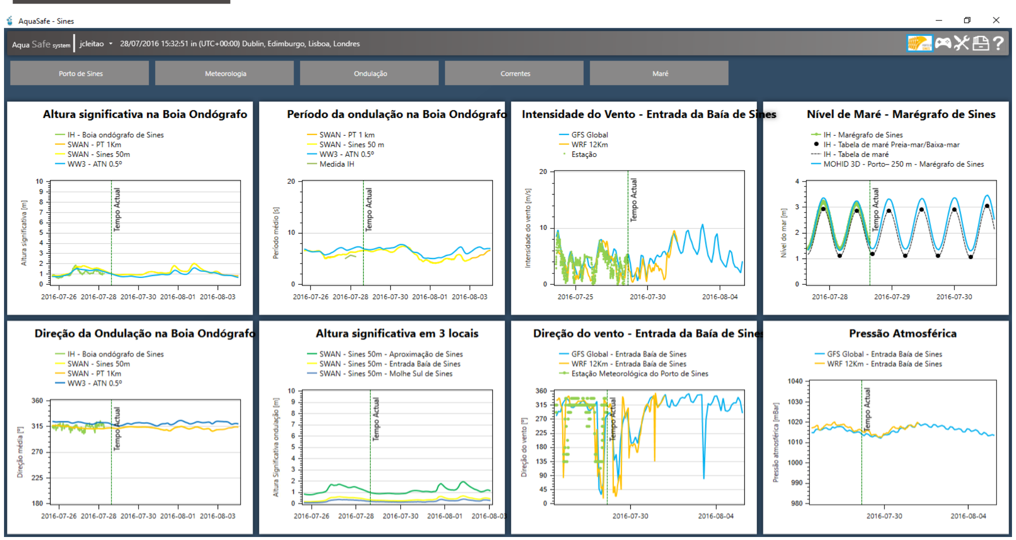
Models: 3D hydrodynamic (Delft3D), Wave (SWAN), Oil spill (MEDSLICK-II), Water quality (DELWAQ), Ecosystem models (Ecopath with Ecosim), Fish and Mussel/oyster culture population growth



The Operational Task Manager Platforms

ODYSSEA

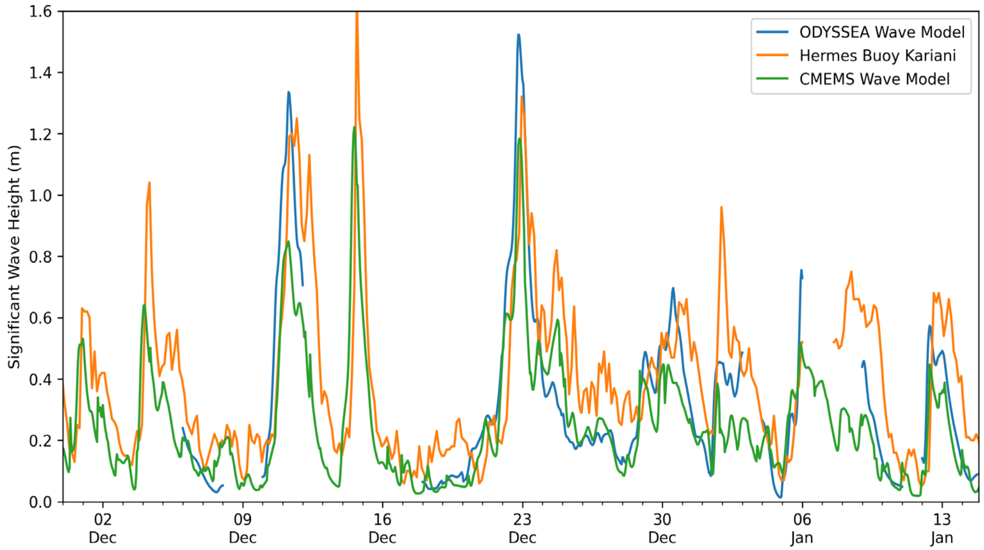


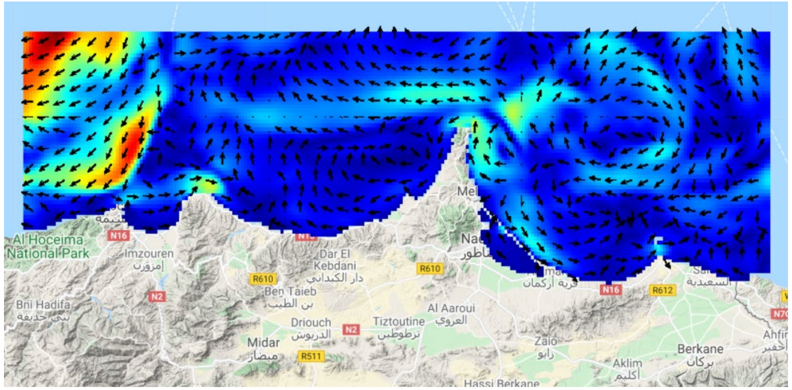


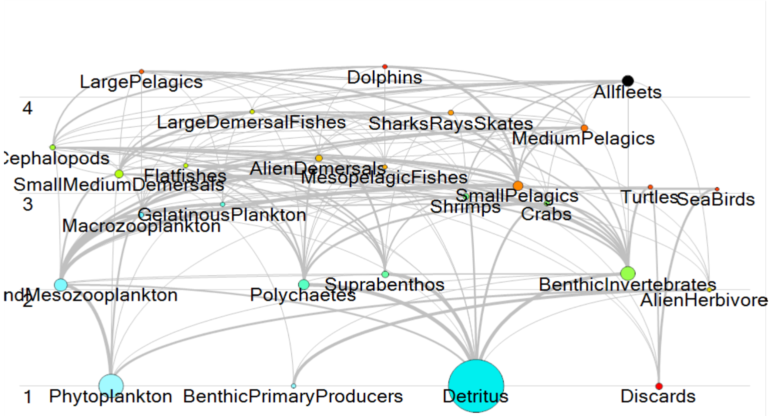
FEWS & Aquasafe:

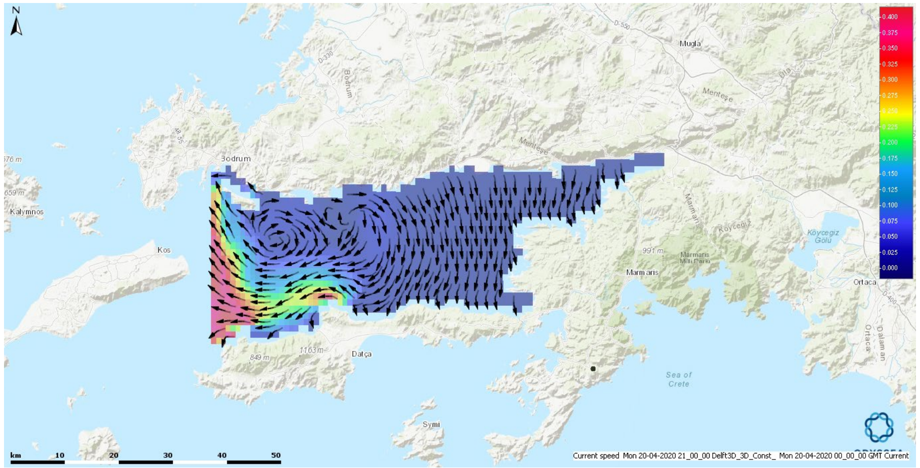
a) automatized data import, storage and pre-processing (from in-situ sensors, remote sensing, etc.); b) linking models to databases for initial and boundary conditions; c) scheduling of tasks to run the series of coupled numerical models; d) models calibration and validation; e) data assimilation, and f) post-processing modules results and transferring data to the Marinomica platform.

The Models – Present Status









SO4

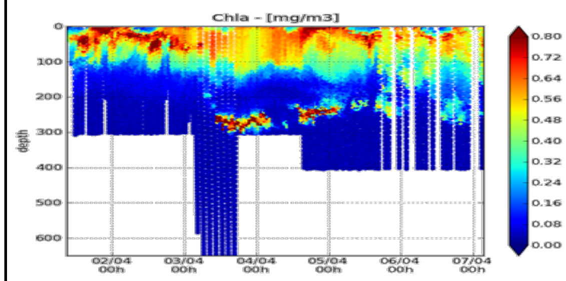
Expand existing operational monitoring systems capacity

Mobile Monitoring Systems

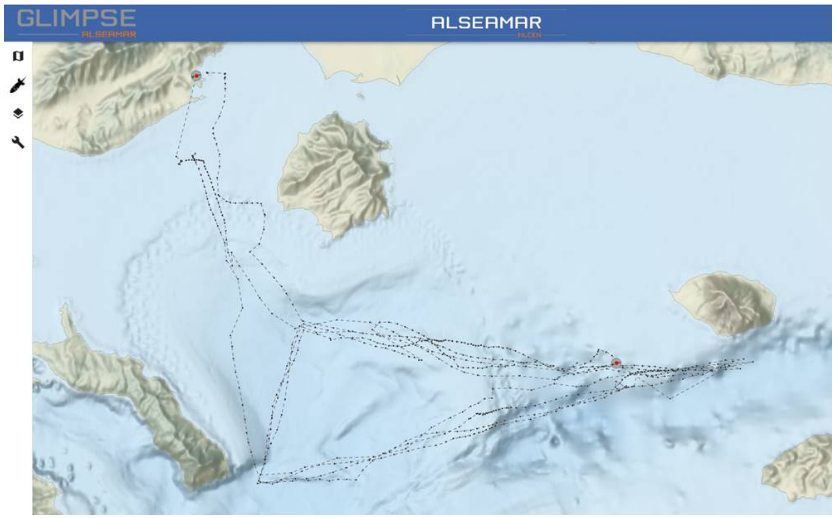
- 2 SEAEXPLORER GLIDERS

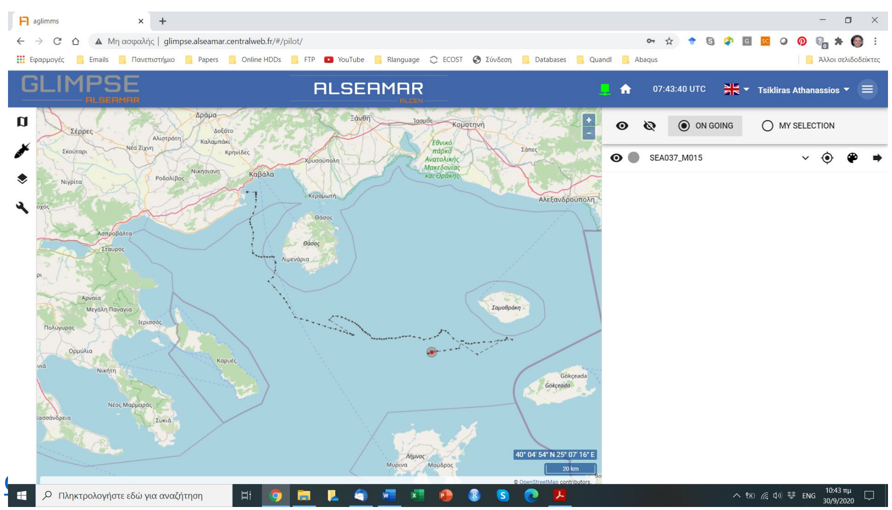
- 3 sensor payloads:
  - ❖ Payload 1
    - ✓ Temperature, salinity, pH, dissolved oxygen, chlorophyll-a, turbidity, CDOM
  - ❖ Payload 2
    - ✓ Passive Acoustic Monitoring (PAM)
  - ❖ Payload 3
    - ✓ Temperature, salinity, microplastics

Mobile Monitoring Systems



Mobile Monitoring Systems





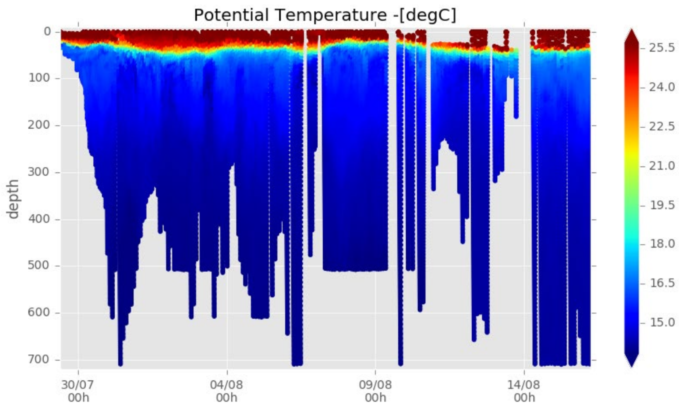
Status Gliders

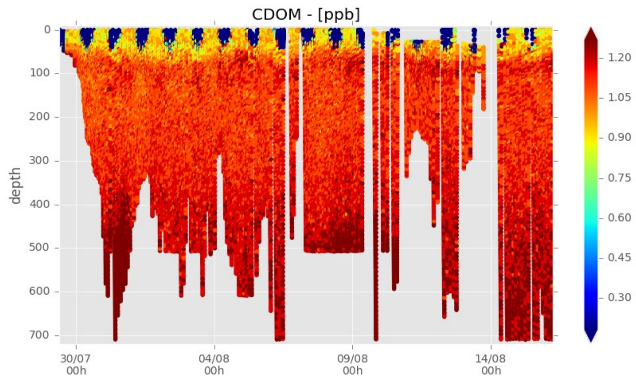
Two CTD glider missions have been completed successfully in Thracian Sea

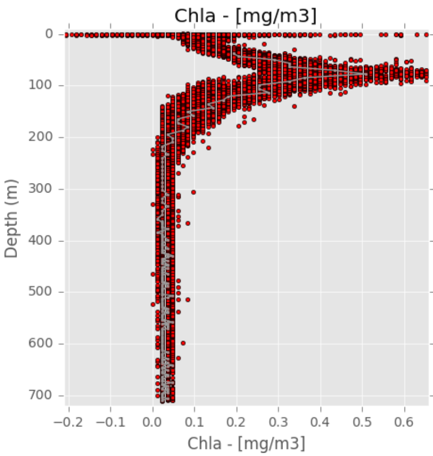
One PAM glider mission is currently in operation

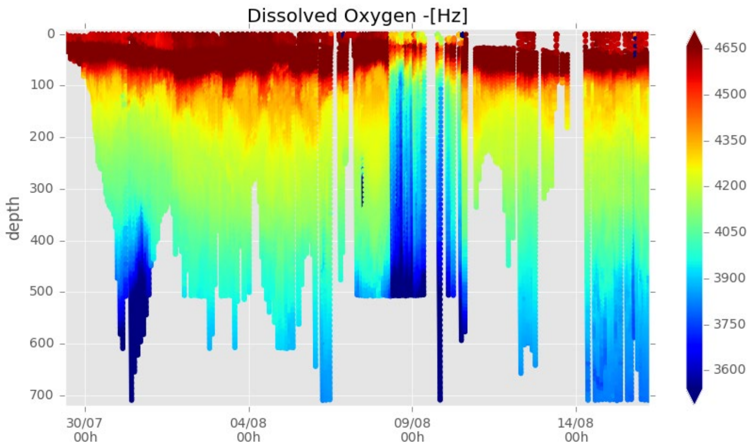
One CTD + MPS glider mission in Morocco is prepared

Mobile Monitoring Systems







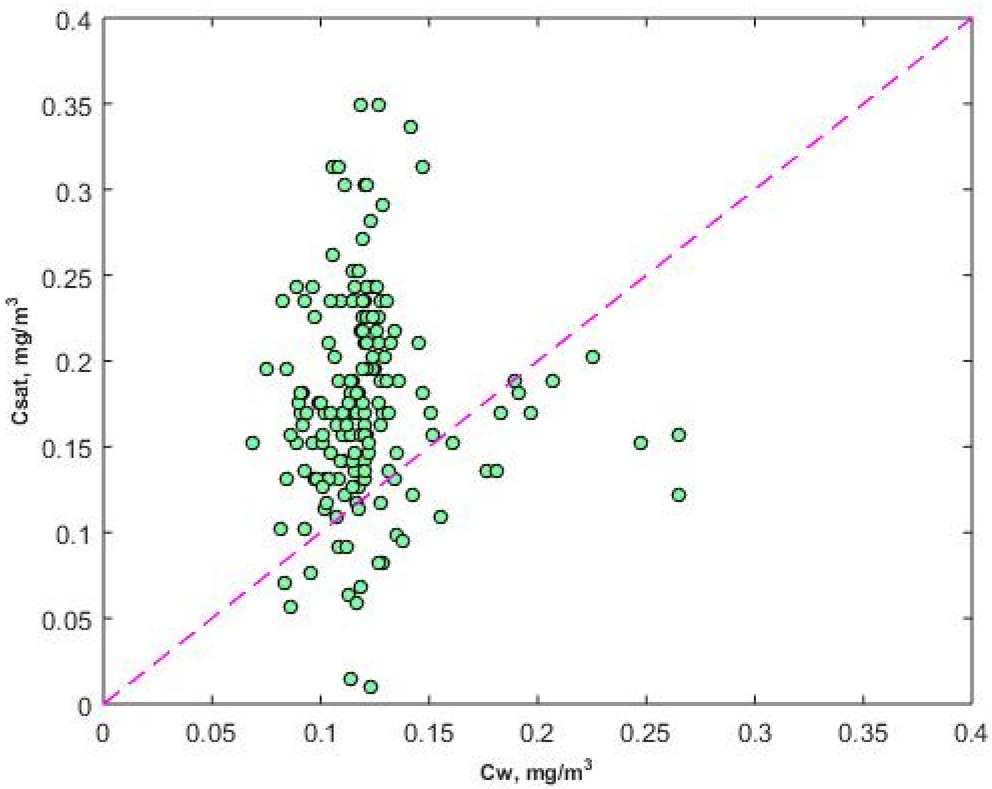


Results illustrate that

- summer DO, when stratification of water the column is at its highest, has high levels at the surface (~ 220 μM),
- reaches a maximum at the bottom of the pycnocline (at 40-60 m depth, DO ~ 260 μM),
- reduces gradually over the water column towards 190 μM, until 500 m depth.
- At 700 m depth DO reduces even more (DO ~ 160 μM).

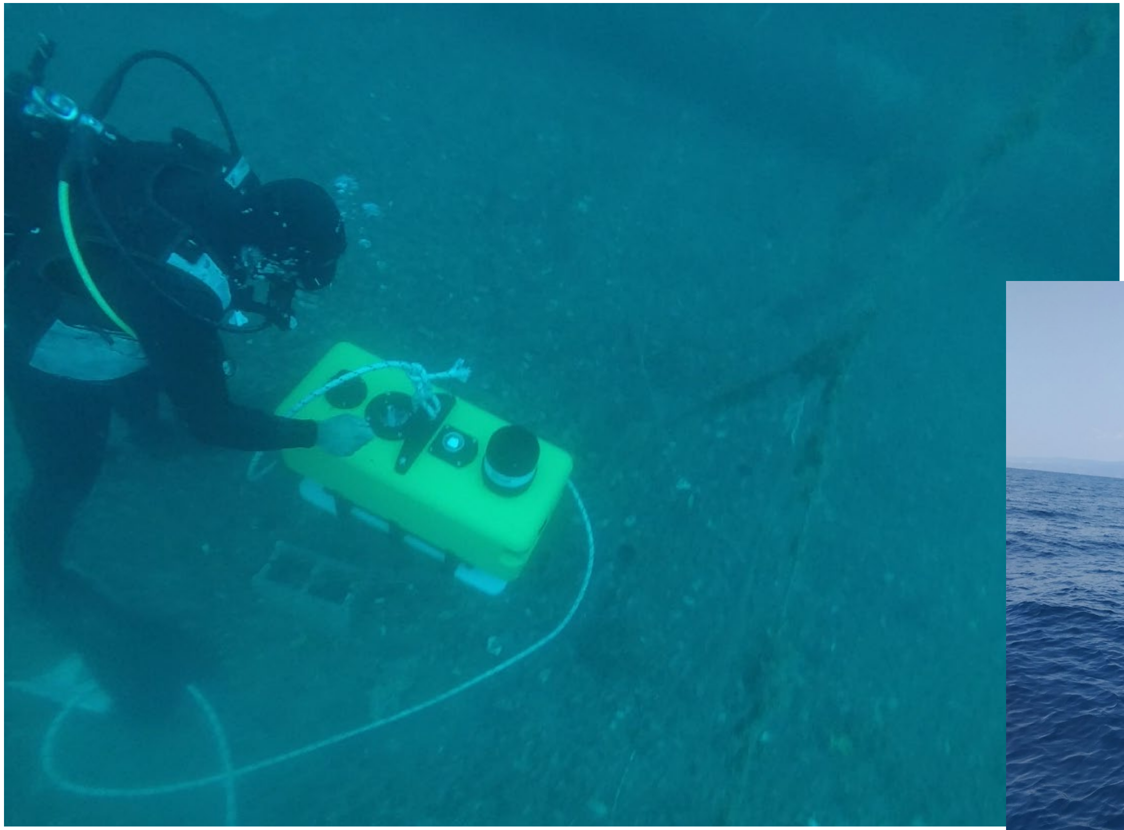
Sentinel Calibration using glider data

ODYSSEA



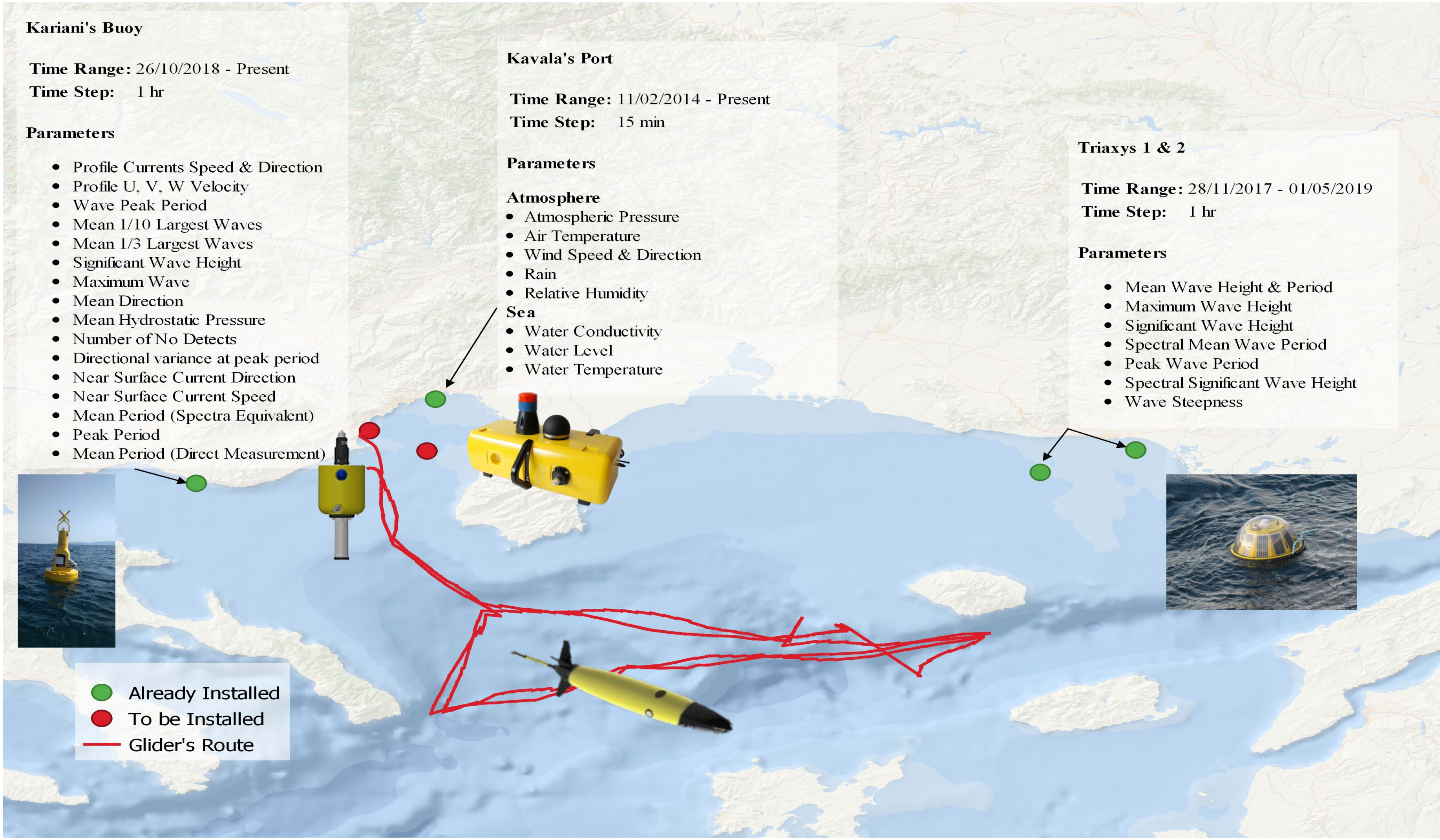
1) From each glider Yo the (lon,lat) were retrieved, representing the glider profile. Overall, 508 Yo's were collected.
2) Depth-integrated Chl-a conc was calculated based on euphotic zone depth.
3) These Chl-a values were correlated to Sentinel 3A data on a pixel-by-pixel basis.
4) Bias= 0.0551; Bias_log= 0.3251; **There exists an overestimation of Sentinel 3A Chl-a compared to in-situ data by 45.59% .**

Bio-acoustics for Marine Mammals

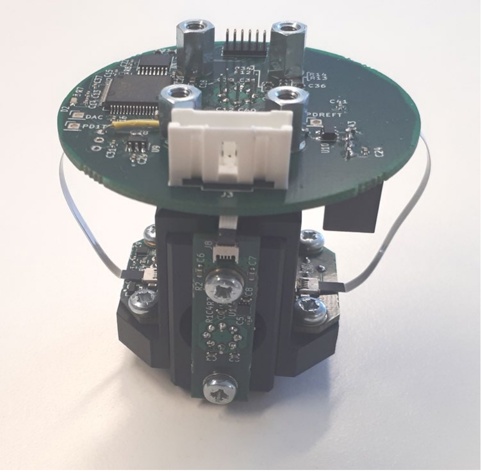


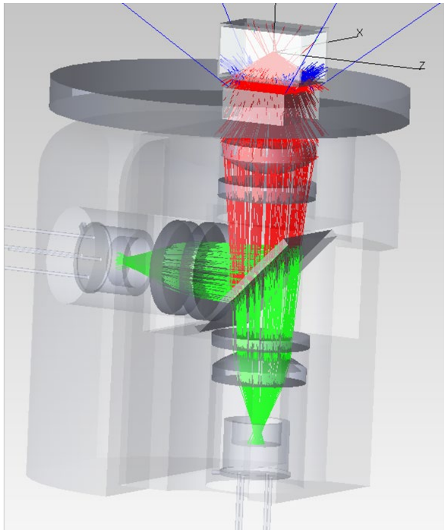
Thracian Sea deployments

ODYSSEA



Upgrading MPS

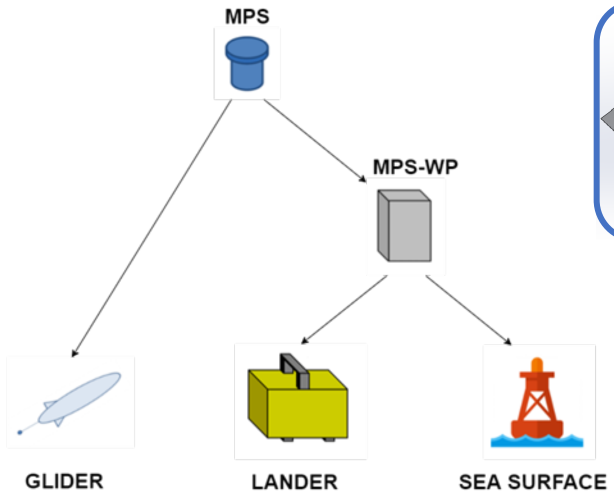


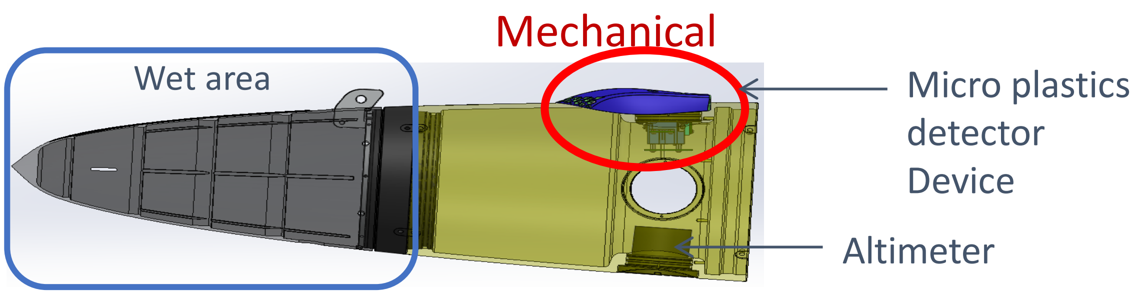


MPS monitoring based on the RT analysis of the fluorescence light emitted by plastic particles when they are excited with a UV light source.

Space, speed and power consumption

Integrating MPS in glider





PROTOTYPE FOR THE GLIDER

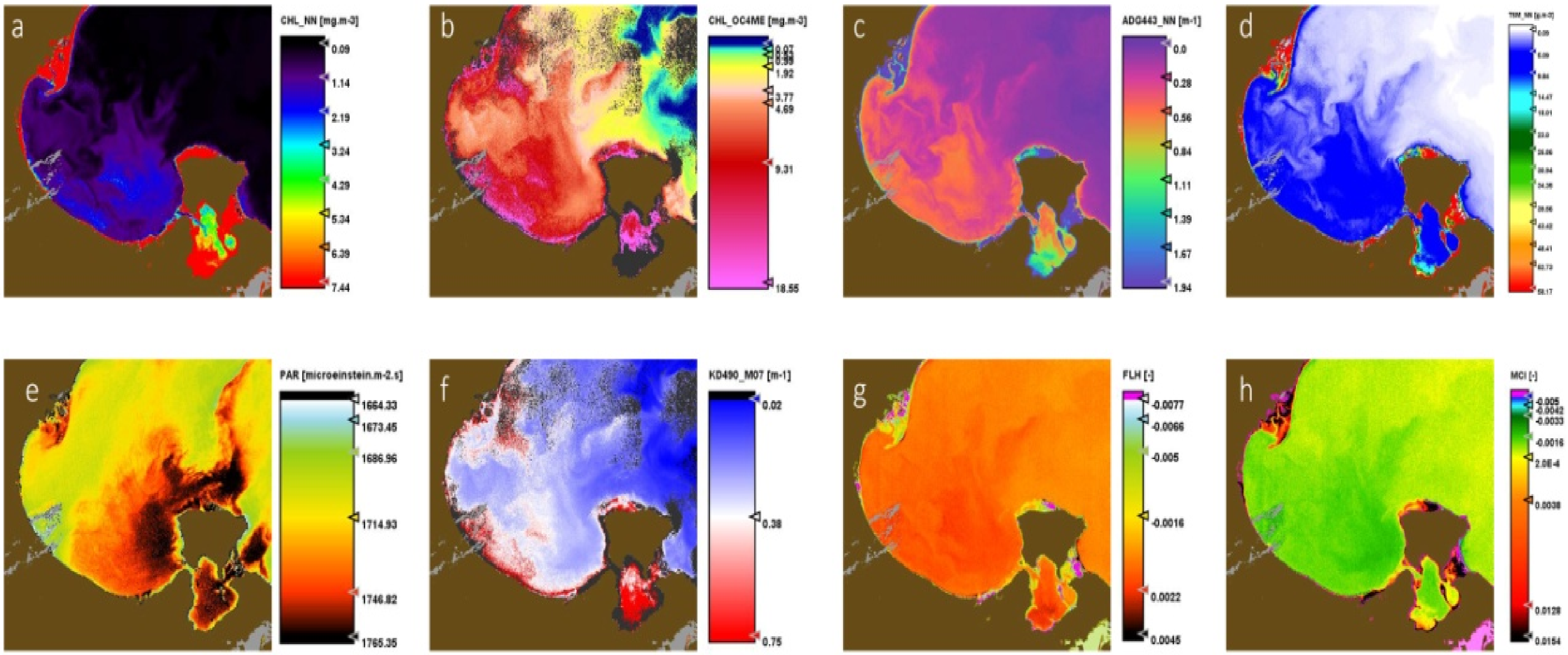
Integrating MPS in Surface Systems and Landers

Surface system

MPS pack

Lander

Remote Sensing



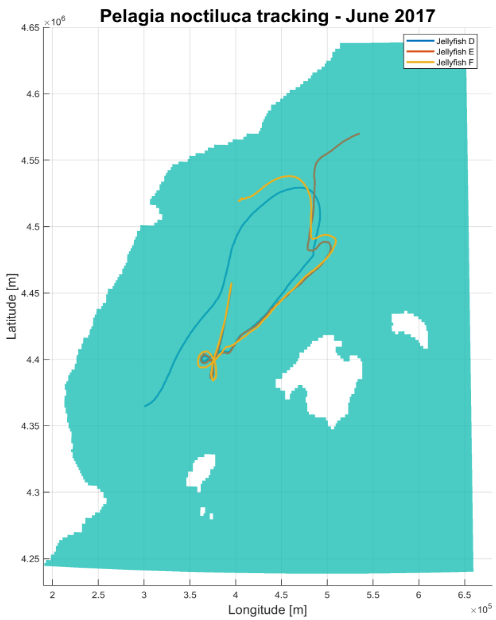
Sentinel-3 Level2 spatial distributions of a) chlorophyll-a conc (mg m^{-3}) Oc4me algorithm, b) chlorophyll-a conc (mg m^{-3}) chlnn neural network algorithm, c) absorption of CDOM at 443 nm (m^{-1}), d) TSM concentration (gm^{-3}), e) PAR in the spectral range 400-700 nm (μEinstein m^{-2} s^{-1}), f) diffuse attenuation coefficient at 490 nm (m^{-1}), g) fluorescence line height and h) max chlorophyll index at Gulf of Gabes.

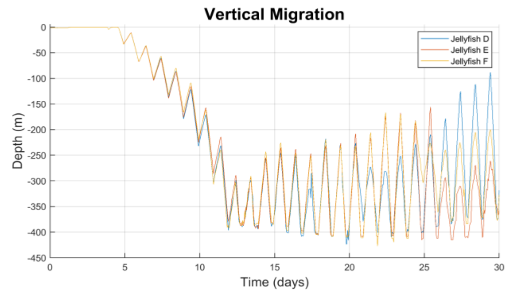
SO5

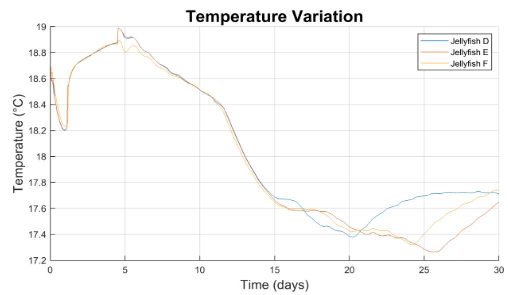
Emphasize on biological datasets

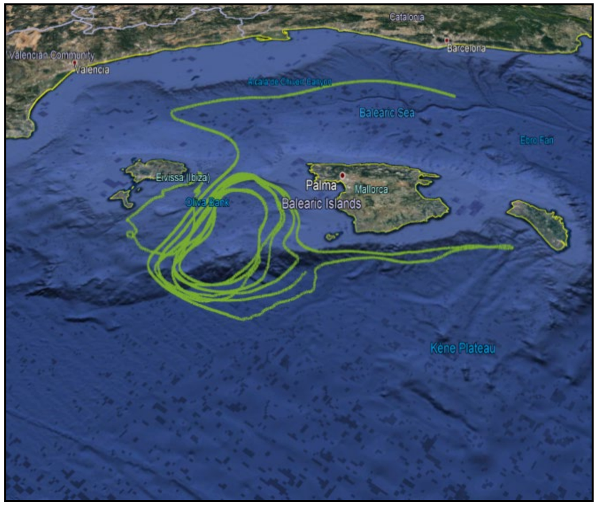
Examine Jelly Fish Blooms

ODYSSEA









Tracking of Pelagia Noctiluca in June 2017.

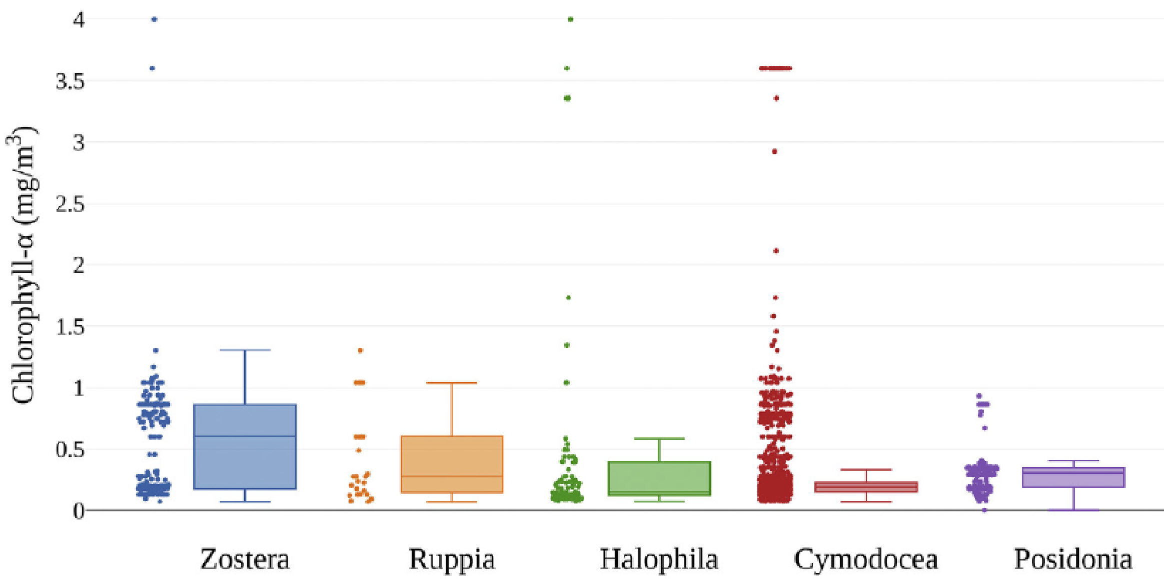


Fig. 9. Distribution of Chlorophyll-*α*-December values per seagrass family.

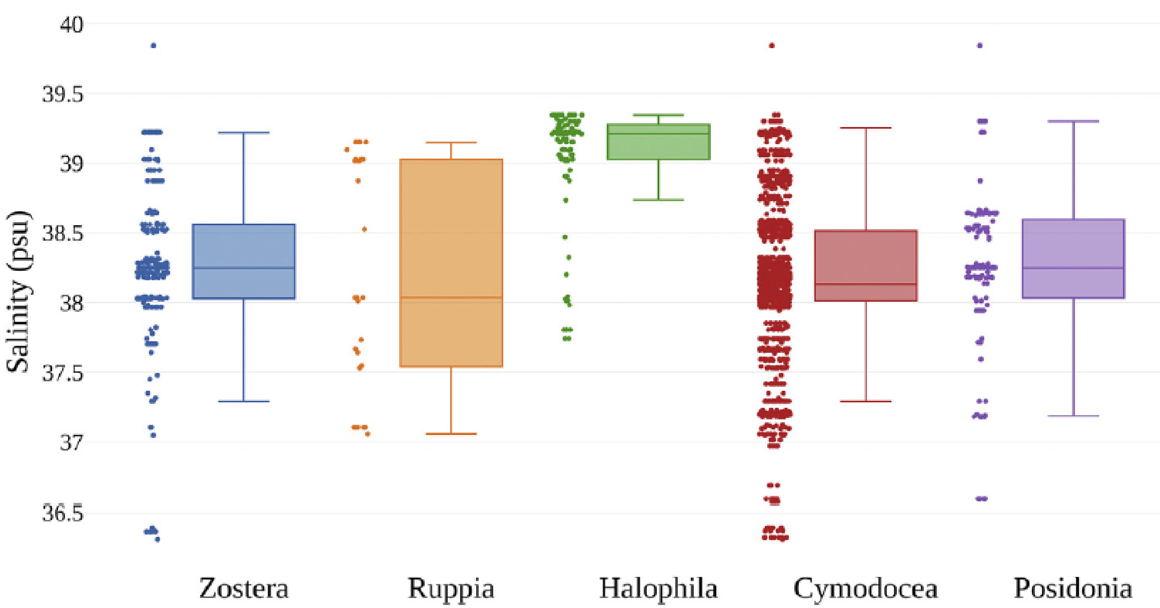
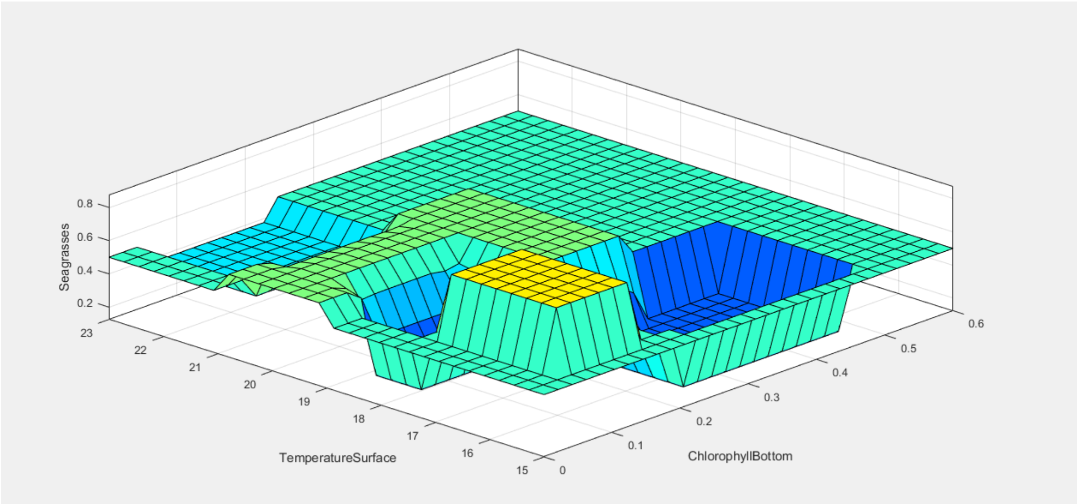


Fig. 10. Distribution of Salinity-December values per seagrass family.

ODYSSEA

We dealt with the problem of detecting seagrass presence/absence and distinguishing seagrass families in the Mediterranean via supervised learning methods. We merged datasets on seagrass presence and other external environmental variables, we develop suitable training data, enhanced by seagrass absence data algorithmically produced based on certain hypotheses

Model CC on Seagrass



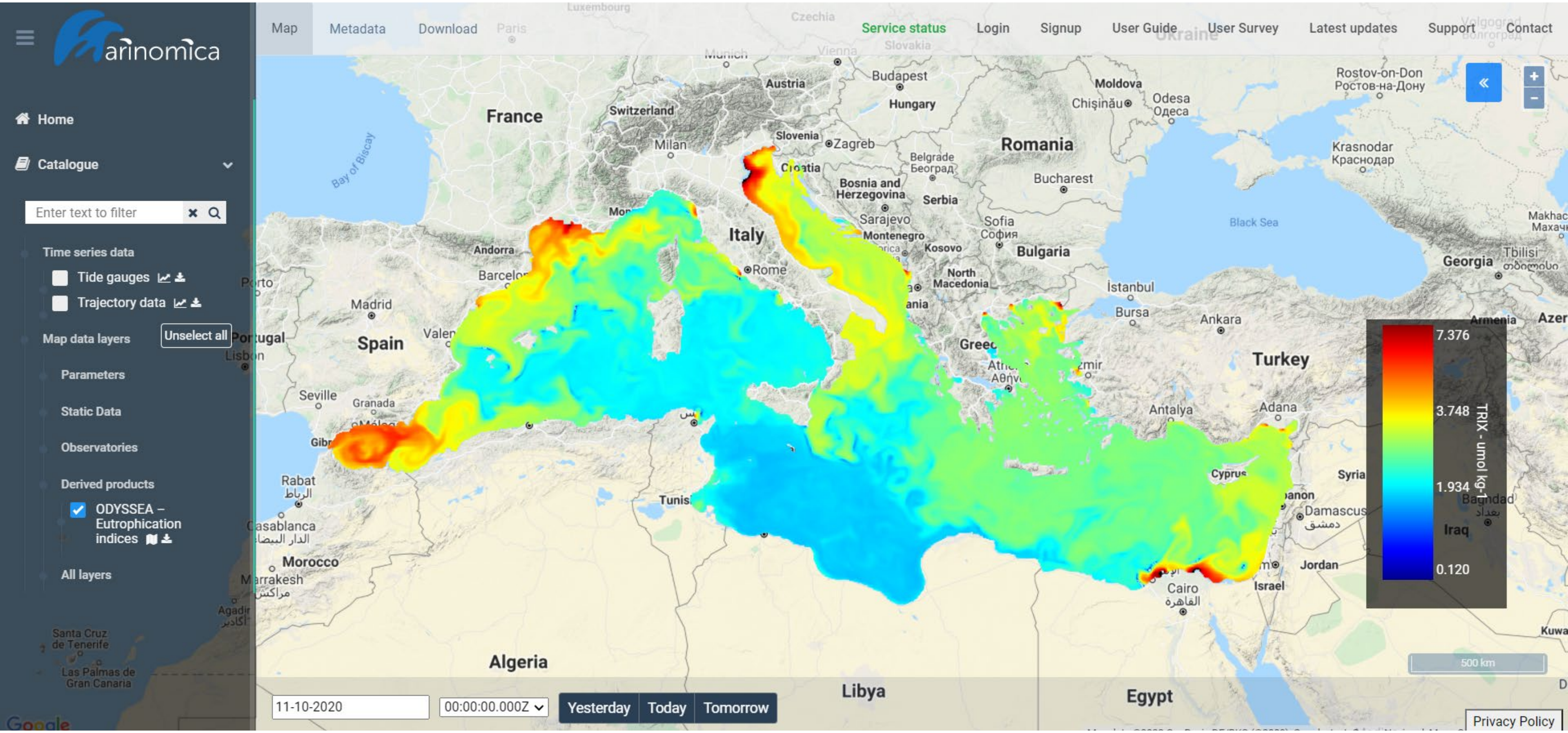
(a) Hydrocharitaceae and Cymodoceaceae are the most sensitive families to increases in water depth with sea level rise, while Posidoniaceae and Zosteraceae are tolerant to the climate change drivers examined; (b) Cymodoceaceae is the family with the higher tolerance to mild (+5%) increases in sea temperature; (c) Hydrocharitaceae exhibits tolerance to higher (+10-15%) increases in sea temperature; (d) Posidoniaceae and Zosteraceae are mostly affected by temperature rise, at any level, and (e) Posidoniaceae exhibited higher tolerance to a decrease in mean water temperature

SO6

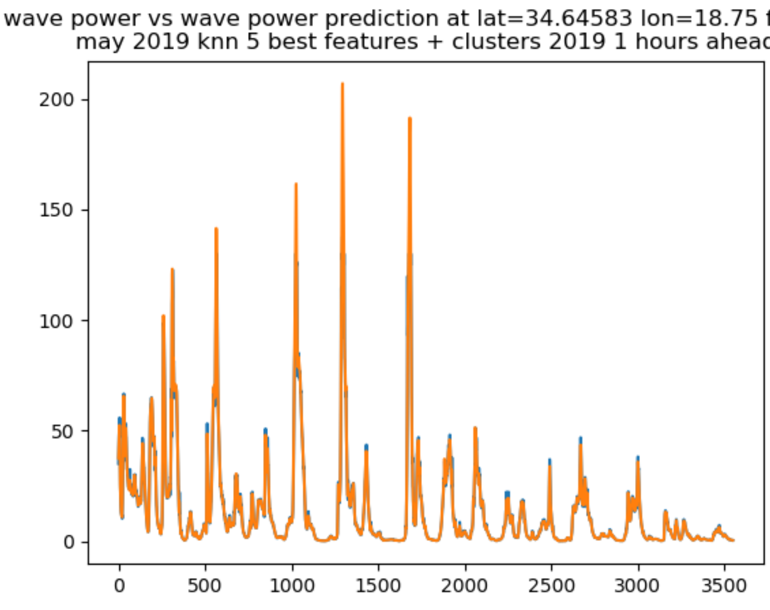
ODYSSEA

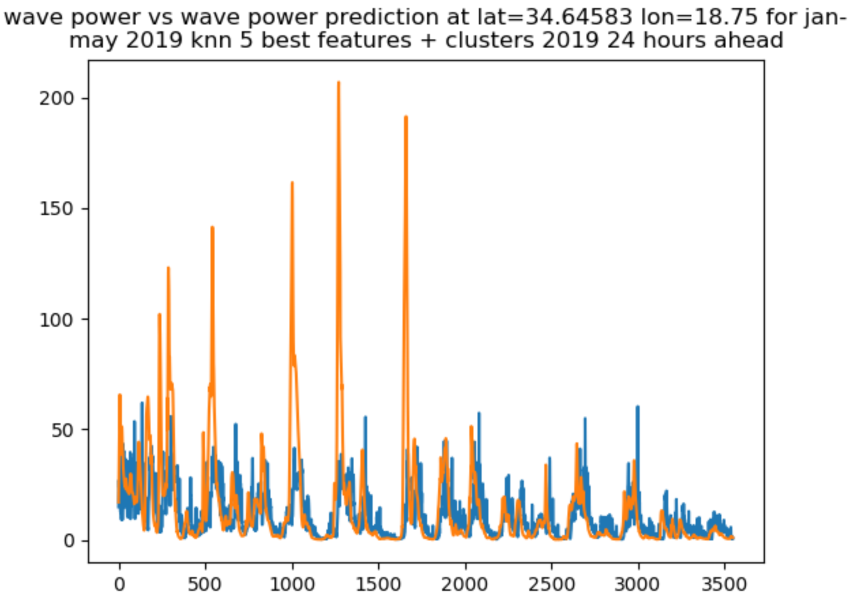
Combine data to extract secondary indicators

TRIX Eutrophication Index



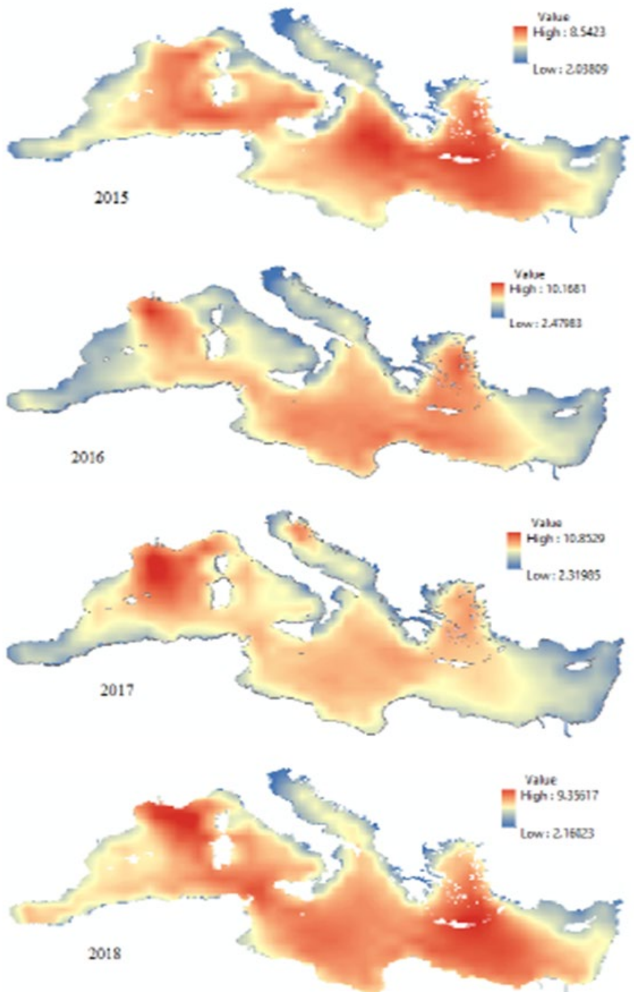
Wave Power Calculation and Forecasting

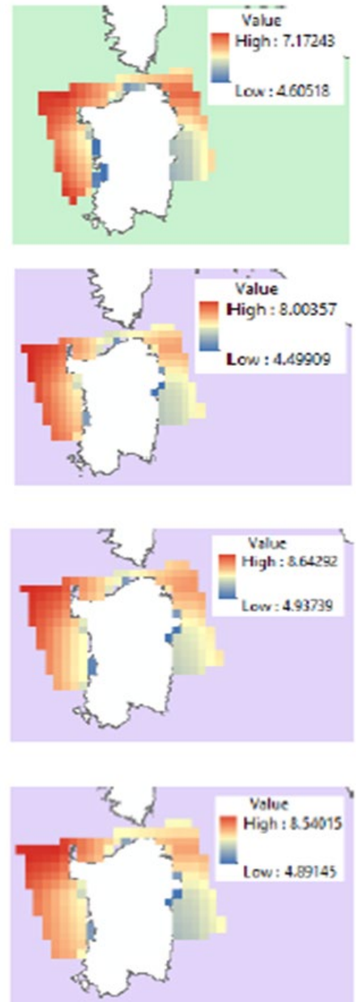


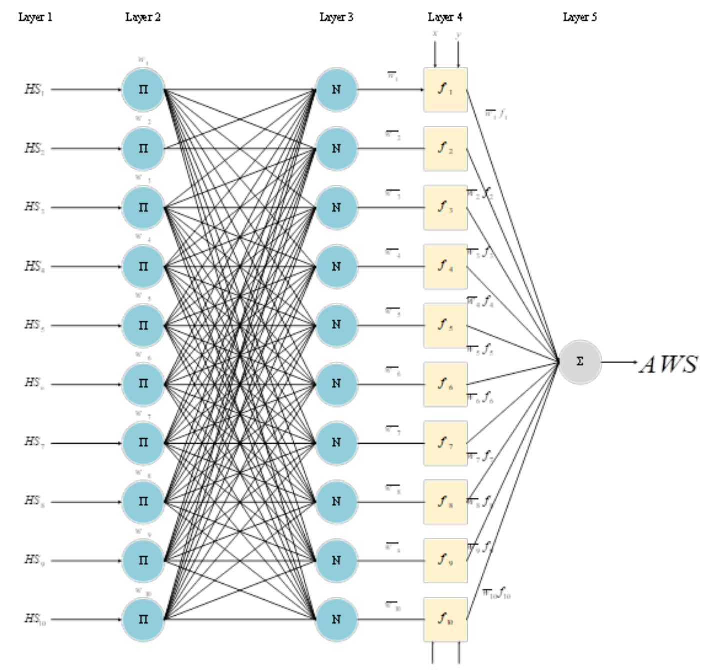


Wind Power Calculation and Forecasting

ODYSSEA



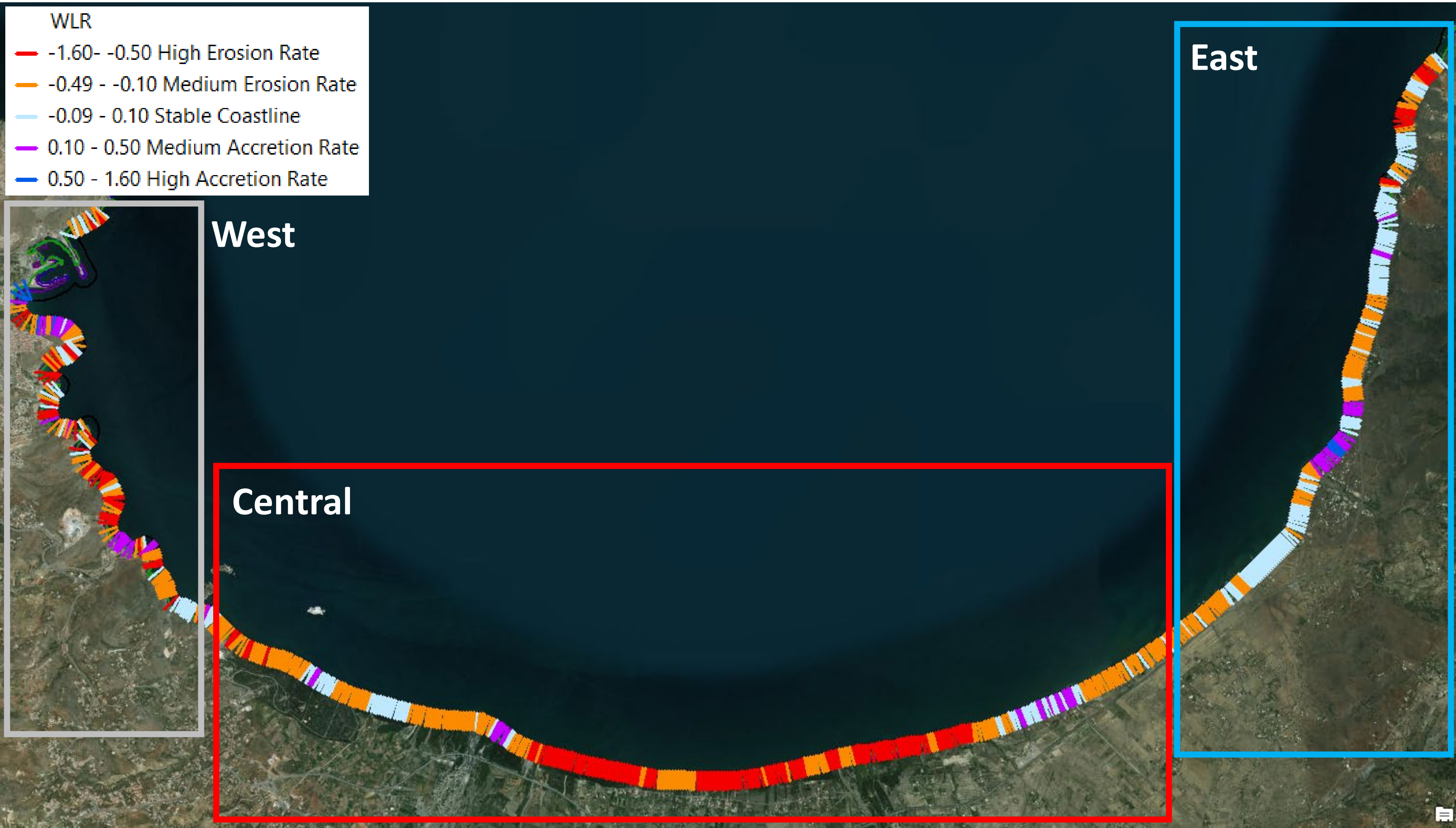




Wind Power assessment based on Sentinel 1 and ECMWF data

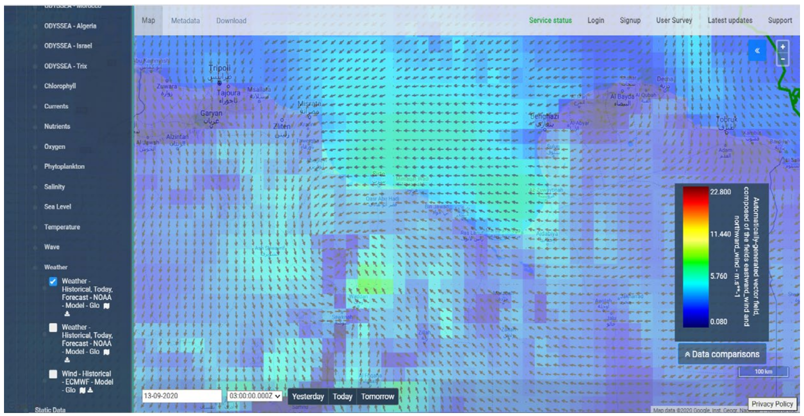
Data for End-Users from Al-Hoceima Observatory

ODYSSEA

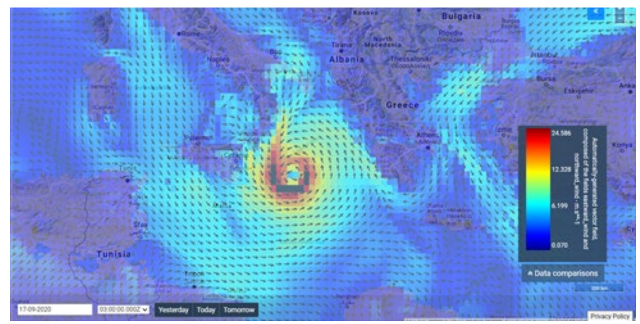


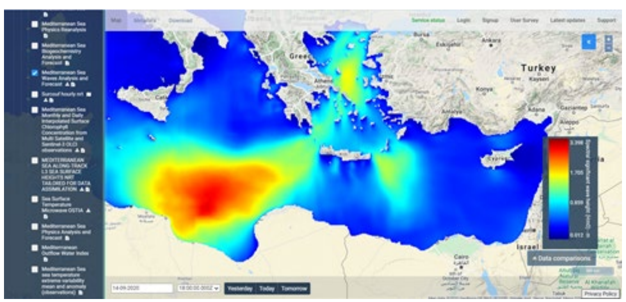
Tracking Medicanes

ODYSSEA

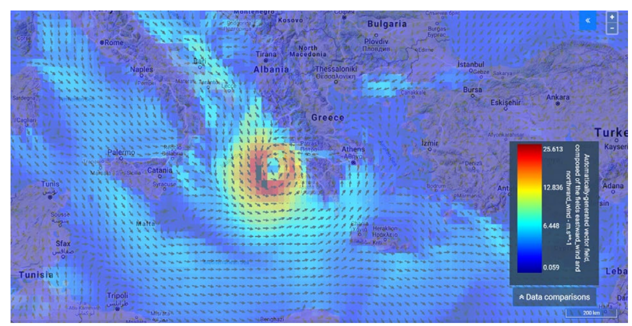


IANOS Medicane commenced on 13/9/2020 03:00 am at the inland parts of Libya over Sahara dessert, approx. 40 km east of Ash Shwayrif (starting point 29.926°N, 14.795°E).



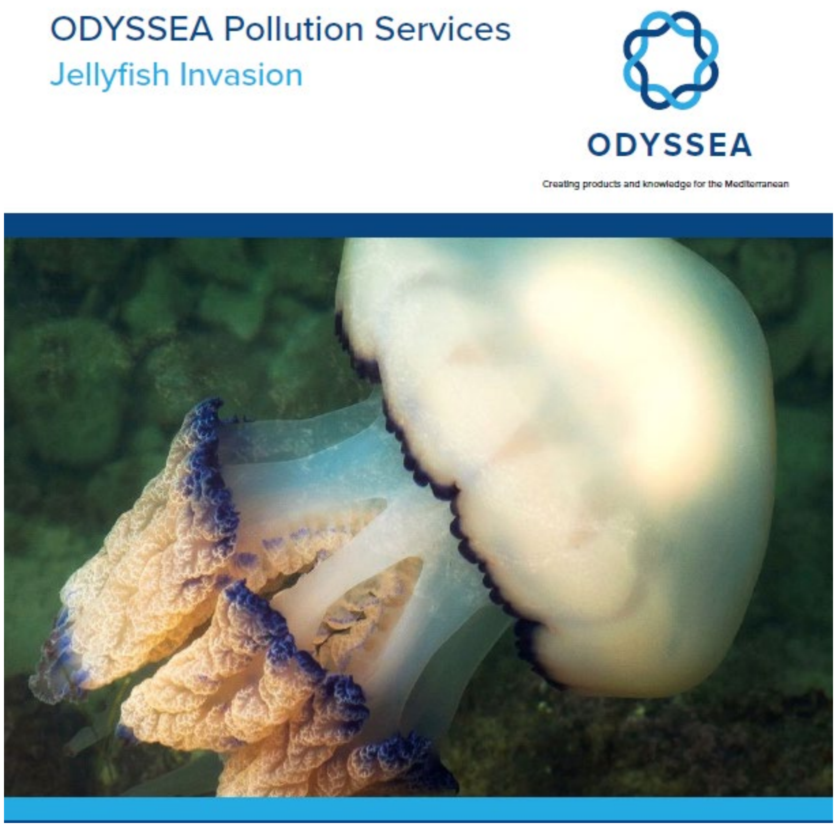


Waves in Libyan Sea
(14/9/2020 18:00, t = +39 hrs)



ODYSSEA Services

ODYSSEA



ODYSSEA Upcoming Services

ODYSSEA

Service Pack	Product
Pollution	TRIX eutrophication index
	Alien Invasive Species (AIS) Control Tool for Ports
	Jellyfish detection
Renewable Energy	Waves and Currents forecast for offshore aquaculture
	Waves and Currents forecast for marine renewable energies
Erosion	Coastal erosion 'hotspots' identification

SO7

Link indicators to EU policies – to be discussed in Policy Session

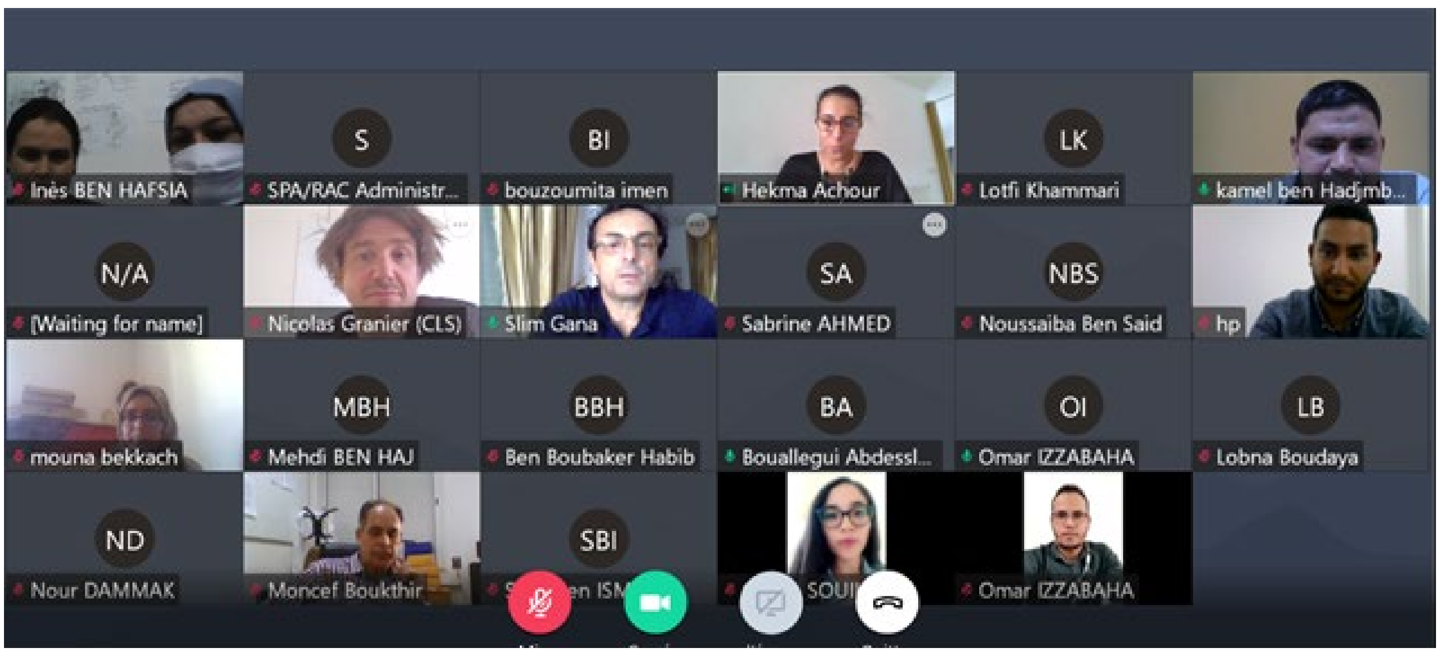
SO8

Involve end-users on platform design, data collection and day-to-day operations

ODYSSEA End-User Workshops

ODYSSEA

ODYSSEA partners developed activities to exchange experiences and collaborate with other European projects and initiatives in the Mediterranean Sea (e.g. ENI SEIS II, Maestrale, LAkHsMI, CLAIM, EuroSea, HiSea, COSPAR Panel for Capacity Building)



ODYSSEA End-User Workshops

MIWS Malta International Winter School

Malta International Winter School 2020
Oceanography and the Blue Economy
8th to 14th January 2020

SSCOE Commonwealth Small States Centre of Excellence | L-Università ta' Malta

	Wednesday 8th January	Thursday 9th January	Friday 10th January	Saturday 11th January	Sunday 12th January	Monday 13th January	Tuesday 14th January
	Intro Day	Marine Observations	Marine Modelling	EMODnet Day	Cultural Tour	COPERNICUS CMEMS Day	Ideathon Day
Morning Session 1 08:30 – 10:30	Argento Hotel **Welcome address by Minister for Foreign Affairs Hon.Carmelo Abela** Opening remarks by UM Rector **Group Photo** Presentation of the course & Participant Intro **Gabriella.Cassola** Intro to the course **Aldo Drago**	Venue: MP602 **Lisa Pace** Marine Foresight initiative – why and what? **Georgios Sylaios** Coastal operational observing systems for ecosystem assessments - ODYSSEA Project	Venue: MP602 **Lorinc Meszaros** High resolution models for coastal areas – the Delft3D Flexible Mesh modelling suite **Georgios Sylaios Nikolaos Kokkos** Application of Operational Modelling Tools in the North Aegean Sea	Venue: MP602 **(9am) Patrick Gorringe Tim Collart** Intro to EMODnet – Scope, evolution and future Linking the European data aggregators; the European Atlas of the Sea	Departure from Argento Hotel **1. Coach from Hotel to Ta' Barkat** **2. Visit to Ta' Barkat** **3. Coach from Ta' Barkat to Birgu** **4. Short Visit to Fort St.Angelo** **5. Walkabout to Ferry Landing Site (Cospicua)**	Venue: MP602 **Fabrice Messal** Overview of the Copernicus Marine Service and presentation of Use Cases **David Bazin** The Copernicus Marine Service Service Desk and User Support **Paz Rotlan Garcia** Focus on the Copernicus Marine Service In Situ Observation component	Venue: MP602 Ideathon Leader **David Mills** Ideathon Mentors **David Mills Aldo Drago Paz Rotlan Fabrice Messal David Bazin Tim Collart Arwel Jones Nick Hardman Mountford** Logistical intro to the ideathon Ideathon Group exercises
10:30 – 11:00	COFFEE BREAK					COFFEE BREAK	
Morning Session 2 11:00 – 12:30	Argento Hotel **Nick Hardman Mountford** The Commonwealth Presentation; Climatology and the Blue Charter	Venue: MP602 **Georgios Sylaios Nikolaos Kokkos** Practical session on the ODYSSEA Project	Venue: MP602 **Georgios Sylaios Nikolaos Kokkos** Application of Operational Modelling Tools in the North Aegean Sea (cont) **Georgios Sylaios Nikolaos Kokkos** Hydrodynamic, wave and biogeochemical models operated in the study area	Venue: MP602 **Tim Collart Patrick Gorringe** The EMODnet data product portfolio, ingestion service & Intro to the practical session.	**6. Three Cities ferry to Valletta (Tickets purchased beforehand)** **7. Lunch in Valletta @ Ta' Nenu, St Dominic Street, Valletta (via Merchants' Street - 11/15 min walk)**	Venue: MP602 **Fabrice Messal** Focus on the Copernicus Marine data and information for ocean climate monitoring (sea level rise, heat content anomalies, acidity trends etc.) Q&A: Face to face meetings with the Copernicus Marine Service experts	Venue: MP602 Ideathon Group exercises (cont.)

Organised by the
Commonwealth Small States Centre of Excellence
Course director: ***Ms. Gabriella Cassola***
(gabriella.cassola@gov.mt)

Coordinated by the
Physical Oceanography Research Group
Dept. of Geosciences, University of Malta
Scientific & technical course coordinator: ***Prof. Aldo Drago***
(aldo.drago@um.edu.mt)

Supported by
Copernicus Marine Service
EMODnet European Marine Observation and Data Network
Copernicus
Mercator Ocean International
Prifysgol Bangor University
Deltares Enabling Delta Life
ODYSSEA
Democritus University of Thrace

SO9

Train and educate policy-makers and end-users on platform usage

ODYSSEA Summer Schools

ODYSSEA

odysseaplatform.eu

2nd ODYSSEA Summer School
Oceanography and Fisheries in the Mediterranean
Patitiri Village, Alonissos, Greece
2-6 September 2019

View of the main harbor (Patitiri Village) of Alonissos Island, Greece

Co-organized through ODYSSEA Project by:

School of Biology
Aristotle University of Thessaloniki

Department of Environmental Engineering
Democritus University of Thrace

Supported by Thalassa Foundation

This project has received funding from the European Union's
Horizon 2020 research and innovation programme under grant agreement No. 727277

SO10

ODYSSEA

Improve professional skills and competences - focus on Northern Africa capacity building

ODYSSEA Training on the Platform


ODYSSEA Training on Sensors

IMPLEMENTATION OF AN INTEGRATED NETWORK OF OBSERVATORIES IN THE MEDITERRANEAN

ارساء شبكة متكاملة لمراكز مراقبة بالبحر المتوسط

OCEAN OBS'19 | ODYSSEA | SPA/RAC

"Supporting UN sustainable development goals and regional ecological objectives in the Mediterranean Sea through integrated marine observing systems, capacity building and tailored information services: ODYSSEA(*) project case"

Slim Gana[1], Laura Friedrich[2], Daniel Cebrian-Menchero[1], Menelaos Chatziapostolidis[3] and ODYSSEA consortium
(1): SPA/RAC – UN Environment – Mediterranean Action Plan – Tunis. Contact: slim.gana@spa-rac.org
(2): WCMC – UN Environment - UK - (3): DUTH University – Greece.

Abstract:

The Mediterranean Sea is governed by a comprehensive framework of global and regional objectives for sustainable development and biodiversity conservation. The Aichi Biodiversity Targets and United Nations (UN) Sustainable Development Goals 13 and 14 set ambitious targets for oceanographic parameters monitoring programmes, conservation and sustainable use of marine ecosystems and resources.

The European Union (EU) aims to achieve good environmental status in its seas by 2020 through the Marine Strategy Framework Directive, while also driving forward the development of a sustainable blue economy. Moreover, the Integrated Monitoring and Assessment Programme (IMAP) adopted under the UN Environment Mediterranean Action Plan sets out monitoring and reporting requirements for 11 ecological objectives.

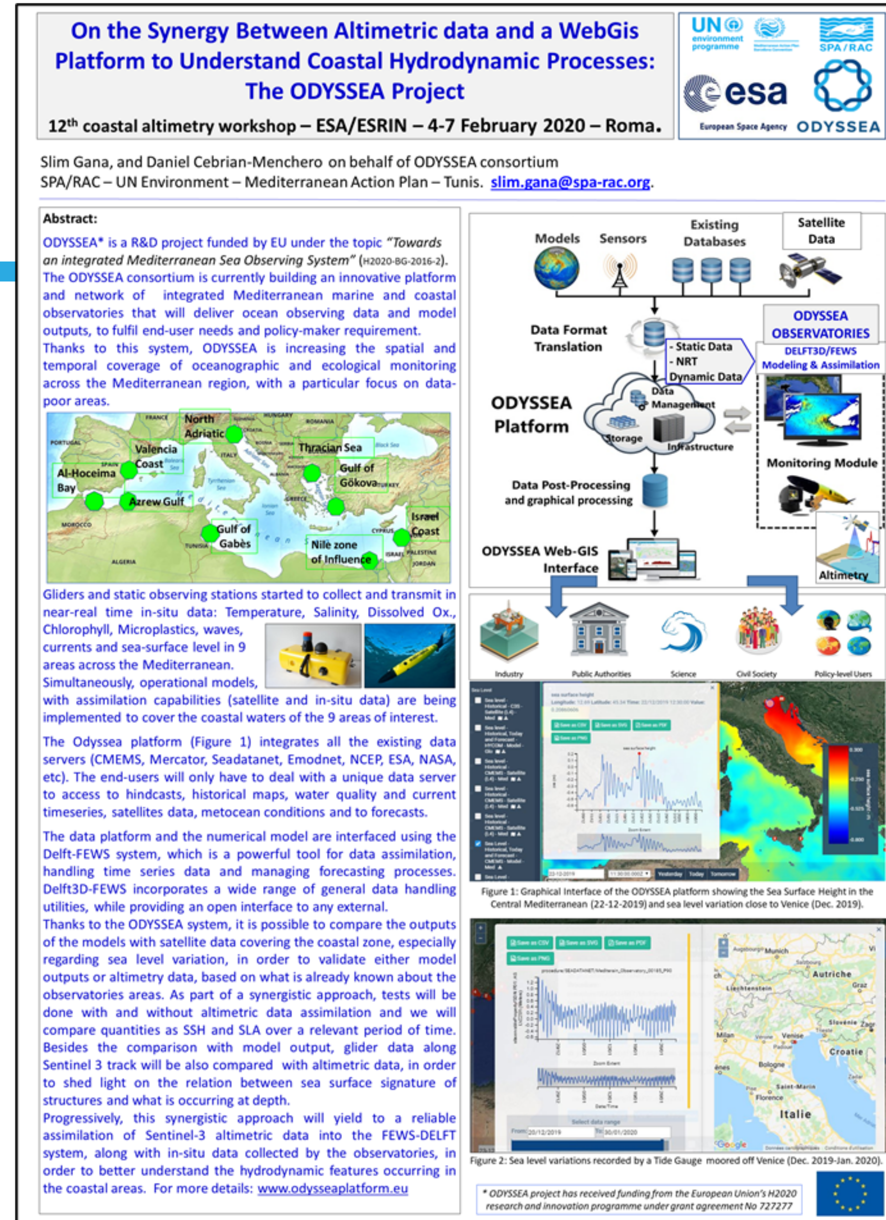
While this policy framework aims to ensure a sustainable future for the Mediterranean Sea, countries are facing challenges in implementing and monitoring progress towards the different objectives as this requires considerable technical and institutional capacity (monitoring of marine parameters, data analysis, database management, translation of data to indicators, etc). Indeed, capacity building, technology and knowledge transfer are recognised as critical to help countries to achieve their commitments by the UN sustainable development and biodiversity conservation agenda, the EU and within the context of IMAP.

The ODYSSEA consortium is currently building an innovative platform and network of marine observatories that will deliver ocean observing data and model outputs to fulfil tailored end-user needs and policy-maker requirement. This project supports capacity building efforts in the Mediterranean in three way:

- First, by setting up a network of integrated marine observing systems, ODYSSEA is increasing the spatial and temporal coverage of oceanographic and ecological monitoring across the region, with a particular focus on data-poor areas;
- Second, this is accompanied by focused capacity building activities which will enable North African countries to expand their own monitoring programmes;
- Third, ODYSSEA will facilitate access to key data for decision makers by providing tailored information services through a user-driven online platform, thus enabling them to make well informed decisions for a sustainable blue economy and effective biodiversity conservation in the Mediterranean Sea.

more information: www.odysseaplatform.eu

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727277



On the Synergy Between Altimetric data and a WebGis Platform to Understand Coastal Hydrodynamic Processes: The ODYSSEA Project

12th coastal altimetry workshop – ESA/ESRIN – 4-7 February 2020 – Roma.

Slim Gana, and Daniel Cebrian-Menchero on behalf of ODYSSEA consortium
SPA/RAC – UN Environment – Mediterranean Action Plan – Tunis. slim.gana@spa-rac.org.

Abstract:

ODYSSEA* is a R&D project funded by EU under the topic *"Towards an integrated Mediterranean Sea Observing System"* (H2020-BG-2016-2). The ODYSSEA consortium is currently building an innovative platform and network of integrated Mediterranean marine and coastal observatories that will deliver ocean observing data and model outputs, to fulfil end-user needs and policy-maker requirement. Thanks to this system, ODYSSEA is increasing the spatial and temporal coverage of oceanographic and ecological monitoring across the Mediterranean region, with a particular focus on data-poor areas.

Gliders and static observing stations started to collect and transmit in near-real time in-situ data: Temperature, Salinity, Dissolved Ox., Chlorophyll, Microplastics, waves, currents and sea-surface level in 9 areas across the Mediterranean. Simultaneously, operational models, with assimilation capabilities (satellite and in-situ data) are being implemented to cover the coastal waters of the 9 areas of interest.

The Odyssea platform (Figure 1) integrates all the existing data servers (CMEMS, Mercator, Seadatanet, Emodnet, NCEP, ESA, NASA, etc). The end-users will only have to deal with a unique data server to access to hindcasts, historical maps, water quality and current timeseries, satellites data, metocean conditions and to forecasts.

The data platform and the numerical model are interfaced using the Delft-FEWS system, which is a powerful tool for data assimilation, handling time series data and managing forecasting processes. Delft3D-FEWS incorporates a wide range of general data handling utilities, while providing an open interface to any external.

Thanks to the ODYSSEA system, it is possible to compare the outputs of the models with satellite data covering the coastal zone, especially regarding sea level variation, in order to validate either model outputs or altimetry data, based on what is already known about the observatories areas. As part of a synergistic approach, tests will be done with and without altimetric data assimilation and we will compare quantities as SSH and SLA over a relevant period of time. Besides the comparison with model output, glider data along Sentinel 3 track will be also compared with altimetric data, in order to shed light on the relation between sea surface signature of structures and what is occurring at depth.

Progressively, this synergistic approach will yield to a reliable assimilation of Sentinel-3 altimetric data into the FEWS-DELFT system, along with in-situ data collected by the observatories, in order to better understand the hydrodynamic features occurring in the coastal areas. For more details: www.odysseaplatform.eu

Figure 1: Graphical Interface of the ODYSSEA platform showing the Sea Surface Height in the Central Mediterranean (22-12-2019) and sea level variation close to Venice (Dec. 2019).

Figure 2: Sea level variations recorded by a Tide Gauge moored off Venice (Dec. 2019-Jan. 2020).

* ODYSSEA project has received funding from the European Union's H2020 research and innovation programme under grant agreement No 727277

ODYSSEA Publications

ODYSSEA

water

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Review for *Water*

Edit a Special Issue

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Special Issue "Observations and Models for End-User Services in Coastal Marine Systems"

- Print Special Issue Flyer
- Special Issue Editors
- Special Issue Information
- Keywords
- Published Papers

A special issue of *Water* (ISSN 2073-4441). This special issue belongs to the section "Hydrology".

Deadline for manuscript submissions: **30 September 2020**.

Share This Special Issue

Special Issue Editors

Prof. Georgios Sylaios E-Mail Website
Guest Editor
Democritus University of Thrace (DUTH), Department of Environmental Engineering, Laboratory of Ecological Engineering and Technology, Xanthi, GREECE
Tel. +30-25410-79398
Interests: coastal processes; numerical models; data analysis; online sensors; forecasting; climate change; machine learning

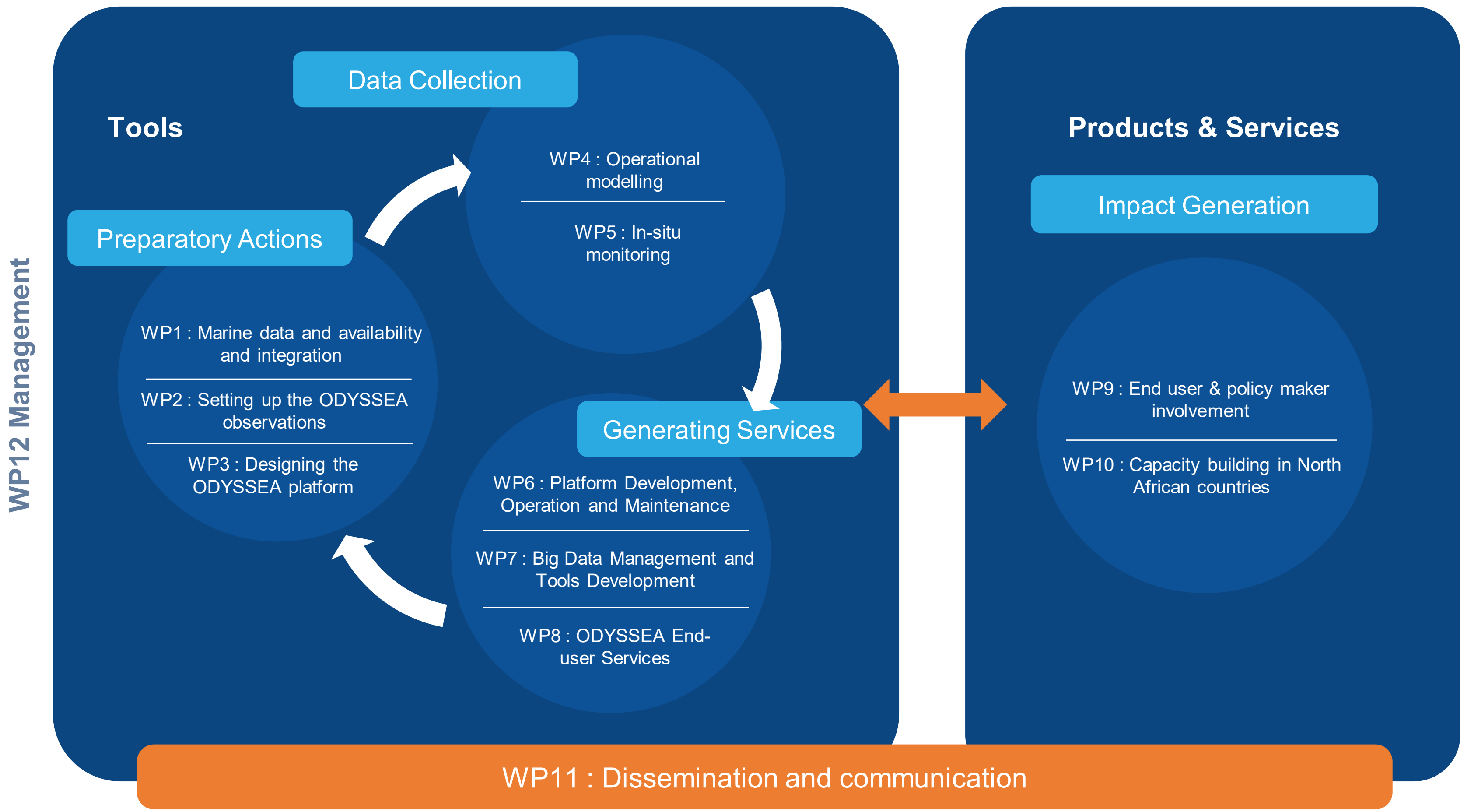
Dr. Ghada El Serafy E-Mail Website
Guest Editor
Deltares, Postbus 177 2600 MH Delft, The Netherlands.
Interests: data assimilation; data sciences; ecosystem modeling; ecosystem services; marine environmental quality; ecosystem health; integrated monitoring and assessment

ODYSSEA's Main Novelties

ODYSSEA

- Both primary data and on-demand derived data services will be made available and accessible through **a single command and via a single public portal**.
- The platform will allow to **search, collect, retrieve and integrate datasets** obtained from an expanded range of existing observational/forecasting systems.
- To reduce costs and ensure active participation of end-users on ODYSSEA platform, **existing facilities (onshore and offshore)**, such as oil and gas terminals and rigs, mariculture installations, ports and harbours, **will be used to deploy static sensors**.
- Gliders will **integrate marine microplastics sensor and novel sensors** for real-time biological monitoring.
- Operational models will be coupled and running in each Observatory providing forecasts and **informing end-users on emergencies and risks**.
- Local/regional/national policy-makers and end-users will be **trained on the optimal platform usage**.

The ODYSSEA Work Plan



THANK-YOU

Prof. Georgios SYLAIOS

Democritus University of Thrace

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727277

MEASURING OCEAN COLOUR FROM SPACE

Dr Hayley Evers-King

EUMETSAT

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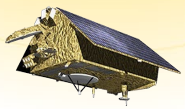
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727277

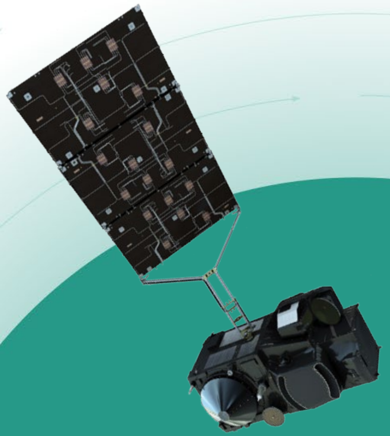
Measuring Ocean Colour from Space

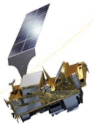
Dr Hayley Evers-King, EUMETSAT

ODYSSEA virtual school – Oceanography from Space

Hayley.EversKing@eumetsat.int, @HayleyEversKing







Why ocean colour?

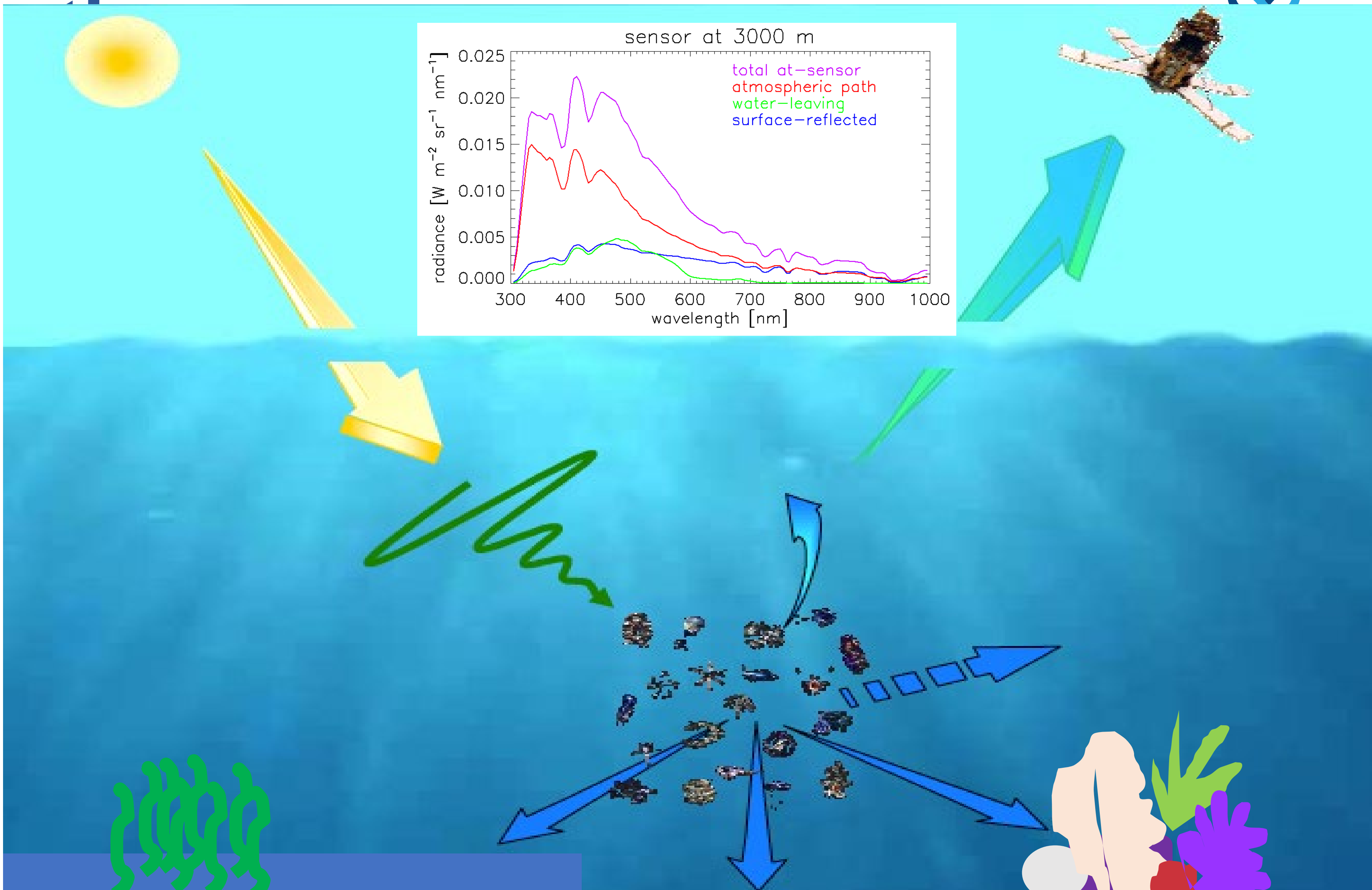
ODYSSEA

- Tells us about what's in ocean waters:
  - Phytoplankton
    - Food chain
    - Carbon
  - Sediments
  - Ice
  - Other things:
    - Pollution
    - Infrastructure
    - Debris



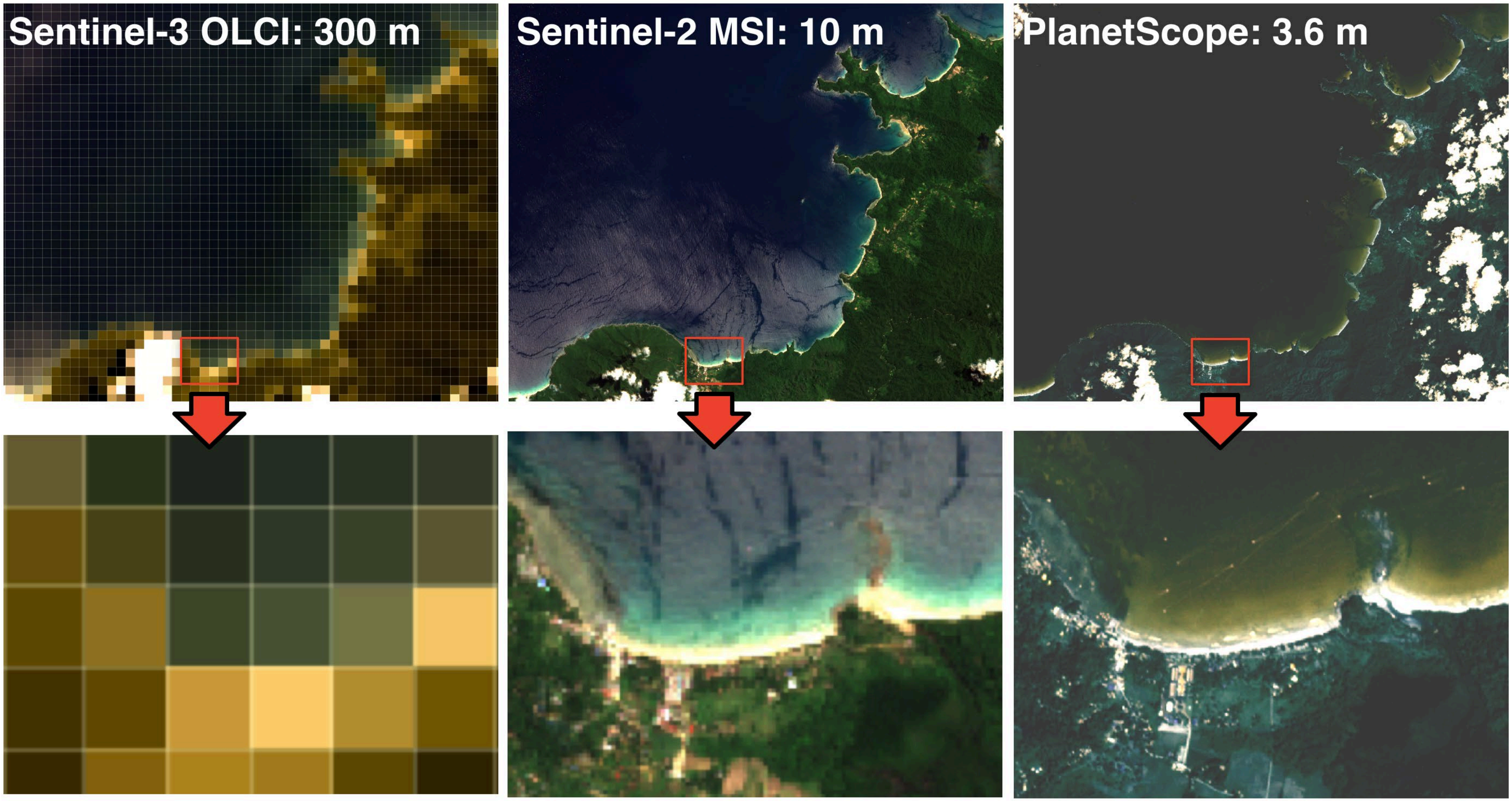



Measuring ocean colour -



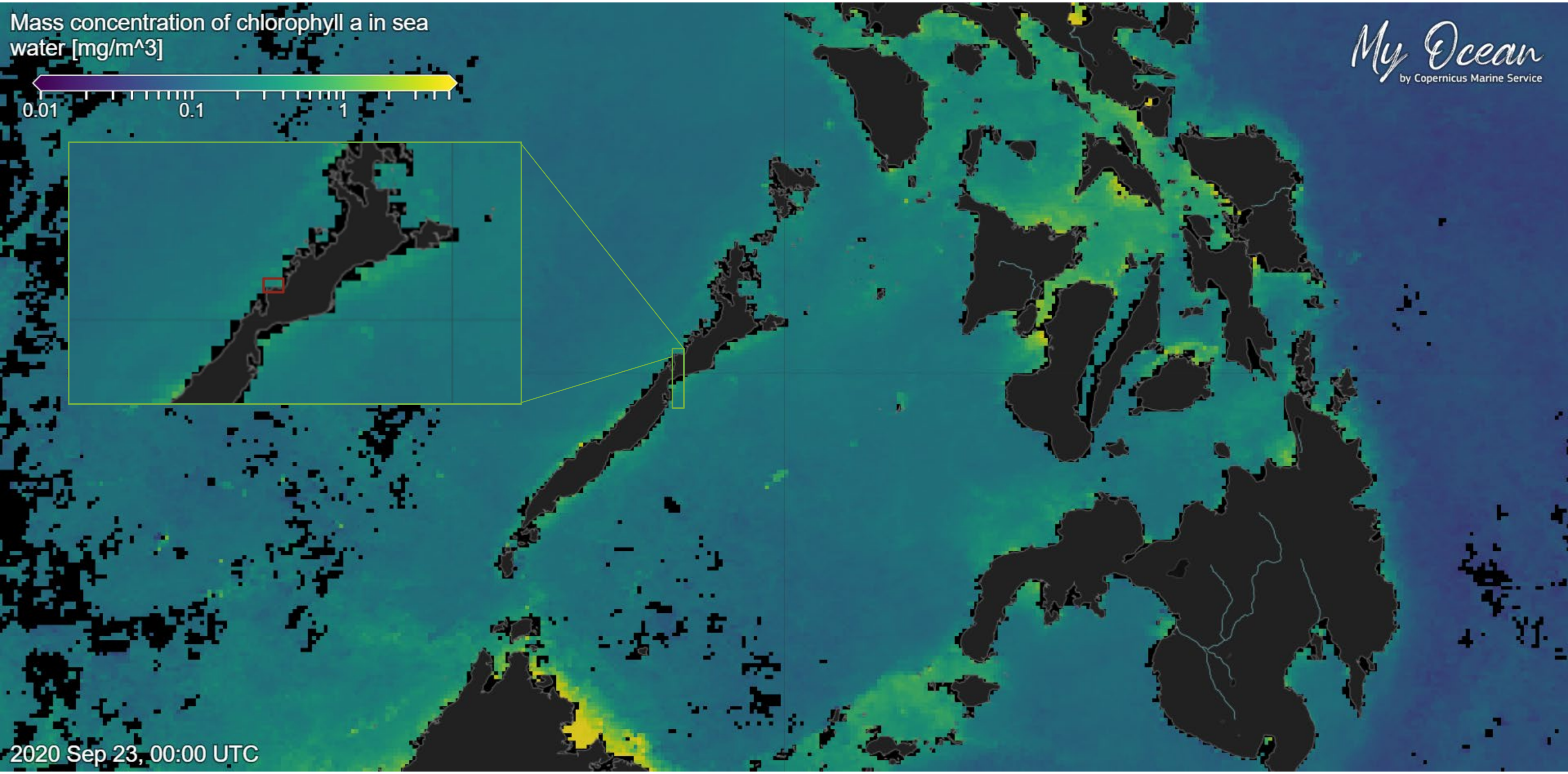
Spatial and spectral resolution – Level 1/2

ODYSSEA

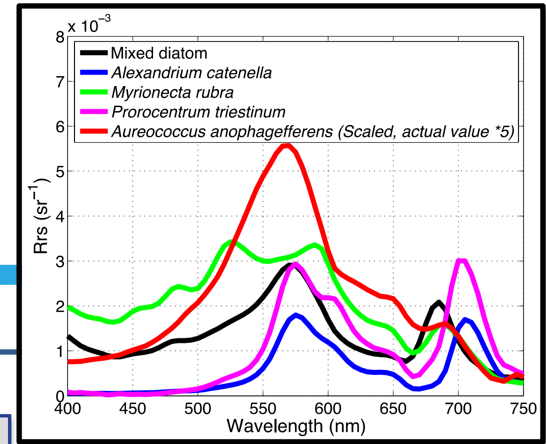


Spatial and spectral resolution – Level 3/4

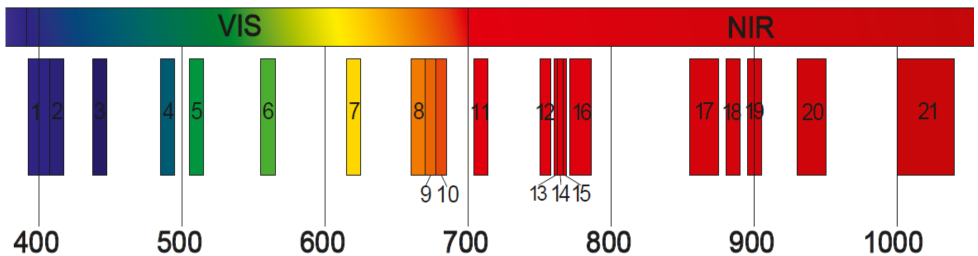
ODYSSEA



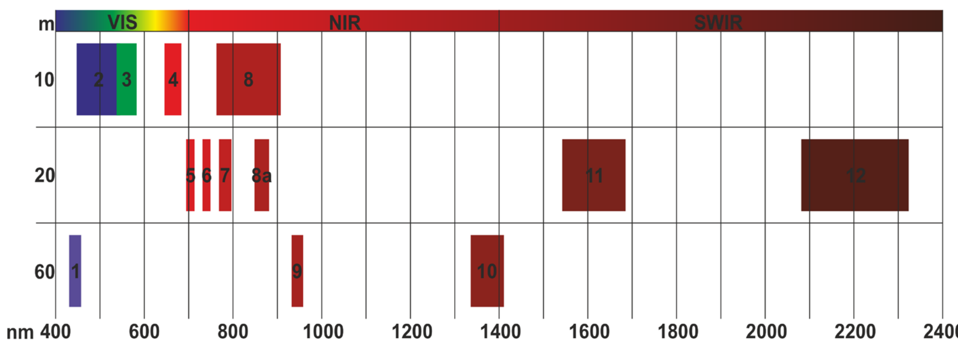
Spatial and spectral resolution

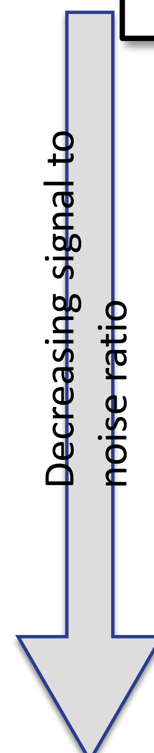


Sentinel-3 OLCI:



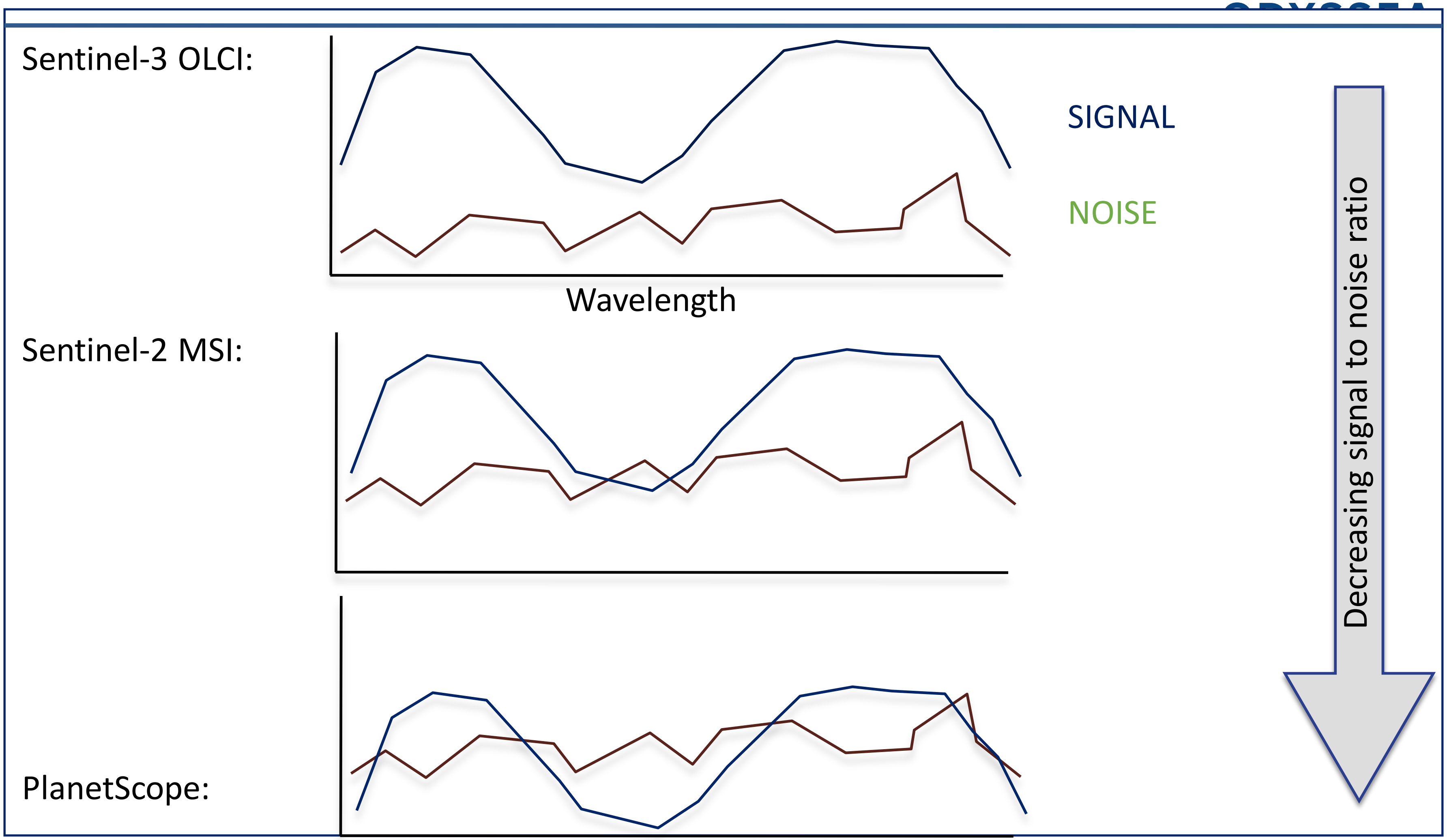
Sentinel-2 MSI:





PlanetScope: Red, Green, Blue, (1 x NIR)

Spatial and spectral resolution



Algorithms and products

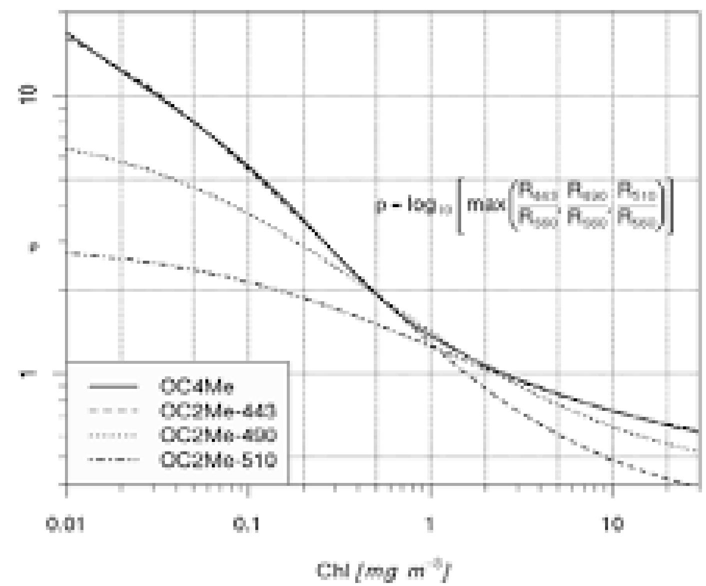
ODYSSEA

- Level 1: Top of atmosphere radiance
- Level 2: R_{rs}, IOPs, [Chl, TSM] at native res.
- Level 3: Merged, regridded – Chl (+)
- Level 4: Gap filled, single algorithm – Chl (+)

- Also many custom approaches that you can (and may need to) take to achieve optimal results:
  - Atmospheric correction, POC, sediments, HABs, bottom type habitats etc.

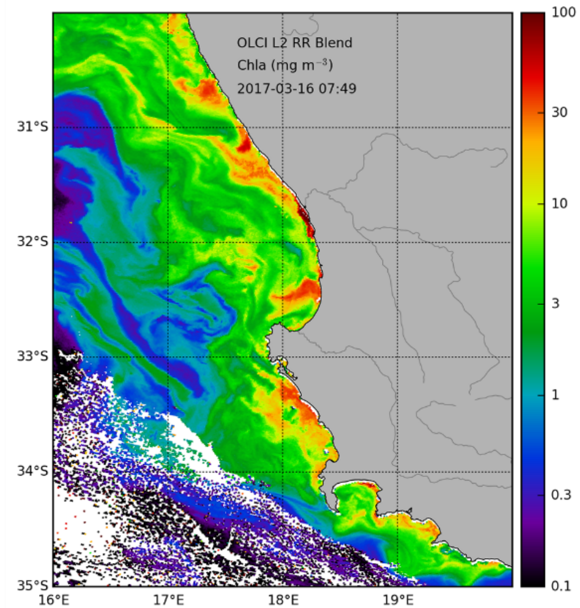
What is an algorithm?

- Links signal to geophysical property
- Simpler approaches – an empirical band ratio e.g. [Chl]
- More complex – inversion models, AI/ML approaches
- Validation and sensitivity is key – varies regionally/by application



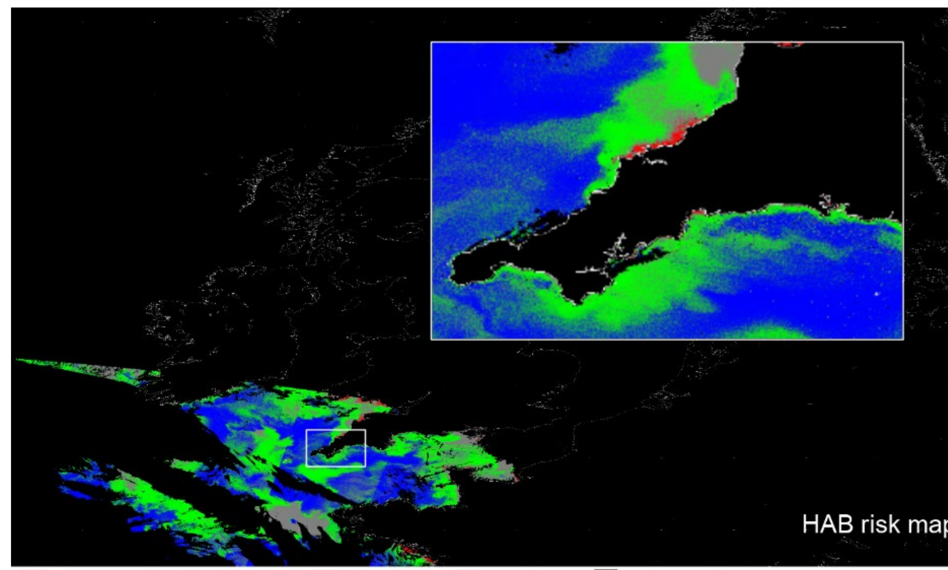
Applications of Ocean Colour - HABs

ODYSSEA

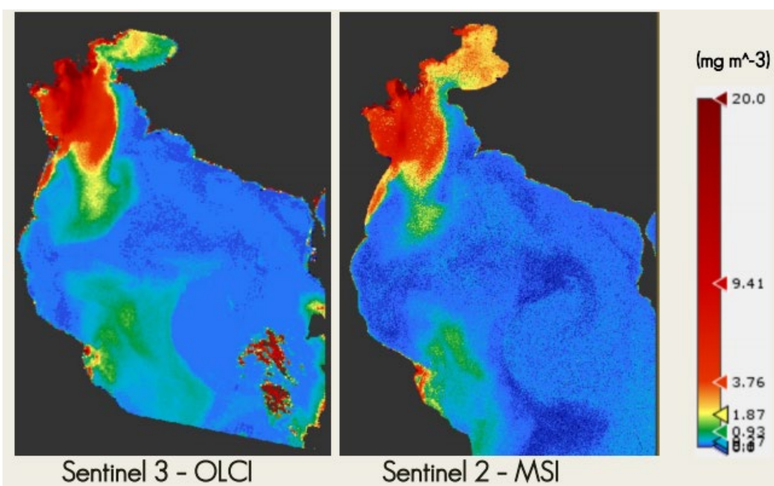


OLCI used to detect high biomass blooms in coastal environment, west coast of South Africa. Forms part of government Operation Phakisa initiatives (Marie Smith)

OLCI spectral data used to classify waters at risk of different Harmful Algal Bloom species including Pseudonitzschia (Andrey Kurekin)



- Pseudo-nitzschia HAB risk - harmless - no bloom - not classified

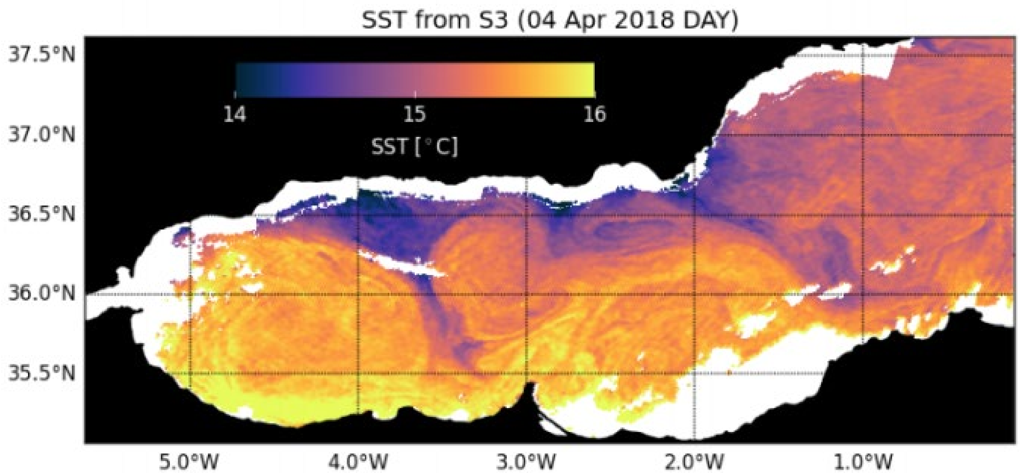


Chlorophyll concentrations for detecting blooms in Greek waters – powerful combination with Sentinel 2 (S3 higher temporal and spectral characteristics, S2 higher spatial resolution) – (Andromachi Kikaki, Riga 2018)

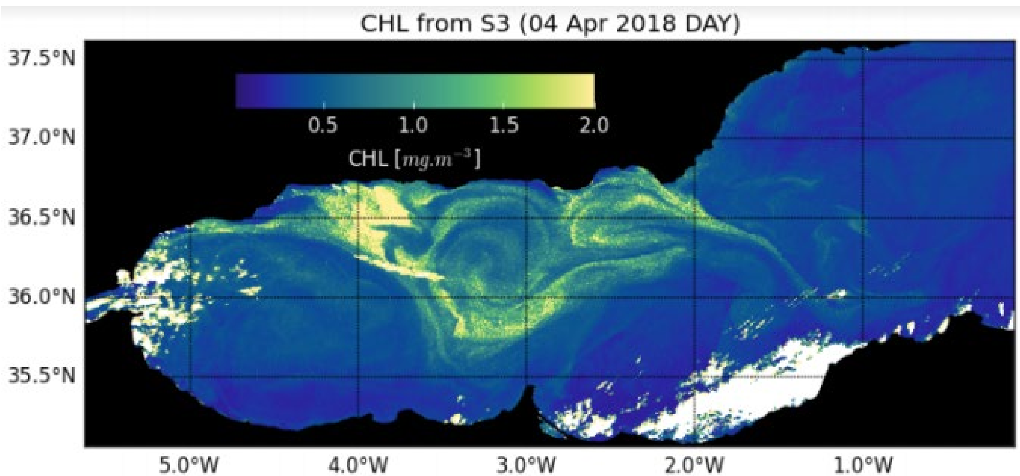
Applications of Ocean Colour – linking with physics

ODYSSEA

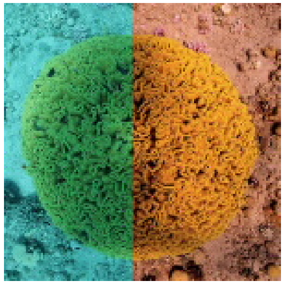
Alboran gyre identified in SST, and …

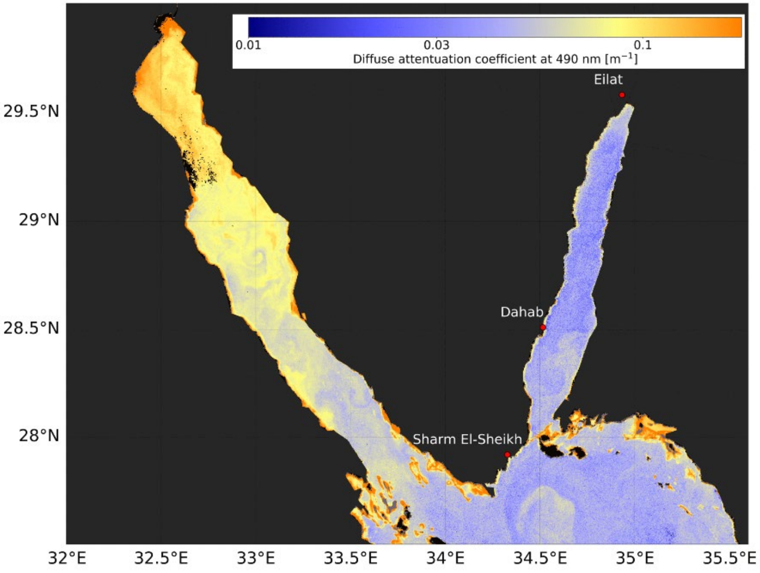


… resultant influences on chl concentration (Luisa Lamas)

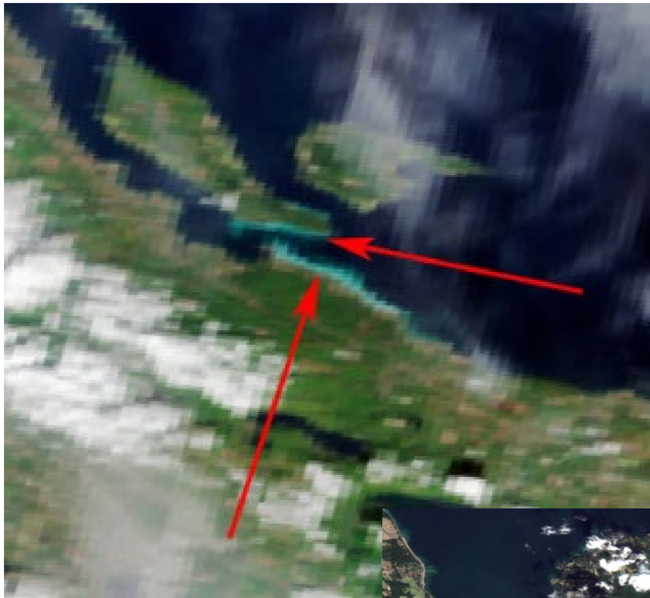


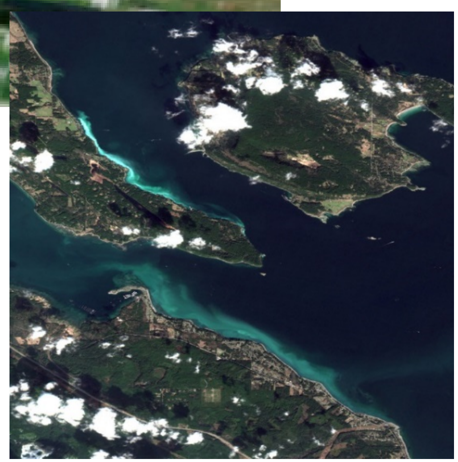
OLCI attenuation data used to correct underwater imagery. (Derya Akkaynak)



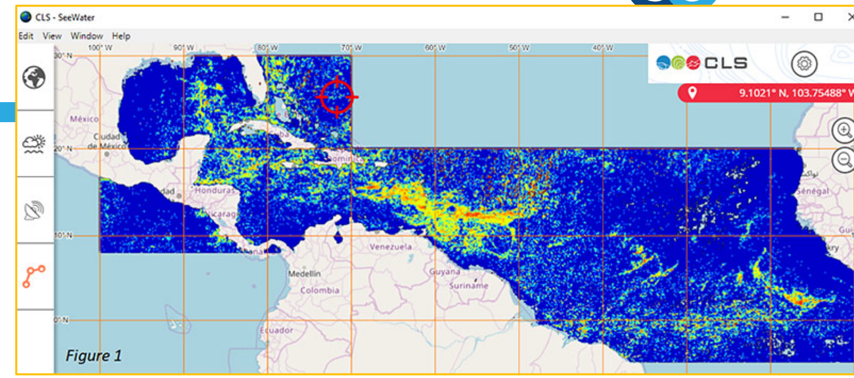


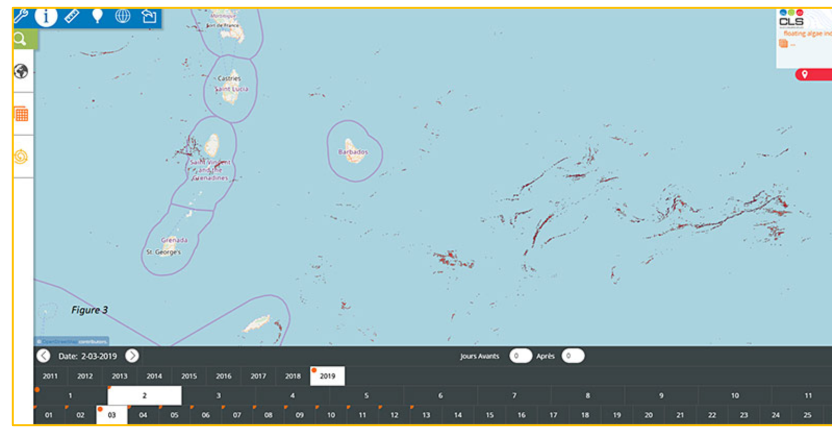
Applications of Ocean Colour – detection





OLCI: Herring Spawn off Vancouver Island (Maycira Costa), synergy with Sentinel-2.

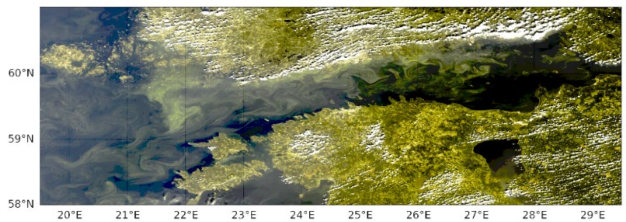


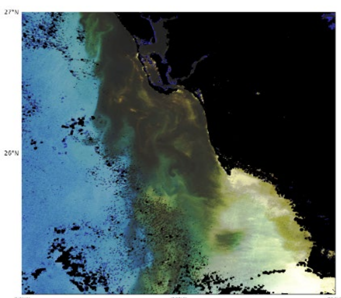


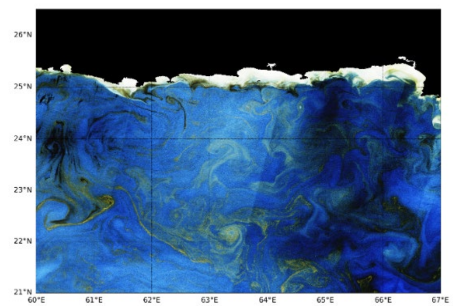
OLCI: Detection of Sargassum. CLS operational service - https://datastore.cls.fr/cls-operational-sargassum-monitoring-service-ready-for-end-users/

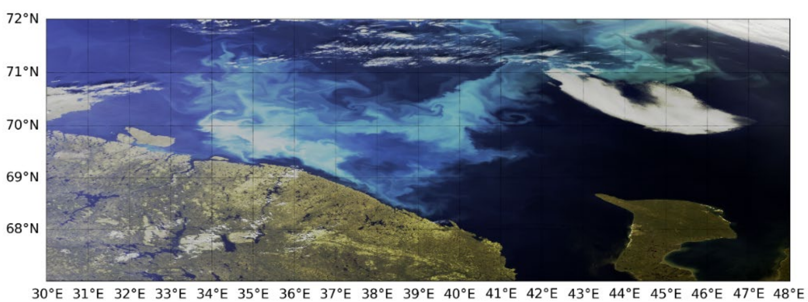
Applications of Ocean Colour – Ice and ecosystems

OLCI: Detection of different types of algal blooms

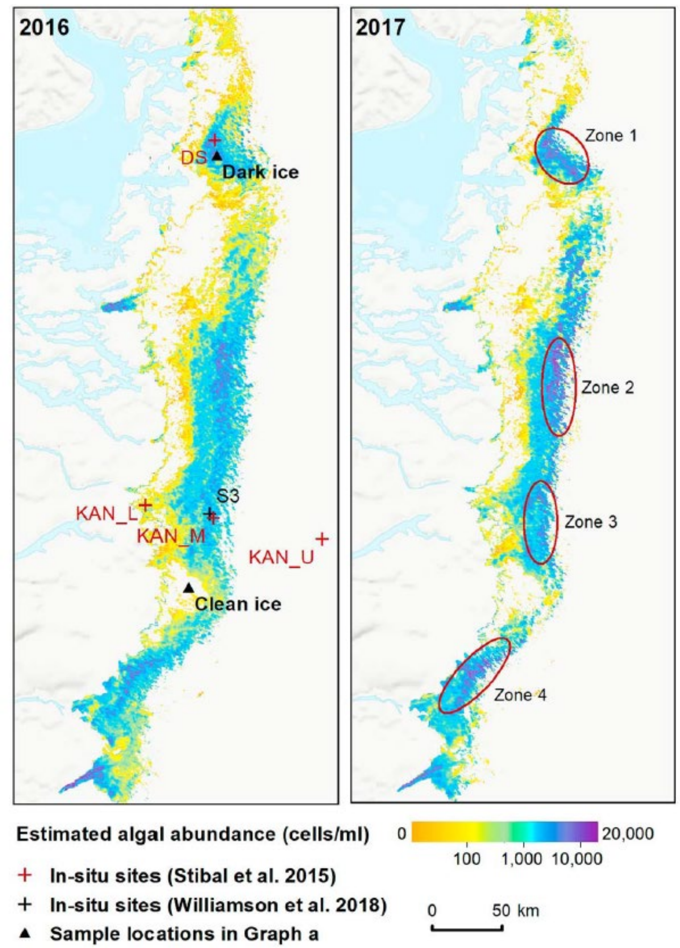








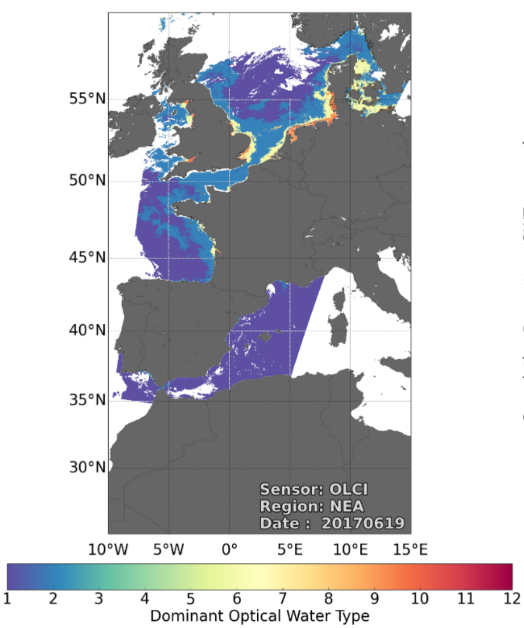
OLCI: Detection of algal blooms in ice (Wang et al., 2018)

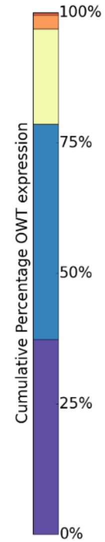


Applications of Ocean Colour Water quality and policy

ODYSSEA

Various applications are exploring the use of OLCI data for meeting Marine Strategy Framework Directive (MSFD), Water Framework Directive and other relevant environmental policy.





ORSECT is a DEFRA / CEFAS funded project to improve estimates of coastal turbidity and TSM around the UK by applying optical water typing approaches to OLCI (Ben Loveday)

highroc.eu

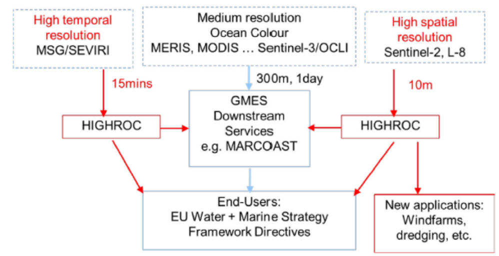
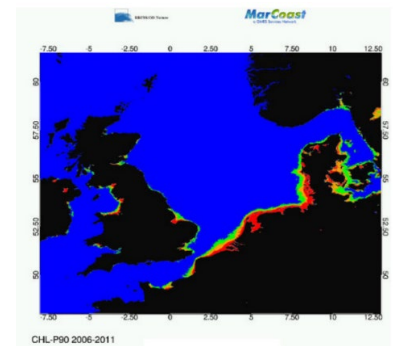


Figure 1. Positioning of the new HIGHROC products and services with respect to the existing medium resolution ocean colour data stream and services.



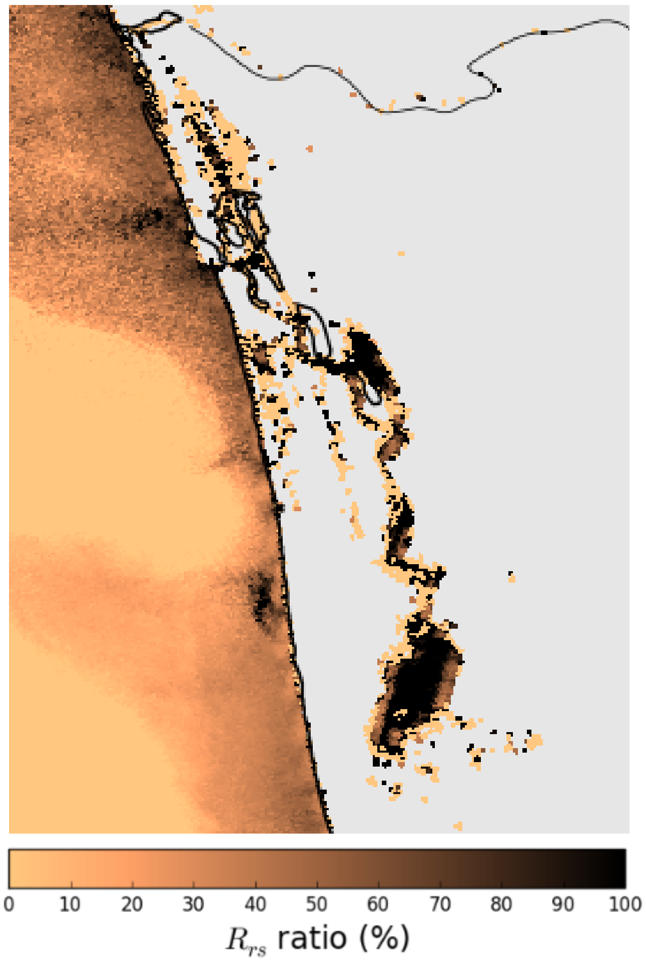
Ruddick et al., 2016

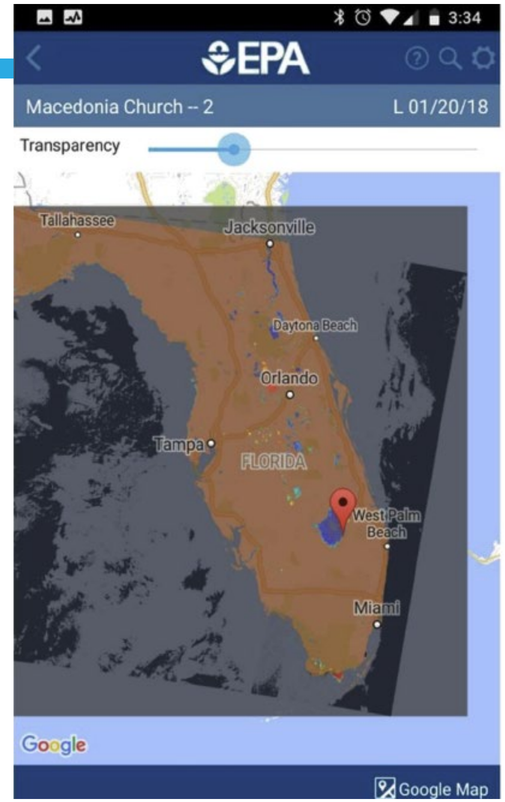
Application Type	User
Water Quality Monitoring and Reporting for the EU Water Framework and Marine Strategy Framework Directives (WFD/MSFD)	National governments
Dredging optimisation and monitoring	Dredging consultancies, Government
Coastal Aquaculture	Aquaculture operators, Government
Environmental Impact Assessment for coastal and offshore construction	Consultancies, Government
Initialisation/validation data for sediment transport and ecosystem models	Sediment transport and ecosystem modelling scientists

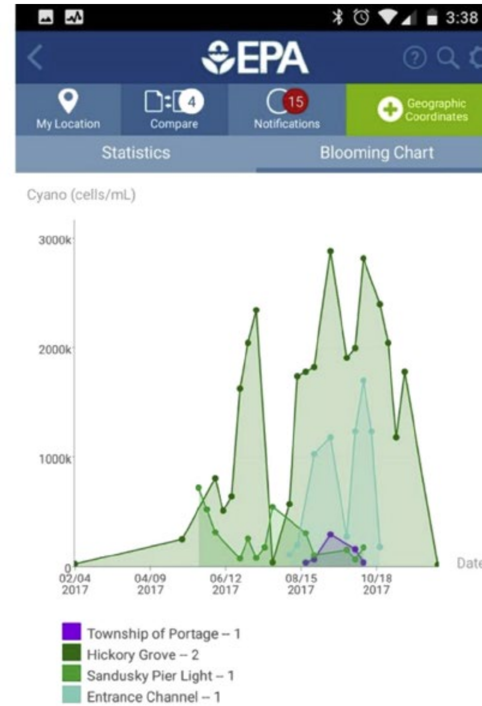
Table 1. Key applications and end-user communities for HIGHROC products and services.

S-3 applications: Water Quality & Human Health

OLCI data used to develop cholera potential indicators, Kerala, India (Hayley Evers-King, Marie-Fanny Racaul, Shubha Sathyendranath)







OLCI: A mobile application providing information about cyanobacterial blooms (Schaeffer et al., 2018)

CYAN

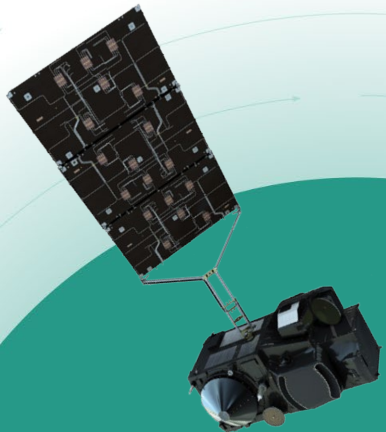
EPA United States Environmental Protection Agency

Working with Ocean Colour data from satellites

Dr Hayley Evers-King, EUMETSAT

ODYSSEA virtual school – Oceanography from Space

Hayley.EversKing@eumetsat.int, @HayleyEversKing



Choosing the right ocean colour product for you

ODYSSEA

- What spatial resolution do I need?
  - High? Coastal? → Sentinel-2
  - Medium? Coastal/global? → Sentinel-3
  - Global coverage? → CMEMS L3/L4
- How big is my signal?
  - Distinct → Sentinel-2
  - Less distinct → Sentinel-3
- How often do I need data?
  - Not too often → Sentinel-2, Landsat etc
  - Every day? → Sentinel-3 or CMEMS L3/L4?
  - For many years? → CMEMS L3/L4
- Do I need to derive my own products from the OC signal?
  - Yes → Sentinel-3, maybe Sentinel-2

Accessing ocean colour data

ODYSSEA

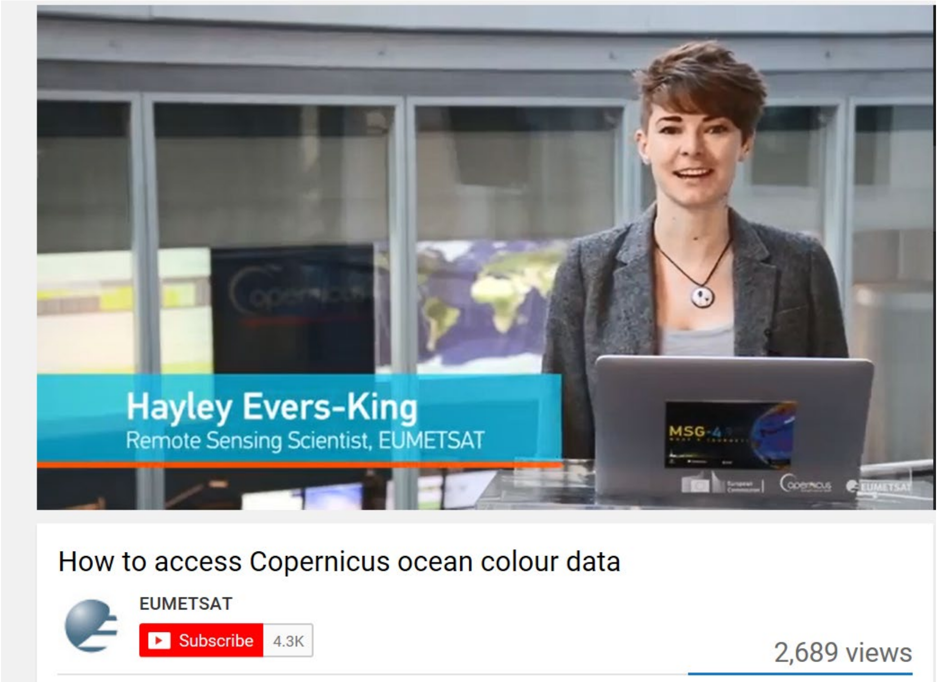
- Example using CODA: https://coda.eumetsat.int
- Example using CMEMS: http://marine.copernicus.eu

- Additional links:
  - CODA downloader - https://gitlab.eumetsat.int/eumetlab/cross-cutting-tools/sentinel-downloader
  - OC-CCI – www.oceancolour.org
  - NASA – https://oceancolor.gsfc.nasa.gov/

Working with Sentinel-3 Ocean Colour in SNAP

ODYSSEA

- Demonstration
- SNAP: https://step.esa.int/main/download/snap-download/
- See also this youtube video: https://www.youtube.com/watch?v=V3NAuafvlFM&list=PLOQg9n6Apif1ODObv39j43j8IAvJDOAVY&index=3
- Details on products: https://www.eumetsat.int/media/45743
- Further training opportunities for using Python – see https://training.eumetsat.int and
- https://wekeo.eu



Working with Copernicus L3/L4 ocean colour data

- Demonstration of new visualisation service
- Can also use any software that will work with NetCDF files
  - Further training courses use Python etc from CMEMS and WEkEO

Questions?

ODYSSEA

- Very quick overview of some of the access methods and tools. Check out youtube and other training resources linked within for more information.
- SST coming up next!

MEASURING SEA SURFACE TEMPERATURE FROM SPACE

Dr Hayley Evers-King

EUMETSAT

Hayley.EversKing@eumetsat.int

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727277

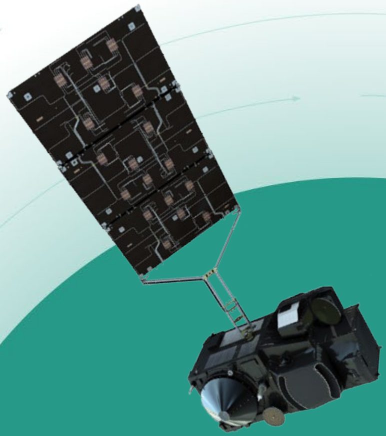
Measuring Sea Surface Temperature from Space

Dr Hayley Evers-King, EUMETSAT

With thanks to Gary Corlett, Ben Loveday and colleagues

ODYSSEA virtual school – Oceanography from Space

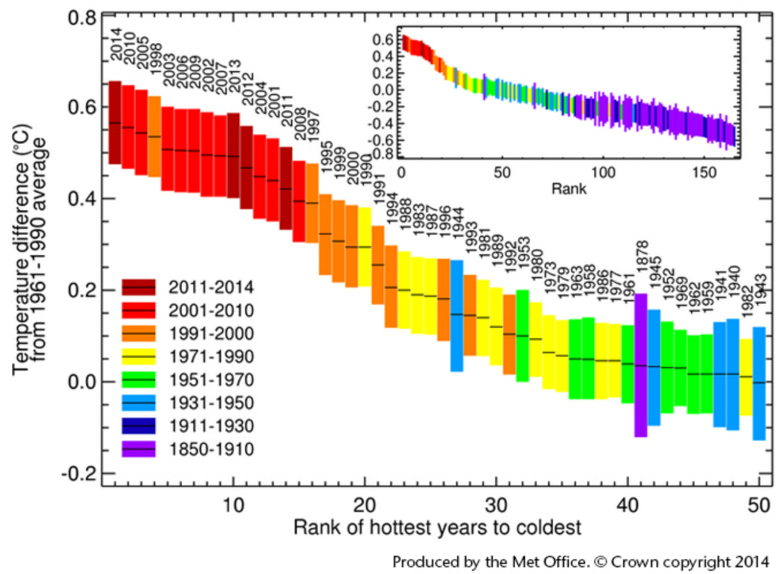
Hayley.EversKing@eumetsat.int, @HayleyEversKing



Why SST?

ODYSSEA

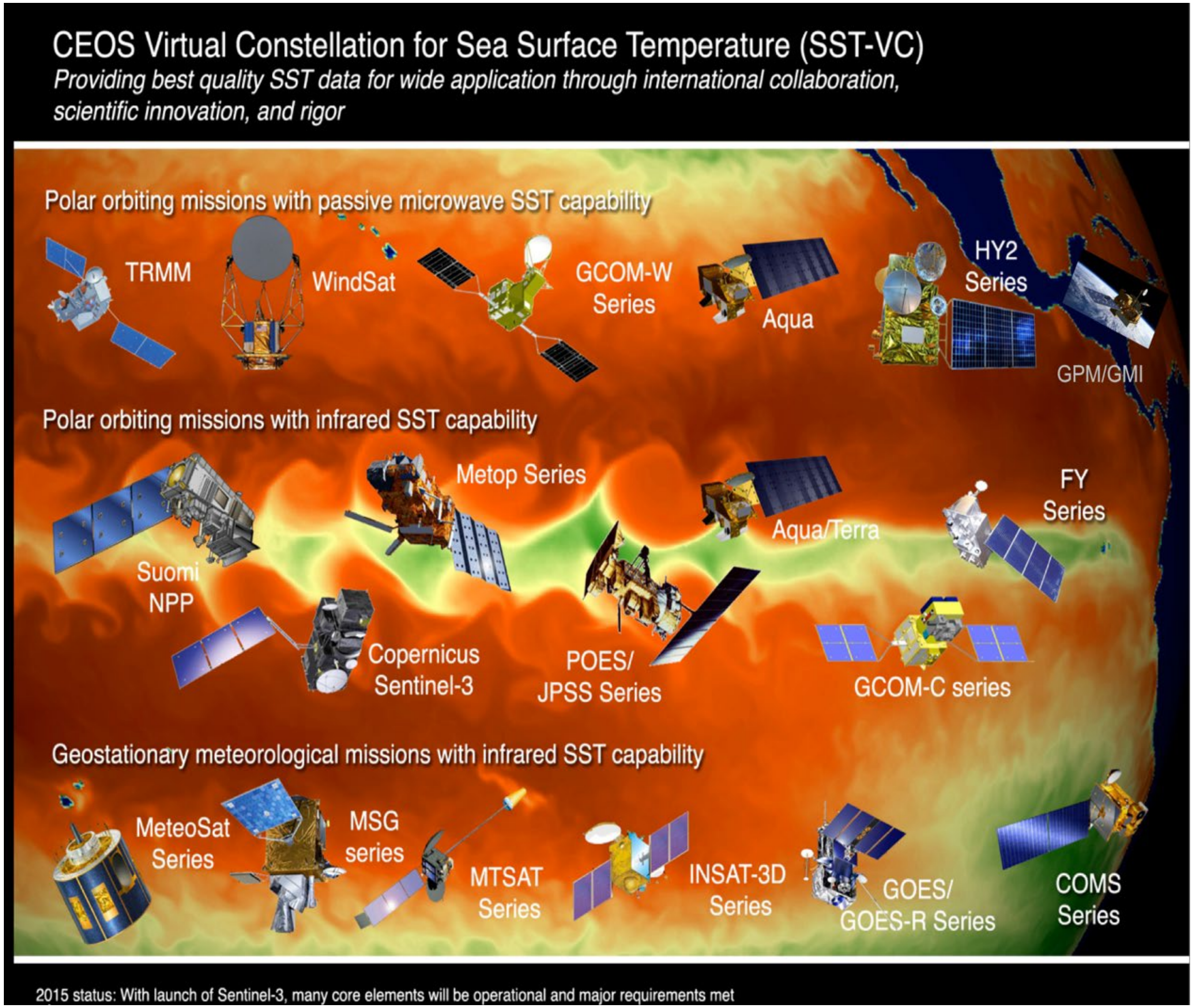
- Influences the weather
- Influences ocean circulation
- Intimately connected to ocean biology
- Climate



Measuring Sea Surface Temperature

ODYSSEA

- SST is derived from radiance; this is measured by radiometers, as with ocean colour, but also using the infrared (or microwave) part of the spectrum.
- Huge variety of missions over history, with strong drive from meteorological community.

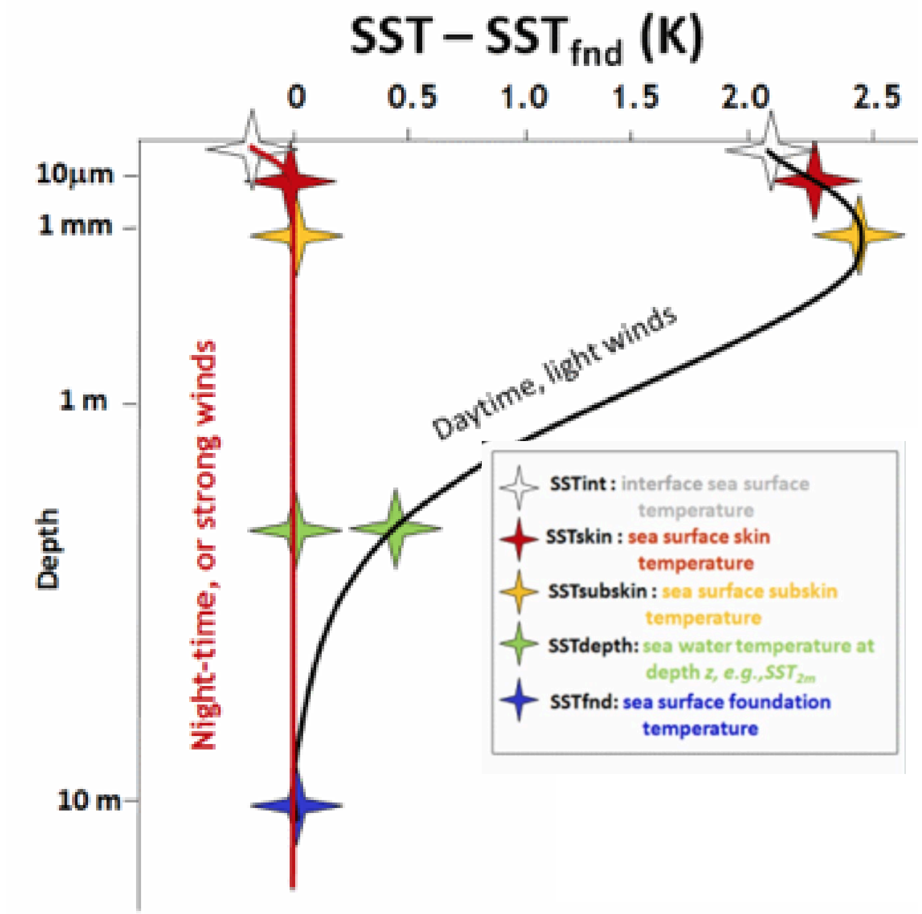


SST missions – SLSTR example

Measuring SST - Theory

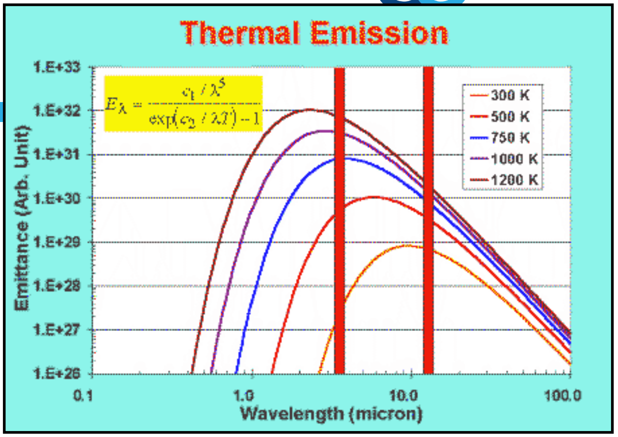
ODYSSEA

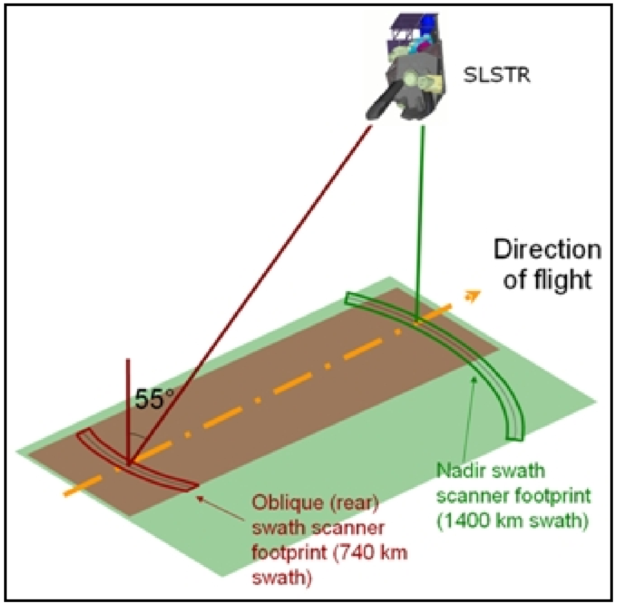
- SST can be defined in many ways (see figure), and is measured differently by different satellite and *in situ* sensors.
- These definitions are set by GHRSST (the group for high resolution sea surface temperature).
- GHRSST provide community resources on SST: www.ghrsst.org
- SLSTR (and many IR radiometers) measure **skin temperature (10 µm)**
- Passive microwave (PWM) radiometers measure sub-skin temperature.
- The IR and PMW channels used are selected as they minimise atmospheric effects.



Measuring SST – Theory (with SLSTR example)

- Microwave – is not strongly affected by cloud scattering but is measured at lower resolution (convergence of black body curves).
- IR is strongly affected by cloud scattering
- Signal at sensor (once calibrated):
  - top of atmosphere brightness temperature for IR channels (S7*-S9)
  - radiance for optical channels (S1-S6). (used primarily, in the marine case, to identify cloud).
- Dual view approach is used to correct for atmosphere (mainly water vapour), and the presence of scattering



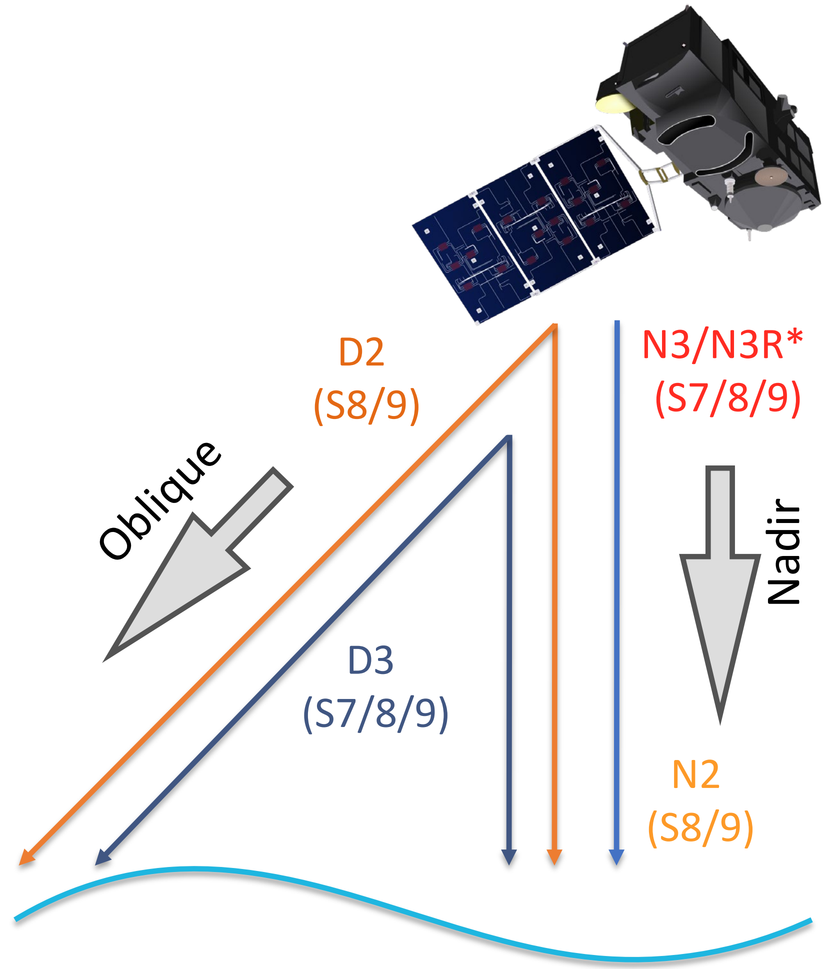


*S7 used at night only

Measuring SST - Algorithms

ODYSSEA

- SLSTR has 5 algorithms for SST retrieval
- "N" only algorithms use only the nadir looking view.
- "D" algorithms combine both nadir and oblique view to give a "dual" view.
- D & N algorithms have variants that use 2 (day) or 3 channels (at night).
- Dual-view retrievals have the ability to provide a better atmospheric correction.



Measuring SST – other sources of data/information

ODYSSEA

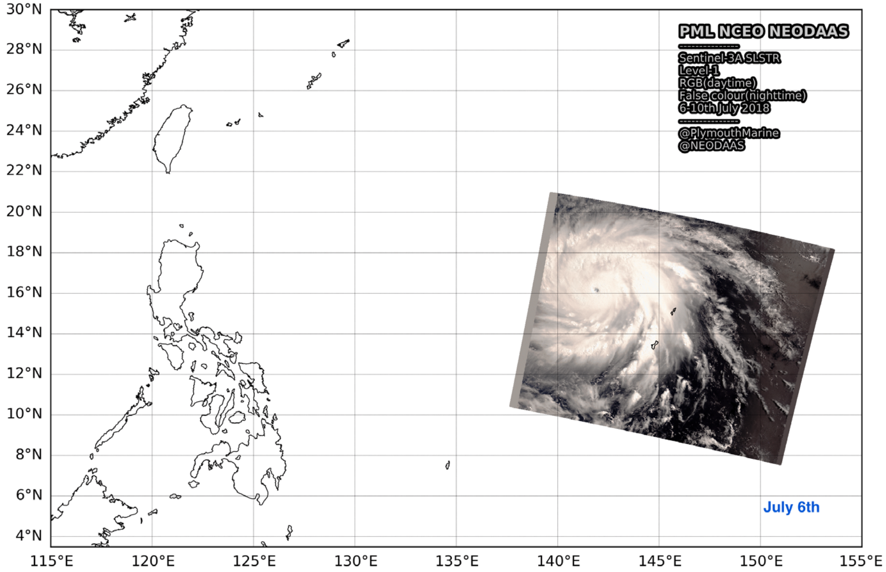
Further information on GHRSST and SST can be found here:

Introduction to GHRSST

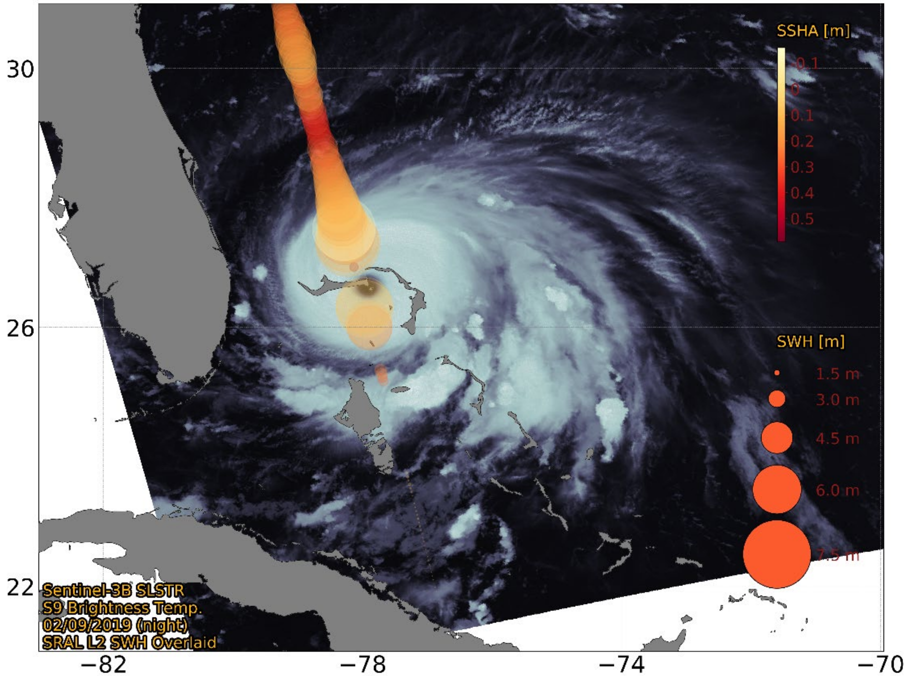
Merged SST products also exist:

- NASA MUR
  - Seeks to get benefit of coverage/resolution/accuracy from multi-scale combination of global TIR and microwave signals (1 km). Cannot separate MW and TIR contributions to final product.
- REMS MWIR
  - Combines MW and TIR signals using optimal interpolation (9 km). Has a mask to allow for MW and TIR separation.
- OSTIA
  - L4 merged product. AVHRR, AATSR, SEVIRI, AMSRE, TMI and *in situ* data. Optimally interpolated to 0.054° grid. Highly smoothed (v1).
- CMEMS
  - Variety of products including OSTIA and ODYSSEA
- SST-CCI

Applications of SST



Tropical Storm Maria from SLSTR

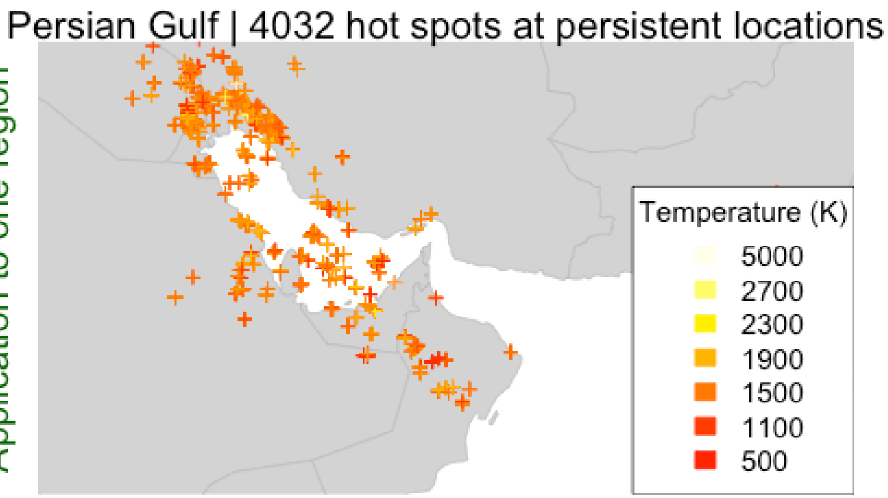


Hurricane Dorian from SLSTR and SRAL

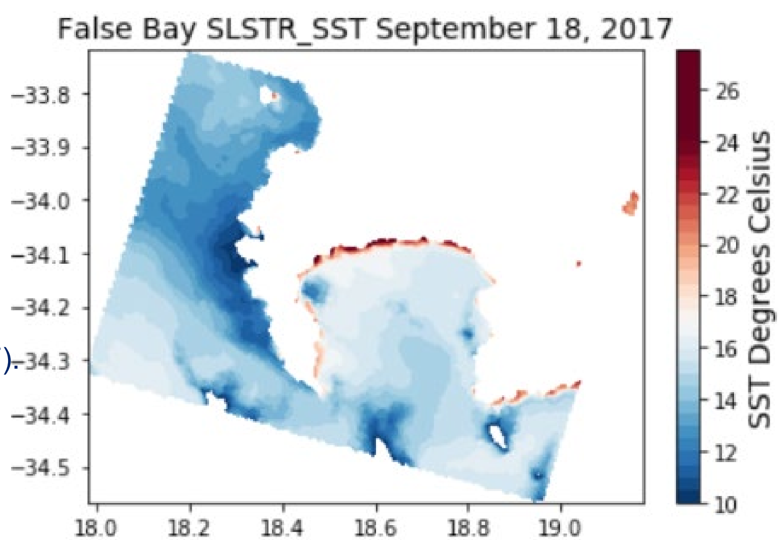
Applications of SST

ODYSSEA

Application to one region



Hotspots from oil/gas works in the Persian Gulf detected in SLSTR night data (Caseiro et al., 2018)

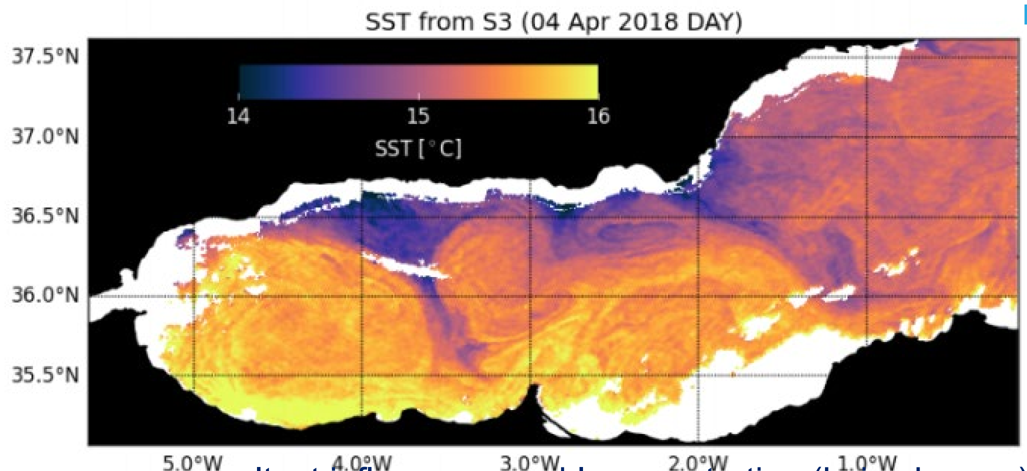


Upwelling dynamics, False Bay, South Africa (Renae Logston, 2017).

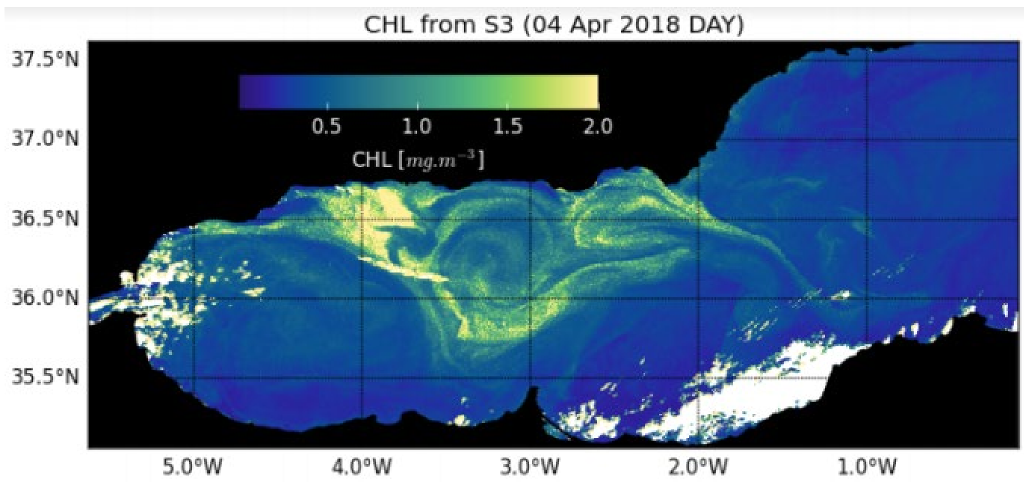
Applications of SST

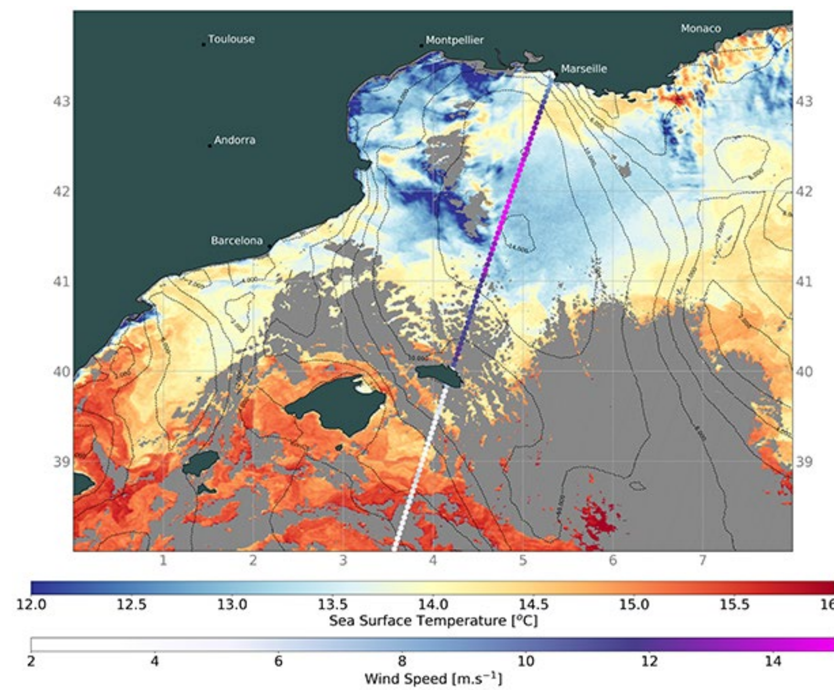
Alboran gyre identified in SST, and …

ODYSSEA



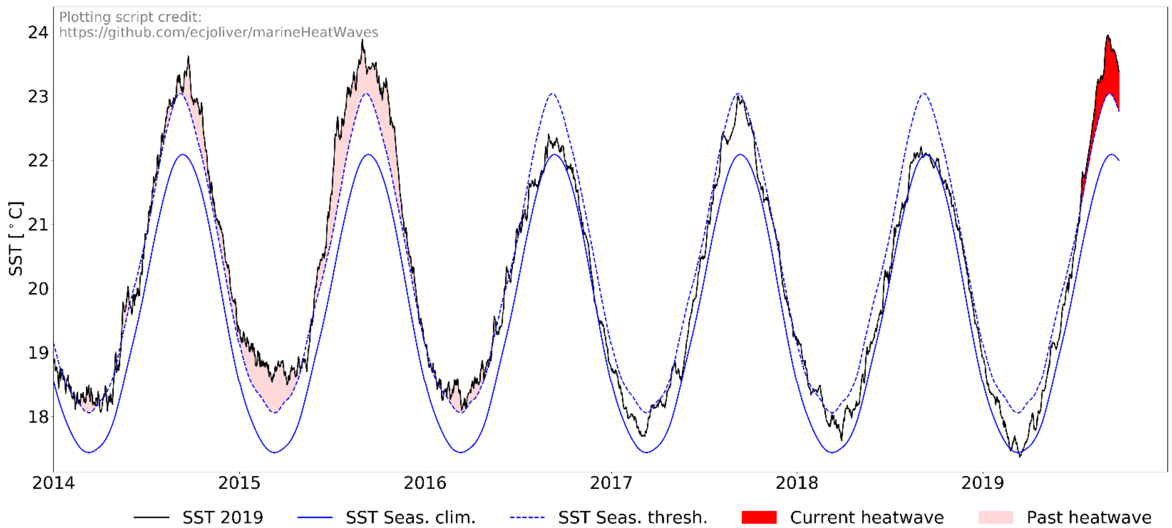
… resultant influences on chl concentration (Luisa Lamas)

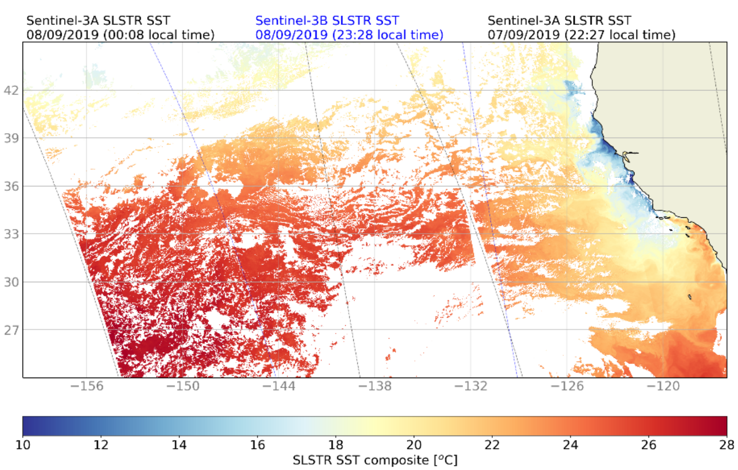


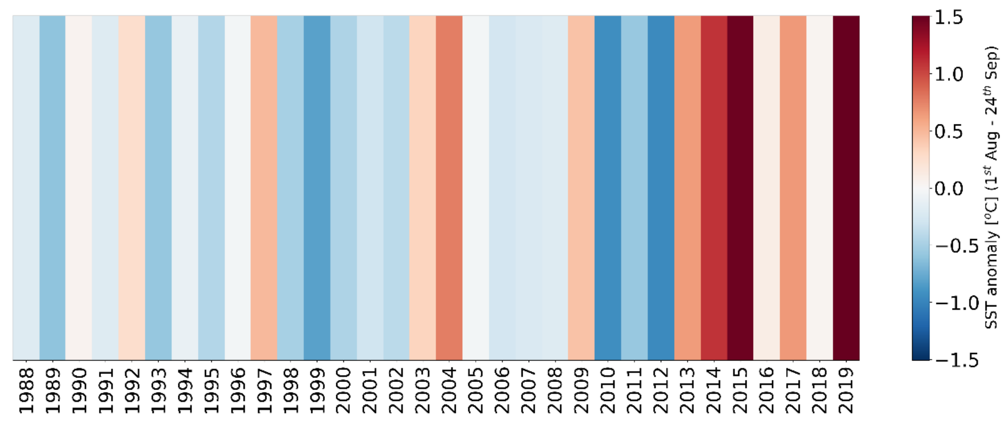


Deep water formation in the Gulf of Lion (SRAL and SLSTR)

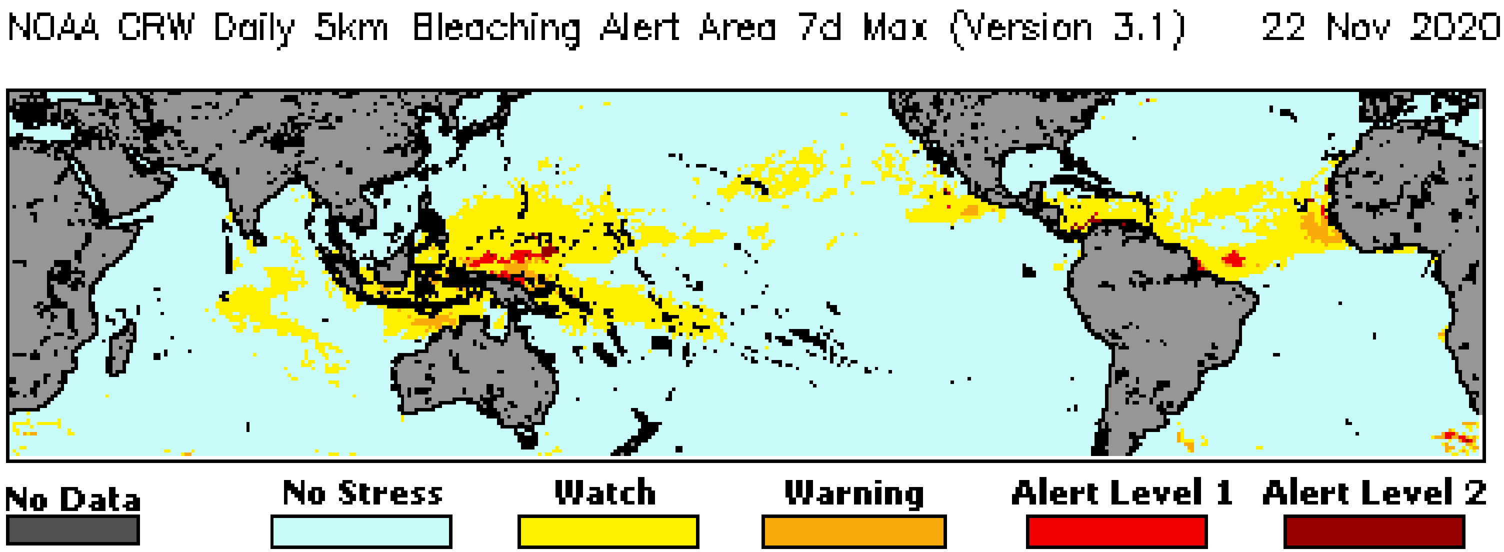
Applications of SST



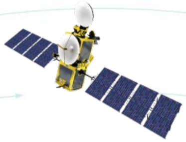


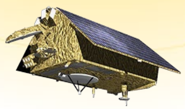


Applications of SST



https://coralreefwatch.noaa.gov/



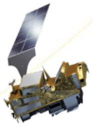


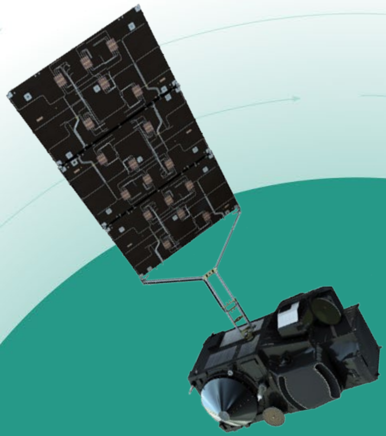
Working with Sea Surface Temperature data from Satellites

Dr Hayley Evers-King, EUMETSAT

ODYSSEA virtual school – Oceanography from Space

Hayley.EversKing@eumetsat.int, @HayleyEversKing





Choosing the right SST product for you

ODYSSEA

- Similar to other data sources:
  - What resolution do I need?
    - Highest – Sentinel-3 SLSTR
    - Global coverage – a merged product
  - What are my accuracy vs coverage requirements?
    - High accuracy/precision? Sentinel-3 with QC, OSTIA
    - More coverage e.g. for feature detection:
      - NASA MUR, ODYSSEA for example
  - What time period do I need?
    - NRT? – NRT products
    - Climate scale? – CDR products/Reprocessed

Accessing SST data

- Example using CODA: https://coda.eumetsat.int
- Example using OSI-SAF: http://www.osi-saf.org/?q=content/sst-products
- Example using CMEMS: https://marine.copernicus.eu

- Additional links:
    - GHRSST: https://www.ghrsst.org/

Working with SST data in SNAP

ODYSSEA

- **Quick demonstration**

- More detail about key processing steps here: https://www.youtube.com/watch?v=lKyUeN3uS0Q&list=PLOQg9n6Apif1ODObv39j43j8IAvJDOAVY&index=4

- Details on products: https://www.eumetsat.int/media/45983

- Further training opportunities for using Python – see https://training.eumetsat.int and https://wekeo.eu

Working with Copernicus L3/L4 SST data

- Demonstration of new CMEMS visualisation service
- Can also use any software that will work with NetCDF files
  - Further training courses use Python etc from CMEMS and WEkEO

THE MARINOMICA PLATFORM

Simon Keeble

Blue Lobster IT Limited

simon@bluelobster.co.uk

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727277

bluelobster
Software • Graphics • Communication

ODYSSEA

Marinomica

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727277

Defining Marinomics

marinomics

/məˈriːn’nɒmɪks/

1. The science of decision making in the marine environment.

2. The branch of knowledge concerned with the production, consumption, and transfer of wealth in the marine environment.

We see this as an opportunity to create and manage a Wikipedia definition and to take this definition forward and, hopefully, spread the definition.

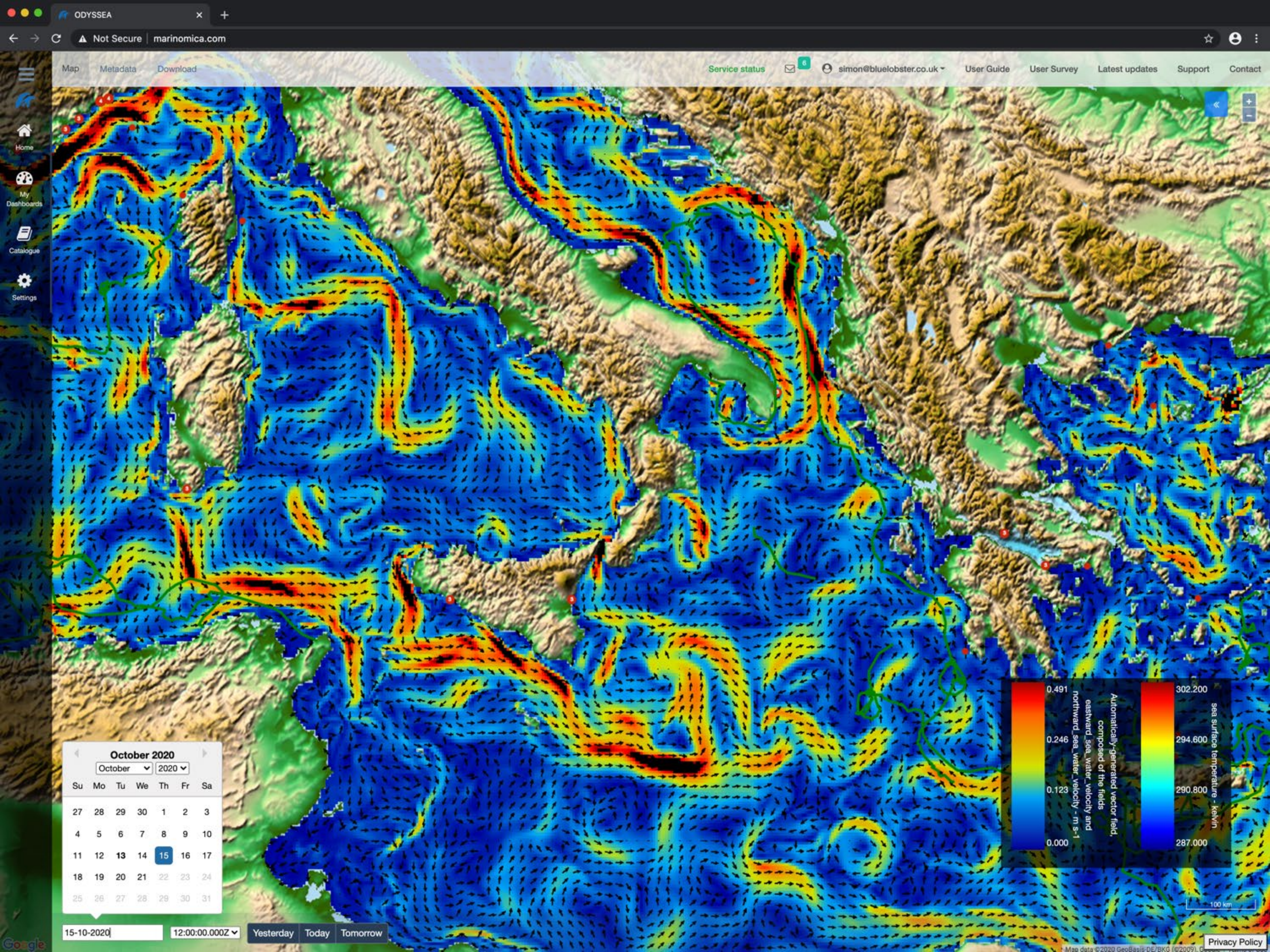
By defining a new field appropriately, this will give us a superb marketing opportunity to talk about a the field, what it includes (data science, economics, intelligent product design etc) and how the platform fills this space.

We have therefore branded the application as ***Marinomica***

Marinomica

The Mediterranean's Digital Twin

Forecasting and simulations to enable decision making and expand knowledge concerned with the production, consumption, and transfer of wealth in the marine environment.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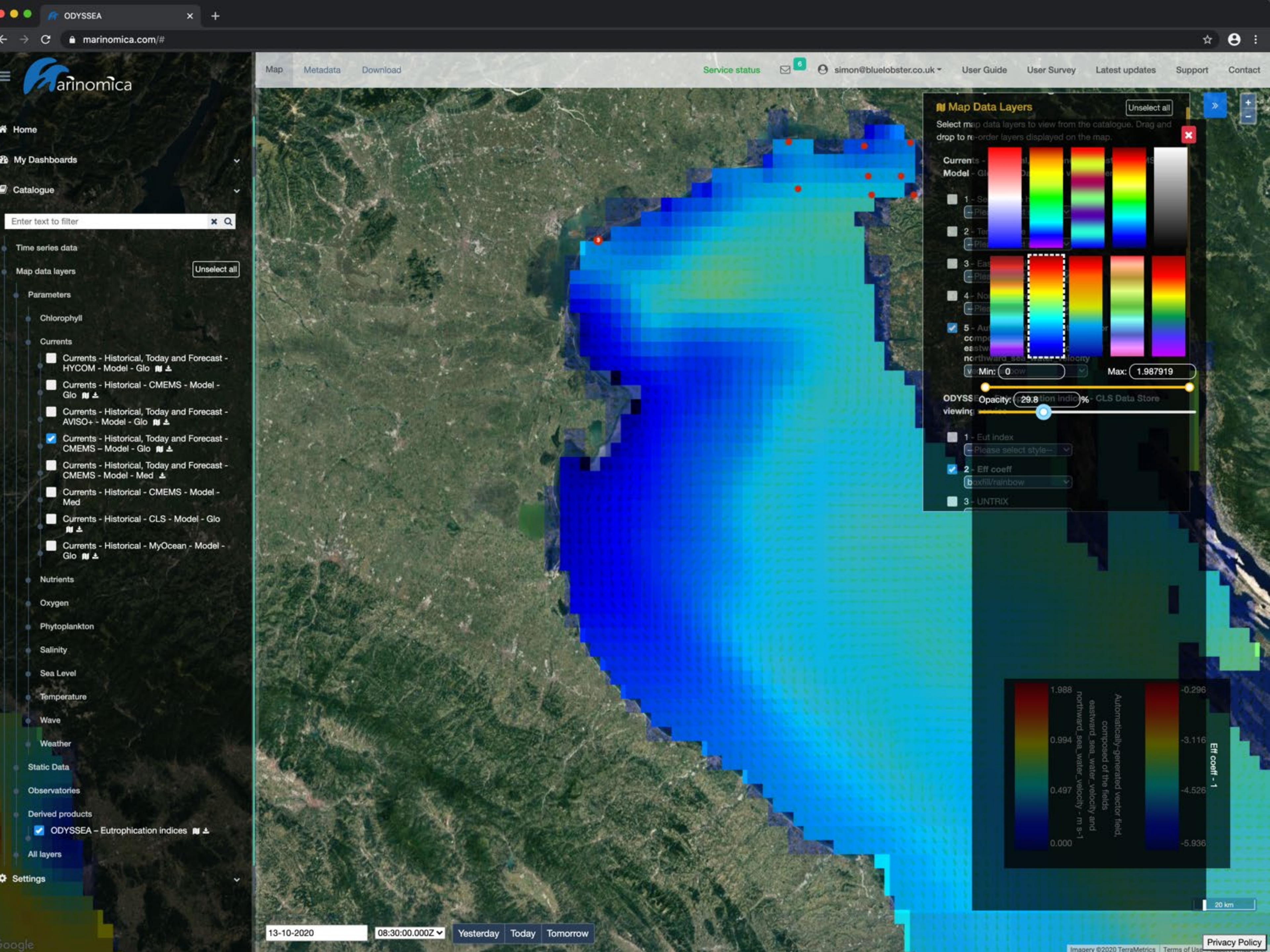
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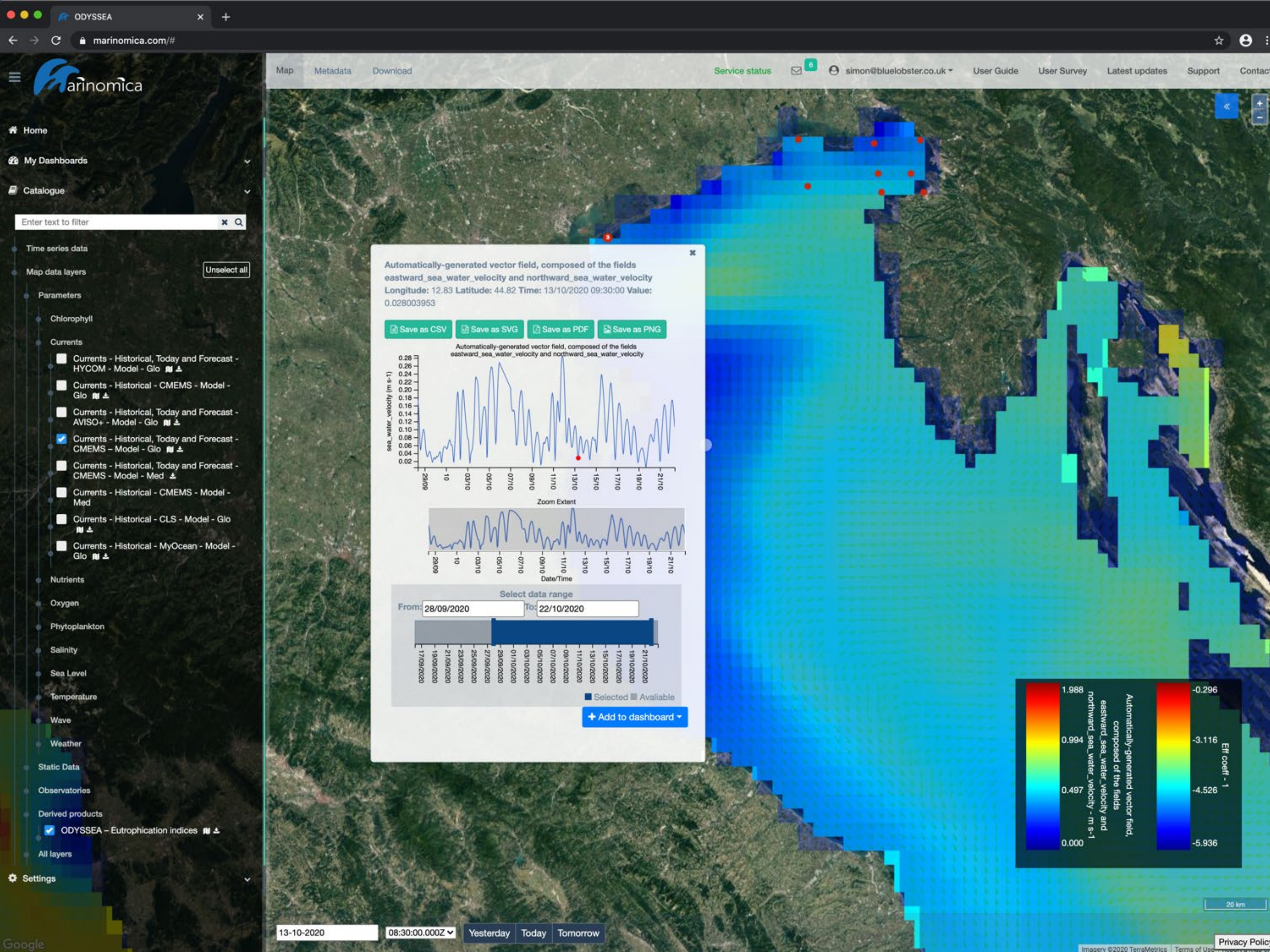
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Longitude: 12.83 Latitude: 44.82 Time: 13/10/2020 09:30:00 Value: 0.028003953
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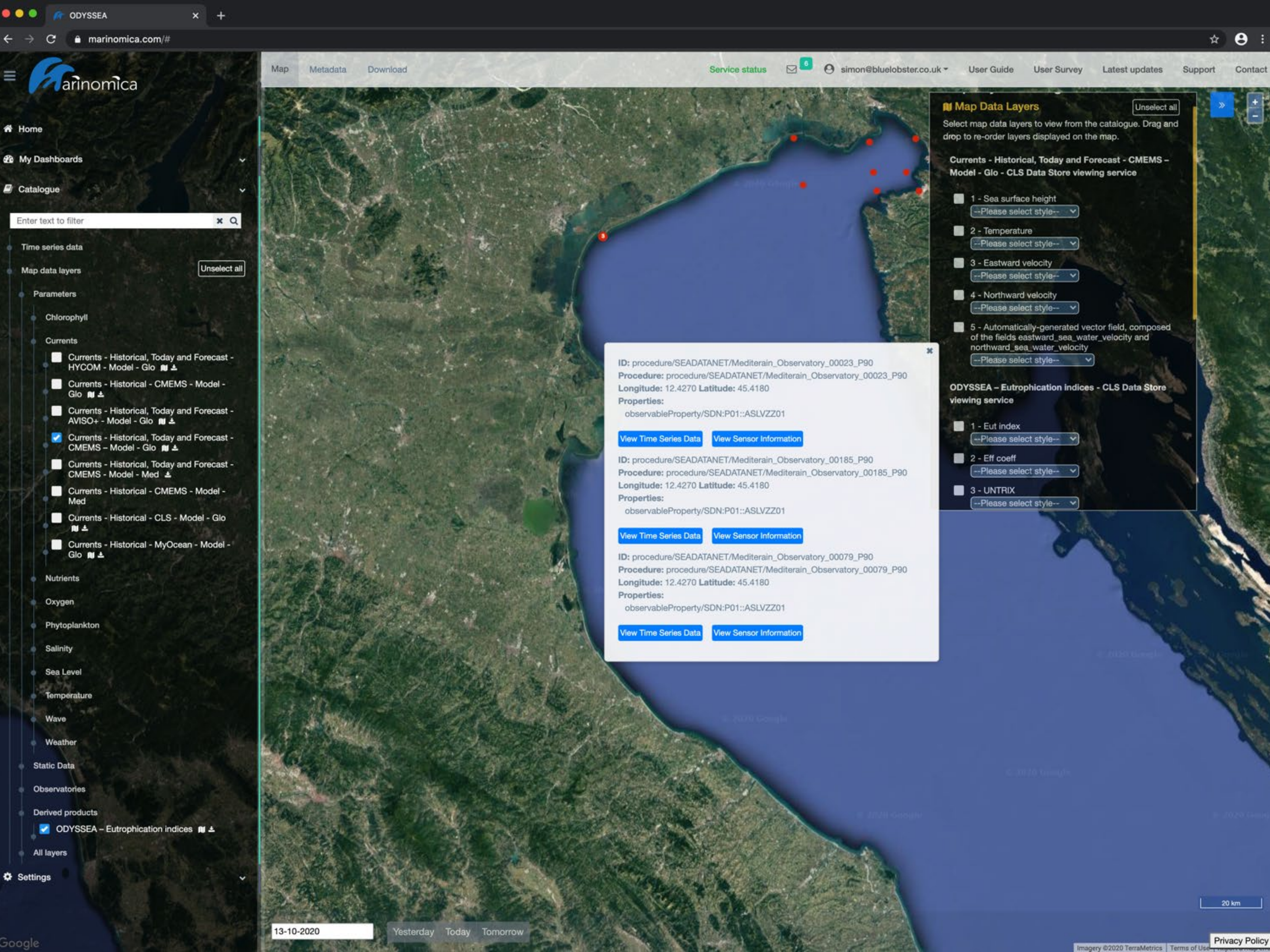
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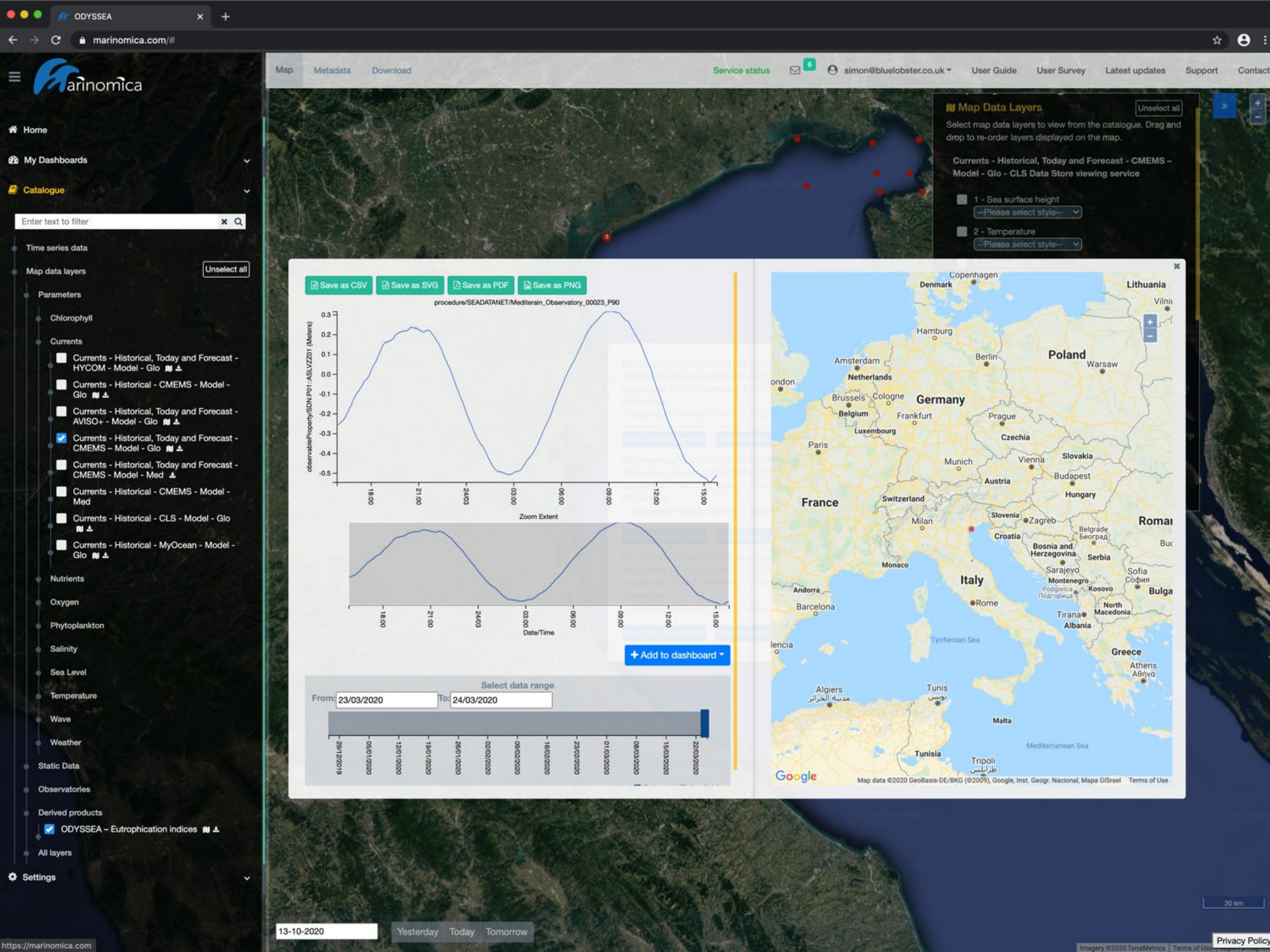
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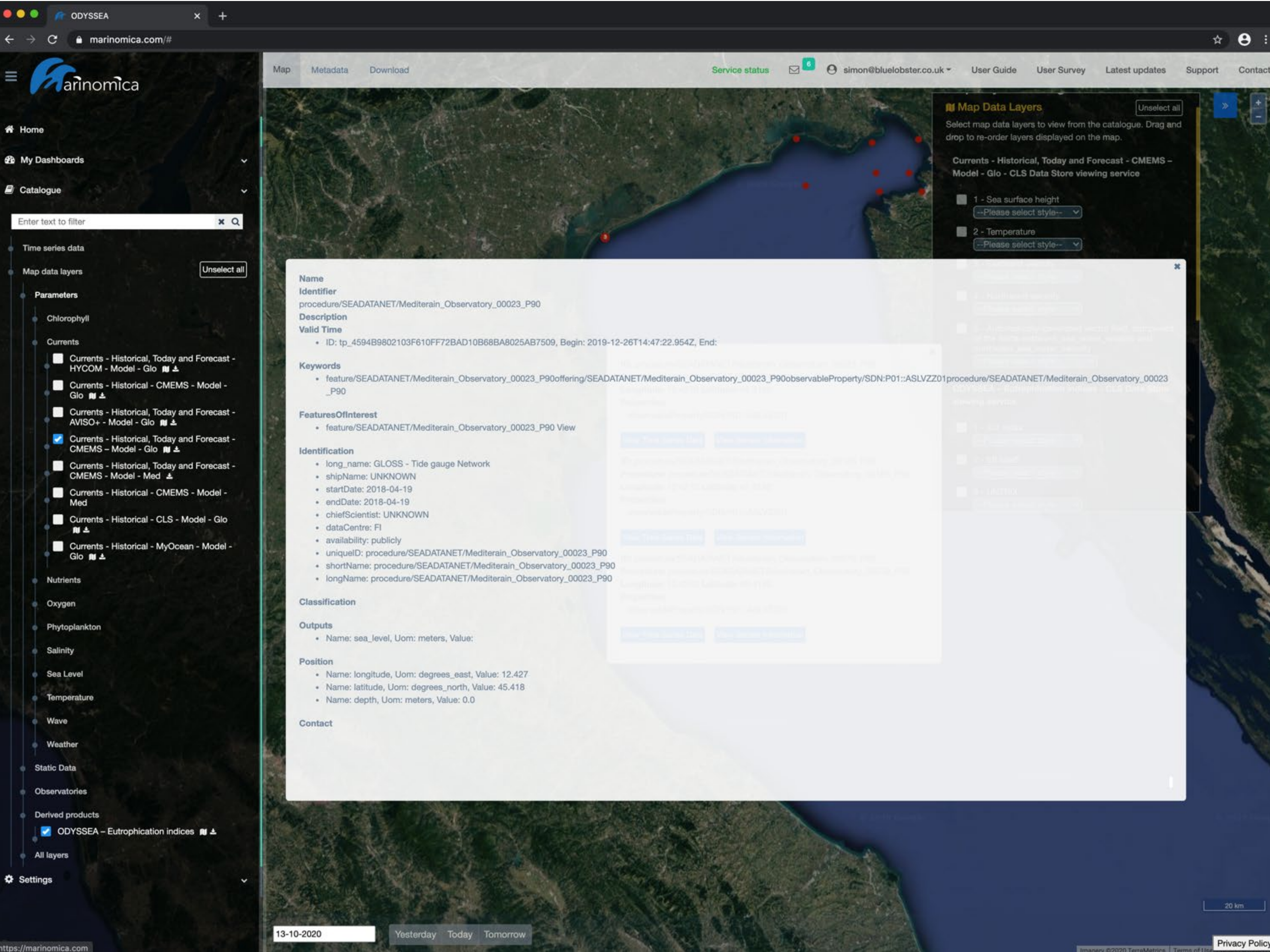

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Keywords
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FeaturesOfInterest
feature/SEADATANET/Mediterain_Observatory_00023_P90 View
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endDate: 2018-04-19
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dataCentre: FI
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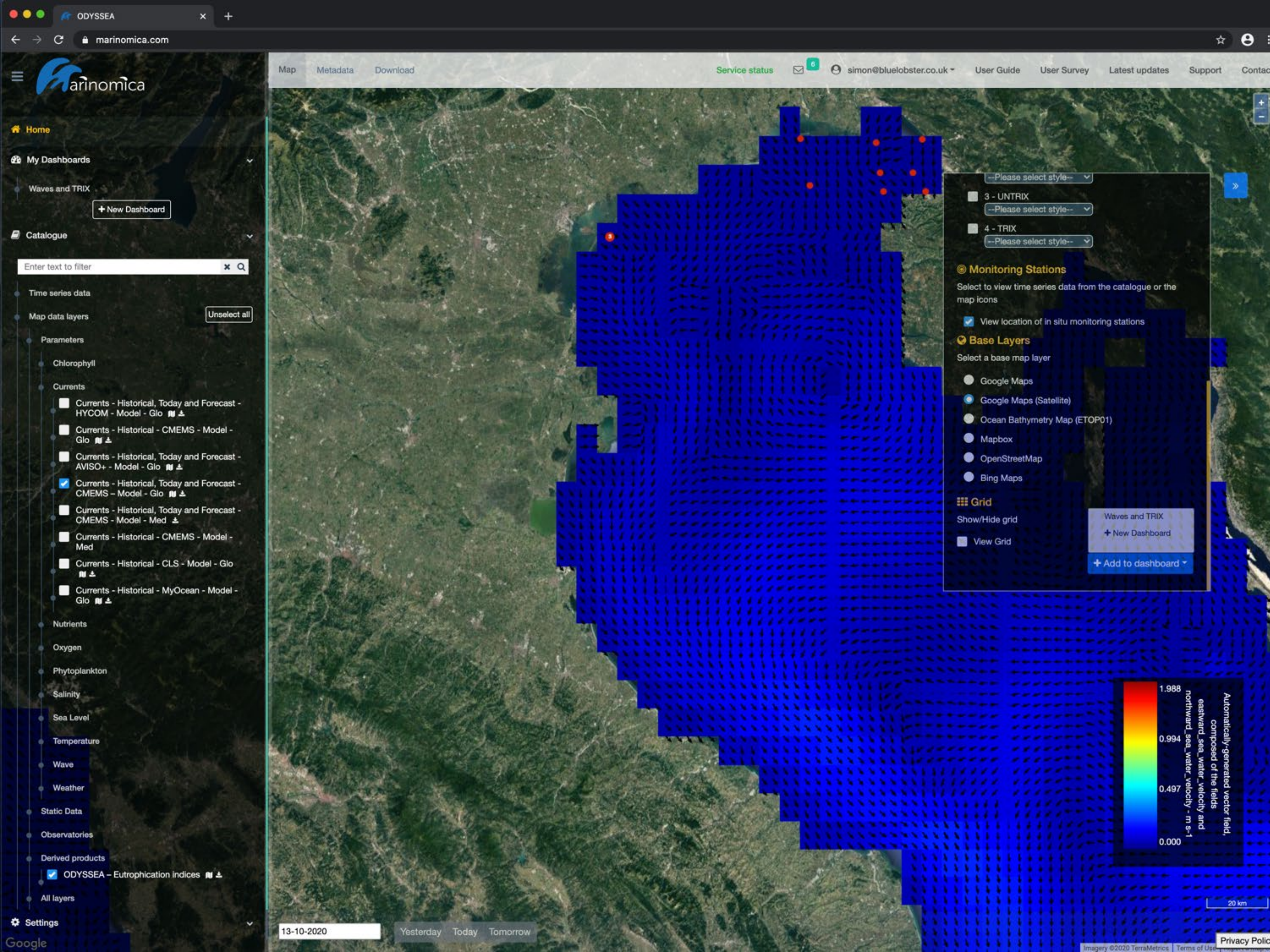
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Ocean Bathymetry Map (ETOP01)
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ODYSSEA – Eutrophication indices

Trophic state index used to explain the eutrophication state at mediterrenean sea

Abstract

TRIX is a trophic state index used to explain the eutrophication state at sea, covering a wide range of trophic conditions from oligotrophy to eutrophy (Vollenweider et al. 1998). According to TRIX scaling, values < 4 refer to oligotrophic waters with good water column transparency; values 4 to 5 refer to moderate productive waters with occasional incidents of hypoxia; values 5 to 6 refer to mesotrophic waters of limited water transparency and hypoxia to occasional anoxic events, and values >6 refer to eutrophic waters with high benthic mortality risk and persistent hypoxic/anoxic incidents.

TRIX has been applied to several coastal marine systems, as the Adriatic (Giovanardi & Vollenweider, 2004), the Black Sea (Dyatlov et al., 2010) and the eastern Mediterranean Sea (Tugrul et al., 2011). TRIX index is based on four state variables directly related to productivity: chlorophyll-a (Chl, mg m−3), dissolved oxygen as the absolute percentage deviation from oxygen saturation (DO, %), dissolved inorganic nitrogen (DIN, mg m−3) and total phosphorus (TP, mg m−3).

For the development and integration of the TRIX index in ODYSSEA platform, several assumptions were made in order to use the data available through CMEMS.

Nitrates are the main nitrogen species contribution to the total DIN, due to the lack of ammonia data. In open sea, ammonia and nitrites are of relative low concentration and at the sea surface ammonia rapidly oxidises to nitrates. (When ODYSSEA models are in place, ammonia concentration will be available and the algorithm will be changed slightly to include it especially in areas where wastewater treatment plants outfall).

Orthophosphates are the main component of total phosphorus. This is true for the inorganic component, perhaps not true for the organic one, but it is very hard to find data on organic phosphorus (particulate and dissolved) and this is a commonly made assumption.

For the computation of deviation of current DO level from saturation a step-by-step procedure was provided in the deliverable 13.2.

Finally, the coefficients of TRIX calculation are based on data from the Adriatic, general applicability to other areas might not be guaranteed. This means that a rescaling will be needed at a later stage.

The algorithm code was initially industrialized in collaboration between Thales and GTD. The work consisted in adding configuration support, integrating automatic source data download from CMEMS, adding error handling & console logging, and generating NetCDF compliant output files.

Later, the industrialized algorithm was taken by GTD, and wrapped into a Docker image based on the WPS 2.0 framework developed by CLS. This is the image that has been finally integrated into ODYSSEA platform in order to launch the product automatically.

Online Resources

Name: CLS Data Store download service
Description: Download with temporal and geospatial extraction (OGC WCS)
Protocol: HTTPS
Link: https://motu-datastore.cls.fr/motu-web/Motu?action=productdownloadhome&service=ODYSSEA_data-TDS&product=dataset-odyssea-trixmedsea

Name: CLS Data Store download service
Description: Download with temporal and geospatial extraction (OGC WCS)
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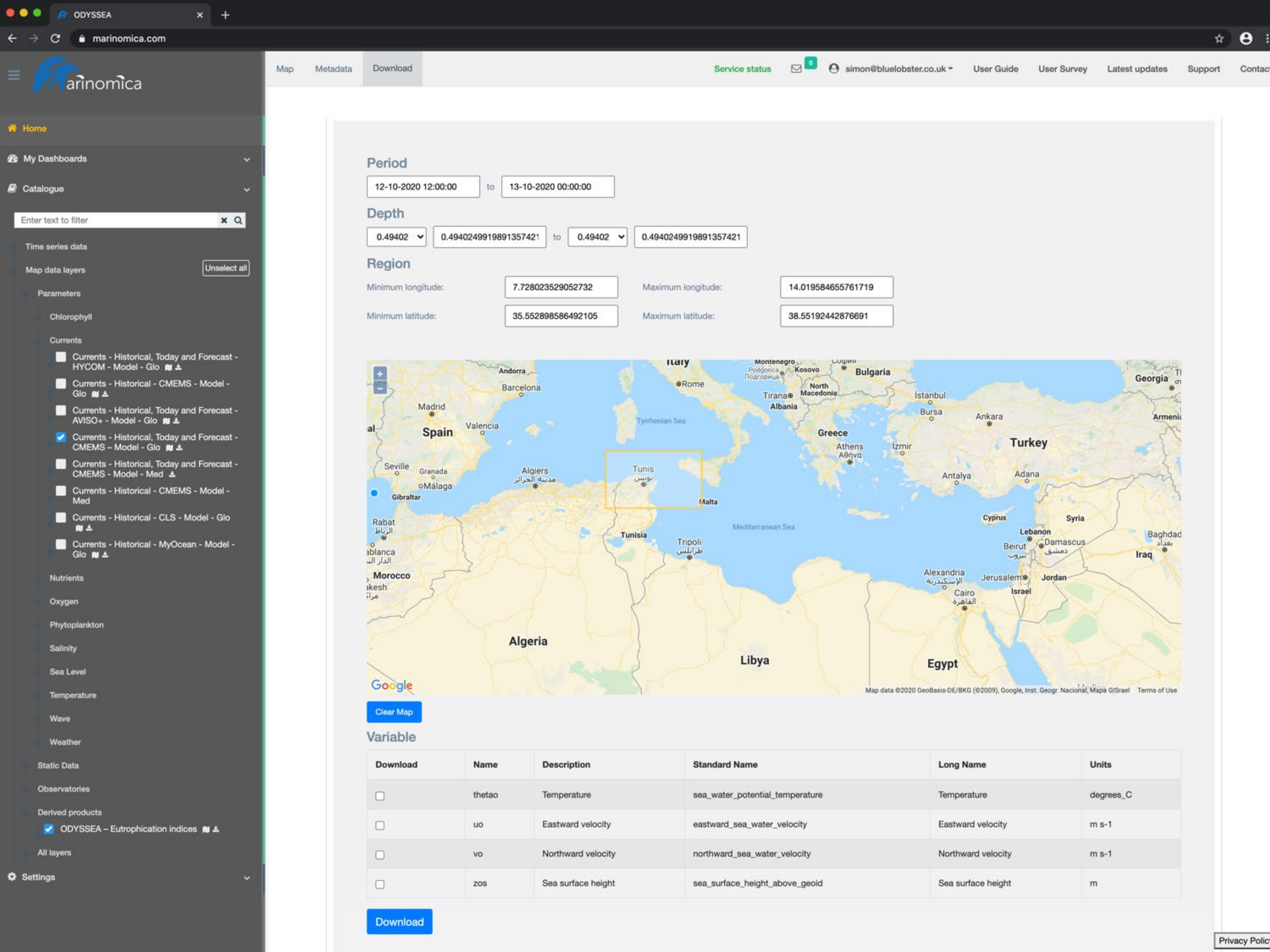
Name: CLS Data Store viewing service
Description: Viewing with temporal and geospatial extraction (OGC WMS)
Protocol: HTTPS
Link: https://tds-datastore.cls.fr/thredds/wms/dataset-odyssea-trixmedsea?service=WMS&version=1.3.0&request=GetCapabilities

Keywords	**Source**	**Modified**
Type	**References**	**Date**
	Rights	**Language**
		URI

Bounding Box

Bottom left corner: lat: 30.1875/lon:36.29166793823242
Top right corner: lat: 45.97916793823242/lon:-5.541666507720947

Privacy Polic


ODYSSEA
marinomica.com
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Map
Metadata
Download
Service status
simon@bluelobster.co.uk
User Guide
User Survey
Latest updates
Support
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Catalogue
Enter text to filter
Time series data
Map data layers
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Parameters
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Nutrients
Oxygen
Phytoplankton
Salinity
Sea Level
Temperature
Wave
Weather
Static Data
Observatories
Derived products
ODYSSEA – Eutrophication indices
All layers
Settings
Period
12-10-2020 12:00:00
to
13-10-2020 00:00:00
Depth
0.49402
0.4940249919891357421
to
0.49402
0.4940249919891357421
Region
Minimum longitude: 7.728023529052732
Maximum longitude: 14.019584655761719
Minimum latitude: 35.552898586492105
Maximum latitude: 38.55192442876691
Italy
Bulgaria
Georgia
Spain
Turkey
Greece
Tunis
Tunisia
Malta
Mediterranean Sea
Morocco
Algeria
Libya
Egypt
Syria
Iraq
Google
Map data ©2020 GeoBasis-DE/BKG (©2009), Google, Inst. Geogr. Nacional, Mapa GISrael
Terms of Use
Clear Map
Variable
Download | Name | Description | Standard Name | Long Name | Units
thetao | Temperature | sea_water_potential_temperature | Temperature | degrees_C
uo | Eastward velocity | eastward_sea_water_velocity | Eastward velocity | m s-1
vo | Northward velocity | northward_sea_water_velocity | Northward velocity | m s-1
zos | Sea surface height | sea_surface_height_above_geoid | Sea surface height | m
Download
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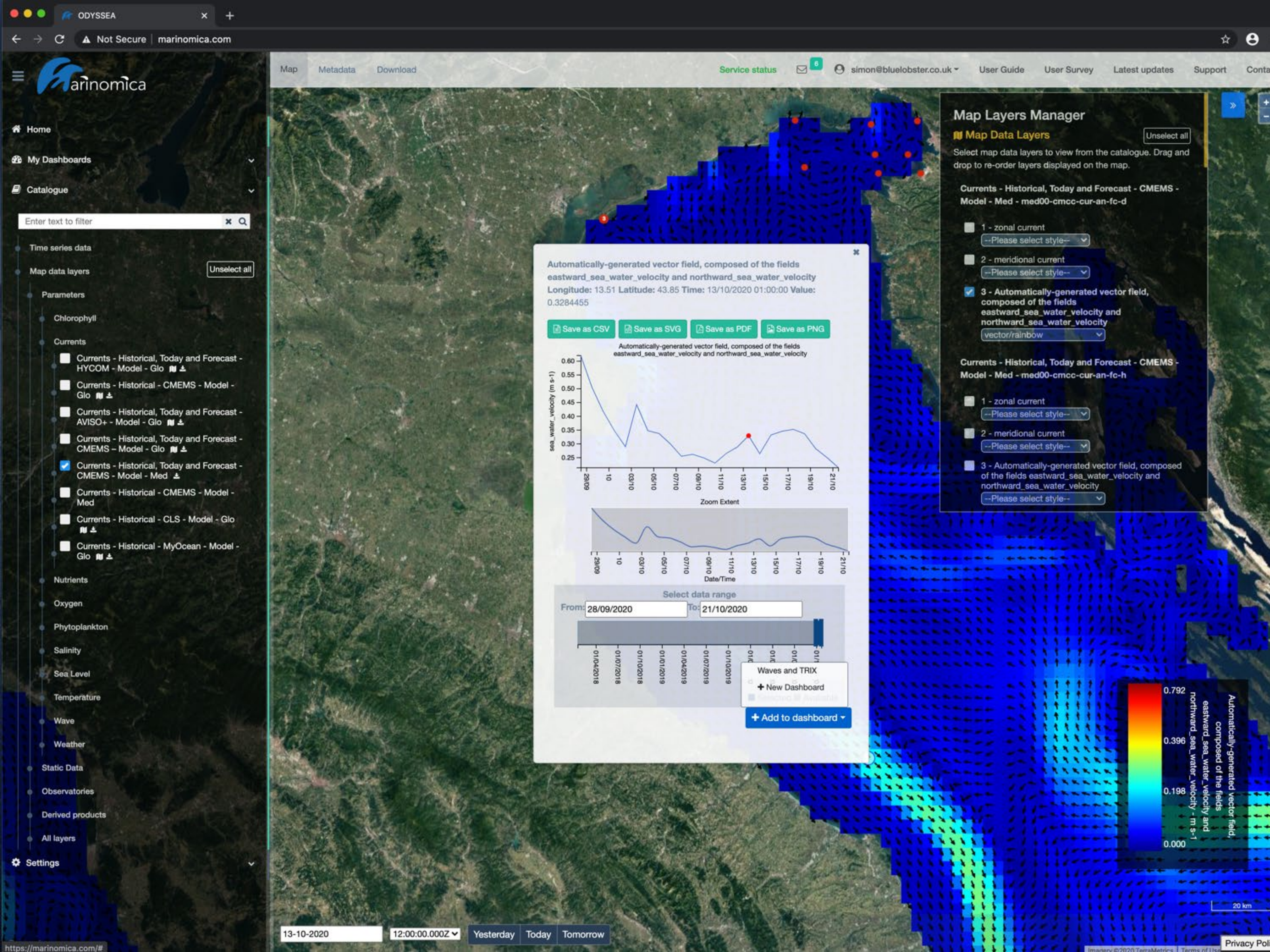
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Nutrients
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Salinity
Sea Level
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Static Data
Observatories
Derived products
All layers
Settings
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simon@bluelobster.co.uk
User Guide
User Survey
Latest updates
Support
Automatically-generated vector field, composed of the fields eastward_sea_water_velocity and northward_sea_water_velocity
Longitude: 13.51 Latitude: 43.85 Time: 13/10/2020 01:00:00 Value: 0.3284455
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Save as SVG
Save as PDF
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sea_water_velocity (m s-1)
Zoom Extent
Date/Time
Select data range
From: 28/09/2020
To: 21/10/2020
Waves and TRIX
New Dashboard
Add to dashboard
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Select map data layers to view from the catalogue. Drag and drop to re-order layers displayed on the map.
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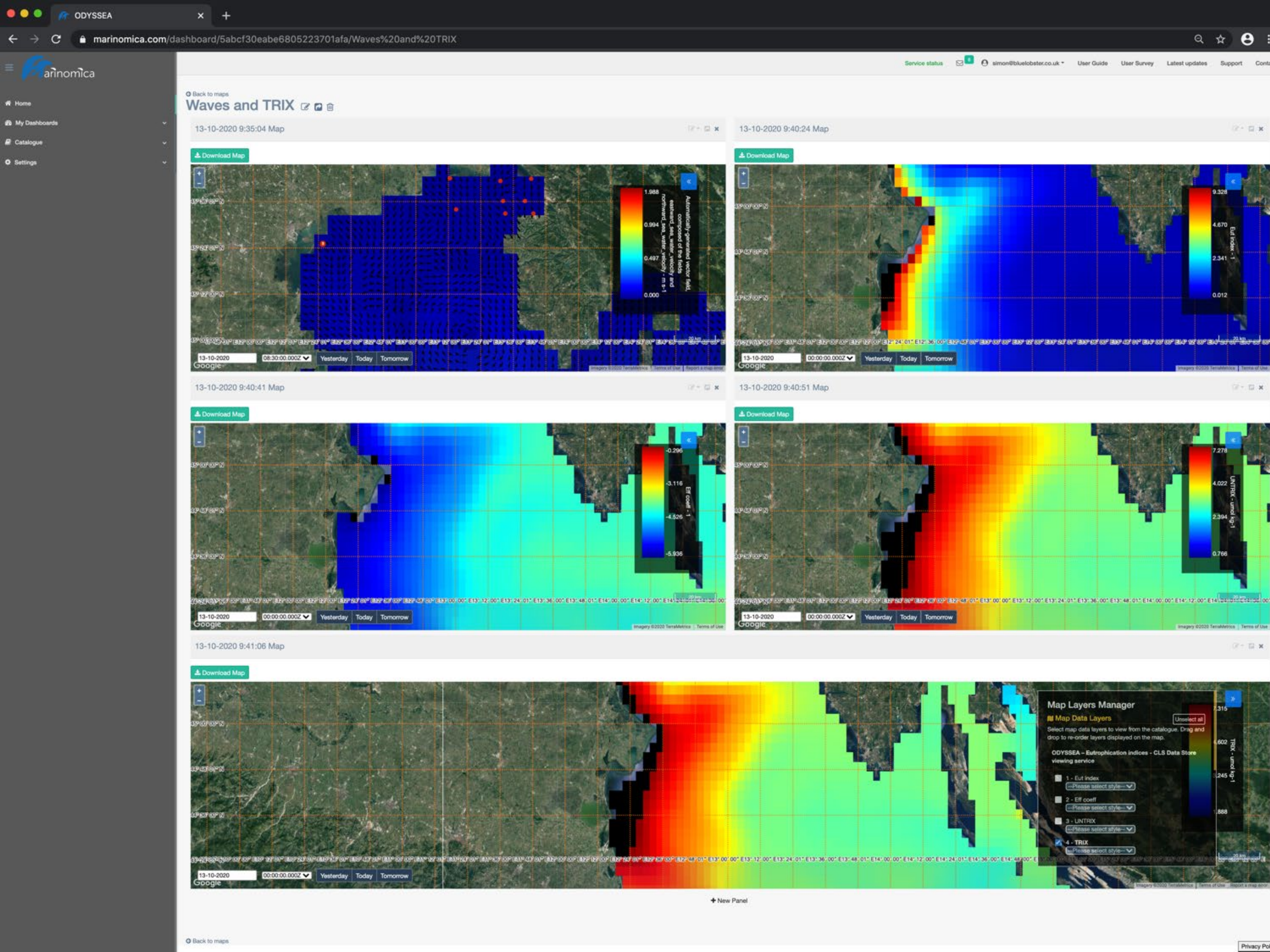

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Service status
simon@bluelobster.co.uk
User Guide
User Survey
Latest updates
Support
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Back to maps
Waves and TRIX
13-10-2020 9:35:04 Map
13-10-2020 9:40:24 Map
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13-10-2020 9:40:41 Map
13-10-2020 9:40:51 Map
13-10-2020 9:41:06 Map
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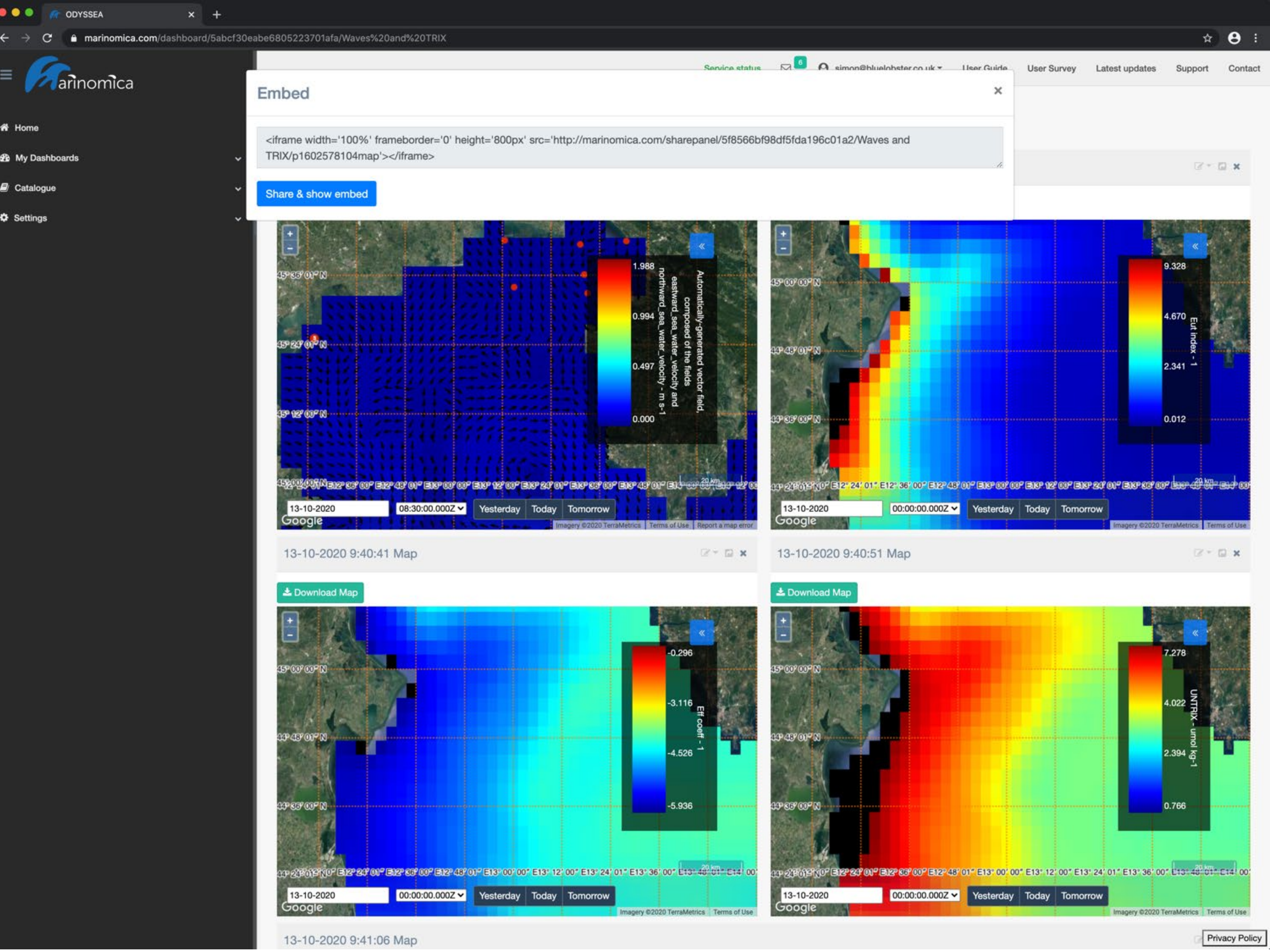
Back to maps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Share & show embed
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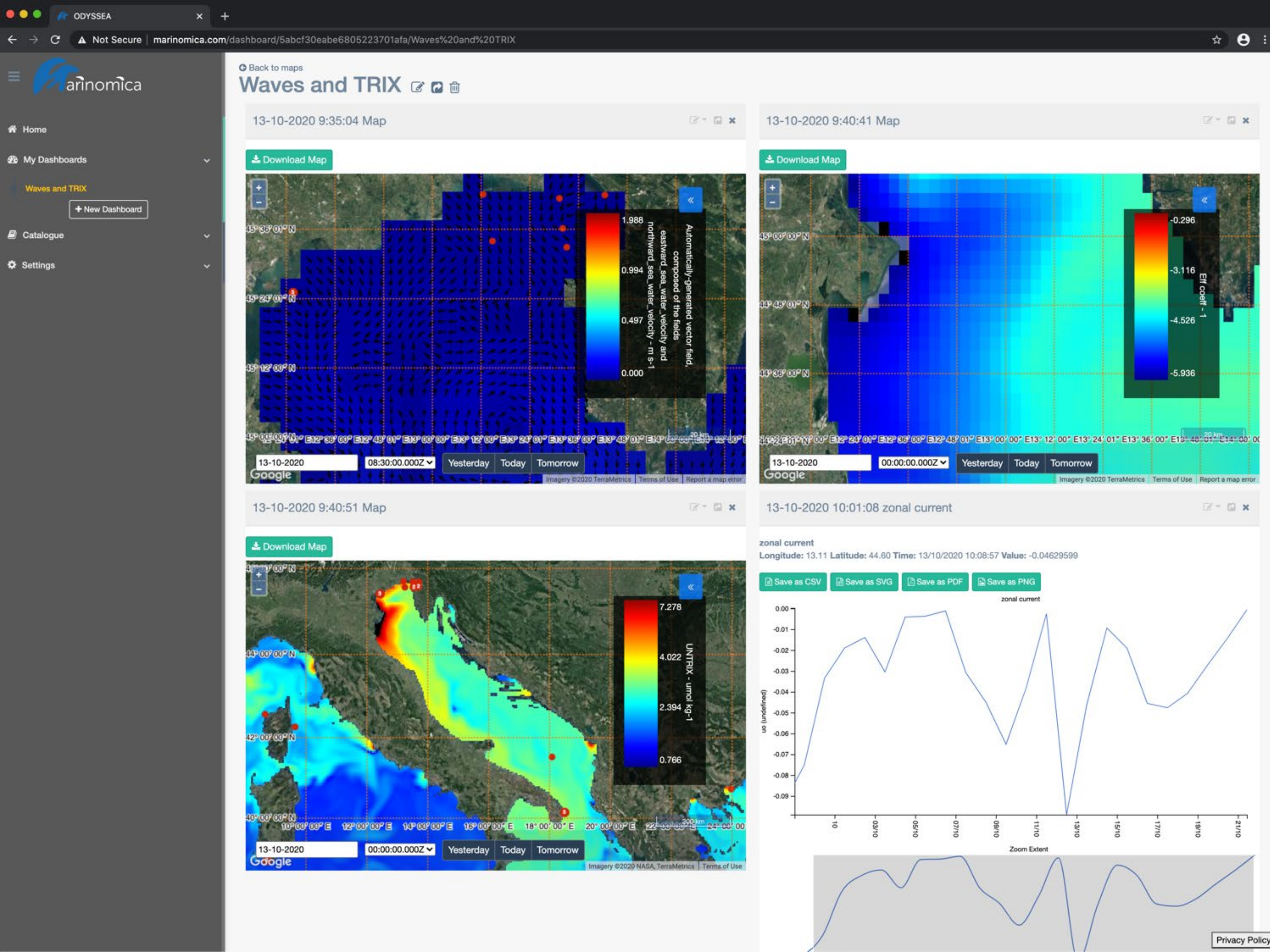
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Longitude: 13.11 Latitude: 44.60 Time: 13/10/2020 10:08:57 Value: -0.04629599
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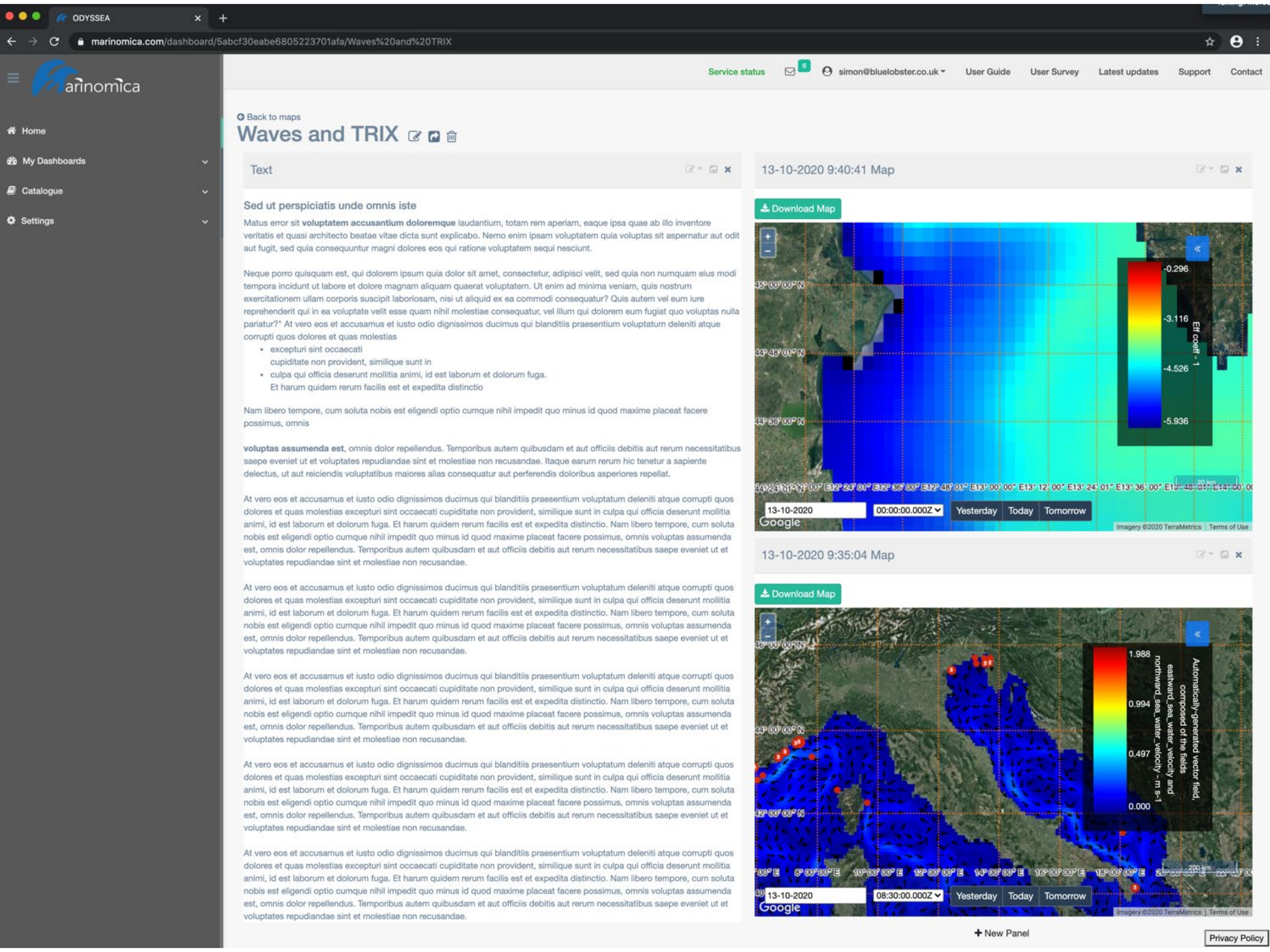
Privacy Policy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Imagery ©2020 TerraMetrics
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Imagery ©2020 TerraMetrics
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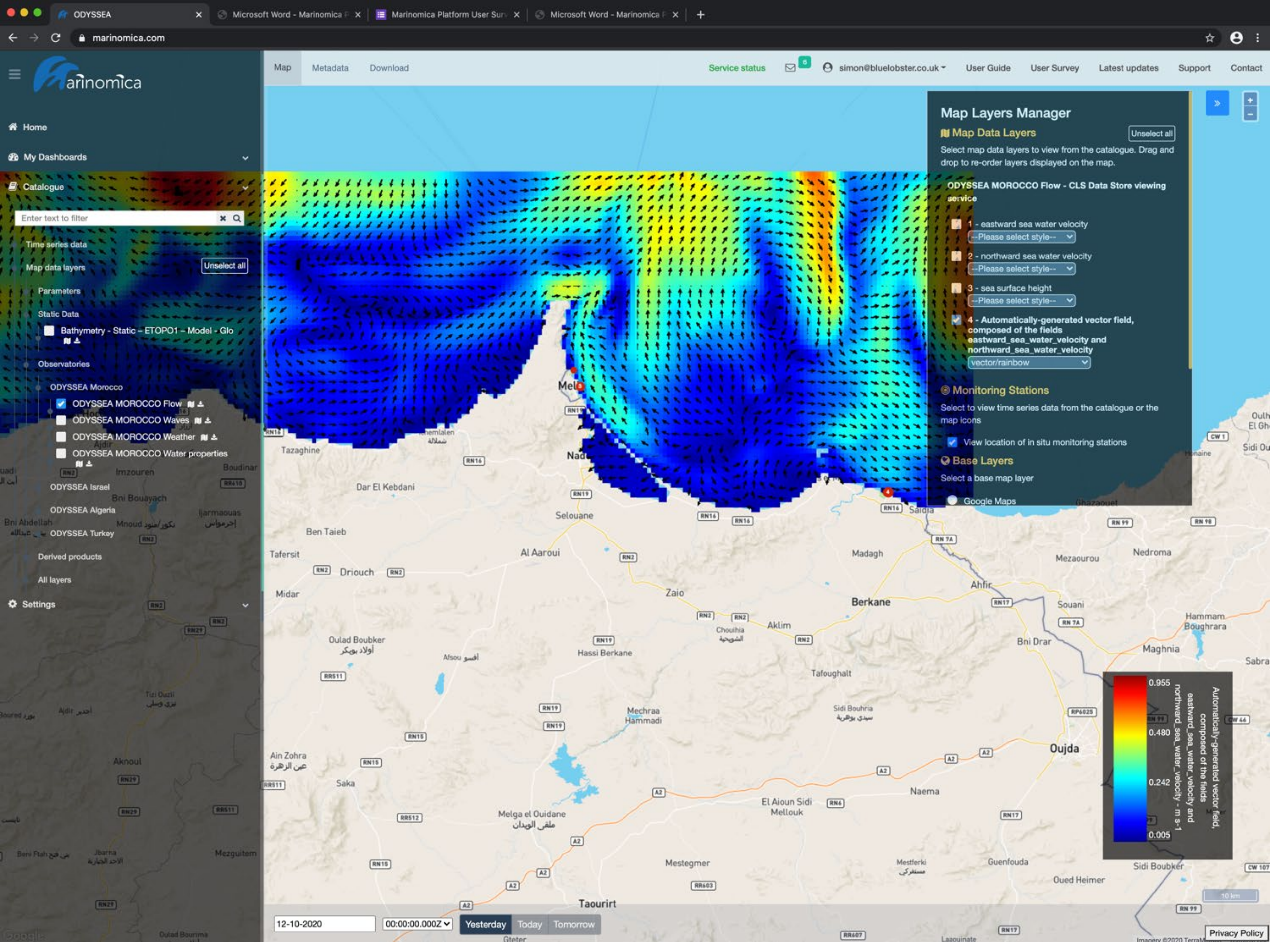
New Panel
Privacy Policy



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Time series data
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Static Data
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ODYSSEA MOROCCO Flow
ODYSSEA MOROCCO Waves
ODYSSEA MOROCCO Weather
ODYSSEA MOROCCO Water properties
ODYSSEA Israel
ODYSSEA Algeria
ODYSSEA Turkey
Derived products
All layers
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Service status
simon@bluelobster.co.uk
User Guide
User Survey
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Support
Contact
Map Layers Manager
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Unselect all
Select map data layers to view from the catalogue. Drag and drop to re-order layers displayed on the map.
ODYSSEA MOROCCO Flow - CLS Data Store viewing service
1 - eastward sea water velocity
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2 - northward sea water velocity
--Please select style--
3 - sea surface height
--Please select style--
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Monitoring Stations
Select to view time series data from the catalogue or the map icons
View location of in situ monitoring stations
Base Layers
Select a base map layer
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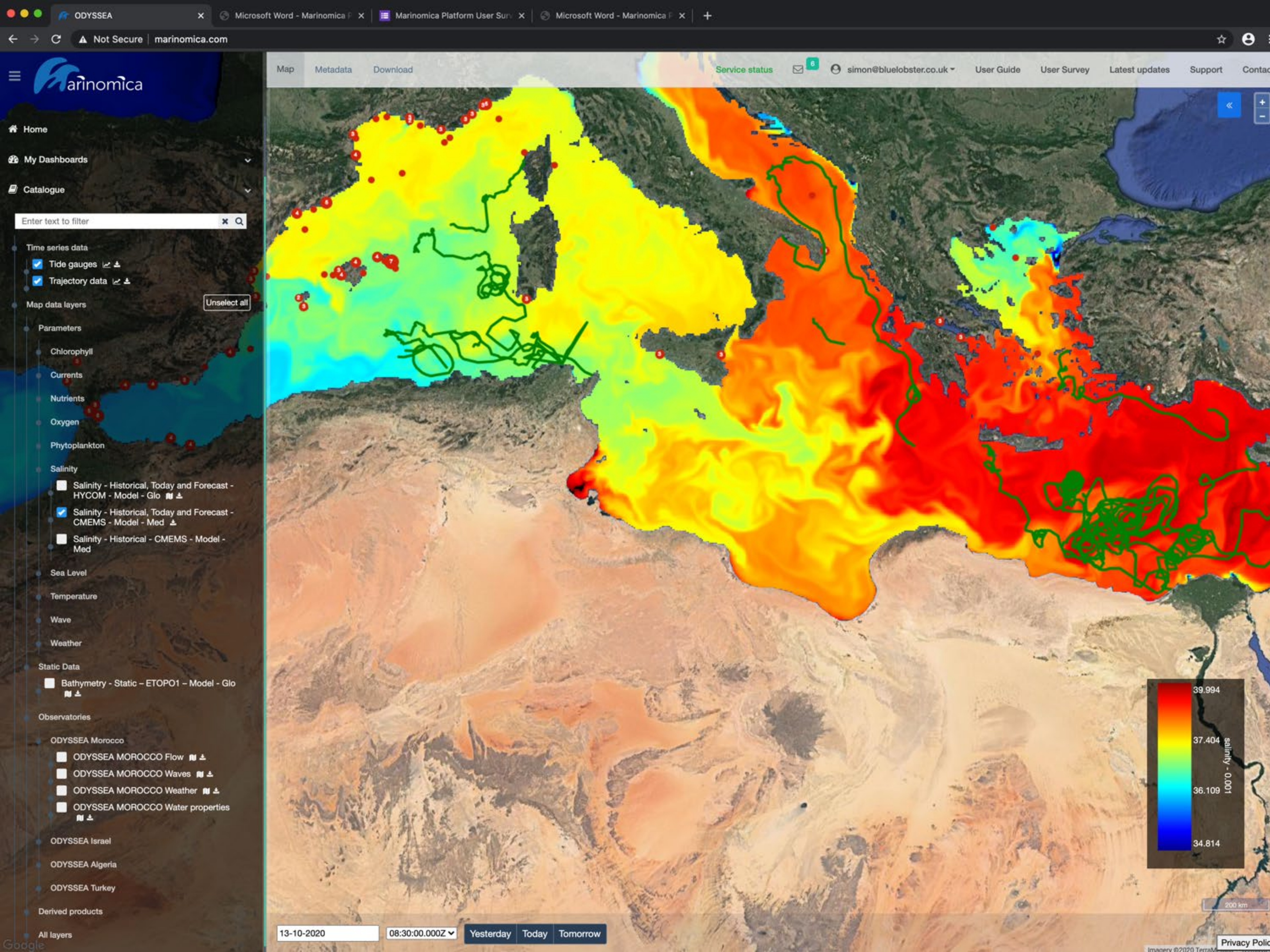
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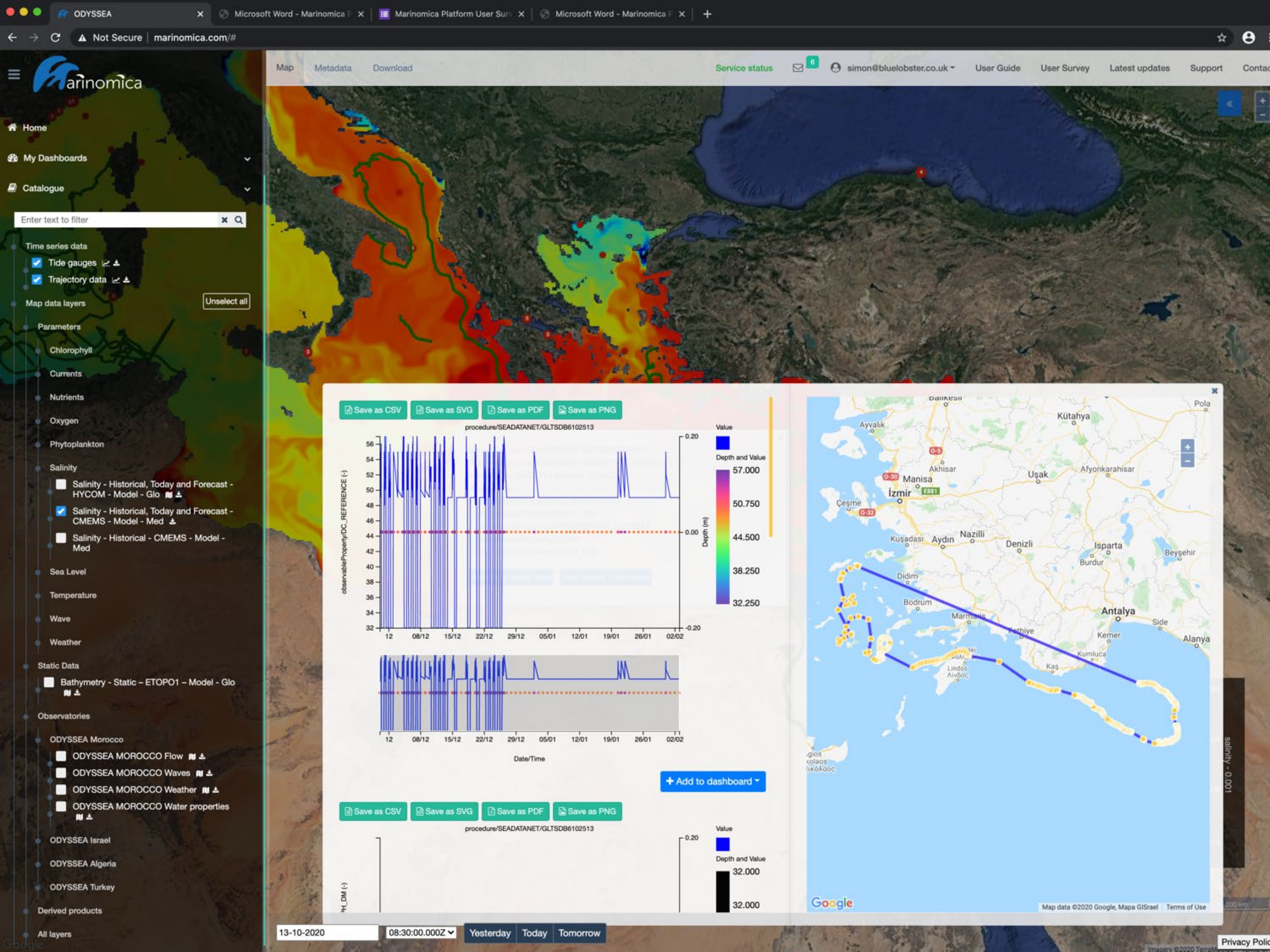
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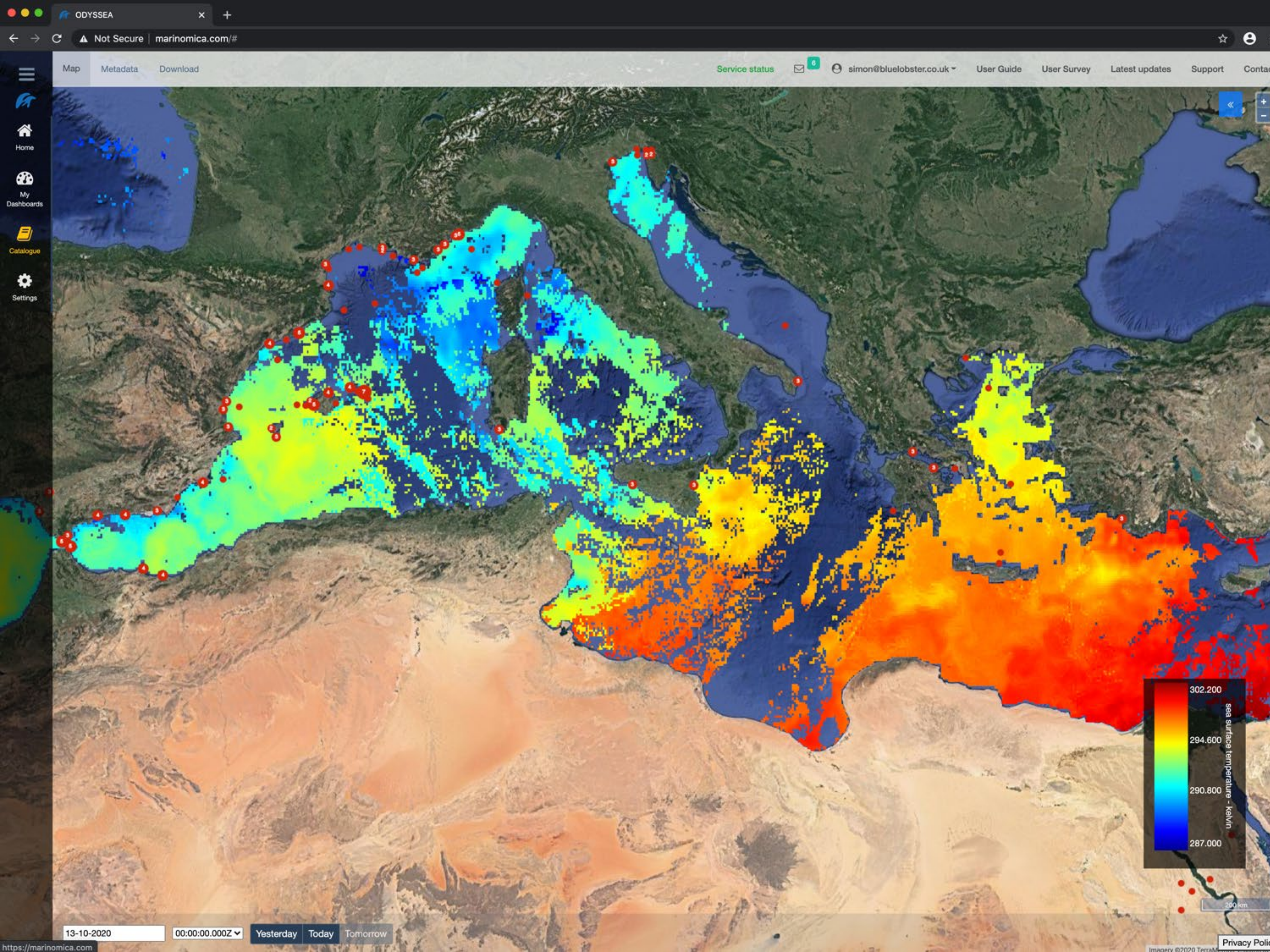
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https://marinomica.com
Privacy Poli

Where are we now

ODYSSEA

- Beta version live at **marinomica.com**
- Receiving feedback now
- Embarking on next evolution of development
- Mobile app in development, combining citizen science data
- Launching early 2021
- Business establishing to take forward

New features in next evolution (in addition to fixes!)

ODYSSEA

Enhanced dashboard functionality

- New visualisations
- Improved performance and user experience
- Simplified visualisations for specific user types
- Pre-configured dashboards for specific fields of interest (Eutrofication, Wave Power, Jellyfish, Marine litter, Climate etc.)
- Sharing dashboards (inside and outside of the application)

ODYSSEA

New user signup and controls

- Enhanced user signup: Google, Twitter, Facebook
- Profile configuration: Location, areas of interest. Dashboards automatically customised.

Alerts

- Set alert conditions: “Oxygen < x” for example
- Customisable – WHERE x > y AND a < b
- Alerts sent to multiple users
- Via website, email, SMS, mobile app

Advanced processing: The Product Factory

- Choose processing and algorithms to run
- Processes triggered by alerts

SATELLITE ALTIMETRY: A WAY OF OBSERVING SEA SURFACE HEIGHT, OCEAN CURRENTS, TIDES, WAVES AND WIND

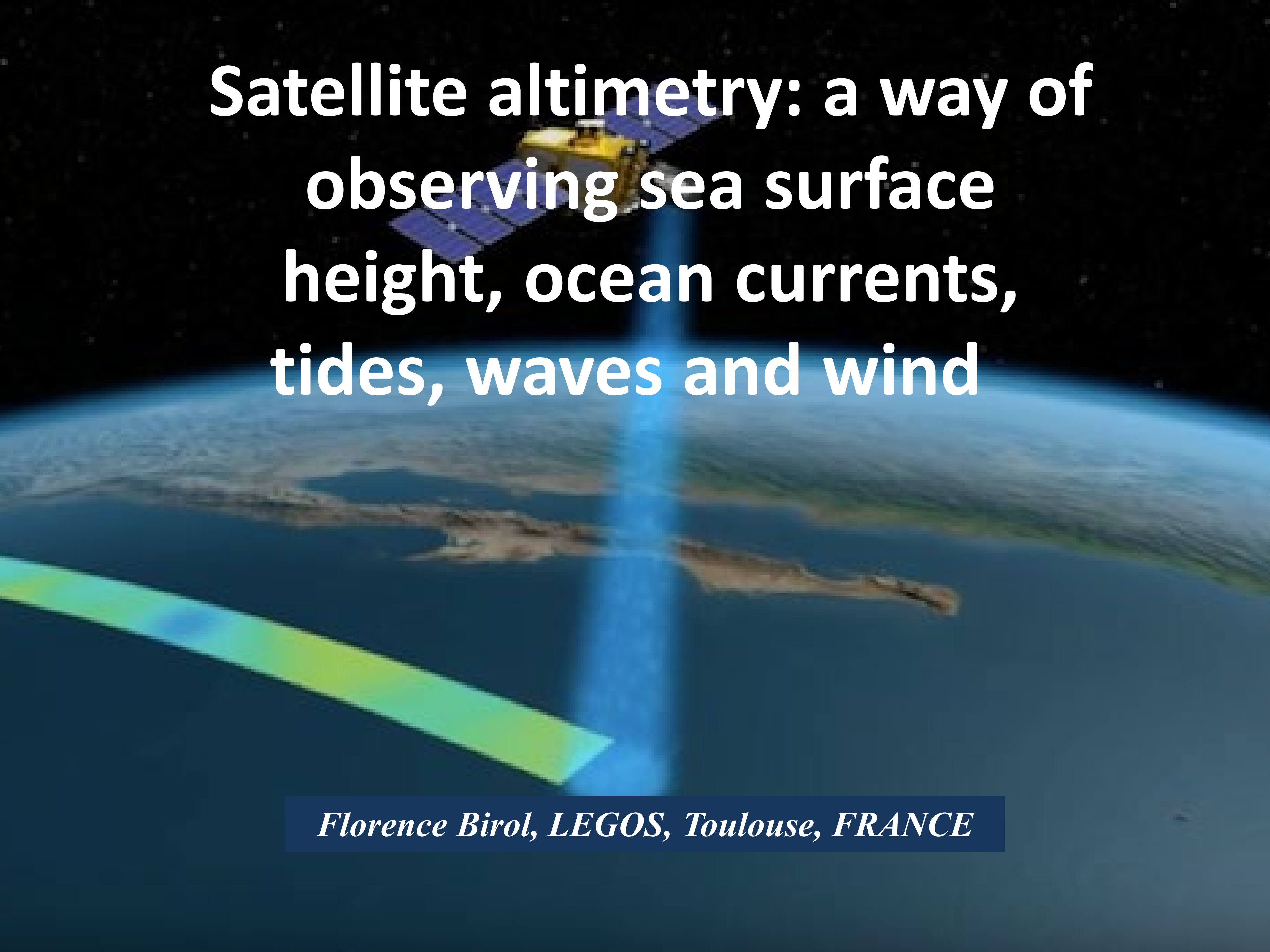
Prof. Florence Birol

Laboratoire d'études en géophysique et océanographie spatiales

florence.birol@legos.obs-mip.fr

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 727277

Satellite altimetry: a way of observing sea surface height, ocean currents, tides, waves and wind



Florence Birol, LEGOS, Toulouse, FRANCE

OUTLINE

1. The system:
   - Principle of altimetry
   - From altimetry measurement to geophysical informations

2. Products and data services

3. Applications over the ocean

4. Conclusion and perspectives

OUTLINE

1. **The system:**
   - **Principle of altimetry**
   - **From altimetry measurement to geophysical informations**

2. Products and data services

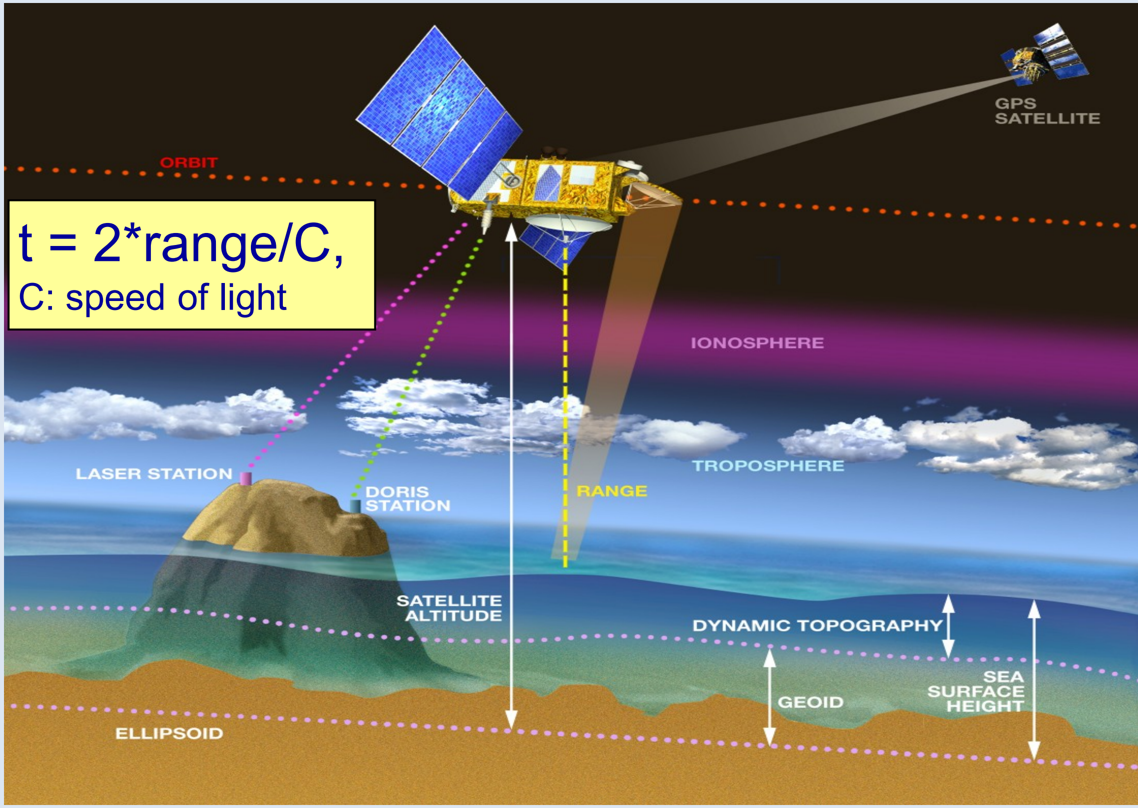
3. Applications over the oceans

4. Conclusion and perspectives

1. The system

Principle of altimetry – a space borne tide gauge:

- **t:** the onboard altimeter measures the round-trip time between the satellite and the sea surface
- **range**: the distance between the altimeter and the surface is derived by scaling t by C
- **altitude**: the position and height of the satellite is computed (DORIS system) relative to an arbitrary reference surface, an ellipsoid
- **SSH** = altitude – range: the sea surface height above a reference ellipsoid.



Centimetre Precision
from an altitude of 800 – 1350 km

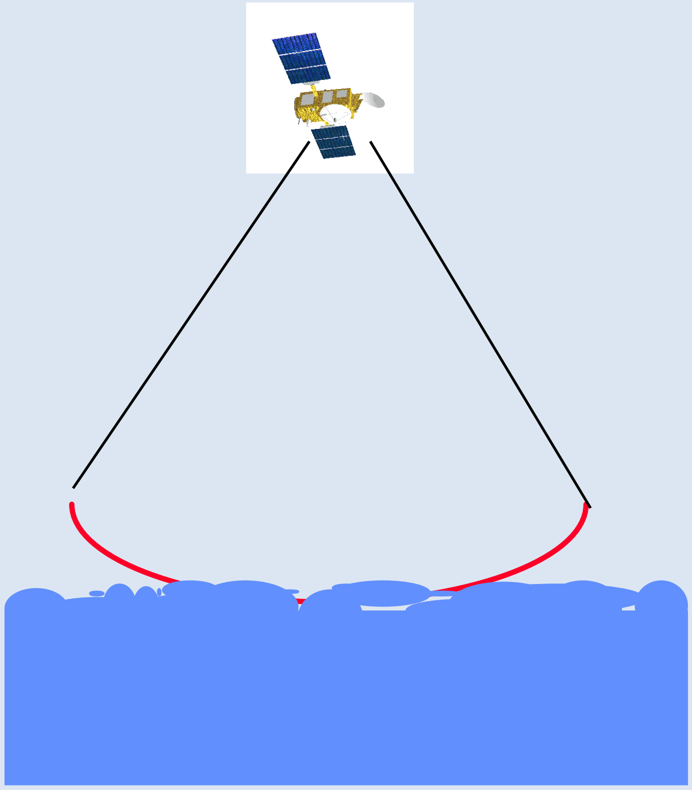
1. The system

Interaction of the altimeter radar echo with the sea surface:

The pulse is generated by a 13.5 GigaHz oscillator (Ku-band), transmitted at 1000 Hz

Principle: The altimeter transmits a short pulse of microwave radiation with known power toward the surface. The pulse interacts with the rough surface and part of the incident radiation reflects back to the altimeter.

The antenna altimeter emits a spherical microwave radiation with known one or two frequencies (13.575 Ghz for the Ku-band and 3.2 GHz for the S-band of Envisat), toward the surface (water or land) on a nadir direction comprised in a 1.29°-cone (in Ku-band for Envisat). On the basis of this radiation, the altimeter emits pulses, but they are not as narrow as with a laser, rather it leaves the antenna as a widening beam, getting wider the further it travels.



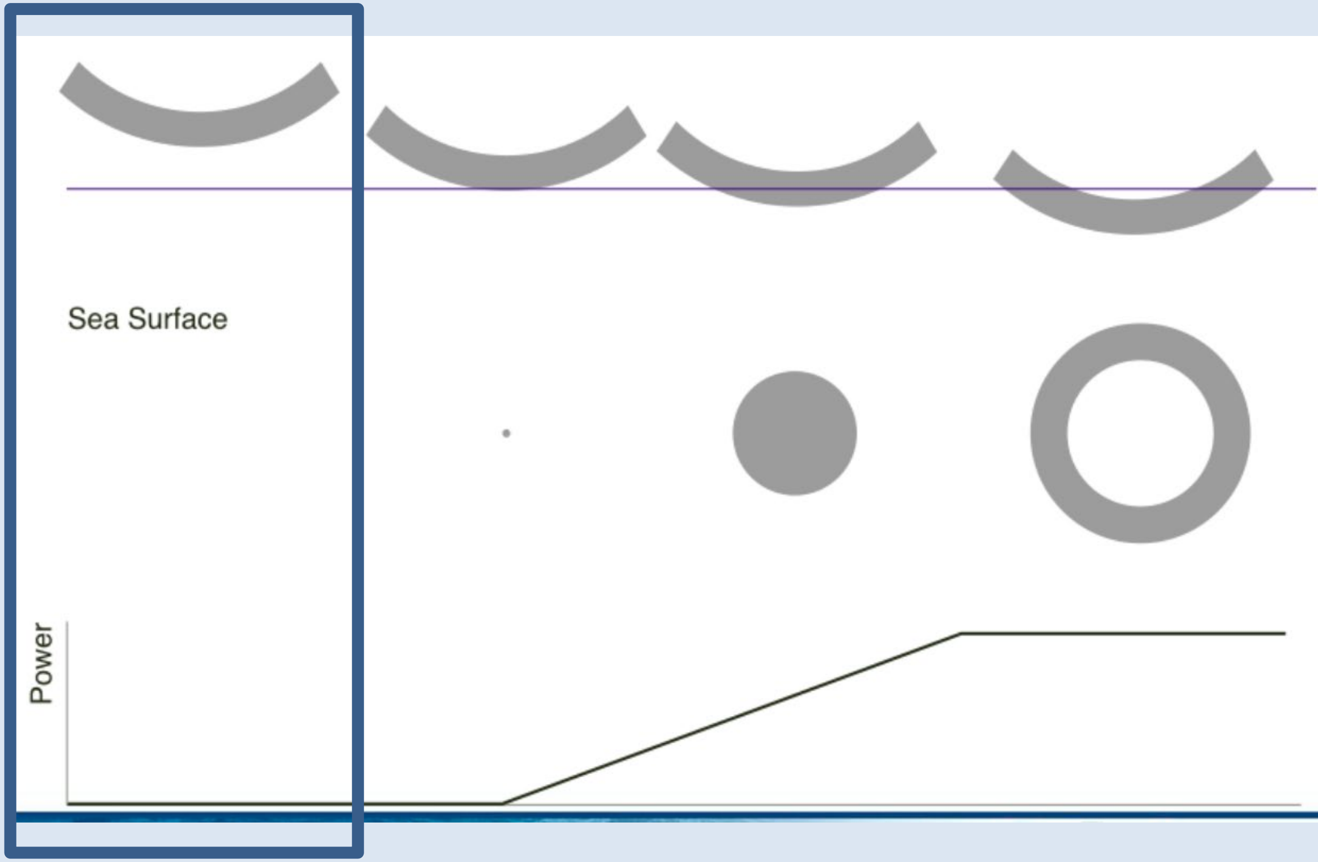
1. The system

Interaction of the altimeter radar echo with the sea surface:

- We send out a thin shell of radar energy which is reflected back from the sea surface
- The power in the returned signal is detected by a number of gates (bins) each at a slightly different time

1. Before the radar pulse hits the sea surface.

The reception mode is activated by the on-board tracking system, a low power noise signal is received corresponding to parasite reflection of the pulse in the ionosphere and atmosphere, in addition to the instrument electronic noise.



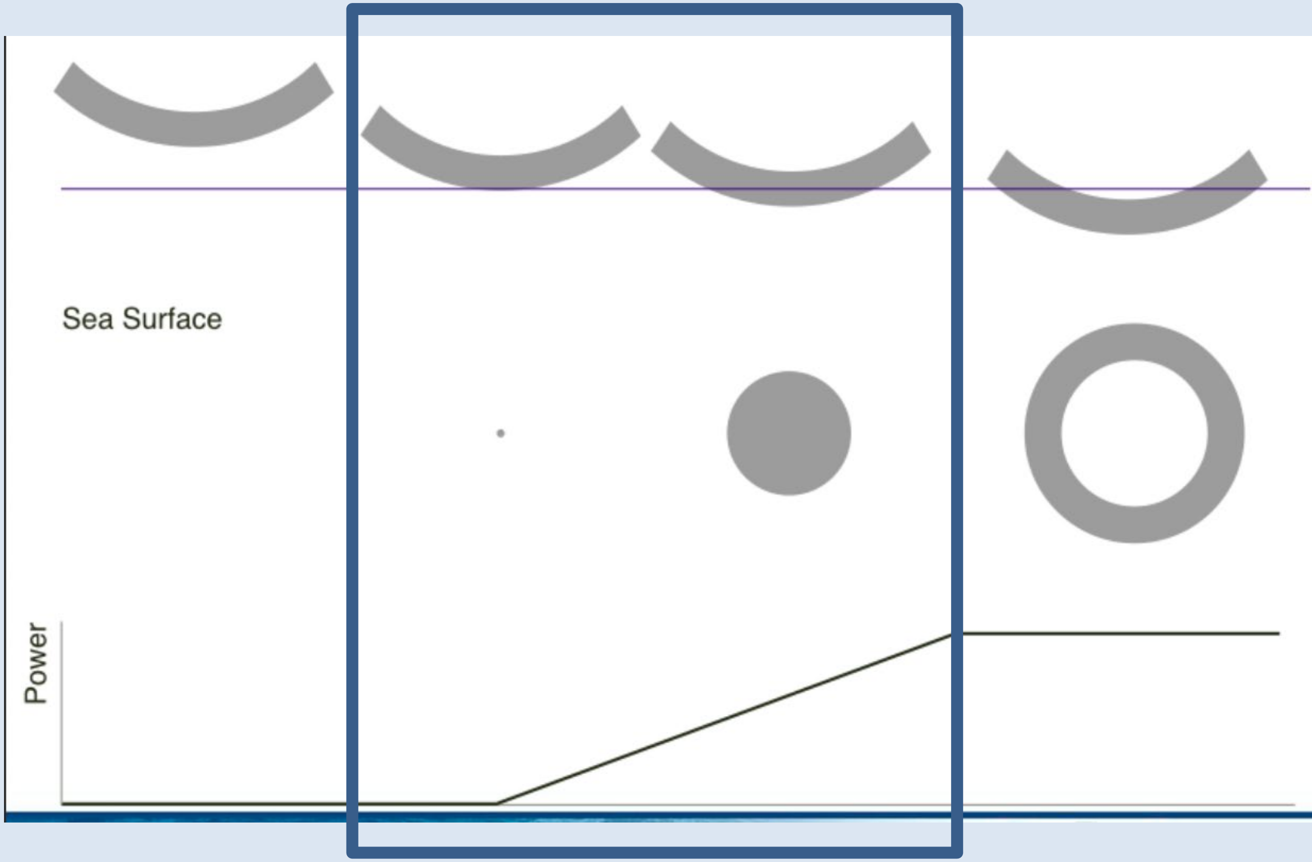
1. The system

Interaction of the altimeter radar echo with the sea surface:

- We send out a thin shell of radar energy which is reflected back from the sea surface
- The power in the returned signal is detected by a number of gates (bins) each at a slightly different time

2. The radar pulse hits the sea surface.

The returned signal rises up, the footprint being a disc linearly spreading with time, which makes the corresponding return signal increase up to a maximum corresponding to the passage of the rear edge of the pulse 'through' the ground surface.



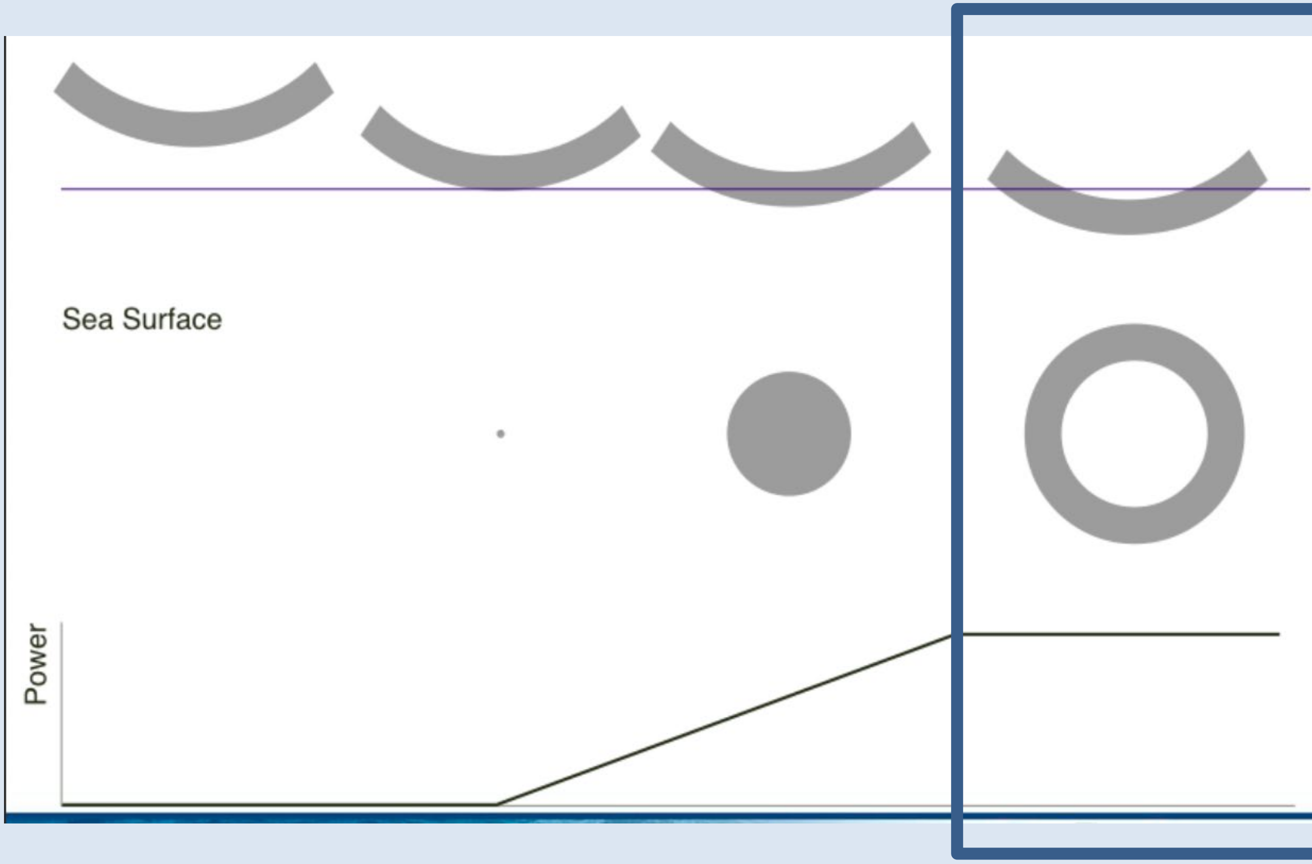
1. The system

Interaction of the altimeter radar echo with the sea surface:

- We send out a thin shell of radar energy which is reflected back from the sea surface
- The power in the returned signal is detected by a number of gates (bins) each at a slightly different time

3. After the rear edge of the pulse passed 'through' the ground level

The footprint turns to a ring with increasing radius and constant area. Then the returned signal to the altimeter decreases

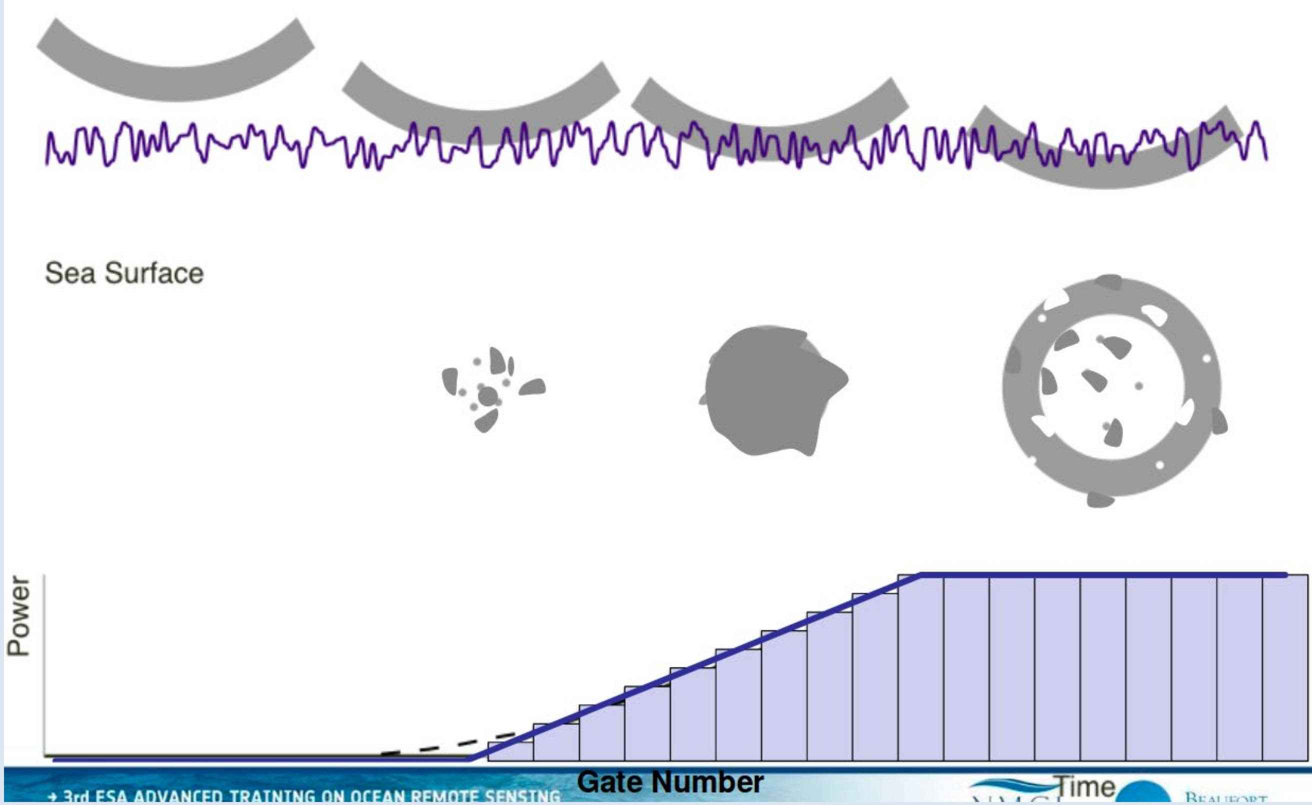


1. The system

Interaction of the altimeter radar echo with the sea surface:

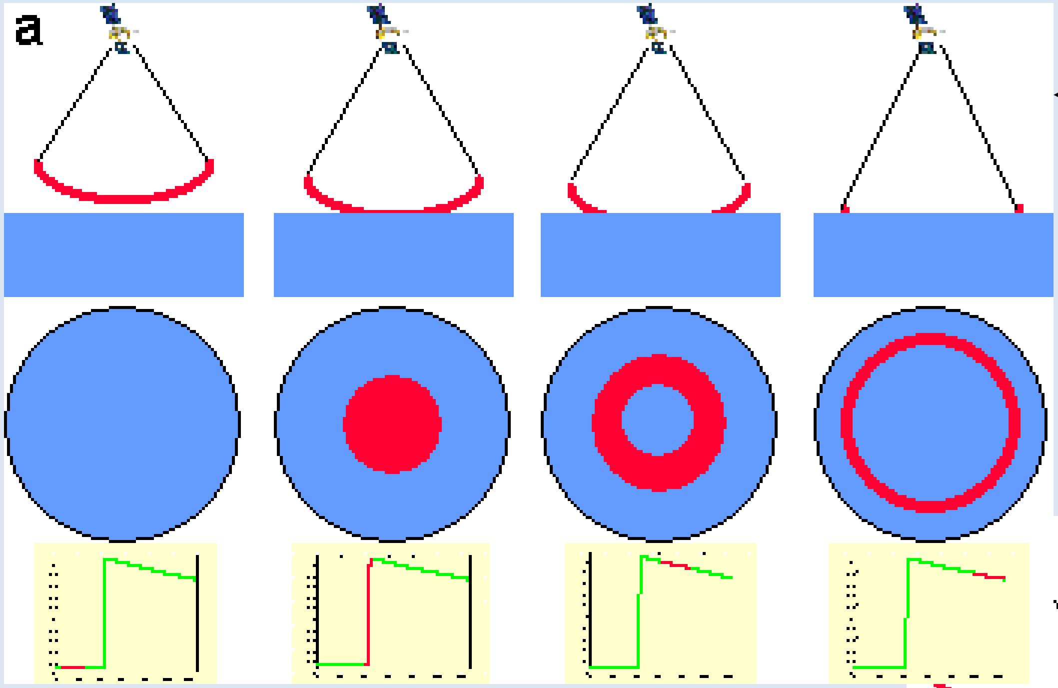
- We send out a thin shell of radar energy which is reflected back from the sea surface
- The power in the returned signal is detected by a number of gates (bins) each at a slightly different time

Now if we add waves…



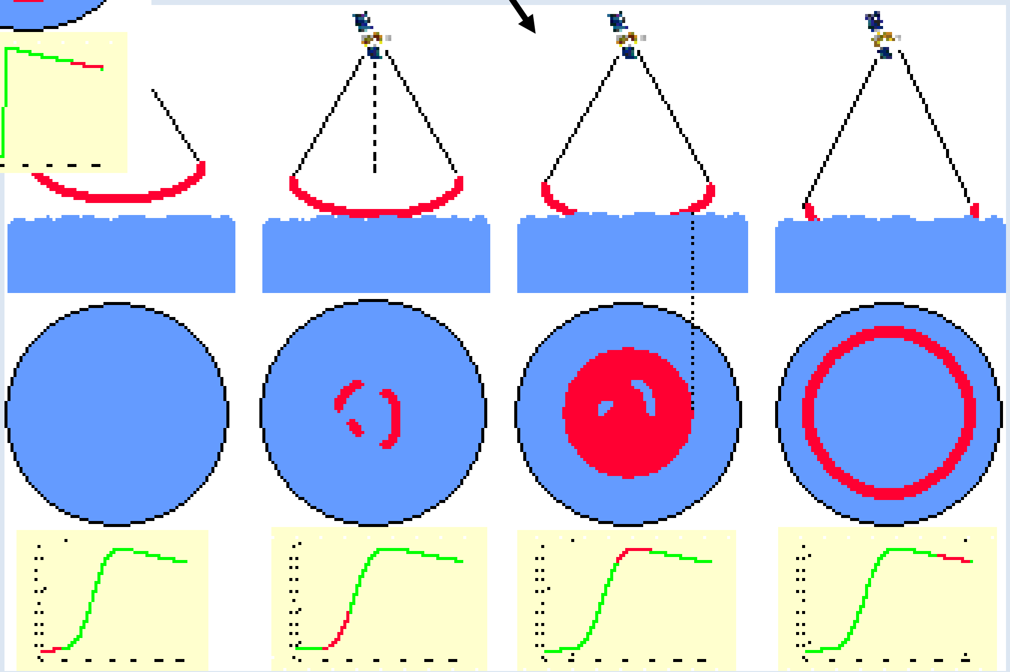
1. The system

Interaction of the altimeter radar echo with the sea surface:



Ideally calm sea: the rise measured by the altimeter when back is linear.

Rough sea: the rise measured by the altimeter when back is gradual.

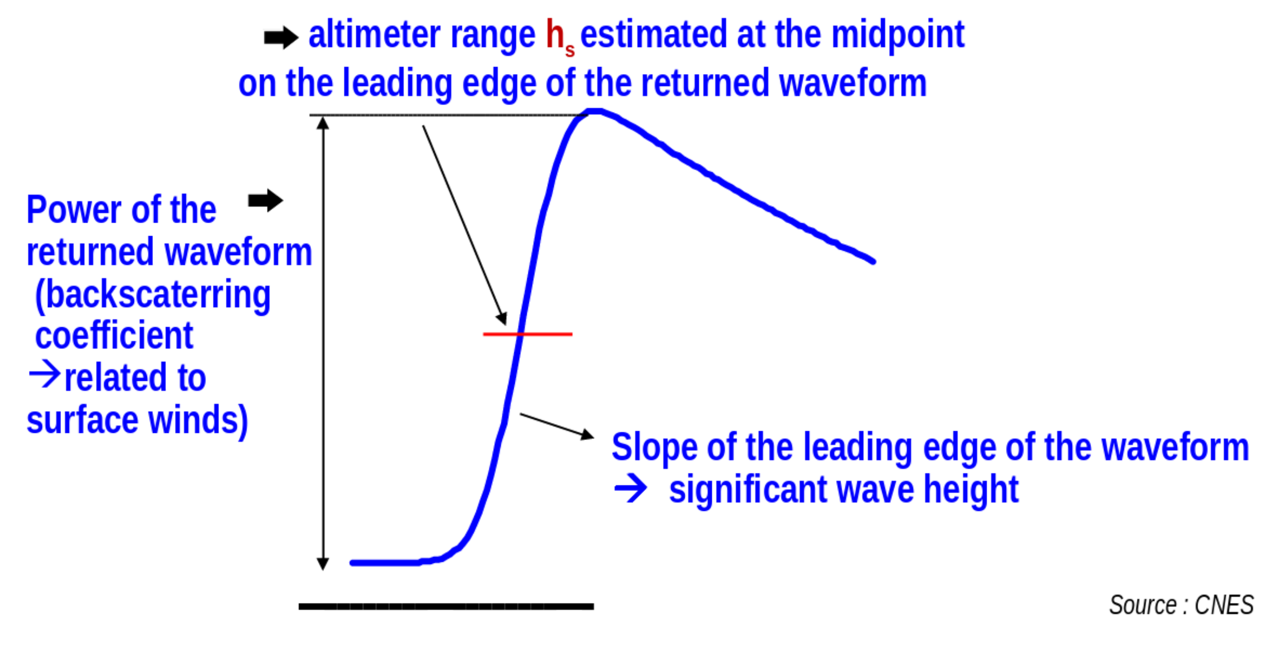


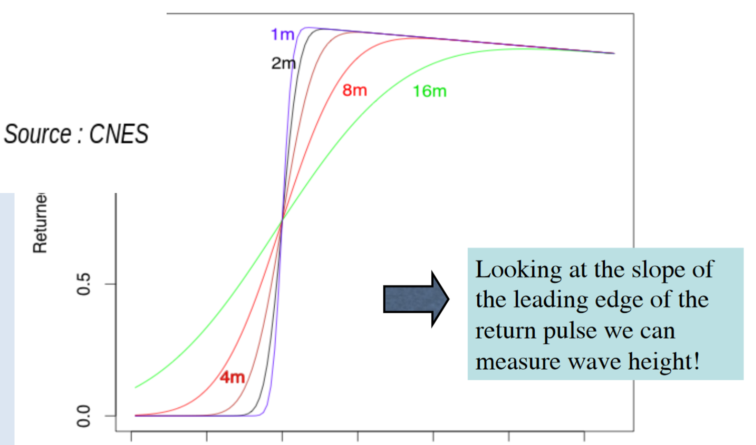
The returned signal is called “waveform”.

→ **The slope of the leading edge of the waveform, representing its amplitude over time, is proportional to wave height**

1. The system

Over the ocean, the echo waveform has a characteristic shape that can be described analytically: the “Brown model”

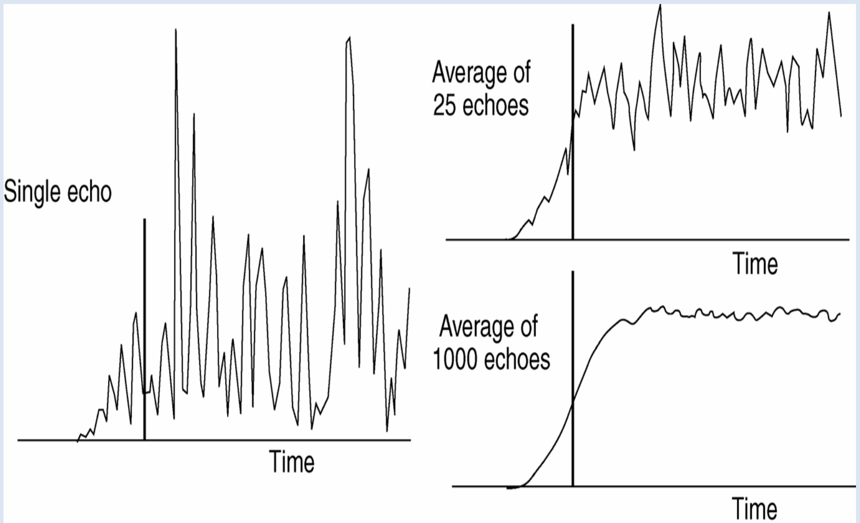




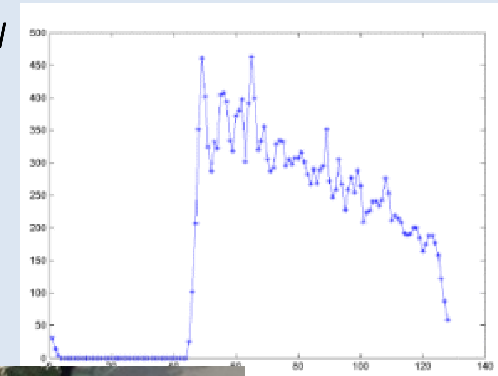
In addition to the altimeter range h_s, the returned waveform informs on other parameters: wave height , surface wind speed & type of surface

1. The system

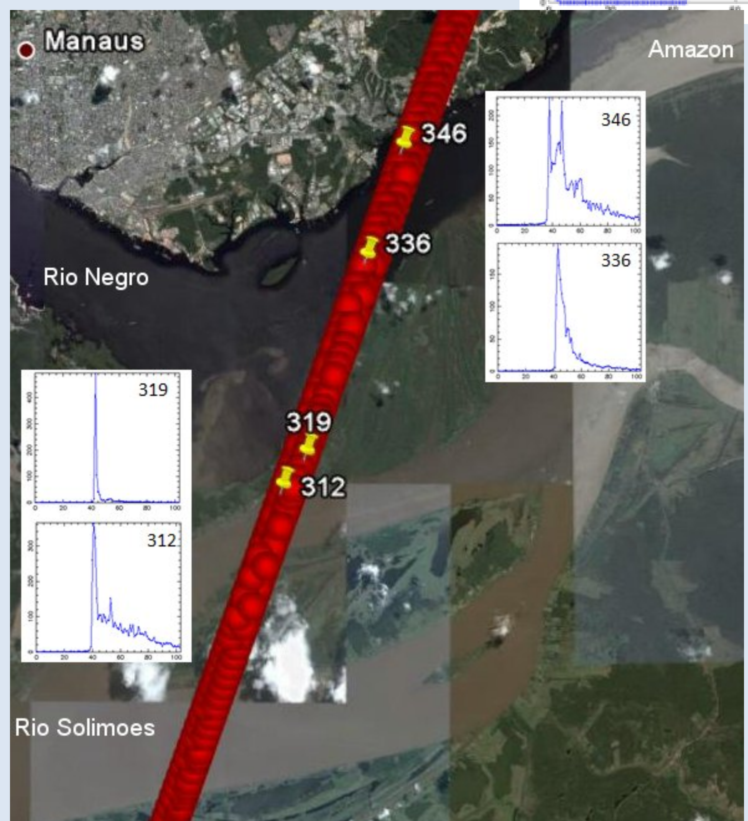
Individual altimeter waveforms are very noisy: generally averaged onboard and transmitted at 20Hz and then at 1Hz



Example of real Envisat waveform over the ocean



Important remark: these results are obtained over the ocean, which is spatially homogeneous and has a surface which conforms with known statistics. Non homogeneous surfaces, such as some land surfaces and near coastal areas make the interpretation much more difficult.

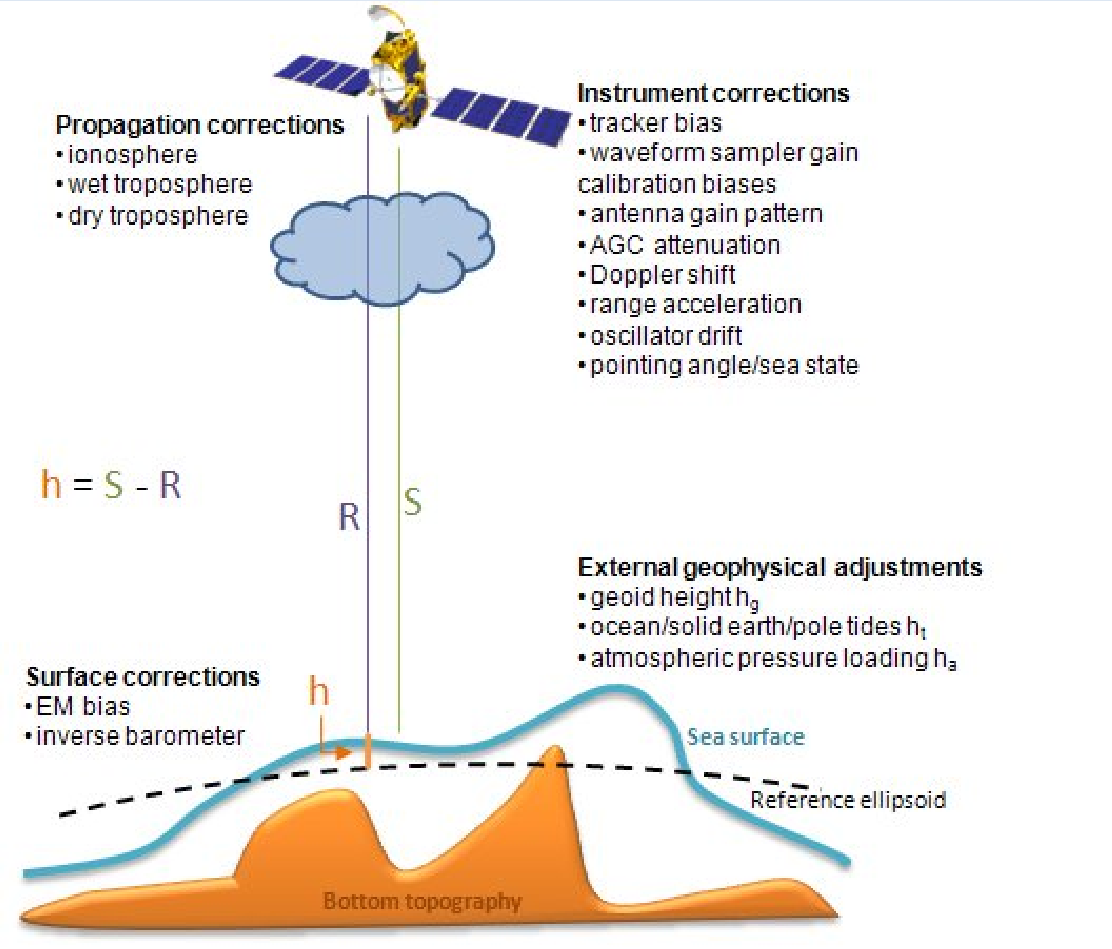


Jason-2 waveforms on Amazon river

1. The system

In practice:

Numerous perturbations have to be taken into account, and corrections need to be subtracted to take into account various physical phenomena



SSH = Altitude – Range – Σ Corr

Instrumental Corrections: Corrections for instrument errors

Atmospheric corrections: Correction for the path delay in the radar return signal due to the atmosphere's electron content, cloud liquid water, water vapour and dry gases in the atmosphere.

Sea state corrections: Correction for bias in measurements introduced by varying reflectivity of wave crests and troughs

Geophysical corrections: Correction for variations in sea surface height due to tides & atmospheric pressure variations

→ **Please remember: The SSH data accuracy depends strongly on the accuracy of the corrections applied**

1. The system

Atmospheric corrections :

The altimeter radar wave is delayed during atmosphere crossing

Ionospheric correction

- The radar pulse is delayed in the ionosphere (50 - 2000 km) due to the presence of electrons

→ **The correction can be estimated using two different frequencies (ocean) or from models.**

Wet tropospheric correction

- Correction for the path delay in the radar return signal due to cloud liquid water and water vapour in the atmosphere.

→ **The correction can be estimated using radiometer measurements (ocean) or from meteorological models.**

Dry tropospheric correction

- Correction for the path delay in the radar return signal due to dry gases in the atmosphere.

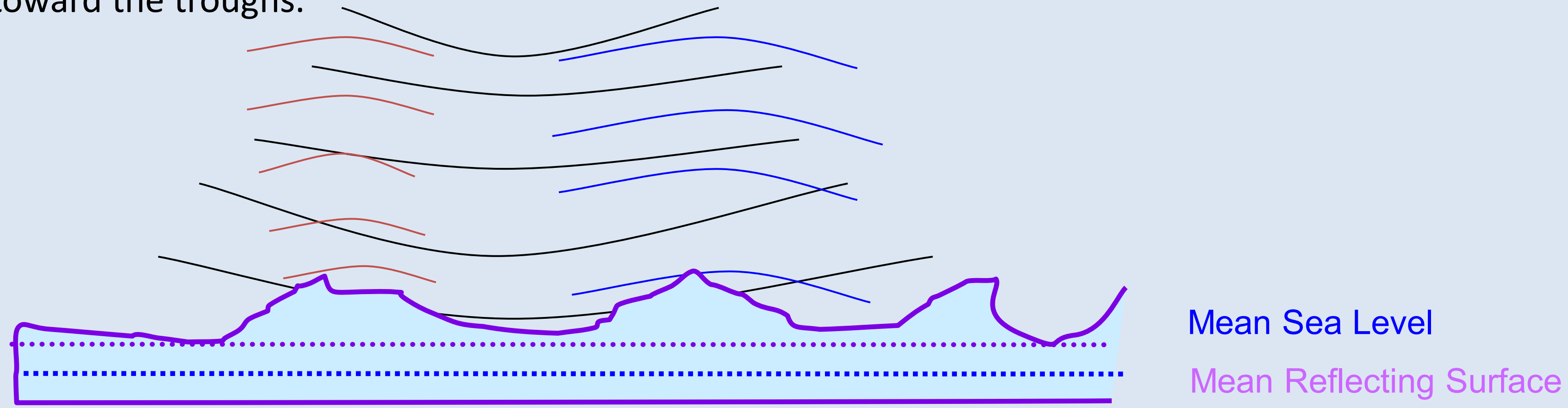
→ **Calculated from meteorological models.**

1. The system

The sea state bias (SSB) correction: h_{EM}

Electromagnetic bias

The concave form of wave troughs tend to concentrate and better reflect the altimetric pulse; wave crests tend to disperse the pulse. So the mean reflecting surface is shifted away from mean sea level toward the troughs.



Skewness bias

For wind waves, wave troughs tend to have a larger surface area than the pointy crests – the difference leads to a skewness bias.

The EM Bias and skewness bias vary with increasing wind speed and wave height, but in a non-linear way.

→ The SSB is estimated using empirical formulas and look-up tables. Bias uncertainty is currently the biggest factor in altimeter error budgets.

1. The system

Geophysical corrections : Tides

Ocean tides : Corrections for solid earth and sea surface height variations due to the attraction of the Sun and Moon.

Solid earth tides

Corrections for solid earth variations due to the attraction of the Sun and Moon. Order of magnitude: 50 cm.

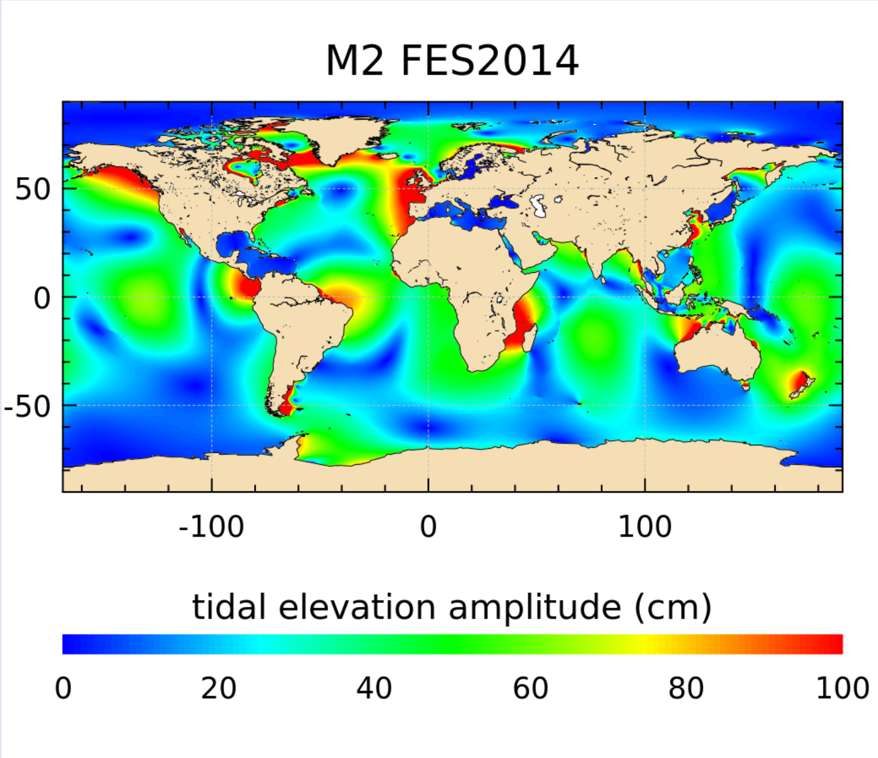
Pole tides

Corrections for variations due to the attraction of the Sun and Moon. Order of magnitude: 2 cm.

Tidal loading

Corrections for height variations due to changes in tide-induced forces acting on the Earth's surface. Order of magnitude: 30 cm

→ **Derived from models.**



Ocean tides: Order of magnitude: 1 m in mid-ocean, up to 15-20 m near some shorelines.

→ Source of uncertainty in the coastal ocean

1. The system

Geophysical corrections : Inverse barometer effect

- Correction for variations in sea surface height due to atmospheric pressure variations (atmospheric loading) : increased atmospheric pressure by 1 mbar pushes the sea level down by 1 cm
- Calculated from meteorological models
- However it does not take into effect a dynamic response, important at high frequency.

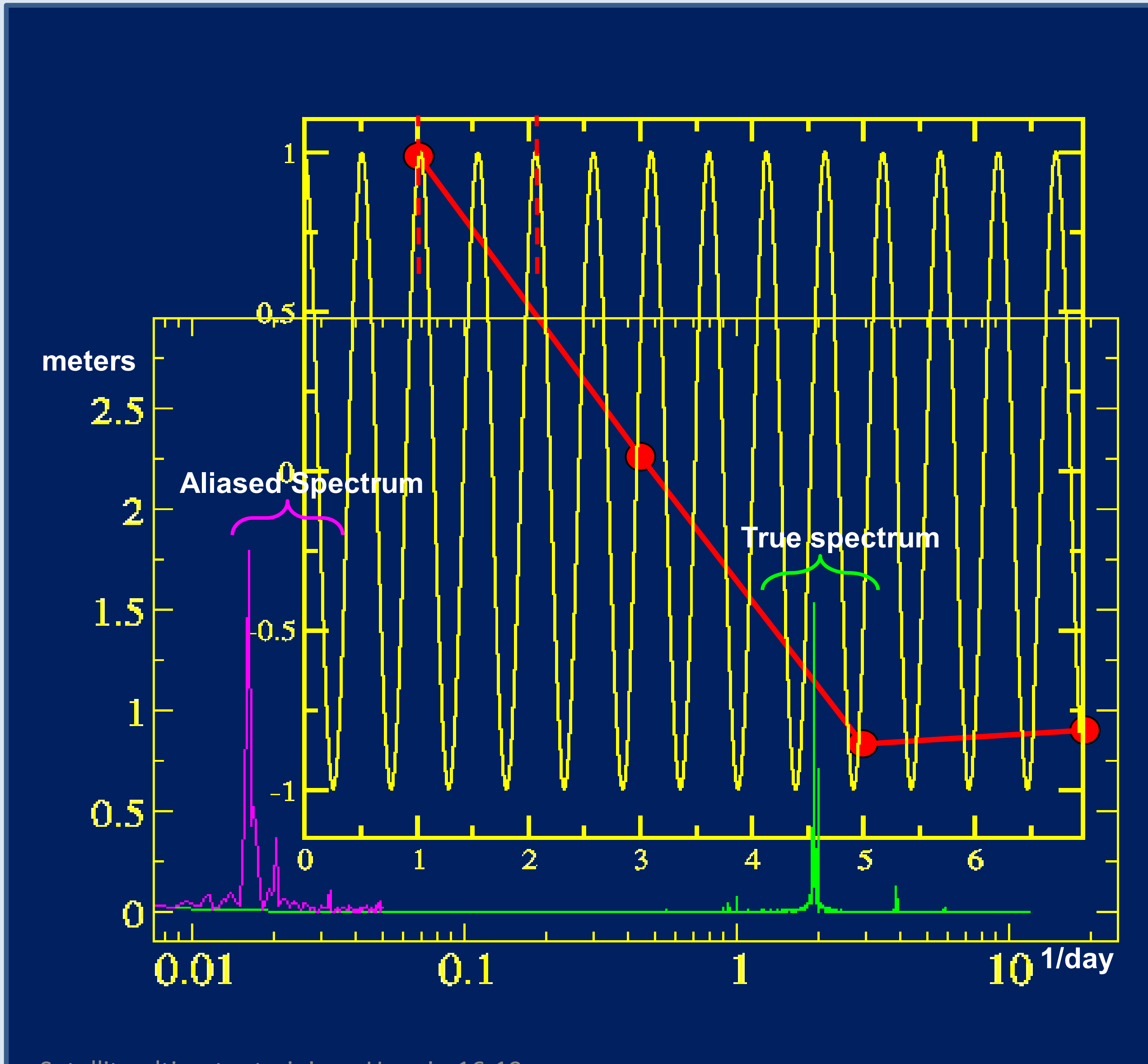
→ **In practice, it is often replaced by the Dynamical Atmospheric correction (DAC),** which is the sum of:

- **Inverse barometer** for period > 20 days (from meteorological models**)**
- **High-frequency Barotropic motions** : wind and pressure forcing creates a high-frequency barotropic response at periods < 20 days which is not resolved by 10-day altimeter sampling. Corrected by ocean models.

1. The system

Aliasing problem:

- if not removed, high-frequency signals which are not resolved by satellite altimetry may cause aliasing errors in the resulting sea level time series.
- the aliasing errors can produce false signals and alter the dynamical explanation



1. The system

The geoid

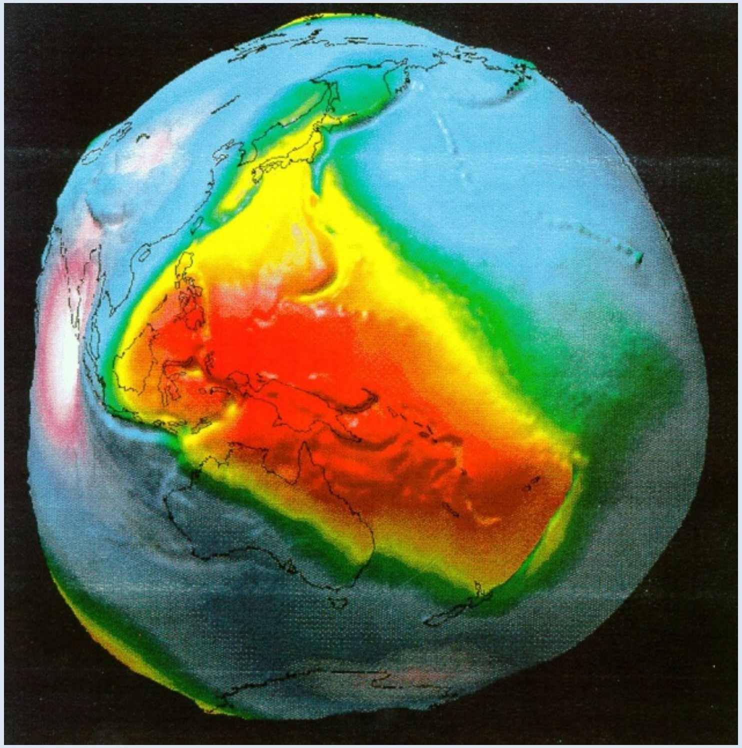
SSH = Altitude – Range – Σ Corr

SSH = Geoid + Absolute Dynamic topography

The height (or "relief") of the sea surface is caused by both gravity (which doesn't change much over hundreds of years) and the dynamic (always changing) ocean circulation.

- The sea surface variations caused by gravity are called the geoid
- Problem: The geoid is **not well known at scales < 100 km**

→ Separating the observed sea surface into ocean dynamic topography and marine geoid is an issue



Max geoid values : ± 100 m
Max dyn. Topo values: ± 1 m

Solution: the marine geoid does not vary in time (or the variations are low)

1. The system

In summary:

= fitting the waveforms with a waveform model (Brown or other), therefore estimating the parameters

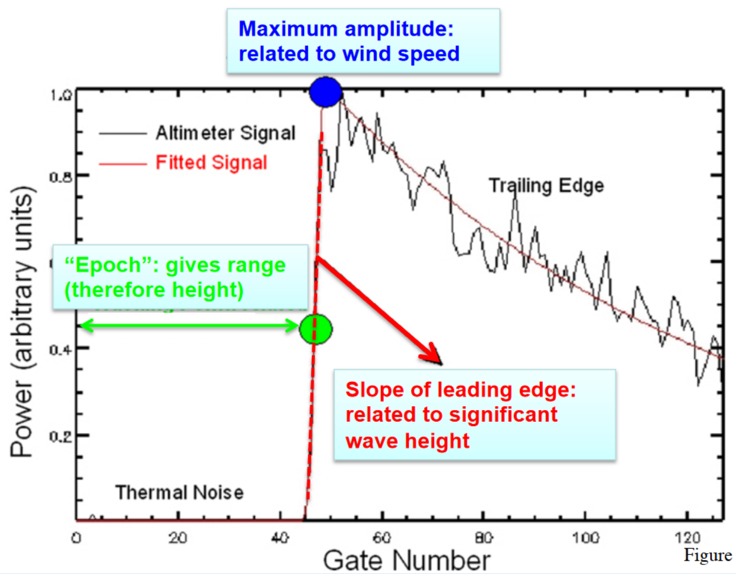


Figure from J Gomez-Enri et al. (2009)

Glossary

- SSH: Sea Surface Height
- MSSH: Mean sea Usrface Height
- SLA (sometimes called SSHA): Sea Level Anomaly
- MDT: Mean dynamic topography
- ADT: Absolute dyn. topography

And then:

- We apply corrections:

  SSH = orbit – range - ∑(corrections)

- We remove the mean sea surface height (which contains the geoid AND the mean dynamic topography because we don't know how to do otherwise today)

  MSSH= mean(SSH) = geoid + MDT

  SLA = SSH – MSSH

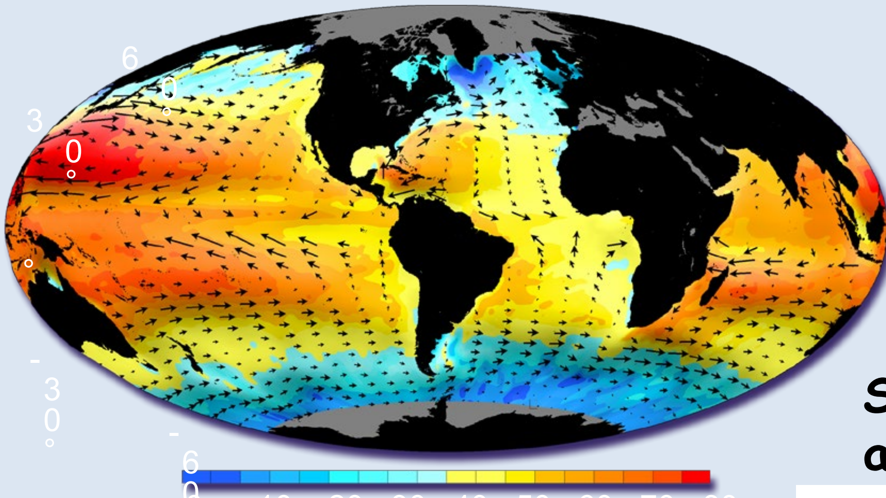
  → Only access to the variable part of the ocean dynamics

- *If we want to access the absolute dynamic topography, we use a mean dynamic topography product*

  ADT = SLA + MDT

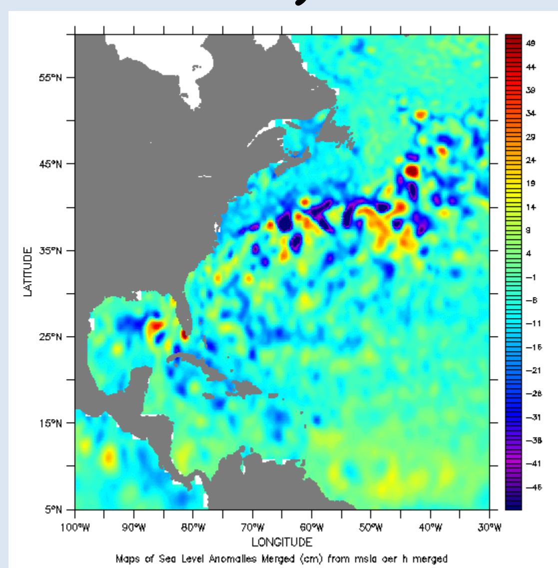
1. The system

Finally, only sea level anomalies are deduced from altimetry measurements

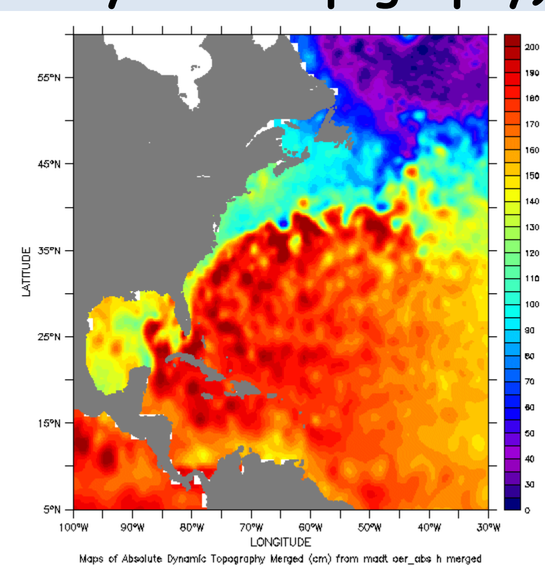


Mean dynamic topography products: limited accuracy at short length scales (use with caution in coastal altimetry applications)

SLA (Sea level anomalies)



ADT (Absolute dynamic topography)

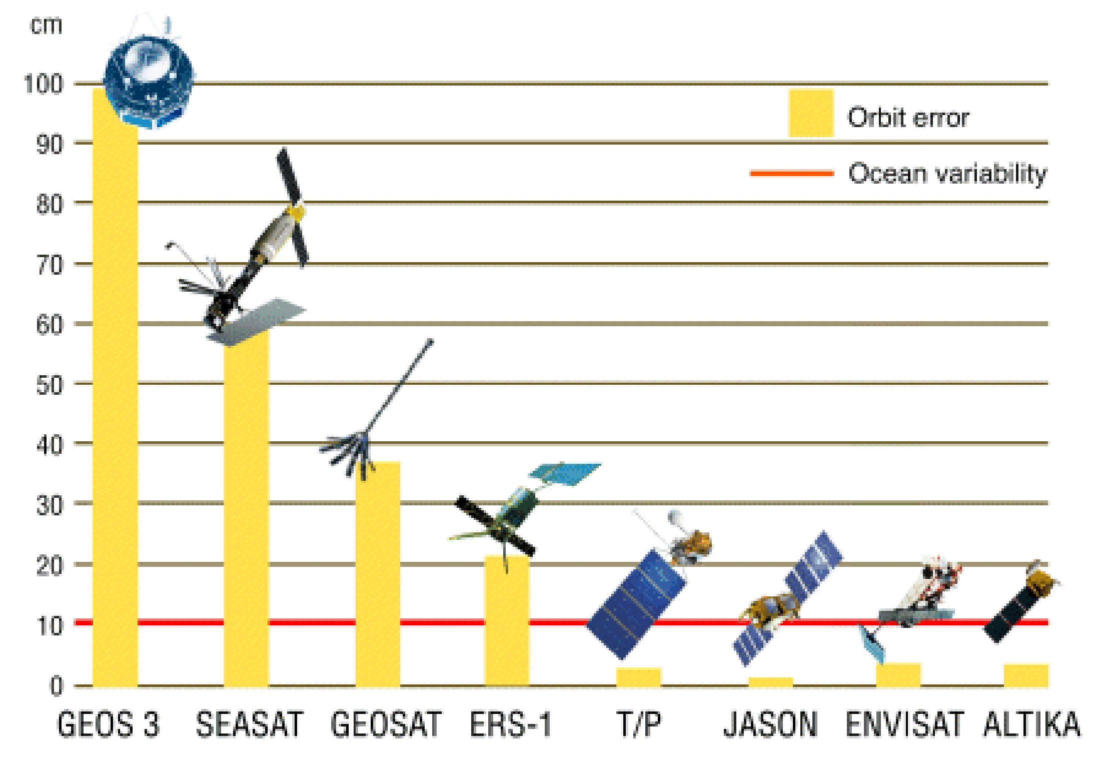


1. The system

Performance's evolution of early satellite altimetry missions

Precision of a single sea surface height measurement:
- 25 years ago: 10 cm
- Today: 1-2 cm !

Improvements in measurement accuracy since the first satellite altimetry missions has enabled us to observe ocean variations since 1992.

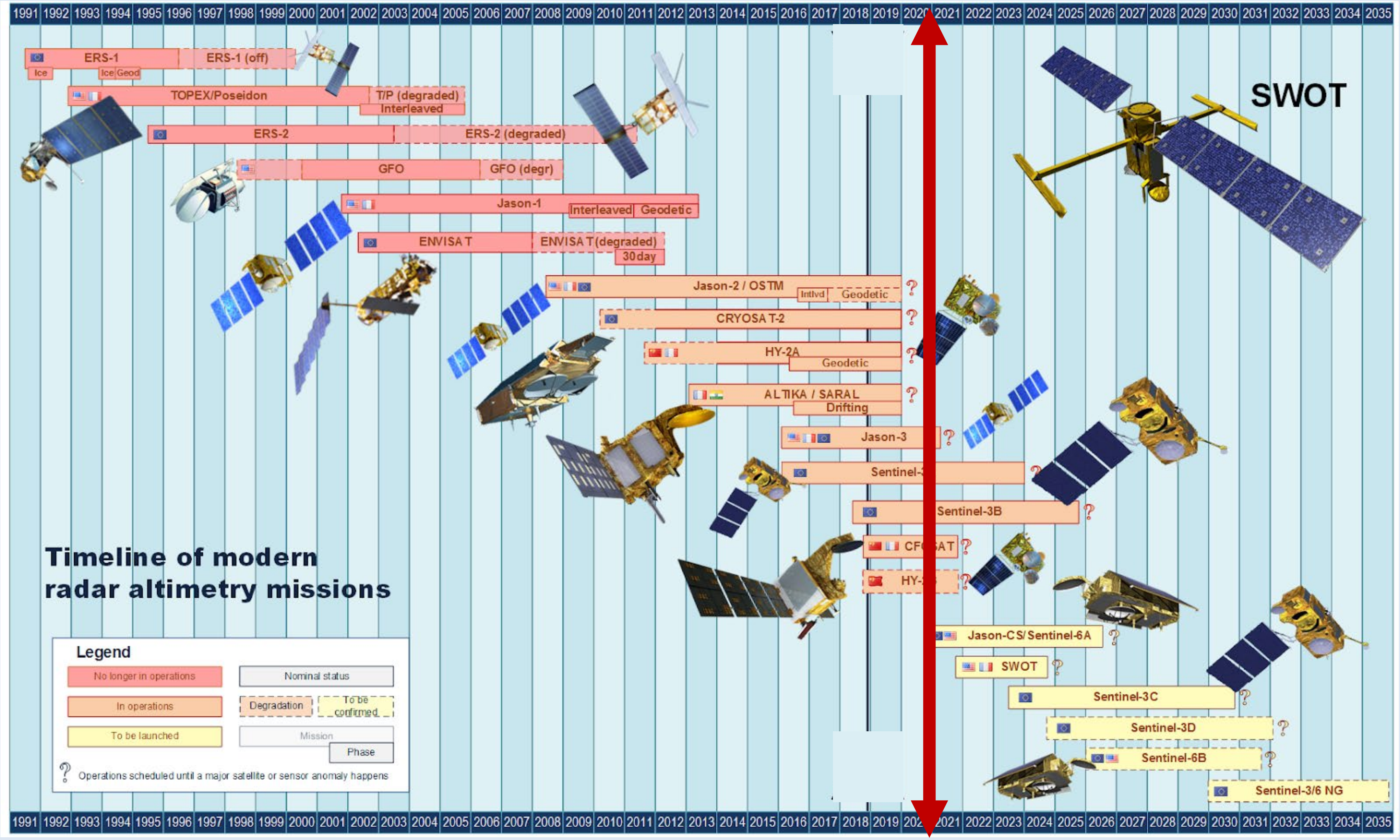


The first altimetric satellites in the 70s: Skylab, GEOS 3, Seasat

Then:
- Geosat (1985)
- ERS-1 (1991)
- Topex/Poseidon (1992)
- GFO (1998)
- ERS-2 (1995)
- Envisat (2002)
- Jason-1,2,3 (2001-today)
- AltiKa (2013)

1. The system

Almost 30 years of high precision data and new altimetry missions already planed



OUTLINE

1. The system:
   - Principle of altimetry
   - From altimetry measurement to geophysical informations

2. **Products and data services**

3. Applications over the oceans

4. Conclusion and perspectives

2. Products and data services

Data flow

- Step 0 – Data from the satellites downlinked to the ground stations.
- Step 1 – Level 0 products

Raw telemetry is forwarded to the quality control and processing centres.

- Step 2 – Level 1 products (SGDRs or waveforms)

Data are timed and located, expressed in the appropriate units, and checked for quality.

- Step 3 – Level 2 geophysical data (GDRs)

Level 1 data are corrected for instrument errors and transformed into geophysical data. Geophysical corrections and a precise orbit determination (POD) are computed and added in the files. The geophysical data are validated for quality assurance. Validation involves precise quality controls and monitoring of instrument drift.

- Step 4 – **Level 3 validated along-track data**

Off-record data are edited. Further computation is performed on level 2 geophysical data (e.g. SSH or SLA). There may be cross-calibration between missions. Time series are constructed

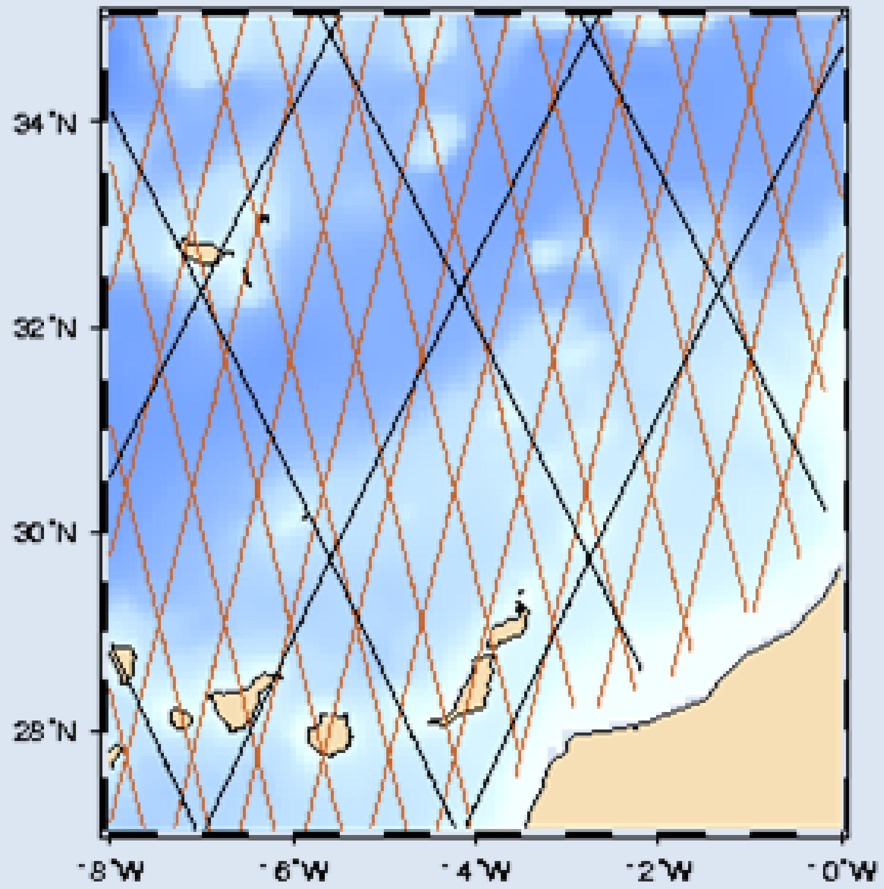
- Step 5: **Level 4 multi-satellite gridded data**

Multi-satellite data are cross-calibrated. Measurements from various altimetry missions are combined.

2. Products and data services

How do we combine several altimetric observations ?

This Figure shows a 10-day coverage of Topex/Jason tracks (black) and 35-day coverage of Envisat/SARAL tracks (brown). During this time, there will be 3.5 Topex/Jason cycles and one single repeat of the Envisat/SARAL tracks.



For many oceanographic applications using time series analysis or spatial analysis, the data are easier to use on a regular grid.

Optimal mapping techniques are developed to transform alongtrack SSH measurements with irregular space and time distributions onto a regular grid.

2. Products and data services

From alongtrack data to a gridded ocean product

Objective analysis mapping uses a **gaussian weighting scheme** to **map irregular data onto a regular grid**.

A gaussian space-time covariance model is used, e.g. :

$$F(r,dt) = [1 + br + 1/6(br)^2 - 1/6(br)^3]e^{-br}\,e^{-(dt/rct)2}$$

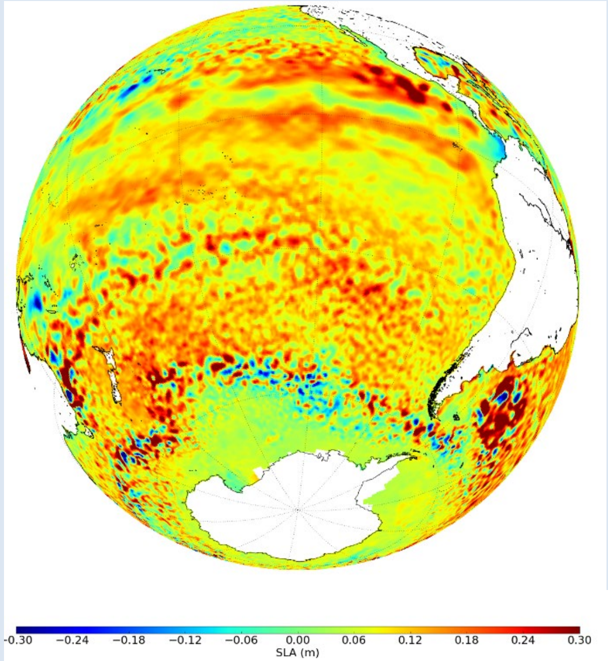
Here r is the non-dimensional radius :

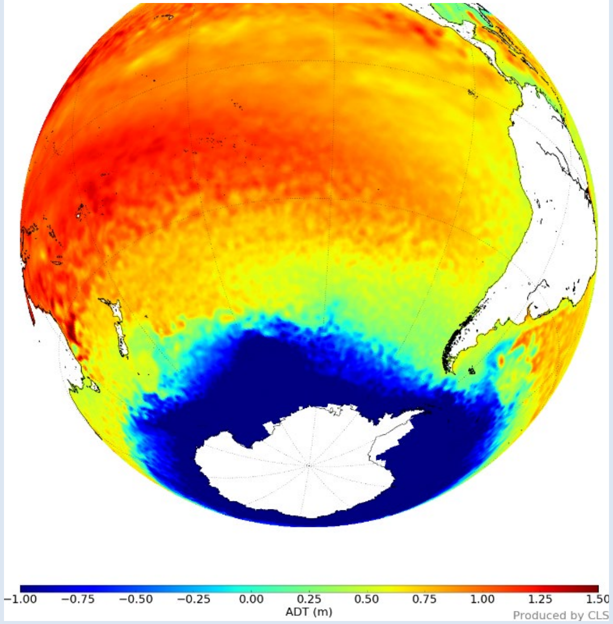
$$r = \sqrt{(dx^2/rcx^2 + dy^2/rcy^2\ )}$$

This function uses different space lags (dx, dy) and time lags (dt).

The choice of decorrelation space and time scales is a balance between resolving the mesoscale ocean signals and having enough data, taking into account the altimetry groundtrack separation and repeat period.

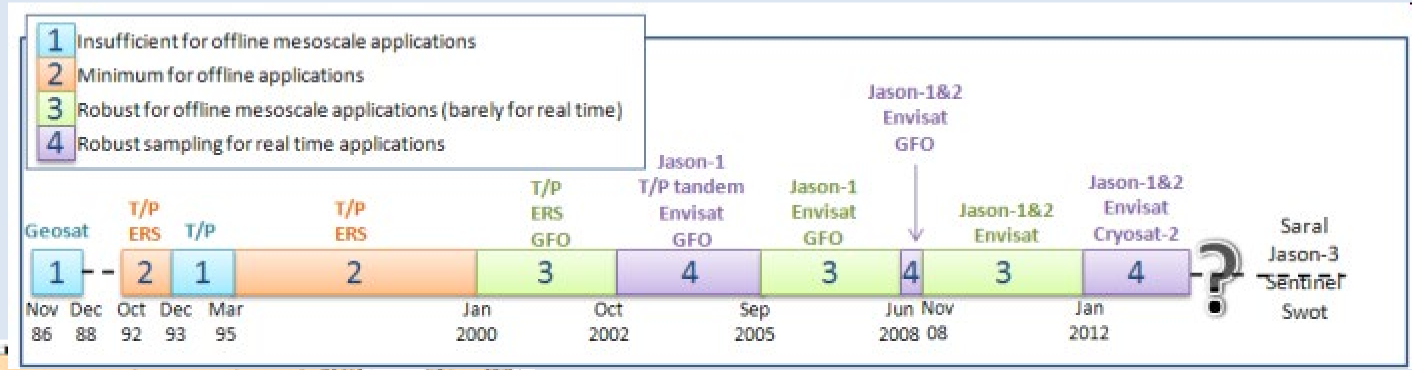
At mid-latitudes, **typical decorrelation space scales** are rcx = 200 km, rcy = 150 km, with **time scales**, rct = 15 days.

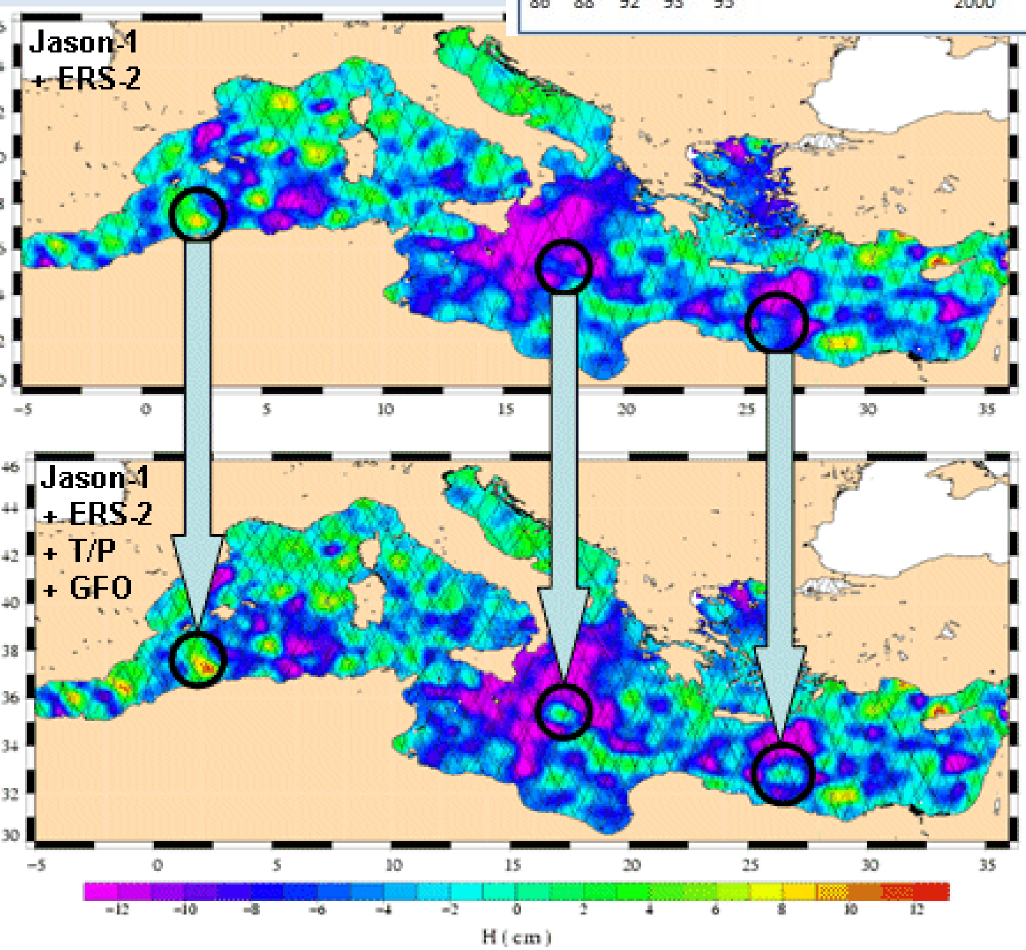




DUACS L4 global product (2019/03/20)

2. Products and data services





Today we have 7 altimetry missions in orbit!

2. Products and data services

Data Unification and Altimeter Combination System (DUACS) : only for the ocean

The DUACS system is the CNES/CLS processing system that provides satellite altimeter sea level products.

Today, the DUACS production system is used for the operational production of sea level products for the Marine (CMEMS) and Climate (C3S) services of the E.U. Copernicus program

- Copernicus Marine Service products
- Copernicus Climate Service products
- Ocean Monitoring Indicators
- CNES/AVISO+ Demonstration and pre-operational products
- Commercial products

2. Products and data services

A more general view (not only DUACS)

Easy-to-use (gridded Level 4 or alongtrack Level 3 products for ocean applications):

- Sea level trends from ESA Climate Change Initiative
- Delayed Time Maps of Sea Level Anomalies Upd and geostrophic velocity anomalies AVISO
- Delayed Time Maps of Absolute Dynamic Topography Upd and absolute geostrophic velocities AVISO
- Near-Real Time Merged Maps of Absolute Dynamic Topography and absolute geostrophic velocities AVISO
- Near-Real Time Merged Maps of Sea Level Anomalies and geostrophic velocity anomalies AVISO
- Sea surface temperature and height, global 0.5 and 1.0 deg grids (JPL, WOCE v3) PO.DAAC
- Near-real time merged maps of Wind speed modulus and maps of Significant Wave Heights AVISO
- Near Real-Time Velocity Viewer CCAR

2. Products and data services

A more general view

Intermediate

- Rain climatologies from dual frequency altimeters   CERSAT – Level 4 for the ocean
- Sea level anomalies and tidal constituents (X-TRACK) CTOH/LEGOS – Level 3 for the coastal ocean
- Envisat Interim Geophysical Data Records ESA   - Level 2 for all applications
- Jason Geophysical Data Records AVISO/CNES - Level 2 for all applications
- Multi-mission RADS database – Level 2 for all applications
- Multi-mission CTOH/LEGOS global database – Level 2 for all applications

Advanced (Level 1 products: waveforms for all applications)

- ESA (Envisat, ERS, Cryosat-2, Sentinel-3),
- AVISO (Jason),
- CERSAT (ERS-2),
- CTOH/LEGOS (different missions)

OUTLINE

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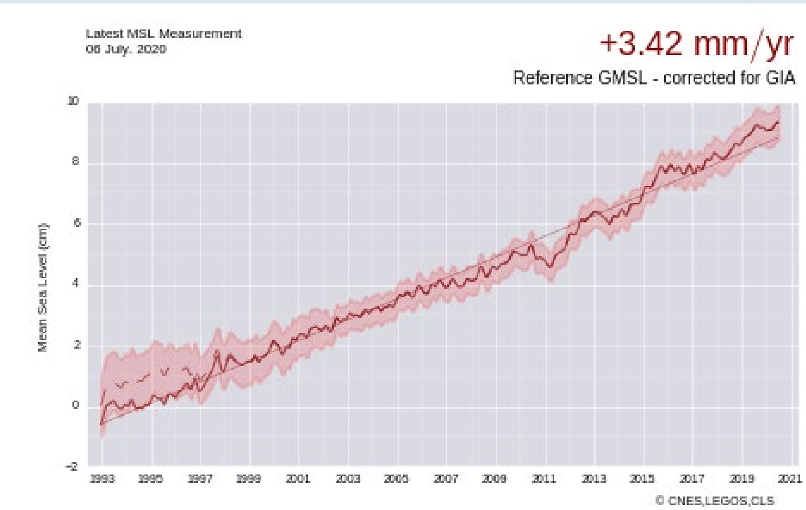
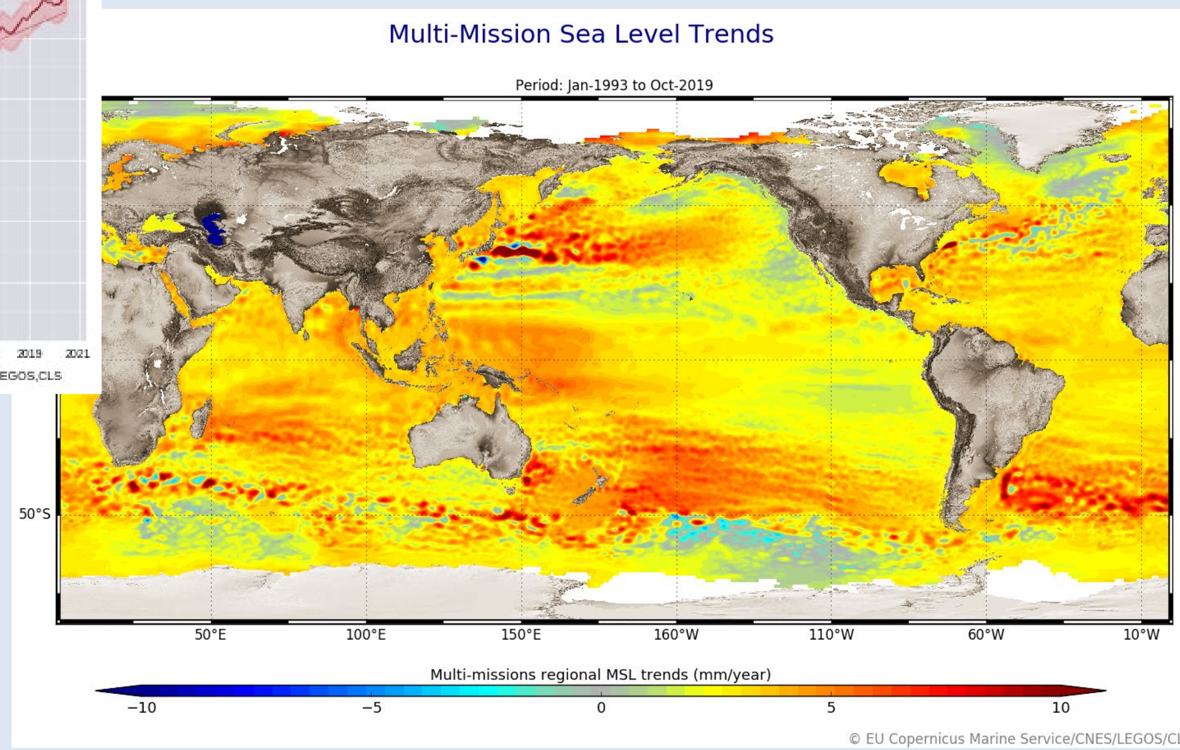
3. Applications over the oceans

From global to regional mean sea level evolution

Global and regional patterns of observed sea level (in mm/year) obtained from gridded, multi-mission SSALTO/DUACS data since 1993

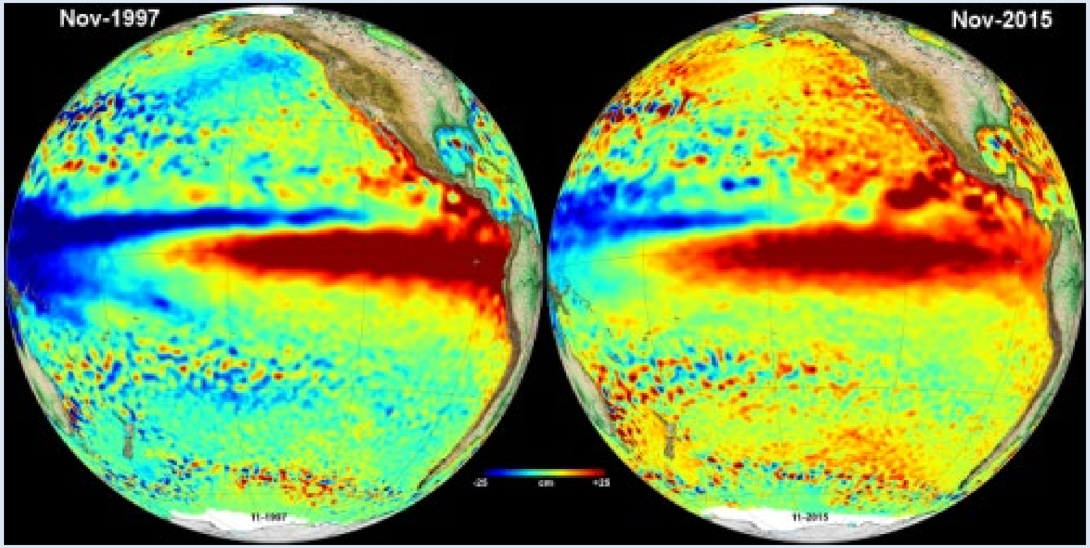




Although the global trend indicates a rise in the mean level of the oceans, there are marked regional differences that vary between -10 and 10 mm/year.

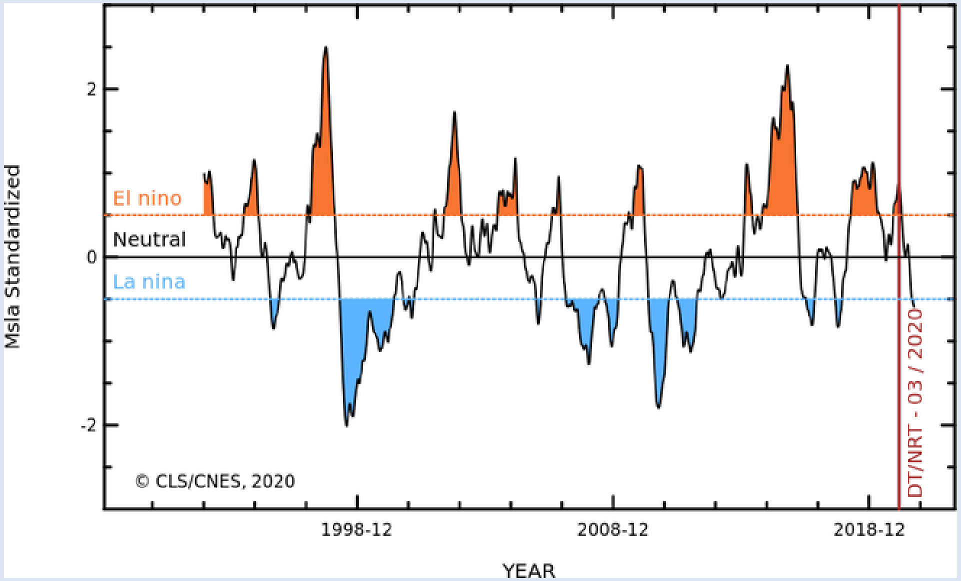
3. Applications over the oceans

Monitoring large climatic events as El Niño



Monthly mean of Sea Level Anomalies (in cm) over the Ocean Pacific as computed for the El Niño indicator Credits CNES/EU Copernicus Marine Service.

El Niño bulletin in September 2020:
Weak La Niña condition



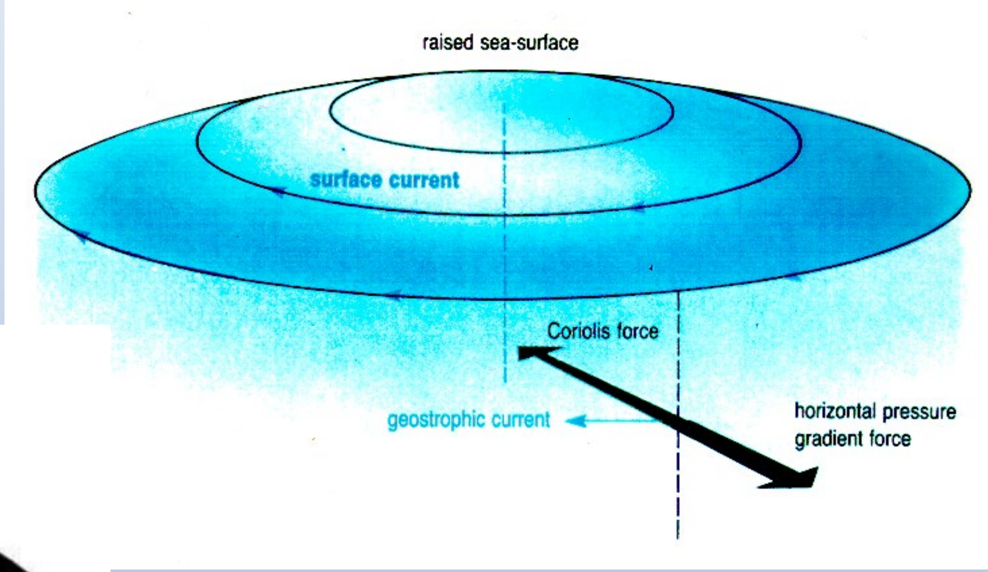
Standardized Sea Level Anomalies over the Nino3.4 region (from SSALTO/DUACS altimetry products)

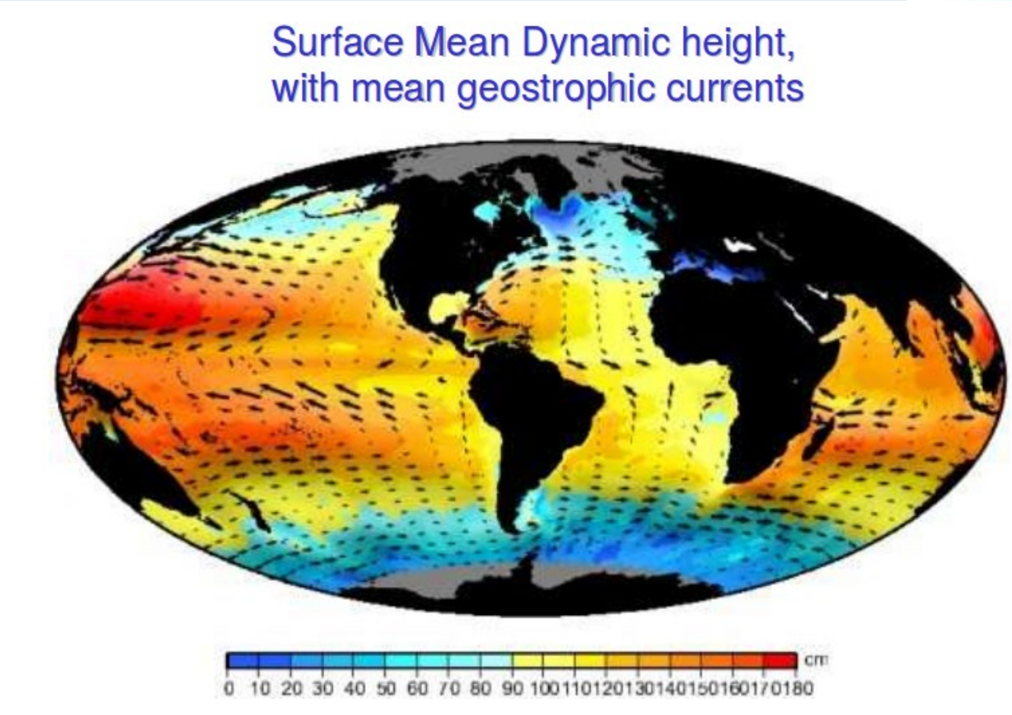
3. Applications over the oceans

From the gradient of the ocean dynamic topography to the general ocean circulation

Geostrophic equations

$$u_S = -\frac{g}{f}\frac{\partial h}{\partial y} \qquad v_S = \frac{g}{f}\frac{\partial h}{\partial x}$$





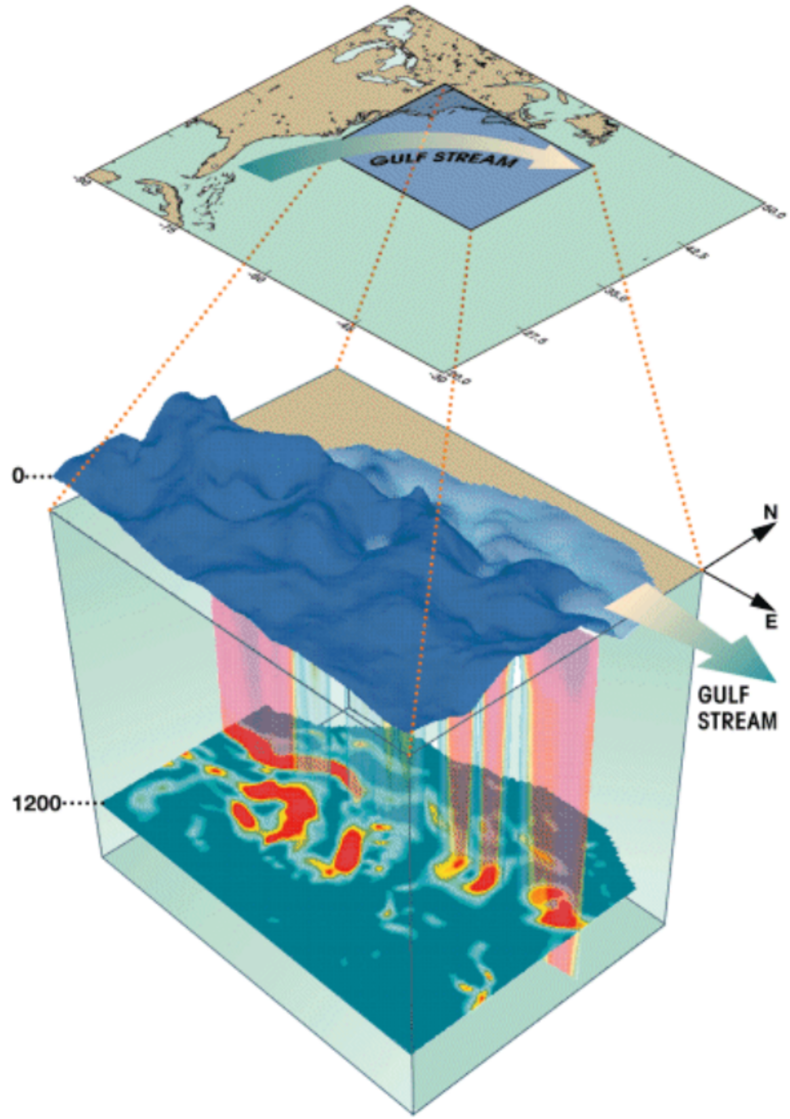
3. Applications over the oceans

Ocean currents and eddies

Mesoscale Eddy Field

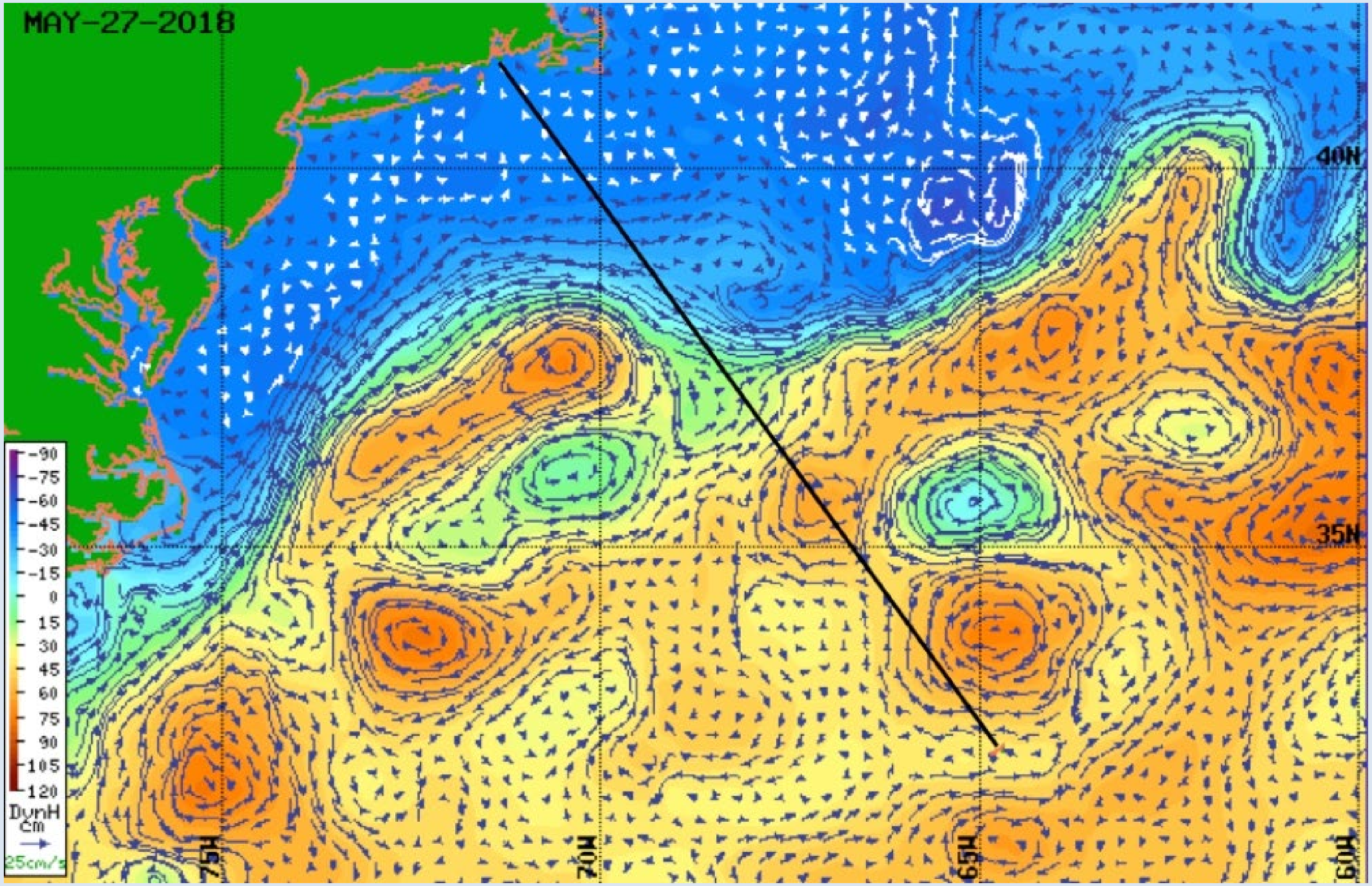
The ocean currents can also become unstable, generating meanders which can pinch off to form mesoscale eddies. These eddies tend to drift westward at Rossby wave speeds unless they are advected by the mean flow.

This example is for the Gulf Stream, with alongtrack altimetric sea level anomalies (SLA) superimposed on the temperature field at 1200 m. Warm core eddies and meanders have high SLAs, cold –core rings and meanders have low SLAs.



3. Applications over the oceans

Ocean currents and eddies



Satellite Altimetry Derived Surface Currents in the Gulf Stream Area

3. Applications over the oceans

From scientific to operational applications:

Altimetry often combined with other observations and/or models

- Measure global sea-level change and provide a continuous view of changing global ocean surface topography
- Calculate the transport of heat, water mass, nutrients and salt by the oceans
- Increase understanding of ocean circulation and seasonal changes and how the general ocean circulation changes through time
- Provide estimates of significant wave height and wind speeds over the ocean
- Improve the knowledge of ocean tides and develop global tide models
- Understand the ocean dynamics and develop a global view of Earth's ocean
- Monitor the variation of global mean sea level and its relation to global climate change
- Improve climate forecasting models
- Navigation
- Managing natural resources (fishing, …)

OUTLINE

1. The system:
   – Principle of altimetry
   – From altimetry measurement to geophysical informations

2. Products and data services

3. Applications over the oceans

4. Conclusion and perspectives

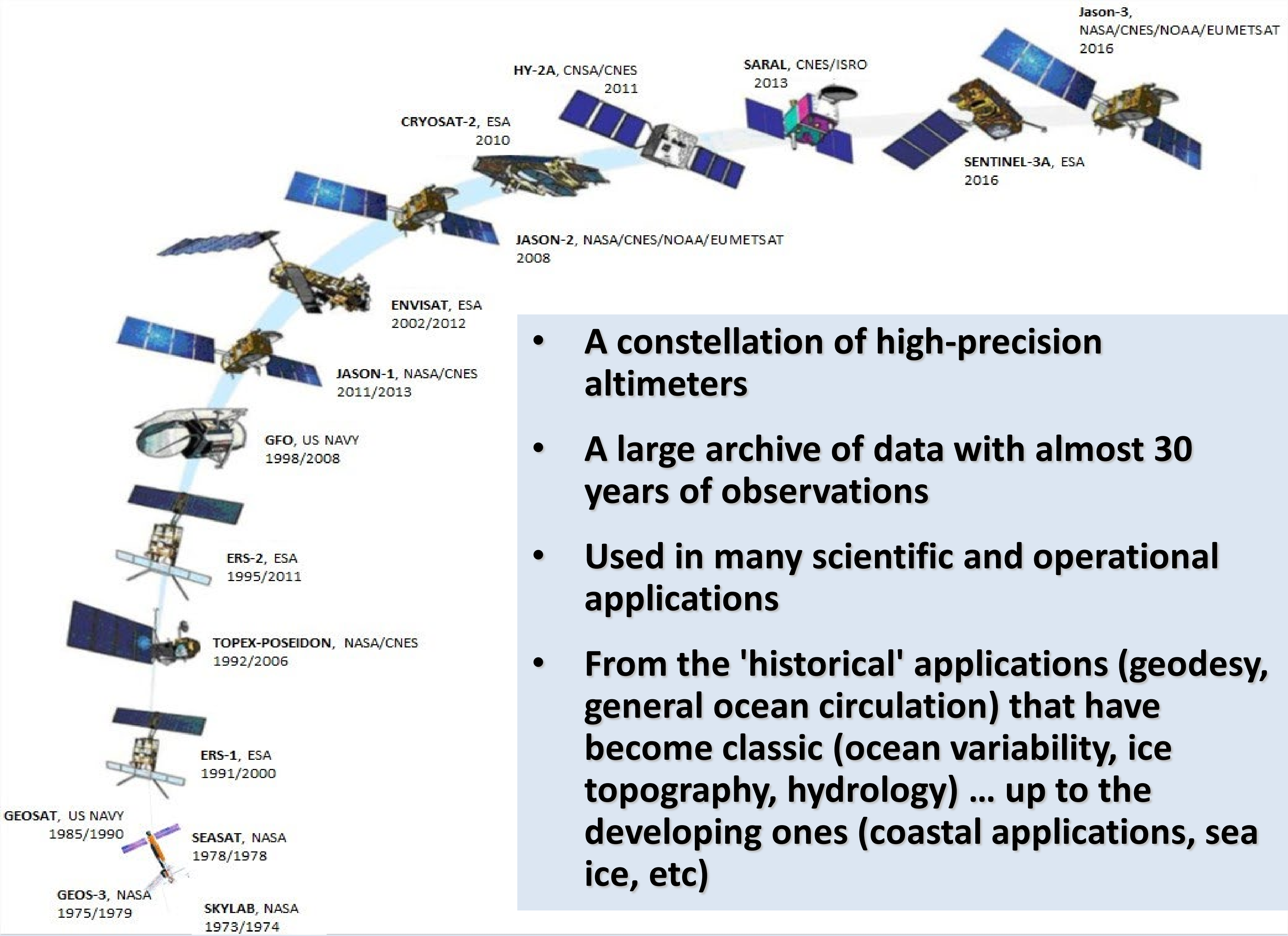
4. Conclusion and perspectives

Main ocean parameters that can be measured from space:

- **Sea surface temperature : Radiometers (passive micro-waves, IR)**
- **Sea surface salinity : Radiometers (active micro-waves)**
- **Ocean surface topography (currents; tides, sea level) : Altimeters**
- **Surface winds : Altimeters/Scatterometers (active microwaves)**
- **Wave height: Altimeters; Synthetic Aperture Radars (SAR)**
- **Ocean mass: Space Gravimeters**
- **Ocean color (phytoplankton→ marine ecosystems): Radiometers (multispectral imagery)**
- **Sea ice thickness : SAR, Altimeters**

→ A lot of them derived from satellite altimetry

4. Conclusion and perspectives



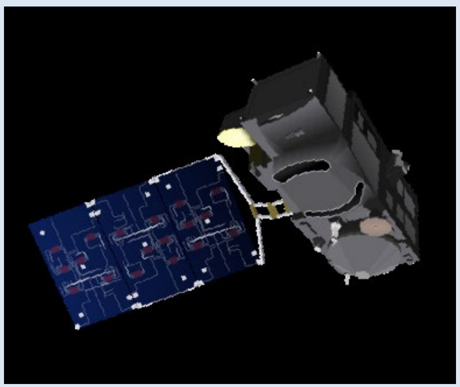
- **A constellation of high-precision altimeters**
- **A large archive of data with almost 30 years of observations**
- **Used in many scientific and operational applications**
- **From the 'historical' applications (geodesy, general ocean circulation) that have become classic (ocean variability, ice topography, hydrology) … up to the developing ones (coastal applications, sea ice, etc)**

4. Conclusion and perspectives

New radar technologies

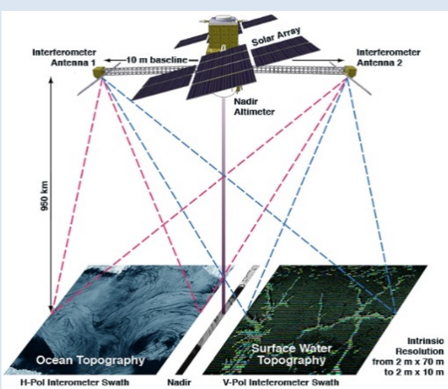
SARAL/AltiKa (CNES-ISRO)
Ka-band Altimetry

2013



Sentinel 3A&B (ESA/EU), Sentinel 6
SAR (doppler) Altimetry

2016, 2018, 2020

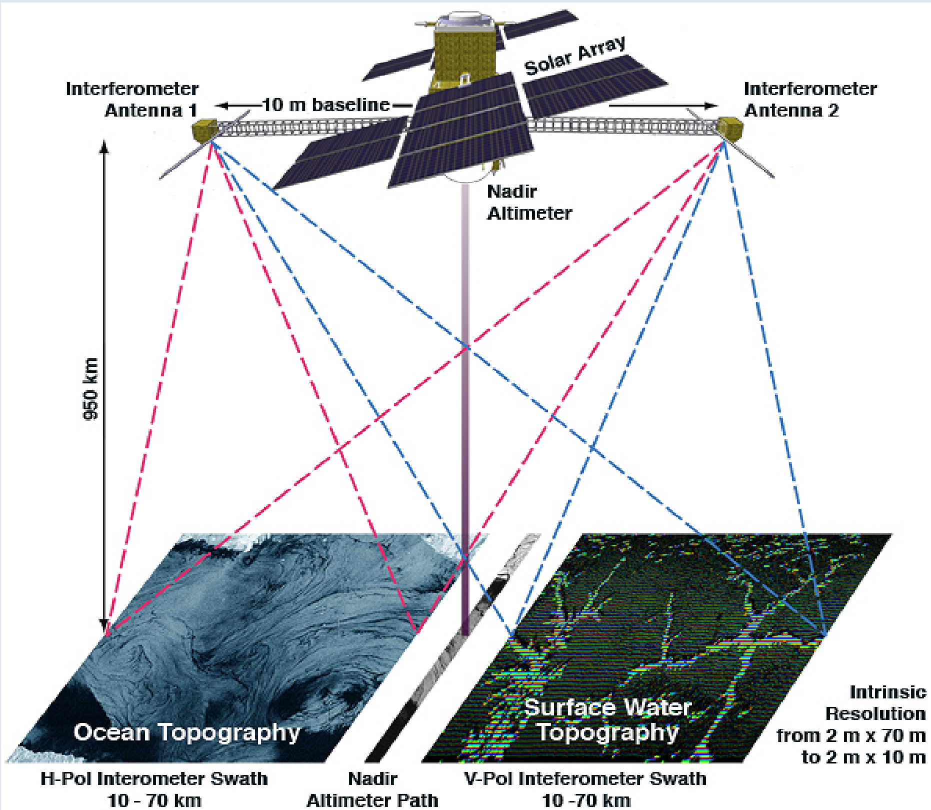


SWOT (CNES/NASA)
Wide-swath Ka-band interferometric radar altimetry

2022

Better accuracy and spatial resolution

4. Conclusion and perspectives



From 1D (nadir-pointing) to 2D altimetry (off-nadir radar interferometry)

Launch planed in 2022

SWOT (The Surface Water and Ocean Topography Satellite Mission)

Scientific objectives:

- **Hydrology**:

Provide a global inventory of all terrestrial water bodies (lakes, reservoirs, wetlands) whose surface area exceeds 250 m by 250 m and rivers whose widths exceed 100 m.

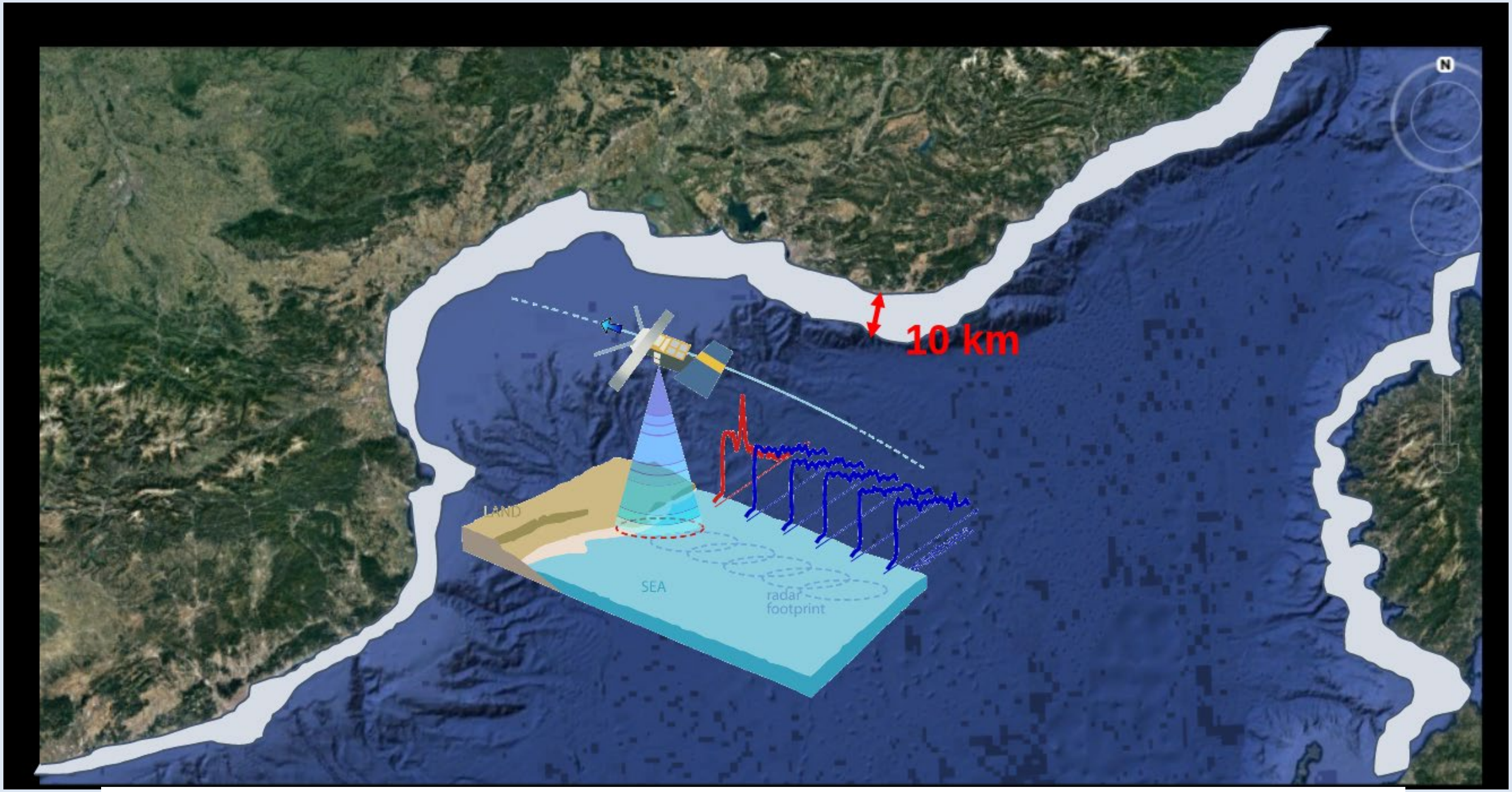
At sub-monthly, seasonal, and annual time scales: Measure the global storage change in freshwater bodies; and Estimate the global change in river discharge.

- **Oceanography:**

Characterize the ocean mesoscale and sub-mesoscale circulation (15 – 200 km) at spatial resolutions of 15 km and greater.

4. Conclusion and perspectives

New challenges for satellite altimetry: Measure coastal sea level variations



- A lot of environmental and societal issues related to the climate change
- Not yet global information from satellite altimetry
- Only very sparse in-situ observations

SATELLITE ALTIMETRY: A WAY OF OBSERVING SEA SURFACE HEIGHT, OCEAN CURRENTS, TIDES, WAVES AND WIND

Prof. Florence Birol
Laboratoire d'études en géophysique et océanographie spatiales

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This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 727277

Satellite altimetry in the coastal zone

Florence Birol, LEGOS, Toulouse, FRANCE

Introduction

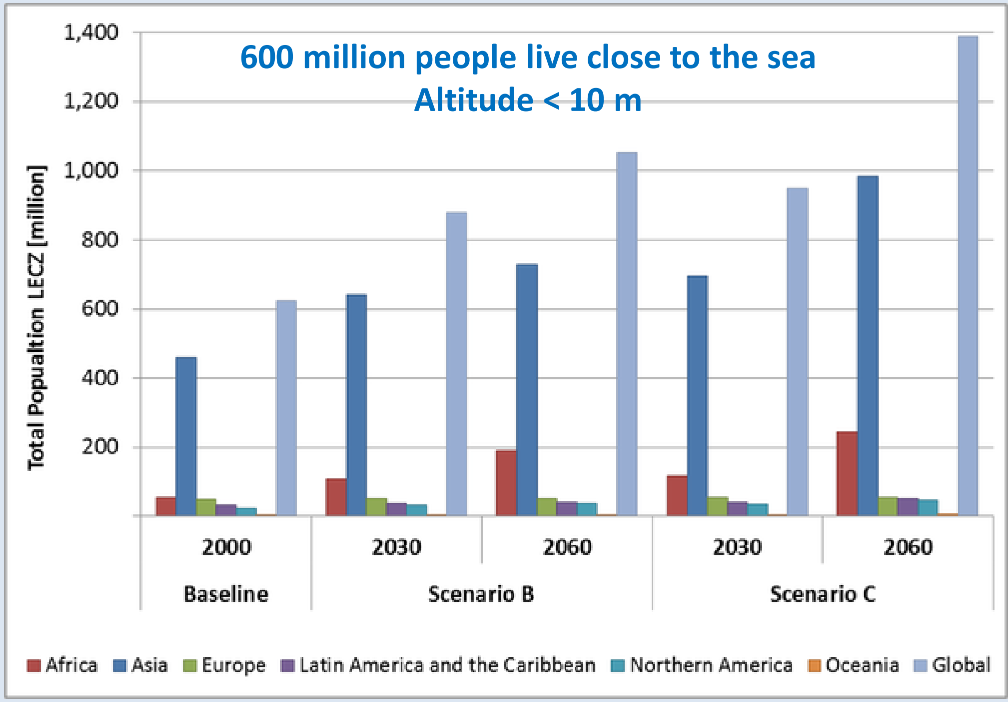
Complex zones, associated to large variations and major economical and ecological issues

Understanding coastal dynamics important for society : economics (fishing, shipping, oil platforms, tourism, ...), environment (pollution control, algal blooms, marine management).

Monitoring coastal processes is difficult:

- rapid time scales,
- small cross-shore space scales,
- shallow-water amplifications & non-linearities

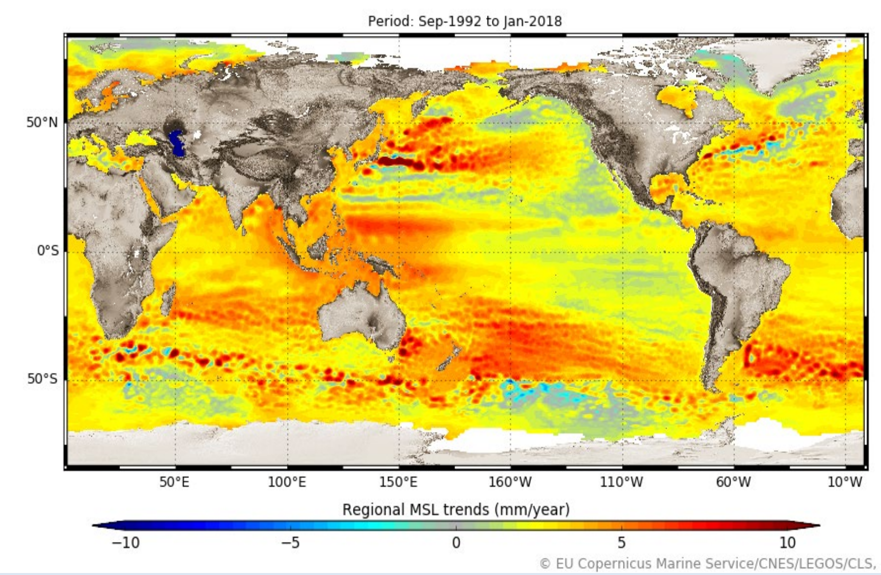
→A lot of instruments needed for the observation and understanding of the ocean… particularly true for the coastal ocean

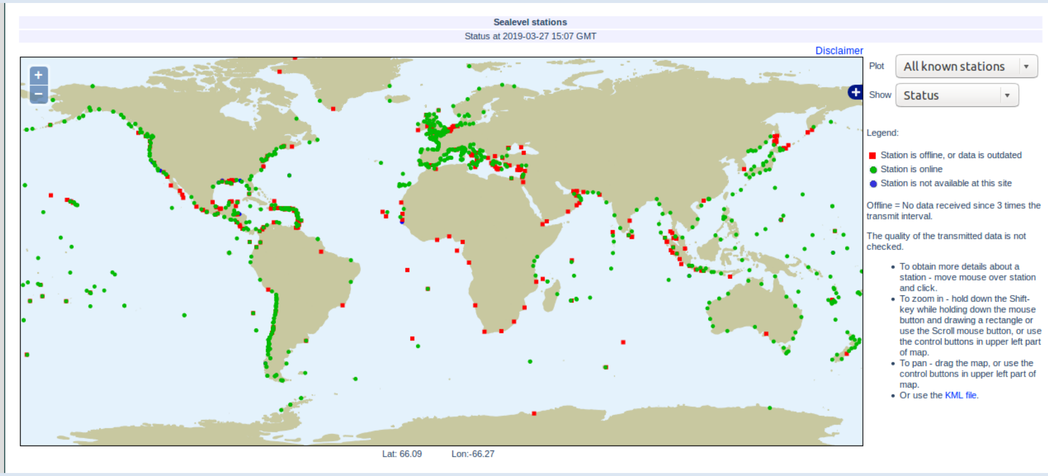


Introduction

Why we need altimetry data in coastal areas?

- Sea level is rising at global scale
- Regional variations of sea level trends are very important.
- **And at a particular place located at the coast, how will the sea level change?**





- Tide gauges data remain sparses and many coastal areas are not covered.

Introduction

Why we need altimetry data in coastal areas?

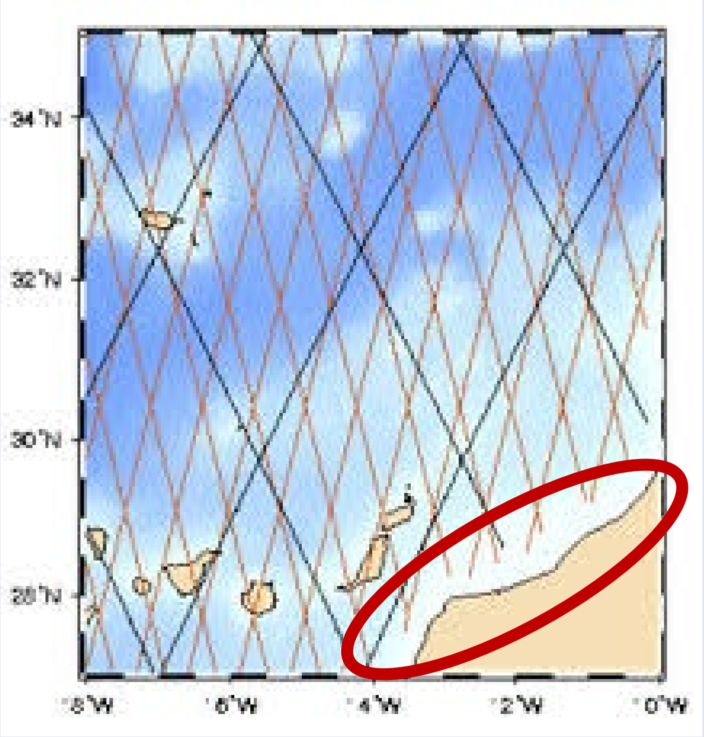
- Sea level variations and extreme events are a major threat for coastal zones. This threat is expected to worsen with time because low-lying coastal areas will become more vulnerable to flooding and land loss as sea level rises in response to climate change.
- Coastal sea level variations result from a combination of different processes that act at different spatial and temporal scales.
- Studying and monitoring such variations requires the development of synergic approaches that use integrated observing systems (in-situ + remote sensing).

Coastal erosion during a king tide, Dania Beach, Florida

Introduction

3 decades of near-global altimetry data for open-ocean oceanography and sea level studies but what about coastal oceanography?

First, definition of coastal zone in satellite altimetry: any place where standard altimetry gets into trouble (from a few km to 20-30 km to land)



Altimetry is poorly used in the coastal zone:

- Issues on waveform analysis
- Issues on altimetry corrections

But the data exist… and we need them!

A lot of research activities during the past 15 years in order to develop new processing strategies for coastal altimetry data

OUTLINE

1. Altimetry data processing near the coast

- **Issues**
- **Solutions**

2. Coastal altimetry products available

3. Example of applications

4. Conclusion and perspectives

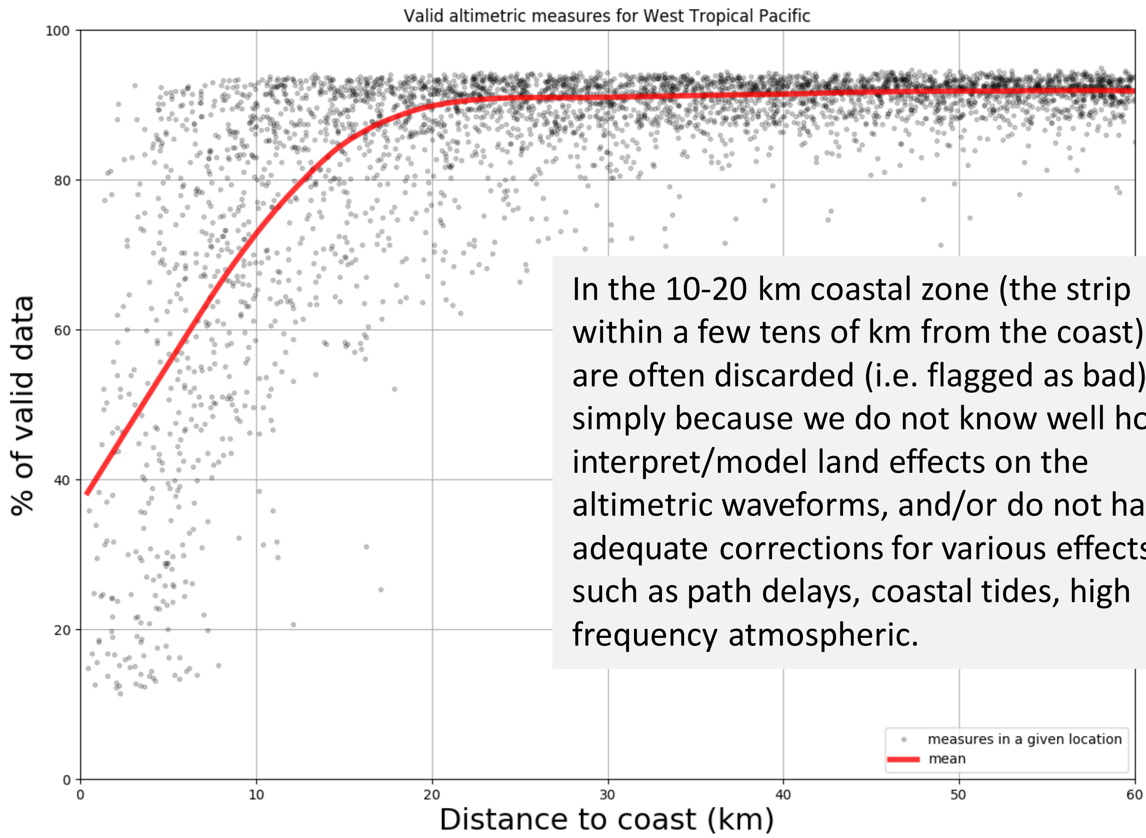
Altimetry data processing near the coast

Some specific issues with altimetry data near the coast

- **Standard altimeter waveforms are deformed by the presence of the land (~10 km from coast),**
- **Radiometer signal (wet troposphere correction) is contaminated by land (30-50 km from coast) as well as other corrections based on altimeter measurements (as SSB).**
- **Tides and atmospheric responses are amplified (any place over the continental shelves). Specific « shallow water » tidal constituents are needed.**
- **The relatively low temporal and spatial sampling of altimetry data compared to the scales of many coastal ocean processes**
- **Altimeter leaving the coast may take 1-2 secs to « lock in » on ocean obs : 7-14 km (only in old missions)!**

Altimetry data processing near the coast

Percentage of valid altimetry measurements as a function of distance to the coast - Example of Jason-2 (X-TRACK product) in the Western Tropical Ocean



In the 10-20 km coastal zone (the strip within a few tens of km from the coast) data are often discarded (i.e. flagged as bad) simply because we do not know well how to interpret/model land effects on the altimetric waveforms, and/or do not have adequate corrections for various effects such as path delays, coastal tides, high frequency atmospheric.

Altimetry data processing near the coast

Some specific issues with altimetry data near the coast

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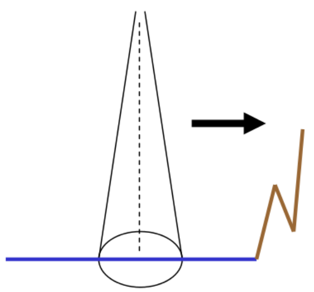
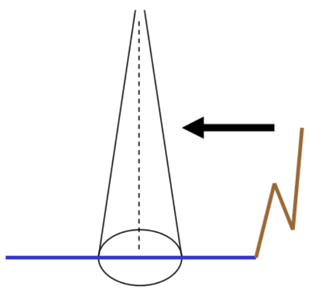
- **Radiometer signal (wet troposphere correction) is contaminated by land (30-50 km from coast) as well as other corrections based on altimeter measurements (as SSB).**
- **Tides and atmospheric responses are amplified (any place over the continental shelves). Specific « shallow water » tidal constituents are needed.**
- **The relatively low temporal and spatial sampling as well as the spatial resolution of altimetry missions**
- **Altimeter leaving the coast may take 1-2 secs to « lock in » on ocean obs : 7-14 km!**





Historically:

- coastal altimetry data where simply rejected by processing algorithms.

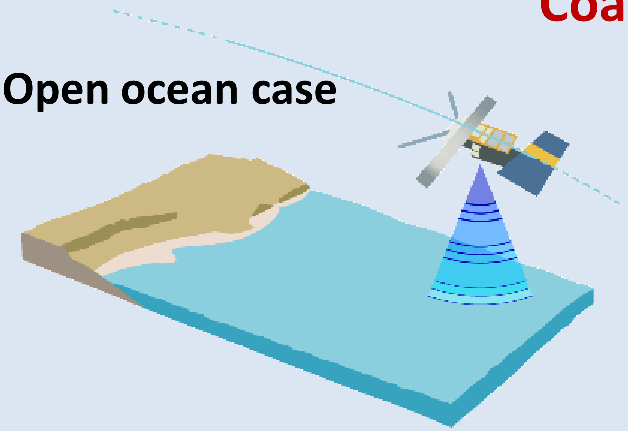
Now:

- many studies & innovations in altimeters are attempting to find solutions to those issues and enhance the number and the quality of altimetry data close to the coasts.

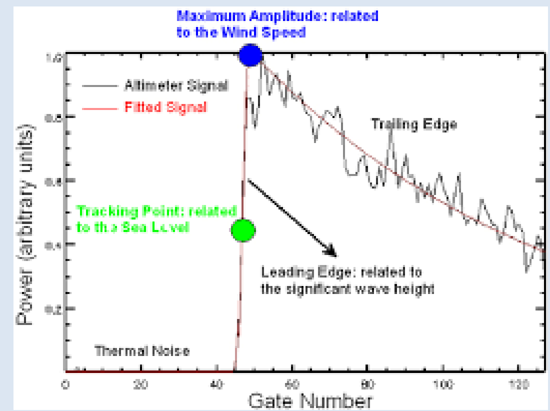
Altimetry data processing near the coast

Coastal altimeter waveforms

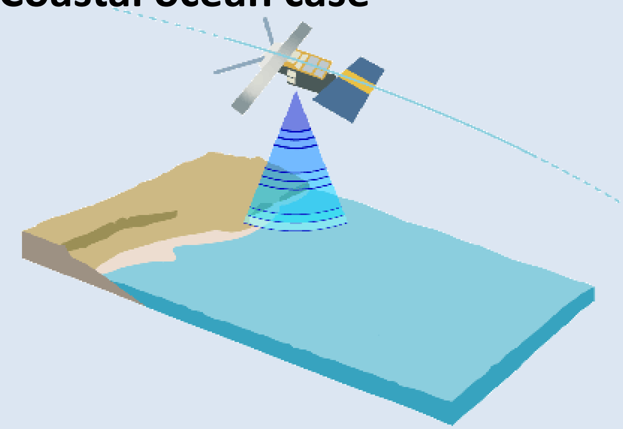
Open ocean case



The well known Brown model



Coastal ocean case



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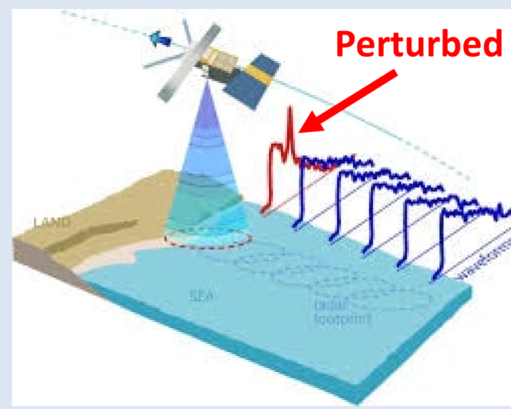
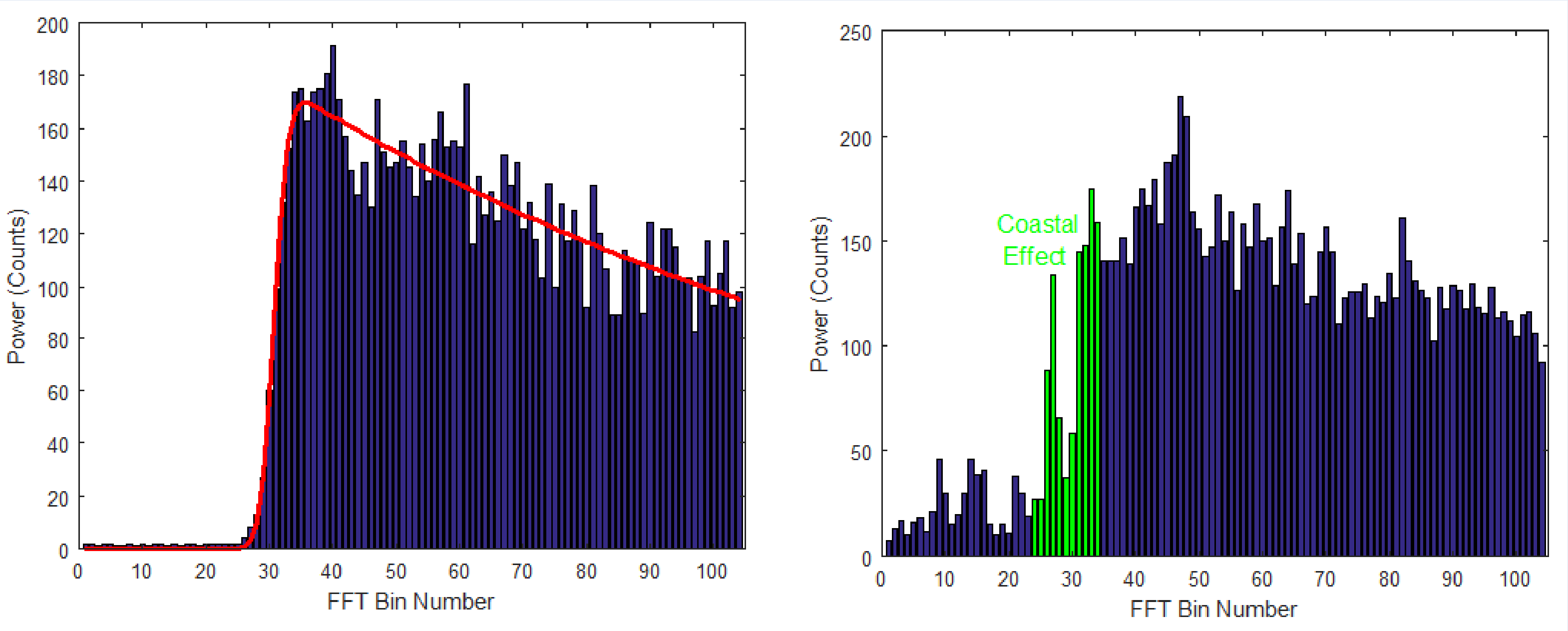


Perturbed altimeter echo

Altimetry data processing near the coast

Coastal altimeter waveforms

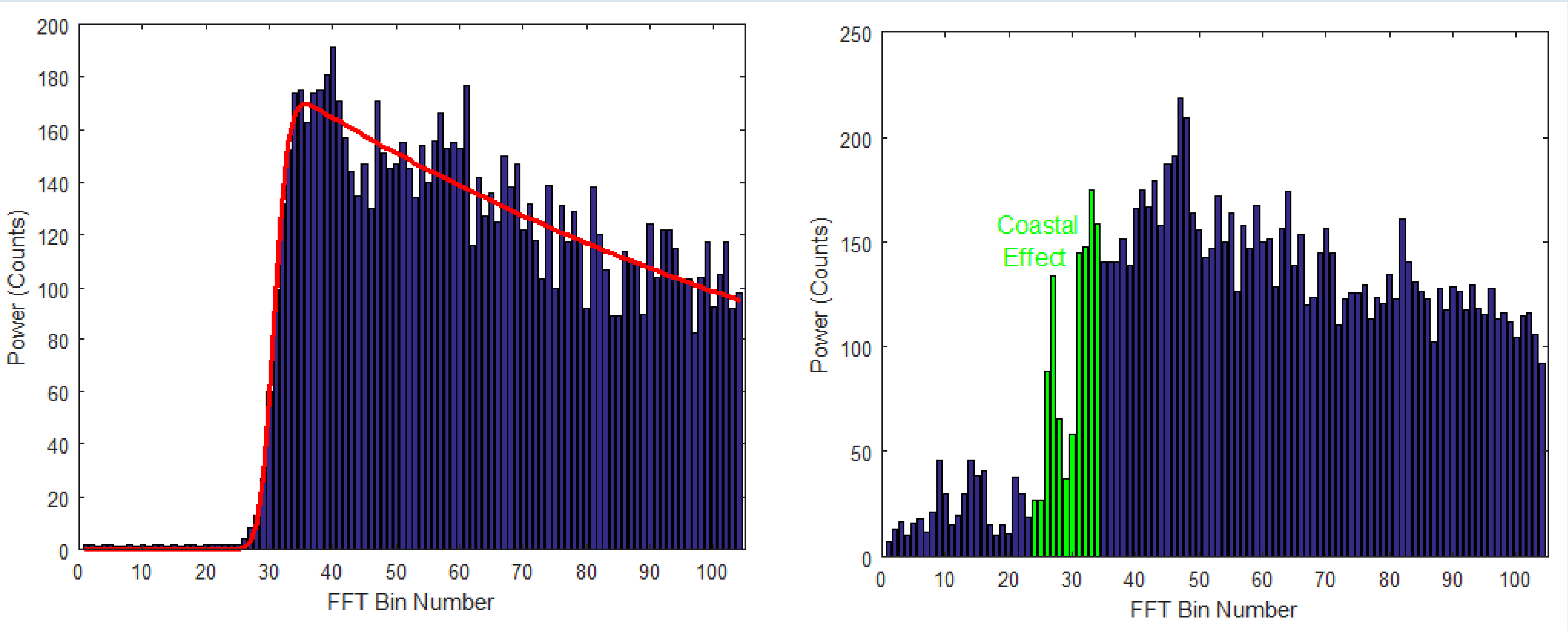


Typical open ocean radar waveform (Brown model)

Example of coastal radar waveform

Altimetry data processing near the coast

Coastal altimeter waveforms



Solutions:

- Waveform classification studies.
- Development of specific retracking algorithms in order to recover « good » geophysical parameters (sea level, wave height, etc) in the nearshore zone
- Altimeter with better performances in coastal areas (typically a smaller footprint)

Altimetry data processing near the coast

Analysis of coastal altimeter waveforms and development of specific retrackers

Example of the ALES retracker
(Passaro et al., 2014)

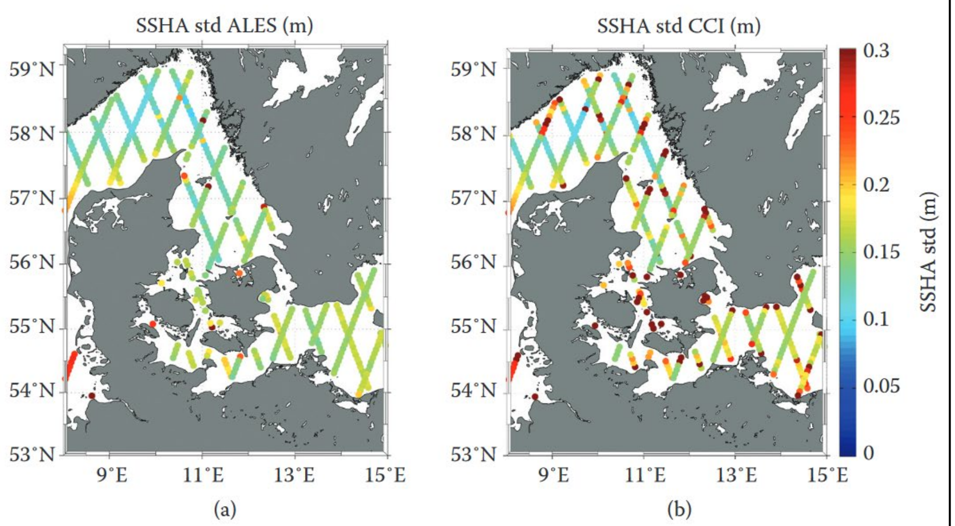


FIGURE 11.11 North Sea/Baltic Sea intersection: Comparison between (a) ALES reprocessed and (b) SL_cci data sets in terms of standard deviation of the Envisat SSHA time series (2002–2010) for each 1-Hz location. (Reprinted from Passaro, M., et al., *J. Geophys. Res. Oceans*, 120(4), 3061–3078, 2015a. With permission. © 2015 American Geophysical Union.)

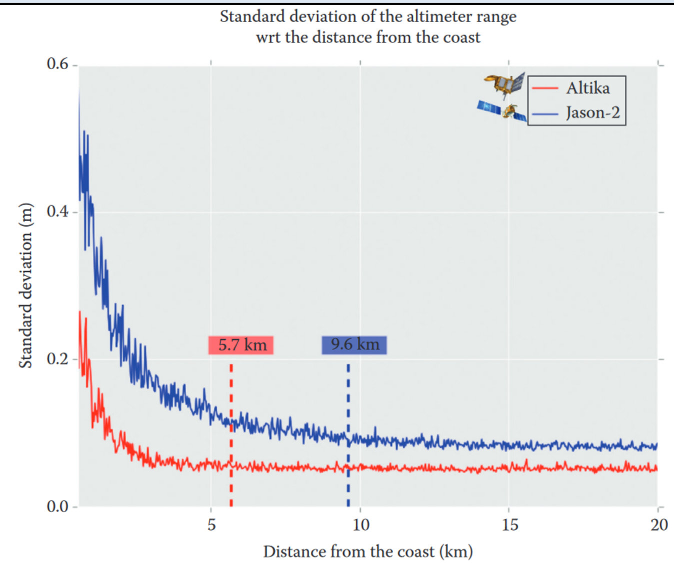


FIGURE 11.10 Performance of SARAL/AltiKa and Jason-2 altimeters near the coast: standard deviation of the altimeter range with respect to the distance from the coast. AltiKa (red curve) is remarkably more precise. (From Cipollini, P., et al., *Surv. Geophys.*, 38, 33, 2017.) Available under the terms of the Creative Commons Attribution 4.0 International License.

Ka-band vs Ku-band altimeters

Altimetry data processing near the coast

The geophysical correction issue

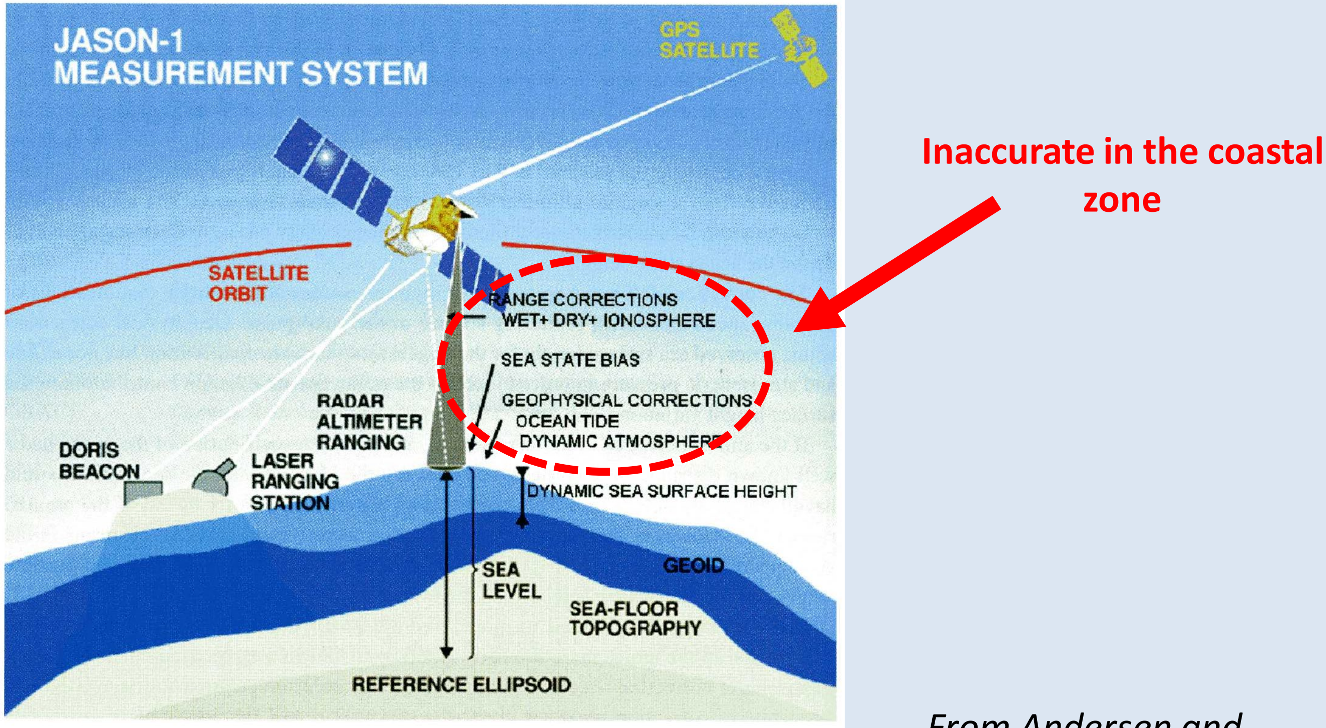
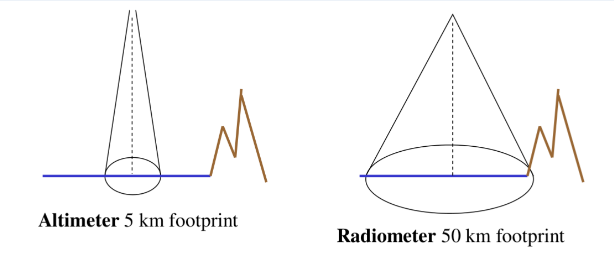


Fig. 5.1 A schematic illustration of the principle of satellite altimetry and the corrections applied to the altimeter observations of sea surface height. The range corrections affect the range through the speed of the radar pulse and sea-state bias. The geophysical corrections removed the largest known contributor to sea level in order to enhance the oceanographic contributor. (Figure modified from AVISO)

From Andersen and Sharroo, 2011

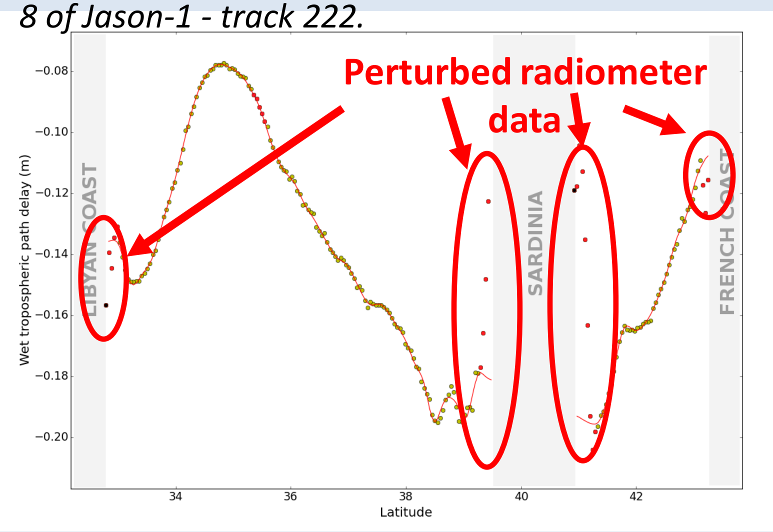
Altimetry data processing near the coast

The wet tropospheric correction

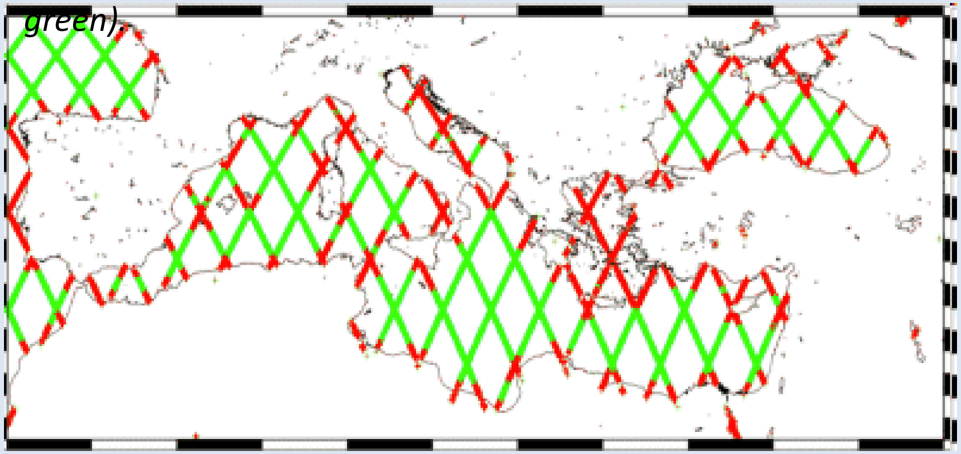


Classically, microwave radiometer measurements of brightness temperature are used. Due to their frequency, their footprint is larger than the altimeter footprint, and the wet troposphere correction is contaminated by land up to 30-50 km from the coast.

Example of wet tropo corr from radiometer – cycle 8 of Jason-1 - track 222.

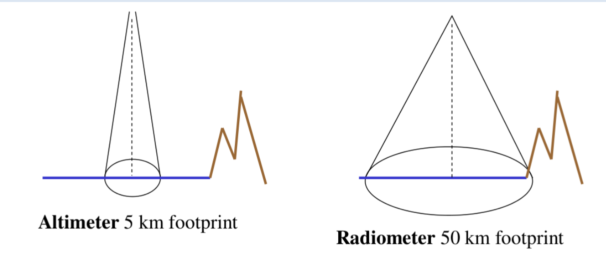


For Jason-1 or Topex/Poseidon, areas where radiometer measurements are typically disregarded by standard processing (in red) and ones where they are retained (in green).



Altimetry data processing near the coast

The wet tropospheric correction



Classically, microwave radiometer measurements of brightness temperature are used. Due to their frequency, their footprint is larger than the altimeter footprint, and the wet troposphere correction is contaminated by land up to 30-50 km from the coast.

Solutions:

- Replace radiometer measurements by model estimates, but the errors are large in coastal zone.
- Extrapolate valid radiometer measurements into the coastal zone (CTOH/LEGOS)
- Radiometer measurement decontamination techniques (JPL, CLS)

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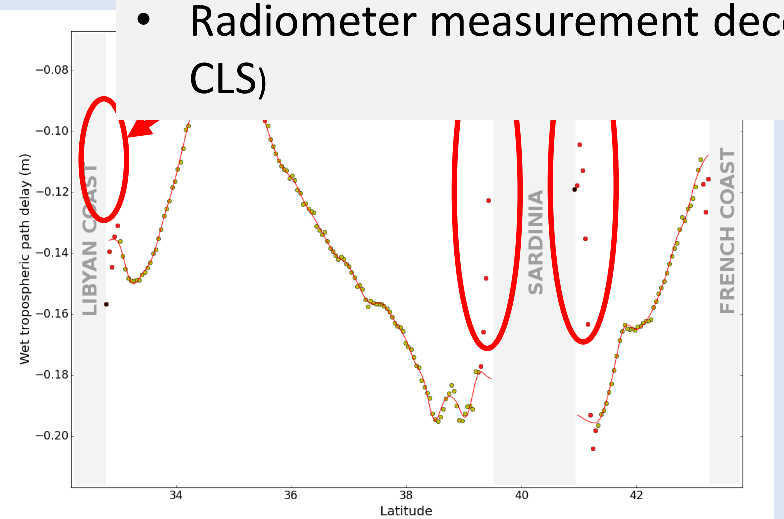

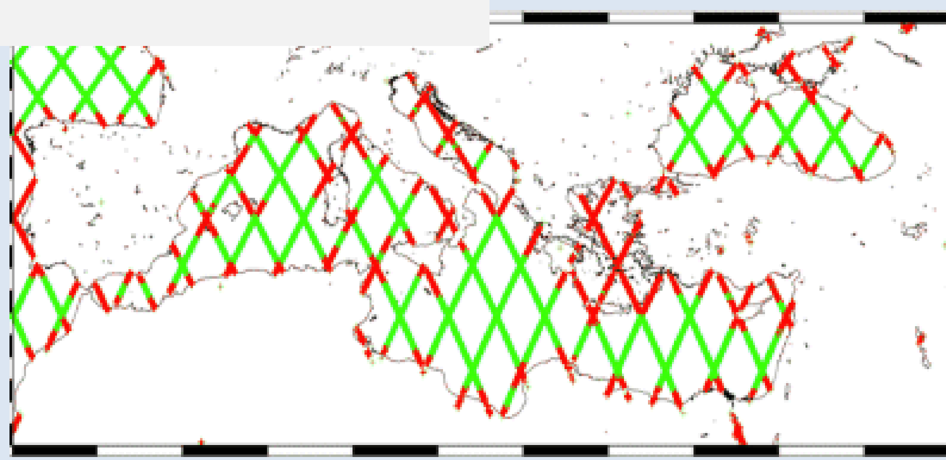

Solutions:

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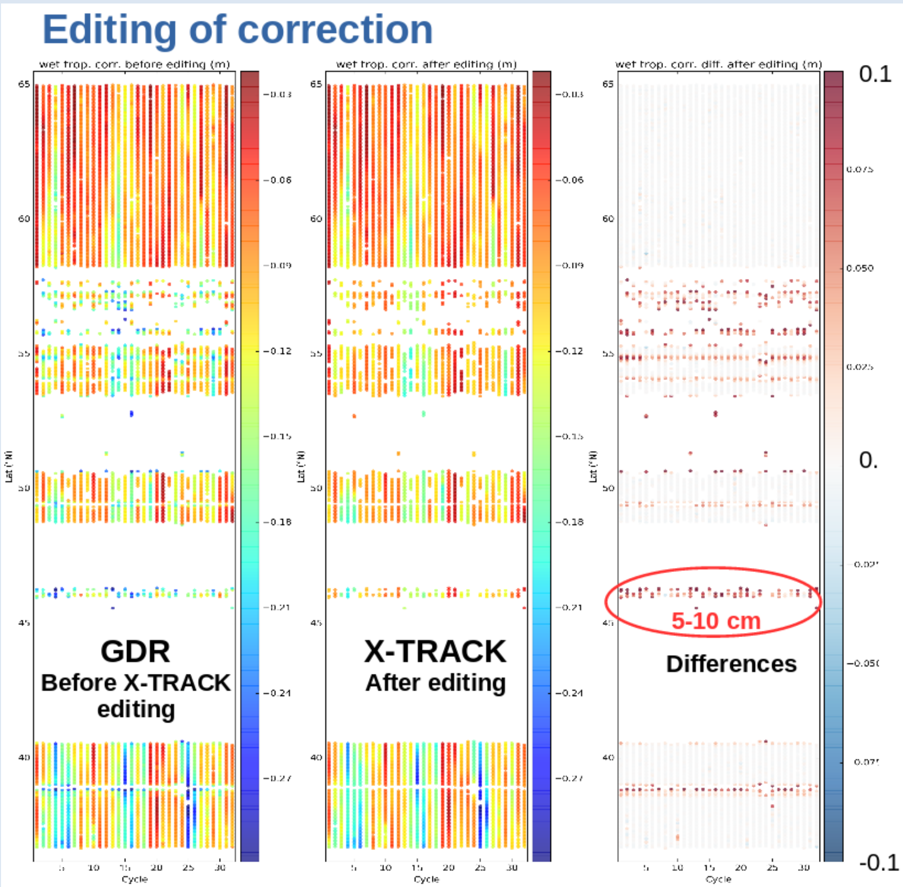
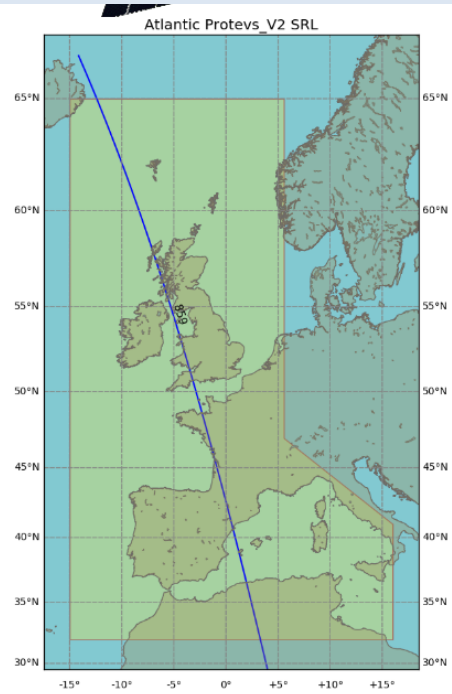
Altimetry data processing near the coast

The wet tropospheric correction





Wet tropospheric correction before/after editing in X-TRACK and difference for the SARAL/ALTIKA track 859 in the North East Atlantic and Mediterranean Sea zones.

Example of the CTOH/LEGOS solution (algorithm detailed in Birol et al., 2017):

Implemented in the X-TRACK processing chain

Altimetry data processing near the coast

The ocean tide and response to atmospheric forcing (DAC) corrections

In shallow coastal zones, tides and atmospheric responses are amplified and more complex.

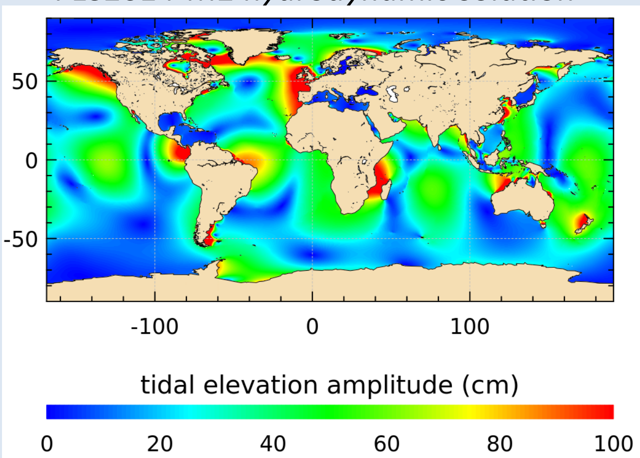
Tides

a) new global tidal models are implemented (FES2014) with improved performance in the coastal zones.
b) Regional tidal models are also used for high space-time resolution.

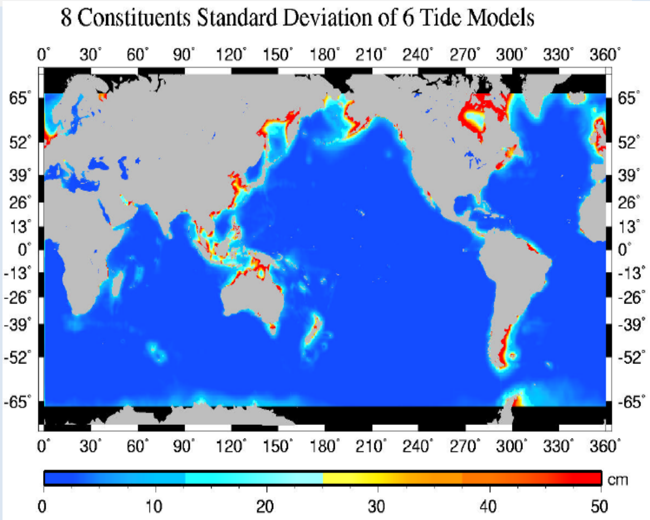
Response to atmospheric forcing

a) new global barotropic model correction are implemented (MOG2D) with improved performance in the coastal zones.
b) Regional, high-resolution versions of these models are also used

FES2014 M2 hydrodynamic solution



Courtesy of F. Lyard



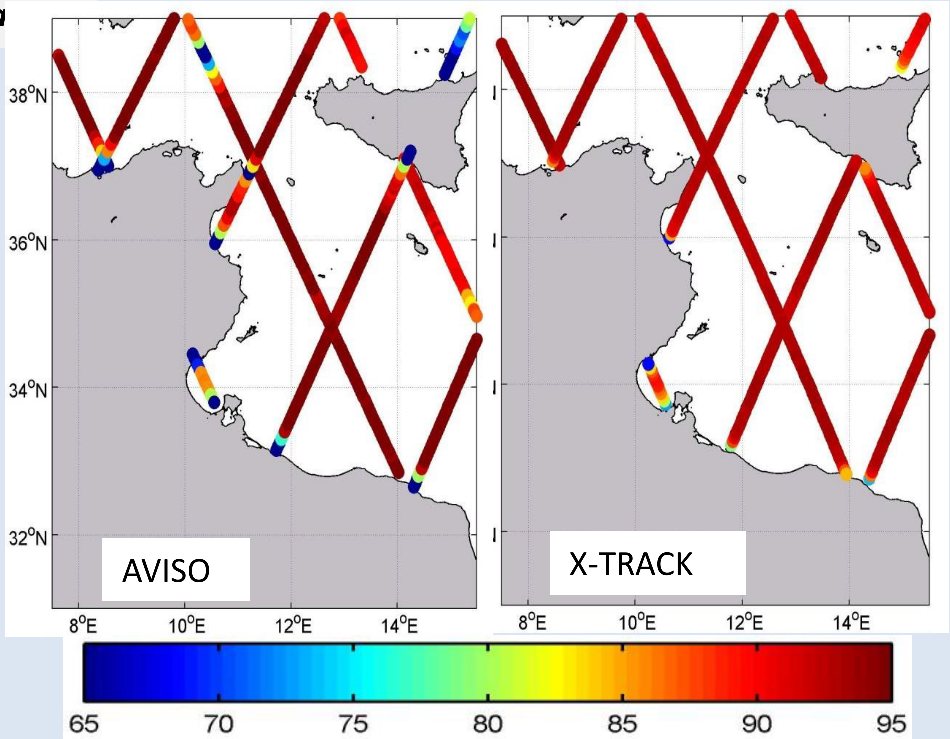
Courtesy of C.K. Shum

Altimetry data processing near the coast

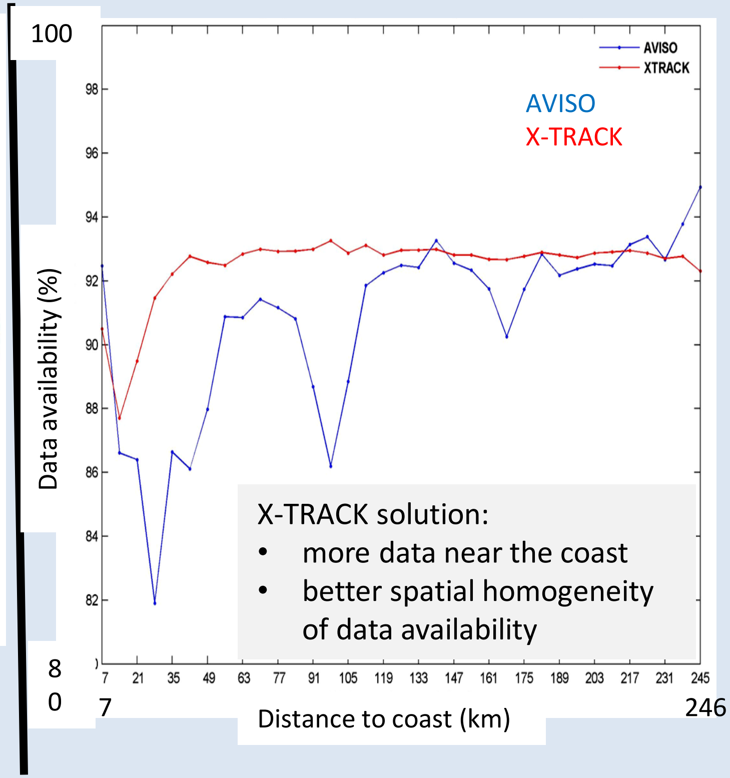
Example of the CTOH/LEGOS X-TRACK project: correction & editing approa

Specific processing developed

Percentage of altimetry data availability from T/P+J1+J2 mission for the period 1993-2013.



Average percentage of X-TRACK and AVISO data availability as a function of the distance to coast.



X-TRACK solution:

- more data near the coast
- better spatial homogeneity of data availability

From Jébri et al., 2016

CONTENT

1. Altimetry data processing near the coast
- Issues
- Solutions

2. Coastal altimetry products available

3. Example of applications

4. Conclusion and perspectives

Coastal altimetry products available

General view

The projects mentioned earlier have generated several dedicated coastal altimetry data sets.

- **ALES: Level 2 product**

Adaptive Leading Edge Subwaveform (ALES) applies a waveform retracker to the high frequency altimetric data to help get rid of land contamination in measurements near the coast. It includes data for both the coast and open ocean in one dataset.
Missions: Jason-2, Envisat, Jason-1 and SARAL/AltiKa.
https://podaac.jpl.nasa.gov/

- **PEACHI: Level 2 product**

PEACHI (Prototype for Expertise on AltiKa for Coastal, Hydrology and Ice) is a project that generates coastal and hydrological altimetric datasets. It retracks the altimeter signal near land to remove aliasing.
Mission: SARAL/AltiKa
https://www.aviso.altimetry.fr/en/data/products/sea-surface-height-products/global/experimental-saral-products-peachi.html

- **PISTACH: Level 2 product**

PISTACH (Prototype Innovant de Systèm de Traitement pour les Applications Côtières et l'Hydrologie) is a project that generates coastal and hydrological altimetric datasets. It retracks the altimeter signal near land to remove aliasing.
Mission: Jason-2
https://www.aviso.altimetry.fr/en/data/products/sea-surface-height-products/global/coastal-and-hydrological-products.html

Coastal altimetry products available

General view

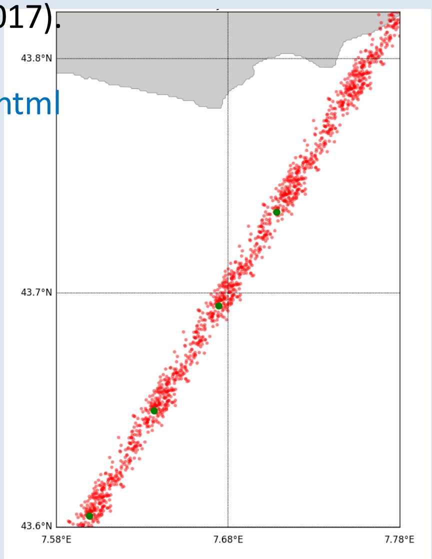
The projects mentioned earlier have generated several dedicated coastal altimetry data sets.

- **X-TRACK: Level-3 product**

CTOH (Center for Topographic studies on the Ocean and Hydrosphere) computes and distributes coastal altimetric datasets. Each correction is severely edited and recomputed in order to minimize the data loss due to inaccurate corrective terms. A statistical approach is implemented along the track in order to detect potential outliers. Then an interpolation/extrapolation strategy allows to reconstruct the missing geophysical corrections up to the coastline (Birol et al., 2017).

Missions: Topex/Poseidon, Envisat, Jason-1&2&3, GFO and SARAL/AltiKa, Sentinel-3 (soon).

https://www.aviso.altimetry.fr/en/data/products/sea-surface-height-products/regional/x-track-sla.html



Level-2 (intermediate level) → Level-3 (easy-to-use) product:

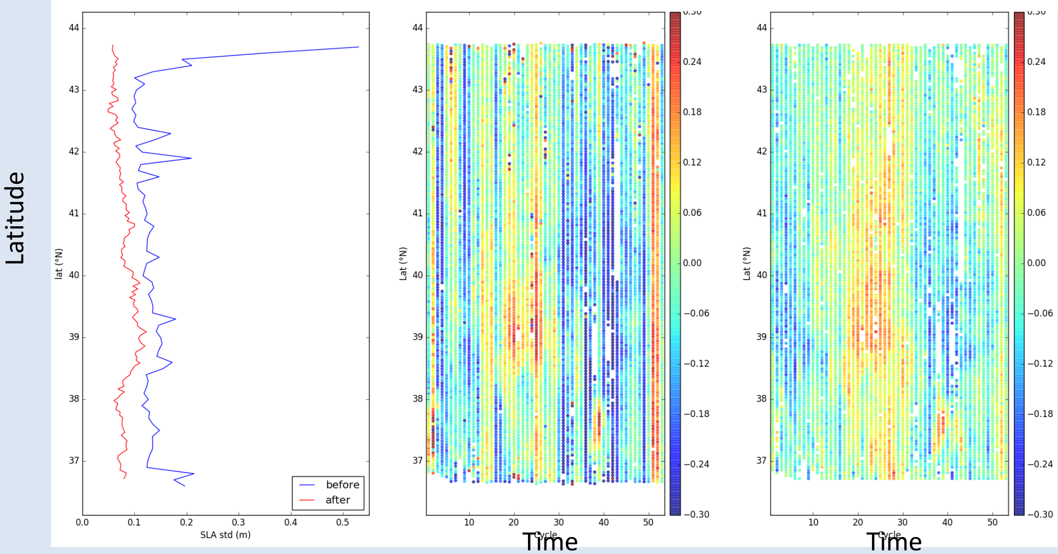
- From original altimetry measurements unevenly spaced along a theoretical groundtrack (red points)…
- … to time series at equally spaced points (6-7 km at 1-Hz) along a nominal groundtrack (green circles)

Coastal altimetry products available

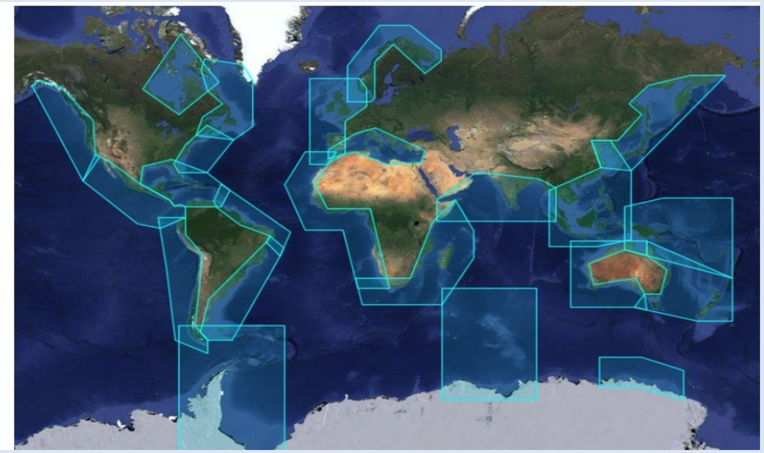
X-TRACK product: a regional product

- X-TRACK software has been developed by CTOH and LEGOS.
- It is tailored for extending the use of altimetry data to coastal ocean applications
- It provides freely available along-track Sea Level Anomaly time series as well as along-track empirical tidal constants that cover all the coastal oceans.

SLA std (left) and SLA before editing (blue / center) and at the end of the X-TRACK processing chain (red / right) for the J2 track 9 in the Mediterranean Sea.



Definition of the regional polygons in release 2017, covering now all the coastal areas (23 regions).



Coastal altimetry products available

X-TRACK SLA: product content

```
<~/Documents/CTOH/CONF/2018/COASTALT2018>leger<pc-fuller> : ncdump -h ctoh.sla.ref.TP+J1+J2+J3.gom.013.nc
netcdf ctoh.sla.ref.TP+J1+J2+J3.gom.013 {

dimensions:
        nbcycles = 899 ;
        nbpoints = 210 ;

variables:
        float lon(nbpoints) ;
                lon:units = "degrees_east" ;
                lon:unit_long = "Degrees East" ;
                lon:long_name = "Longitude" ;
                lon:short_name = "Lon" ;
                lon:_FillValue = 99.999901f ;
                lon:lon_min = -67.f ;
                lon:lon_max = -61.f ;
                lon:missing_value = 99.999901f ;
                lon:scale_factor = 1.f ;
                lon:add_offset = 0.f ;
        …
        float sla(nbpoints, nbcycles) ;
                sla:units = "m" ;
                sla:unit_long = "Meter" ;
                sla:long_name = "XTRACK Sea Level " ;
                sla:short_name = "SLA" ;
                sla:_FillValue = 99.999901f ;
                sla:missing_value = 99.999901f ;
                sla:scale_factor = 1.f ;
                sla:add_offset = 0.f ;
                sla:comment = "All corrections applied
                        including tide, wind and pressure effects" ;
        …

// global attributes:
                :title = "CTOH Along track Sea Level Anomalies" ;
                :institution = "CTOH/LEGOS, Toulouse Univ., CNRS, IRD,
                        CNES, UPS, France" ;
                :Conventions = "CF-1.6" ;
                :history = "creation: 2018/02/27" ;
                :contact = "ctoh_products@legos.obs-mip.fr
                        http://ctoh.legos.obs-mip.fr" ;
                :source = "Version X-TRACK: 1.02.post10
                        - Version mercurial: hgc059b8811cc6" ;
                :doi = "10.6096/CTOH_X-TRACK_2017_02" ;
                :reference = "Birol, F. et al. "Coastal Applications from Nadir
                        Altimetry: Example of the X-TRACK Regional Products."
                        Advances in Space Research 59, no. 4 (February 2017):
                        936–53. doi:10.1016/j.asr.2016.11.005." ;
                :NCO = "4.0.9" ;
```

Variables	
Latitude	DAC correction
Longitude	Tide correction
Mean Sea Surface (X-TRACK)	Mean Dynamic Topography
Cycle / missions_cycles	Distance to the coast GSHHS
Sea Level Anomaly	Distance to the coast Stumpf
Time	

Coastal altimetry products available

X-TRACK: also a regional tidal constant product

Along-track Tidal Constants

Along-track tidal constants (amplitude and phase lags) derived from the X-TRACK T/P and Jason are available every 6-7 km along the satellite ground tracks by using harmonic analysis for a number of 73 tidal constituents

They have been computed with the 1hz SLA for the whole TP, Jason1&2 period and for the TP/J1 interleaved combined mission.

Tidal constant product names :

ctoh.harmonics.ref.[**satname**].[**region**].[**numtrack**].nc

Example for the track n°9 of the tidal constant computed with Topex, Jason-1, Jason-2 combined data in the patagonia zone :

=> ctoh.harmonics.ref.TP+J1+J2.patagonia.009.nc

Sa	Ssa	MSm	Mm	Mqm
Mf	MStm	Mtm	MSqm	O1
2Q1	Sig1	Q1	Ro1	P1
MP1	M1	KI1	Pi1	J1
K1	Psi1	Phi1	Tta1	MNS2
SO&	OO1	KQ1	OQ2	N2
E2	2mk2	2N2	Mu2	M(KS)2
Nu2	MSK2	M(SK)2	M2	S2
MKS2	La2	L2	T2	2SM2
R2	K2	MSN2	KJ2	S3
2MK3	M3	SO3	MK3	M4
SK3	N4	3MS4	MN4	SK4
SN4	MS4	MK4	S4	2MK6
2MN6	M6	MSN6	2MS6	
2SM6	MSK6	3MS8	MSf	

List of the 73 tidal constituents in the X-TRACK tidal constant product.

Coastal altimetry products available

X-TRACK: also a regional tidal constant product

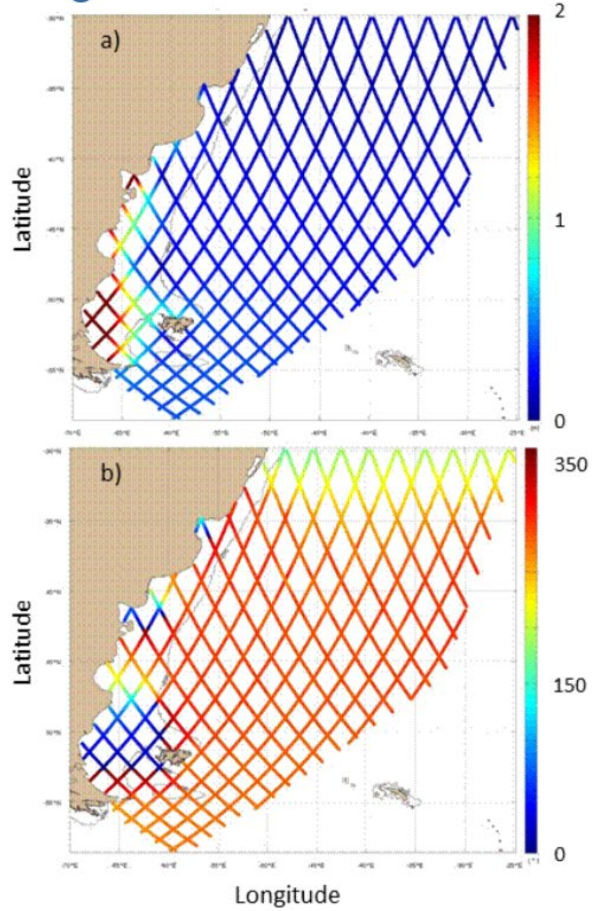
Along-Track tidal Constant:

Constants	Real Period (hours)	Aliasing Period (days)
M_2	12.42	62.11
S_2	12.00	58.74
N_2	12.66	49.53
K_2	11.98	86.60
K_1	23.93	173.19
O_1	25.82	45.71
M_4	6.21	31.05
MS_4	6.10	1083.94
M_6	4.14	20.70

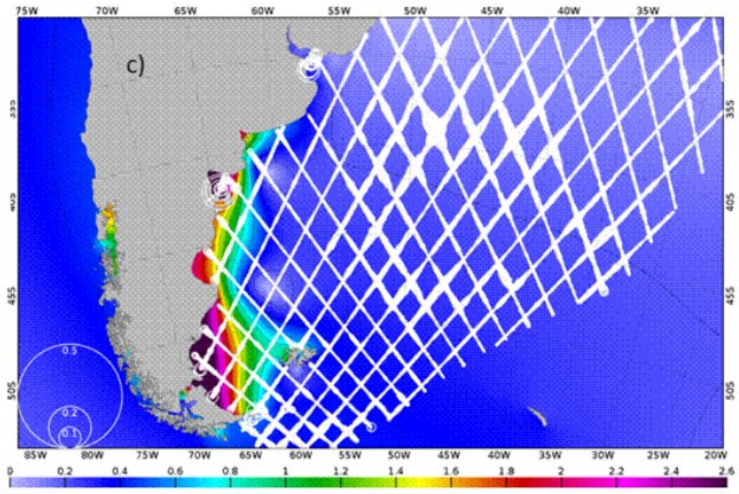
Recording time required for separation.	
Hourly frequency	TP/J frequency (~10 days)
Optimal separation 1 year	Optimal separation 10 years
Minimum separation 2 months	Minimum separation 2 years

Coastal altimetry products available

Along-Track tidal Constant



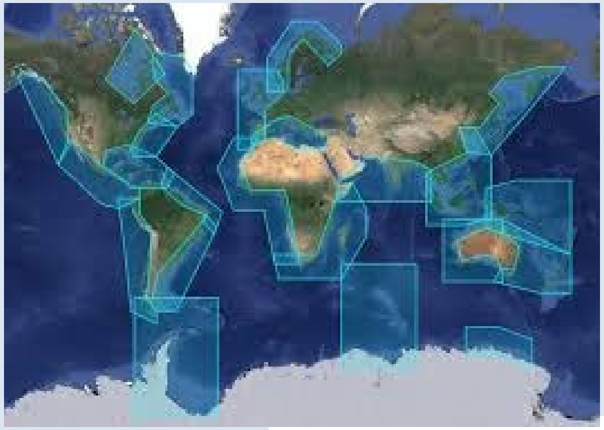
(a) Amplitude and (b) phase of M2 from the X-TRACK tidal constant product. (c) Vector differences between FES2012 global tidal model and the X-TRACK tidal constants for M2. The background color shows the amplitude of the M2 tidal constant from the model (in m). The white dots represent the vector difference.

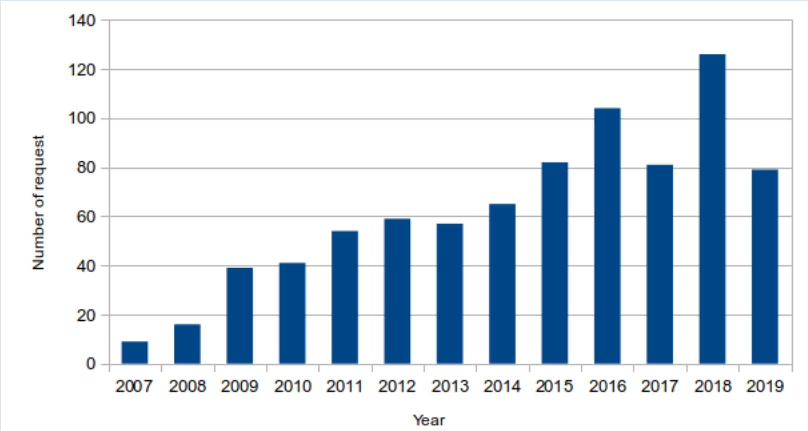


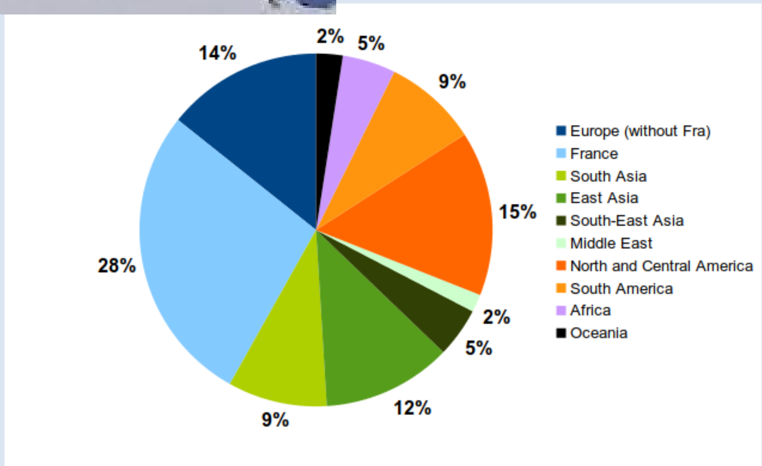
From Birol et al. 2017

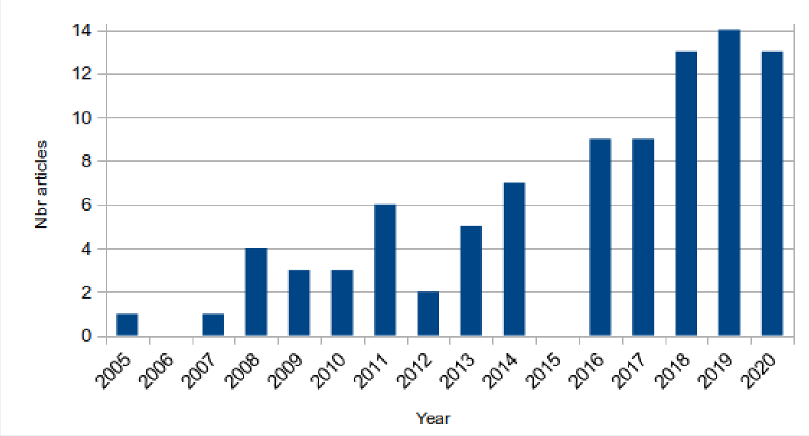
Coastal altimetry products available

X-TRACK: user statistics



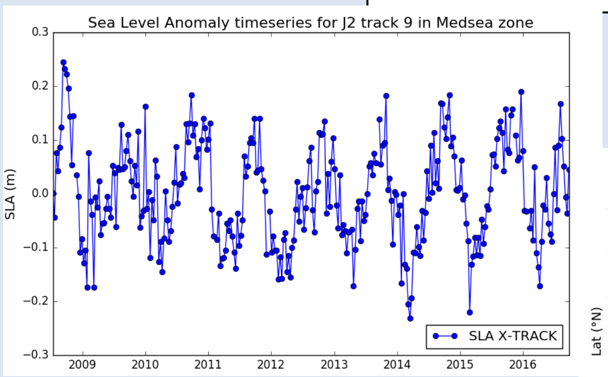


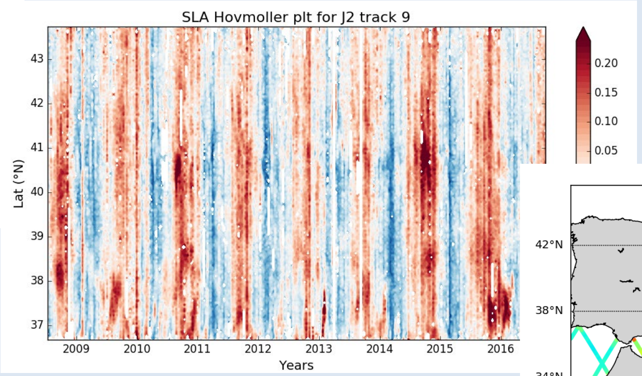


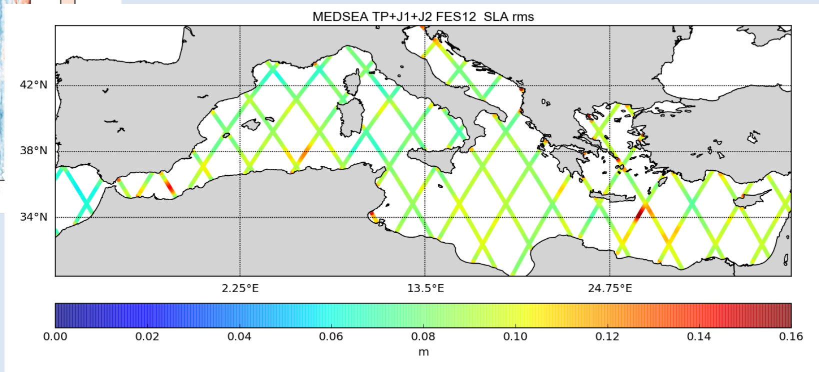


Coastal altimetry products available

More informations in exercises on satellite altimetry data scheduled tomorrow







CONTENT

1. Altimetry data processing near the coast
   - Issues
   - Solutions

2. Coastal altimetry products available

3. Example of applications

4. Conclusion and perspectives

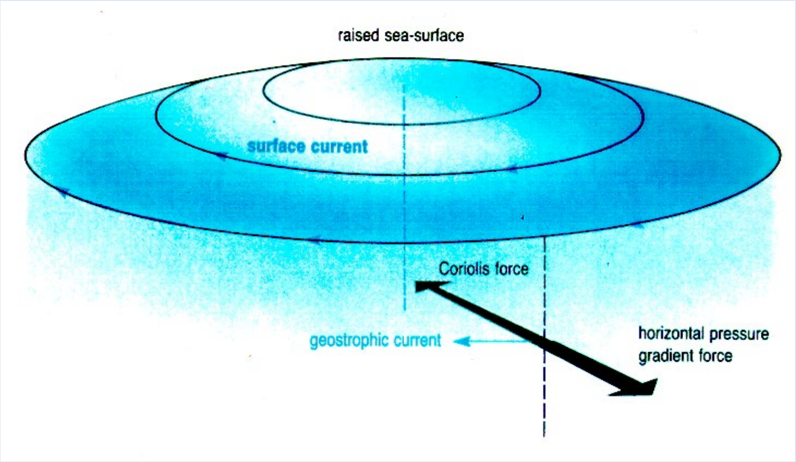
Example of applications

Surface currents

Geostrophic currents

A geostrophic current is an oceanic current in which the pressure gradient force is balanced by the Coriolis effect. The direction of geostrophic flow is parallel to the isobars

Geostrophic equation: $u = -\frac{g}{f}\frac{\partial h}{\partial y}$; $v = \frac{g}{f}\frac{\partial h}{\partial x}$



Geostrophic currents derived from altimetry data

- Surface geostrophic current only
- Only one direction for alongtrack data (both components for gridded data but gridded data are too smooth for coastal applications): Cross-track component
- Computation not directly possible at the equator
- Current anomaly from SLA
- Absolute current if we add a MDT product … but MDT not always accurate in coastal areas

Example of applications

Objective

Investigate the seasonal and interannual variations of the coastal circulation in the northern South China Sea.

Methodology

Geostrophic current anomalies derived from the long time series of X-TRACK SLA data (T/P+Jason-1,2 missions) + ADCP + tide gauge data

water

MDPI

Article

Seasonal and Interannual Variability in Coastal Circulations in the Northern South China Sea

Jin Liu [1], Juanjuan Dai [1], Dongfeng Xu [2], Jun Wang [2] and Yeping Yuan [1,2,*]

1 Institute of Physical Oceanography, Ocean College, Zhejiang University, Zhoushan 316021, China; jinliu@163.com (J.L.); dai_jjuan@163.com (J.D.)
2 State Key Laboratory of Satellite Ocean Environment Dynamics, Second Institute of Oceanography, State Oceanic Administration, Hangzhou 310000, China; xudongfengsio@sio.org.cn (D.X.); wangjun@sio.org.cn (J.W.)
* Correspondence: yyping@zju.edu.cn

check for updates

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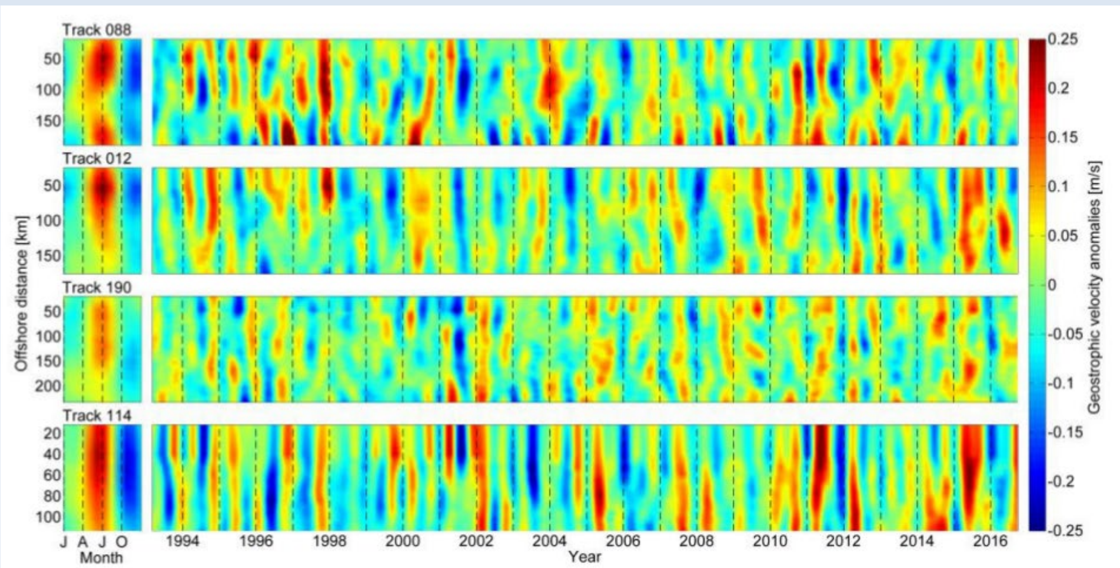
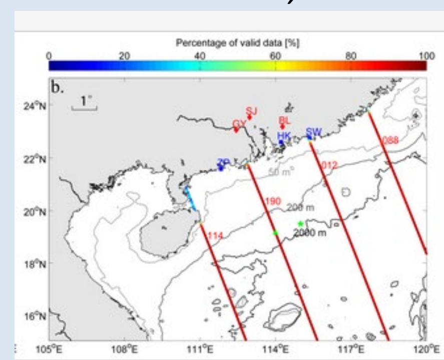
From Liu et al., 2018





Map of the Northern South China Sea and Jason altimeter ground tracks (right). Seasonal cycles and interannual variabilities in geostrophic velocity anomalies across the four ground tracks (left).

Example of applications

Objective
Investigate the seasonal and interannual variations of the coastal circulation in the Central Mediterranean Sea.

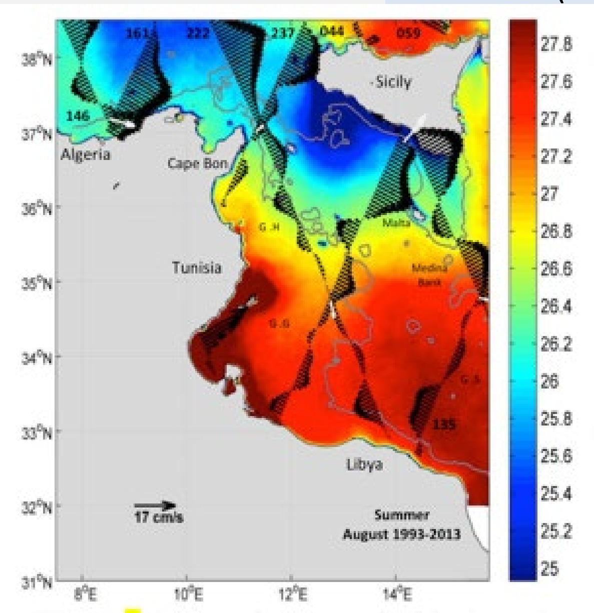
Methodology
Geostrophic current anomalies derived from the long time series of X-TRACK SLA data (T/P+Jason-1,2 missions) + SST

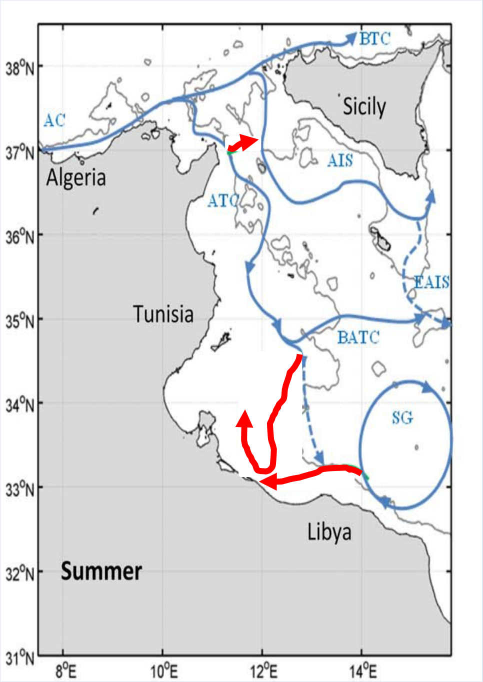
From Jebri et al., 2016

Monthly climatology (1993-2013):
- *SST (AVHRR)*
- *geostrophic currents (altimetry+MDT)*

Summer case

SST (°C)





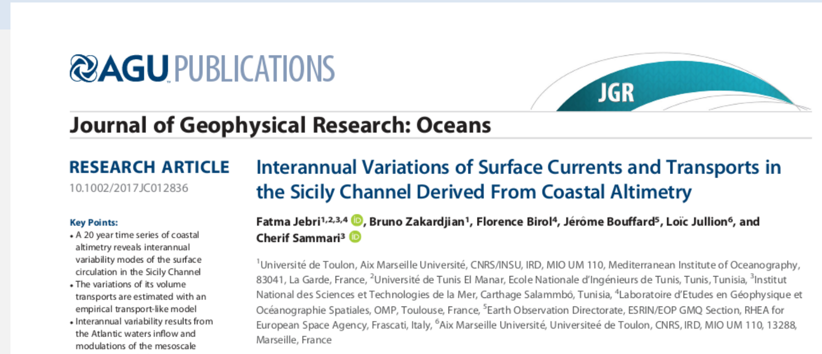
Example of applications

Objective

Compute and analyze water mass budgets at regional scale.

Methodology

Derivation of an empirical model from CTD data in order to extrapolate altimetry-derived currents in the vertical direction and then compute transports



AGU PUBLICATIONS

JGR

Journal of Geophysical Research: Oceans

RESEARCH ARTICLE

10.1002/2017JC012836

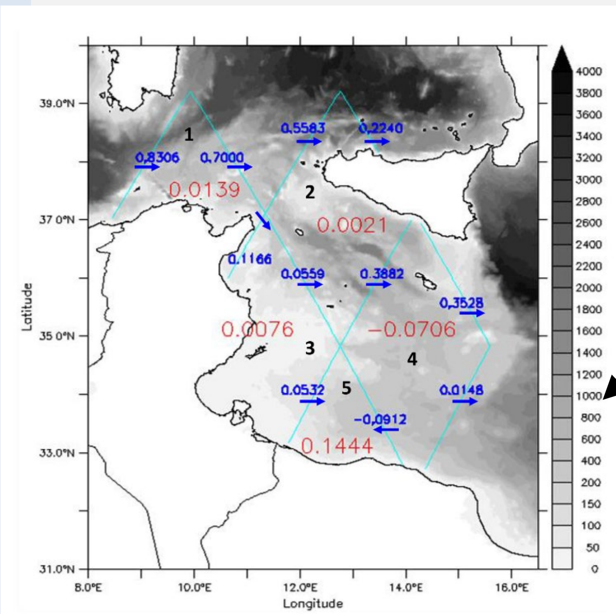
Interannual Variations of Surface Currents and Transports in the Sicily Channel Derived From Coastal Altimetry

Fatma Jebri[1,2,3,4], Bruno Zakardjian[1], Florence Birol[4], Jérôme Bouffard[5], Loïc Jullion[6], and Cherif Sammari[3]

[1]Université de Toulon, Aix Marseille Université, CNRS/INSU, IRD, MIO UM 110, Mediterranean Institute of Oceanography, 83041, La Garde, France, [2]Université de Tunis El Manar, Ecole Nationale d'Ingénieurs de Tunis, Tunis, Tunisia, [3]Institut National des Sciences et Technologies de la Mer, Carthage Salammbô, Tunisia, [4]Laboratoire d'Etudes en Géophysique et Océanographie Spatiales, OMP, Toulouse, France, [5]Earth Observation Directorate, ESRIN/EOP GMQ Section, RHEA for European Space Agency, Frascati, Italy, [6]Aix Marseille Université, Universiteé de Toulon, CNRS, IRD, MIO UM 110, 13288, Marseille, France

Key Points:

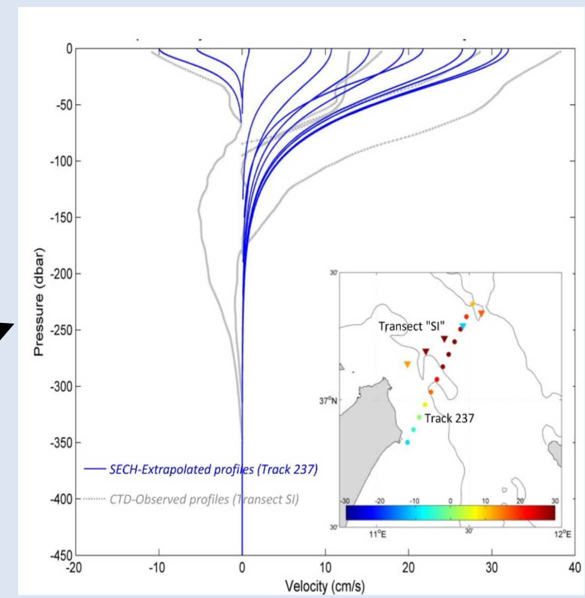
- A 20 year time series of coastal altimetry reveals interannual variability modes of the surface circulation in the Sicily Channel
- The variations of its volume transports are estimated with an empirical transport-like model
- Interannual variability results from the Atlantic waters inflow and modulations of the mesoscale activity in coupled or compensating



From Jebri et al., 2017

Mean transports (in blue) and track-closed transport residuals (in red) over the 1993–2013 period (left) the transports unit is in Sv.

Altimetry vertical profiles (right) extrapolated with a secant hyperbolic velocity function (solid blue lines) for track 237 on 4 November 1996 against observed CTD vertical velocity profiles (dotted grey lines) for a Sicily transect.



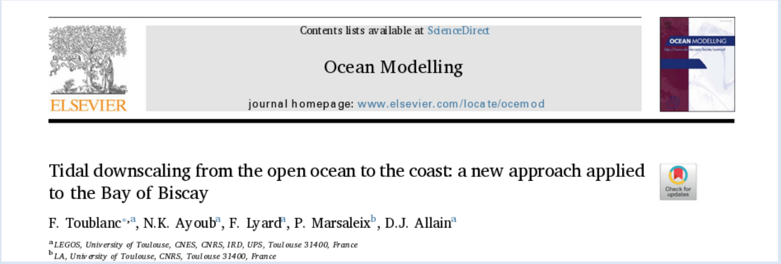
Example of applications

Objective

Develop and validate a regional tidal model for coastal applications.

Methodology

Comparison of the model and altimetry solutions for the different tidal constituents



Contents lists available at ScienceDirect

Ocean Modelling

journal homepage: www.elsevier.com/locate/ocemod

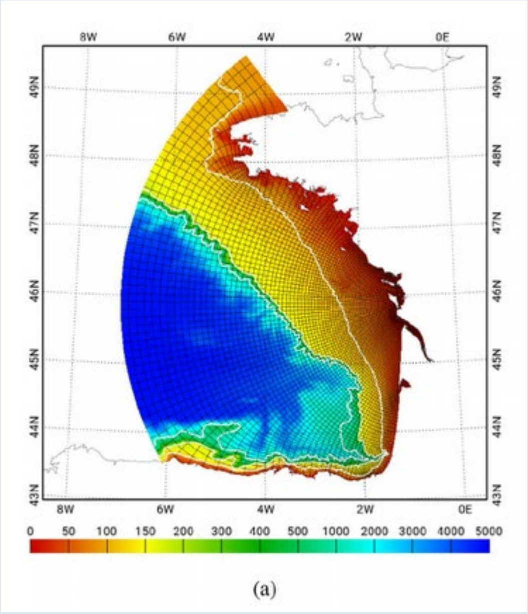
Tidal downscaling from the open ocean to the coast: a new approach applied to the Bay of Biscay

F. Toublanc[a], N.K. Ayoub[a], F. Lyard[a], P. Marsaleix[b], D.J. Allain[a]

[a] LEGOS, University of Toulouse, CNES, CNRS, IRD, UPS, Toulouse 31400, France

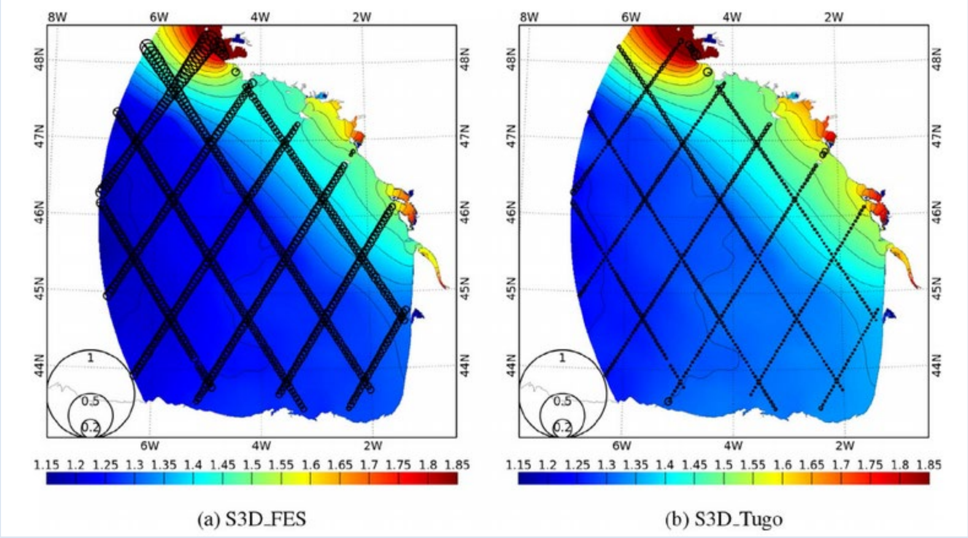
[b] LA, University of Toulouse, CNRS, Toulouse 31400, France

From Toublanc et al., 2018



Bathymetry and grid used for the model configuration (left).

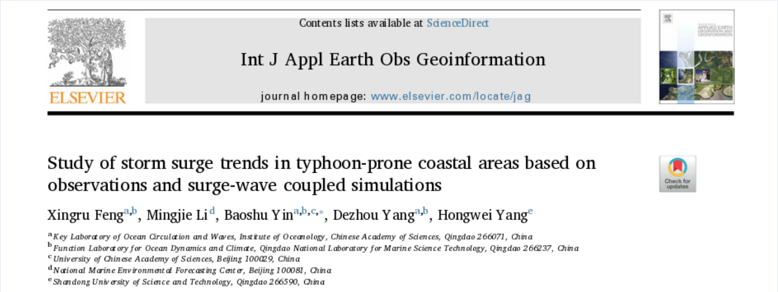
Comparison between the M2 tide obtained from satellite altimetry and model. In the background: M2 amplitude (m). The circle size is proportional to the complex error (m).



Example of applications

Objective
Develop and validate a regional storm surge model.

Methodology
Comparison of the model and altimetry solutions
SL(surge) = SL – SL(tide)


Contents lists available at ScienceDirect
Int J Appl Earth Obs Geoinformation
journal homepage: www.elsevier.com/locate/jag

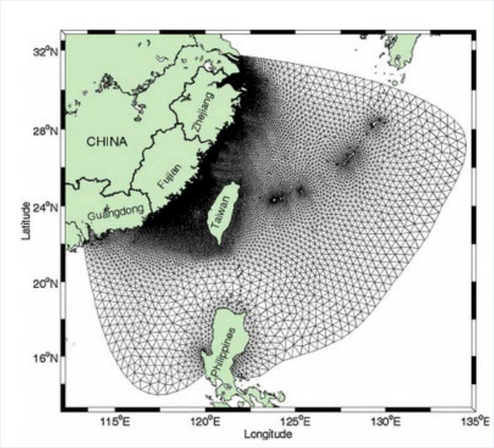
Study of storm surge trends in typhoon-prone coastal areas based on observations and surge-wave coupled simulations

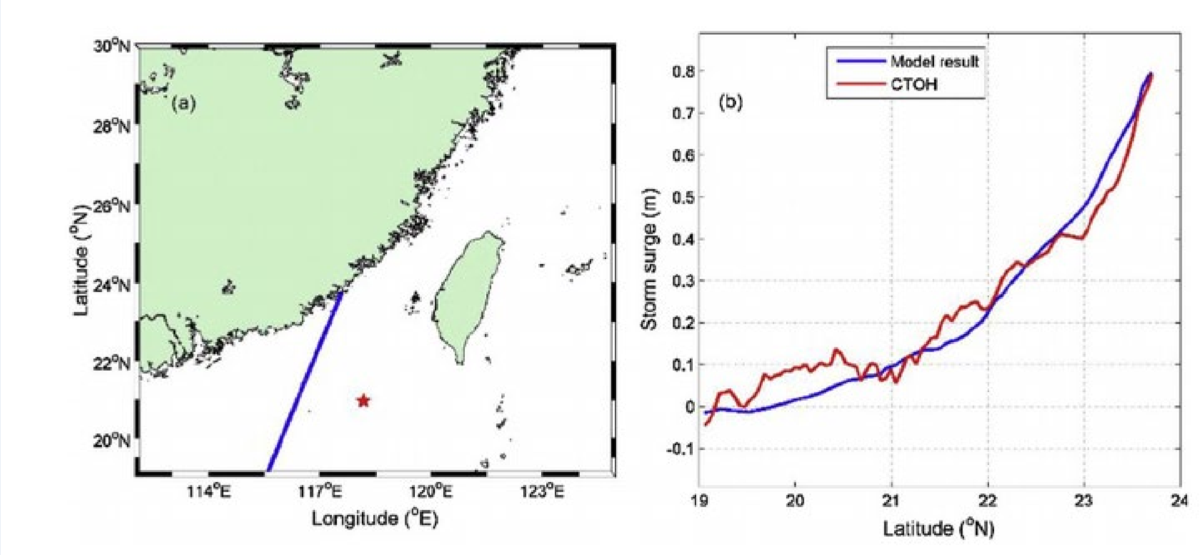
Xingru Feng[a,b], Mingjie Li[d], Baoshu Yin[a,b,c,*], Dezhou Yang[a,b], Hongwei Yang[e]

[a] Key Laboratory of Ocean Circulation and Waves, Institute of Oceanology, Chinese Academy of Sciences, Qingdao 266071, China
[b] Function Laboratory for Ocean Dynamics and Climate, Qingdao National Laboratory for Marine Science Technology, Qingdao 266237, China
[c] University of Chinese Academy of Sciences, Beijing 100029, China
[d] National Marine Environmental Forecasting Center, Beijing 100081, China
[e] Shandong University of Science and Technology, Qingdao 266590, China

From Feng et al., 2018

Bathymetry and grid used for the model configuration.





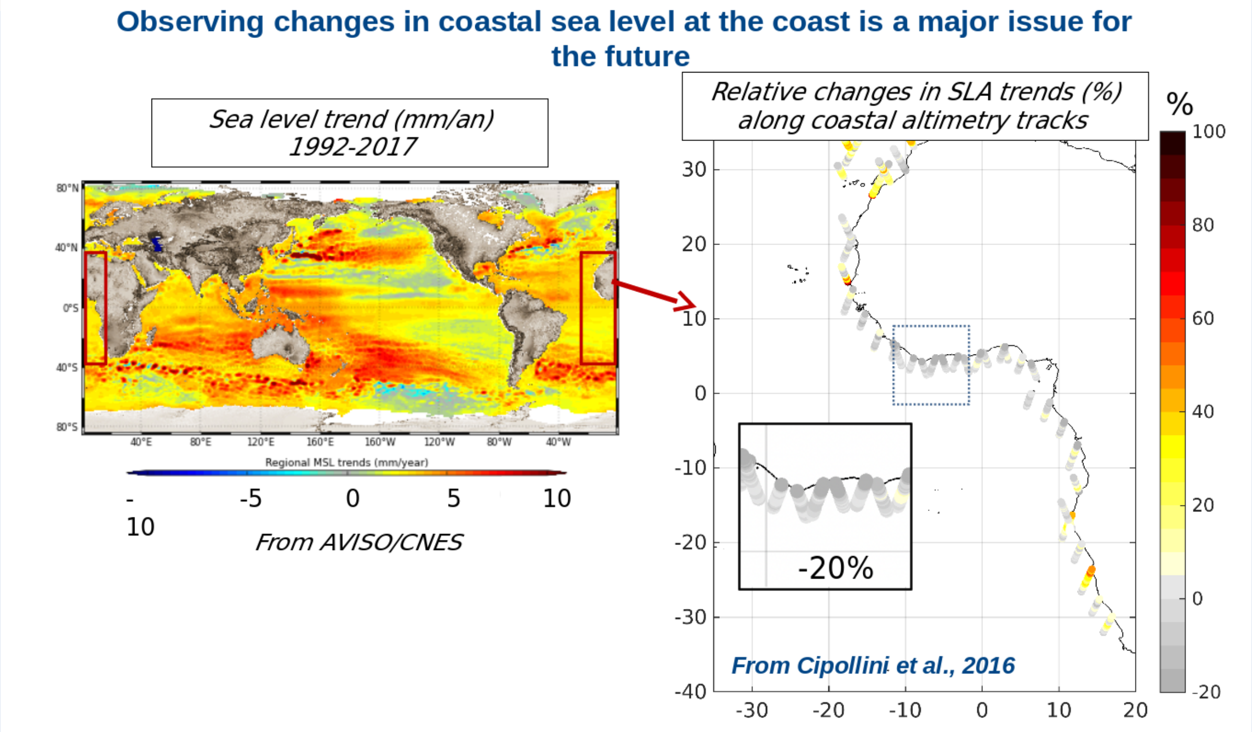
(a) Satellite track and typhoon center at 2010.10.21 23:30. (b) Comparison between the simulated storm surges and the X-TRACK data.

Example of applications

Objective
Investigate long-term coastal sea level changes

From Cipollini et al., 2016

Methodology
Computation of sea level trends from long time series of altimetry SLA



Example of applications

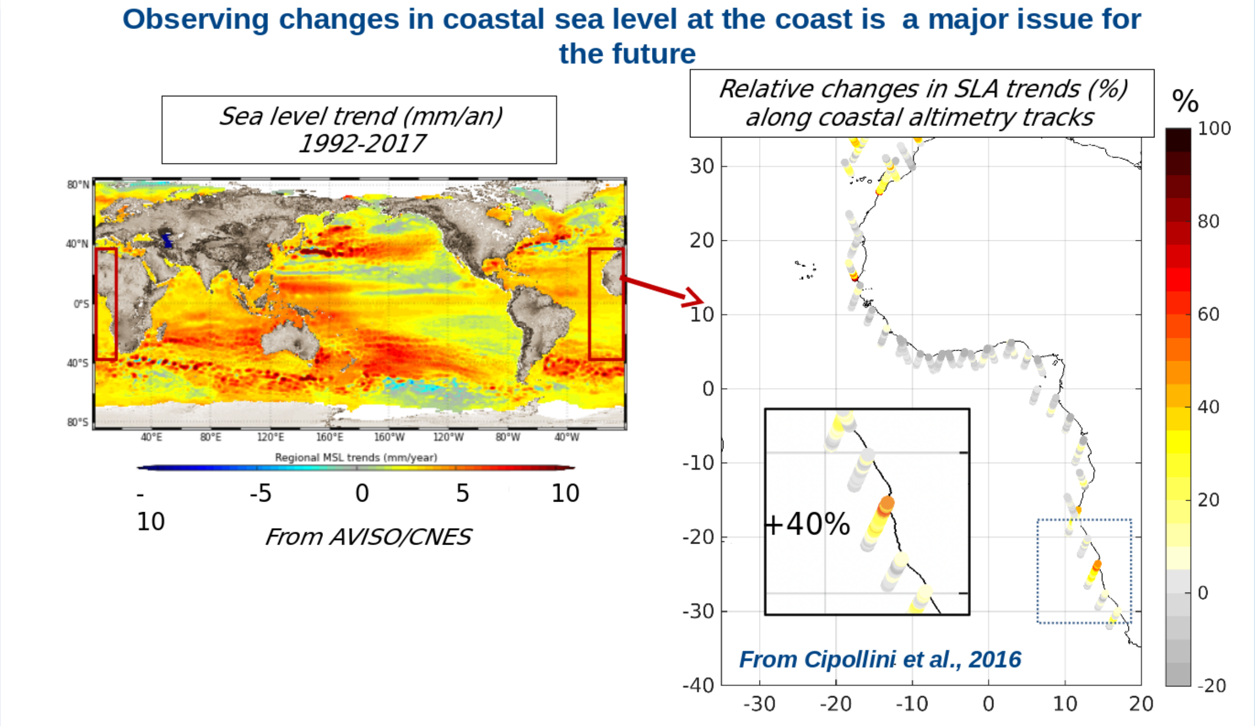
Objective

Investigate long-term coastal sea level changes

Methodology

Computation of sea level trends from long time series of altimetry SLA

From Cipollini et al., 2016



CONTENT

1. Altimetry data processing near the coast
   - Issues
   - Solutions

2. Coastal altimetry products available

3. Example of applications

4. Conclusion and perspectives

Conclusion/summary

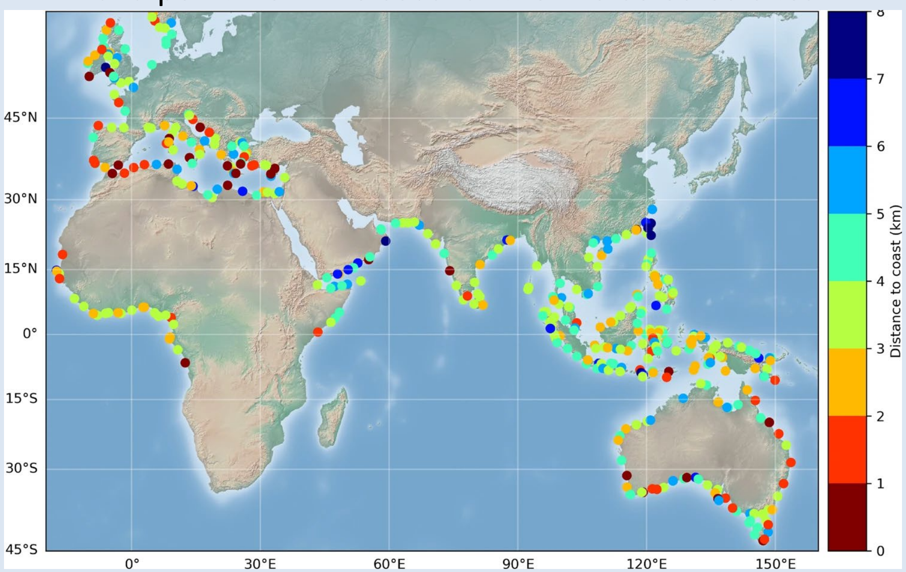
- While research in satellite altimetry has a long history over the open ocean, in coastal seas it is still at a very young stage.
- The reasons are mainly due to intrinsic limitations of the technology (e.g. sampling) and difficulties in processing and interpretation (e.g., proximity of land, control of seabed, rapid variations due to tides and atmospheric effects);
- However there are newly exploited possibilities (e.g., waveform retracking, higher along track data rates, development of dedicated corrections and processing algorithms, new altimetry technologies, …).
- The projects mentioned earlier have generated several dedicated coastal altimetry data sets. Different use cases and studies exist and all agree that these new data lead to a better understanding and monitoring of the coastal ocean dynamics.
- Satellite altimetry currently has an observational record of ~30 years from a series of missions starting in the early 1990s. This huge amount of unused data over the coastal regions needs to be re-analyzed, improved and more efficiently exploited.

Perspectives

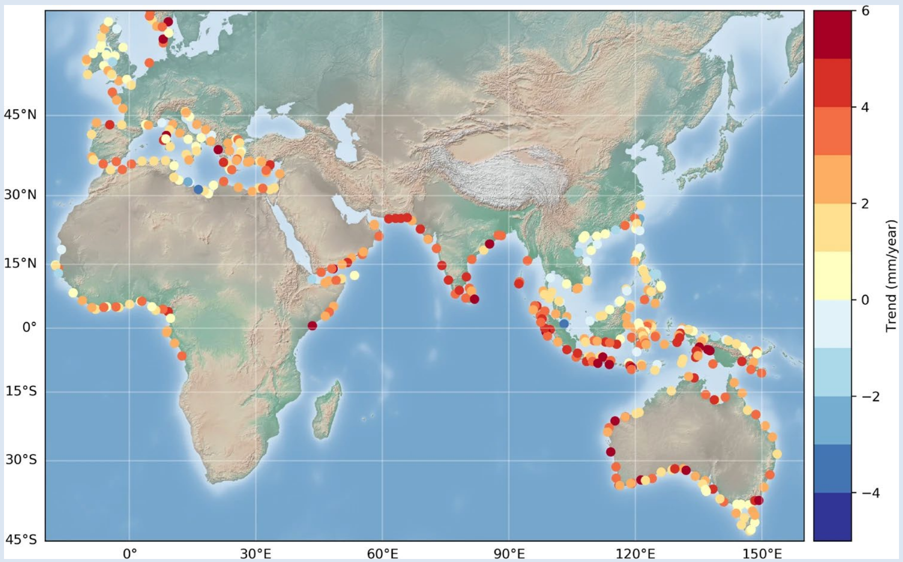
Exploiting higher alongtrack data rate, new retrackers & an adapted processing strategy (including corrections)

CCI Sea level Project (ESA)

Map of the closest distance (km) to the coast of the first valid point from the coast at the 429 selected sites.



Coastal sea level trends (mm/yr) at the first valid point from the coast at the 429 selected sites.



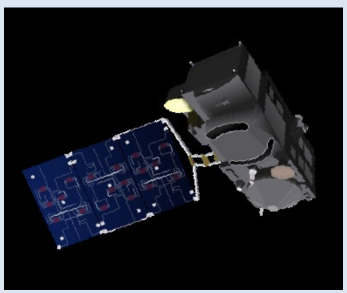
From The Climate Change Initiative Coastal Sea Level Team., Benveniste, J., Birol, F. et al. , 2020

Conclusion and perspectives

New radar technologies

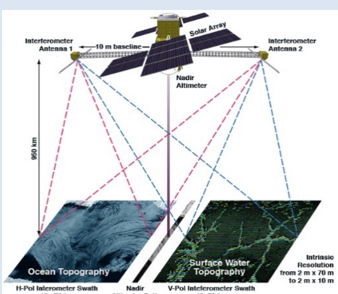
SARAL/AltiKa (CNES-ISRO)
Ka-band Altimetry

2013



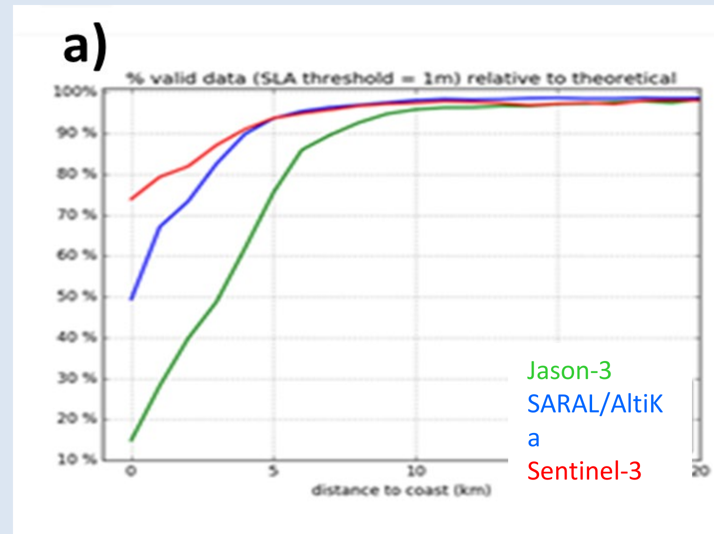
Sentinel 3A&B (ESA/EU)
SAR (doppler) Altimetry

2016 & 2018



SWOT (CNES/NASA)
Wide-swath Ka-band interferometric radar altimetry

2022



Percentage of 20Hz valid measurement computed for Sentinel-3A, SARAL/AltiKa and Jason-3 datasets as a function of the distance to the coast (*from Vignudelli et al., 2019*)

MESOSCALE EDDIES AND THEIR DYNAMICS IN THE MEDITERRANEAN SEA

Dr Cori PEGLIASCO
Collecte Localisation Satellite
cpegliasco@groupcls.com

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727277

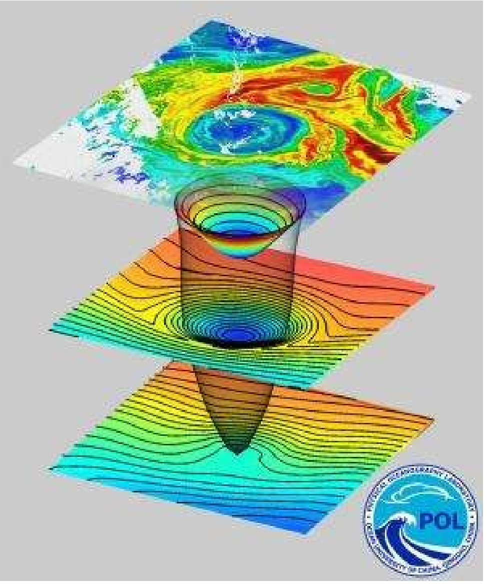
Mesoscale eddies and their dynamics in the Mediterranean Sea

Lecturer : Dr Cori PEGLIASCO

What is a mesoscale eddy?

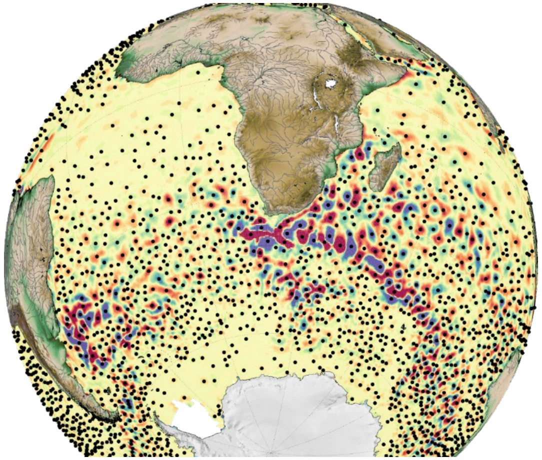
- Rotating structure ranging from 10 – 100s km, with lifetime from few days to few years
- Everywhere in the oceans and seas
- Generated by the destabilization of currents, topography, islands, winds,…

- Anticyclones are associated with highs in the Sea Surface Height, Cyclones are associated with lows.

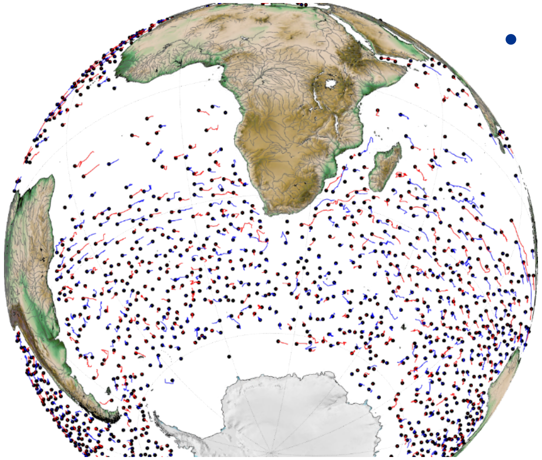


Credits : Sergey Kryazhimskiy

How to study mesoscale eddies?



- **Detect them** on altimetric maps, from Sea Level Anomaly, Absolute Dynamic Topography or from derived speed (Operationnally produced by CMEMS), to have a global census of the structures



- **Track them** in time and space

- **Bonus :** colocate data with the eddies (SST, SSS, chlorophyll, *in situ* data,…)

Global Mesoscale Eddy Trajectories Atlases:

- **META2.0** : global atlas over 1993 – 2020, produced in collaboration with D. Chelton and M. Schlax (Oregon State University, *Chelton et al. 2011*), with support from CNES, available on AVISO+ (https://www.aviso.altimetry.fr/en/data/products/value-added-products/global-mesoscale-eddy-trajectory-product.html)
- **META3.0exp** : global atlas produced in collaboration with E. Mason (IMEDEA, *Mason et al. 2014*), with support from CNES, available on AVISO+ in NRT and soon in DT over 1993 – 2020

DYNED-Atlas project : PI A. Stegner (LMD)

- Description of the mesoscale eddies in the Mediterranean Sea and the Arabian Sea fro 2000 to 2017, from the AMEDA algorithm (*Le Vu et al. 2018*), in collaboration with LMD, LEGOS, LOPS, ECTIA, CLS, SHOM with support from CNES, ANR-ASTRID, SHOM, available from here https://www.lmd.polytechnique.fr/dyned/data-base

Combination of AVISO/DUACS and Argo data sets to follow the evolution of long-lived eddies and their 3D structure from 2000 to 2017 in the Mediterranean Sea

A.Stegner [1],B. LeVu[1],C. Pegliasco [2],A. Chaigneau [2], A.Ioannou[1], F. Dumas[3], Y. Faugere[4], X.Carton[5]

(1) LMD, CNRS, Ecole Polytechnique, Palaiseau,France. (2) LEGOS, CNRS, Toulouse, France.
(2) (3) SHOM, Brest, France. (4) CLS, Toulouse, France. (5) LOPS, UBO, Brest.

AVISO/DUACS and Argo data to follow
long lived eddies and their 3D structure (Med Sea)

ODYSSEA

An up to date individual eddy data-base:

dynamical parameters and 3D structure

AVISO/DUACS

Surface velocity
daily maps

1/8°

AVISO/DUACS and Argo data to follow long lived eddies and their 3D structure (Med Sea)

ODYSSEA

An up to date individual eddy data-base:

dynamical parameters and 3D structure

AVISO/DUACS

Surface velocity daily maps

1/8°

→

Cyclogeostrophic velocity daily maps

1/8°

Cyclogeostrophic corrections

AVISO/DUACS and Argo data to follow long lived eddies and their 3D structure (Med Sea)

ODYSSEA

An up to date individual eddy data-base:

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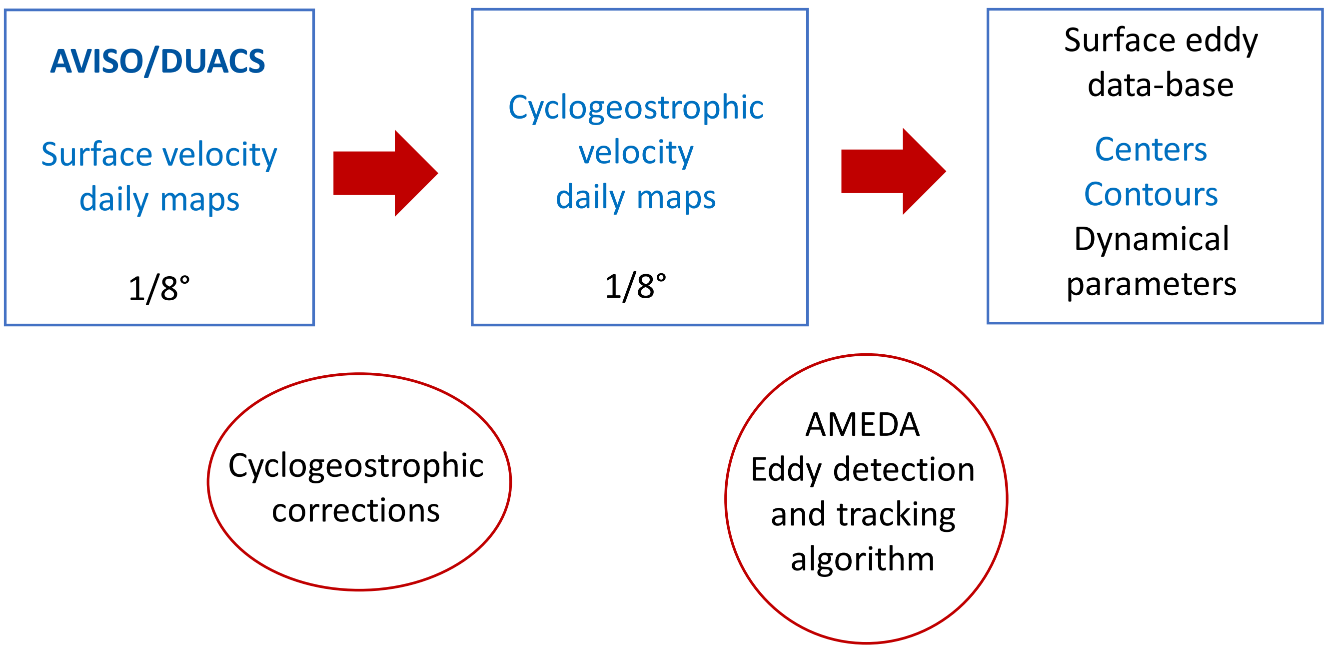

AVISO/DUACS and Argo data to follow long lived eddies and their 3D structure (Med Sea)

ODYSSEA

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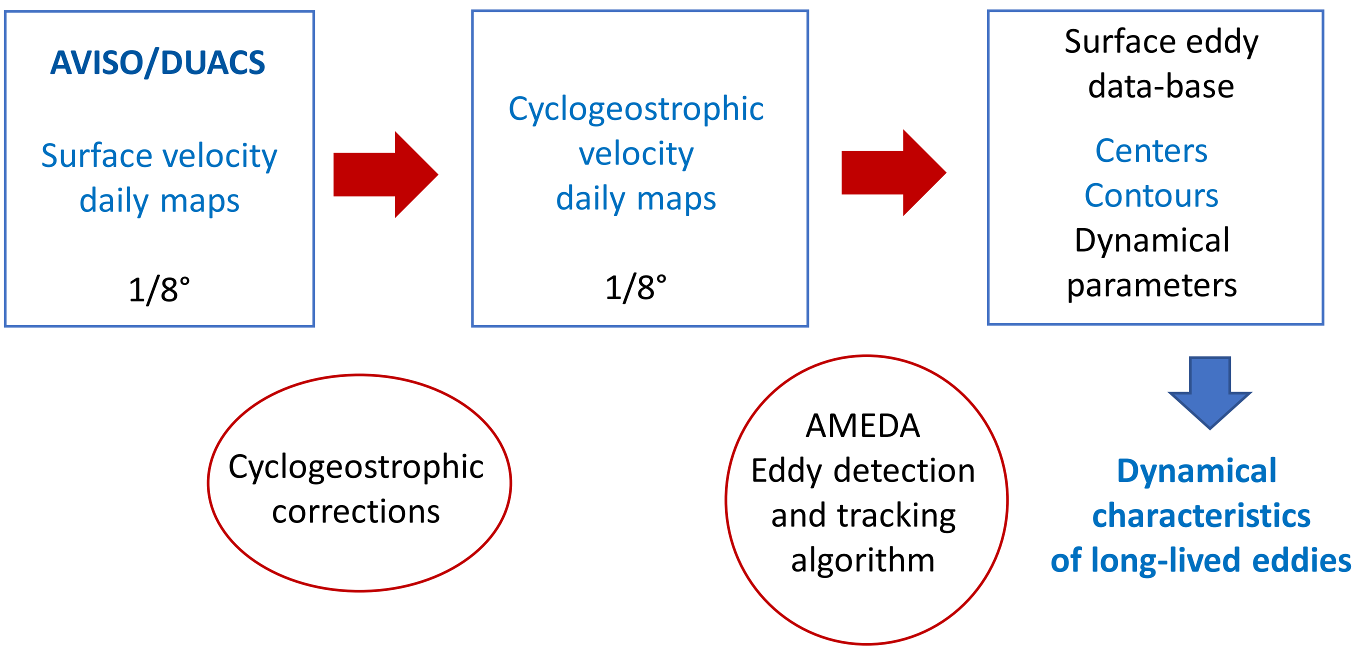

AVISO/DUACS and Argo data to follow long lived eddies and their 3D structure (Med Sea)

ODYSSEA

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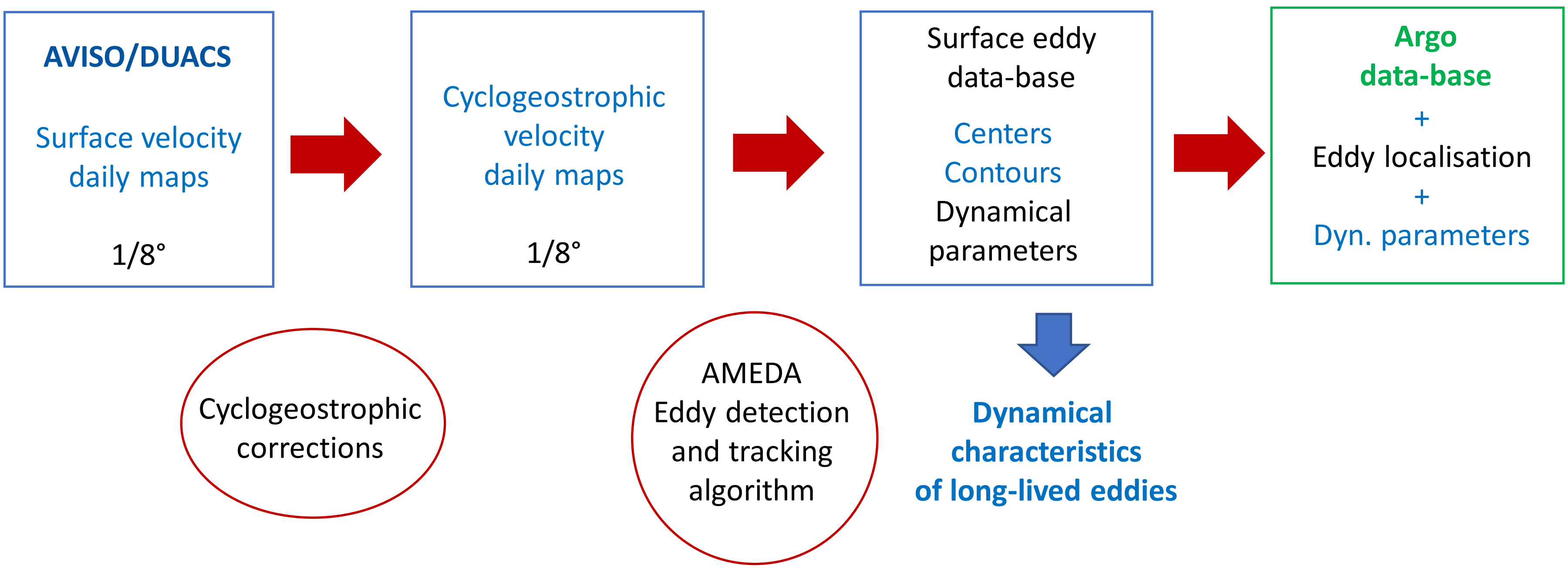
dynamical parameters and 3D structure



AVISO/DUACS and Argo data to follow long lived eddies and their 3D structure (Med Sea)

ODYSSEA

An up to date individual eddy data-base:

dynamical parameters and 3D structure

AVISO/DUACS

Surface velocity daily maps

1/8°

Cyclogeostrophic corrections

Cyclogeostrophic velocity daily maps

1/8°

AMEDA Eddy detection and tracking algorithm

Surface eddy data-base

Centers

Contours

Dynamical parameters

Dynamical characteristics of long-lived eddies

Argo data-base

+

Eddy localisation

+

Dyn. parameters

First estimation 3D structure of individual eddies

OUTLINE

1. Cyclogeostrophic corrections
2. AMEDA eddy detection and tracking algorithm
3. Characteristics of long-lived eddies in the Med Sea
4. Preliminary results : estimation of their 3D structure

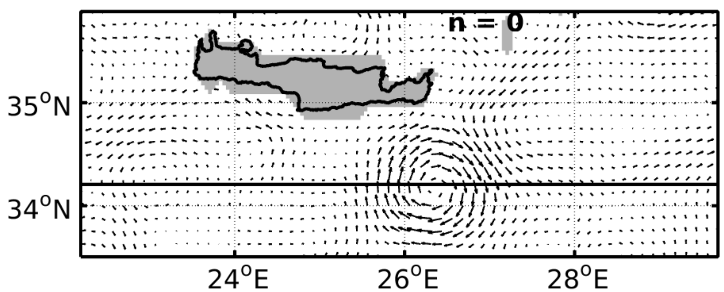
AVISO/DUACS and Argo data to follow long lived eddies and their 3D structure (Med Sea)

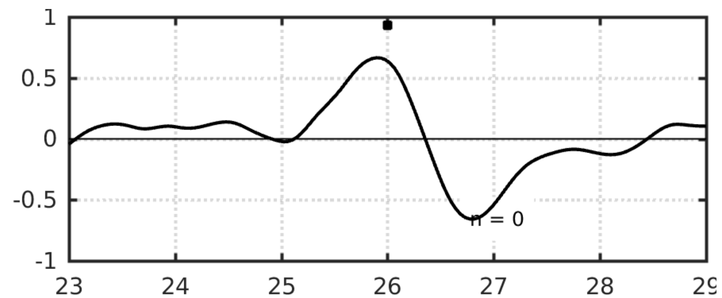
ODYSSEA

Cyclogeostrophic corrections *of AVISO/DUACS geostrophic velocities*

$$f\,V_{geo} = g\partial_r \eta$$

geostrophic balance





AVISO/DUACS and Argo data to follow long lived eddies and their 3D structure (Med Sea)

ODYSSEA

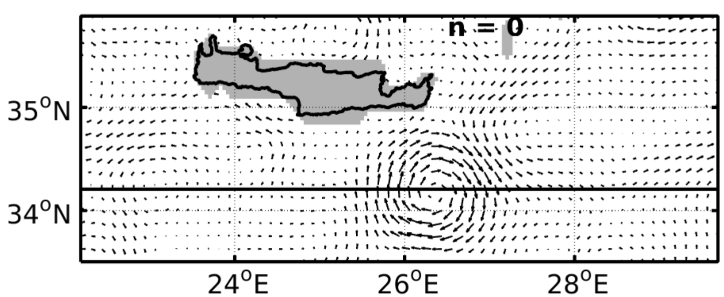
Cyclogeostrophic corrections *of AVISO/DUACS geostrophic velocities*

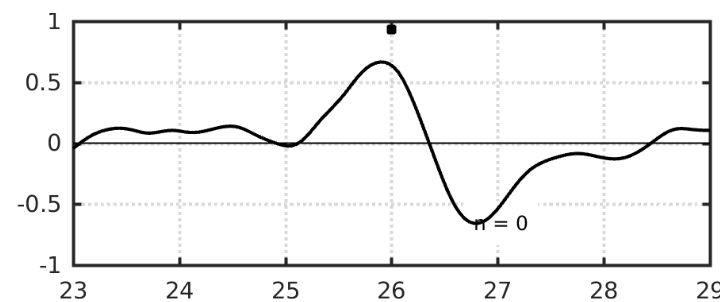
$$f\,V_{geo} = g\partial_r \eta$$

geostrophic balance

$$\frac{V^2}{r} + f\,V = g\partial_r \eta$$

cyclogeostrophic





AVISO/DUACS and Argo data to follow long lived eddies and their 3D structure (Med Sea)

ODYSSEA

Cyclogeostrophic corrections *of AVISO/DUACS geostrophic velocities*

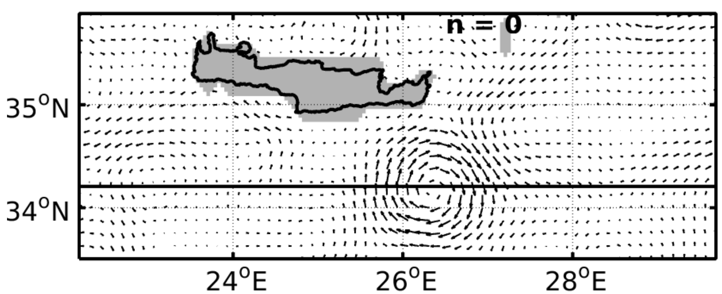
$$f\, V_{geo} = g \partial_r \eta$$

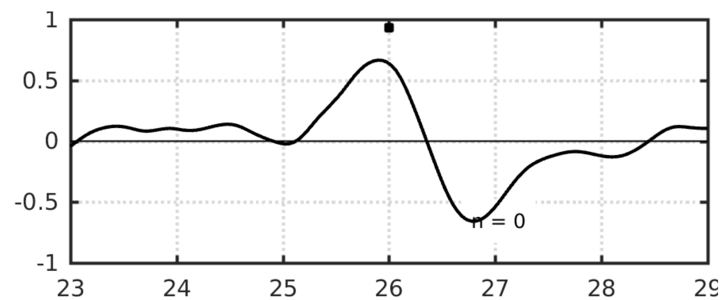
geostrophic balance

Iterative method

$$\vec{V}^{n+1} = \vec{V}_{geo} + \frac{1}{f} \vec{k} \times \left(\vec{V}^{n} . \vec{\nabla} \right) \vec{V}^{n}$$

Knoxx and Ohmann (2006),
Penven *et al.* (2014)
Ioannou *et al.* in prep.





AVISO/DUACS and Argo data to follow long lived eddies and their 3D structure (Med Sea)

ODYSSEA

Cyclogeostrophic corrections *of AVISO/DUACS geostrophic velocities*

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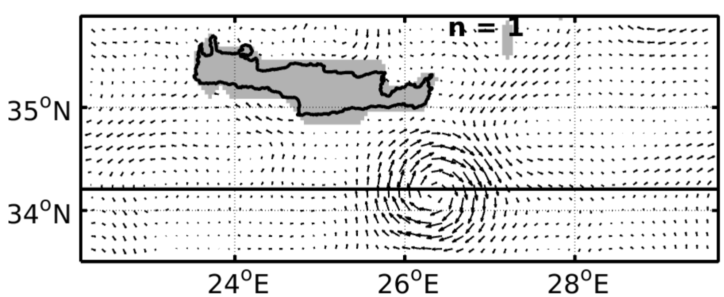

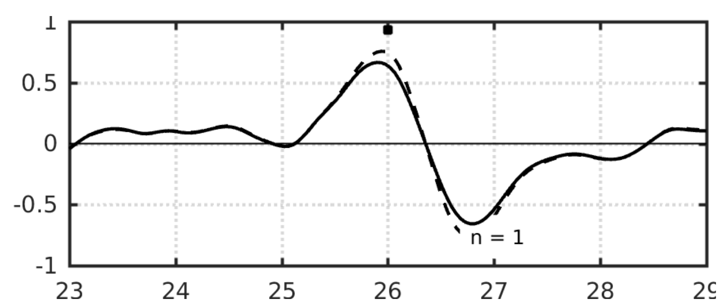

AVISO/DUACS and Argo data to follow long lived eddies and their 3D structure (Med Sea)

ODYSSEA

Cyclogeostrophic corrections *of AVISO/DUACS geostrophic velocities*

$$f\, V_{geo} = g\partial_r \eta$$

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Knoxx and Ohmann (2006),
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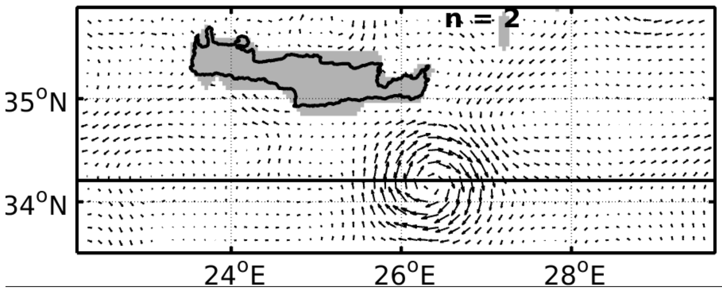

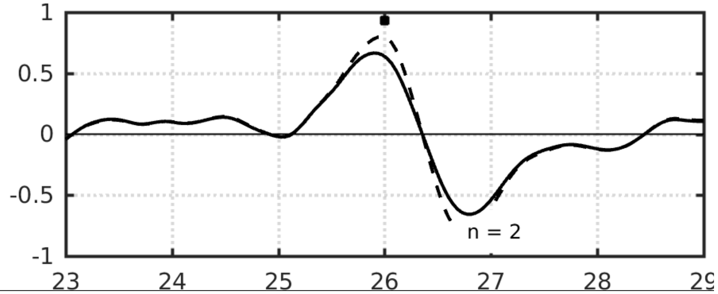

Cyclogeostrophic corrections *of AVISO/DUACS geostrophic velocities*

$$f\,V_{geo} = g\partial_r \eta$$

geostrophic balance

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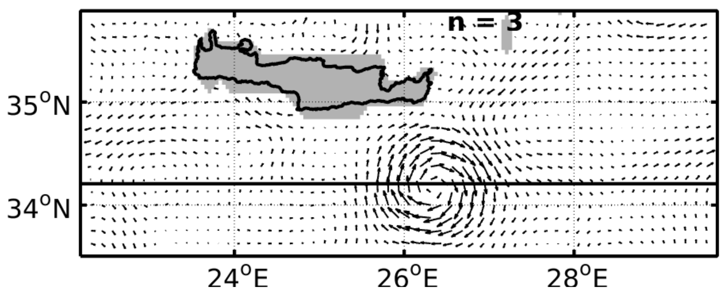
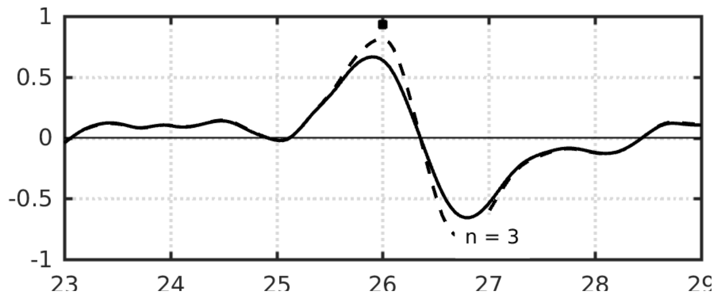




AVISO/DUACS and Argo data to follow long lived eddies and their 3D structure (Med Sea)

ODYSSEA

Cyclogeostrophic corrections *of AVISO/DUACS geostrophic velocities*

Knoxx and Ohmann (2006), Penven *et al.* (2014) Ioannou *et al.* in prep.

$$f\,V_{geo} = g\partial_r \eta$$

geostrophic balance

→

Iterative method

$$\vec{V}^{n+1} = \vec{V}_{geo} + \frac{1}{f}\vec{k} \times \left(\vec{V}^{n}.\vec{\nabla}\right)\vec{V}^{n}$$

We stop the iteration when

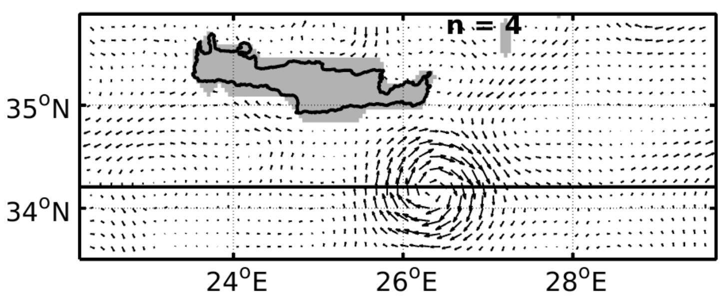
$$\left\| \vec{V}^{n+1} - \vec{V}^{n} \right\|$$

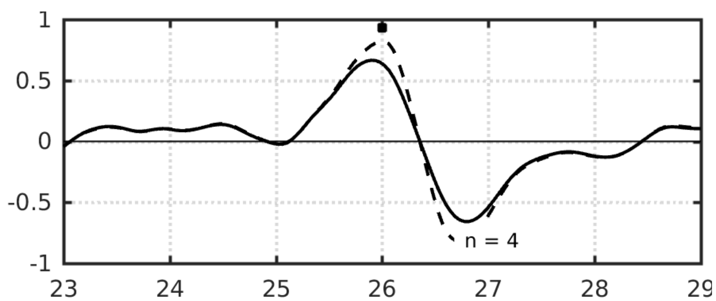
starts to increase

→

$$\frac{V^2}{r} + f\,V = g\partial_r \eta$$

cyclogeostrophic





AVISO/DUACS and Argo data to follow long lived eddies and their 3D structure (Med Sea)

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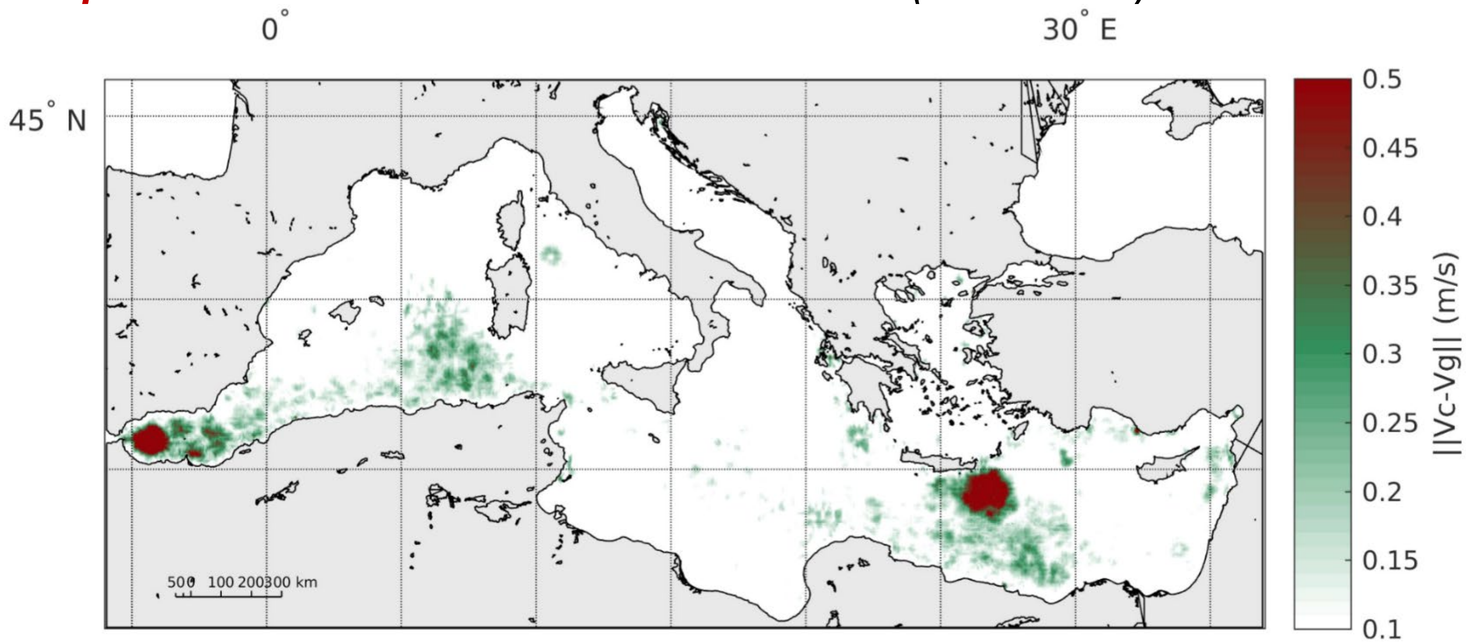
Cyclogeostrophic corrections *in the Mediterranean Sea (2000-2017)*



Corrections below 10cm/s are not shown

AVISO/DUACS and Argo data to follow long lived eddies and their 3D structure (Med Sea)

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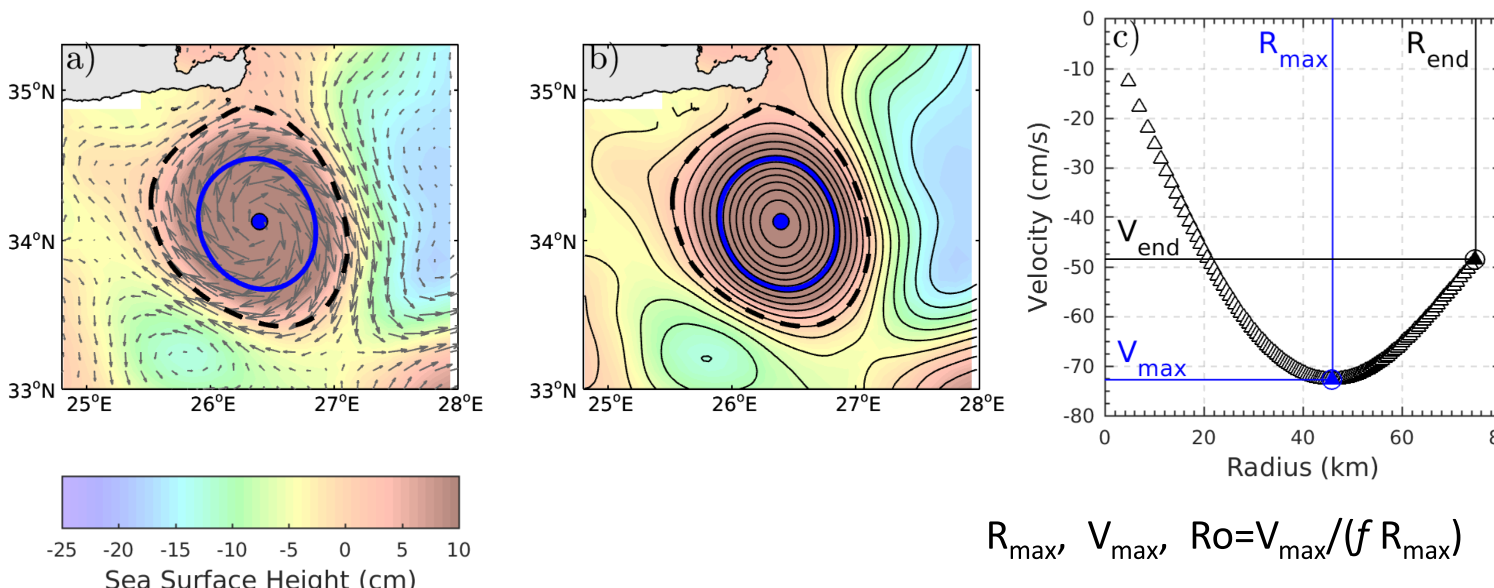
AMEDA: Angular Momentum Eddy Detection Algorithm

Le Vu *et al.*, JAOT (2018)

Velocity Fields → Eddy centers → *Characteristic contours* → *Dynamical parameters*



R_{max}, V_{max}, $Ro=V_{max}/(f\ R_{max})$

$\zeta(0)/f$ (core vorticity) ,ellipticity

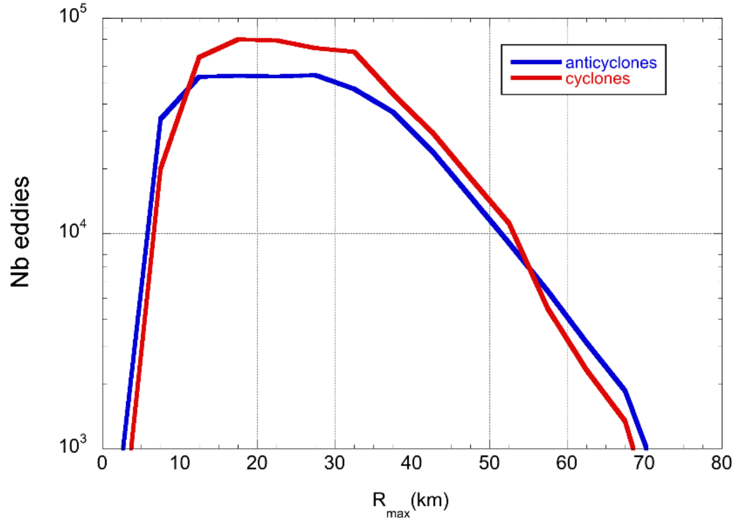
AVISO/DUACS and Argo data to follow long lived eddies and their 3D structure (Med Sea)

ODYSSEA

Few statistics of individual detections of eddies

~ 400 10^3 Anticyclones

~ 500 10^3 Cyclones



$\langle R_{max} \rangle \sim \langle R_{max} \rangle \sim 25$ km $\sim 2 \langle R_d \rangle$

AVISO/DUACS and Argo data to follow long lived eddies and their 3D structure (Med Sea)

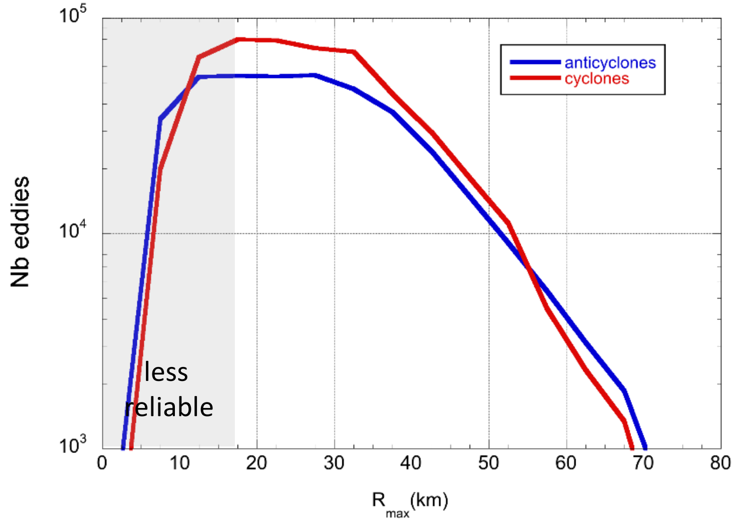
ODYSSEA

Few statistics of individual detections of eddies

~ 400 10^3 Anticyclones (R$_{max}$>18km~ 1.5Δx)

~ 500 10^3 Cyclones

Le Vu *et al.*, JAOT (2018)



$\langle R_{max} \rangle \sim \langle R_{max} \rangle \sim 25$ km $\sim 2 \langle R_d \rangle$

AVISO/DUACS and Argo data to follow
long lived eddies and their 3D structure (Med Sea)

ODYSSEA

Few statistics of individual detections of eddies

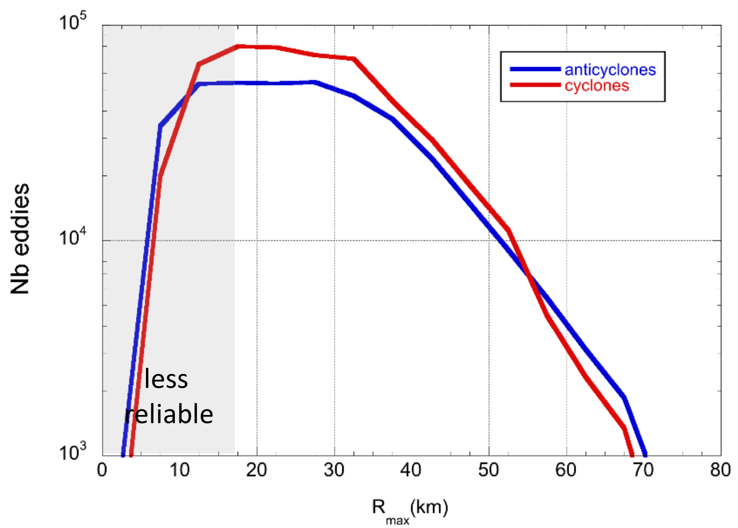
~ 400 10^3 Anticyclones

~ 500 10^3 Cyclones

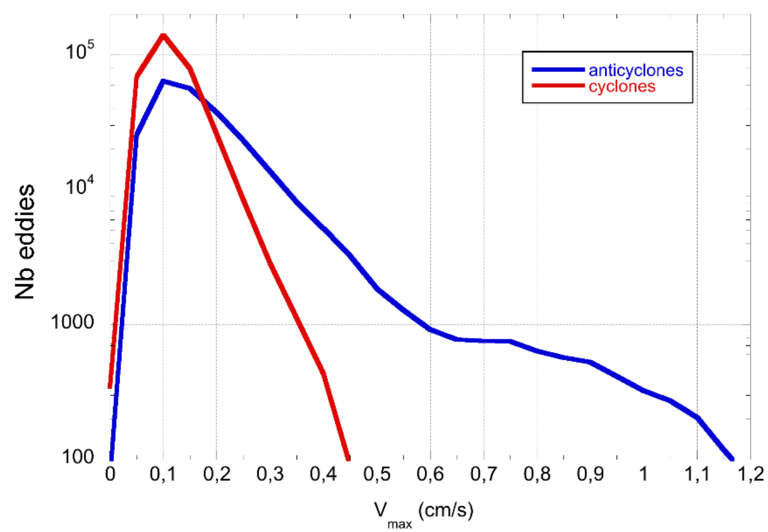
(R_{max}>18km~ 1.5Δx)

~ 240 10^3 Anticyclones

~ 320 10^3 Cyclones



$<R_{max}>$ ~ $<R_{max}>$ ~ 25 km ~ 2 $<R_d>$

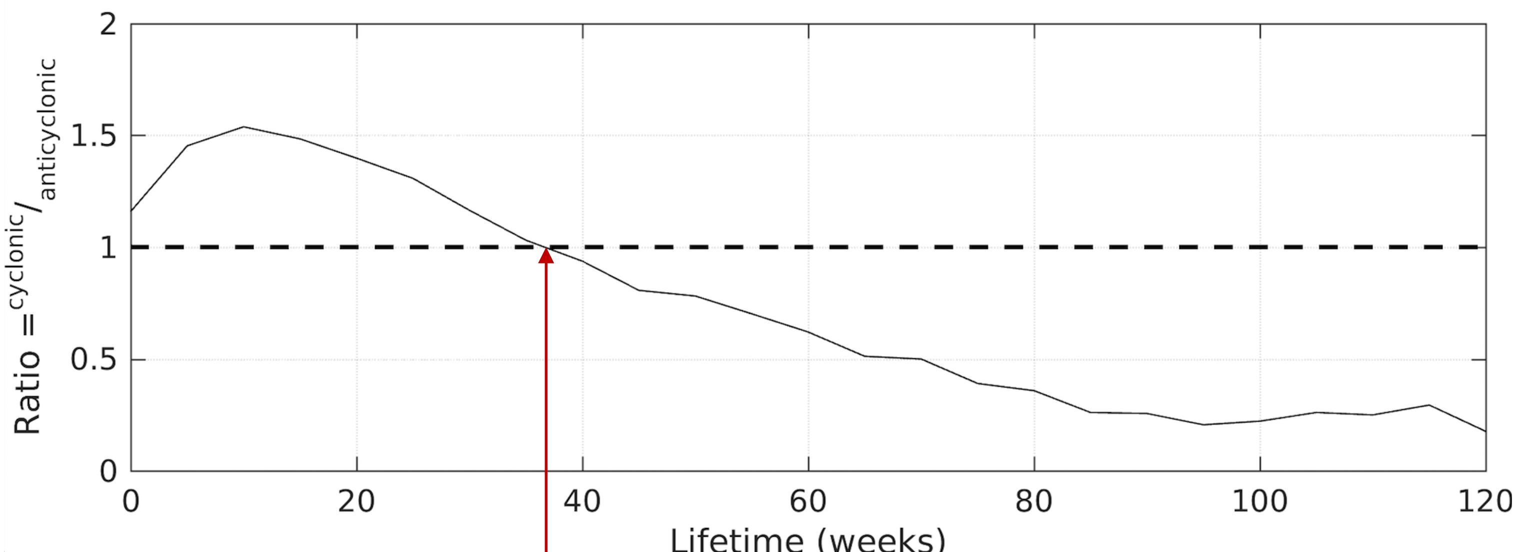


$<V_{max}>$ = 19 cm/s $<V_{max}>$ = 11.6 cm/s

AVISO/DUACS and Argo data to follow
long lived eddies and their 3D structure (Med Sea)

ODYSSEA

Anticyclones are predominant among long-lived eddies



37 weeks
(~400 eddies)

AVISO/DUACS and Argo data to follow long lived eddies and their 3D structure (Med Sea)

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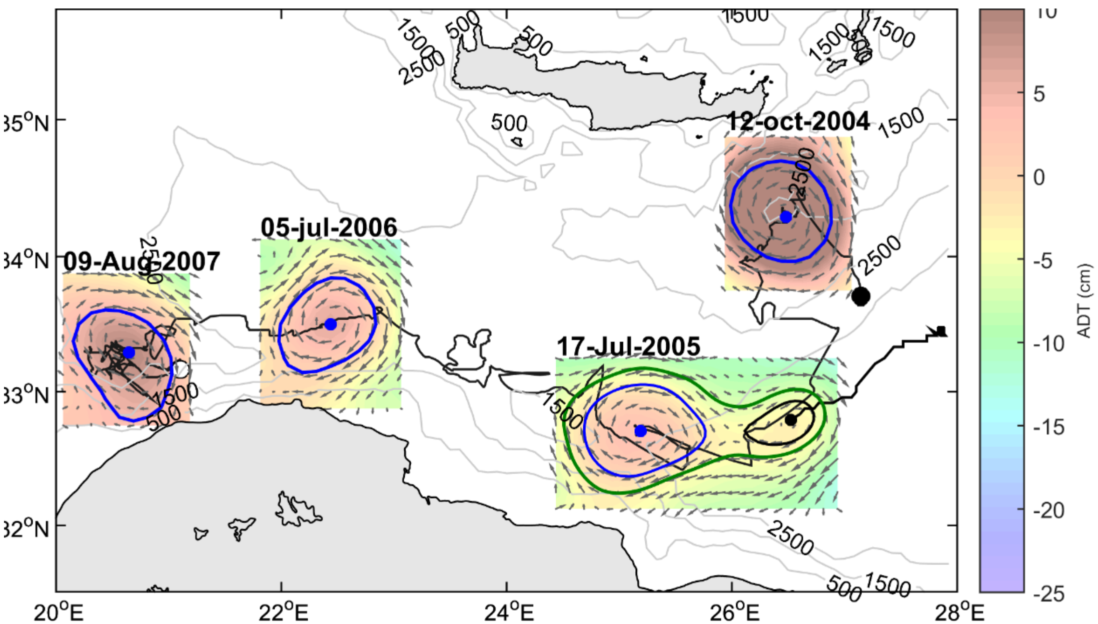
Dynamical evolution of long-lived eddies

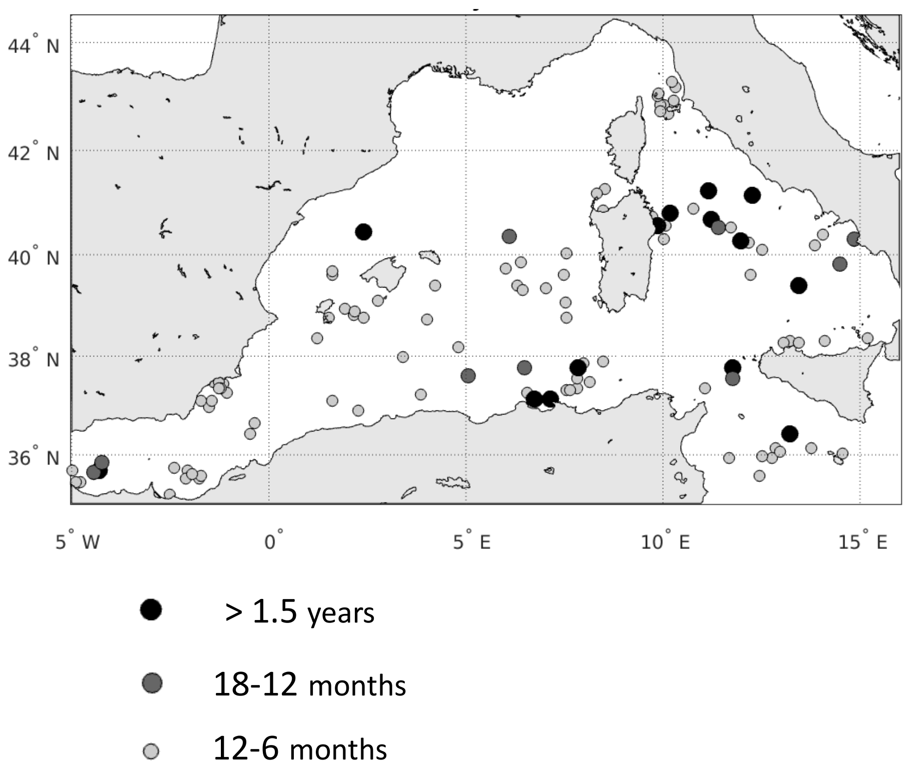


- Origin / formation processes
- Trajectory
- Merging / splitting events
- Dissipation / end of life

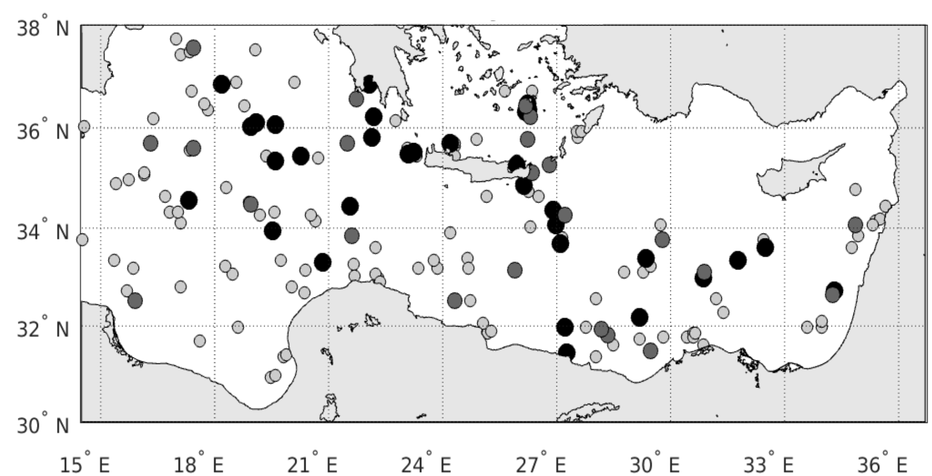
Ioannou *et al.*, JGR (2017)

AVISO/DUACS and Argo data to follow long lived eddies and their 3D structure (Med Sea)

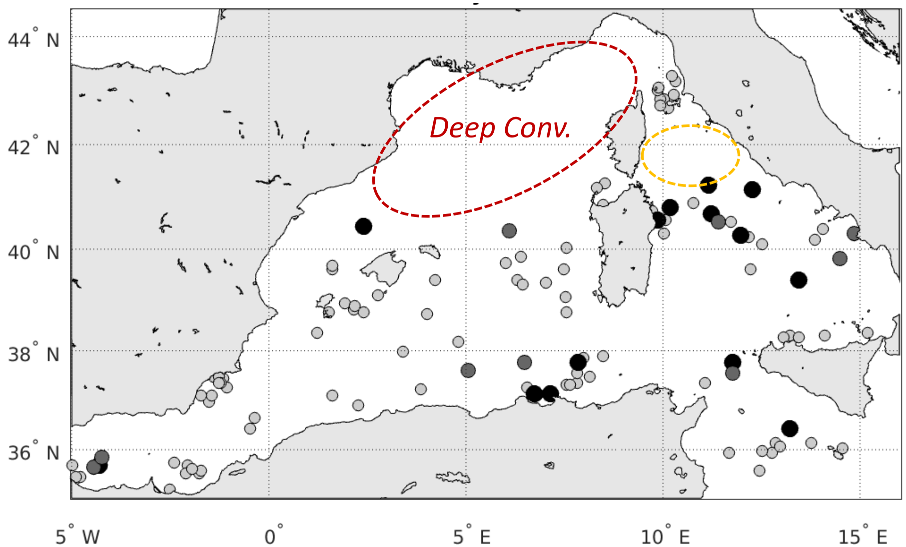
ODYSSEA



Formation point of long-lived ***ANTICYCLONES***



AVISO/DUACS and Argo data to follow long lived eddies and their 3D structure (Med Sea)

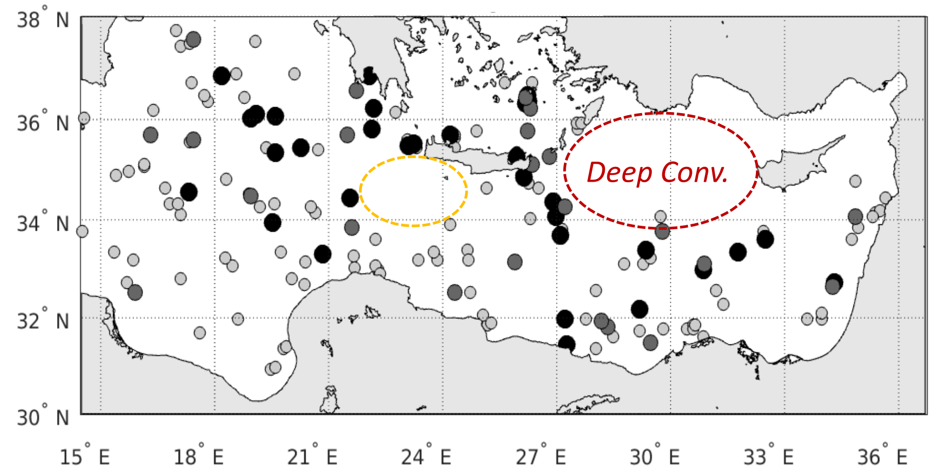


> 1.5 years

18-12 months

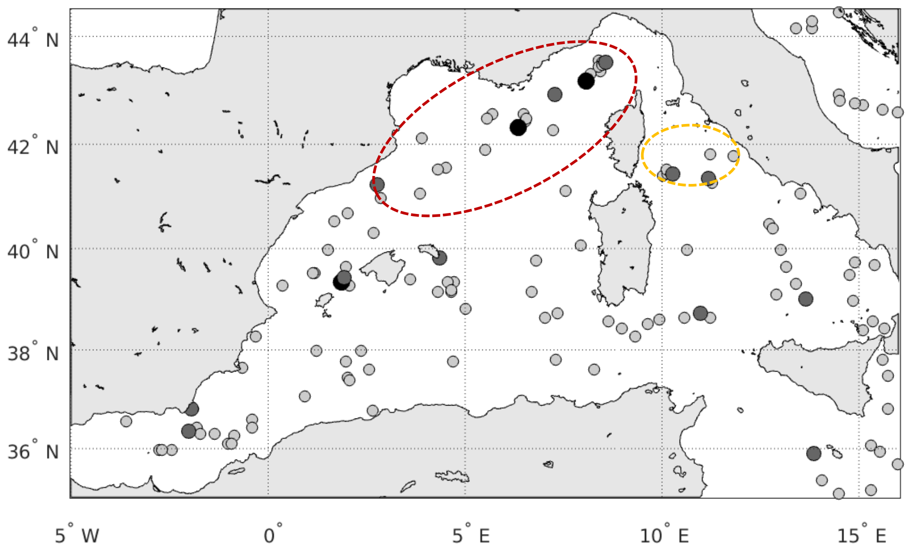
12-6 months

Formation point of long-lived ***ANTICYCLONES***



AVISO/DUACS and Argo data to follow long lived eddies and their 3D structure (Med Sea)

ODYSSEA

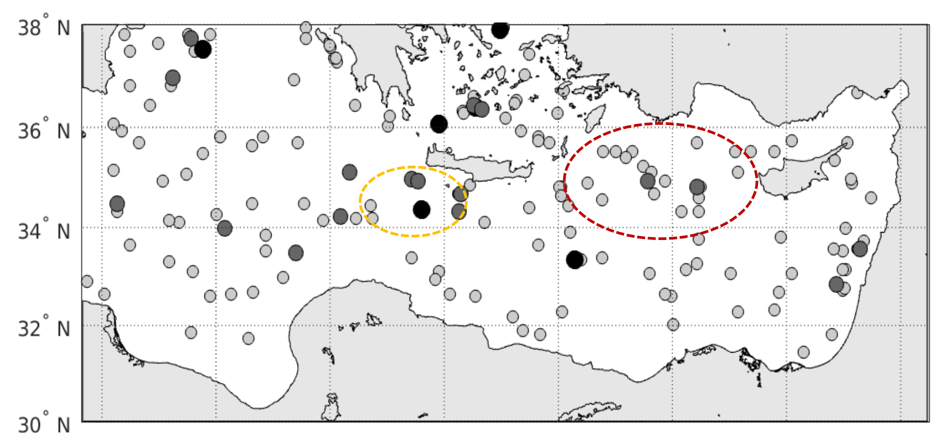


● > 1.5 years

● 18-12 months

● 12-6 months

Formation point of long-lived
CYCLONES

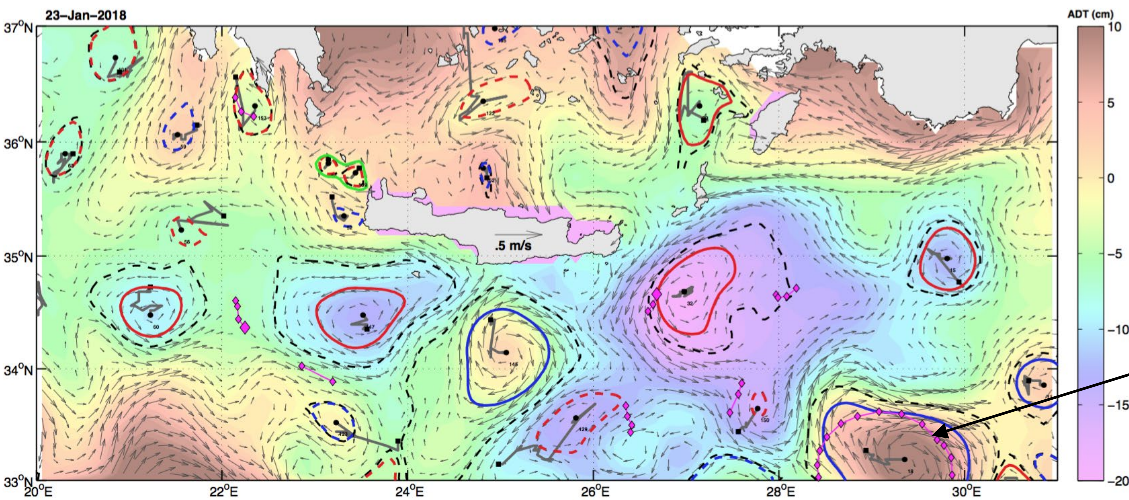


AVISO/DUACS and Argo data to follow long lived eddies and their 3D structure (Med Sea)

ODYSSEA

AVISO/DUACS + Automatic eddy detection

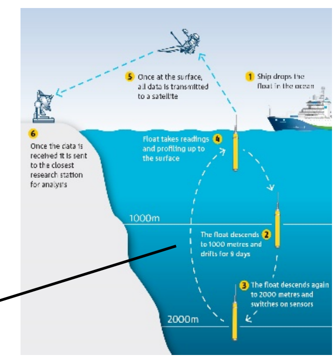
Localization of surface eddies

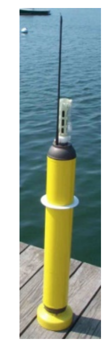


+

ARGO floats

Vertical density profiles



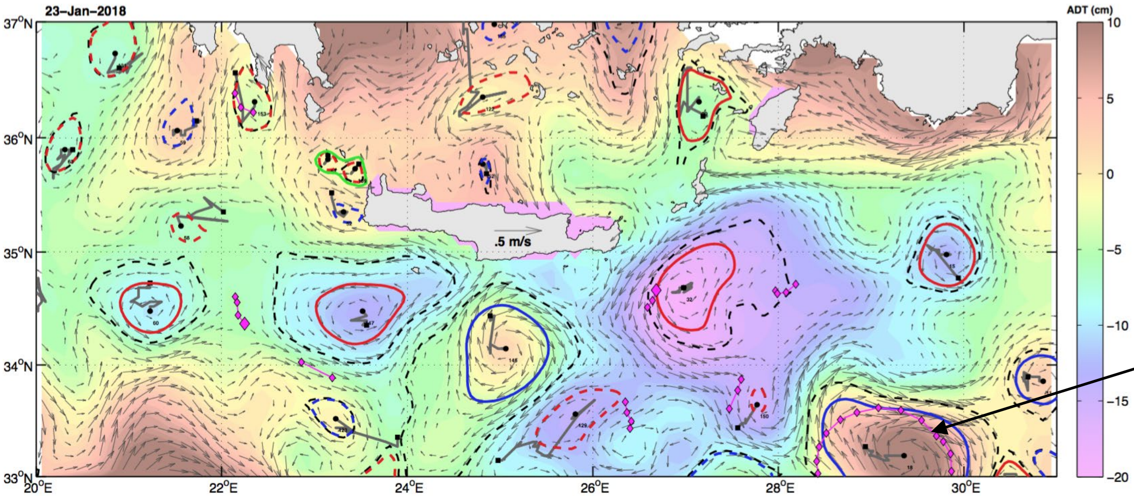


AVISO/DUACS and Argo data to follow long lived eddies and their 3D structure (Med Sea)

ODYSSEA

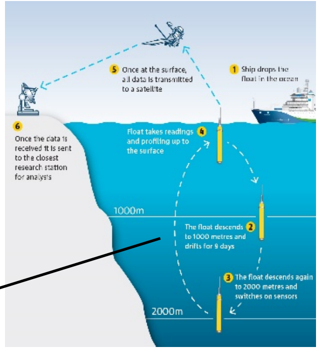
AVISO/DUACS + Automatic eddy detection

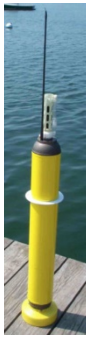
Localization of surface eddies



ARGO floats

Vertical density profiles





Chaigneau *et al.* (2011); Peglisaco *et al.* (2015); Nencioli *et al.* (2018); Laxenaire *et al.* in press (2018)

*Estimation of the dynamics and the **vertical structure** of individual eddies*

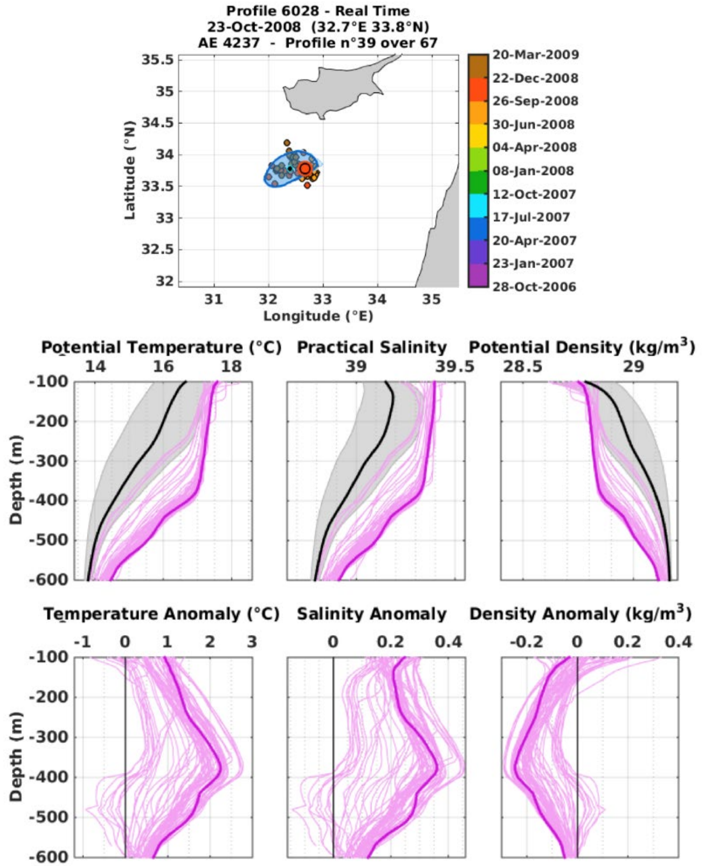
AVISO/DUACS and Argo data to follow long lived eddies and their 3D structure (Med Sea)

ODYSSEA

Estimation of the
3D structure
of individual eddies

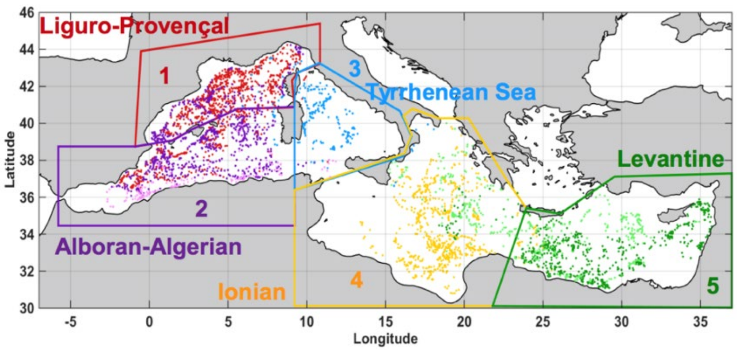
Mean climatological profile outside all eddies

Argo profile inside the selected eddy



AVISO/DUACS and Argo data to follow long lived eddies and their 3D structure (Med Sea)

ODYSSEA

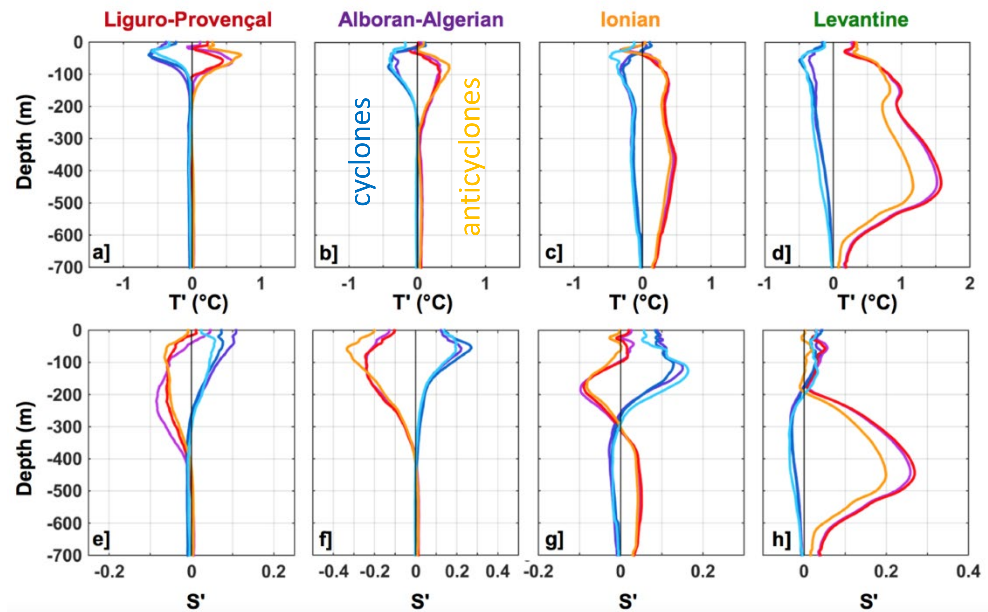


Hierarchical classification of background Argo profiles (outside eddies)

5 BASINS

Mean temperature anomalies inside eddies

Mean salinity anomalies inside eddies



AVISO/DUACS and Argo data to follow long lived eddies and their 3D structure (Med Sea)

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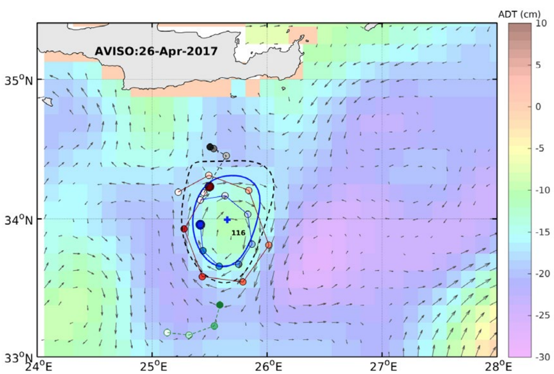
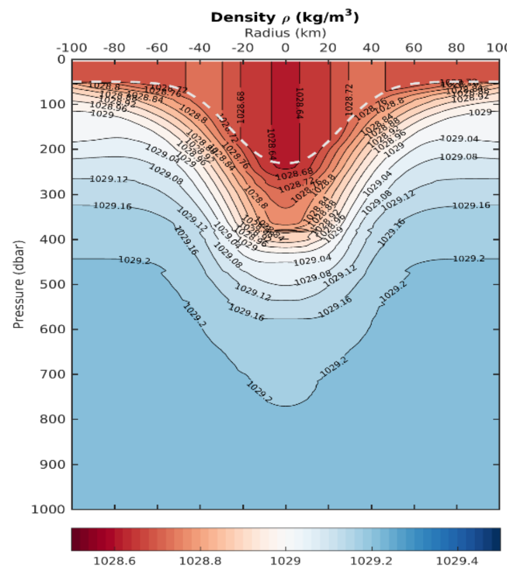
The best case !

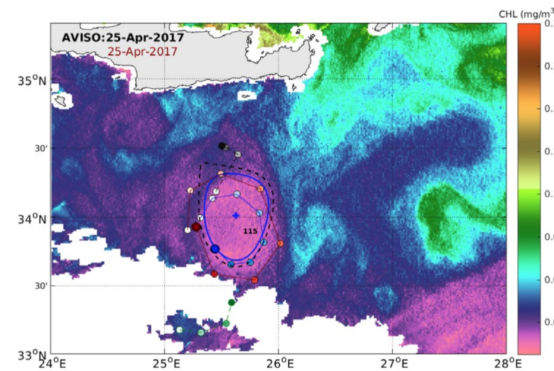


Up to 3 Argo/Arvor were trapped in a single anticyclone

215 Argo profiles inside it !



Full 3D reconstruction (6 months period)



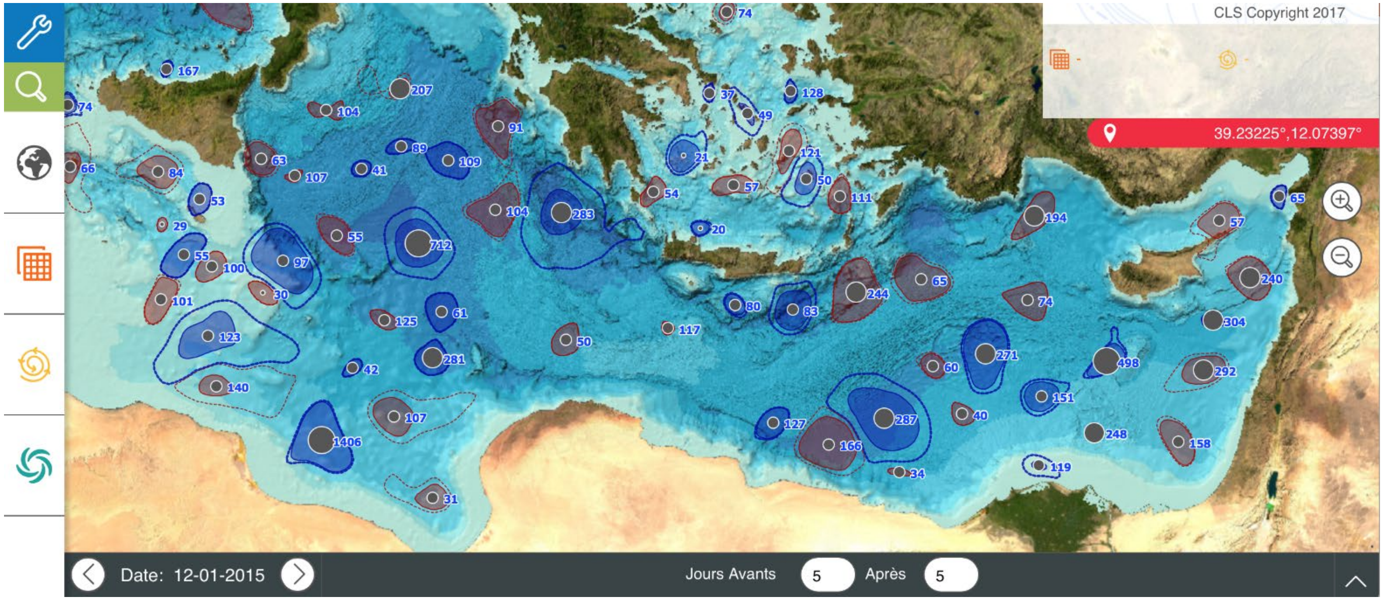
Correct agreement with CHL and SST signature

ellipticity do matters…

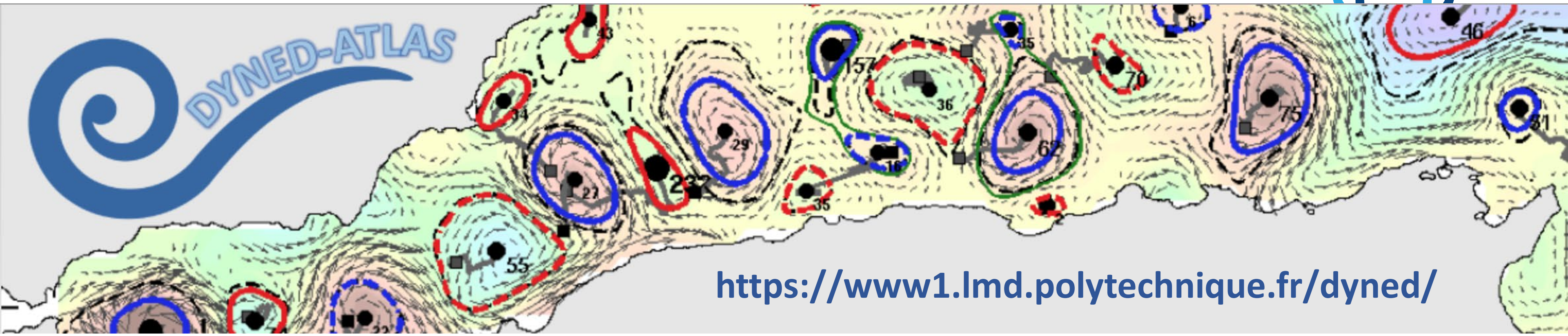
AVISO/DUACS and Argo data to follow long lived eddies and their 3D structure (Med Sea)

ODYSSEA

Graphical user interface



https://dyned.cls.fr/seewater



DYNED-Med data-base (*beta version*) is now released

- Cyclogeostrophic corrections might be significant
- Predominance of anticyclones among long-lived eddies
- Lifetimes and 3D structure differ between Western / Eastern basin
- Anticyclones control the sub-thermocline (T,S) anomalies (300-400m) in Eastern Med
- Future uses of DYNED-Atlas: oceanic model validation, local air-sea interactions, biogeochemical transport, halieutic resources, micro-plastic distribution…

astegner@lmd.polytechnique.fr

AVISO/DUACS and Argo data to follow long lived eddies and their 3D structure (Med Sea)

ODYSSEA

- N.Mkhinini, A.L. Santi-Coimbra, A.Stegner, T. Arsouze, I. Taupier-Letage and K. Béranger « Long-lived meso-scale eddies in the Eastern Mediterranean Sea: analysis of 20 years of AVISO geostrophic velocities » J. Geophys. Res. Oceans, 119, 8603–8626, doi:10.1002/2014JC010176 (2014).

- B.Levu, A.Stegner, T. Arsouze «Angular Momentum Eddy Detection and tracking Algorithm (AMEDA) and its application to coastal eddy formation **»** *J. Atmos. Oceanic Technol,* (2018) doi:10.1175/JTECH-D-17-0010.1

- A.Ioannou, A.Stegner, B.Levu, I.Taupier-Letage and S. Speich "Dynamical evolution of intense Ierapetra Eddies on a 22 year long period " *J. Geophys. Res. Oceans*, v.122, 9276-9298 (2017) doi: 10.1002/2017JC013158.

- P. Garreau, F. Dumas, S. Louazel, A. Stegner, B. Le Vu "High resolution in situ observations and tracking of a dual core anticyclonic eddy in the Algerian Basin" minor revision *J. Geophys. Res. Oceans*.

- R.Laxenaire, S. Speich, B. Blanke, A.Chaigneau, C. Pegliasco, A.Stegner "Indian anticyclonic eddies connecting western boundaries as inferred from altimetry " minor revision *J. Geophys. Res. Oceans*.

- R.Laxenaire, S. Speich, A.Stegner "Evolution of the thermohaline structure of one Agulhas Ring reconstructed from satellite altimetry and Argo floats" submitted to *J. Geophys. Res. Oceans*.

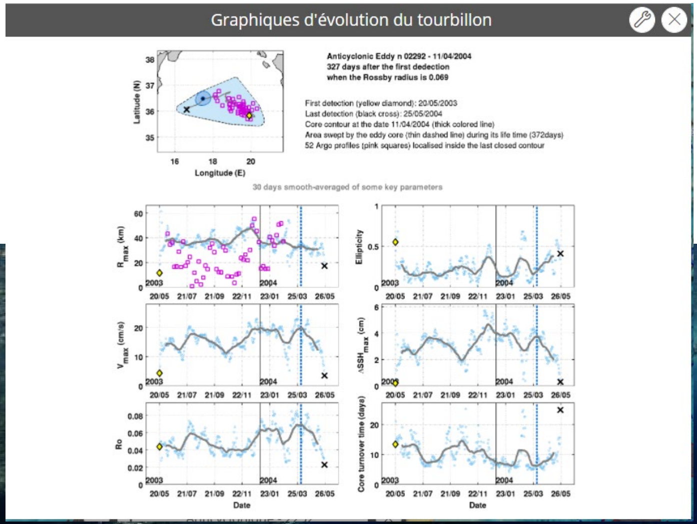
- A.Ioannou, A.Stegner, A. Tuel and S. Speich "Cyclogeostrophic corrections of AVISO surface velocities for meso scale eddies and its application to the Mediterranean Sea " in prep.

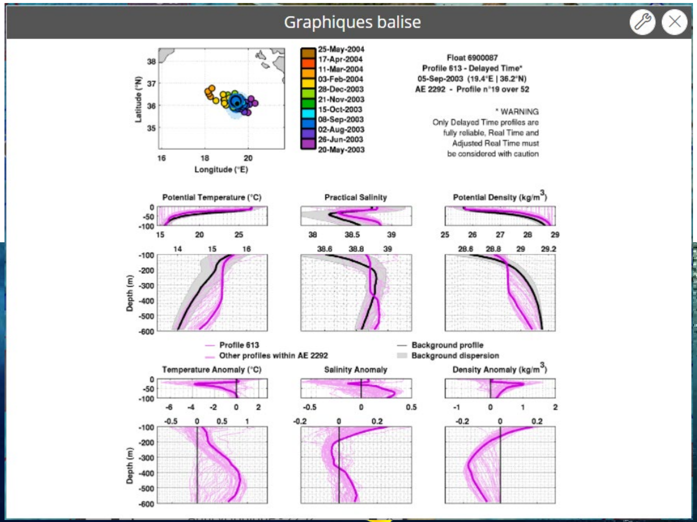
https://www.researchgate.net/profile/Alexandre_Stegner

Quick demo of the graphic interface for a long-lived Anticyclonic eddy in the Ionian Basin : 6th of September, 2003

Global view of the date : global_20200906

- Zoom on the eddy + general characteristics : AE2292_general
- Temporal evolution and vertical structure





FORECASTING TOOLS IN MARINOMICA

VIRTUAL SCHOOL « OCEANOGRAPHY FROM SPACE » November 26th 2020

Katerina Spanoudaki

FORTH

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727277

Outline

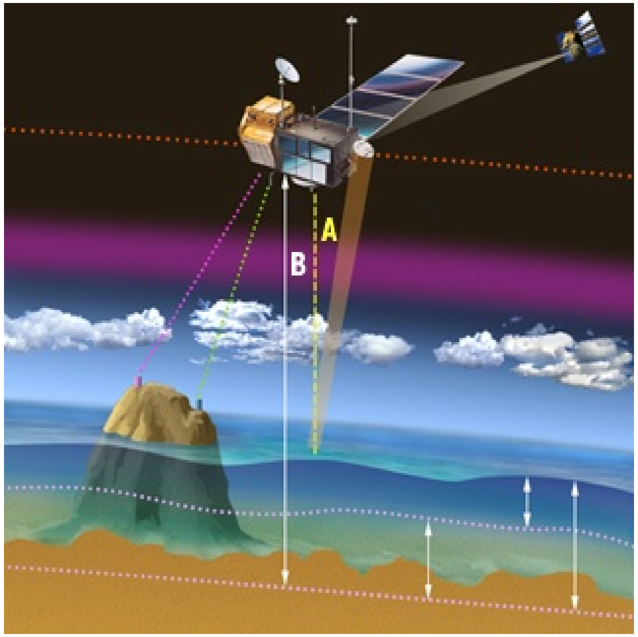
ODYSSEA

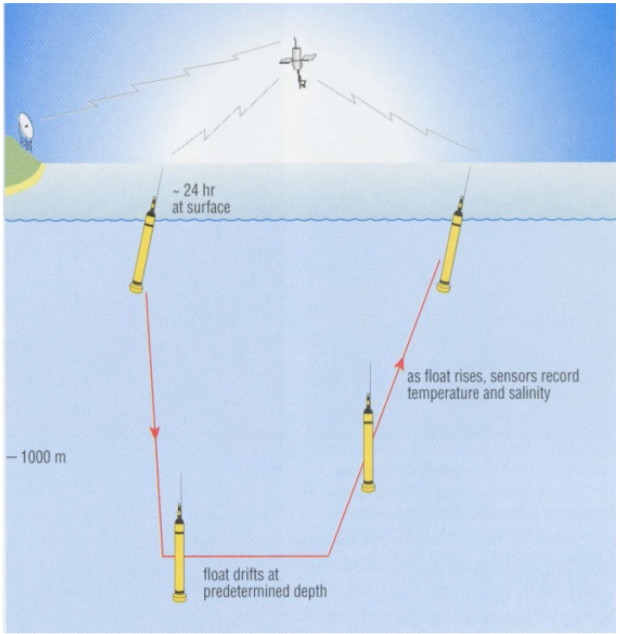
- The key European priorities in OO
- Copernicus - CMEMS
- Forecasting tools in Marinomica platform
  - hydrodynamic models
  - wave models
  - downscaling at coastal scales
- in-situ observations
- Satellite data

What is Operational Oceanography?

ODYSSEA

…can be defined as the activity of systematic and long-term **routine monitoring** of the seas and oceans and their **rapid interpretation and dissemination** (EuroGOOS).





What is Operational Oceanography?

ODYSSEA

…It combines and it completes the knowledge and experience from other sectors of **oceanography**, while it uses elements of **meteorology, technology for autonomous in-situ and satellite remote sensing measurements**, RT t**elecommunications** and advance methods of **numerical modeling**.

.

Which are the problems that OO tries to solve today?

ODYSSEA

- **Predict** the future state of the oceans and seas for both, abiotic and biotic components;
- **Estimate** as accurately as possible the present and past state of the ocean from all available data sources;
- **Understand** changes and impacts of human activities on the oceans to manage adaptation and preservation with a *'science based approach'*
- Efficient and cost effective way to **monitor** the marine components of the earth, both in RT as well as in delayed mode

Operational Approach to Oceanography

ODYSSEA

3 pillars of prediction science

- Multi-disciplinary Multi-platform Observing systems (static or mobile, fixed or relocatable)
- Numerical models of hydrodynamics, waves and biogeochemical, coupled to atmospheric forecast
- Data assimilation for optimal field estimates and uncertainty estimates

2 pillars of Operational Oceanography

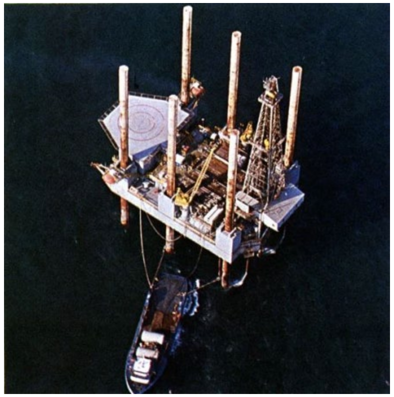
- Continuous production of nowcasts/forecasts of ocean variables
- From regional to coastal scales (nesting)

Why there is a need to develop Operational Oceanography?

ODYSSEA

Increase of activities associated with marine environment:

- Navigation (security)
- Fisheries-aquaculture
- sea bed mining
- Renewable energy
- Tourism ....



Need for rational management – security

- Increase of pressures to environment: the need for protection from pollution

Climatic Variability and Change

- need for understanding and forecasting

An area of high-risk for oil pollution:
220.000 vessels / year (>100 tn) (250-300 tankers / day)
30% of global merchant shipping
20% of oil shipping

Between August 1977 and December 2011, approximately 310,000 tones of oil were spilled in the Mediterranean Sea whilst 572 significant incidents that caused or were likely to cause oil pollution of the Mediterranean Sea were reported to REMPEC

The explosion and fire on board of the MT HAVEN off Genoa, followed by the sinking of the ship with its cargo of 144.000 tones of crude oil, in 1991, is considered the largest oil spill incident in the Mediterranean region.

The key European priorities in OO

- Modelling and forecasting,
- Advancing coastal oceanography,
- Operational oceanography for ecosystem based management

Why? →in order to contribute to the implementation of the:

- **EU Blue Growth strategy** for sustainable economic growth in the marine and maritime sector including, integrated forecasting and observing systems, multi-disciplinary research, biotechnology, aquaculture, ocean energy

- **EU Directives :** Marine Strategy-*MSFD, Marine Safety,* Water and Common Fisheries Policy, etc.

The key European priorities in OO

ODYSSEA

Modelling and Forecasting

1. improve the models by:
   - increasing the time and space resolution
   - advancing the model accuracy and quality of forecasts
   - access to high quality boundary and forcing data with high resolution bathymetry, meteo inputs.

2. Ensure the uptake from scientists and users by:
   - harmonizing the interface between the Member States oceanographic forecasting and observing data with Copernicus Marine Environmental Monitoring Service-CMEMS and the European Marine Observation Data Network- EMODNET.

The key European priorities in OO

ODYSSEA

Advancing coastal oceanography to:

- Use new in-situ observational variables using low cost sensors.
- Improve data assimilation, use high resolution meteo-data.

Operational ecology for ecosystem based management to:

- advance basic research to fill the gaps in understanding and modeling biochemical cycles, at coastal and offshore, including interaction between low and high trophic levels and benthic ecosystems.
- integrate the existing knowledge into ecological models.

OO products

ODYSSEA

Essential Ocean Variables (identified by the GOOS Expert Panels)

Essential Ocean Variables and readiness level

CONCEPT PILOT MATURE

Physics
- Sea State
- Ocean surface vector stress
- Sea Ice
- Sea level
- SST
- Subsurface temperature
- Surface currents
- Subsurface currents
- SSS
- Subsurface salinity

Biogeochemistry
- Oxygen
- Inorganic macro nutrients
- Carbonate system
- Transient tracers
- Suspended particulates
- Nitrous oxide
- Carbon isotope (^{13}C)
- Dissolved organic carbon

Biology and Ecosystems
- Phytoplankton biomass and productivity
- HAB incidence
- Zooplankton diversity
- Fish abundance and distribution
- Apex predator abundance and distribution
- Live coral cover
- Seagrass cover
- Mangrove cover
- Macroalgal canopy cover

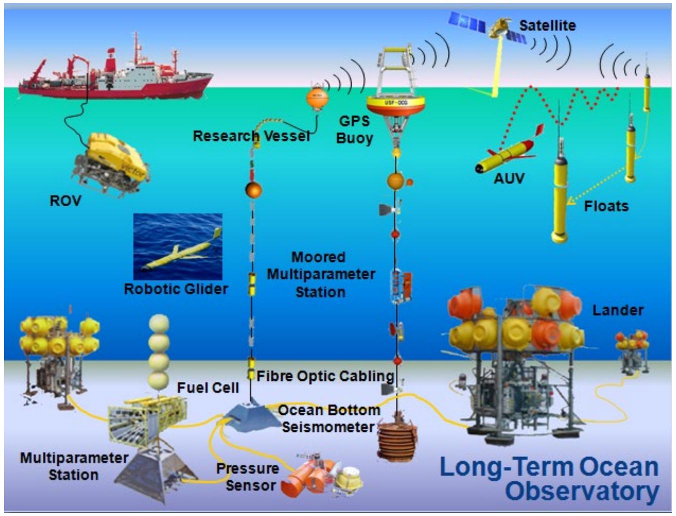
Main observing systems in OO

ODYSSEA

- **global:** cover the entire ocean (ARGO floats, satellite remote sensing; measured parameters: SST, SSH, temperature and salinity profiles, sea level, currents;

- **regional:** monitoring of regional phenomena (for example: the POSEIDON buoys network in the Aegean Sea; gliders, Euro-Argo, Med-Argo, etc.); temporal scales – from hours to days;

- **coastal:** monitoring of water quality, observations of wind, wave and tides near ports HF radar for monitoring of surface currents and waves at distances up to 100 Km, coastal buoys, gliders.



Synergy between Satellite and in-situ observing systems

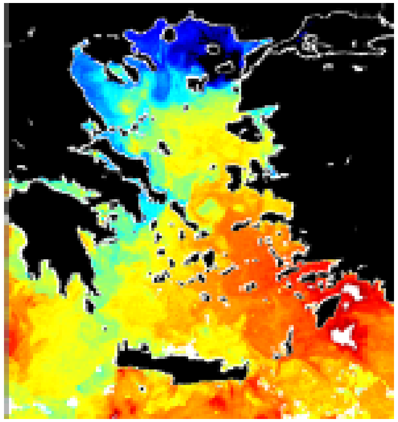
ODYSSEA

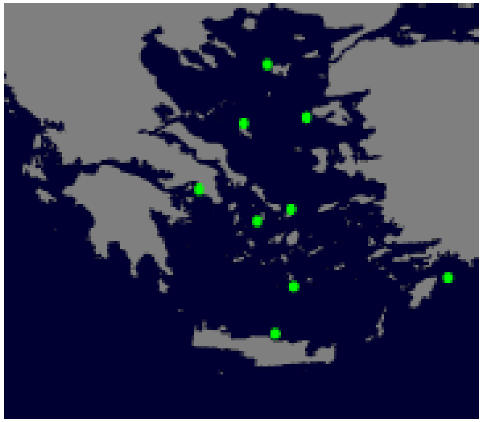
Satellite R/S

- Large spatial coverage
- Lower accuracy
- Less frequency of measurements
- Limited parameters
- Surface measurements

In-situ

- Limited spatial coverage
- Higher accuracy
- Higher frequency of measurements
- Variety of parameters
- Entire water column measurements





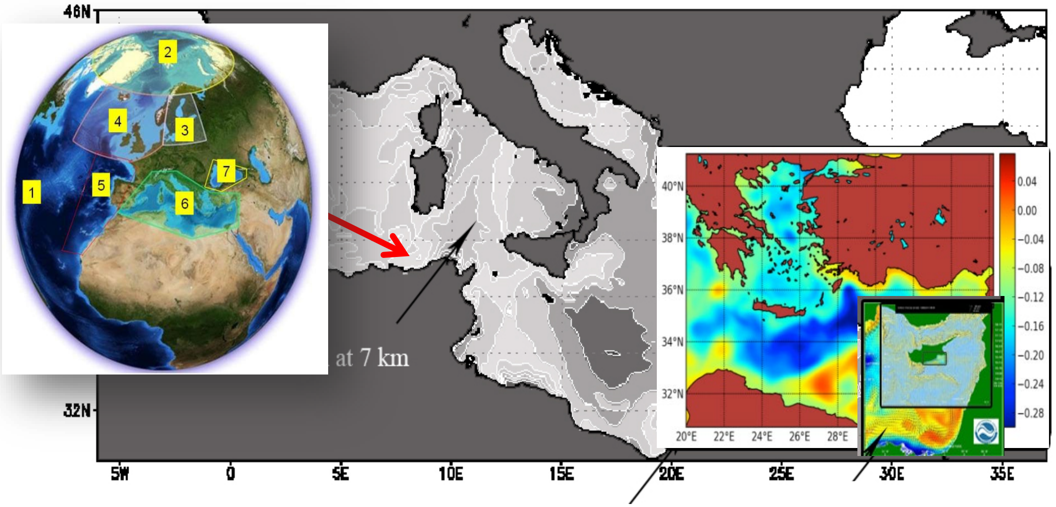
Numerical models in Operational Oceanography

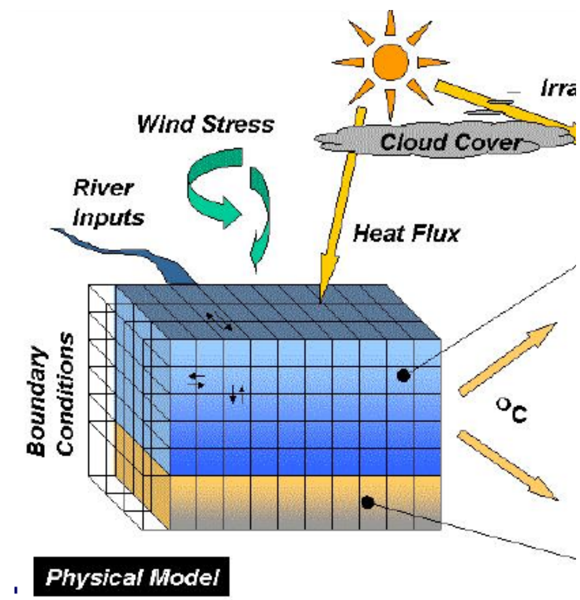
ODYSSEA

Hydrodynamic, wave, biochemical, pollutant dispersion

Hydrodynamic models: Solve the equation of momentum and continuity (Navier-Stokes) to derive: 3D currents, temperature and salinity profiles, sea level and many other parameters used for other numerical applications (dispersion, biochemical)

Downscaling/Hierarchical nesting





Major products derived from operational oceanography forecasting

ODYSSEA

* **Nowcasts**: providing the most accurate description of the present state of the sea.
* **Forecasts**: providing daily predictions of the future condition of the sea for up to 10 days ahead.
* **Hindcasts**: providing long term data for the description of past states, and time series showing trends and changes of the modeled parameters.

Operational Oceanography based on

ODYSSEA

* real time data transmission from the **monitoring platforms** to be **used by the forecasting models,**

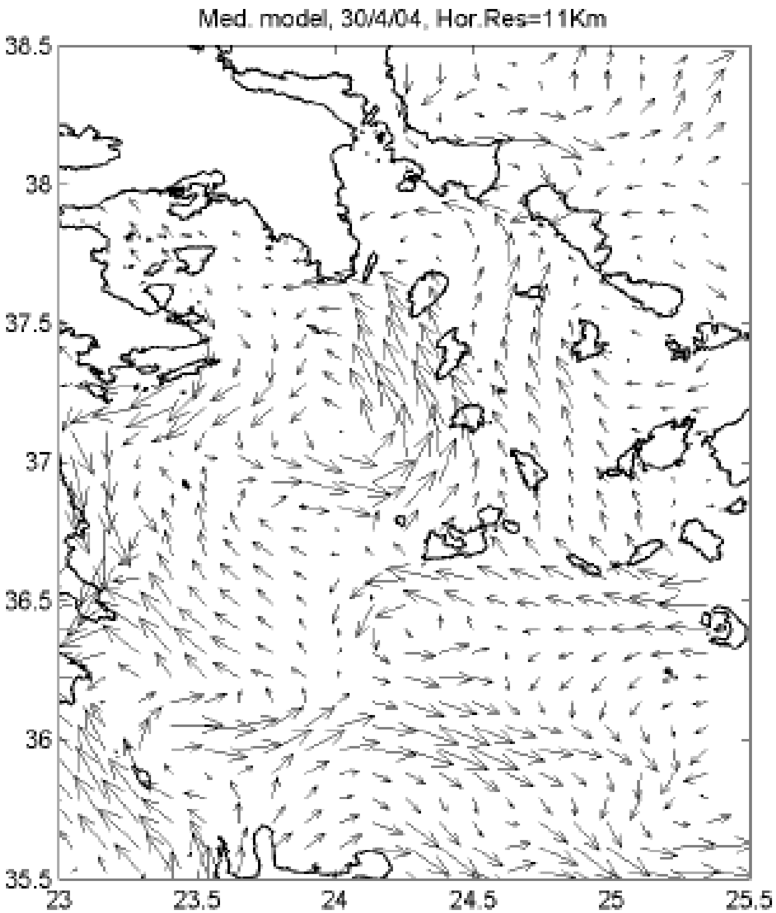
* implementation of methods to increase the capacity of numerical models to **forecast the dynamics** of the **marine environment,**

* **downscaling applications** in coastal areas at different spatial and temporal scales,

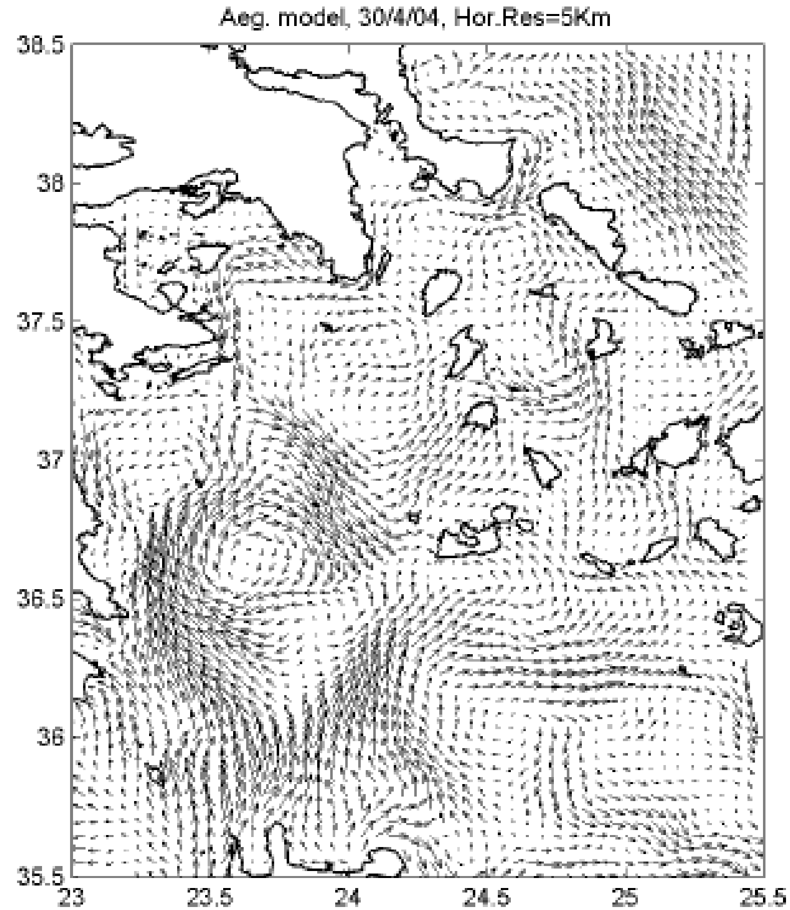
* **down streaming applications** to support a number of services, such as search and rescue, assessment and mitigation of risks, maritime safety, coastal erosion, climate change, ocean governance, marine industries and emergencies situations at sea, etc.

Numerical models in OO: importance of the horizontal resolution

ODYSSEA



Horizontal resolution 10 km

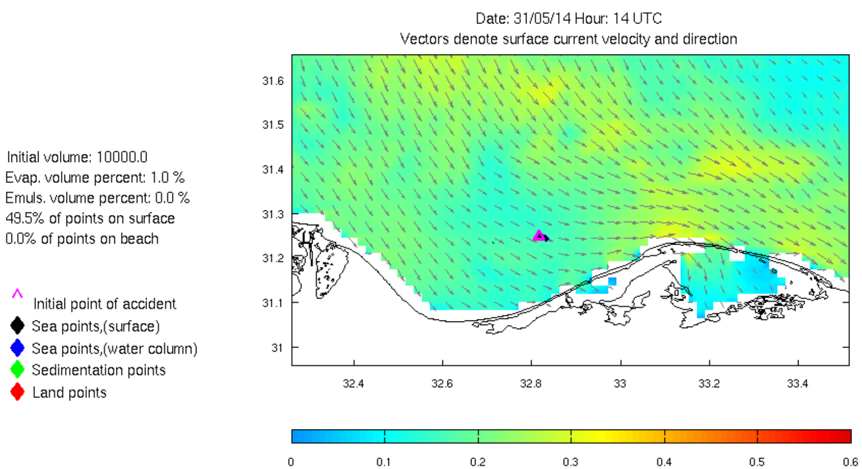


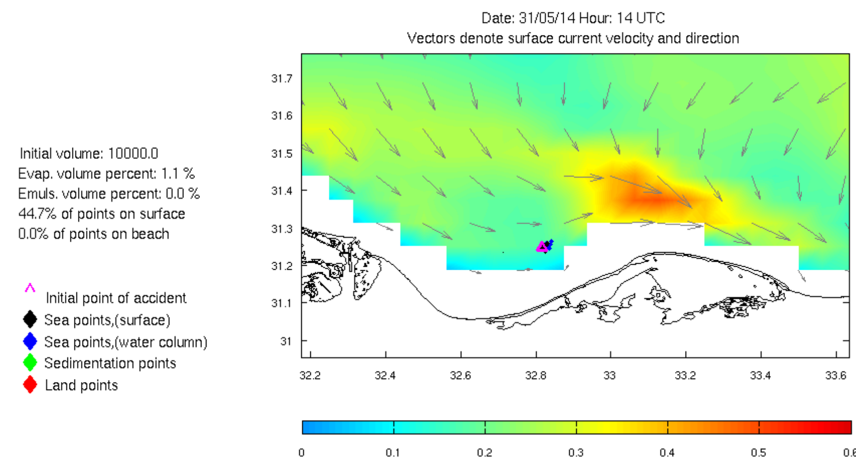
Horizontal resolution 5km

Numerical models in OO: importance of the horizontal resolution

ODYSSEA

Use of the same oil spill model with 2 different data set





OCEAN data	METEO data	WAVES data
CYCOFOS AEG LEV (2×2 km)	Skiron (5×5 km)	CYCOFOS WAM4 (5×5 km)

Higher resolution forcing data

OCEAN data	METEO data	WAVES data
MFS (6.5×6.5 km)	ECMWF (25×25 km)	INGV WWIII (6.5×6.5 km)

Lower resolution forcing data

the key European priorities in OO

ODYSSEA

To achieve the EU priorities in OO, EU builds on large initiatives such as:

- ***Copernicus Marine Environmental Monitoring Service-CMEMS***
- ***European Marine Observation Data Network- EMODNET***
- and relevant strategic projects (MyOcean, SeaDataNet, etc.).

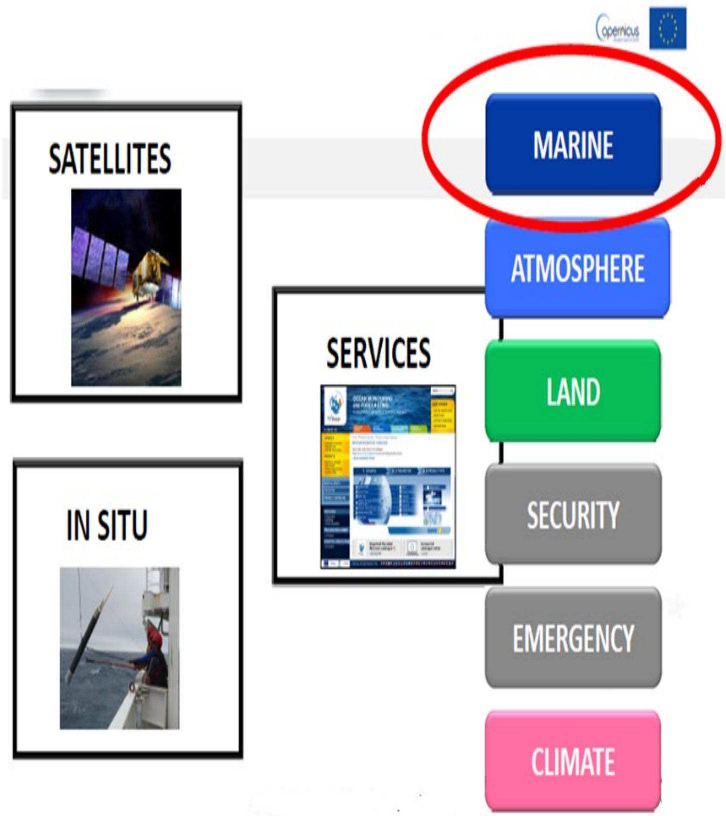
One of the major EU Space program is the :

- **Copernicus, former GMES-**global monitoring for environment and security:
  - is based on **Earth monitoring data, collected from** space (satellites), air (airborne instruments, etc.), **in-situ monitoring of seas** (floats, gliders, shipboard instruments, etc.) or land (measuring stations, seismographs, etc.)
  - produce **output information** in the form of **maps, datasets**, reports, targeted alerts, etc.

Copernicus
The European Earth Observation Programme

ODYSSEA

1) aims to setup operational services, related to:



2) provide access to **monitoring** and **forecasting** information at regional and global scale, based on Earth monitoring data, collected from satellites and other monitoring platforms.

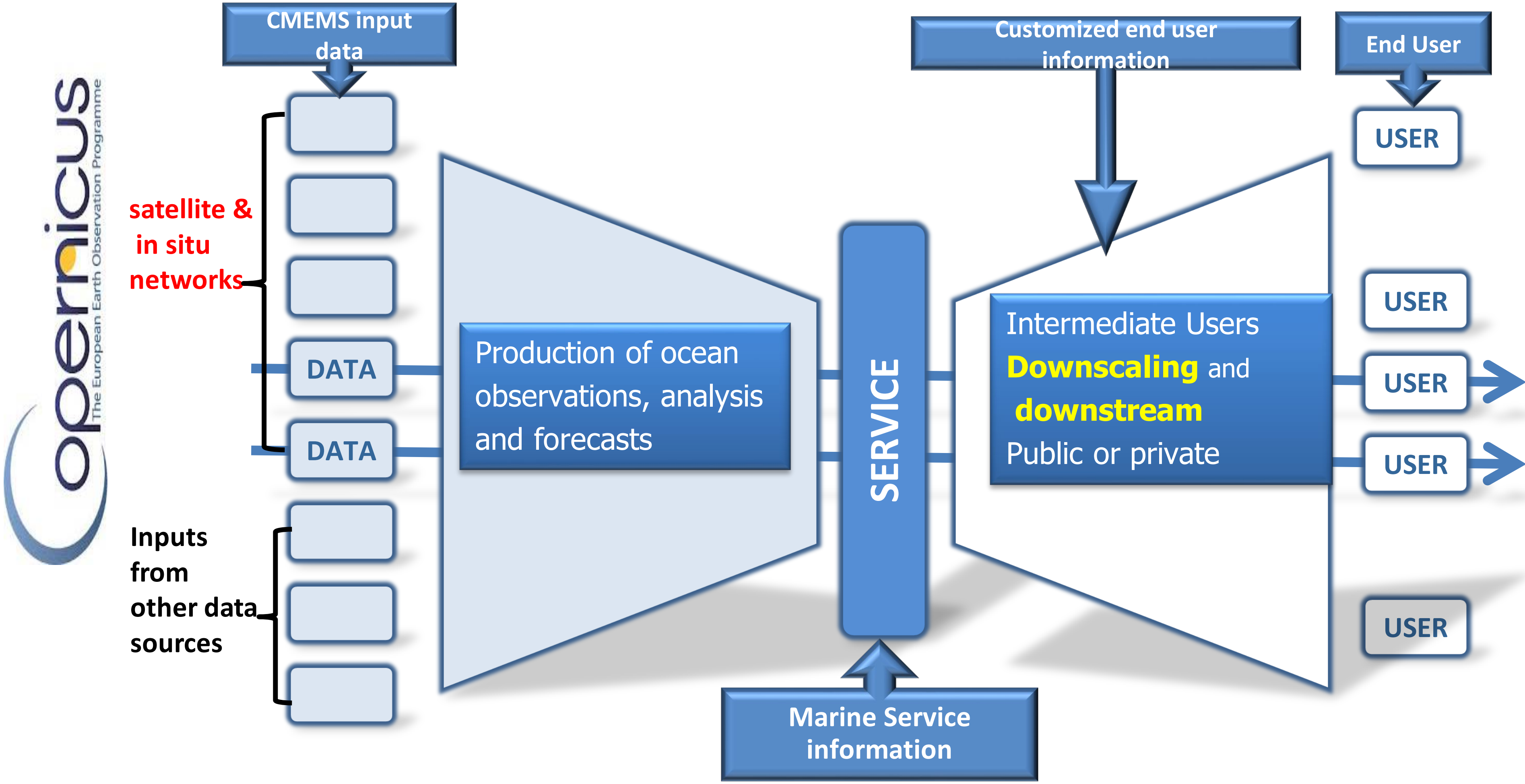
3) assist the Policy-makers and the authorities in the preparation of environmental legislation and policies, for example the EU Directives on Marine Safety, climate change, etc.

4) Support the citizen's protection in emergency, search and rescue, civil protection, response in pollution, coastal erosion, etc.

General aims of the Copernicus MARINE component- CMEMS:

ODYSSEA

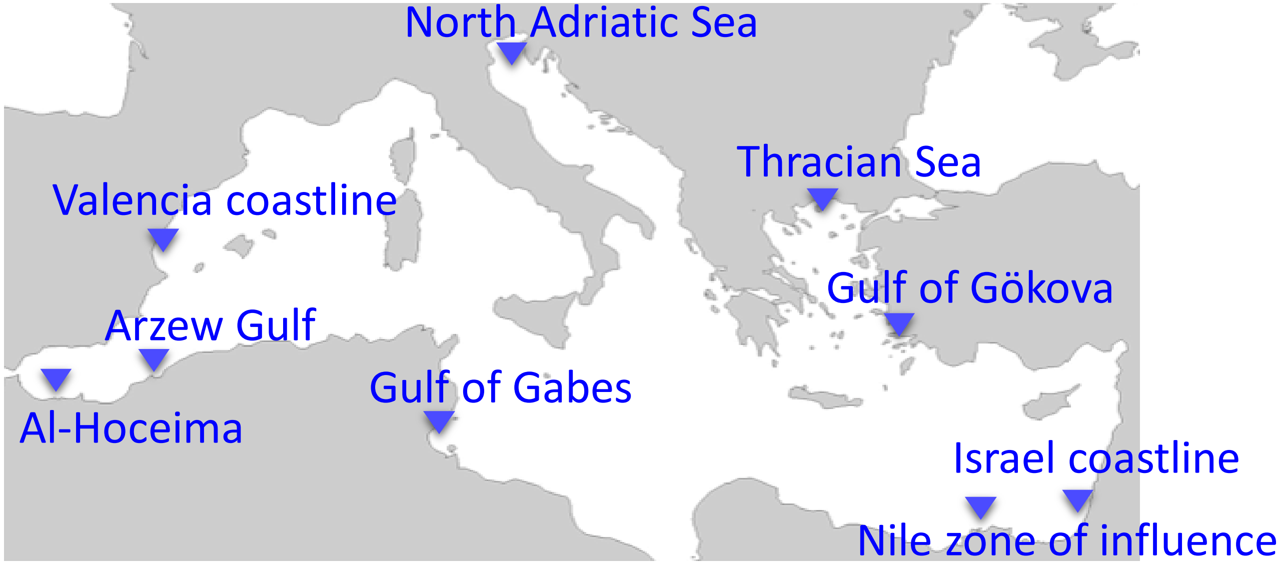
a) Produce regular and systematic information on the state of the oceans-analyses and forecasts, on global and for regional seas.
b) OBSERVATIONAL and FORECASTING data and products, available in NRT.



Forecasting tools in ODYSSEA project/Marinomica platform: The Observatories

ODYSSEA

- ✓ Integrate and Operate a network of 9 observing and forecasting systems covering coastal and shelf zone environments,
- ✓ Diverse systems from Ecologically-vulnerable systems (MPAs) to systems with increased human pressure,
- ✓ Combine monitoring and modeling activities,
- ✓ Produce new datasets with increased spatial and temporal resolution, stored, manipulated, made accessible through the ODYSSEA platform.



The models

✓ A prototype 'chain' of operational models will be developed,

✓ Link models to existing databases,

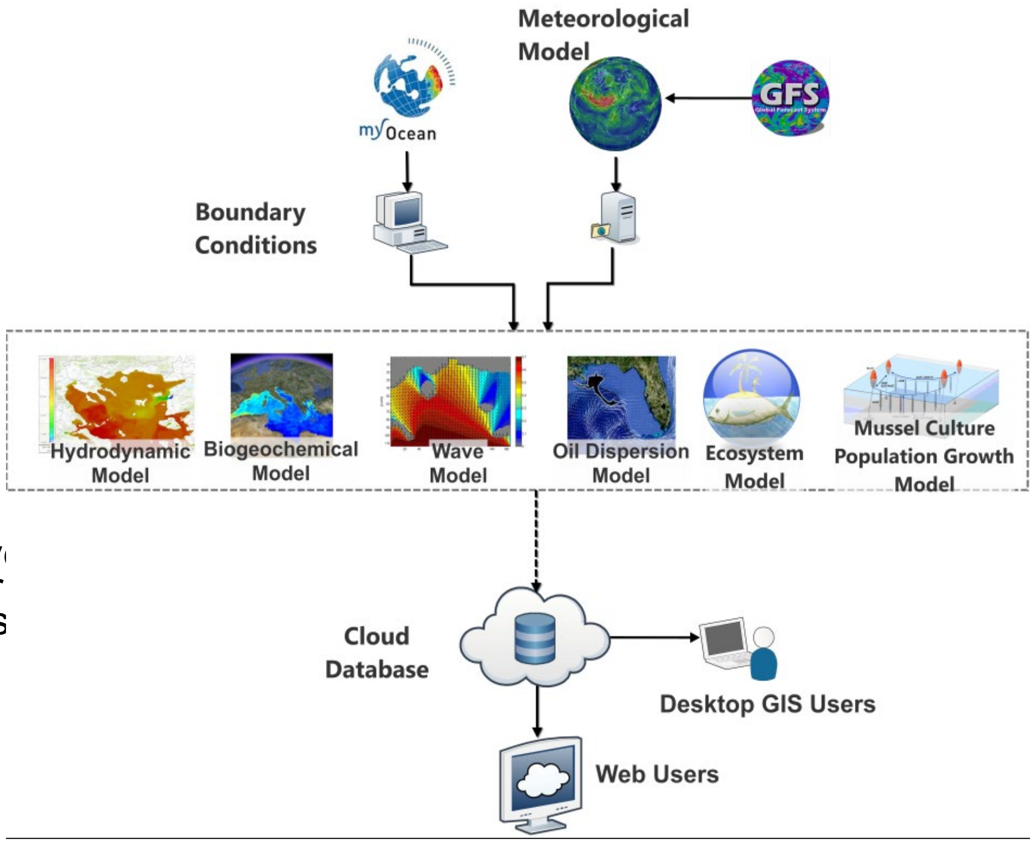
✓ Provide short- and long-term prognostic results,

✓ Manage risks and emergencies in coastal and offshore areas,

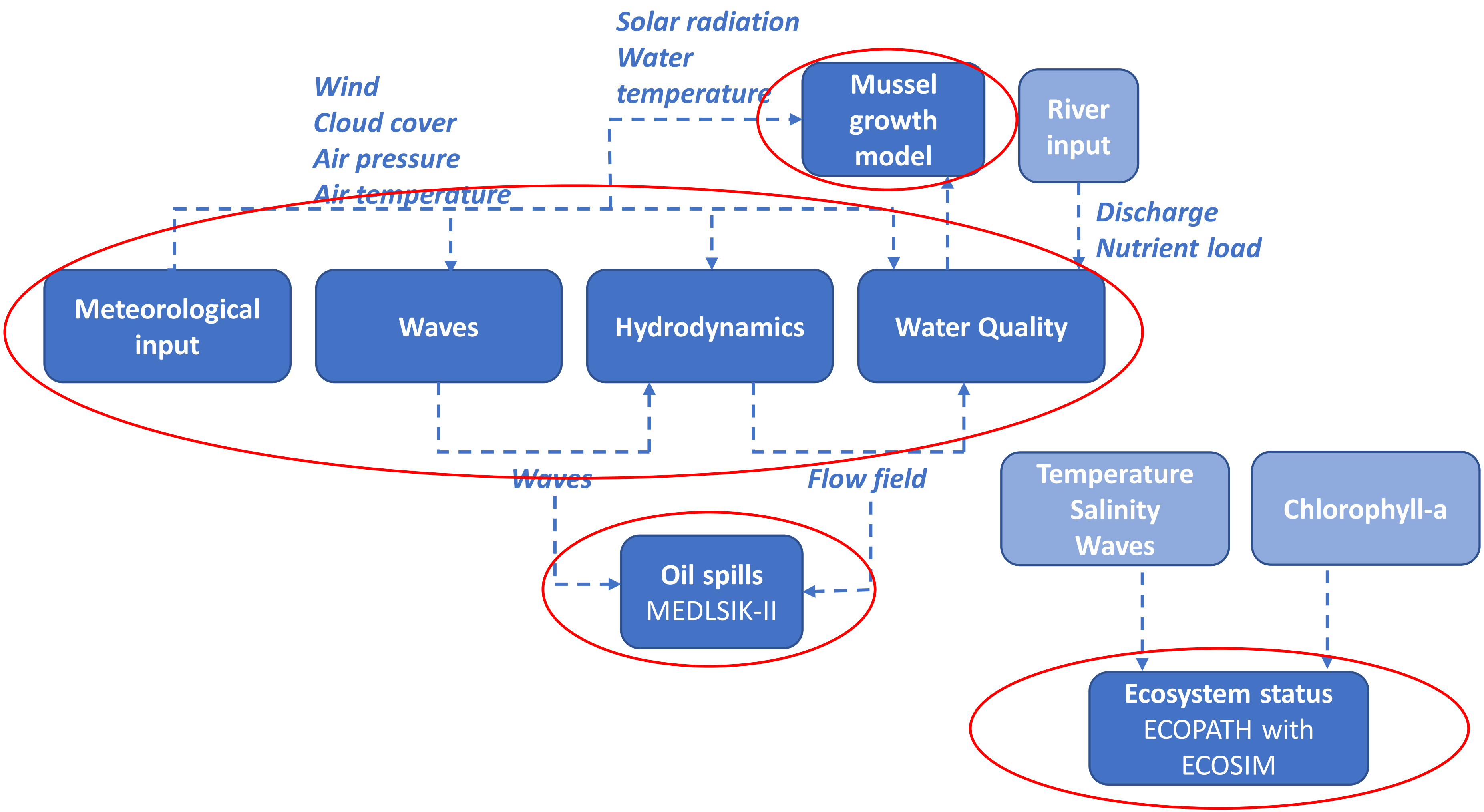
✓ Meet the requirements of various end-user groups,

✓ Report on parameters never previously reported,

- Models: hydrodynamic (Delft3D), Wav (SWAN), Oil spill (MEDSLIK-II), Water quality (DELWAQ), Ecosystem models (Ecopath with Ecosim), Fish and Mussel/oyster culture population growth

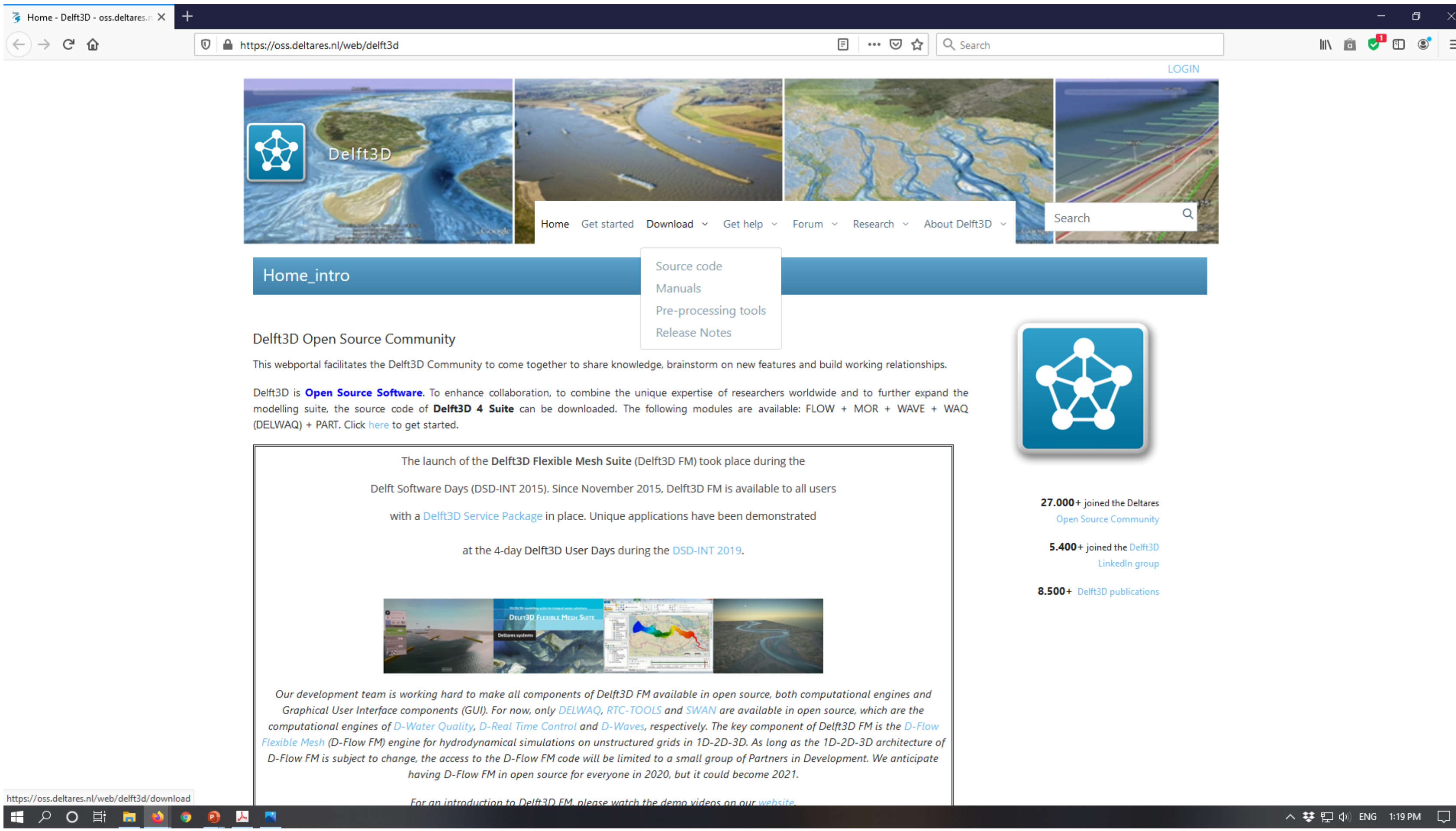


The models


Solar radiation
Water temperature
Wind
Cloud cover
Air pressure
Air temperature
Mussel growth model
River input
Discharge
Nutrient load
Meteorological input
Waves
Hydrodynamics
Water Quality
Waves
Flow field
Temperature
Salinity
Waves
Chlorophyll-a
Oil spills
MEDLSIK-II
Ecosystem status
ECOPATH with ECOSIM

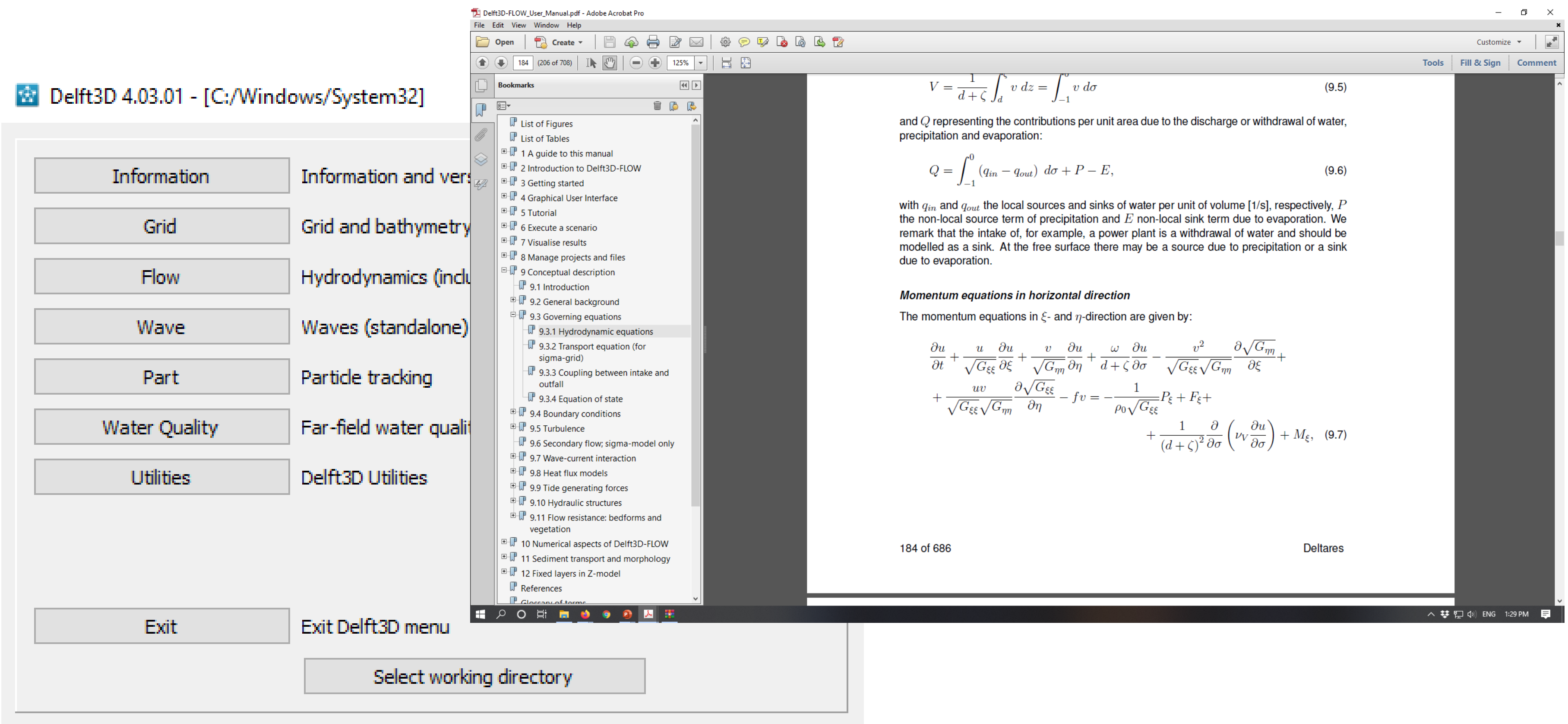
Delft3D modelling suite

ODYSSEA



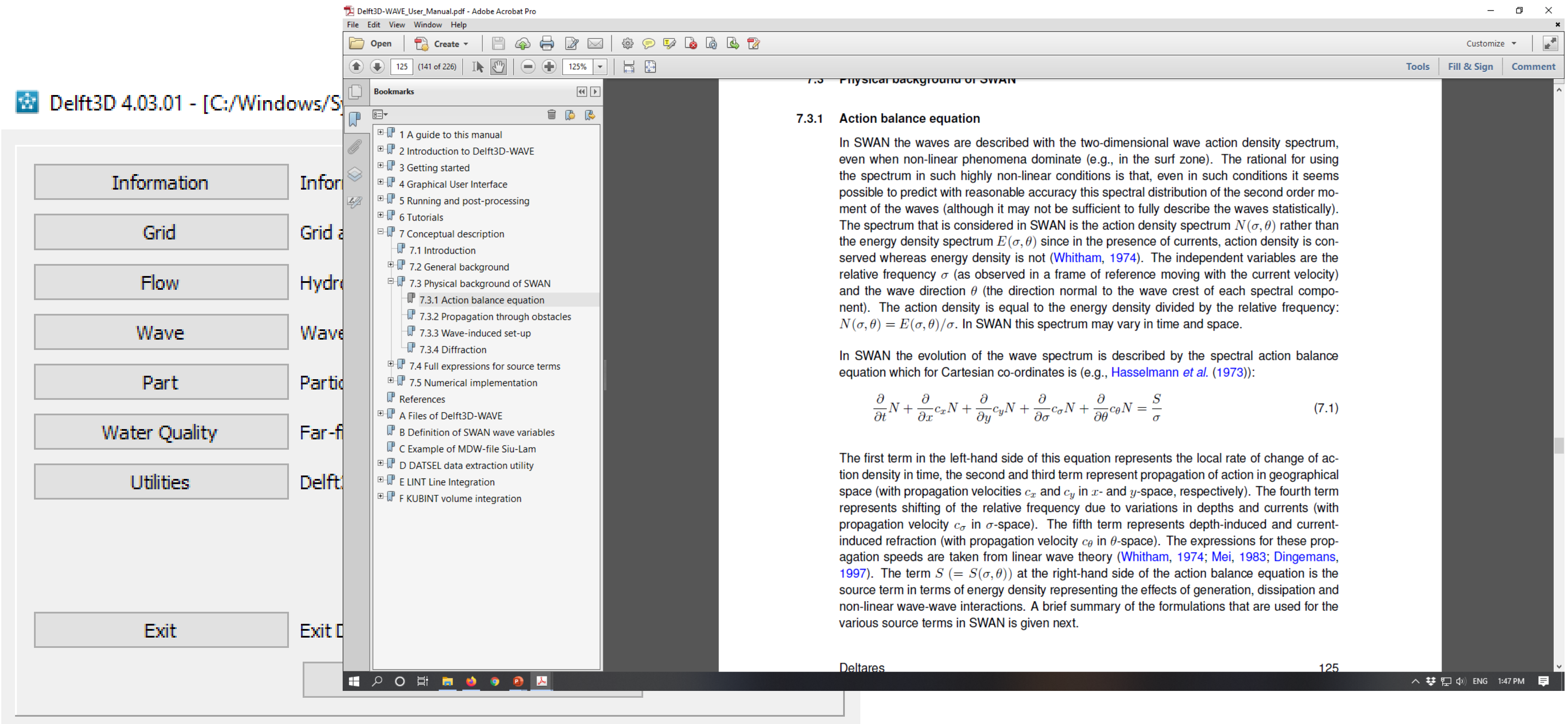
Delft3D modelling suite

ODYSSEA

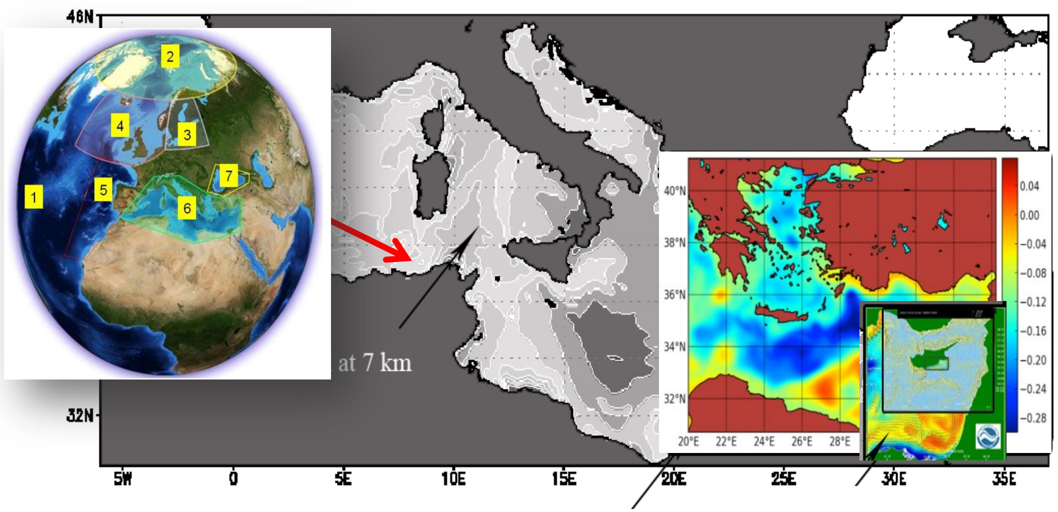


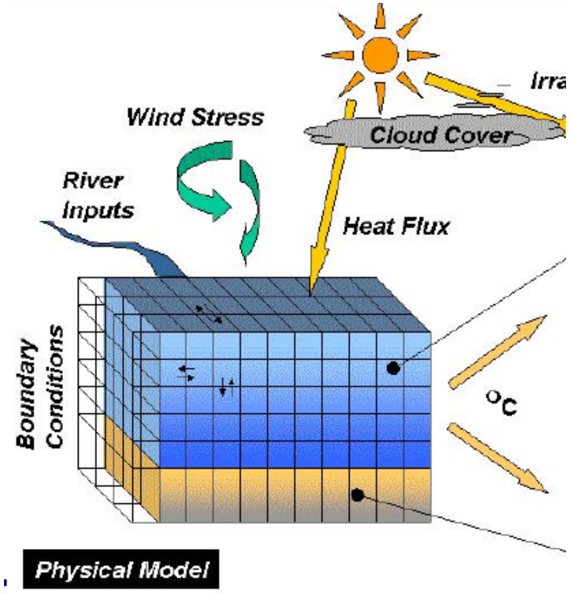
Delft3D modelling suite

ODYSSEA



Downscaling from CMEMS products





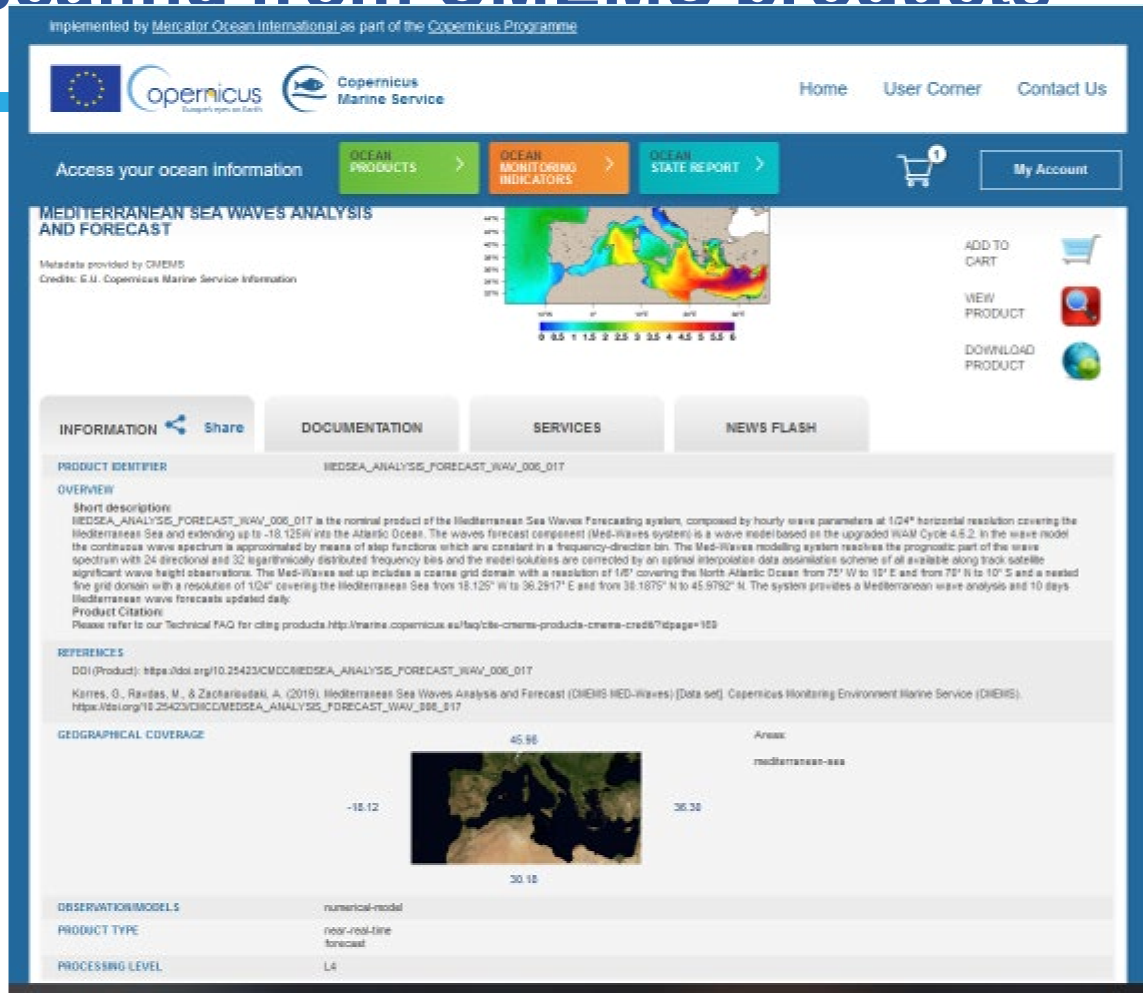
Downscaling from CMEMS products

ODYSSEA

- ✓ sea_water_potential_temperature (T)
- ✓ sea_water_salinity (S)
- ✓ sea_surface_height_above_geoid (SSH)
- ✓ eastward_sea_water_velocity (3DUV)
- ✓ northward_sea_water_velocity (3DUV)

Downscaling from CMEMS products

ODYSSEA



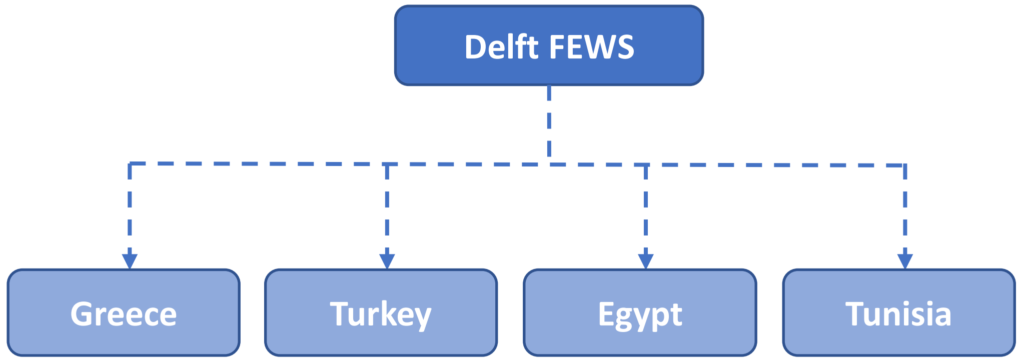
Operationalisation of models, set-up at Observatory scale and upload to Marinomica

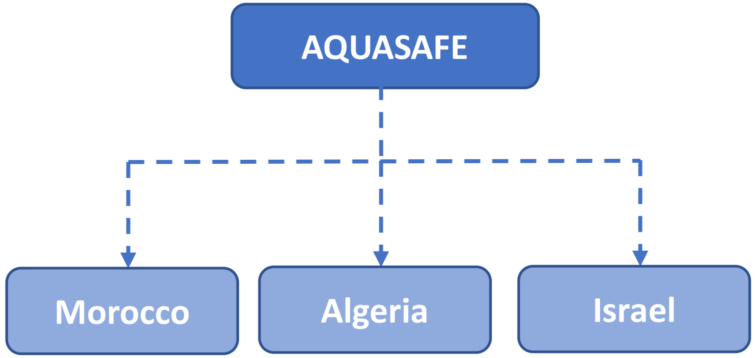
ODYSSEA

- ✓ For the operation of the numerical models, a series of tasks needs to be performed in an automated manner:
- ✓ Link models to appropriate initial and boundary conditions,
- ✓ Couple and initiate the “chain” of
- ✓ Integrate data from in-situ sensors and remote sensing data
- ✓ Perform models validation and data assimilation
- ✓ Post-process models results and upload to Marinomica platform

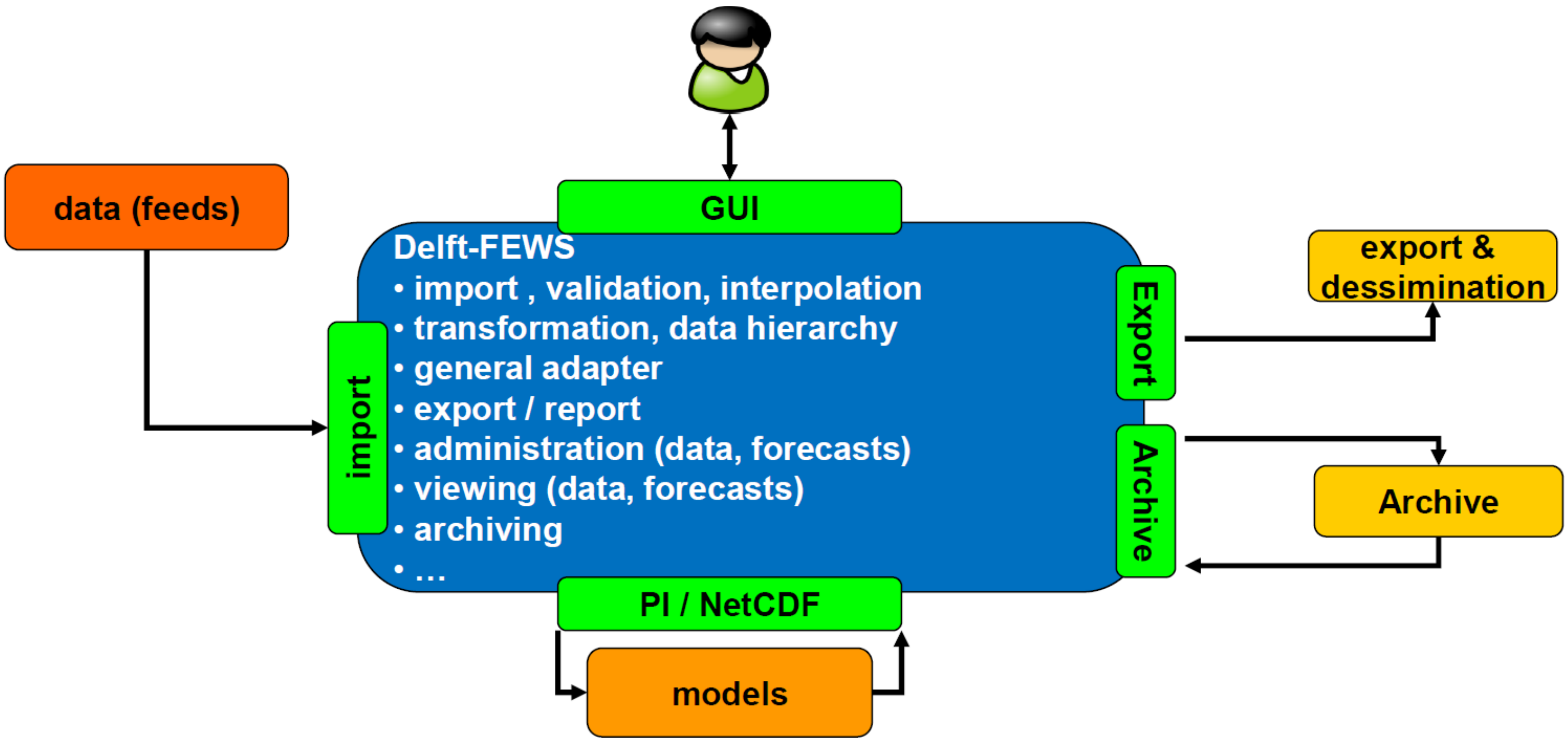
The platforms used at ODYSSEA project

ODYSSEA



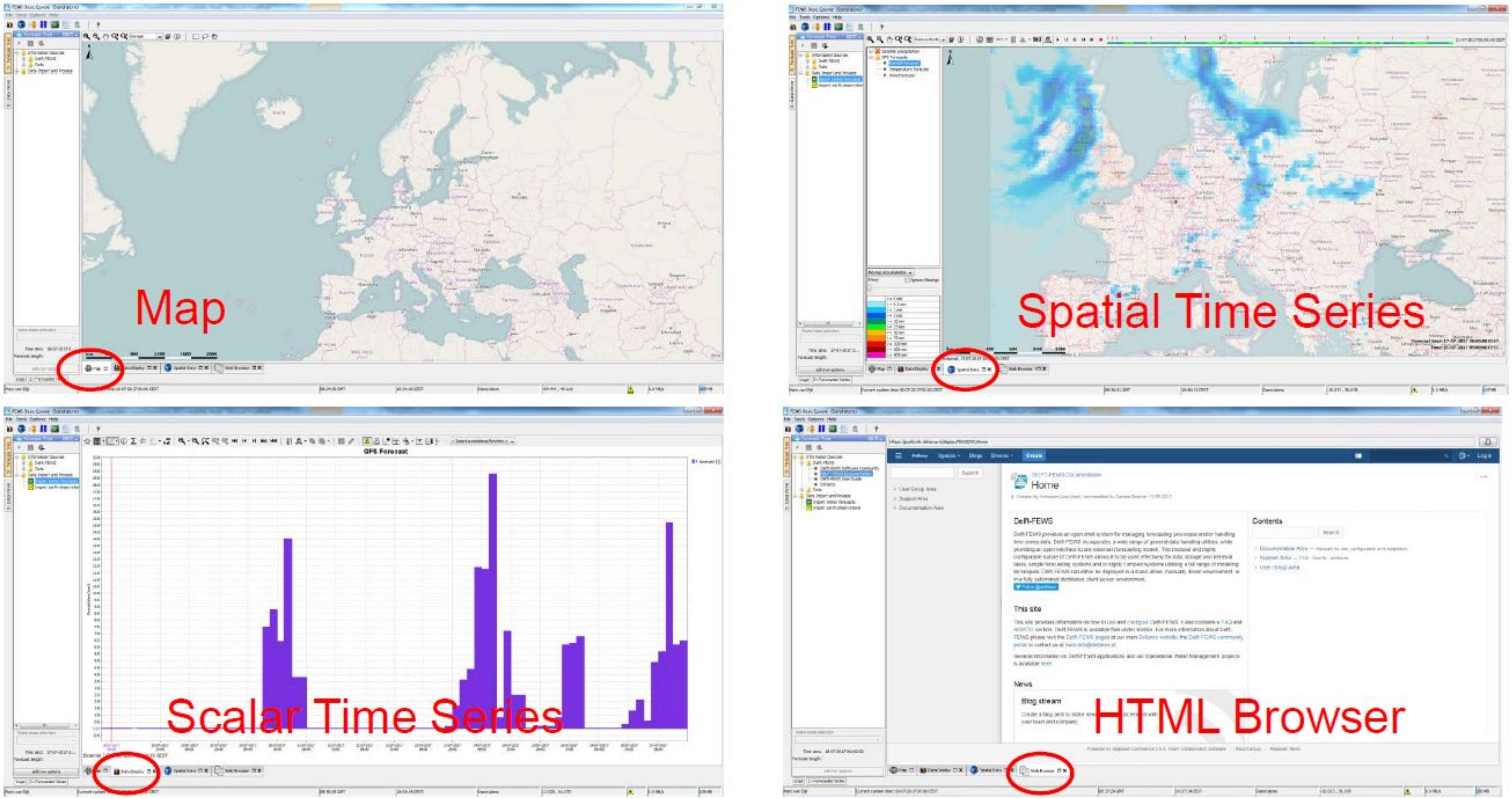


The platforms used at ODYSSEA project: Delft-FEWS



The platforms used at ODYSSEA project: Delft-FEWS

ODYSSEA



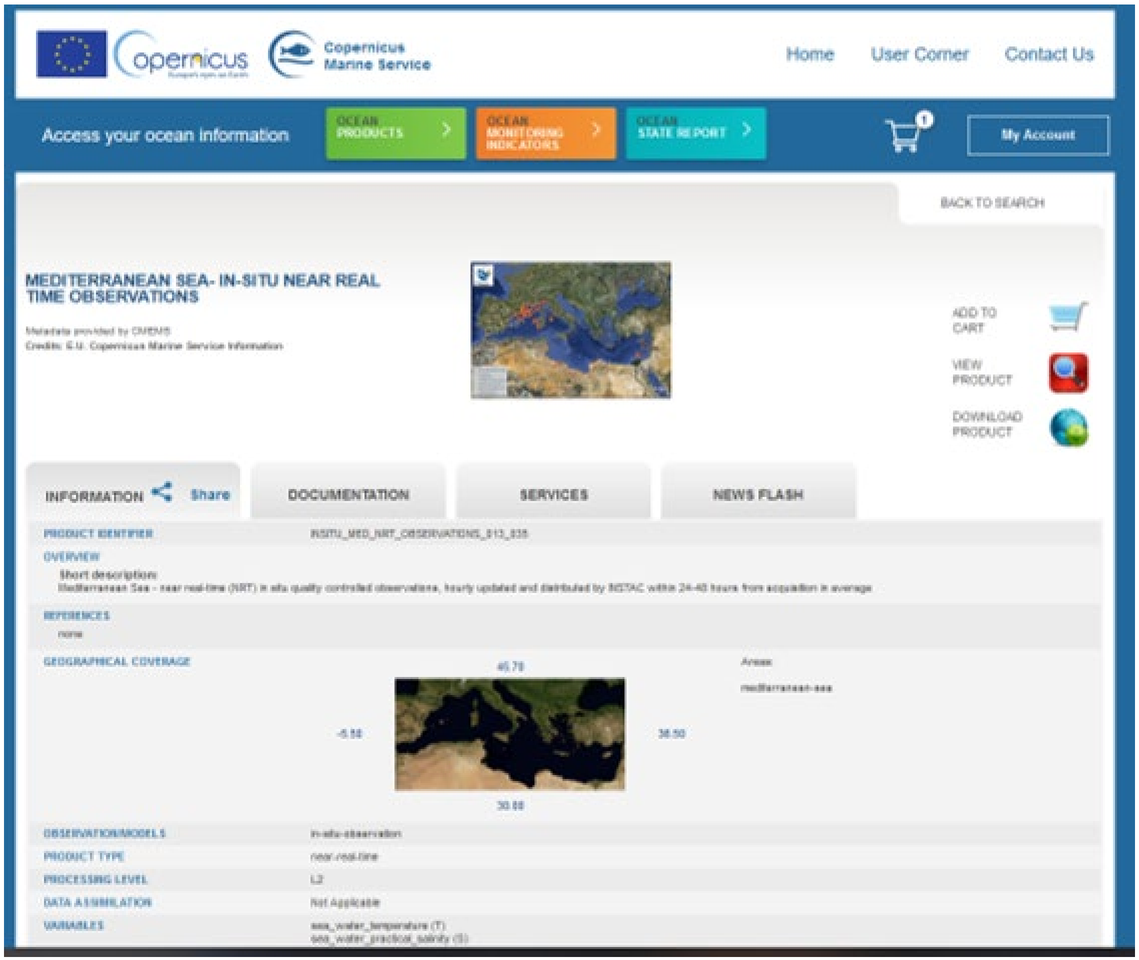
Satellite and in-situ products used for hydrodynamic models validation

ODYSSEA

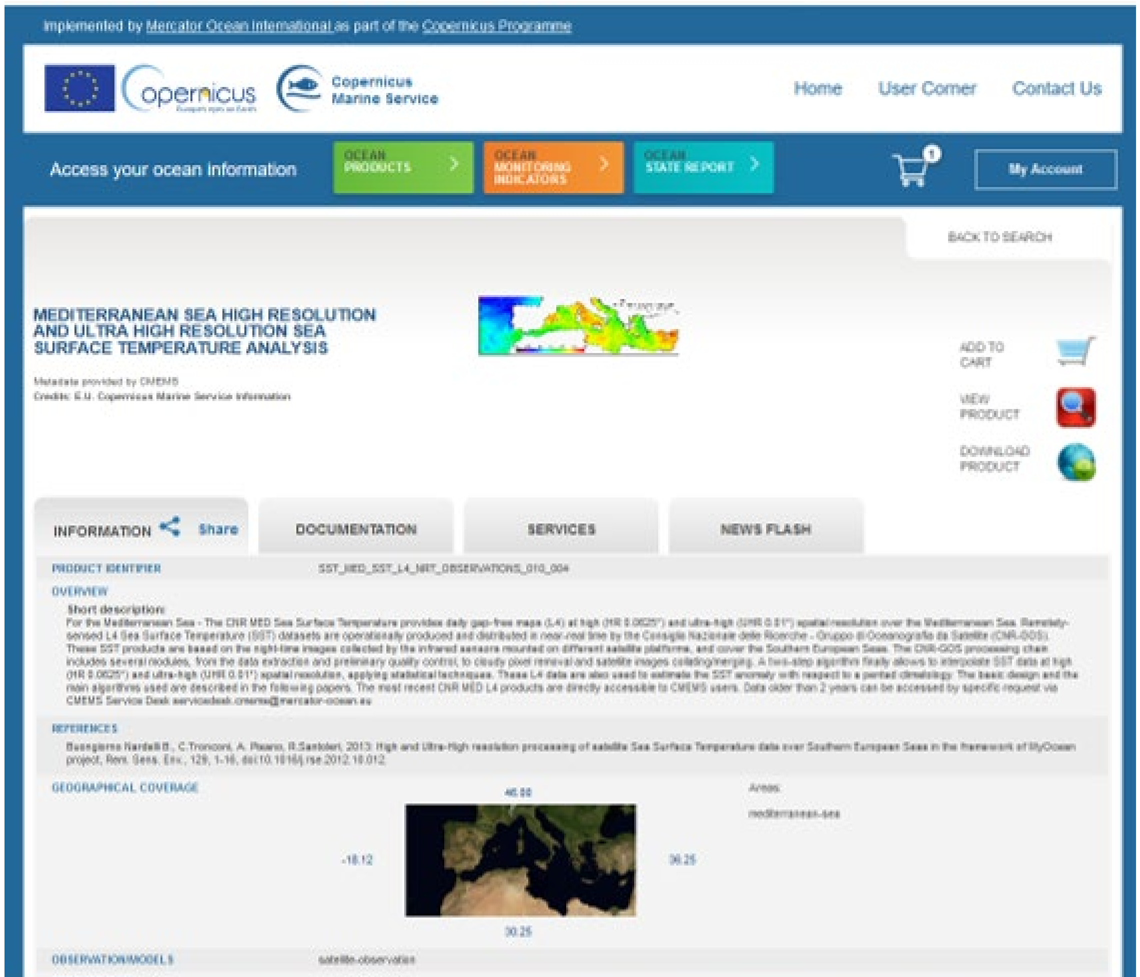
- satellite and in-situ observations are used to assess the skill of temperature, salinity and sea level anomaly
- In-situ observations to assess currents

Satellite products used for hydrodynamic models validation

ODYSSEA



Satellite products used for hydrodynamic models validation



Satellite products used for hydrodynamic models validation

ODYSSEA

SEALEVEL_MED_PHY_ASSIM_L3_NRT_OBSERVATIONS_008_048

MEDITERRANEAN SEA ALONG-TRACK L3 SEA SURFACE HEIGHTS NRT TAILORED FOR DATA ASSIMILATION

OBSERVATION	L3	MED

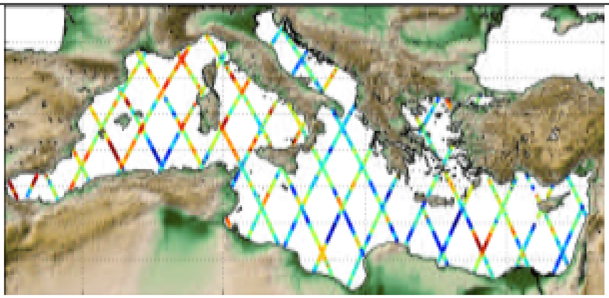
SSH

7 km x 7 km (Surface only)

From 2017-03-28 to 2019-06-16

instantaneous

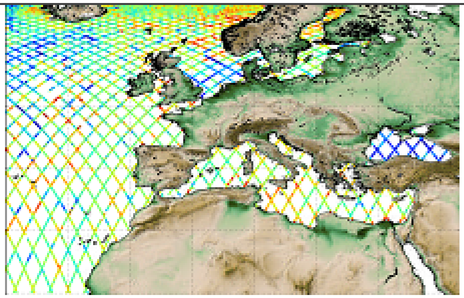
MORE INFO | ADD TO CART | WMS | **Sub-setting**



Satellite products used for hydrodynamic models validation

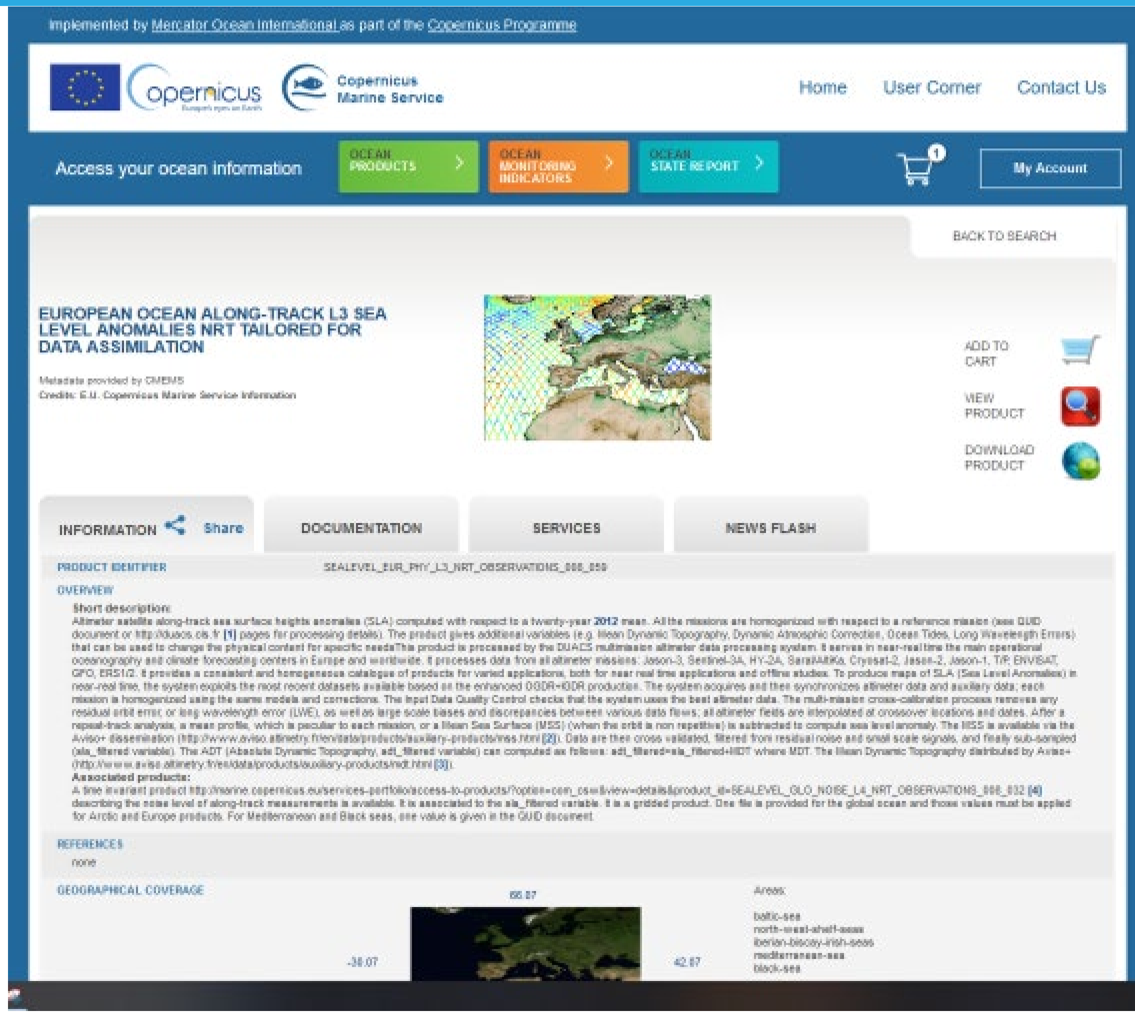
ODYSSEA

Satellite products used for hydrodynamic models validation

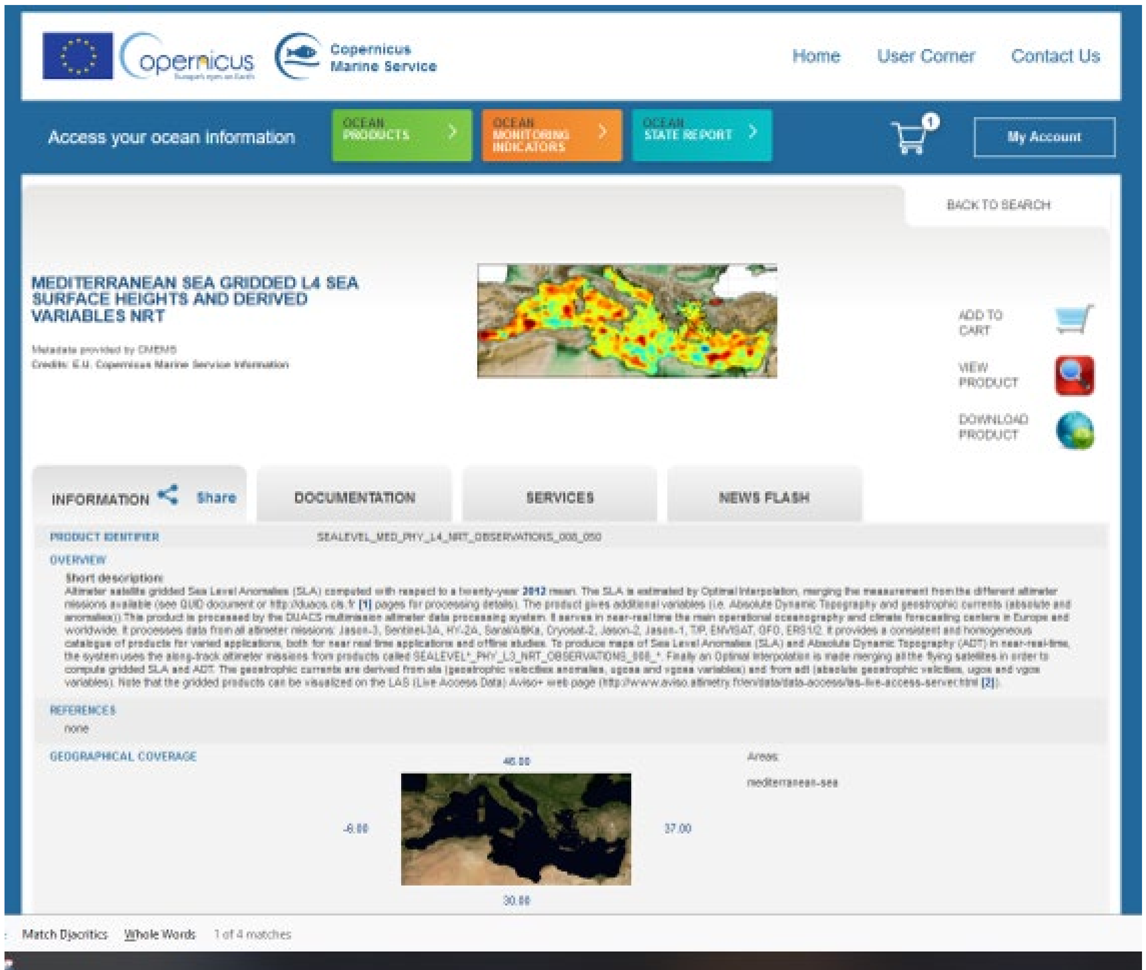
SEALEVEL_EUR_PHY_L3_NRT_OBSERVATIONS_008_059		
EUROPEAN OCEAN ALONG-TRACK L3 SEA LEVEL ANOMALIES NRT TAILORED FOR DATA ASSIMILATION		
OBSERVATION	L3	BAL NWS IBI MED BS
SSH		
7 km x 7 km (Surface only)		
From 2020-10-09 to Present		
instantaneous		
MORE INFO / ADD TO CART / WMS / Sub-setting		

Satellite products used for hydrodynamic models validation

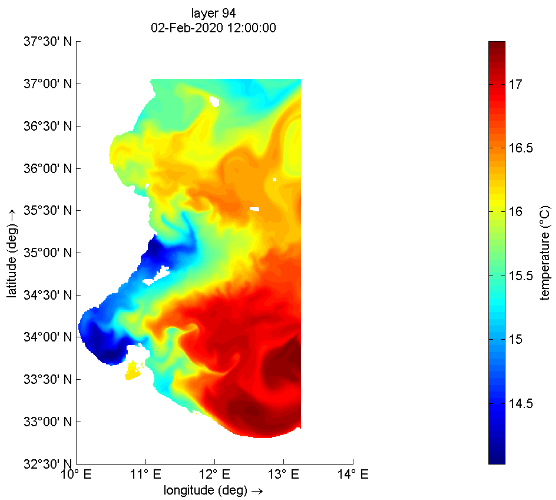
ODYSSEA



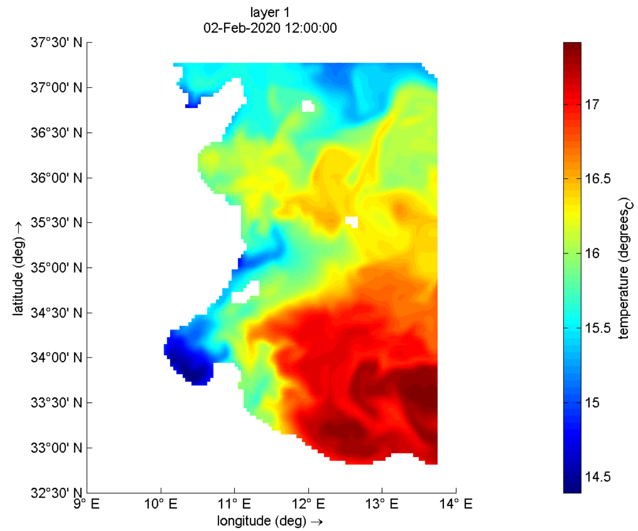
Satellite products used for hydrodynamic models validation



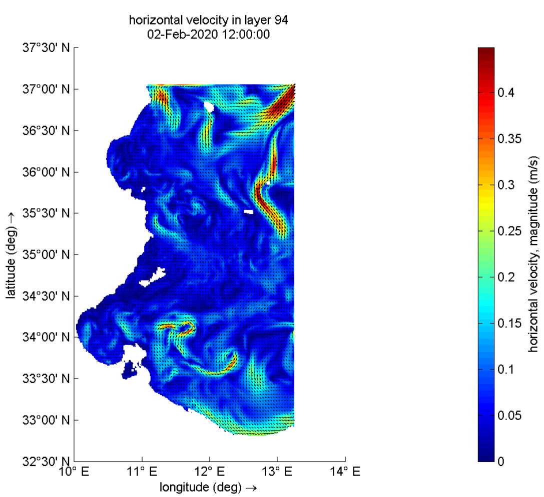
Hydrodynamic models validation – the example of the Gulf of Gabes



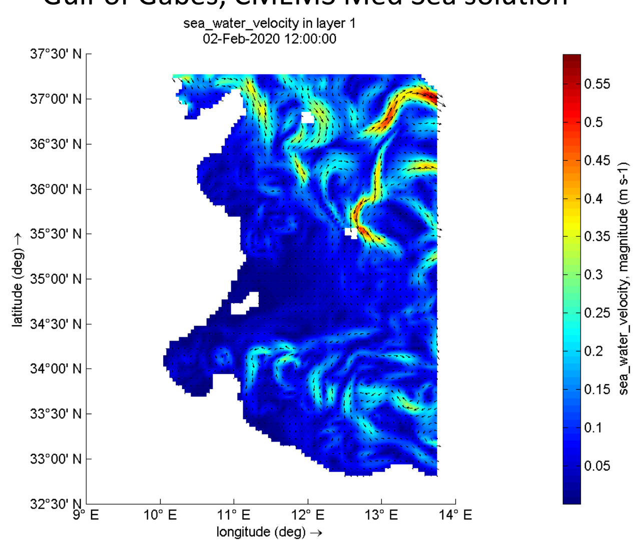
Gulf of Gabes, ODYSSEA, SST



Gulf of Gabes, CMEMS Med Sea solution



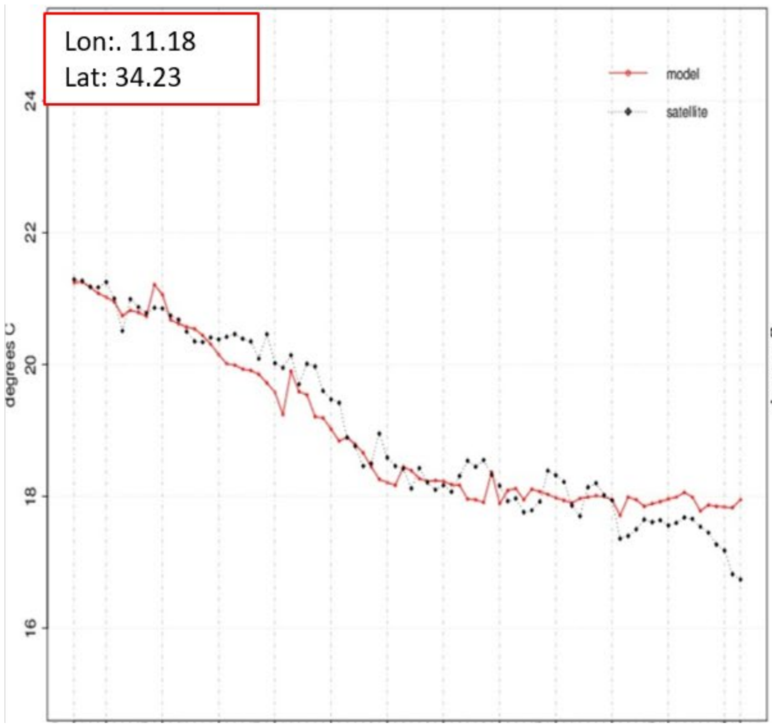
Gulf of Gabes, ODYSSEA, sea water velocity

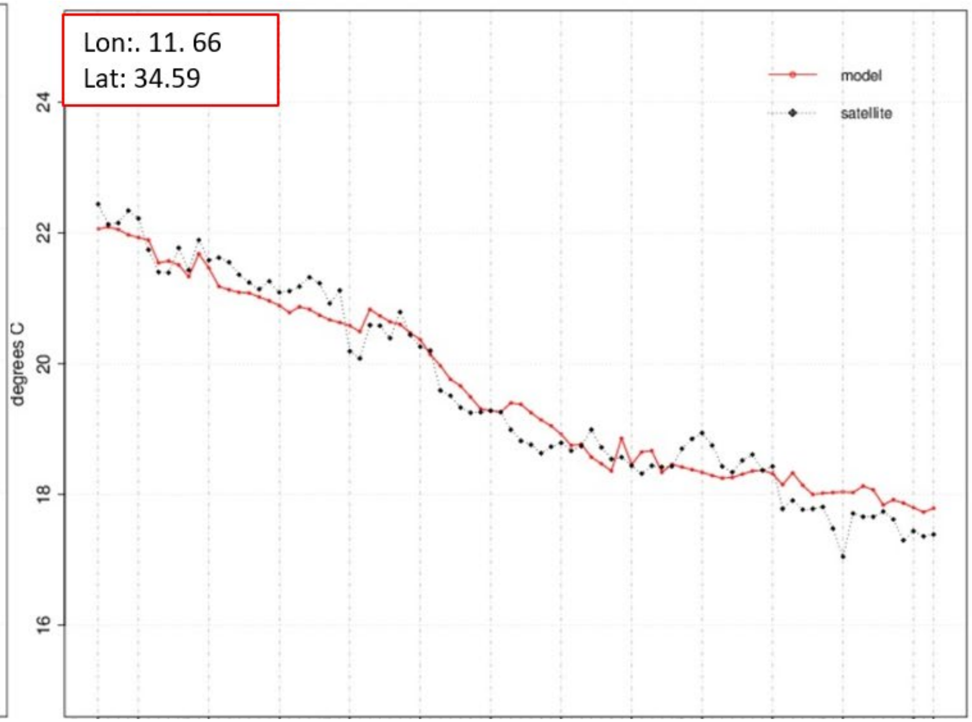


Gulf of Gabes, CMEMS Med Sea solution

Hydrodynamic models validation – the example of the Gulf of Gabes

ODYSSEA

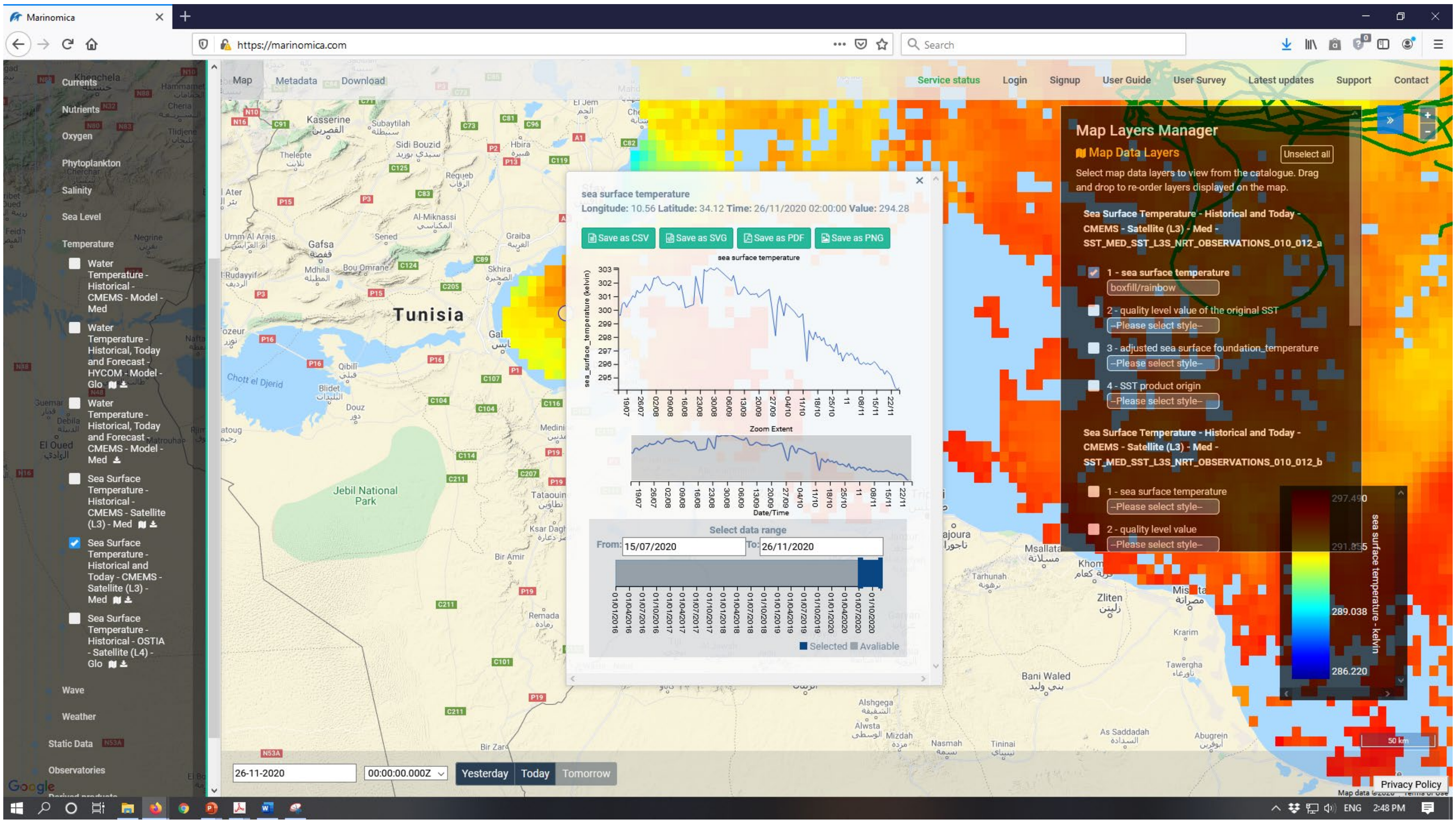




Gabes ODYSSEA model SST vs Satellite.
Calibration period: December 2019-February 2020
2 randomly selected points in Gabes Observatory domain

Hydrodynamic models validation – the example of the Gulf of Gabes

ODYSSEA



Satellite and in-situ products used for wave models validation

ODYSSEA

- Wave parameters compared with Observations:
  - Significant wave height
  - Mean wave period

- For the CMEMS solution, the wave model is validated against:
  - independent in-situ observations from moored wave buoys obtained from the CMEMS INSITU_MED_NRT_OBSERVATIONS_013_035 dataset, available through the CMEMS In Situ Thematic Assemble Centre (INS-TAC)Mean wave period
  - satellite altimeter observations from a merged altimeter wave height database setup at CERSAT - IFREMER

Satellite and in-situ products used for wave models validation

ODYSSEA

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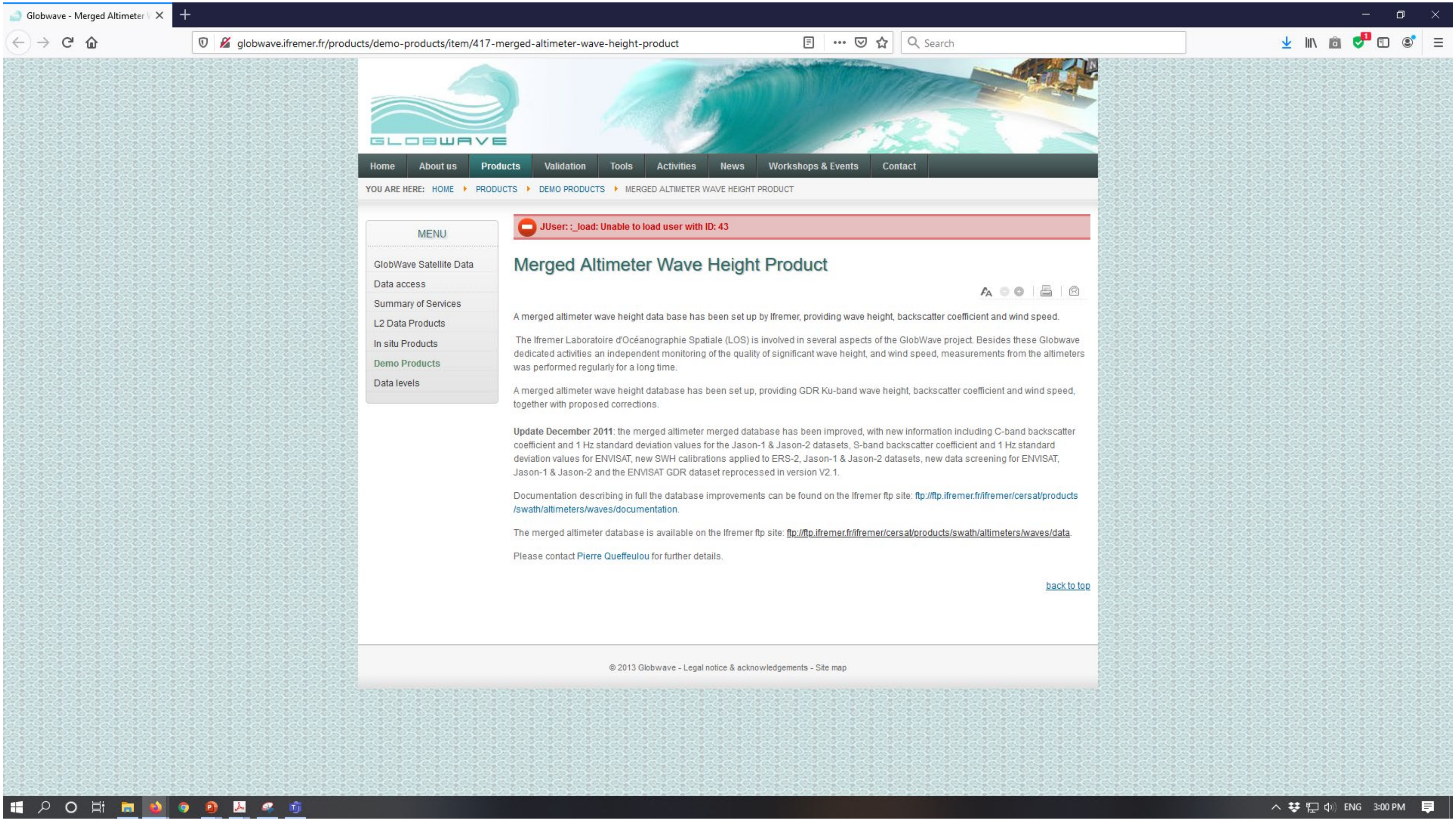
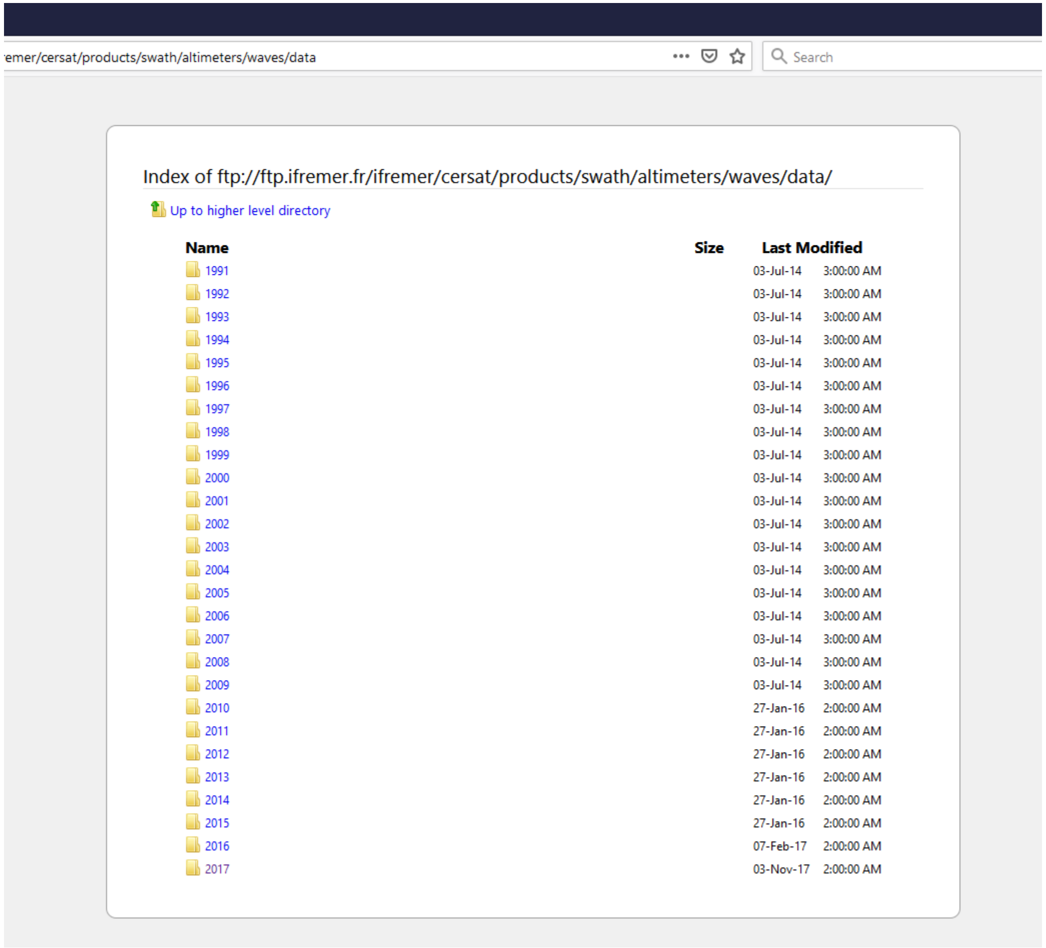
Satellite and in-situ products used for wave models validation

ODYSSEA



Satellite and in-situ products used for wave models validation

ODYSSEA



Index of ftp://ftp.ifremer.fr/ifremer/cersat/products/swath/altimeters/waves/data/

Up to higher level directory

Name	Size	Last Modified	
1991		03-Jul-14	3:00:00 AM
1992		03-Jul-14	3:00:00 AM
1993		03-Jul-14	3:00:00 AM
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1995		03-Jul-14	3:00:00 AM
1996		03-Jul-14	3:00:00 AM
1997		03-Jul-14	3:00:00 AM
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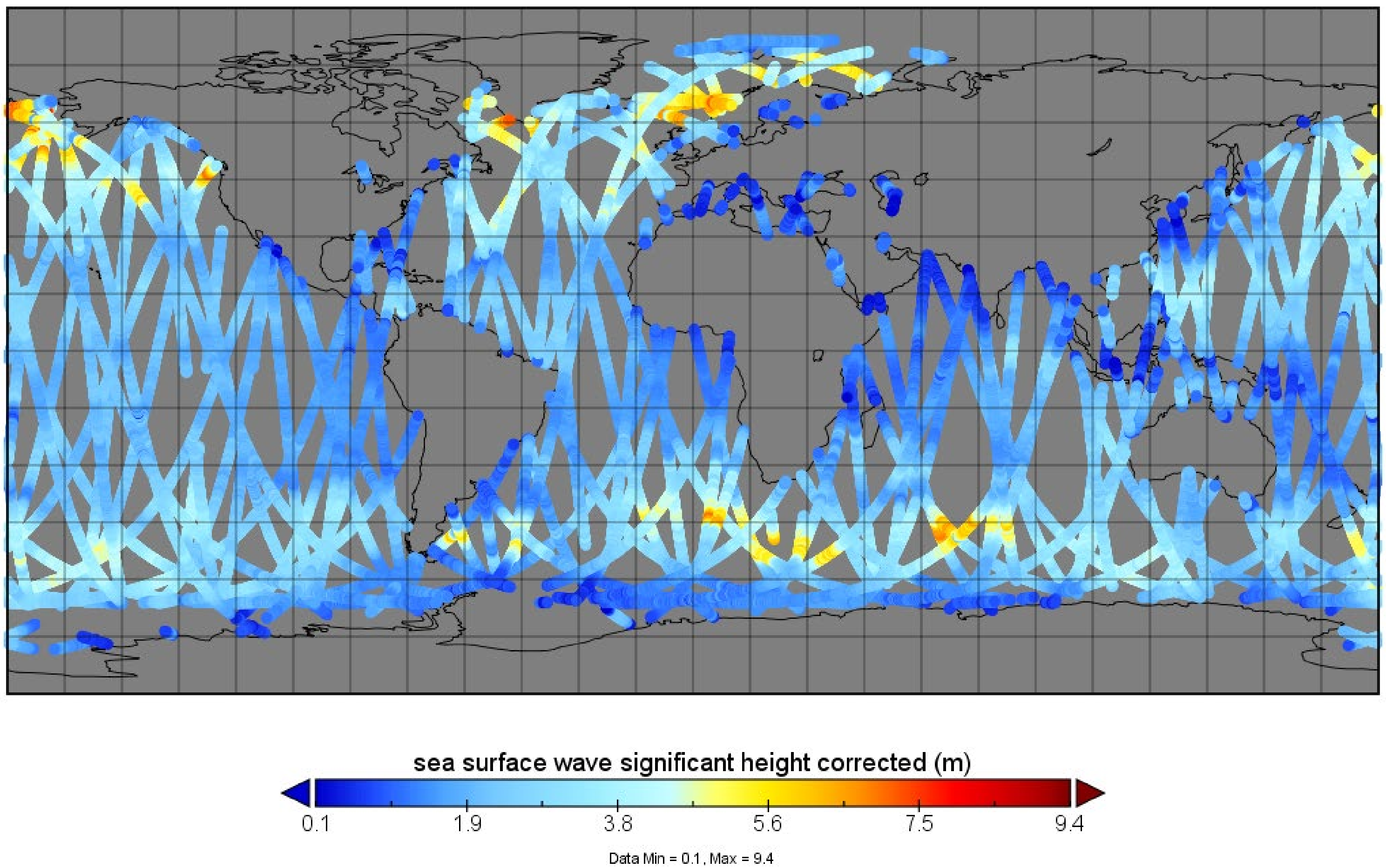
2011		27-Jan-16	2:00:00 AM
2012		27-Jan-16	2:00:00 AM
2013		27-Jan-16	2:00:00 AM
2014		27-Jan-16	2:00:00 AM
2015		27-Jan-16	2:00:00 AM
2016		07-Feb-17	2:00:00 AM
2017		03-Nov-17	2:00:00 AM

Satellite and in-situ products used for wave models validation

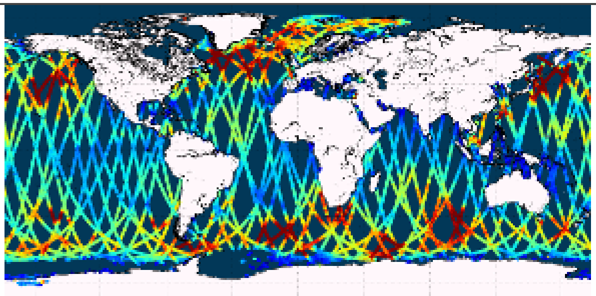
ODYSSEA

sea surface wave significant height corrected



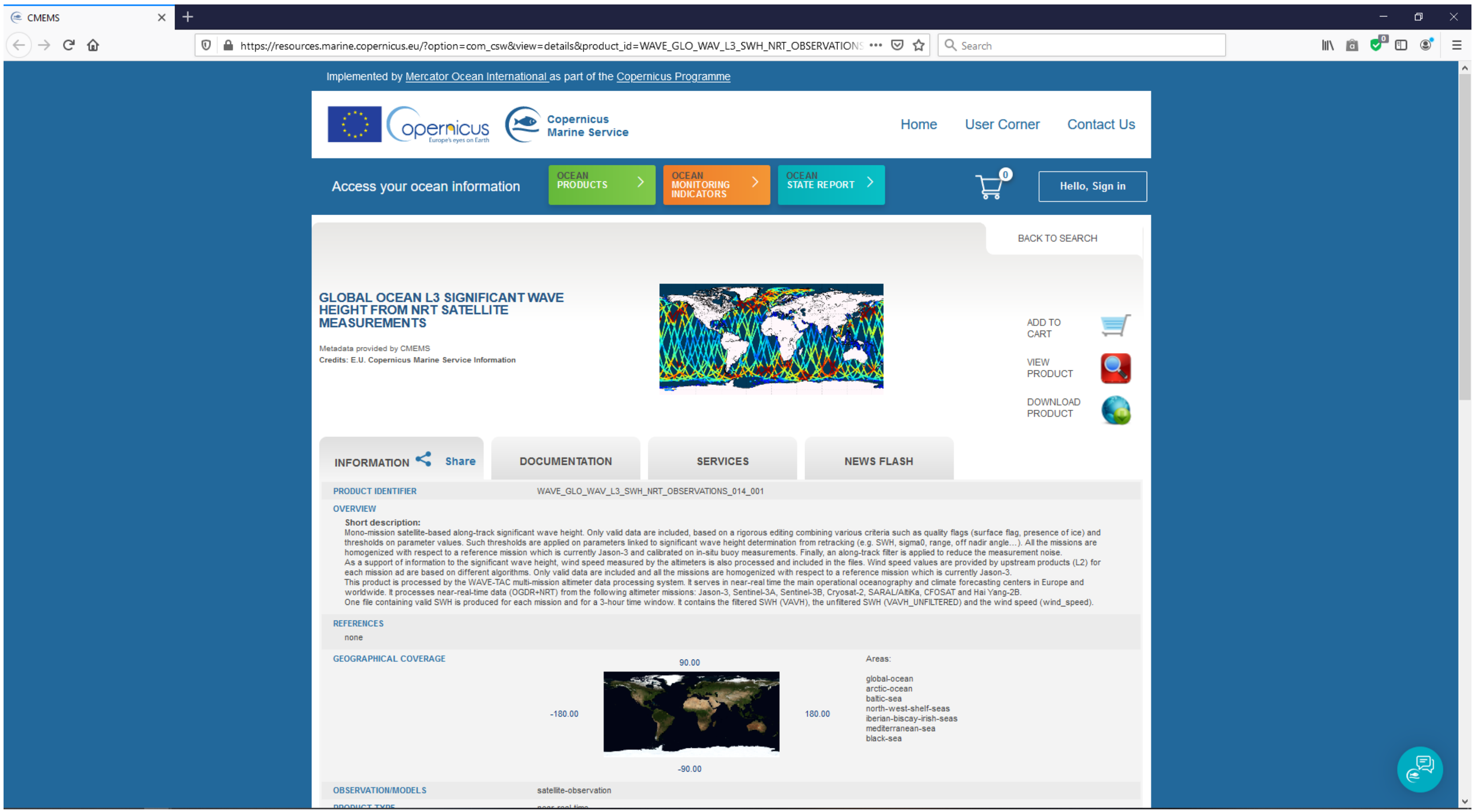
Satellite and in-situ products used for data assimilation

ODYSSEA

WAVE_GLO_WAV_L3_SWH_NRT_OBSERVATIONS_014_001		
GLOBAL OCEAN L3 SIGNIFICANT WAVE HEIGHT FROM NRT SATELLITE MEASUREMENTS		
OBSERVATION	L3	GLO ARC BAL NWS IBI MED BS
WIND SWH		
7 km x 7 km (Surface only)		
From 2020-01-01 to Present		
instantaneous		
MORE INFO	ADD TO CART	WMS Subsetting

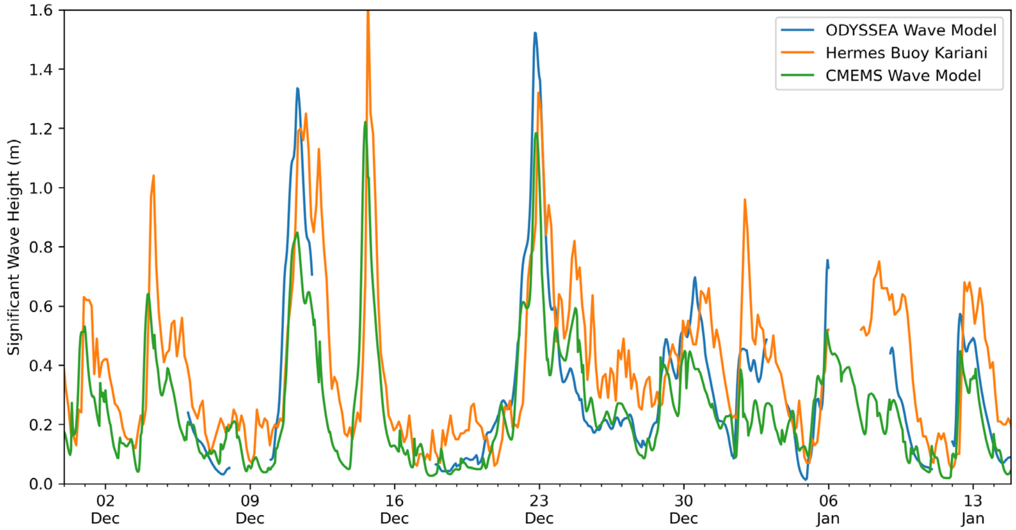
Satellite and in-situ products used for data assimilation

ODYSSEA

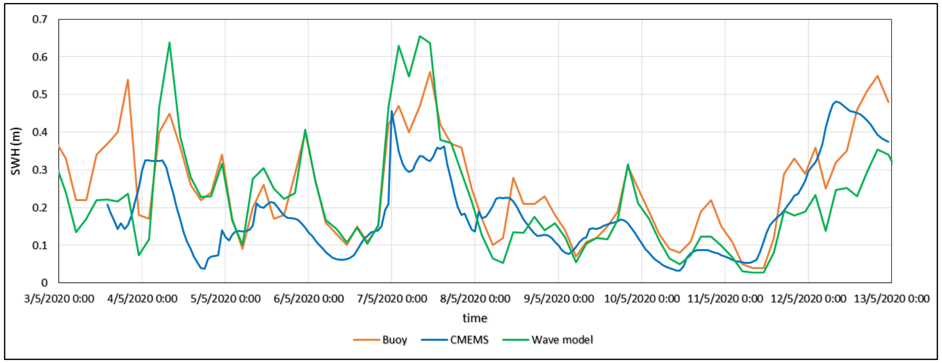


Wave models validation – the example of Thracian Sea

ODYSSEA



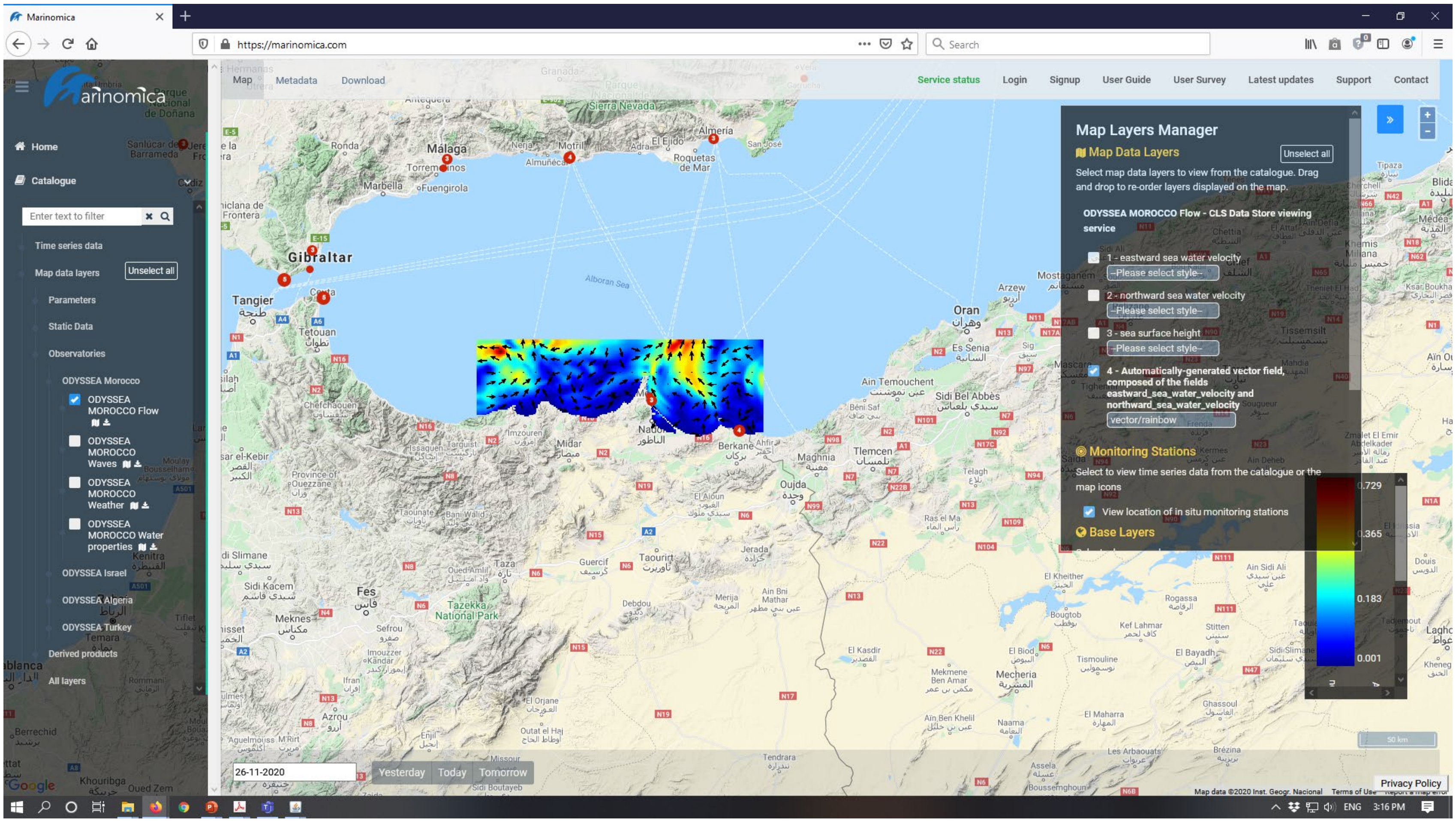
Bias	-0.15
RMSE	0.35
R	0.87



Evaluation of the Thracian Sea Wave model: Significant Wave Height comparison with Kariani buoy in-situ measurements and CMEMS wave product
Calibration period: October 2019-May 2020

Models in Marinomica platform

ODYSSEA



Creating products and knowledge for the Mediterranean

ODYSSEA

THANK-YOU

Katerina SPANOUDAKI (FORTH)

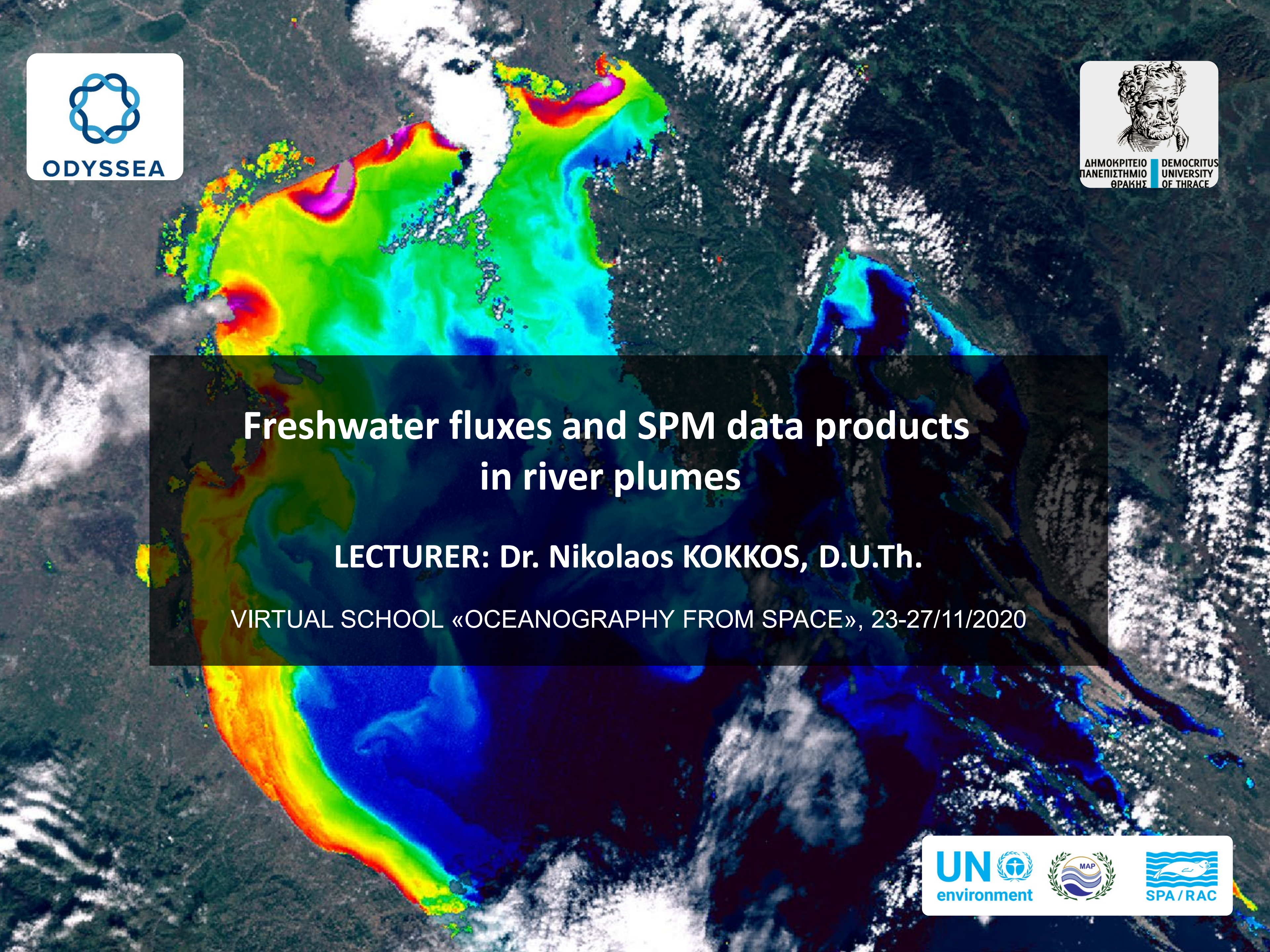
kspanoudaki@gmail.com; kspanoudaki@iacm.forth.gr

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727277

FRESHWATER FLUXES AND SPM DATA PRODUCTS IN RIVER PLUMES

Dr. Nikolaos KOKKOS
Democritus University of Thrace
gsylaios@env.duth.gr

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727277



Freshwater fluxes and SPM data products in river plumes

LECTURER: Dr. Nikolaos KOKKOS, D.U.Th.

VIRTUAL SCHOOL «OCEANOGRAPHY FROM SPACE», 23-27/11/2020

ΔΗΜΟΚΡΙΤΕΙΟ ΠΑΝΕΠΙΣΤΗΜΙΟ ΘΡΑΚΗΣ | DEMOCRITUS UNIVERSITY OF THRACE

What is SPM?

ODYSSEA

Plumes of turbid water are a quite frequent phenomenon in coastal waters, in particular in **shallow soft bottom coasts** and at **the mouths of rivers and estuaries**.

Turbidity **is caused by small particles in the water**, ranging from half a micron to several millimeters, some of **mineralic composition**, such as clay minerals, and others of **organic origin**.

All these particles can be summarised under the term **Suspended Particulate Matter (SPM)**.

SPM Terms

ODYSSEA

- Suspended Particulate Matter (**SPM**)
- Total Suspended Solids (**TSS**)
- Total Suspended Matter (**TSM**)
- Total Suspended Sediment (**TSS**)

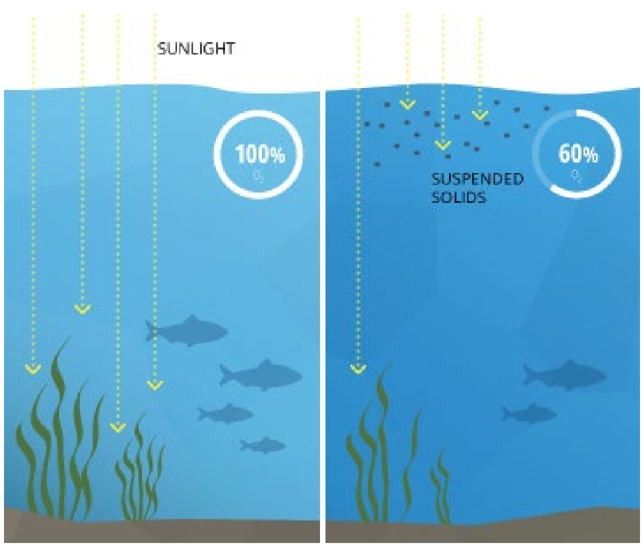
Why SPM is important?

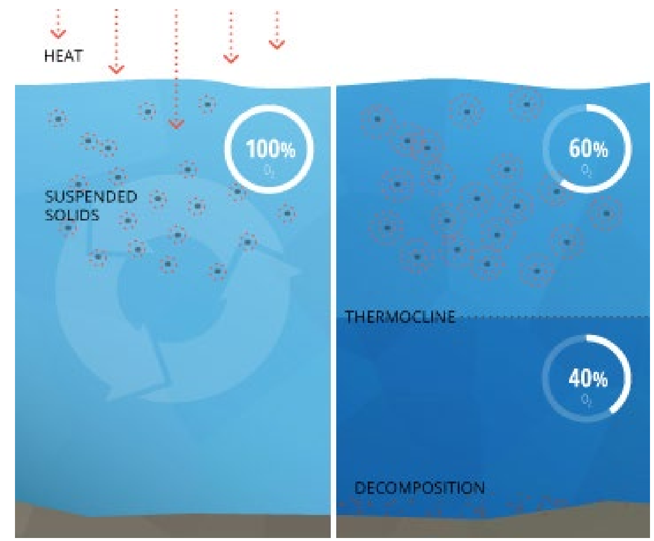
ODYSSEA

Knowledge about the distribution of suspended particulate matter (SPM) is a **very important key for the description and prediction of the ecological conditions of the coastal environment**.

- The **organic part**, the detritus, **is composed of decaying fragments of organisms** or fecal material.
- The different particles **form flakes of** complex and **undefined structure**.
- These **flakes are substrate for many microorganisms**, which **colonise the surface** and holes in the **flakes** and which live from decomposing and mineralising the organic material.
- Due to the organic content, including their microbes, **detritus is an important food for many benthic organisms**.
- A number of different **organic and inorganic trace substances**, which **are then transported by suspended matter**, **are adsorbed to** the complex large **surface of the flakes**.

Why SPM is important





The **SPM concentration** in the water column **regulates the penetration depth of light** and, therefore, it is an important parameter **influencing the primary production of plankton as it reduces the available solar radiance for photosynthesis.**

Suspended solids **can increase the temperature of water as they absorb additional heat from the sun**. This can also **cause the reduction of dissolved oxygen levels below the thermocline, creating hypoxic conditions**.

Why SPM is important

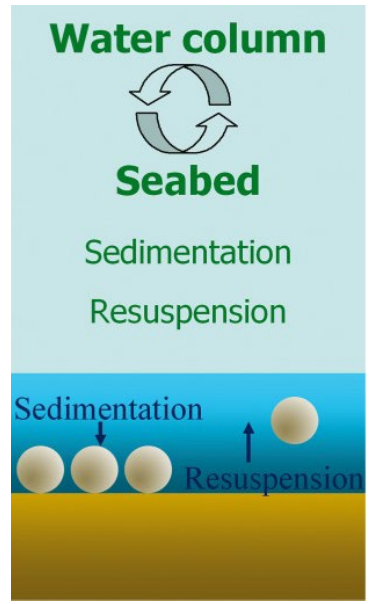
ODYSSEA

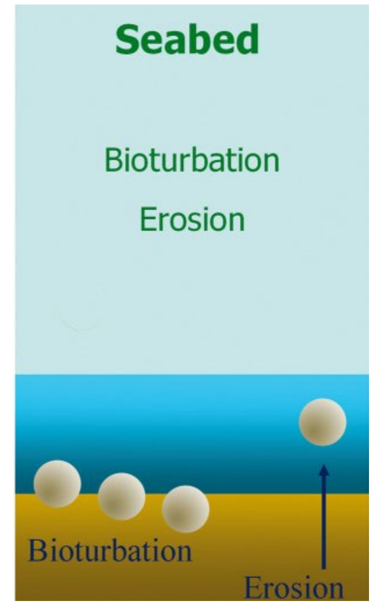
In terms of water clarity, **reduced light penetration due to suspended sediment can obscure aquatic organisms' vision**, reducing their ability to find food.

An increase in SPM concentration can also indicate **increased erosion of river banks**, which may have a long-term effect on a body of water.

SPM motion in water column

ODYSSEA





- SPM particles, advected by ocean currents **will gradually sink to the sea floor**.
- This may be **counteracted or amplified by shear currents and wave** motion.

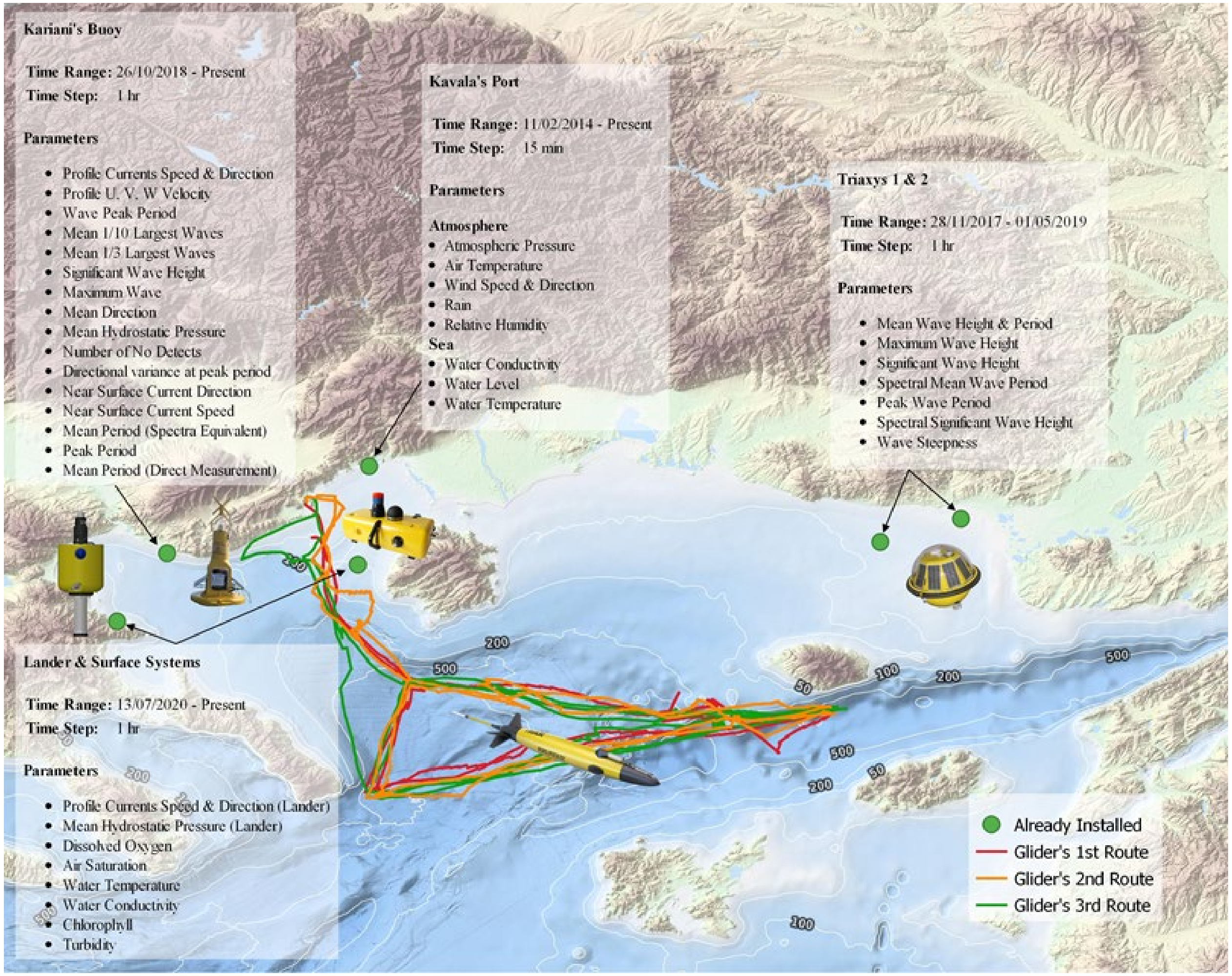
- On top of the sea bed**, a thin sedimentation layer is formed**, which **may be destroyed** gradually **by consumption** (e.g. by mussels) or **bioturbation** (e.g. by worms), or instantaneously **resuspended** by wave and current forces (shear stresses).
- At even stronger stresses, **fine sediment is eroded** from the bottom sediment.

How we measure SPM

ODYSSEA

How we measure SPM

ODYSSEA



How we measure SPM

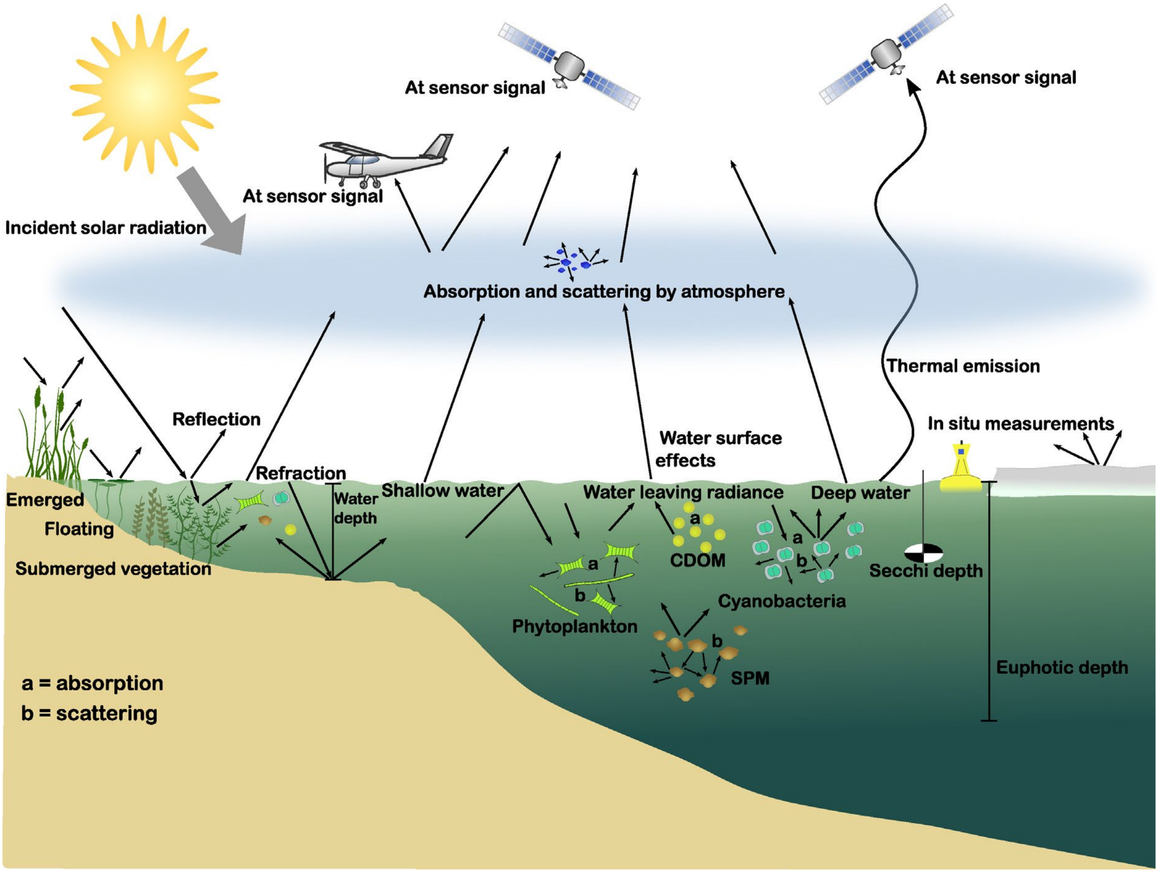
Satellite remote-sensing, associated with instrumented moorings, provide useful data **for investigating both the spatial and temporal variation of SPM in estuarial and coastal zones**.

Use of algorithms empirical or semi-analytical which make use of the Inherent Optical Properties (IOPs) of the water constituents.

How we measure SPM

ODYSSEA

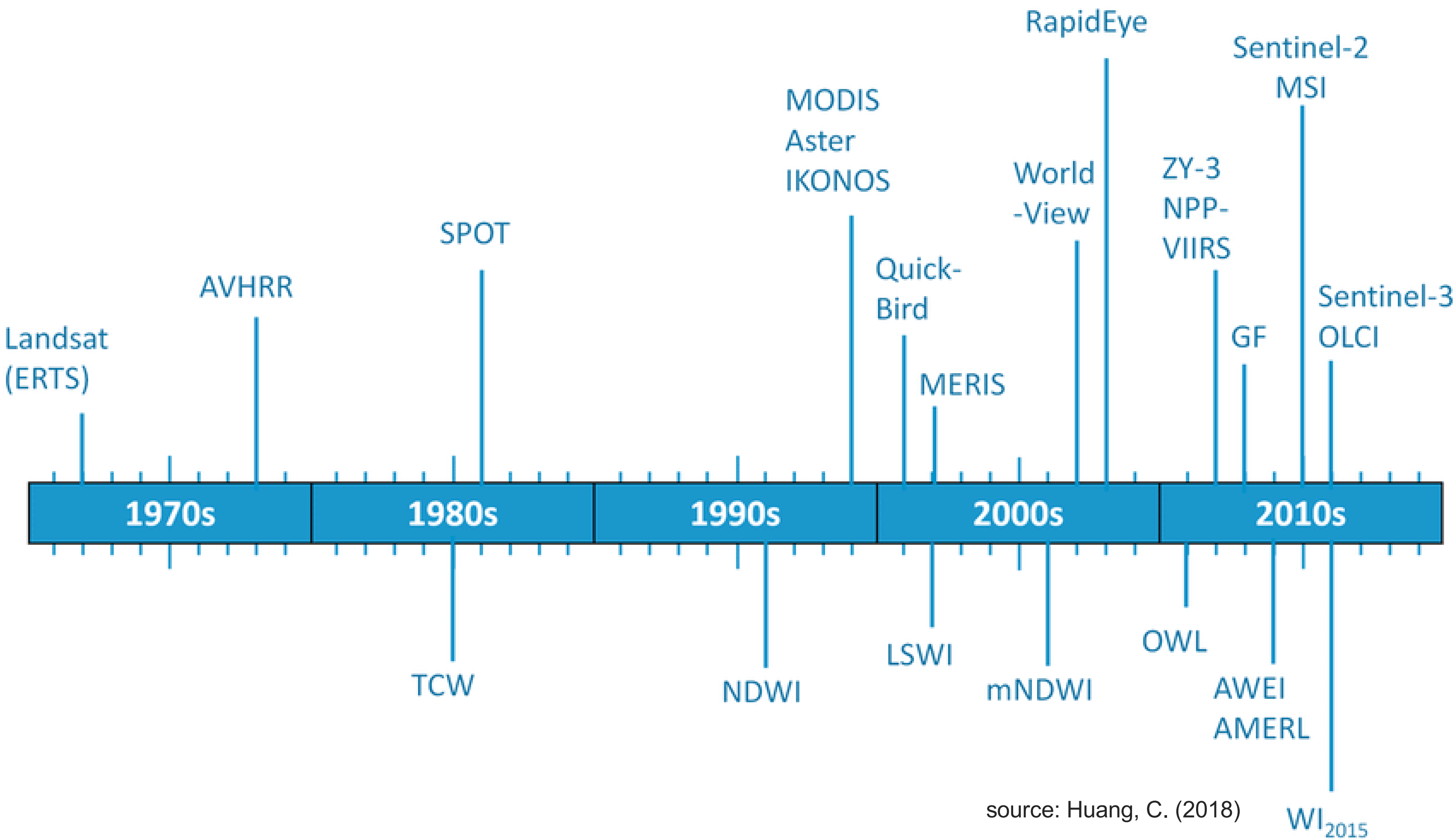
- Complex interactions of the incoming solar irradiance with the water body and adjacent land areas
- **radiance measured by sensor** is **a sum of radiation reflected and scattered** by the water surface, water volume, water bottom, atmosphere and adjacent areas
- dependent on the transmittance of the atmosphere
- only 2-10% include the signal interesting for remote sensing



source: Dörnhöfer, K., & Oppelt, N. (2016)

How we measure SPM

ODYSSEA

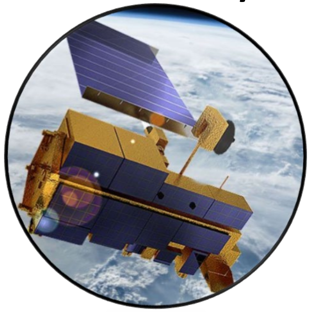


source: Huang, C. (2018)

Satellites used in SPM measurements

ODYSSEA

MODIS (250m)
2000 - Today

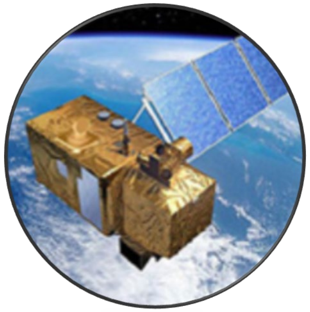


EnviSat (260m)
2002 - 2012

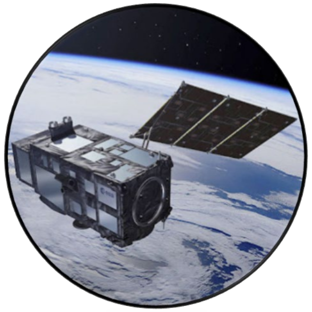
Landsat 8 (15m)
2013 - Today

Gaofen-1 (30m)
2013 - Today

Sentinel 2 (10m)
2015 - Today



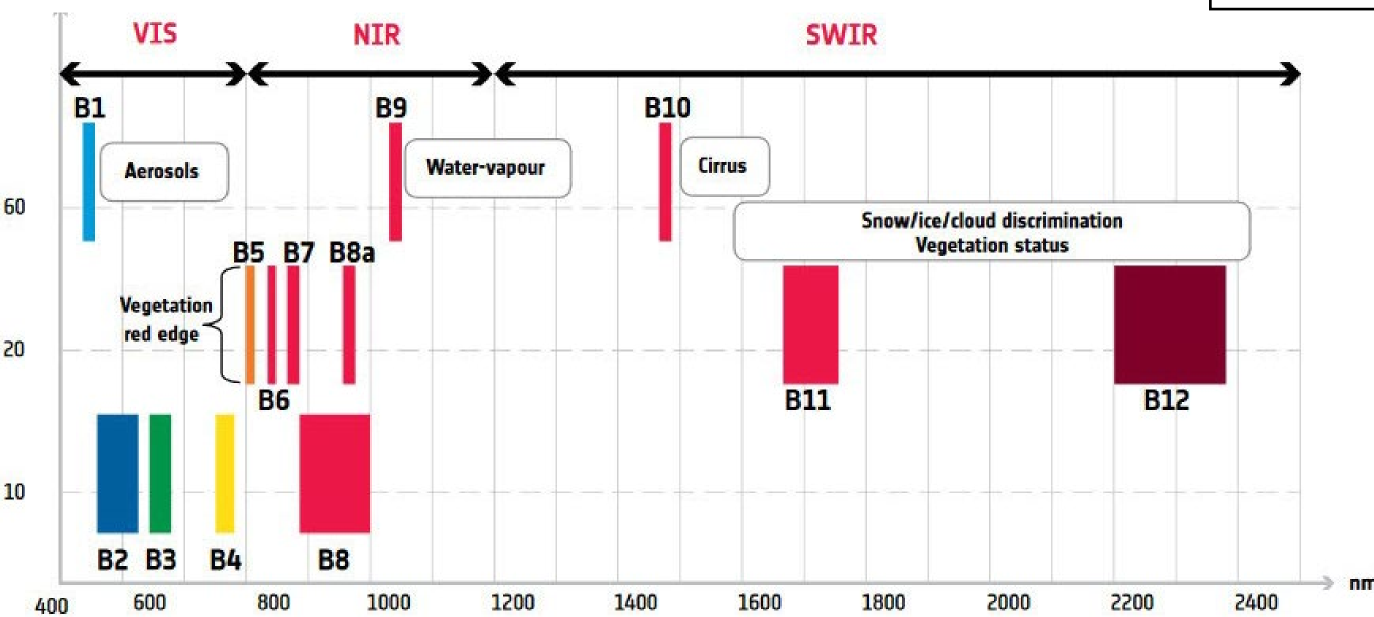
Sentinel 3 (300m)
2016 - Today



Satellites used in Remote Sensing

ODYSSEA

- Sentinel 2A and 2B: polar orbit, phased at 180° to each other
- Equipped with multispectral instrument with 13 spectral bands
- Wide swath width (290 km)
- Revisit: 5 days at equator (2 satellites)
- Level 1C and 2A (atmospherically corrected)



Atmospheric Bands

Red edge and shortwave infrared Bands

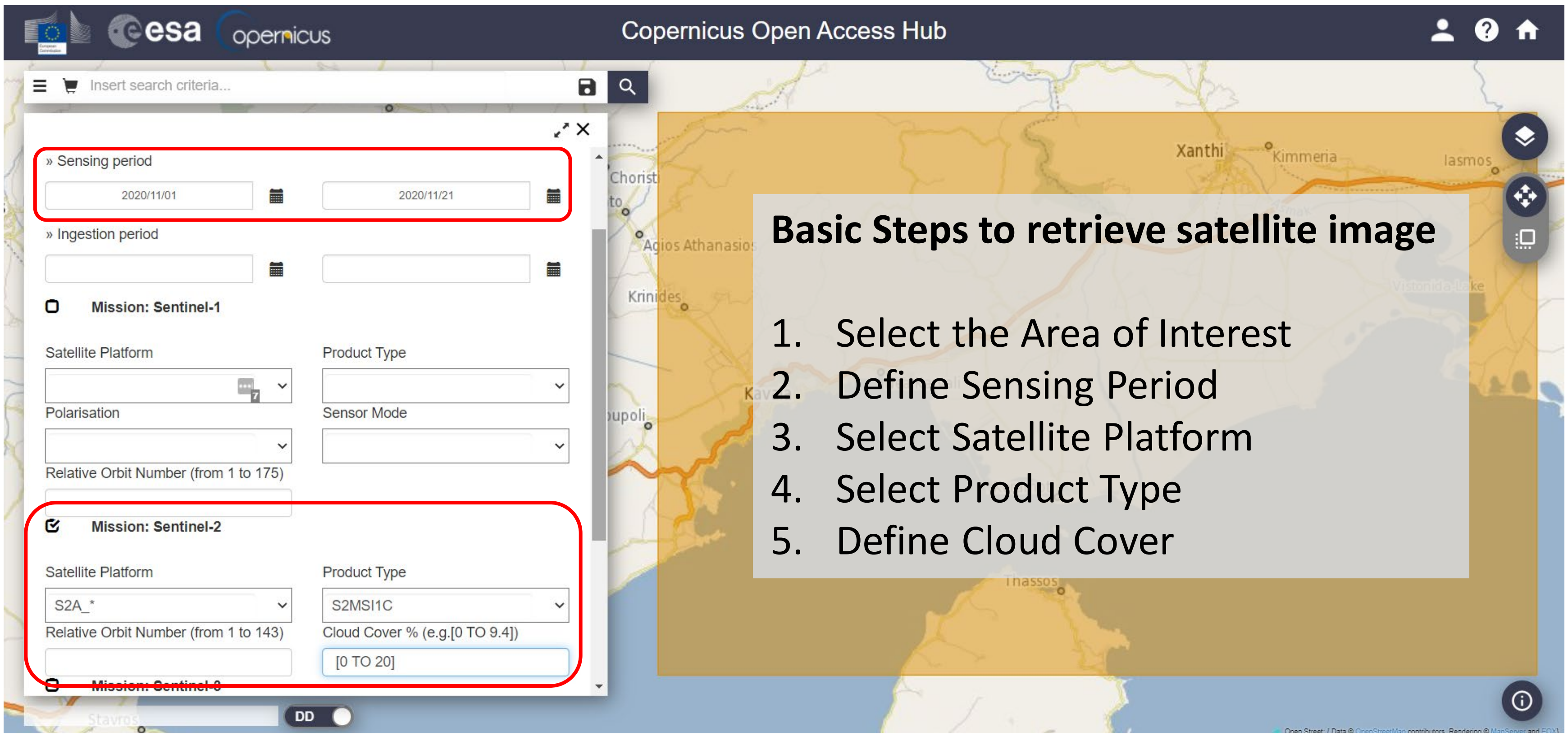
Visible and Near-infrared Bands

How to access Satellite Images

Copernicus Open Access Hub

ODYSSEA

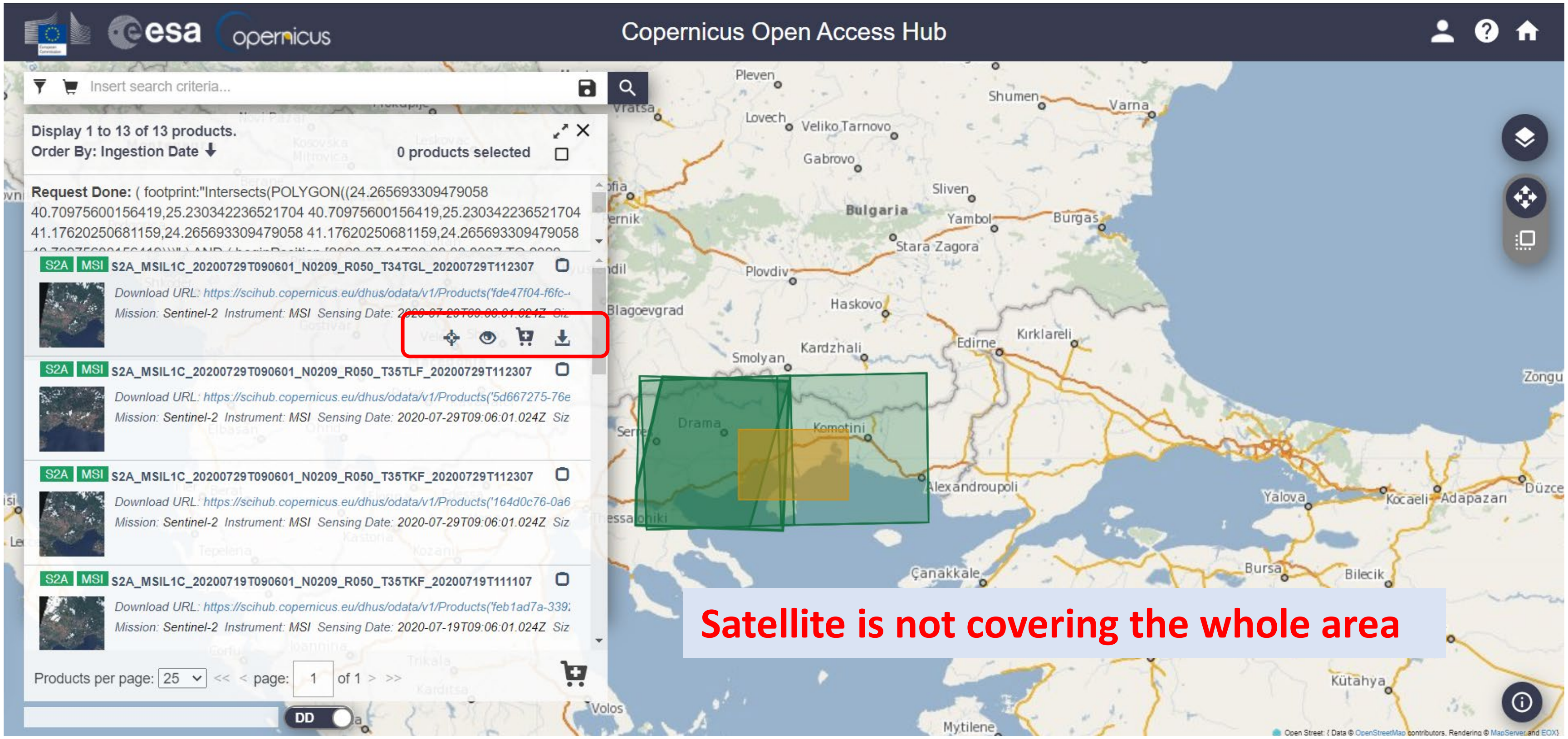
https://scihub.copernicus.eu/dhus/



Basic Steps to retrieve satellite image

1. Select the Area of Interest
2. Define Sensing Period
3. Select Satellite Platform
4. Select Product Type
5. Define Cloud Cover

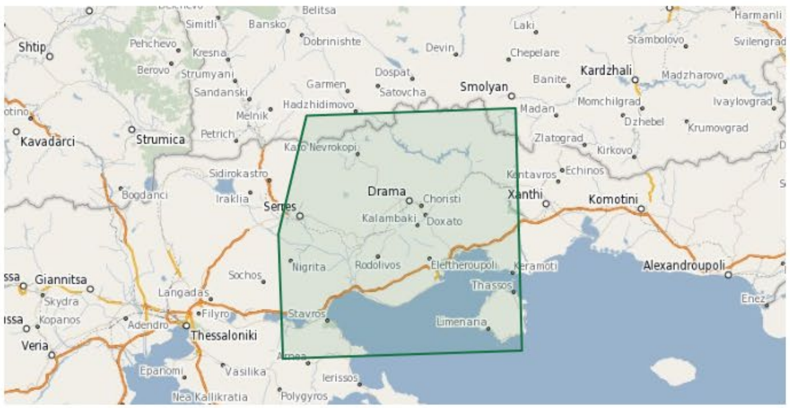
Copernicus Open Access Hub



Copernicus Open Access Hub

ODYSSEA

Footprint



Quicklook

Copernicus Open Access Hub

ODYSSEA

Product

Cloud cover percentage: 5.3525

Datatake sensing start: 2020-11-16T09:12:41.024Z

Degraded ancillary data percentage: 0.0

Degraded MSI data percentage: 0

Footprint: <gml:Polygon srsName="http://www.opengis.net/gml/srs/epsg.xml#4326" xmlns:gml="http://www.opengis.net/gml"> <gml:outerBoundaryIs> <gml:LinearRing> <gml:coordinates>41.01769423139836,23.43168197889632 41.08913306854,23.45343561400113 41.23552971032567,23.500990190065725 41.38243838492305,23.547112404289248 41.50019059992416,23.583652410233235 41.52923550071836,24.719948115495857 40.54090999482793,24.75381388159868 40.50846282585221,23.459177397466938 41.01769423139836,23.43168197889632</gml:coordinates> </gml:LinearRing> </gml:outerBoundaryIs> </gml:Polygon>

Format: SAFE

Format correctness: PASSED

General quality: PASSED

Generation time: 2020-11-16T10:43:17.000000Z

Geometric quality: PASSED

Ingestion Date: 2020-11-16T13:22:28.989Z

JTS footprint: MULTIPOLYGON (((23.459177397466938 40.50846282585221, 24.75381388159868 40.54090999482793, 24.719948115495857 41.52923550071836, 23.583652410233235 41.50019059992416, 23.547112404289248 41.38243838492305, 23.500990190065725 41.23552971032567, 23.45343561400113 41.08913306854, 23.43168197889632 41.01769423139836, 23.459177397466938 40.50846282585221)))

Level-1C PDI Identifier: S2A_OPER_MSI_L1C_TL_EPAE_20201116T104317_A028218_T35TKF_N02.09

Mission datatake id: GS2A_20201116T091241_028218_N02.09

Orbit number (start): 28218

Pass direction: DESCENDING

Processing baseline: 02.09

Processing level: Level-1C

Product type: S2MSI1C

Radiometric quality: PASSED

Relative orbit (start): 50

Sensing start: 2020-11-16T09:12:41.024Z

Sensing stop: 2020-11-16T09:12:41.024Z

Sensor quality: PASSED

Tile Identifier: 35TKF

Tile Identifier horizontal order: TF35K

Access Sentinel Images through API

ODYSSEA

https://sentinelsat.readthedocs.io/en/stable/

```
from sentinelsat import SentinelAPI, read_geojson, geojson_to_wkt
from datetime import date

api = SentinelAPI('user', 'password', 'https://scihub.copernicus.eu/dhus')

# search by polygon (WKT format), time, and SciHub query keywords
footprint = geojson_to_wkt(read_geojson('/path/to/map.geojson'))

products = api.query(footprint,
                     date = ('20151219', date(2015, 12, 29)),
                     order_by = 'ingestiondate',
                     orbitdirection: 'DESCENDING',
                     platformname = 'Sentinel-2',
                     producttype = 'S2MSI1C',
                     cloudcoverpercentage = (0, 20))

# download all results from the search
api.download_all(products)

# GeoJSON FeatureCollection containing footprints and metadata of the scenes
api.to_geojson(products)
```

Sentinels naming scheme

ODYSSEA

S2A_MSIL1C_20200729T090601_N0209_R050_T35TKF_20200729T112307.SAFE

mission ID

Product Level

sensing start time

PDGS Processing Baseline number

Relative Orbit number

Tile Number field

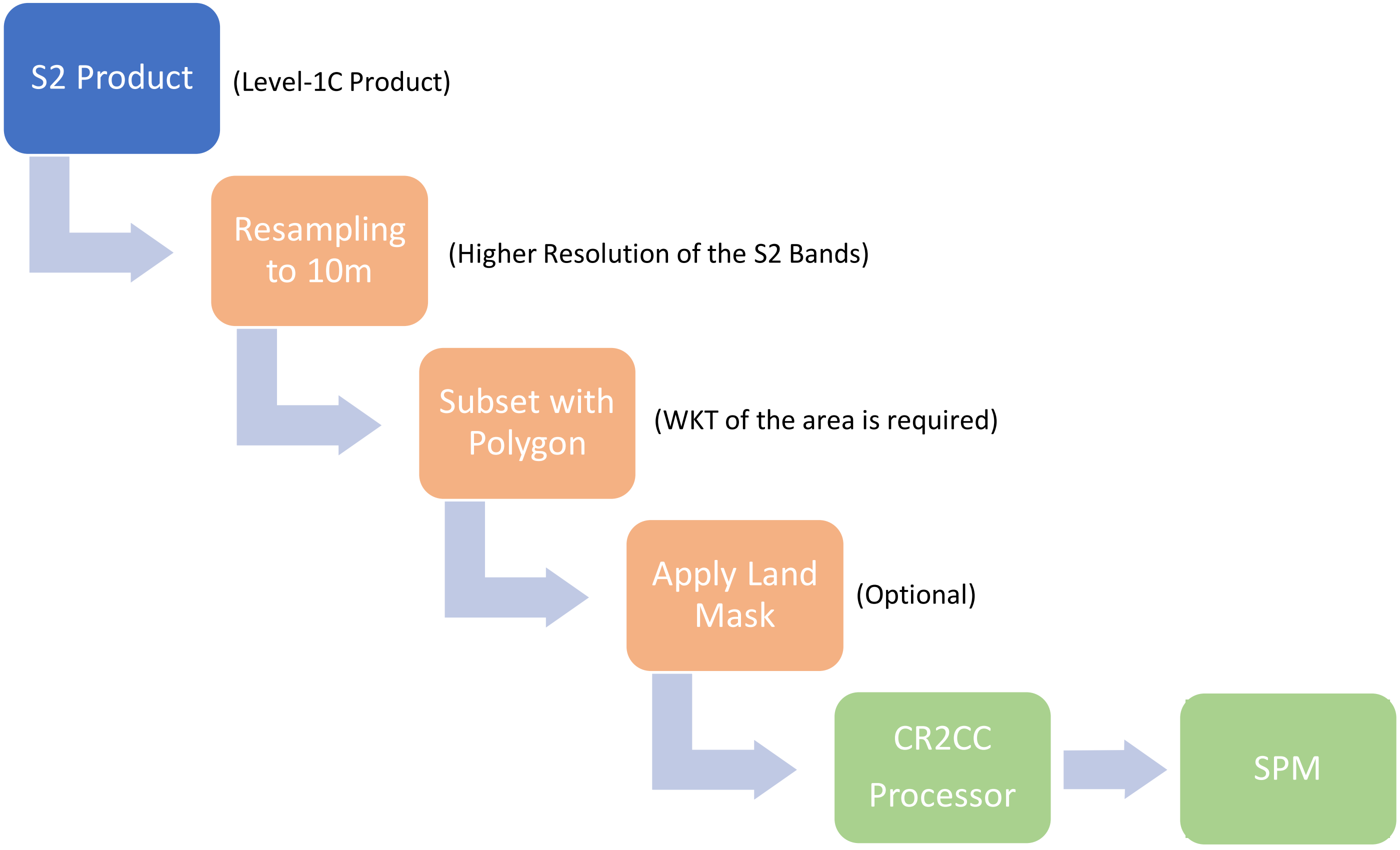
Product Discriminator

Identifies a **Level-1C** product acquired by **Sentinel-2A** on the **29th of July, 2020 at 9:06:01 AM**. It was acquired over **Tile 35TKF** during **Relative Orbit 050**, and processed with **PDGS Processing Baseline 02.09**.

- All the bands included in the file are in JPEG2000 format.
- In addition, a "**True Colour Image**" in JPEG2000 format is included within the Tile folder of Level-1C products in this format and a **manifest** xml file that tells the computer what is inside the file.

Calculate SPM from Sentinel-2 Images

Sentinel 2 Products to SPM



CR2CC Processor

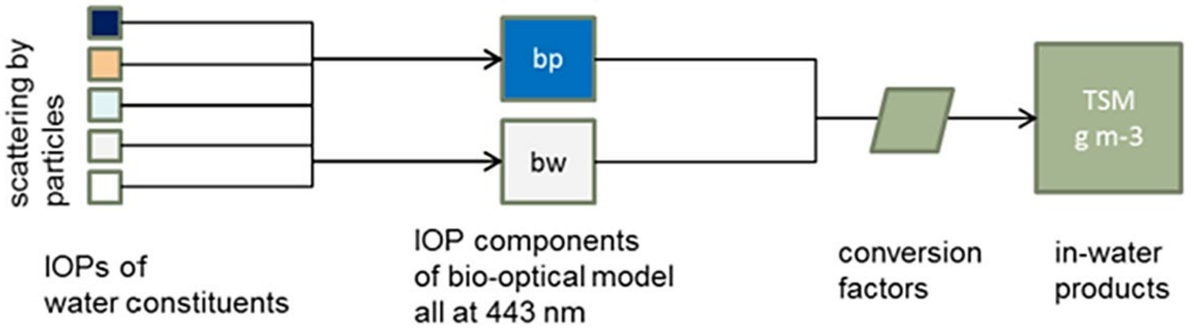
The Case-2 Regional CoastColour (C2RCC) processor **relies on a large database of simulated water leaving reflectances**, and related **top-of atmosphere radiances**.

Neural networks are trained in order to perform:

- the **determination of the water leaving radiance** from the top of atmosphere radiances, as well as
- the **retrieval of inherent optical properties (IOP)** of the water body.

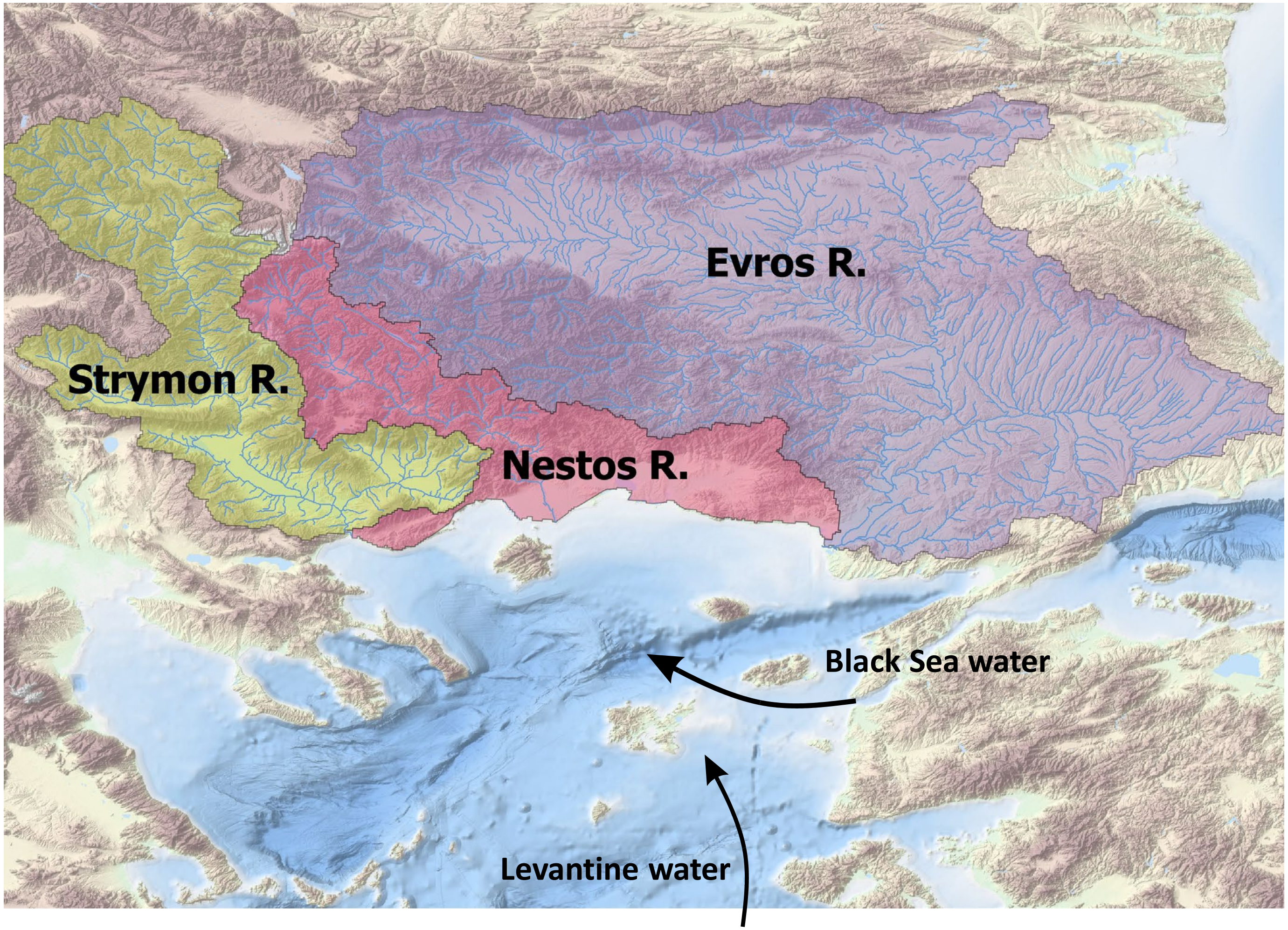
The **conversion from IOPs to concentration** is done using **scaling factors**.

CR2CC is capable of processing data from **Sentinels–2 and 3, MERIS, VIIRS, MODIS, and Landsat-8**.



source: Brockmann, C. (2016)

Test Site

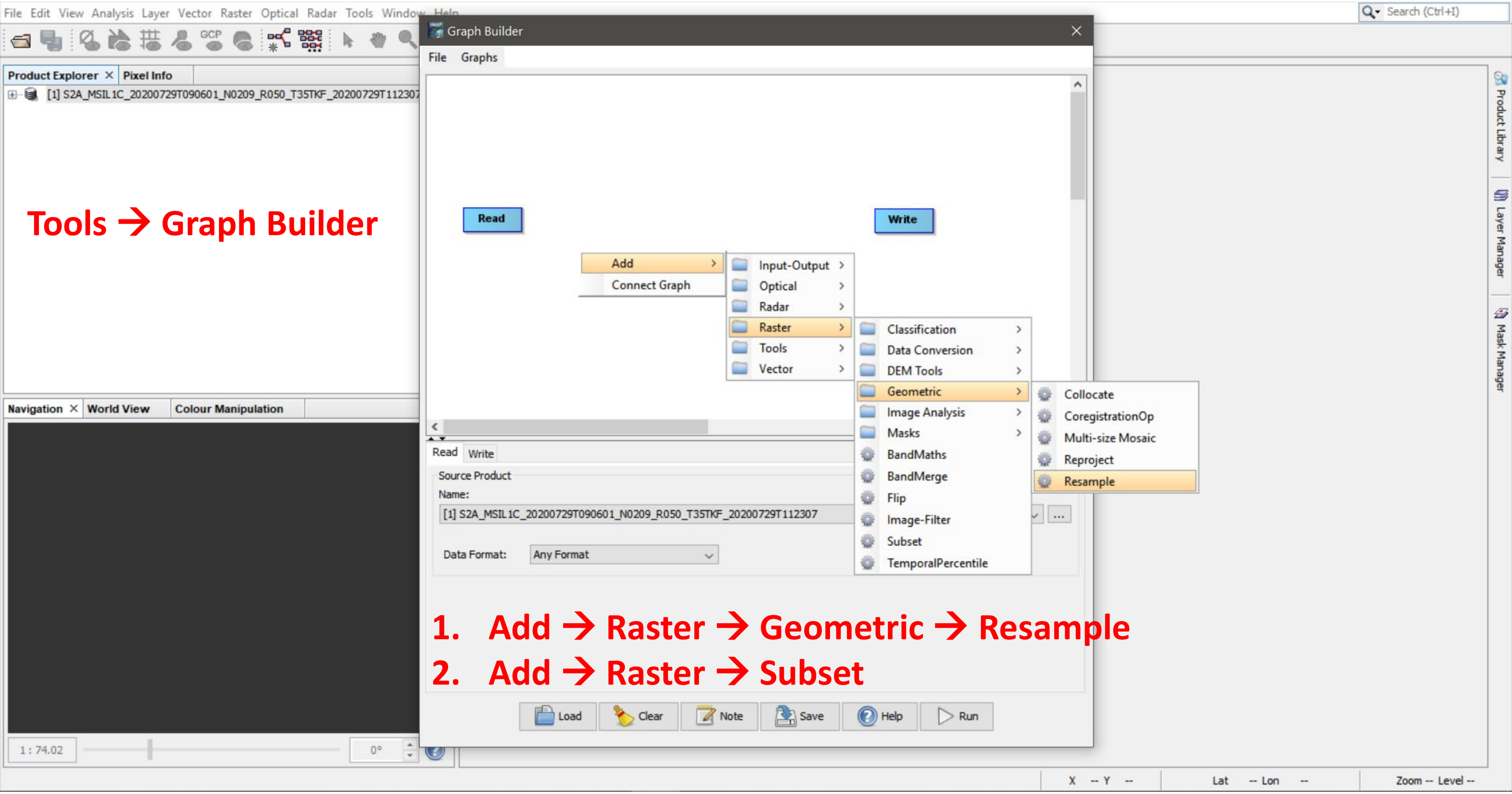


Sentinel Application Platform (SNAP)

A common architecture **for all Sentinel Toolboxes** is being jointly developed by Brockmann Consult, SkyWatch and C-S called the **Sentinel Application Platform (SNAP)**.

https://step.esa.int/main/toolboxes/snap/

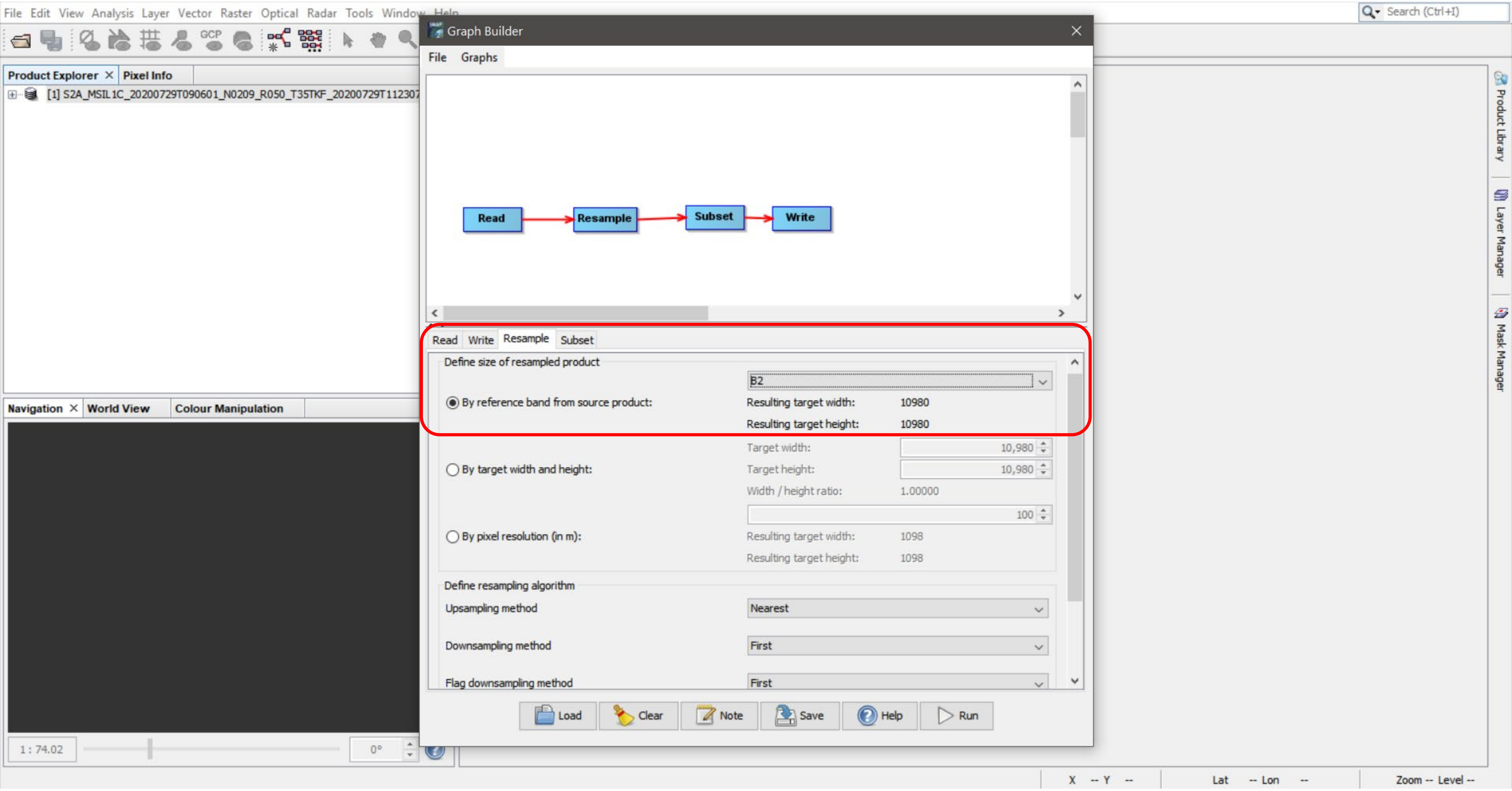
SNAP – Graph Builder



Tools → Graph Builder

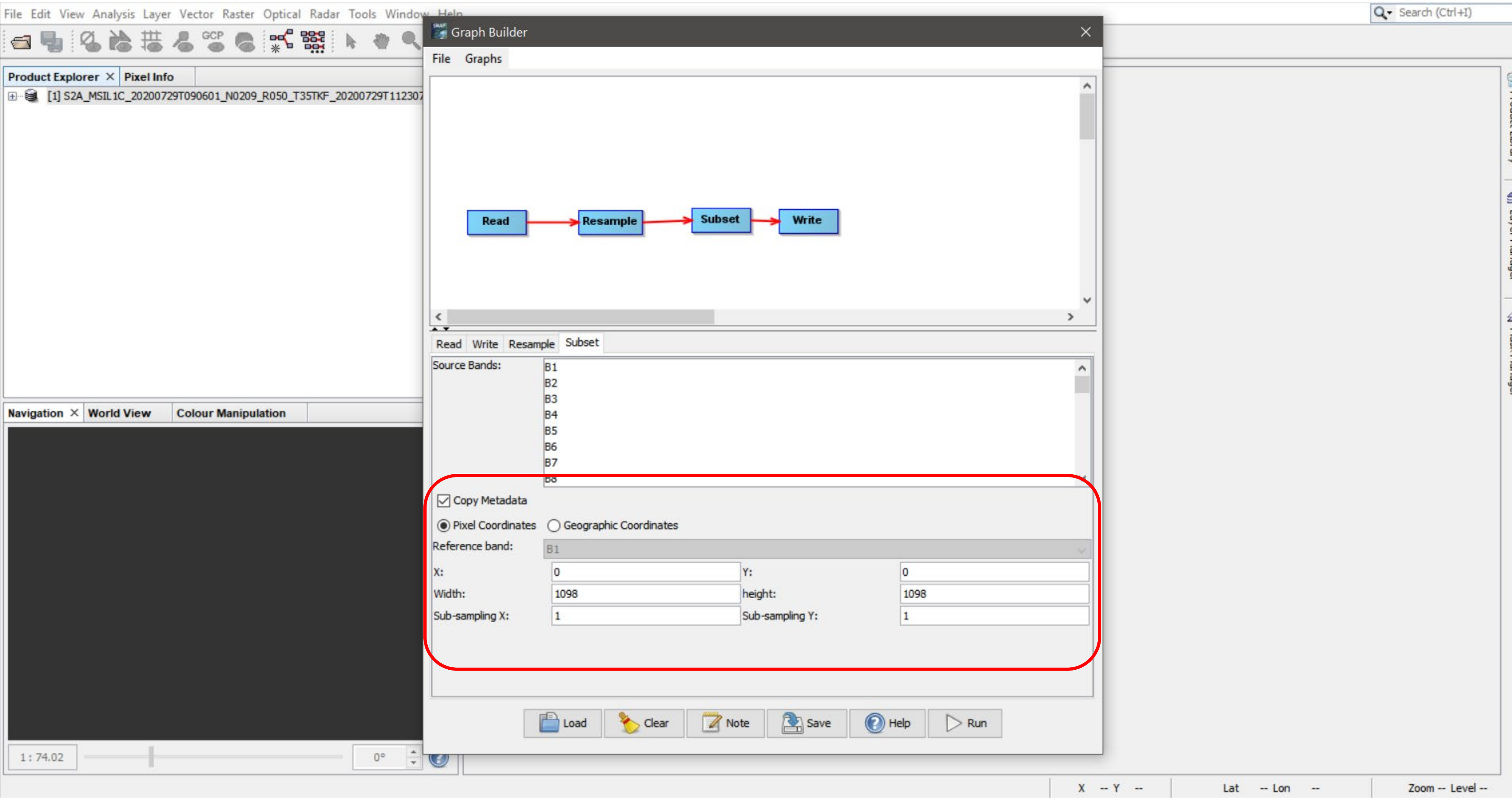
1. **Add → Raster → Geometric → Resample**
2. **Add → Raster → Subset**

SNAP – Graph Builder

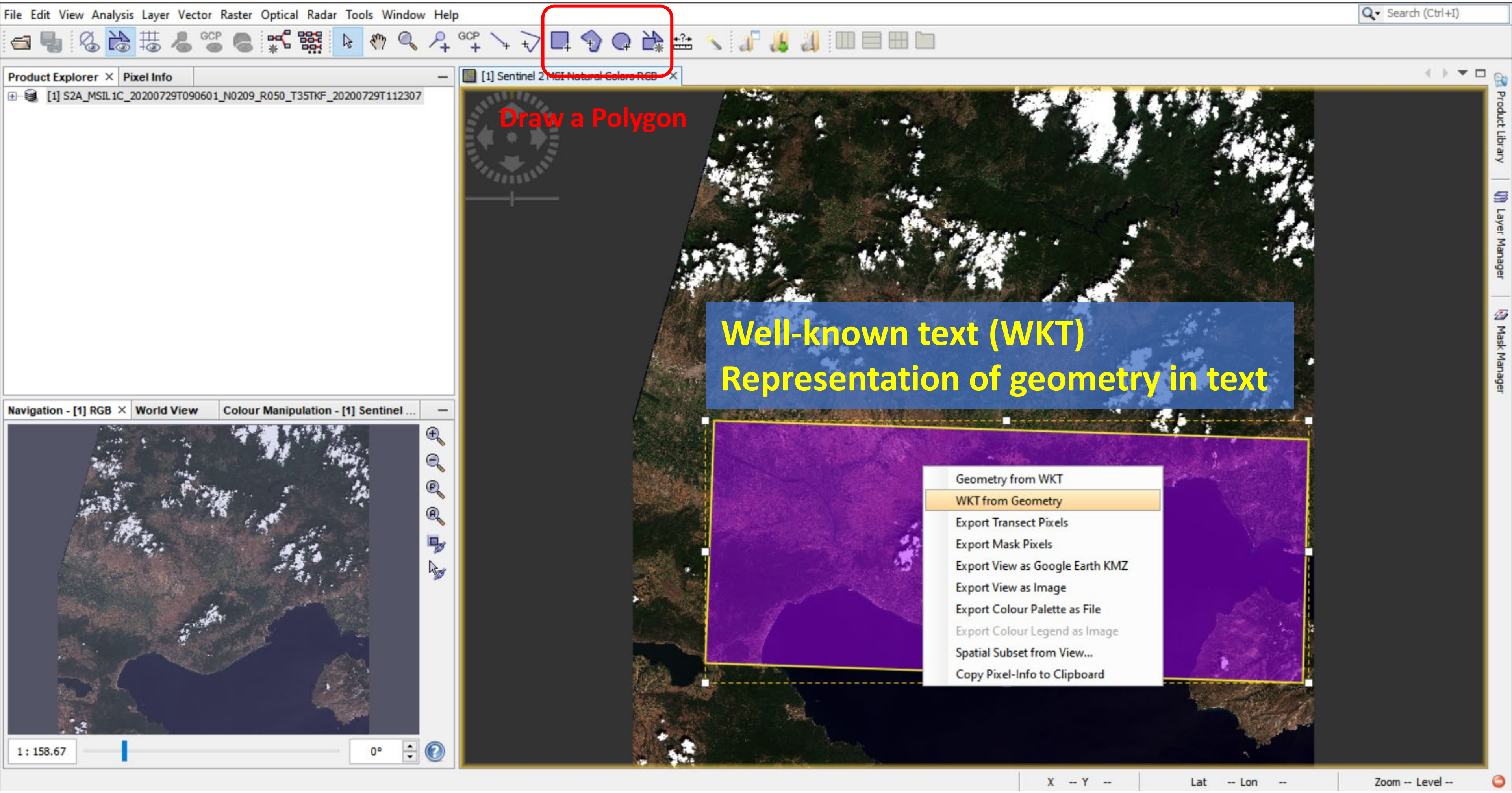


SNAP – Graph Builder

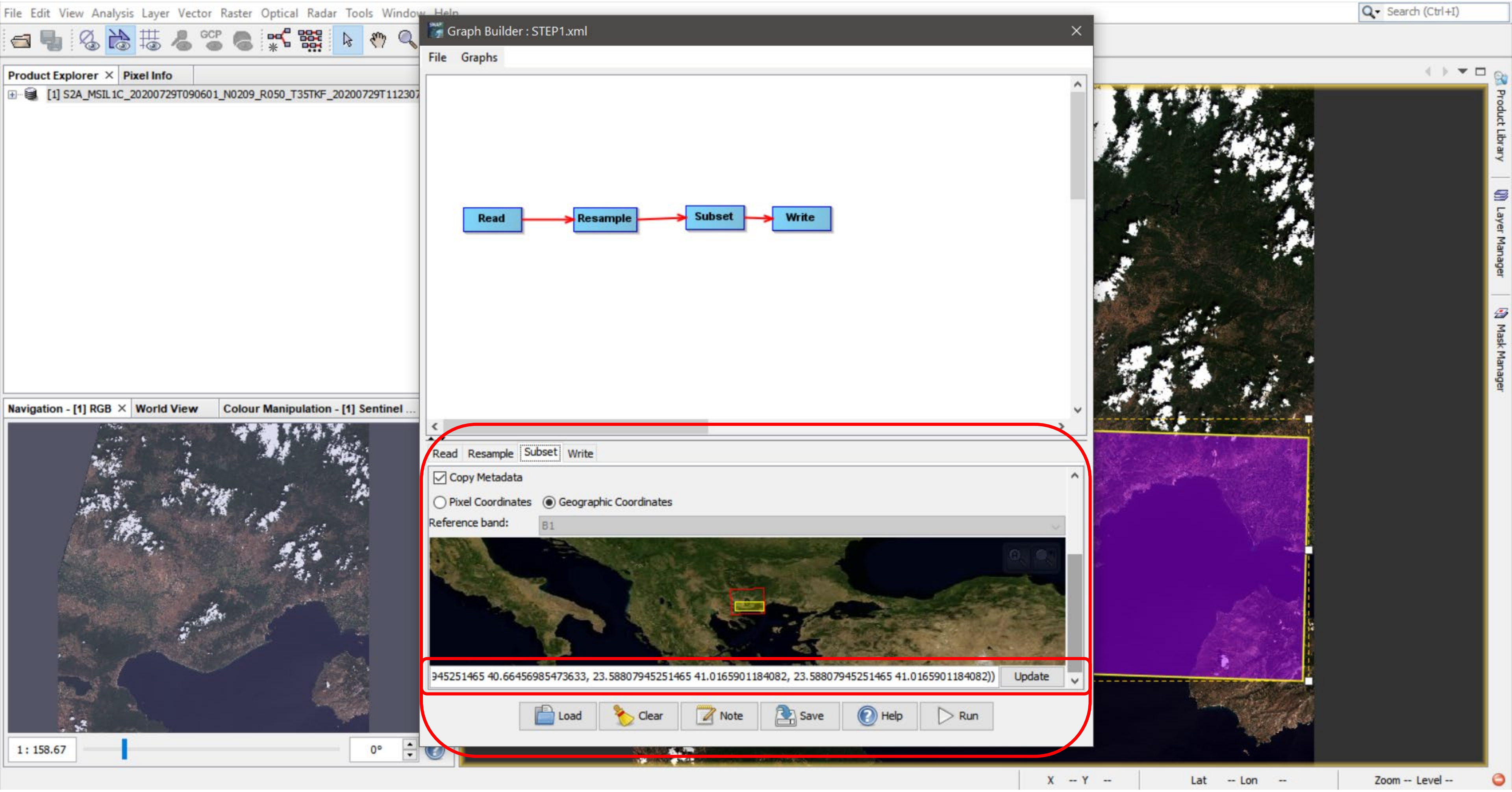
ODYSSEA



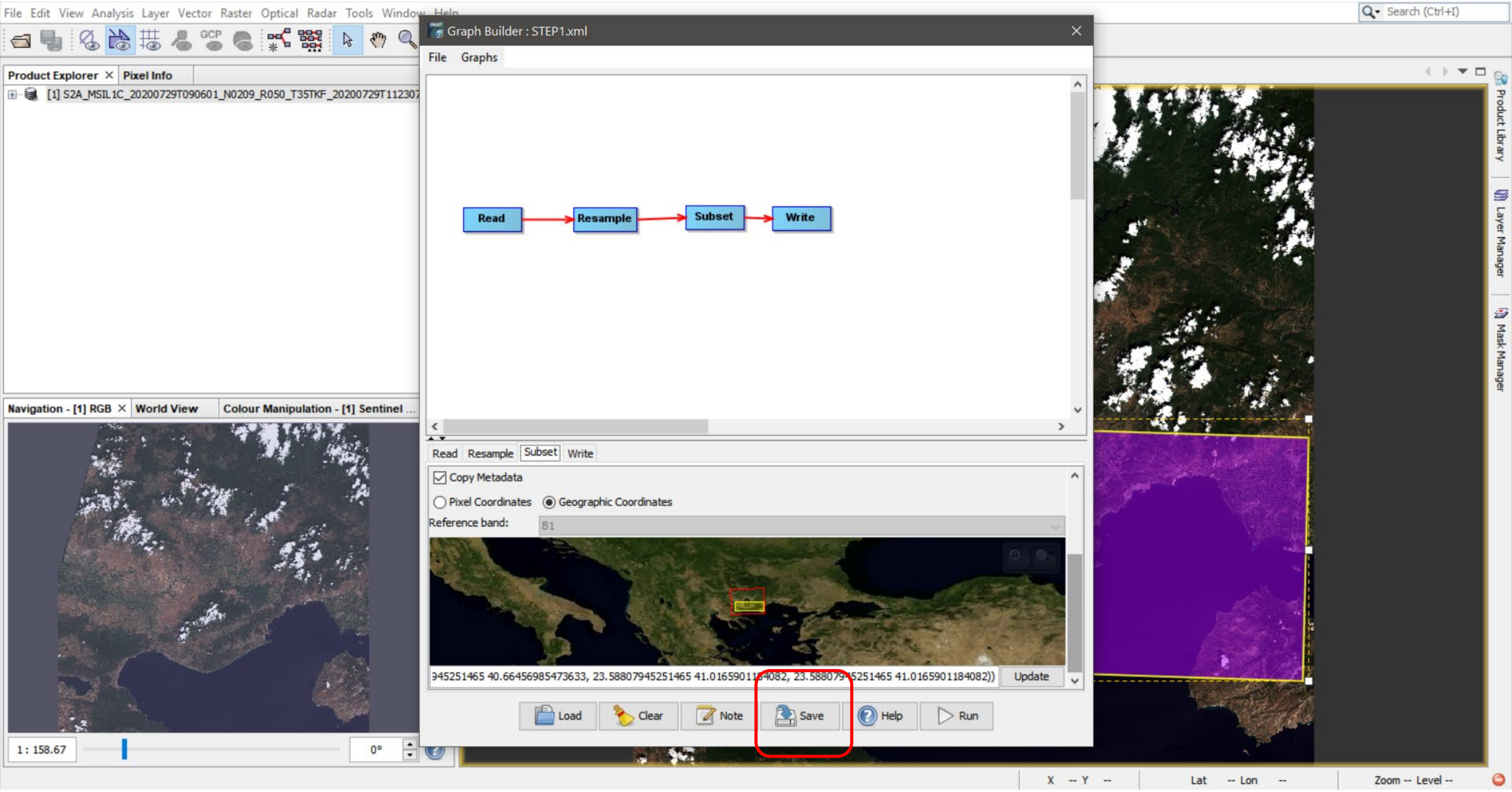
SNAP – Polygon



SNAP – Graph Builder



SNAP – Graph Builder



SNAP – Graph Builder

ODYSSEA

Bulk Processing with Graph Processor Tool (GPT)

$variable

Resample

Subset

```xml
<graph id="Graph">
  <version>1.0</version>
  <node id="Read">
    <operator>Read</operator>
    <sources/>
    <parameters class="com.bc.ceres.binding.dom.XppDomElement">
      <file>D:\Desktop\Παρουσίαση SPM\Images from SPM MArre\Satellite\S2A_MSIL1C_20200729T090601_N0209_R050_T35TKF_20200729T112307.zip</file>
    </parameters>
  </node>
  <node id="Resample">
    <operator>Resample</operator>
    <sources>
      <sourceProduct refid="Read"/>
    </sources>
    <parameters class="com.bc.ceres.binding.dom.XppDomElement">
      <referenceBand>B2</referenceBand>
      <targetWidth/>
      <targetHeight/>
      <targetResolution/>
      <upsampling>Nearest</upsampling>
      <downsampling>First</downsampling>
      <flagDownsampling>First</flagDownsampling>
      <resamplingPreset/>
      <bandResamplings/>
      <resampleOnPyramidLevels>true</resampleOnPyramidLevels>
    </parameters>
  </node>
  <node id="Subset">
    <operator>Subset</operator>
    <sources>
      <sourceProduct refid="Resample"/>
    </sources>
    <parameters class="com.bc.ceres.binding.dom.XppDomElement">
      <sourceBands/>
      <region>0,0,0,0</region>
      <referenceBand/>
      <geoRegion>POLYGON ((23.58807945251465 41.0165901184082, 24.727497100830078 41.0165901184082, 24.727497100830078 40.66456985473633, 23.58807945251465 40.66456985473633, 23.58807945251465 41.0165901
      <subSamplingX>1</subSamplingX>
      <subSamplingY>1</subSamplingY>
      <fullSwath>false</fullSwath>
      <tiePointGridNames/>
      <copyMetadata>true</copyMetadata>
    </parameters>
  </node>
  <node id="Write">
    <operator>Write</operator>
    <sources>
      <sourceProduct refid="Subset"/>
```

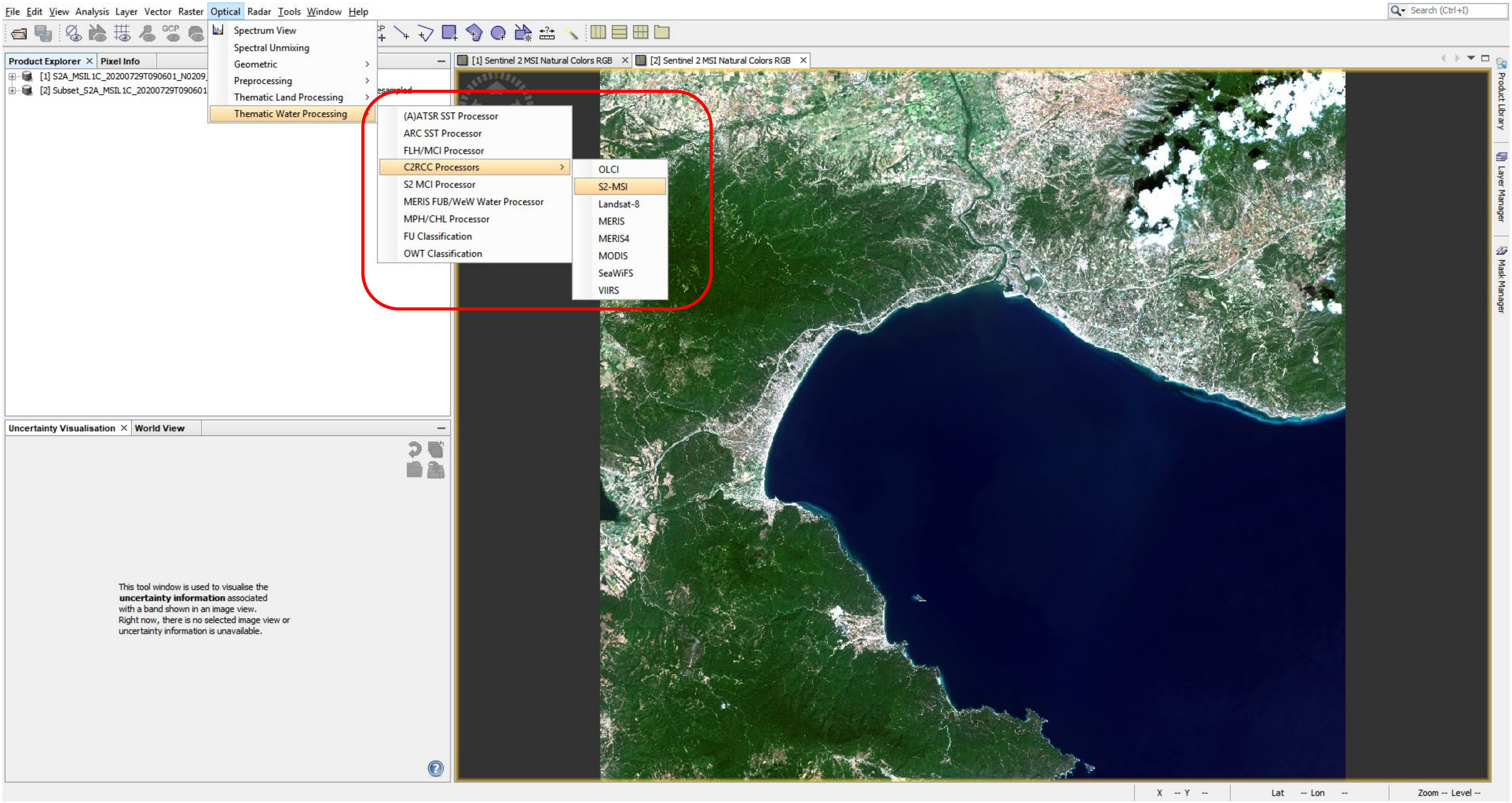
eXtensible Markup Language file | length : 2,479 lines : 70 | Ln : 18 Col : 22 Sel : 0 | 0 | Unix (LF) | ISO 8859-7 | INS

SNAP – Graph Builder

Initial

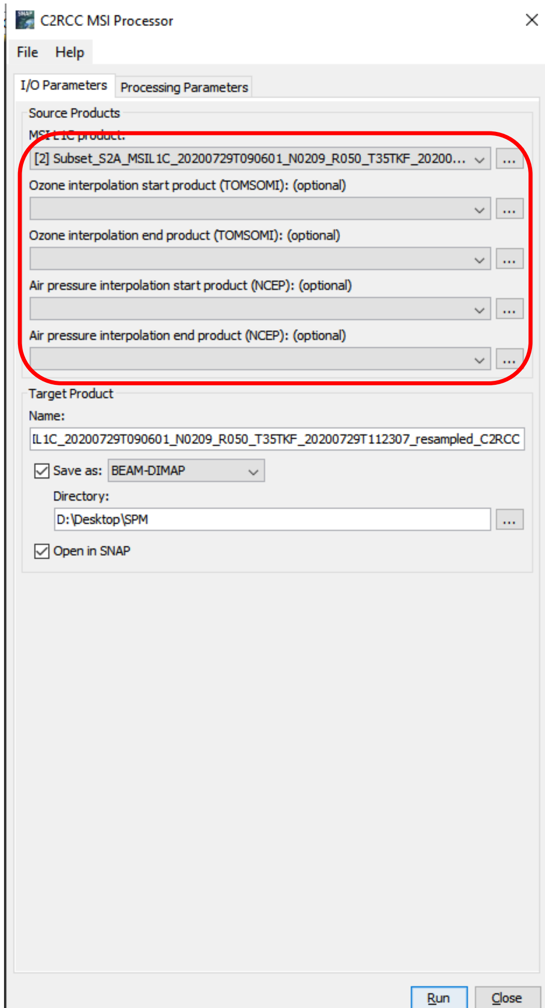
Resample - Subset

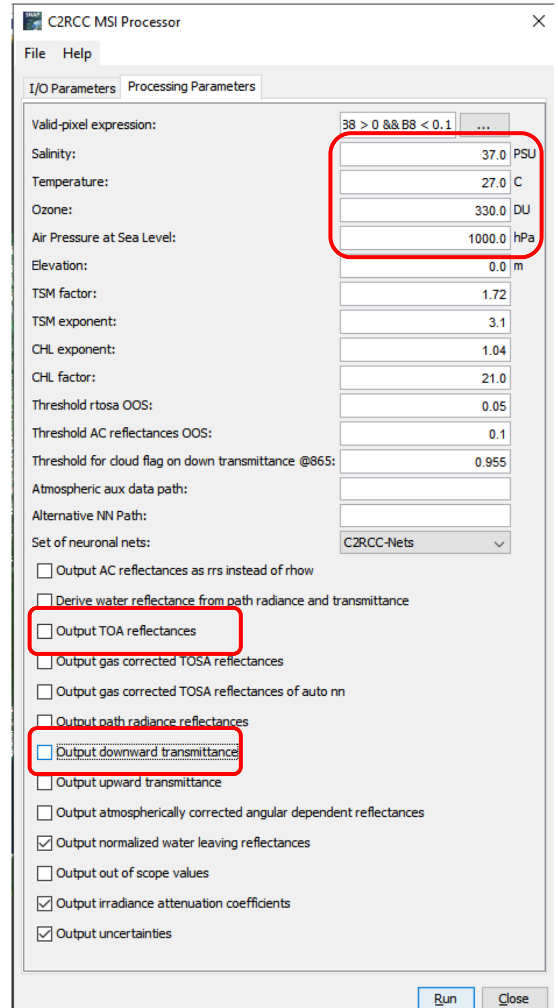
SNAP – CR2CC Processor



SNAP – CR2CC Processor

Reduces resolution to 1 degree





- **Salinity**
- **Temperature**
- **Ozone**
- **Pressure**

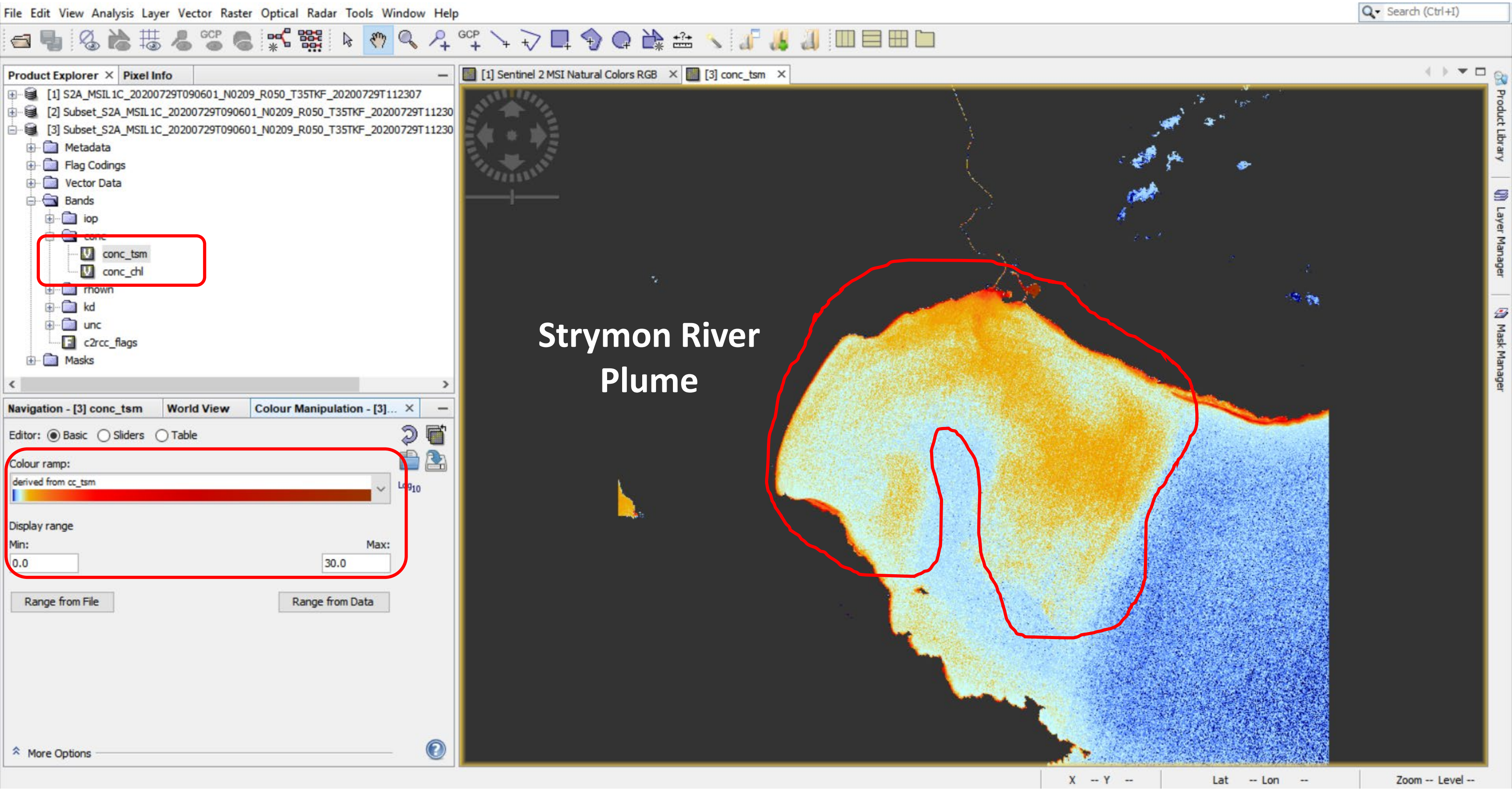
SNAP – CR2CC Processor

ODYSSEA

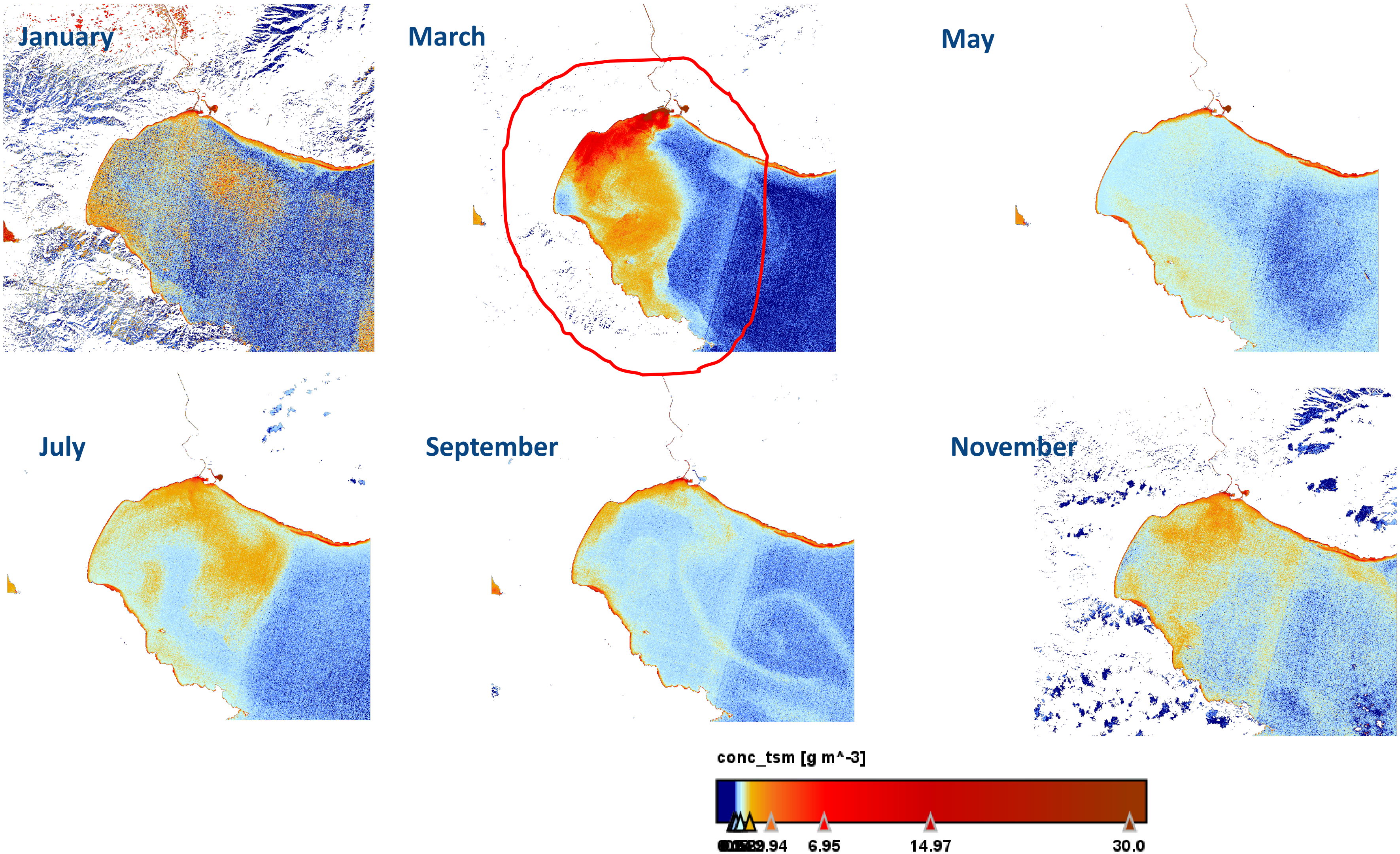

```xml
<parameters>
    <validPixelExpression>B8 &gt; 0 &amp;&amp; B8 &lt; 0.1</validPixelExpression>
    <salinity>37.1</salinity>
    <temperature>15.1</temperature>
    <ozone>330.0</ozone>
    <press>1000.0</press>
    <elevation>0.0</elevation>
    <TSMfac>1.72</TSMfac>
    <TSMexp>3.1</TSMexp>
    <CHLexp>1.04</CHLexp>
    <CHLfac>21.0</CHLfac>
    <thresholdRtosaOOS>0.05</thresholdRtosaOOS>
    <thresholdAcReflecOos>0.1</thresholdAcReflecOos>
    <thresholdCloudTDown865>0.955</thresholdCloudTDown865>
    <atmosphericAuxDataPath/>
    <netSet>C2RCC-Nets</netSet>
    <outputAsRrs>false</outputAsRrs>
    <deriveRwFromPathAndTransmittance>false</deriveRwFromPathAndTransmittance>
    <outputRtoa>false</outputRtoa>
    <outputRtosaGc>false</outputRtosaGc>
    <outputRtosaGcAann>false</outputRtosaGcAann>
    <outputRpath>false</outputRpath>
    <outputTdown>false</outputTdown>
    <outputTup>false</outputTup>
    <outputAcReflectance>false</outputAcReflectance>
    <outputRhown>false</outputRhown>
    <outputOos>false</outputOos>
    <outputKd>true</outputKd>
    <outputUncertainties>true</outputUncertainties>
</parameters>
```


Variables

SNAP – SPM Results



SNAP – SPM Results



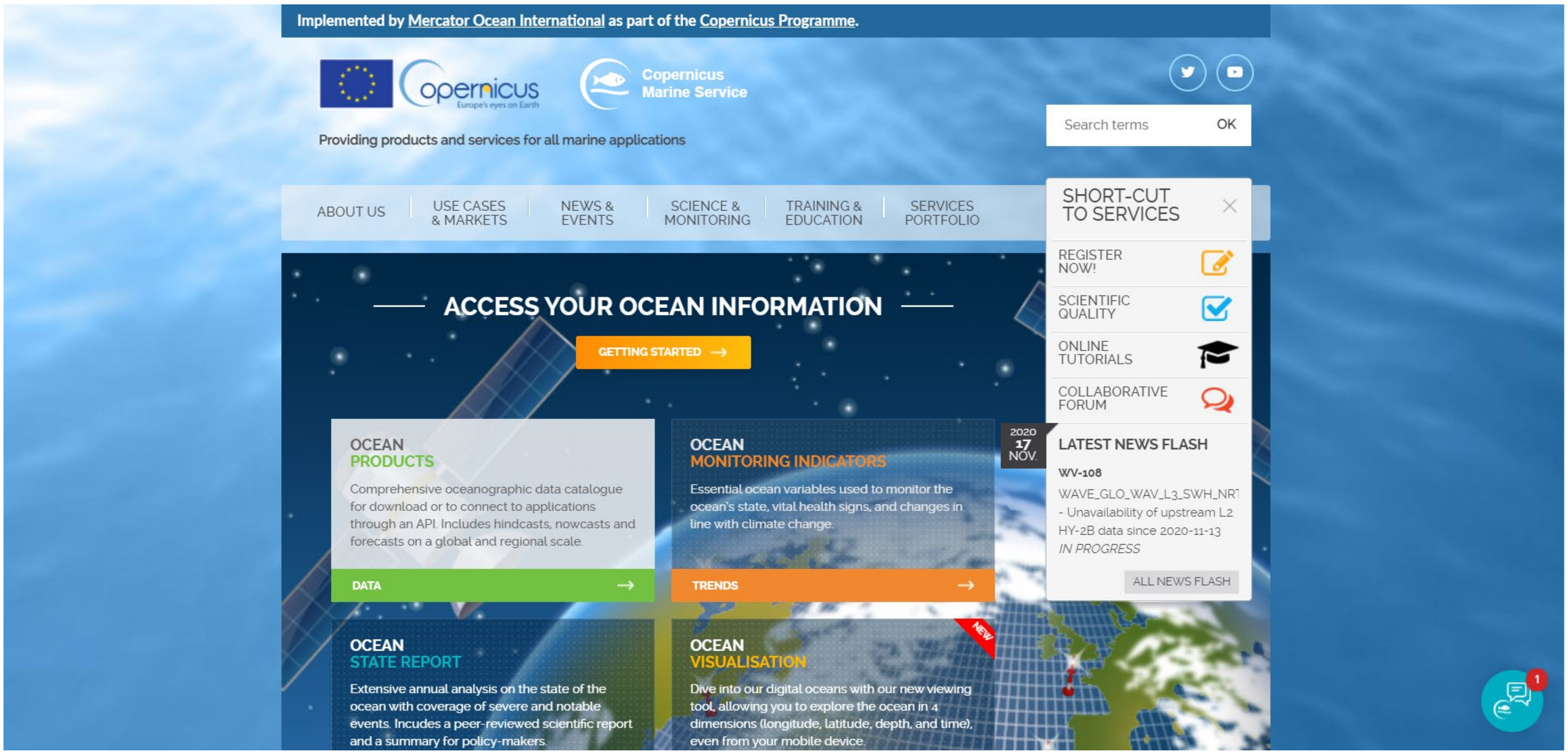
Access SPM data on CMEMS

CMEMS

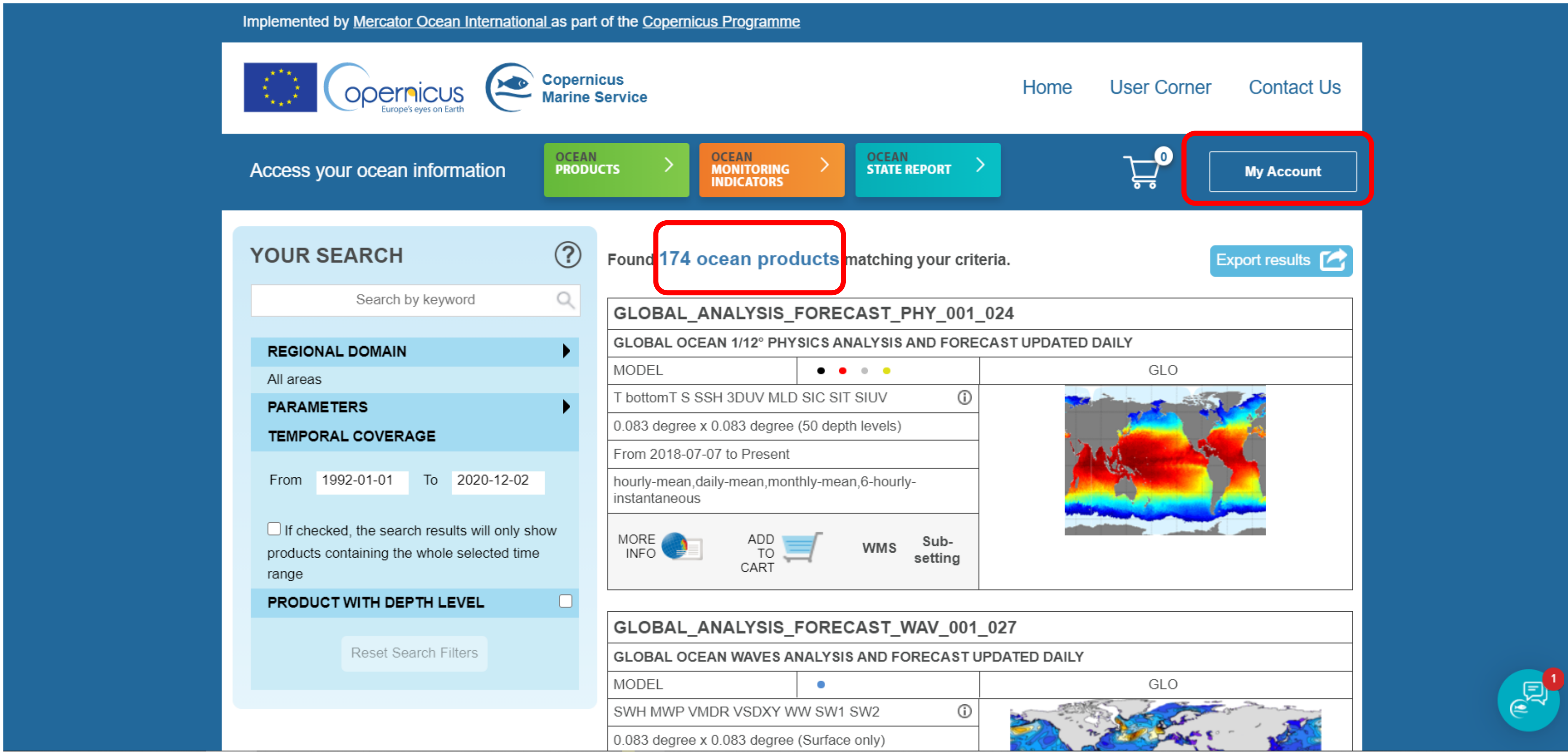
- CMEMS is the **Copernicus Marine Environment Monitoring Service**, operated by Mercator Ocean in Toulouse, France
- It is a service providing **full, free and open access marine data** to regular and systematic reference
- It covers **all European regional seas**
- It is **based** largely **on satellite measurements** of parameters such as surface temperature, ocean color, sea surface height and sea ice, **as well as information from** circulation, wave and biogeochemical **models** validated **from measurements received from instruments in the sea**.

CMEMS

marine.copernicus.eu



CMEMS – Data Products



CMEMS Download Mechanisms

CMEMS – Download Mechanisms

ODYSSEA

CMEMS is offering 2 different authenticated Download Mechanisms. **For both of them, the user can authenticate with his CMEMS login and password**.

- **Subsetter**: The "Subsetter" allows you to **subset the data**, and should be used if you wish to download a small part of the total dataset.
- **CMEMS FTP**: The "FTP download" allows to download an **entire dataset** directly from the FTP server at the supply center.

Access on download services:

- via Graphical User Interface, GUI (through the web portal),
- via a machine to machine interface (script)

For FTP:

- via a web browser,
- via an FTP client with GUI.
- via a machine to machine interface (script)

CMEMS – Machine to machine interface
Motu Server

ODYSSEA

Motu is a **high efficient and robust Web Server** which fills the gap between heterogeneous Data Providers to End Users.

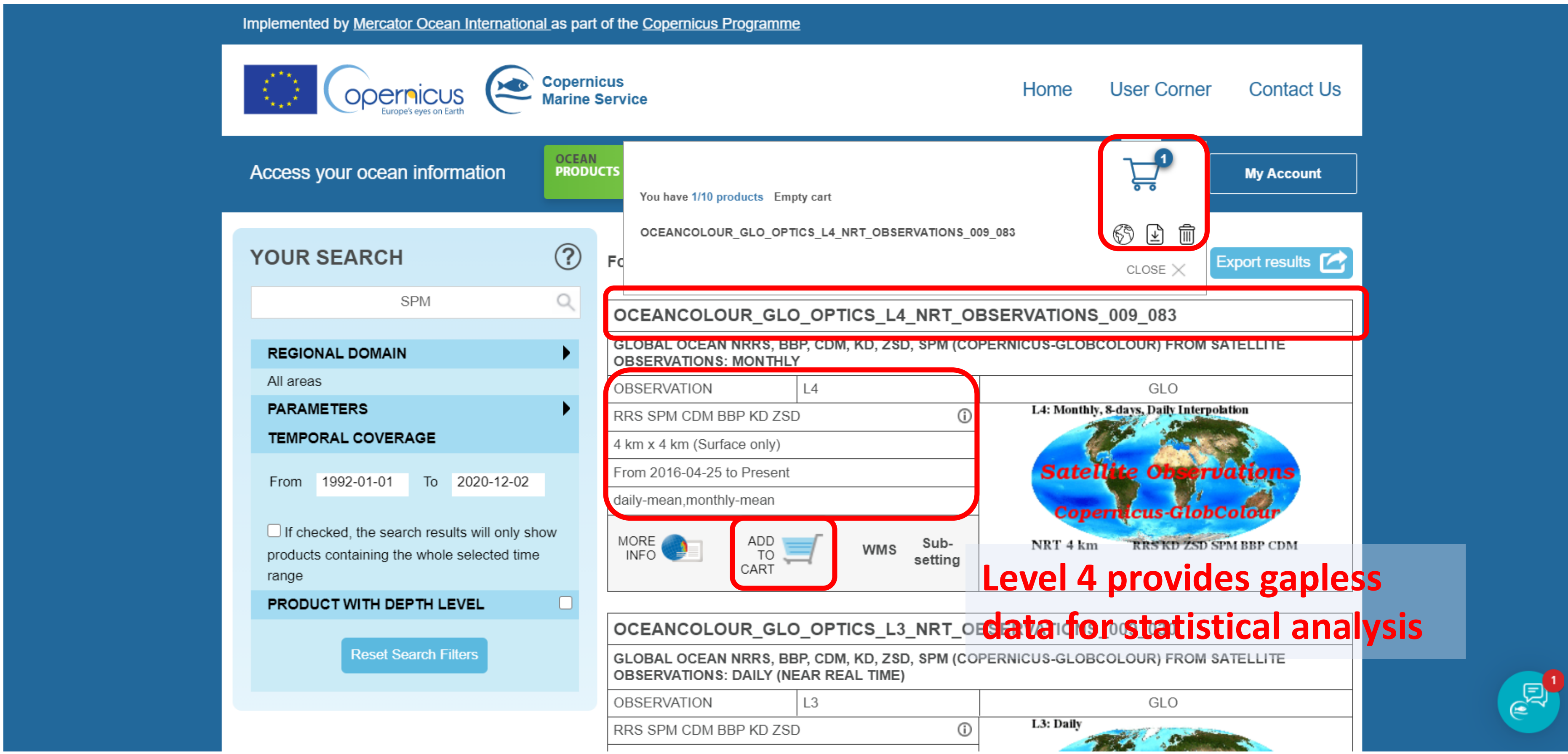
Motu handles, extracts and transforms oceanographic huge volumes of data without performance collapse.

To download Copernicus Marine Products hosted on MOTU server, using scripts, there are two options:

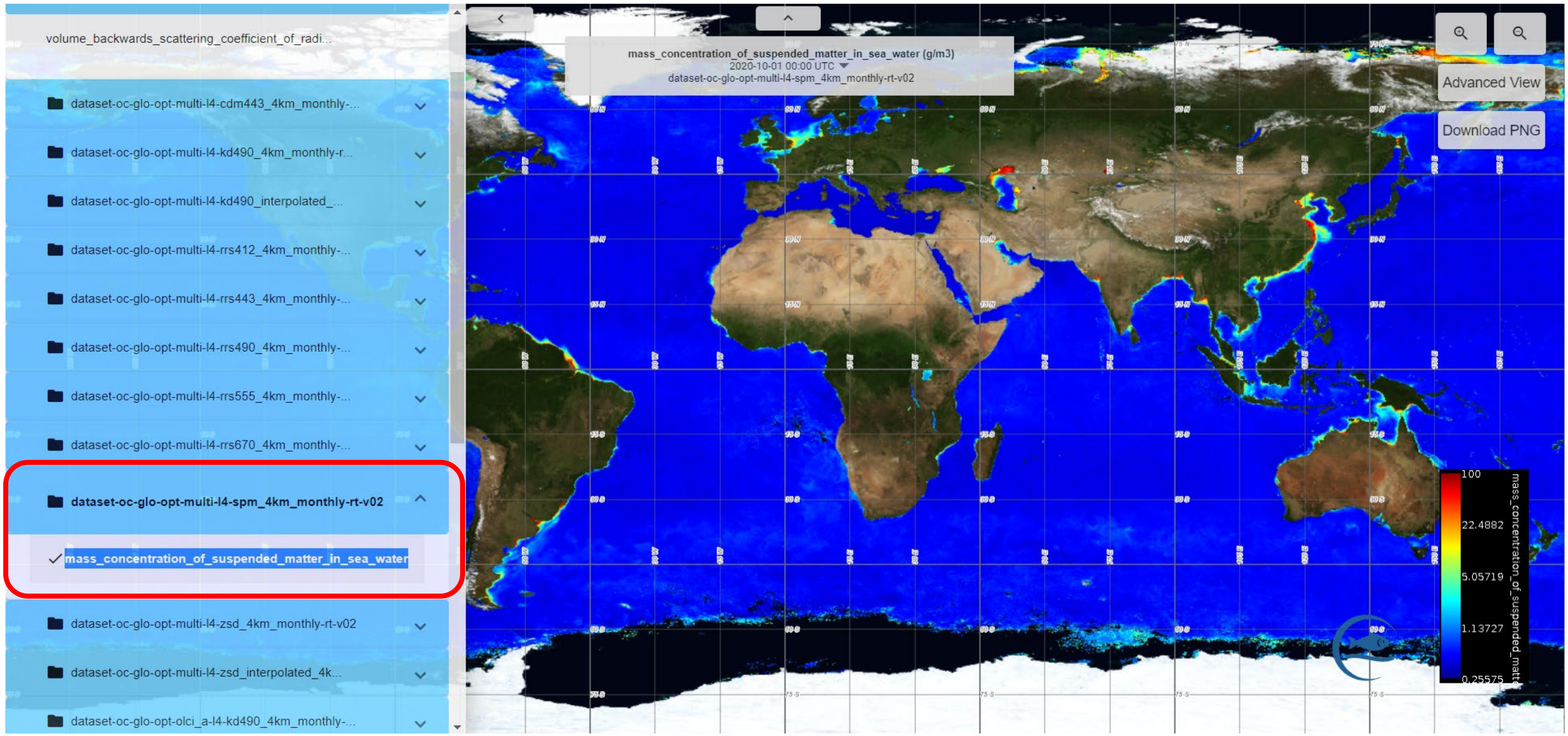
1. via MOTU CLIENT (for End-Users)
2. via MOTU REST API (for Developers)

CMEMS – Download SPM data

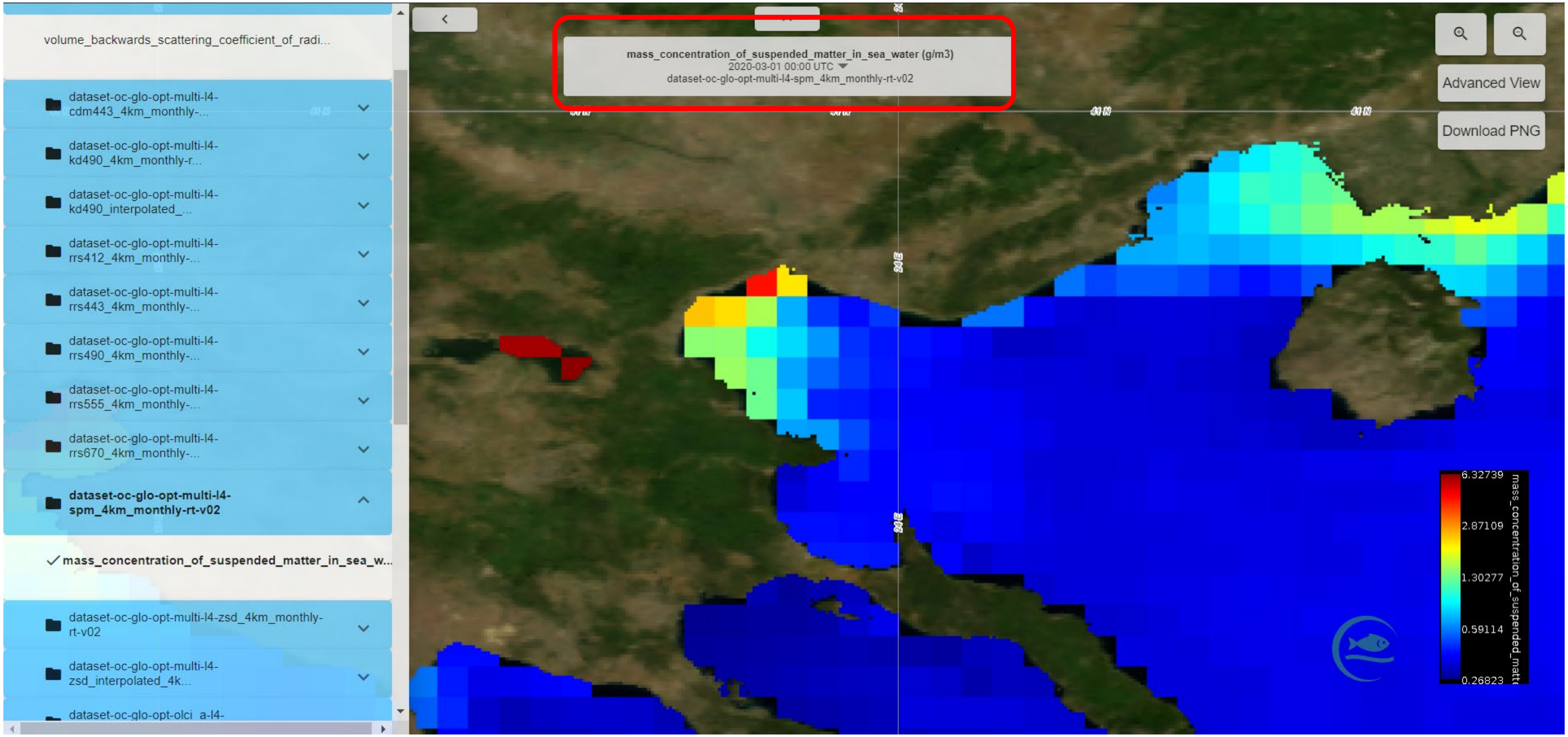
ODYSSEA



CMEMS – View SPM Data

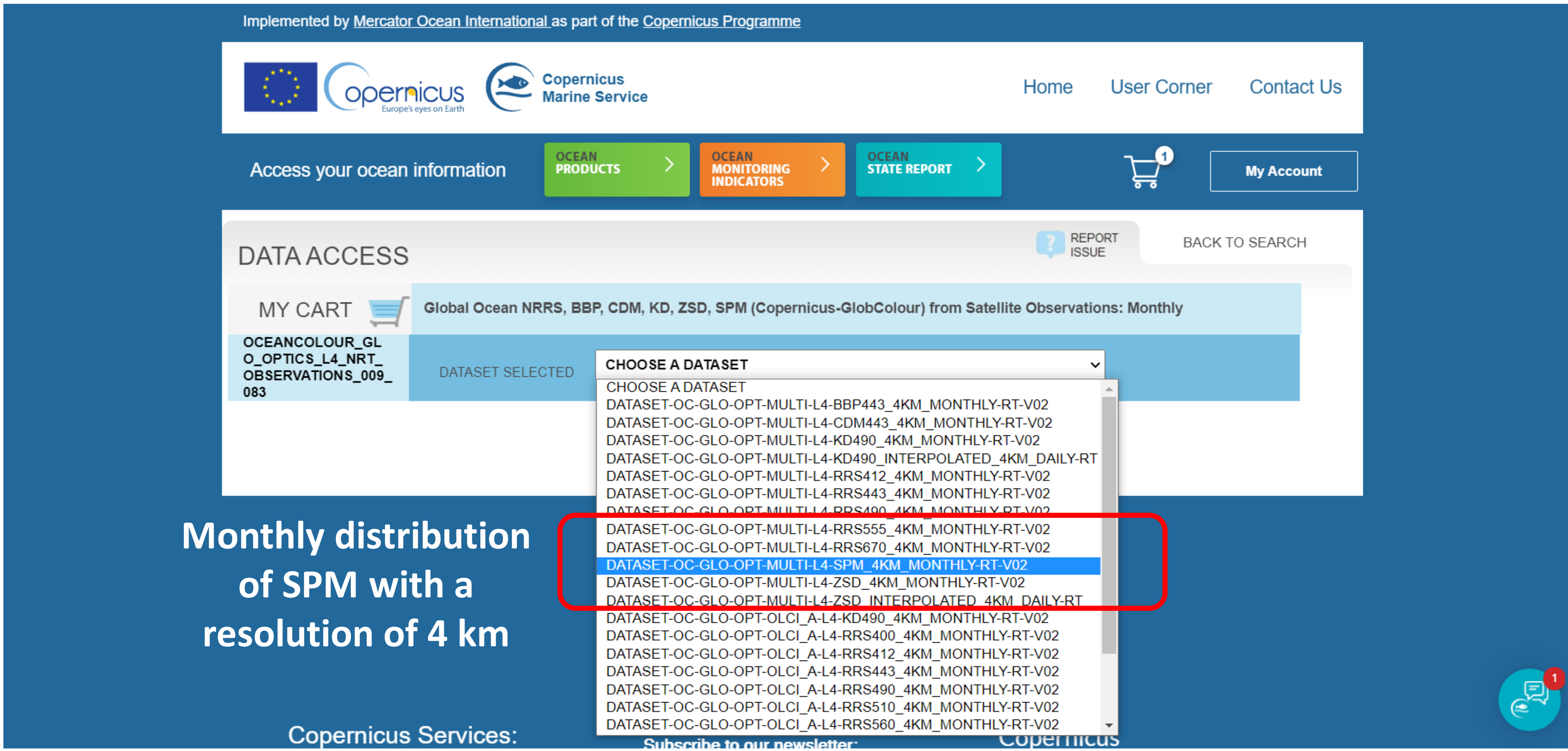


CMEMS – View SPM Data



CMEMS – Download SPM data

ODYSSEA



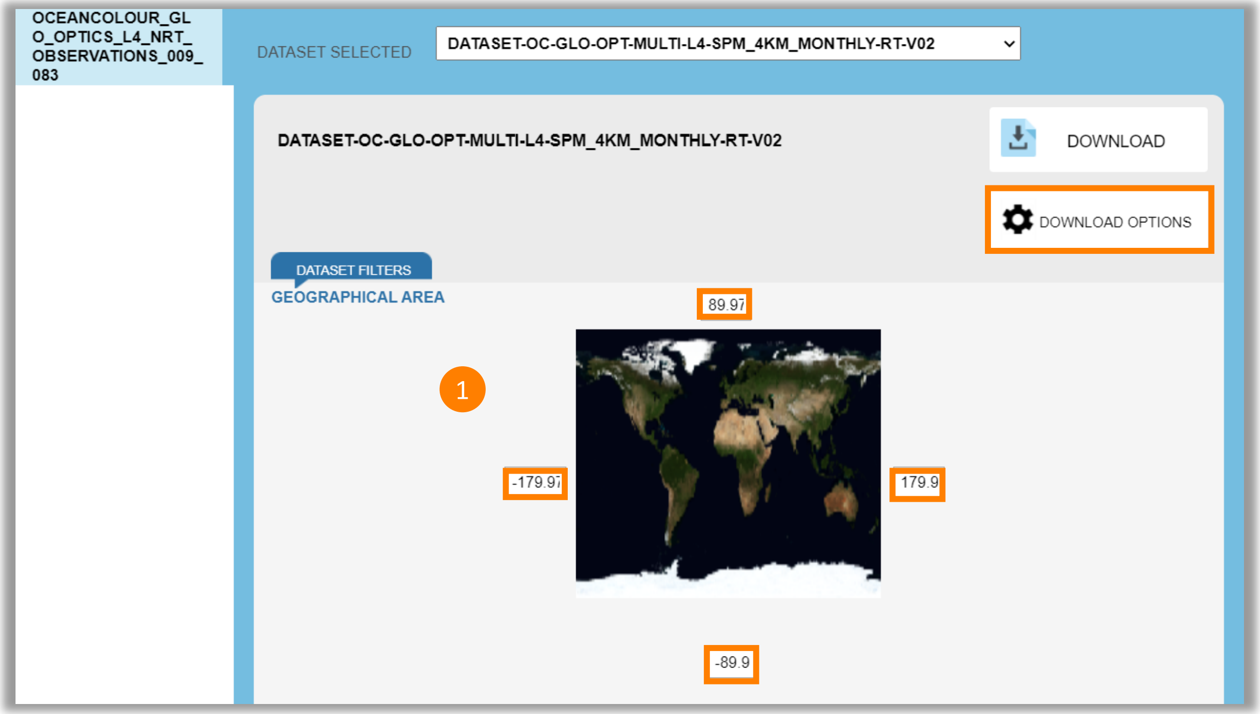
Monthly distribution of SPM with a resolution of 4 km

CMEMS – Download SPM data

ODYSSEA

Depending on Product Type (namely GRID), the GUI will display the extraction settings to enable the creation of a subset of the dataset over its dimensions:

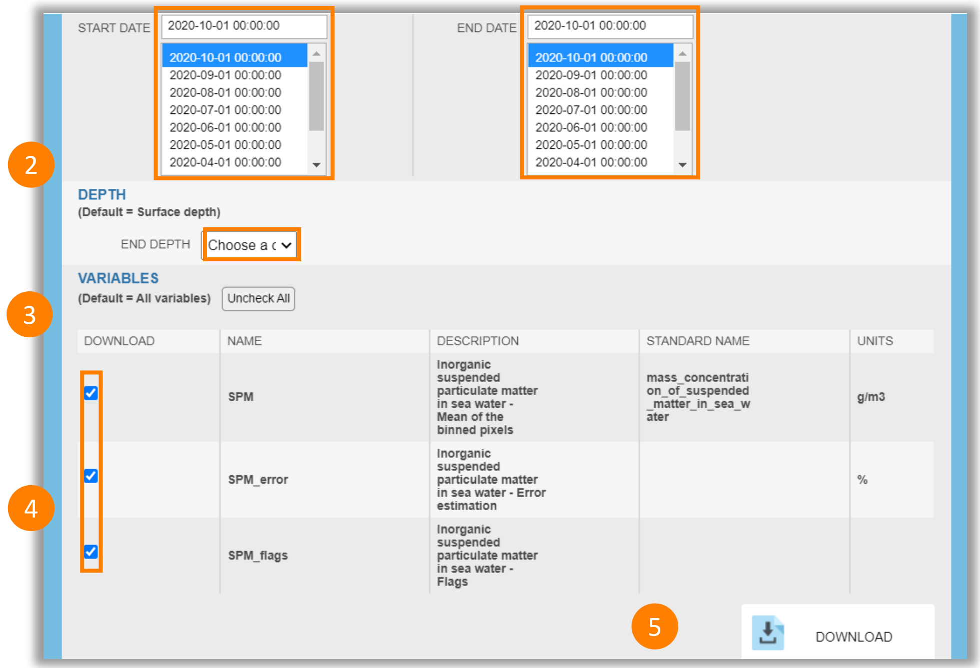
Geographical area (bounding box of longitudes and latitudes; NB: to select one point just input the same minimum and maximum)



CMEMS – Download SPM data

ODYSSEA

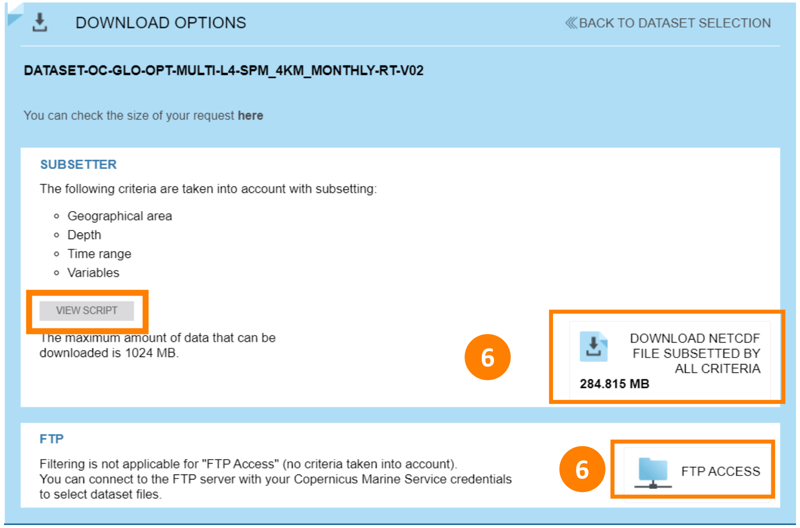
- Time range
- Depth (to select one layer, just select the same minimum and maximum)
- Ocean Variables



Validate the extraction by clicking on "DOWNLOAD" (5).

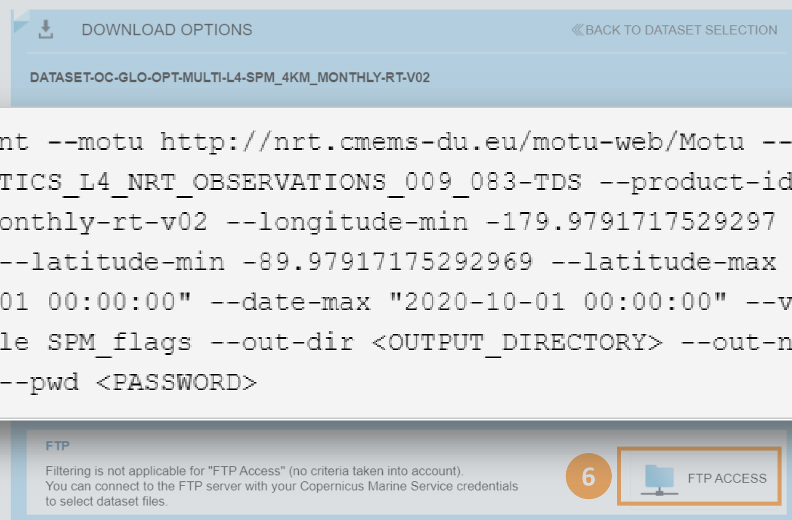
CMEMS – Download SPM data

A new window displays the size of the file and let you choose the download method of your interest:



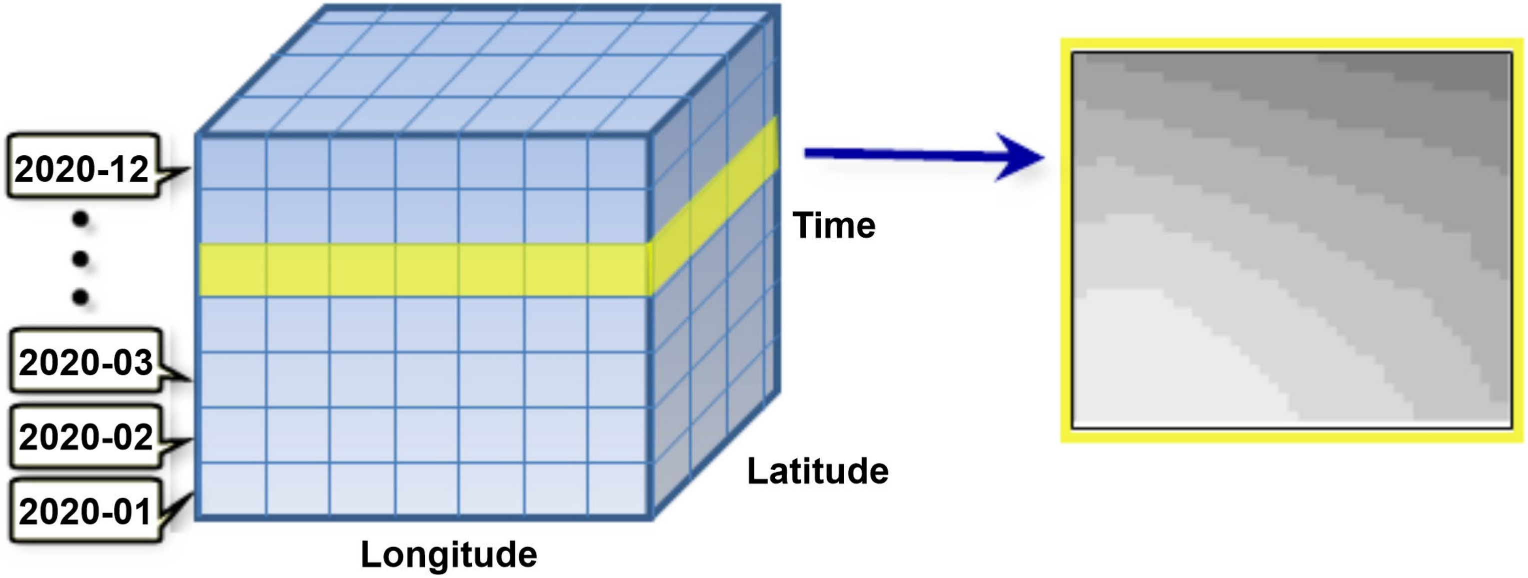
CMEMS – Download SPM data

ODYSSEA




```
python -m motuclient --motu http://nrt.cmems-du.eu/motu-web/Motu --service-id
OCEANCOLOUR_GLO_OPTICS_L4_NRT_OBSERVATIONS_009_083-TDS --product-id dataset-oc-glo-opt-
multi-l4-spm_4km_monthly-rt-v02 --longitude-min -179.9791717529297 --longitude-max
179.9791717529297 --latitude-min -89.97917175292969 --latitude-max 89.97916412353516 --
date-min "2020-10-01 00:00:00" --date-max "2020-10-01 00:00:00" --variable SPM --variable
SPM_error --variable SPM_flags --out-dir <OUTPUT_DIRECTORY> --out-name <OUTPUT_FILENAME>
--user <USERNAME> --pwd <PASSWORD>
```

CMEMS - netCDF file



source: www.arcgis.com

CMEMS – clip netCDF file to AOI

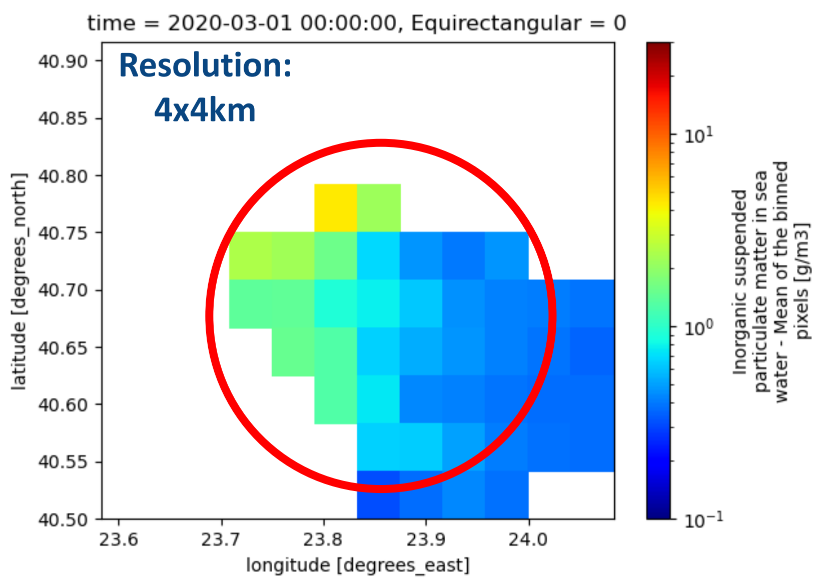
ODYSSEA

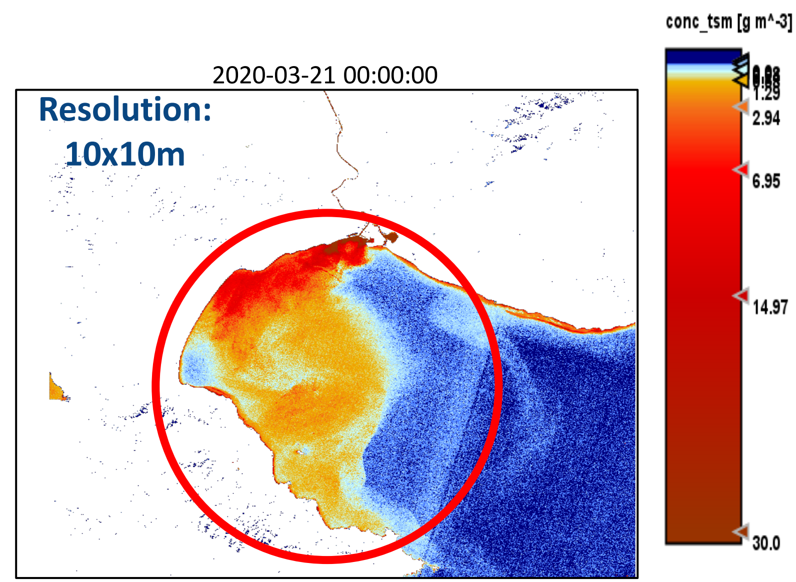
```
import xarray
import geopandas
from shapely.geometry import mapping

# Open Area of Interest shapefile
AOI = geopandas.read_file('AOI.shp')

# Open retrieved netcdf file
xds = xarray.open_dataset('dataset-oc-glo-opt-multi-l4-spm_4km_monthly-rt-v02_1606059041510.nc')

# Read SPM data
xds = xds[['SPM']]

# Clip data to Area of Interest
xds.rio.write_crs('EPSG:4326', inplace=True)
clipped = xds.rio.clip(AOI.geometry.apply(mapping), AOI.crs)

# Export clipped data to netcdf
clipped.to_netcdf('clipped_SPM.nc')
```

CMEMS – clip netCDF file to AOI

ODYSSEA

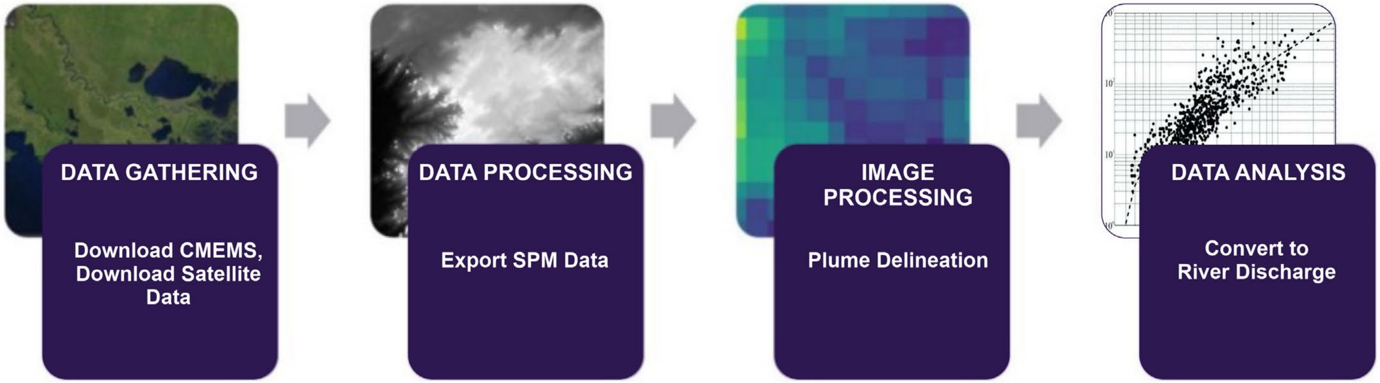
```
import matplotlib.colors as mcolors

# Plot third time (SPM[2]) of the file
norm = mcolors.LogNorm(1e-1, 3e1)
clipped.SPM[2].plot(norm=norm, cmap='jet')
```





Plume Dynamics to data

SPM to River Discharge

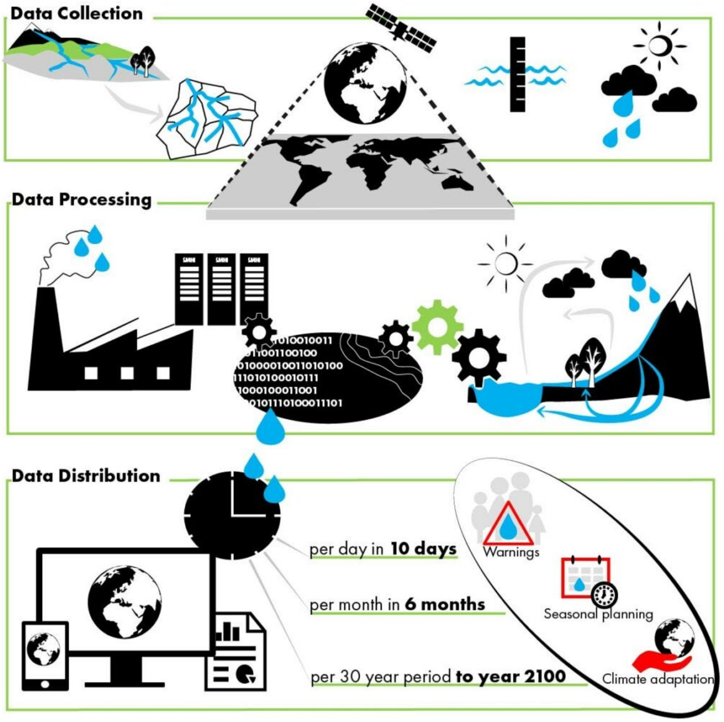


HYPE model

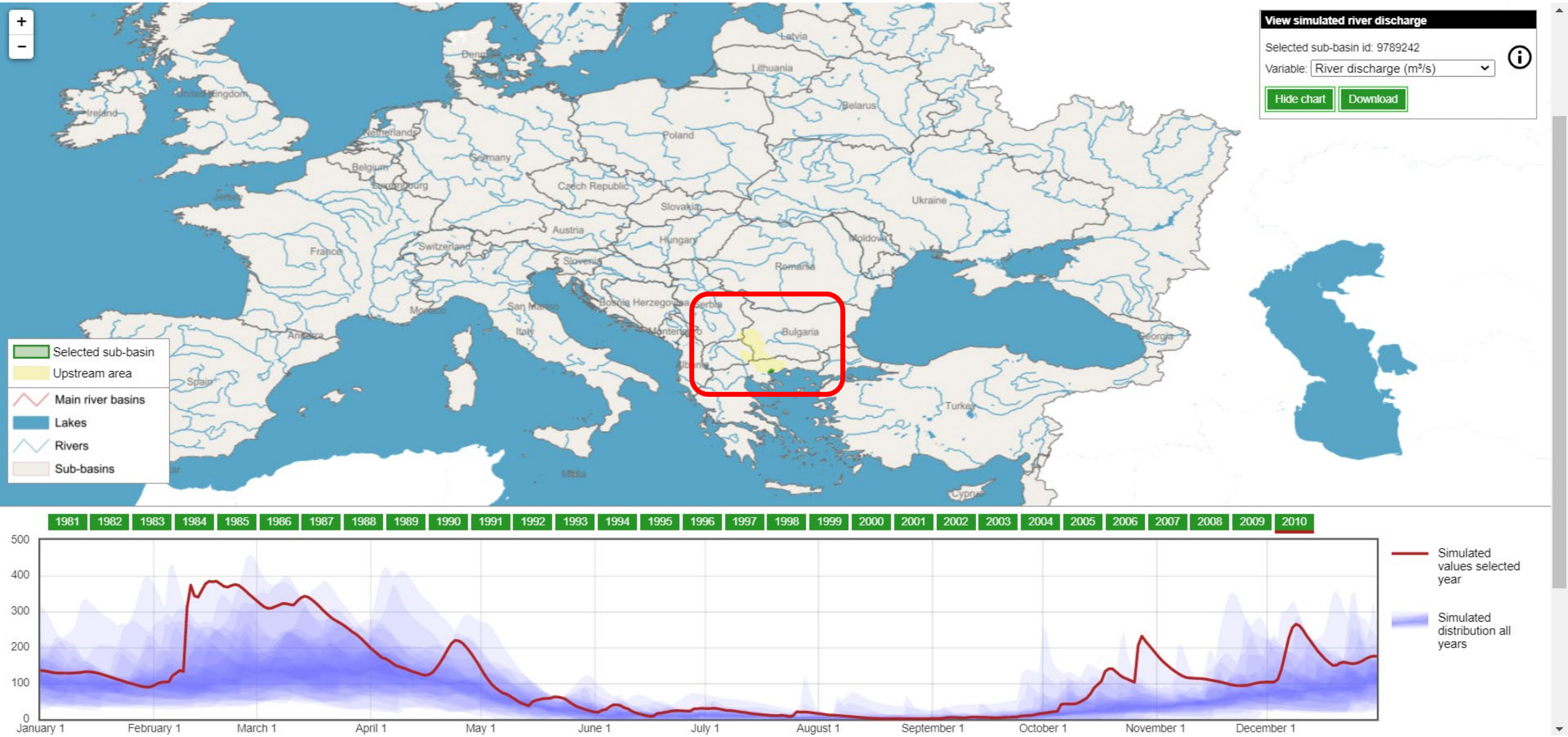
The **Hydrological Predictions for the Environment** (HYPE) model developed by **Swedish Meteorological and Hydrological Institute** (SMHI) and is a semi-distributed, **physically based catchment model**, which **simulates water flow and substances** on their way from precipitation through different storage compartments and fluxes to the sea.

- Operational model
- Data collection based on **physiographical characteristics of the landscape**.
- Use of **temperature and precipitation coming from forecasts**
- 1-10 days forecast

https://hypeweb.smhi.se/

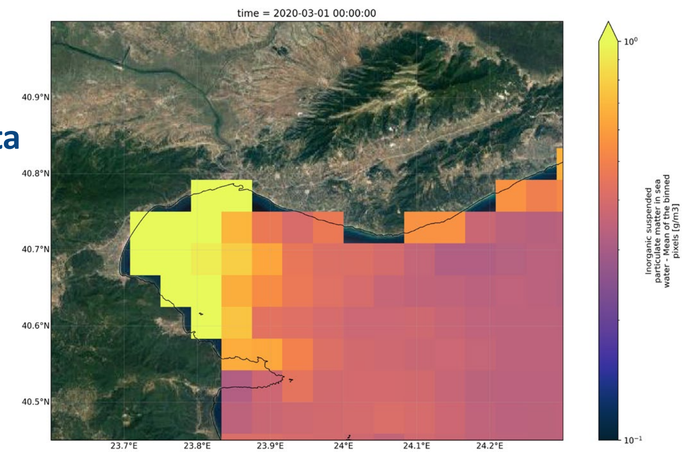


HypeWeb

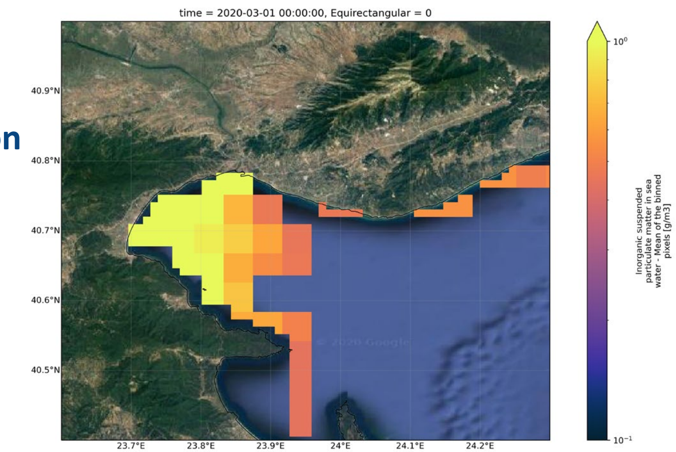

View simulated river discharge
Selected sub-basin id: 9789242
Variable: River discharge (m³/s)
Hide chart
Download
Selected sub-basin
Upstream area
Main river basins
Lakes
Rivers
Sub-basins
1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010
500
400
300
200
100
0
January 1
February 1
March 1
April 1
May 1
June 1
July 1
August 1
September 1
October 1
November 1
December 1
Simulated values selected year
Simulated distribution all years

Plume Delineation

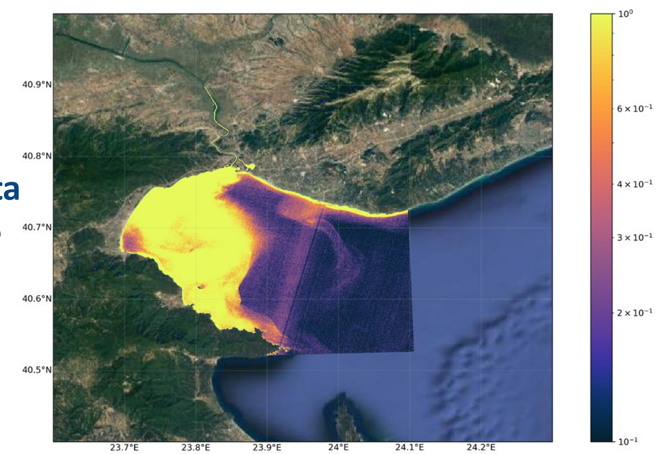
Initial SPM data from CMEMS



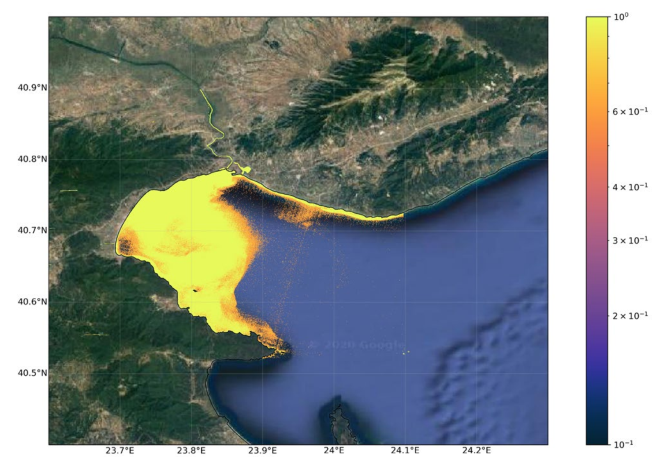
Plume Delineation CMEMS data



Initial SPM data from Satellite



Plume Delineation Satellite data



Results

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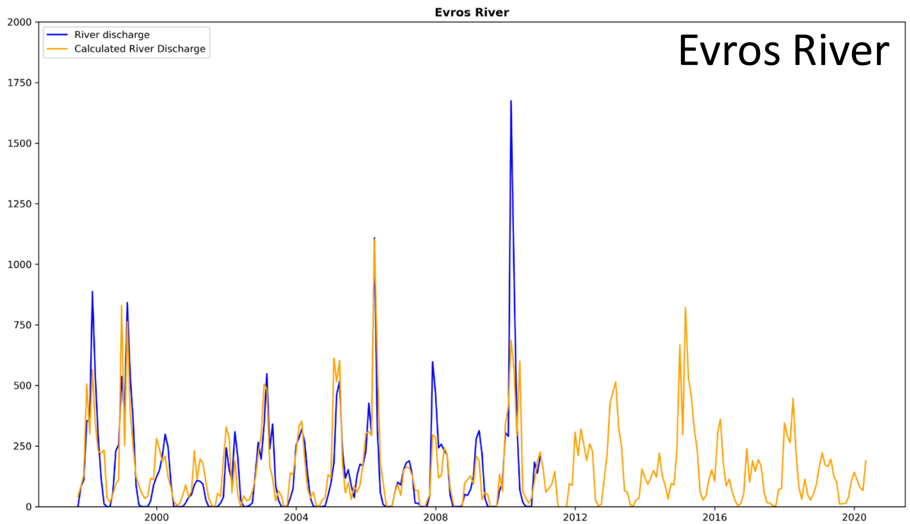

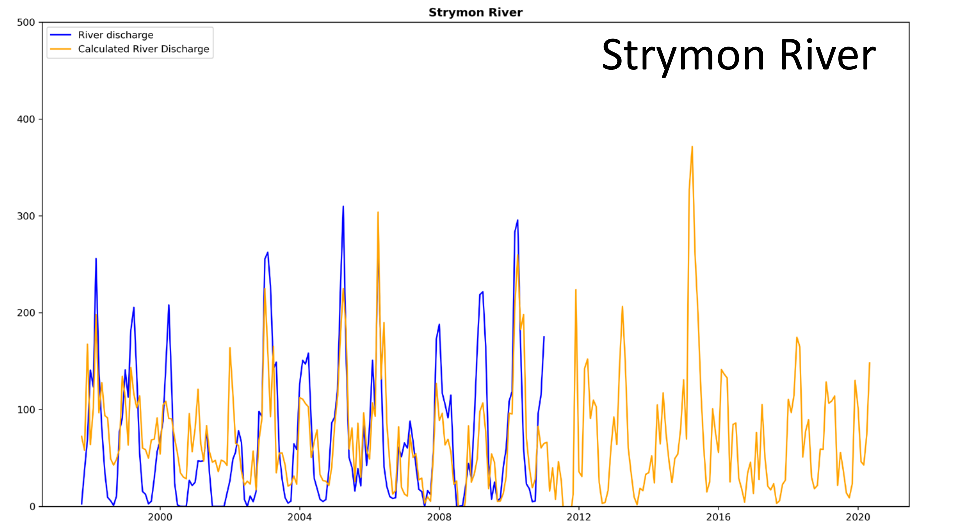

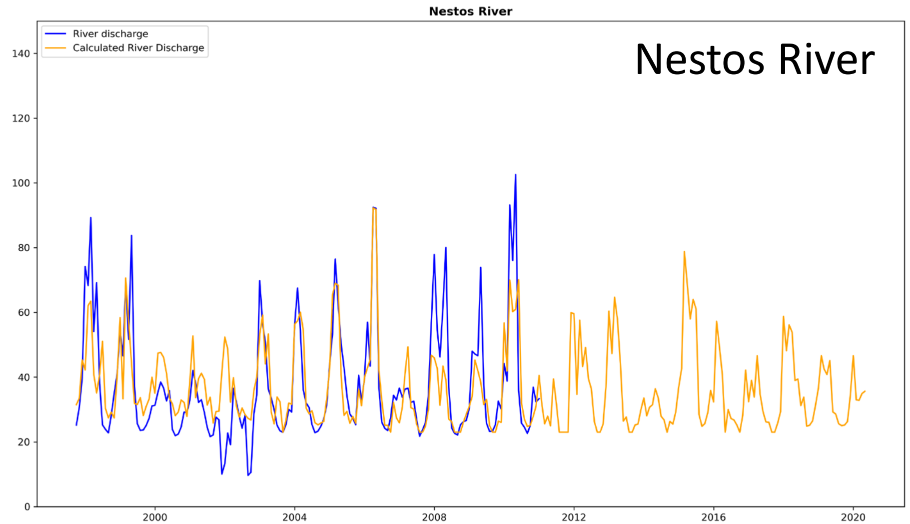

Links for data and software

ODYSSEA

Satellite images:

- Earth Explorer: https://earthexplorer.usgs.gov/
- Copernicus Hub: https://scihub.copernicus.eu/dhus/
- Sentinel-2 Documentation: https://sentinel.esa.int/web/sentinel/missions/sentinel-2

Data

- HypeWeb: https://hypeweb.smhi.se/
- CMEMS: https://marine.copernicus.eu/

Tools

- SNAP: https://step.esa.int/main/toolboxes/snap/
- Sentinelsat module: https://sentinelsat.readthedocs.io/en/stable/
- Graph Processing Tool: http://step.esa.int/docs/tutorials/SNAP_CommandLine_Tutorial.pdf

THANK-YOU

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UN environment programme | Mediterranean Action Plan Barcelona Convention | SPA / RAC

ΔΗΜΟΚΡΙΤΕΙΟ ΠΑΝΕΠΙΣΤΗΜΙΟ ΘΡΑΚΗΣ | DEMOCRITUS UNIVERSITY OF THRACE

ODYSSEA

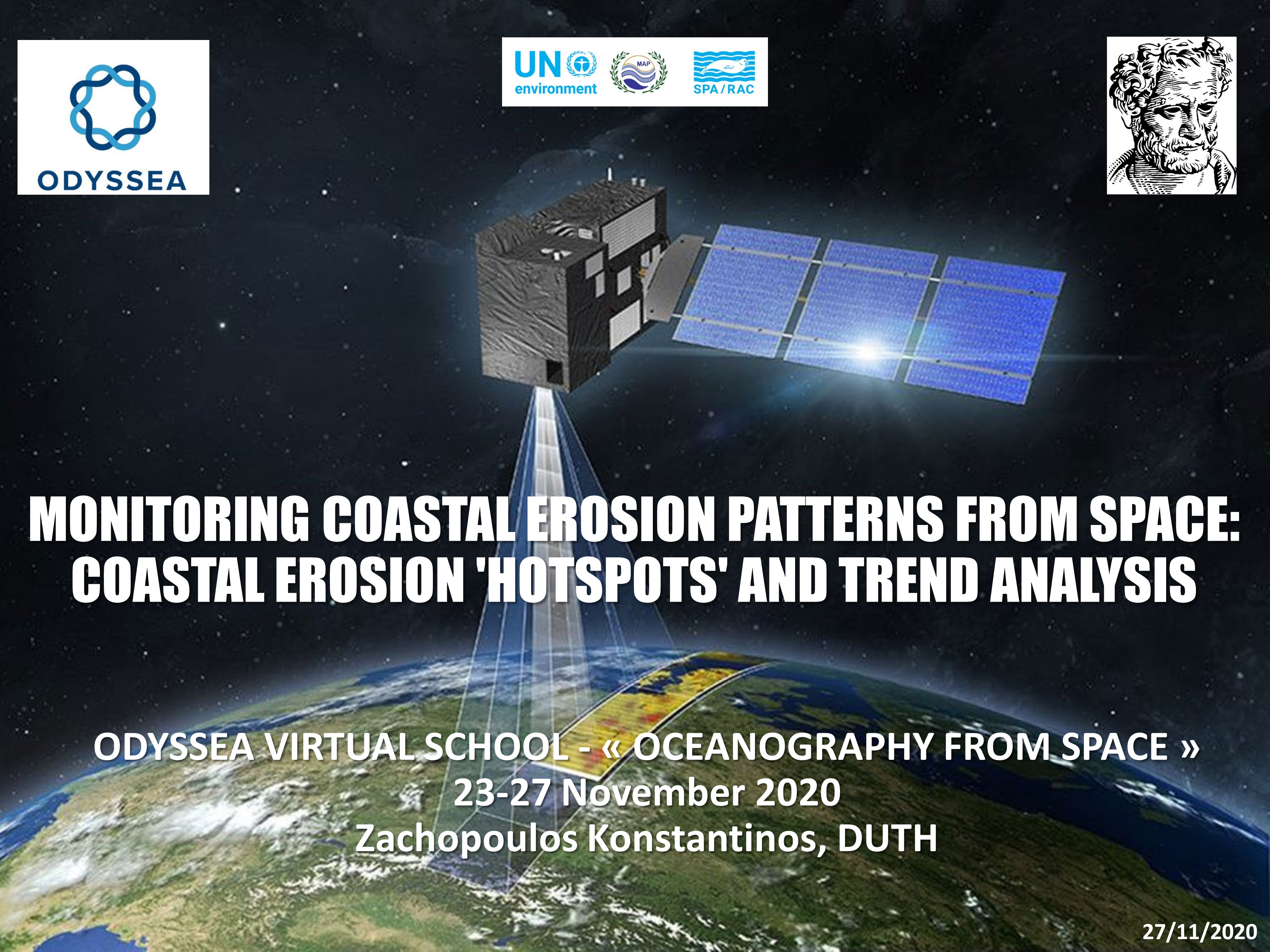
MONITORING COASTAL EROSION PATTERNS FROM SPACE: COASTAL EROSION 'HOTSPOTS' AND TREND ANALYSIS

Zachopoulos Konstantinos

Democritus University of Thrace

E-mail: zachopoulosk@gmail.com

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727277



ODYSSEA

UN environment MAP SPA/RAC

MONITORING COASTAL EROSION PATTERNS FROM SPACE: COASTAL EROSION 'HOTSPOTS' AND TREND ANALYSIS

ODYSSEA VIRTUAL SCHOOL - « OCEANOGRAPHY FROM SPACE »

23-27 November 2020

Zachopoulos Konstantinos, DUTH

27/11/2020

Introduction to Remote Sensing and Coastal Erosion

ODYSSEA

- Introduction to Coastal Erosion
- Introduction to Remote Sensing
- Open source databases for satellite images
- Methodology applied in a coastal erosion assessment
- Shoreline Extraction
- Evaluation of the Shoreline Evolution

Introduction to coastal erosion

Introduction to Coastal Erosion

ODYSSEA

- Coastal erosion is one of the **highly growing environmental concerns** faced by coastal communities

- It is aggravated by the prospect of **accelerated sea level rise** due to **climate change** and accumulated negative effects of **mismanagement practices**

- Over the past 100 years about 70% of the world's sandy shorelines have been retreating due to coastal erosion, while currently around 20% of EU coastline is eroding

Indicative factors affecting coastal erosion

Coastal Erosion

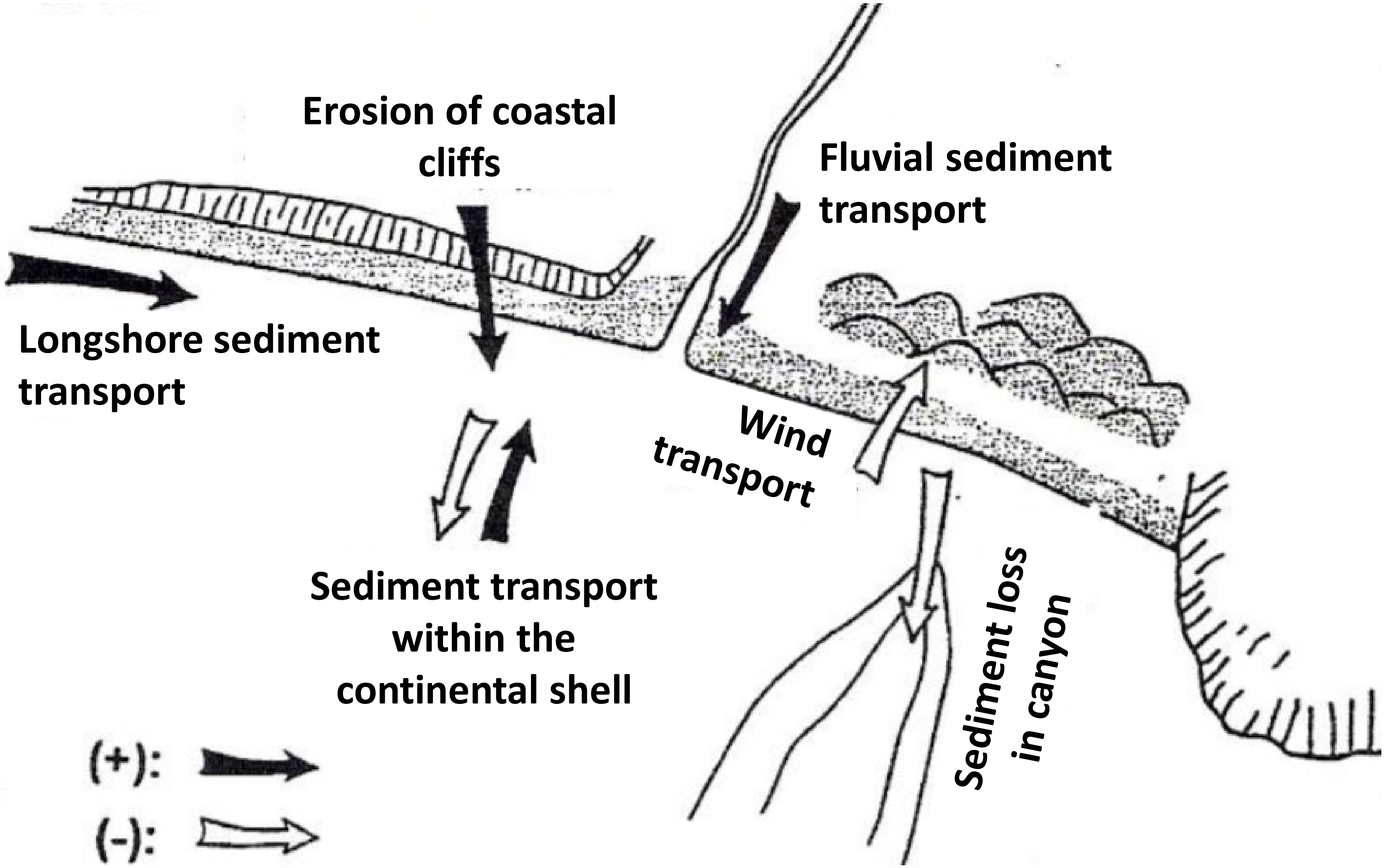
Natural processes

- Wave force
- Tide
- Sea currents
- Storms
- Sea lever rise
- Extreme weather events

Anthropogenic interventions

- Urbanization
- Tourism
- Coastal structures
- Dredging
- Dams construction

ODYSSEA


Erosion of coastal cliffs
Fluvial sediment transport
Longshore sediment transport
Wind transport
Sediment transport within the continental shell
Sediment loss in canyon
(+):
(-):

ODYSSEA

Historical images from Google Earth Pro

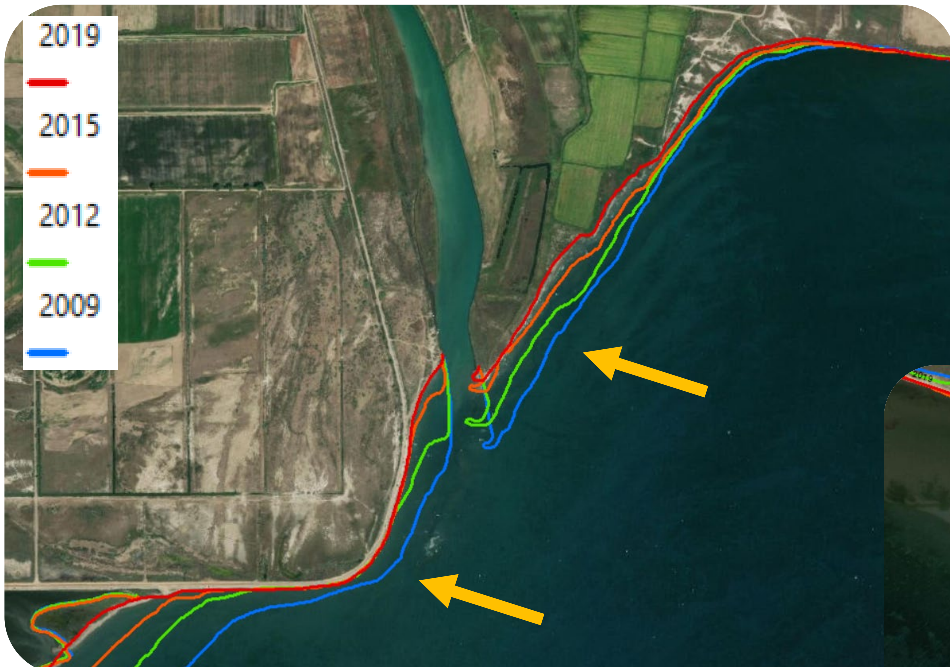
2003

2013

2019

Coastal Erosion/Deposition

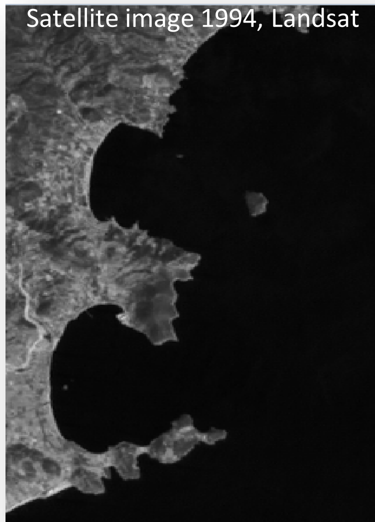
ODYSSEA

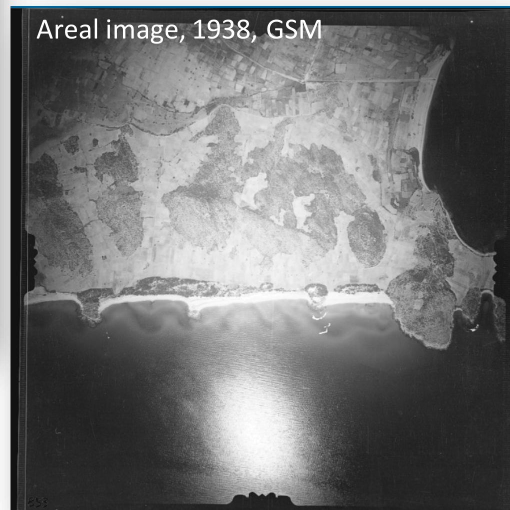


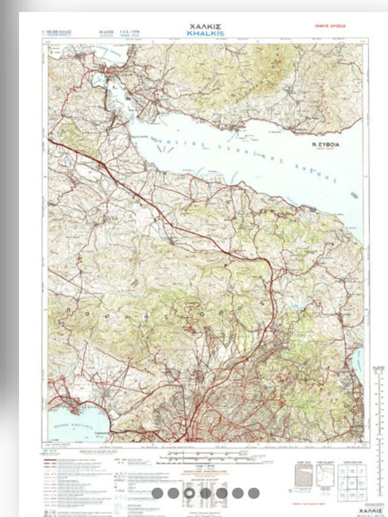
ODYSSEA

By processing, analyzing and comparing historical data such as:

- ✓ **Areal Images**
- ✓ **Topographic maps**
- ✓ **Other historical maps**
- ✓ **In-situ measurements**
- ✓ **Satellites**







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Introduction to Remote Sensing

- **Spatial Resolution**

The spatial resolution specifies the pixel size of satellite images covering the Earth surface.

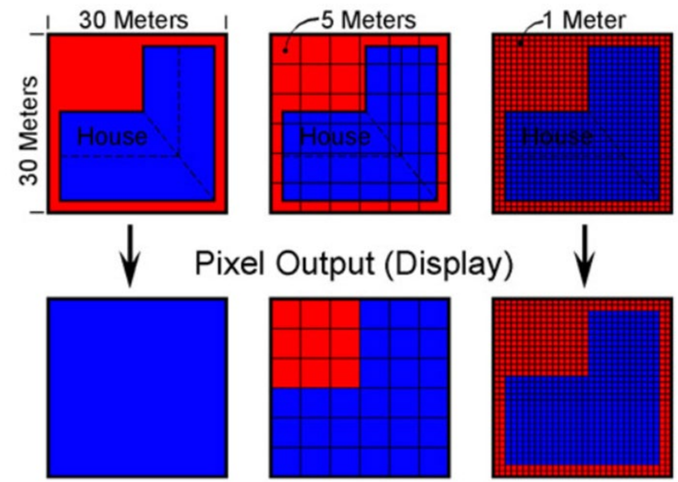
- **Temporal Resolution**

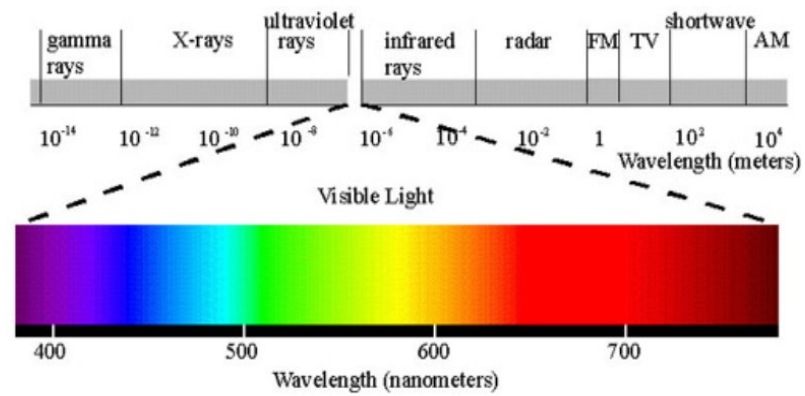
The temporal resolution specifies the revisiting frequency of a satellite sensor for a specific location.

- **Spectral Resolution**

The number of spectral bands in which the sensor can collect reflected radiance.

But also the position of bands in the electromagnetic spectrum.





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Cloud percentage	Percentage of the image covered by clouds
Ground sample distance	The distance in meters between pixel centers measured on the ground
Pixel Resolution	Pixel resolution of the image in meters
Off-nadir angle	Spacecraft across-track off-nadir viewing angle used for imaging, in degrees ("+" being East and "-" being West)
Sun elevation	Elevation angle of the sun in degrees (0-90)
Sun azimuth	Angle from the true North to the sun vector projected on the horizontal plane in degrees (0-360)

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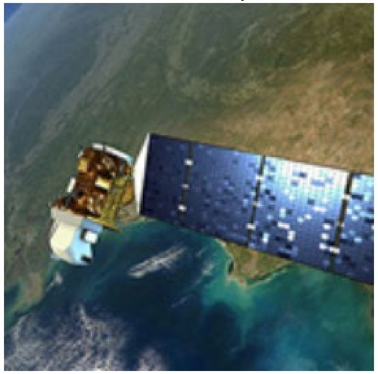
Landsat (30 - 15m)

1972 - Today

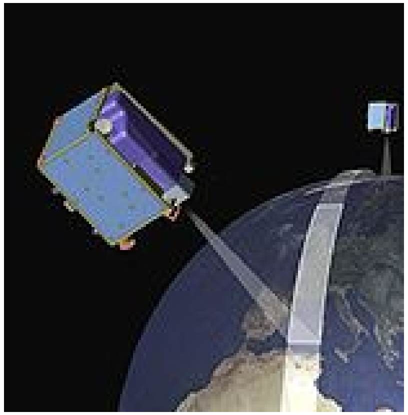


Sentinel 2 (10m)

2017 – Today

RapidEye (5m)

2009 – 2020



PlanetScope (3.6m)

2016 – Today

Kompsat (0.55m)

1999 – Today

WorldView (0.31m)

2007 – Today

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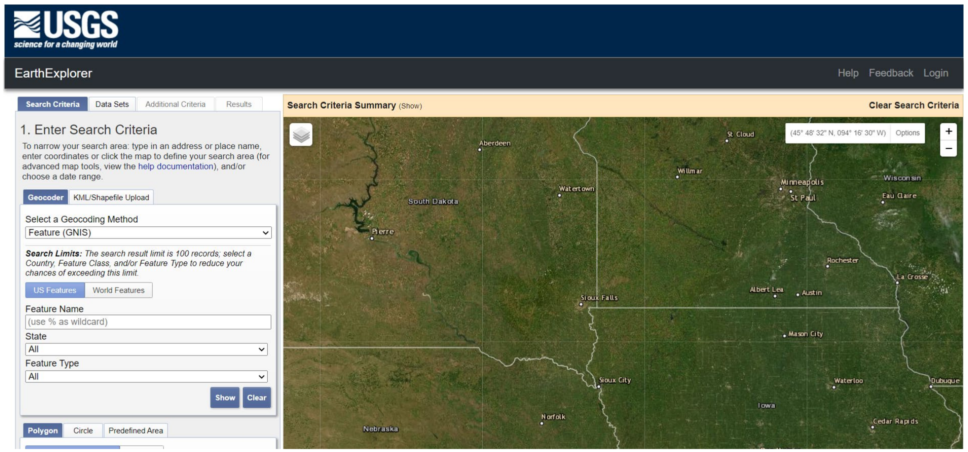
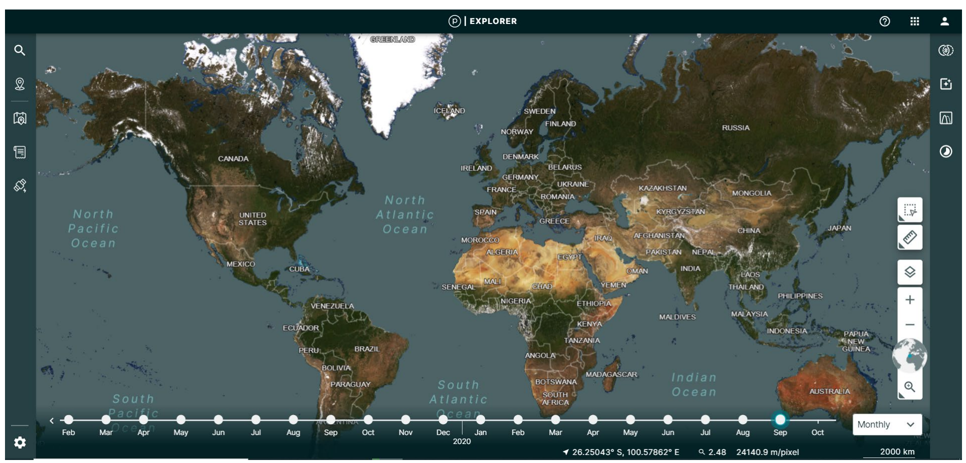
Open source databases for satellite images

Open source databases for satellite images

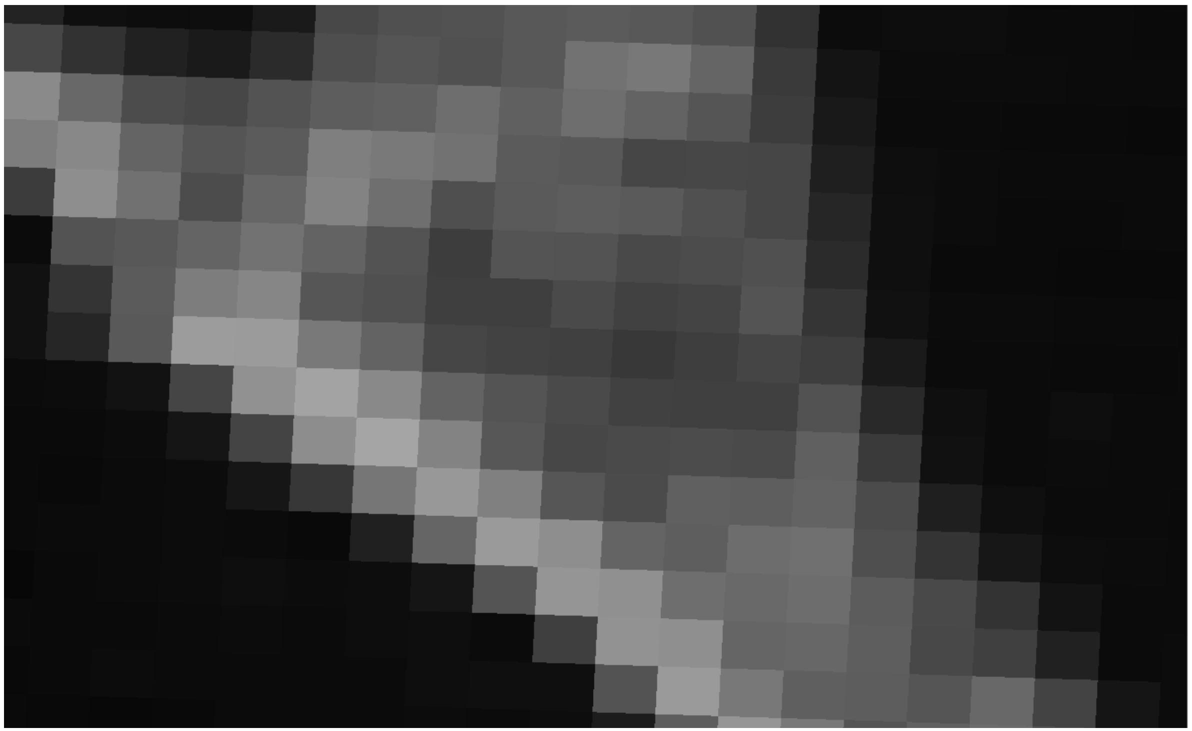


https://earthexplorer.usgs.gov/

https://scihub.copernicus.eu/dhus/



https://www.planet.com/explorer/



Earth Explorer

Landsat 5 ETM
- Spatial Resolution: 30m
- 1984 – 2013
- Number of Bands: 7

Landsat 7 (ETM+)
- Spatial Resolution: 15, 30, 60m
- 1999 – Still active
- Number of Bands: 8

Landsat 8 (OLI)
- Spatial Resolution: 15, 30, 60m
- 2013 - Still active
- Number of Bands: 11

Copernicus Hub

Sentinel 2A & 2B

- Spatial Resolution: 10, 20, 60m
- 2015 – Still active
- Number of Bands: 13
- Number of Satellites: 2

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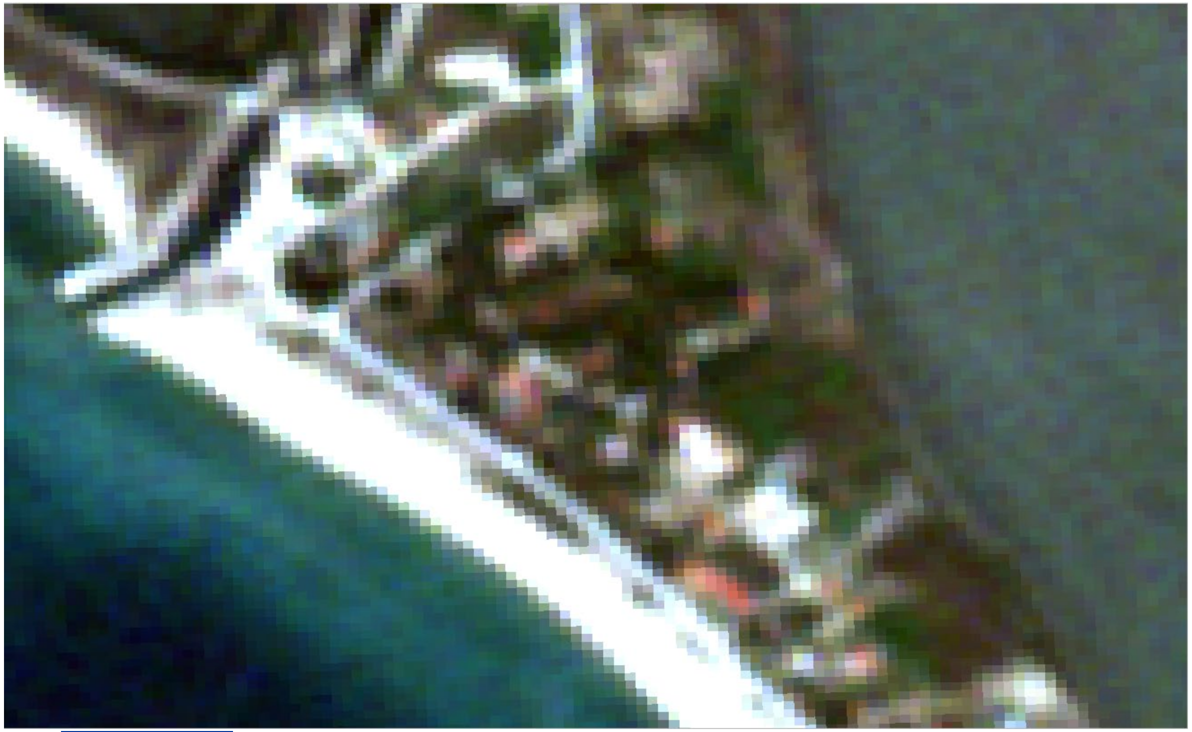
Planet Explorer



RapidEye

- Spatial Resolution: 5 m
- 2009 – March 2020
- Number of Bands: 5
- Number of Satellites: 5

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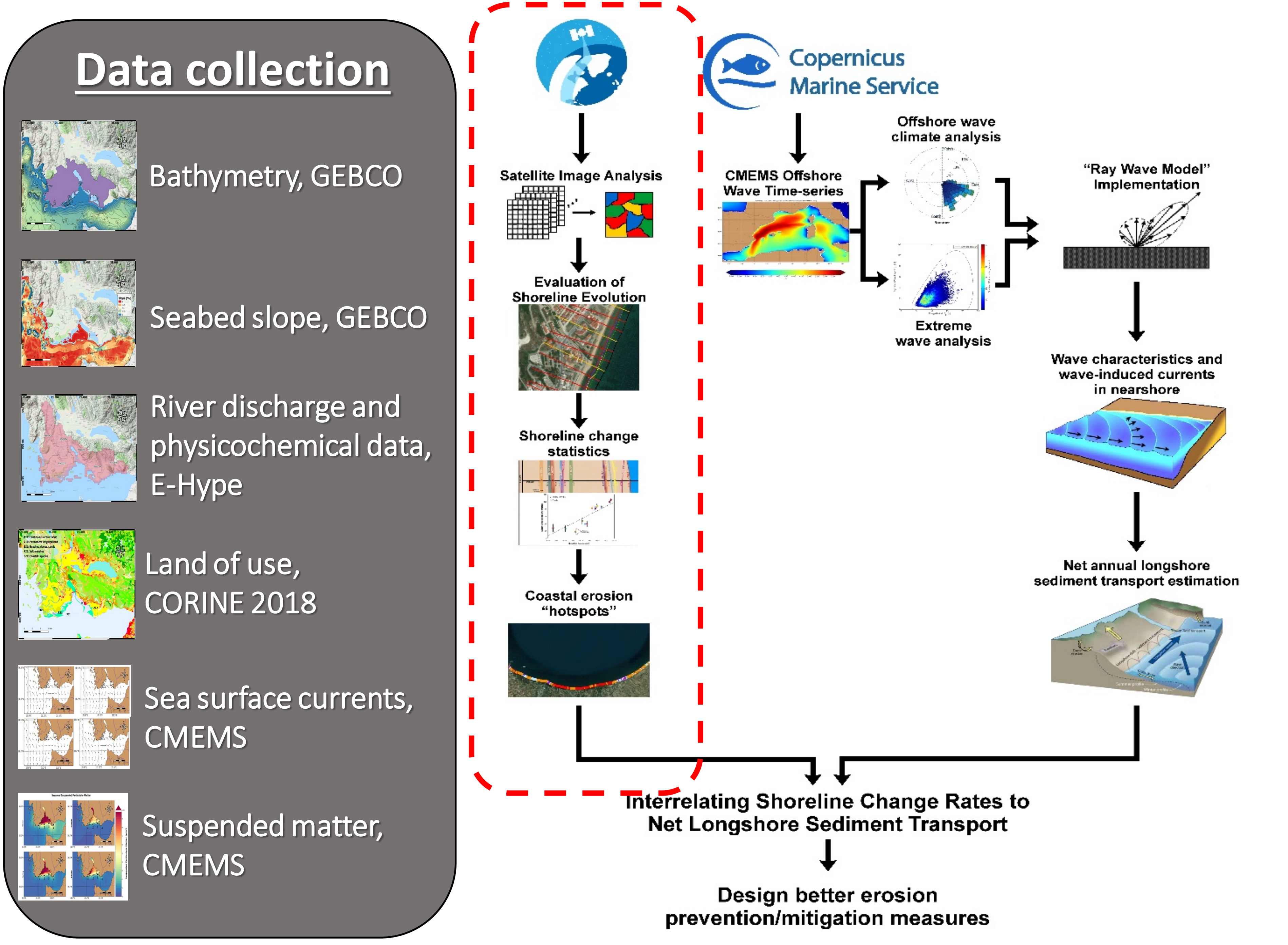
Planet Explorer

PlanetScope

- Spatial Resolution: 3.6 m
- 2016 – Still active
- Number of Bands: 4
- Number of Satellites: more than 120 optical satellites

Methodology applied in a coastal erosion assessment


Data collection
Bathymetry, GEBCO
Seabed slope, GEBCO
River discharge and physicochemical data, E-Hype
Land of use, CORINE 2018
Sea surface currents, CMEMS
Suspended matter, CMEMS
Copernicus Marine Service
Satellite Image Analysis
Evaluation of Shoreline Evolution
Shoreline change statistics
Coastal erosion "hotspots"
CMEMS Offshore Wave Time-series
Offshore wave climate analysis
Extreme wave analysis
"Ray Wave Model" Implementation
Wave characteristics and wave-induced currents in nearshore
Net annual longshore sediment transport estimation
Interrelating Shoreline Change Rates to Net Longshore Sediment Transport
Design better erosion prevention/mitigation measures

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Shoreline Extraction

Image selection should be based on:

- **Clarity** from cloud cover
- The correct **geo-reference**
- The **seasonality** (all images retrieved in the summer months)
- **Sea surface height** (CMEMS data)

The **NDWI** value is used to produce a binary classification of **water** vs. **non-water**. As water bodies strongly absorb light in the visible to the infrared electromagnetic spectrum, NDWI uses **green** and **near-infrared** bands to highlight water bodies. The formula for calculating NDWI according to McFeeters (1996) is

$$NDWI = \frac{(GREEN - NIR)}{(GREEN + NIR)}$$

NDWI is a very useful index in Remote Sensing:

- Crop health monitoring,
- Land / sea interface mapping,
- Inland water detection

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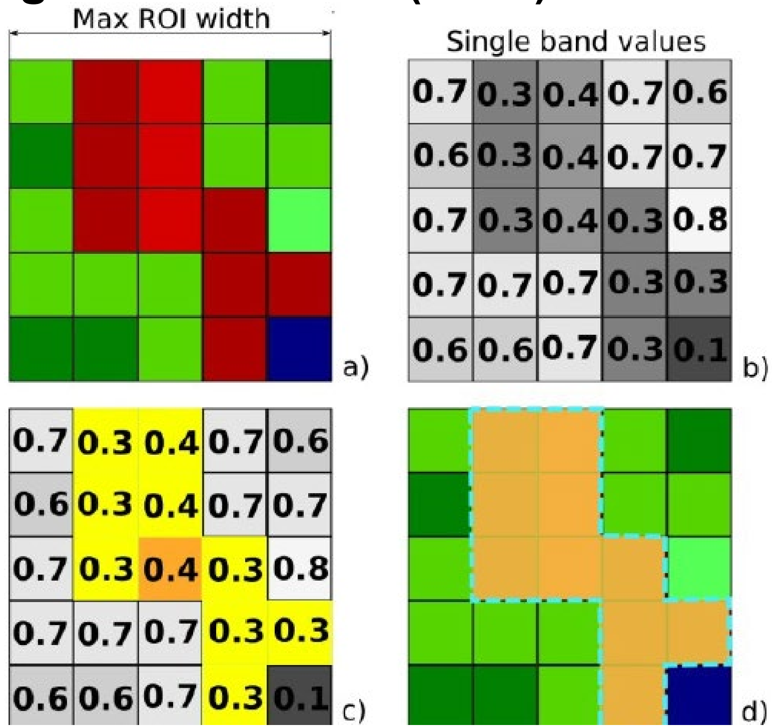
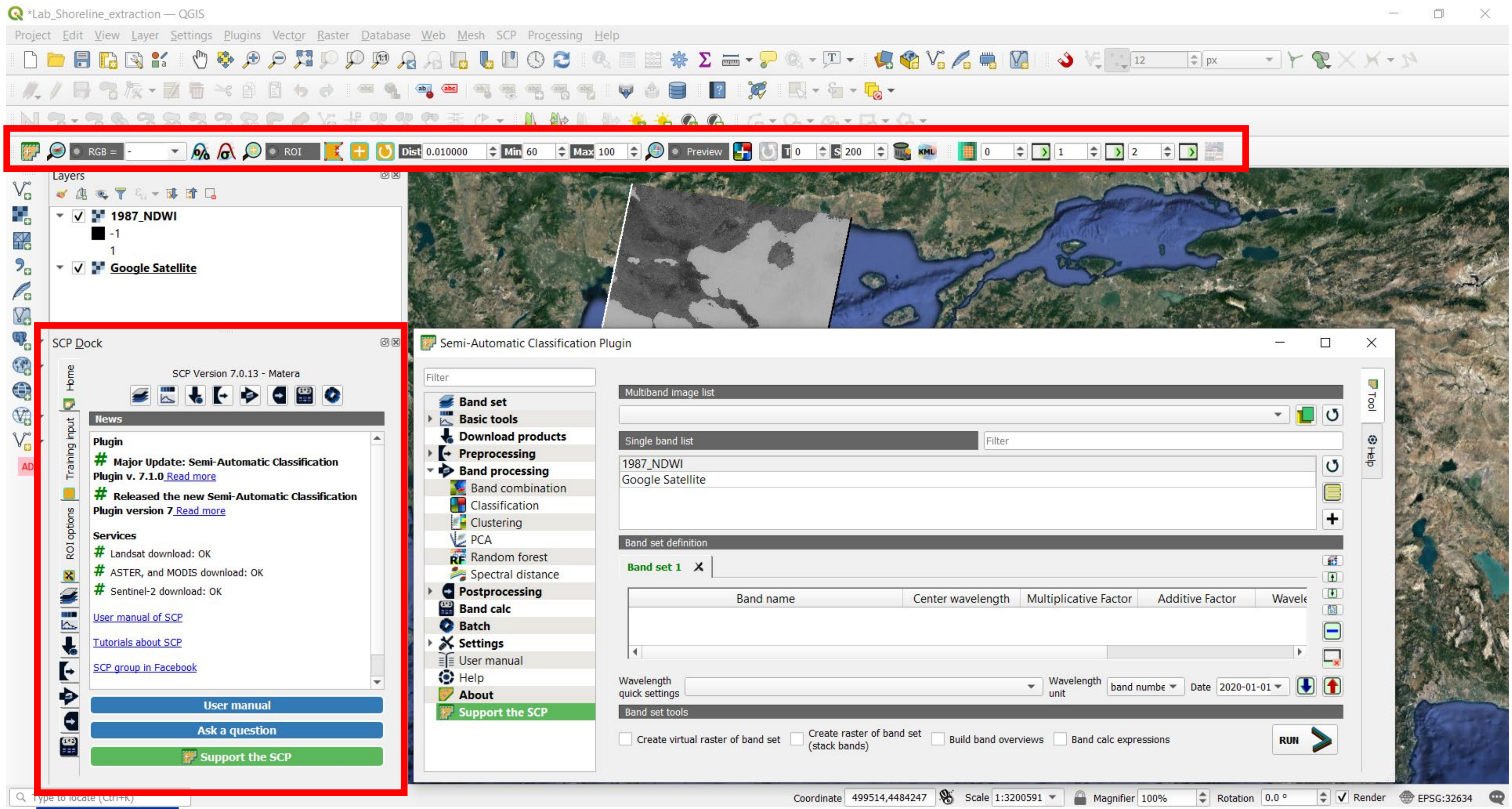
Semi-automatic classification (Supervised Classification) is an image processing technique that identifies the pixels of an image according to their spectral identity (spectral ID).

- **Training Areas - Regions of Interest (ROIs)**

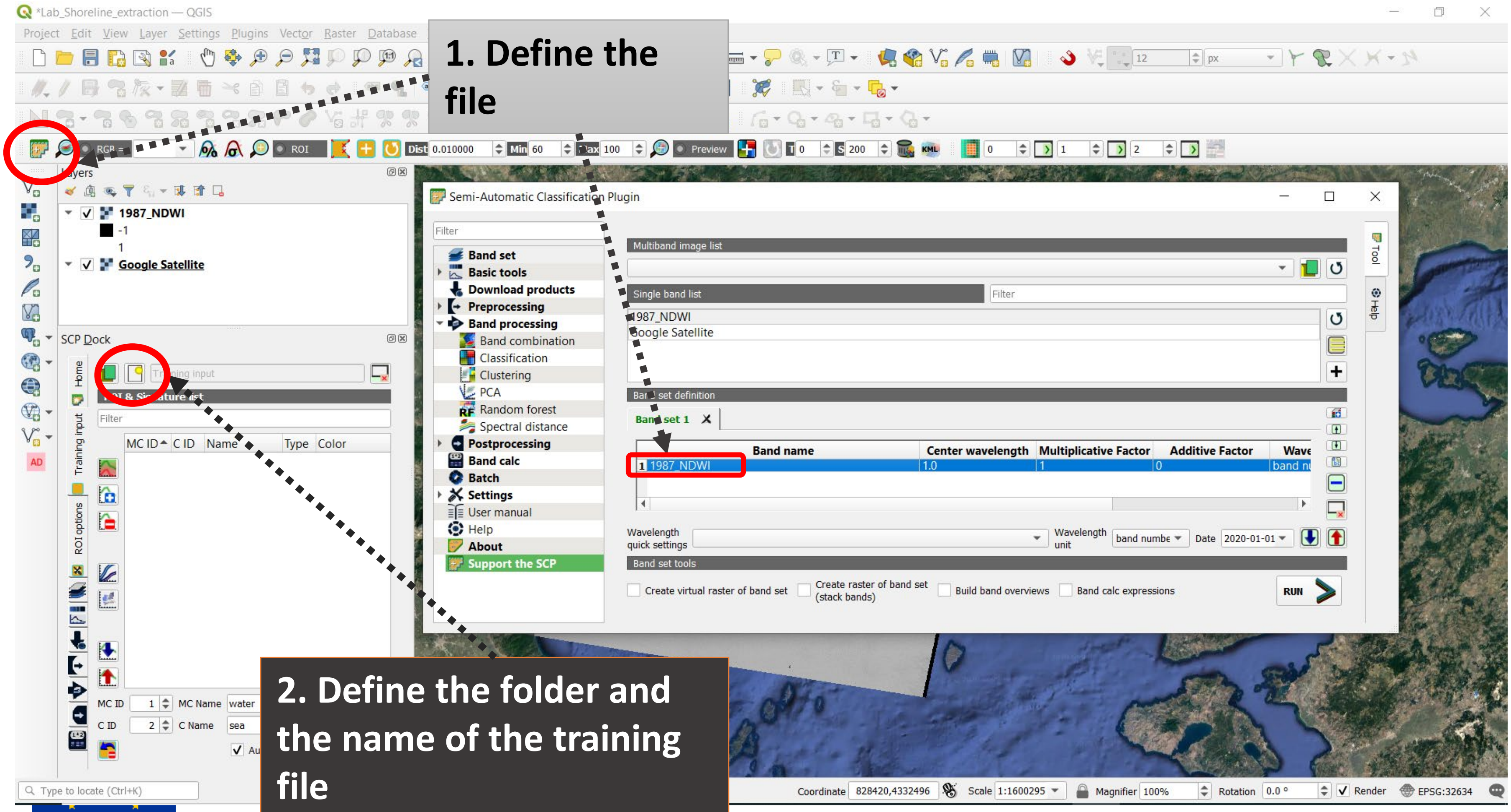


ODYSSEA



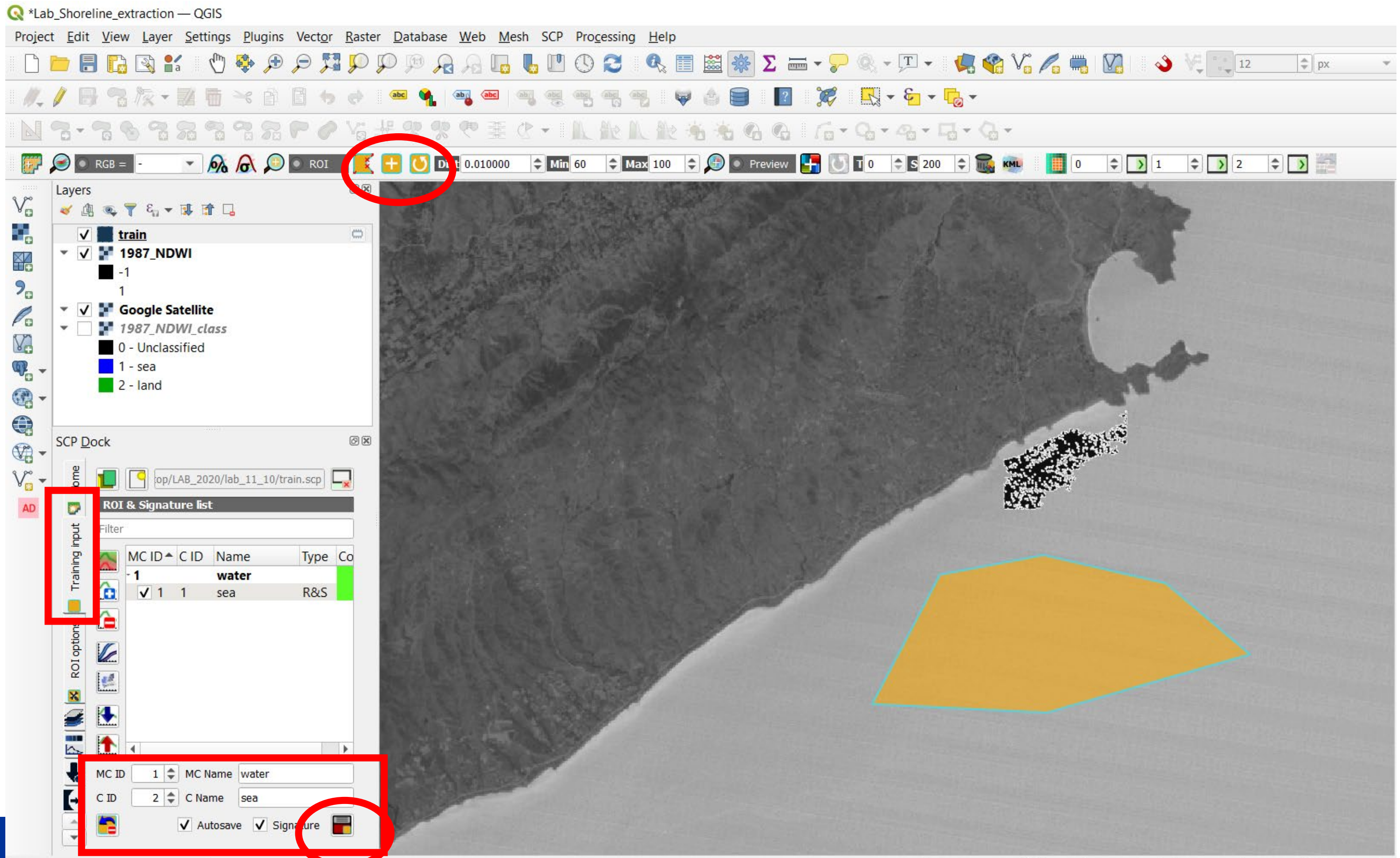
*Lab_Shoreline_extraction — QGIS
Project Edit View Layer Settings Plugins Vector Raster Database Web Mesh SCP Processing Help
RGB = ROI Dist 0.010000 Min 60 Max 100 Preview T 0 S 200
Layers
1987_NDWI
-1
1
Google Satellite
SCP Dock
SCP Version 7.0.13 - Matera
News
Plugin
Major Update: Semi-Automatic Classification Plugin v. 7.1.0 Read more
Released the new Semi-Automatic Classification Plugin version 7 Read more
Services
Landsat download: OK
ASTER, and MODIS download: OK
Sentinel-2 download: OK
User manual of SCP
Tutorials about SCP
SCP group in Facebook
User manual
Ask a question
Support the SCP
Home
Training input
ROI options
Semi-Automatic Classification Plugin
Filter
Band set
Basic tools
Download products
Preprocessing
Band processing
Band combination
Classification
Clustering
PCA
Random forest
Spectral distance
Postprocessing
Band calc
Batch
Settings
User manual
Help
About
Support the SCP
Multiband image list
Single band list
1987_NDWI
Google Satellite
Band set definition
Band set 1
Band name
Center wavelength
Multiplicative Factor
Additive Factor
Wavelength quick settings
Wavelength unit
band number
Date 2020-01-01
Band set tools
Create virtual raster of band set
Create raster of band set (stack bands)
Build band overviews
Band calc expressions
RUN
Tool
Help
Type to locate (Ctrl+K)
Coordinate 499514,4484247
Scale 1:3200591
Magnifier 100%
Rotation 0.0 °
Render
EPSG:32634

ODYSSEA

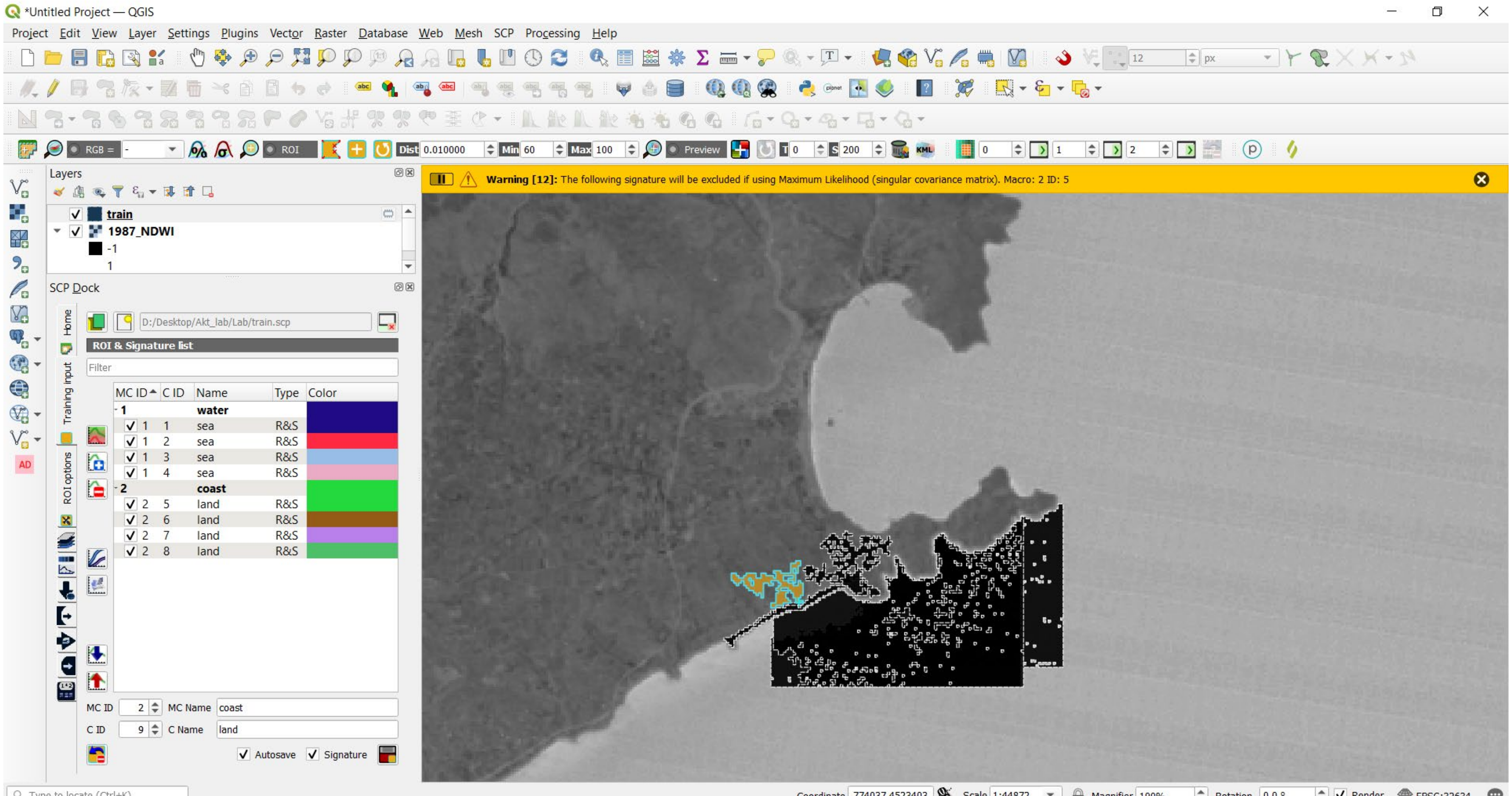


*Lab_Shoreline_extraction — QGIS
Project Edit View Layer Settings Plugins Vector Raster Database
1. Define the file
Layers
1987_NDWI
-1
1
Google Satellite
SCP Dock
ROI & Signature list
Filter
MC ID C ID Name Type Color
MC ID 1 MC Name water
C ID 2 C Name sea
Semi-Automatic Classification Plugin
Filter
Band set
Basic tools
Download products
Preprocessing
Band processing
Band combination
Classification
Clustering
PCA
Random forest
Spectral distance
Postprocessing
Band calc
Batch
Settings
User manual
Help
About
Support the SCP
Multiband image list
Single band list
1987_NDWI
Google Satellite
Band set definition
Band set 1
Band name Center wavelength Multiplicative Factor Additive Factor
1987_NDWI 1.0 1 0
Wavelength quick settings
Wavelength unit
Date 2020-01-01
Band set tools
Create virtual raster of band set
Create raster of band set (stack bands)
Build band overviews
Band calc expressions
RUN
2. Define the folder and the name of the training file
Type to locate (Ctrl+K)
Coordinate 828420,4332496
Scale 1:1600295
Magnifier 100%
Rotation 0.0 °
Render
EPSG:32634

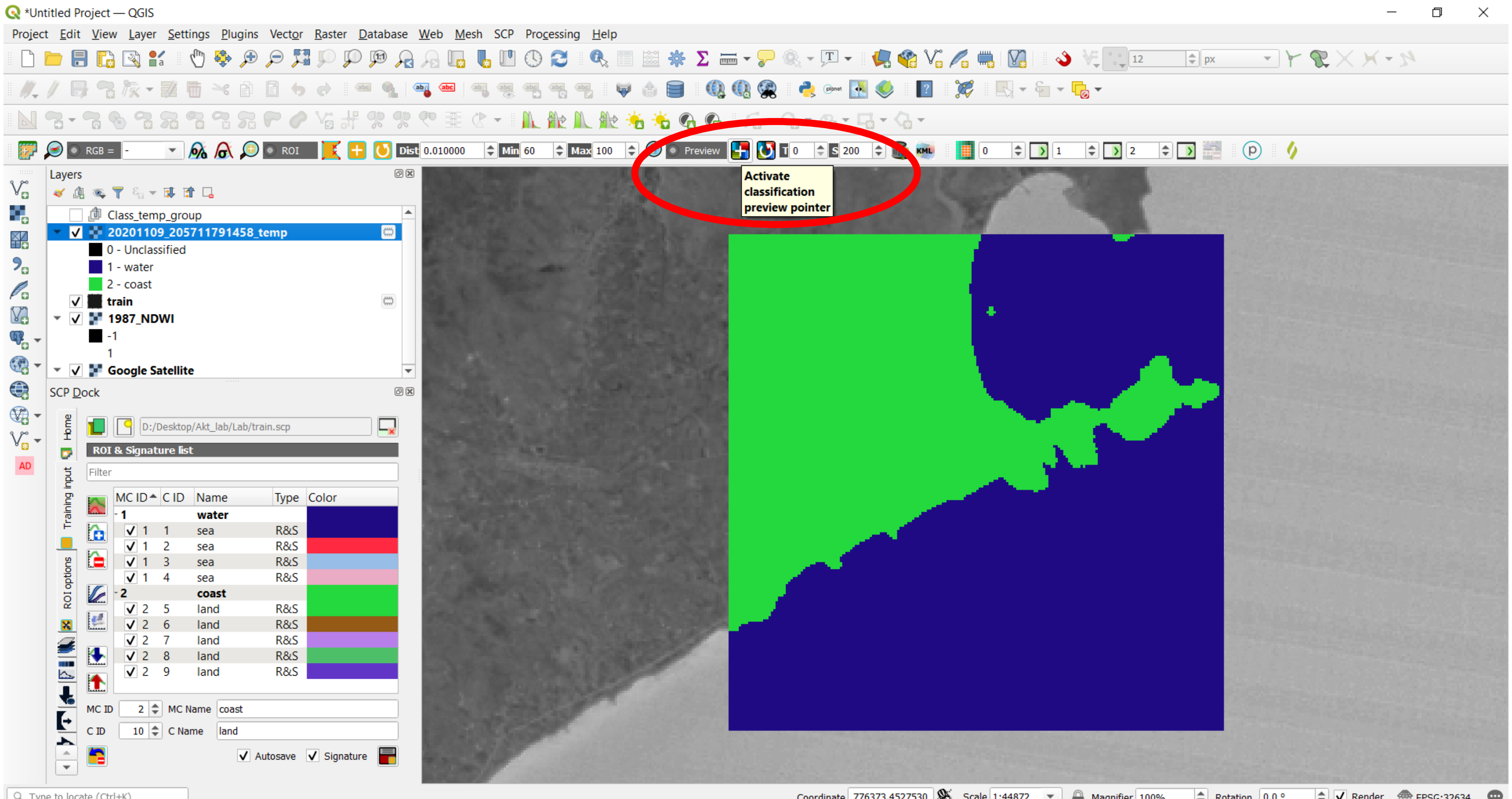
ODYSSEA


*Lab_Shoreline_extraction — QGIS
Project Edit View Layer Settings Plugins Vector Raster Database Web Mesh SCP Processing Help
RGB =
ROI
0.010000
Min 60
Max 100
Preview
S 200
Layers
train
1987_NDWI
-1
1
Google Satellite
1987_NDWI_class
0 - Unclassified
1 - sea
2 - land
SCP Dock
Training input
ROI options
ROI & Signature list
Filter
MC ID
C ID
Name
Type
1
water
1
1
sea
R&S
MC ID 1
MC Name water
C ID 2
C Name sea
Autosave
Signature

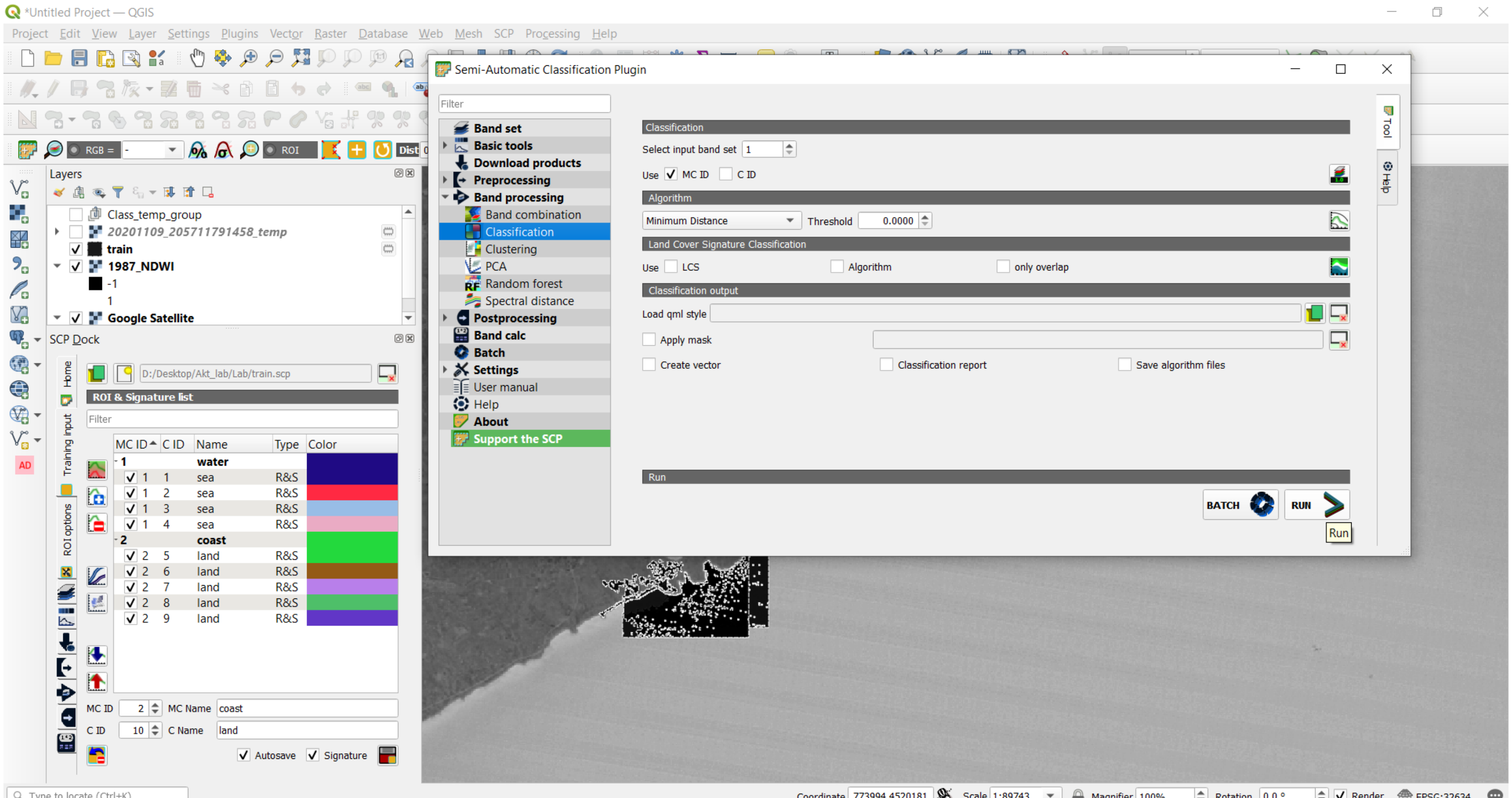
ODYSSEA


*Untitled Project — QGIS
Project Edit View Layer Settings Plugins Vector Raster Database Web Mesh SCP Processing Help
RGB = ROI Dist 0.010000 Min 60 Max 100 Preview T 0 S 200 0 1 2
Layers
train
1987_NDWI
-1
1
Warning [12]: The following signature will be excluded if using Maximum Likelihood (singular covariance matrix). Macro: 2 ID: 5
SCP Dock
D:/Desktop/Akt_lab/Lab/train.scp
ROI & Signature list
Filter
Home
Training input
ROI options
MC ID C ID Name Type Color
1 water
1 1 sea R&S
1 2 sea R&S
1 3 sea R&S
1 4 sea R&S
2 coast
2 5 land R&S
2 6 land R&S
2 7 land R&S
2 8 land R&S
MC ID 2 MC Name coast
C ID 9 C Name land
Autosave Signature
Type to locate (Ctrl+K)
Coordinate 774037,4523403 Scale 1:44872 Magnifier 100% Rotation 0.0 ° Render EPSG:32634

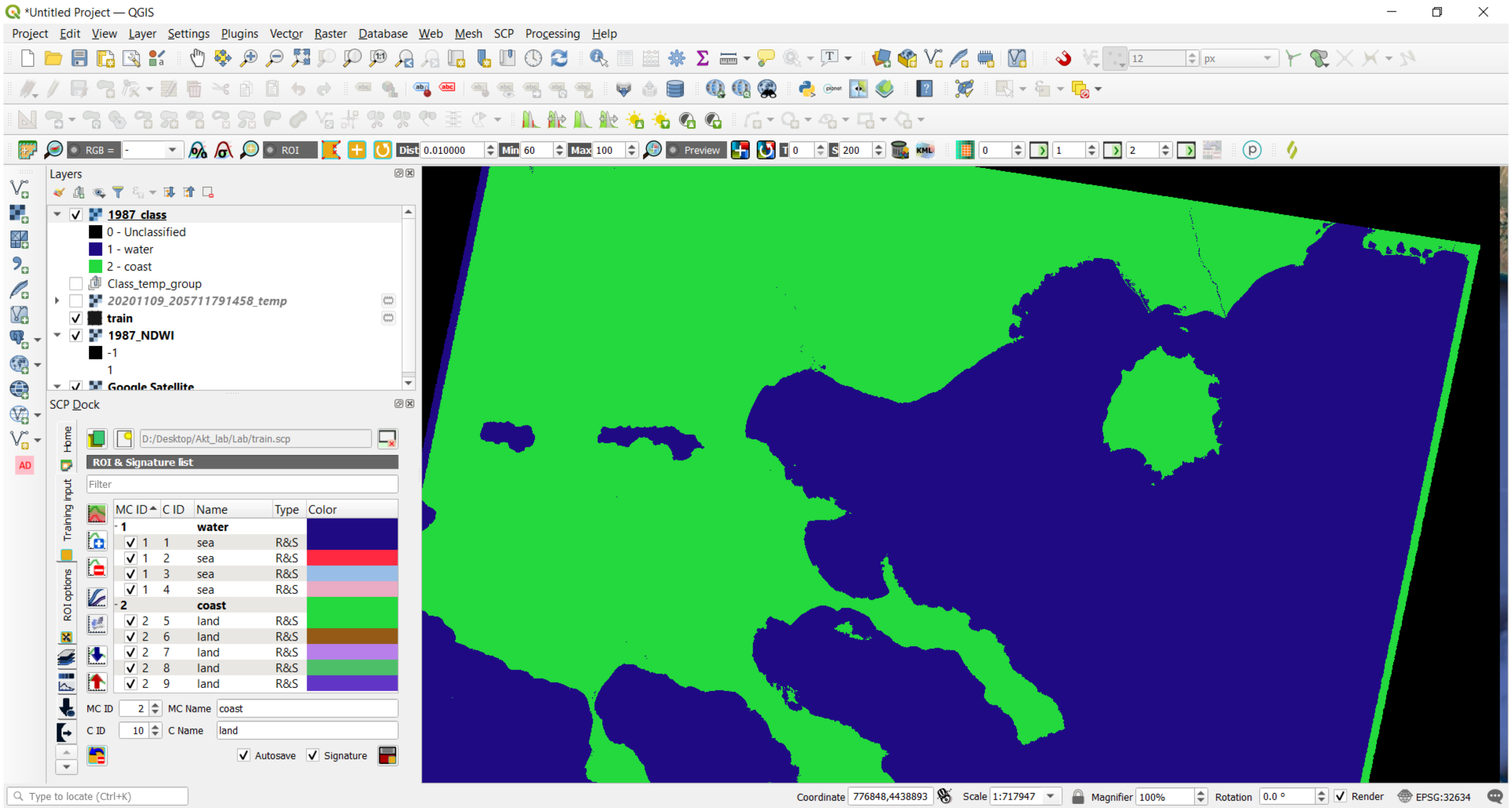
ODYSSEA


*Untitled Project — QGIS
Project Edit View Layer Settings Plugins Vector Raster Database Web Mesh SCP Processing Help
Activate classification preview pointer
Layers
Class_temp_group
20201109_205711791458_temp
0 - Unclassified
1 - water
2 - coast
train
1987_NDWI
-1
1
Google Satellite
SCP Dock
D:/Desktop/Akt_lab/Lab/train.scp
ROI & Signature list
Filter
MC ID C ID Name Type Color
1 water
1 1 sea R&S
1 2 sea R&S
1 3 sea R&S
1 4 sea R&S
2 coast
2 5 land R&S
2 6 land R&S
2 7 land R&S
2 8 land R&S
2 9 land R&S
MC ID 2 MC Name coast
C ID 10 C Name land
Autosave Signature
Type to locate (Ctrl+K)
Coordinate 776373,4527530
Scale 1:44872
Magnifier 100%
Rotation 0.0 °
Render
EPSG:32634

ODYSSEA

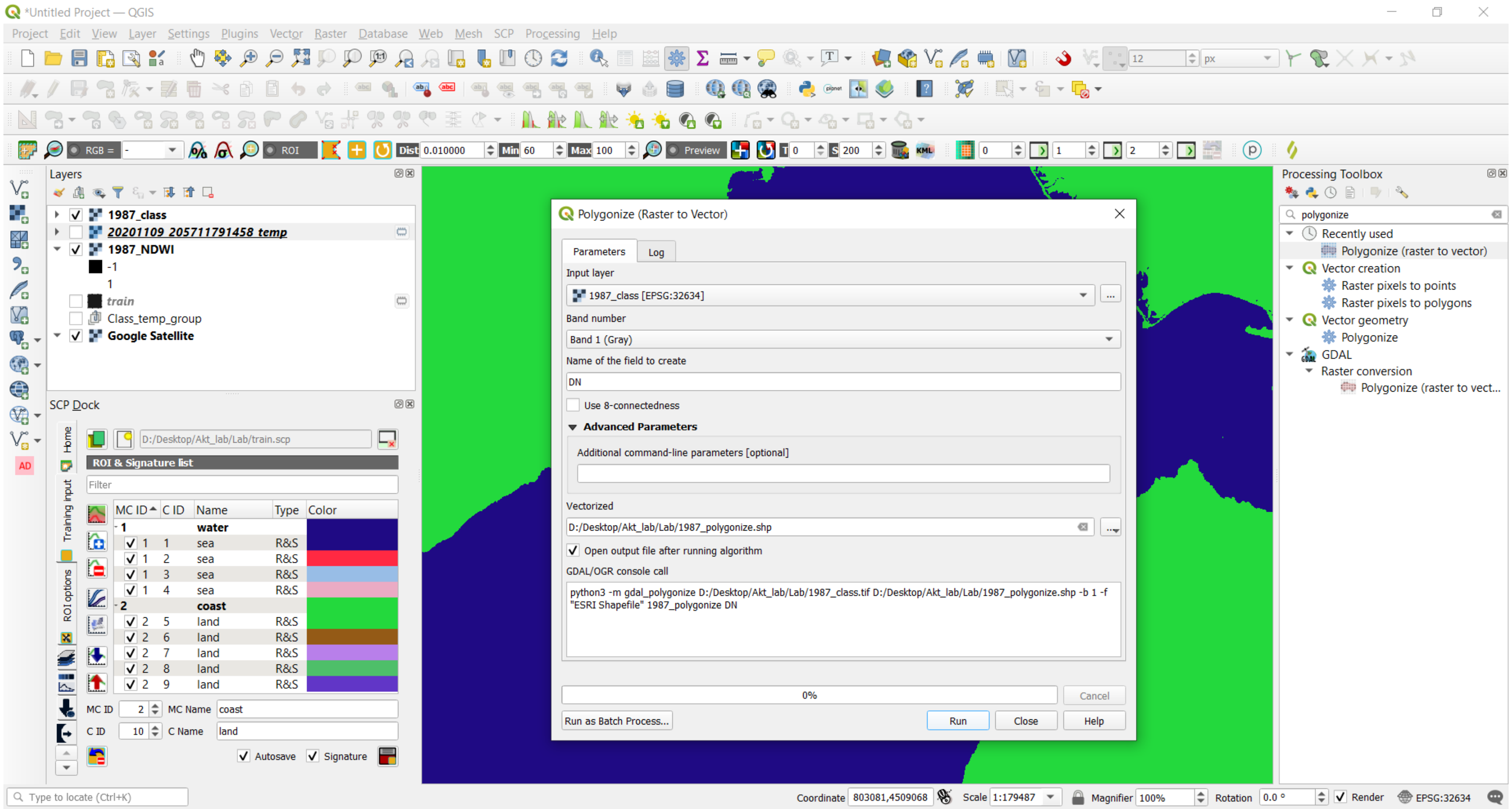

*Untitled Project — QGIS
Project Edit View Layer Settings Plugins Vector Raster Database Web Mesh SCP Processing Help
Semi-Automatic Classification Plugin
Band set
Basic tools
Download products
Preprocessing
Band processing
Band combination
Classification
Clustering
PCA
Random forest
Spectral distance
Postprocessing
Band calc
Batch
Settings
User manual
Help
About
Support the SCP
Classification
Select input band set 1
Use MC ID C ID
Algorithm
Minimum Distance
Threshold 0.0000
Land Cover Signature Classification
Use LCS Algorithm only overlap
Classification output
Load qml style
Apply mask
Create vector
Classification report
Save algorithm files
Run
BATCH
RUN
Layers
Class_temp_group
20201109_205711791458_temp
train
1987_NDWI
Google Satellite
SCP Dock
D:/Desktop/Akt_lab/Lab/train.scp
ROI & Signature list
MC ID C ID Name Type Color
1 water
1 1 sea R&S
1 2 sea R&S
1 3 sea R&S
1 4 sea R&S
2 coast
2 5 land R&S
2 6 land R&S
2 7 land R&S
2 8 land R&S
2 9 land R&S
MC ID 2 MC Name coast
C ID 10 C Name land
Autosave Signature
Type to locate (Ctrl+K)
Coordinate 773994,4520181
Scale 1:89743
Magnifier 100%
Rotation 0.0 °
Render
EPSG:32634

ODYSSEA

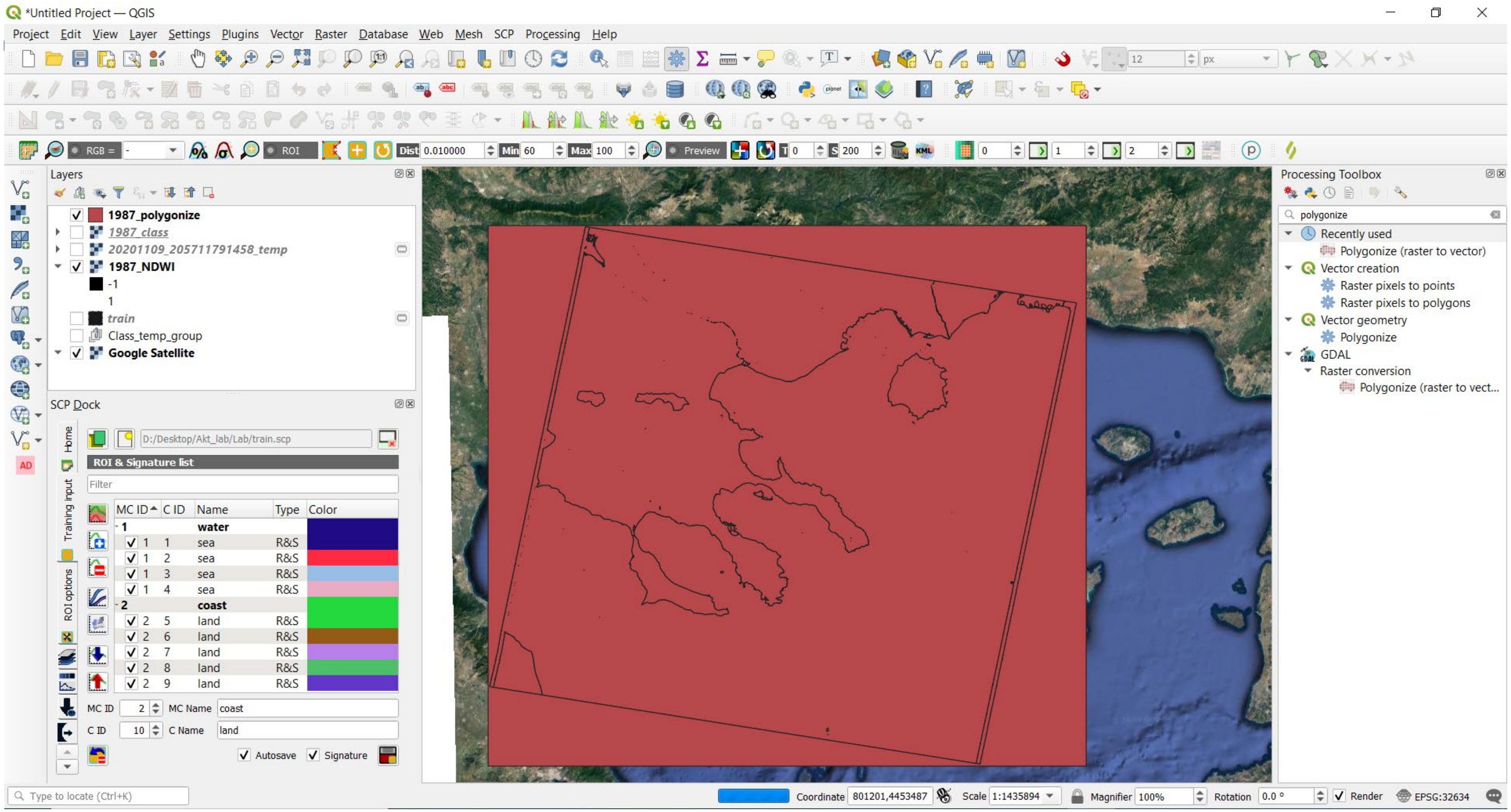


*Untitled Project — QGIS
Project Edit View Layer Settings Plugins Vector Raster Database Web Mesh SCP Processing Help
RGB =
ROI
Dist 0.010000
Min 60
Max 100
Preview
Layers
1987_class
0 - Unclassified
1 - water
2 - coast
Class_temp_group
20201109_205711791458_temp
train
1987_NDWI
-1
1
Google Satellite
SCP Dock
D:/Desktop/Akt_lab/Lab/train.scp
ROI & Signature list
Filter
MC ID C ID Name Type Color
1 water
1 1 sea R&S
1 2 sea R&S
1 3 sea R&S
1 4 sea R&S
2 coast
2 5 land R&S
2 6 land R&S
2 7 land R&S
2 8 land R&S
2 9 land R&S
MC ID 2 MC Name coast
C ID 10 C Name land
Autosave Signature
Home
Training input
ROI options
Type to locate (Ctrl+K)
Coordinate 776848,4438893
Scale 1:717947
Magnifier 100%
Rotation 0.0 °
Render
EPSG:32634

ODYSSEA

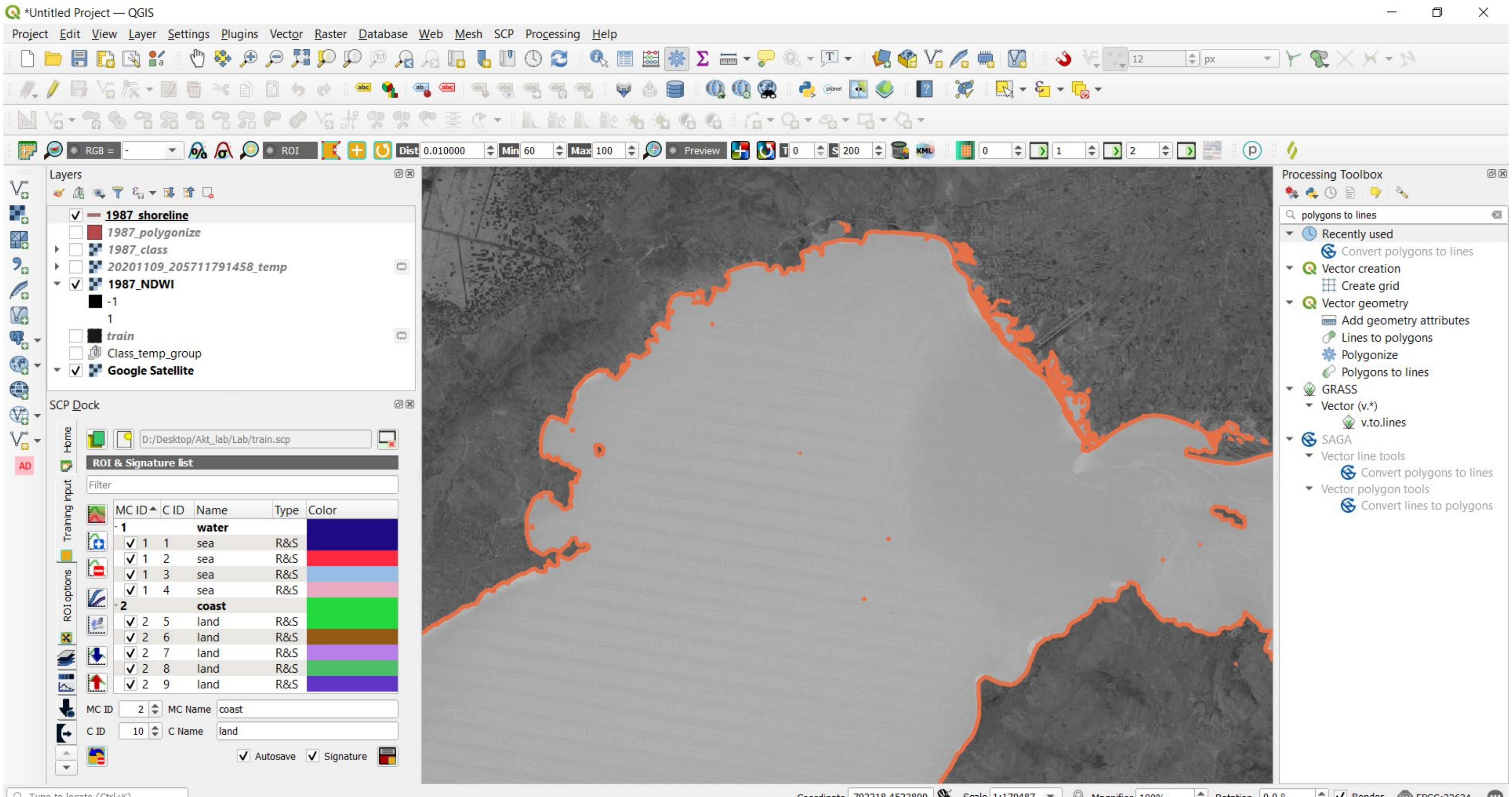


*Untitled Project — QGIS
Project Edit View Layer Settings Plugins Vector Raster Database Web Mesh SCP Processing Help
Layers
1987_class
20201109 205711791458 temp
1987_NDWI
-1
1
train
Class_temp_group
Google Satellite
SCP Dock
D:/Desktop/Akt_lab/Lab/train.scp
ROI & Signature list
MC ID C ID Name Type Color
1 water
1 1 sea R&S
1 2 sea R&S
1 3 sea R&S
1 4 sea R&S
2 coast
2 5 land R&S
2 6 land R&S
2 7 land R&S
2 8 land R&S
2 9 land R&S
MC ID 2 MC Name coast
C ID 10 C Name land
Autosave Signature
Polygonize (Raster to Vector)
Parameters Log
Input layer
1987_class [EPSG:32634]
Band number
Band 1 (Gray)
Name of the field to create
DN
Use 8-connectedness
Advanced Parameters
Additional command-line parameters [optional]
Vectorized
D:/Desktop/Akt_lab/Lab/1987_polygonize.shp
Open output file after running algorithm
GDAL/OGR console call
python3 -m gdal_polygonize D:/Desktop/Akt_lab/Lab/1987_class.tif D:/Desktop/Akt_lab/Lab/1987_polygonize.shp -b 1 -f "ESRI Shapefile" 1987_polygonize DN
0%
Cancel
Run as Batch Process...
Run Close Help
Processing Toolbox
polygonize
Recently used
Polygonize (raster to vector)
Vector creation
Raster pixels to points
Raster pixels to polygons
Vector geometry
Polygonize
GDAL
Raster conversion
Polygonize (raster to vect...
Type to locate (Ctrl+K)
Coordinate 803081,4509068 Scale 1:179487 Magnifier 100% Rotation 0.0 ° Render EPSG:32634



Convert the Polygons to Lines

ODYSSEA

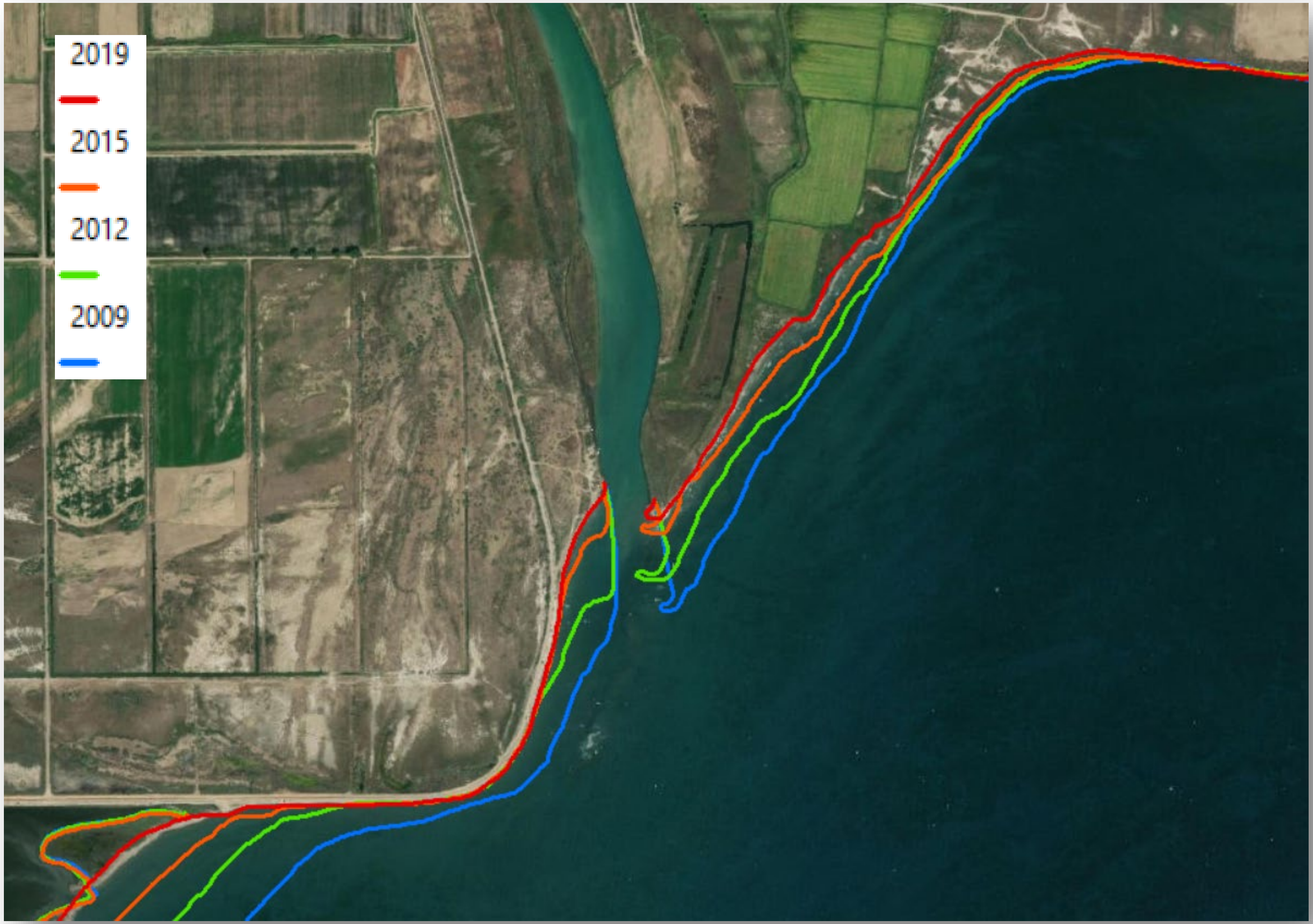


*Untitled Project — QGIS
Project Edit View Layer Settings Plugins Vector Raster Database Web Mesh SCP Processing Help
Layers
1987_shoreline
1987_polygonize
1987_class
20201109_205711791458_temp
1987_NDWI
-1
1
train
Class_temp_group
Google Satellite
SCP Dock
D:/Desktop/Akt_lab/Lab/train.scp
ROI & Signature list
Filter
MC ID C ID Name Type Color
1 water
1 1 sea R&S
1 2 sea R&S
1 3 sea R&S
1 4 sea R&S
2 coast
2 5 land R&S
2 6 land R&S
2 7 land R&S
2 8 land R&S
2 9 land R&S
MC ID 2 MC Name coast
C ID 10 C Name land
Autosave Signature
Processing Toolbox
polygons to lines
Recently used
Convert polygons to lines
Vector creation
Create grid
Vector geometry
Add geometry attributes
Lines to polygons
Polygonize
Polygons to lines
GRASS
Vector (v.*)
v.to.lines
SAGA
Vector line tools
Convert polygons to lines
Vector polygon tools
Convert lines to polygons
Type to locate (Ctrl+K)
Coordinate 792218,4523809 Scale 1:179487 Magnifier 100% Rotation 0.0 ° Render EPSG:32634

ODYSSEA

Name	Date modified	Type	Size
1987_class.qml	09-Nov-20 9:00 PM	QGIS Layer Settings	2 KB
1987_class.tif	09-Nov-20 9:00 PM	TIF File	940 KB
1987_polygonize.dbf	09-Nov-20 9:42 PM	DBF File	13 KB
1987_polygonize.prj	09-Nov-20 9:42 PM	PRJ File	1 KB
1987_polygonize.shp	09-Nov-20 9:42 PM	SHP File	2,001 KB
1987_polygonize.shx	09-Nov-20 9:42 PM	SHX File	10 KB
1987_shoreline.dbf	09-Nov-20 9:44 PM	DBF File	22 KB
1987_shoreline.mshp	09-Nov-20 9:44 PM	MSHP File	2 KB
1987_shoreline.prj	09-Nov-20 9:44 PM	PRJ File	1 KB
1987_shoreline.shp	09-Nov-20 9:44 PM	SHP File	2,001 KB
1987_shoreline.shx	09-Nov-20 9:44 PM	SHX File	10 KB
1987_shoreline_smooth.dbf	09-Nov-20 9:53 PM	DBF File	22 KB
1987_shoreline_smooth.prj	09-Nov-20 9:53 PM	PRJ File	1 KB
1987_shoreline_smooth.shp	09-Nov-20 9:53 PM	SHP File	3,859 KB
1987_shoreline_smooth.shx	09-Nov-20 9:53 PM	SHX File	10 KB
lab_test.qgz	09-Nov-20 8:38 PM	QGIS Project	3 KB
train.scp	09-Nov-20 8:51 PM	Text Document	3 KB

Historical shorelines

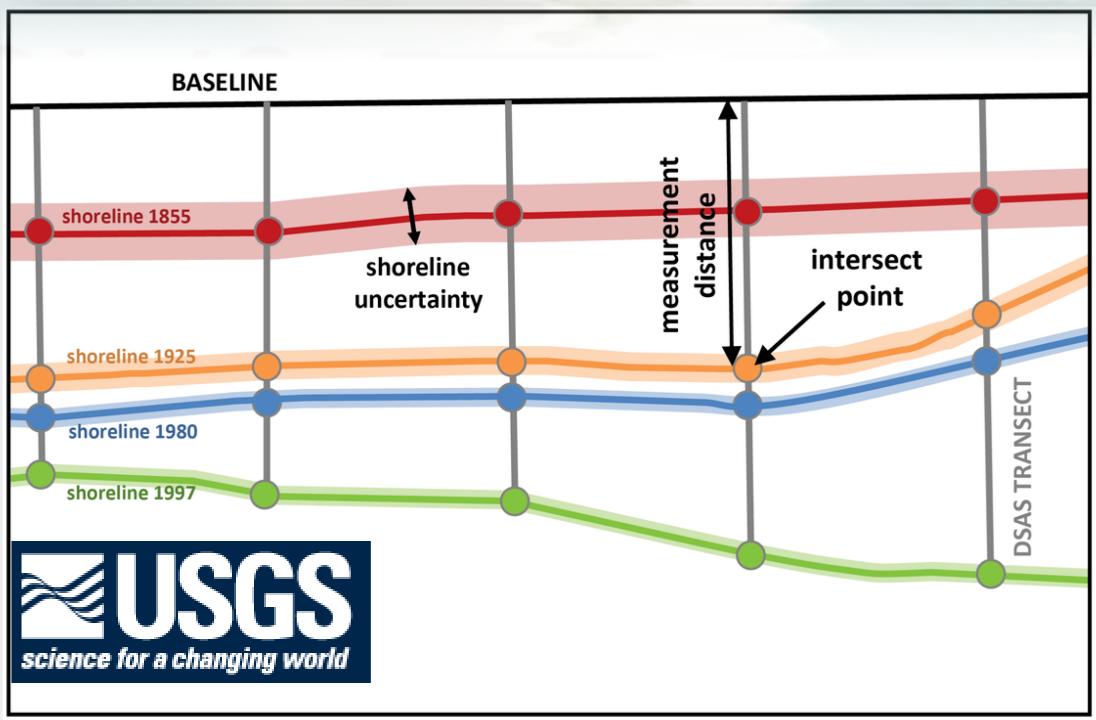


Evaluation of the Shoreline Evolution

Introduction in DSAS tool

ODYSSEA

DSAS
DIGITAL SHORELINE ANALYSIS SYSTEM



DSAS statistical parameters

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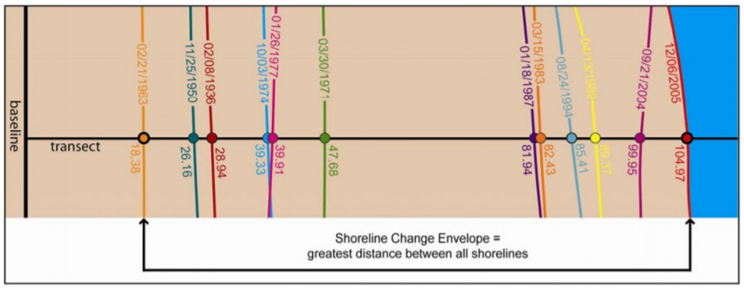
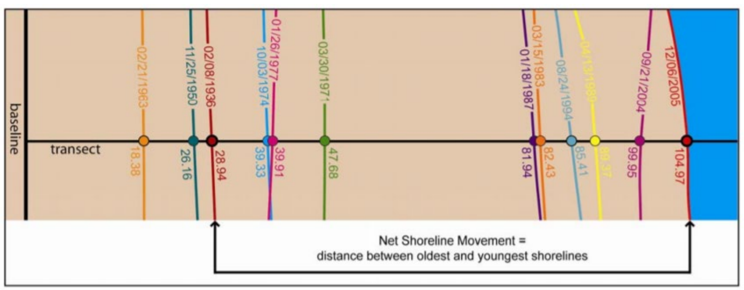
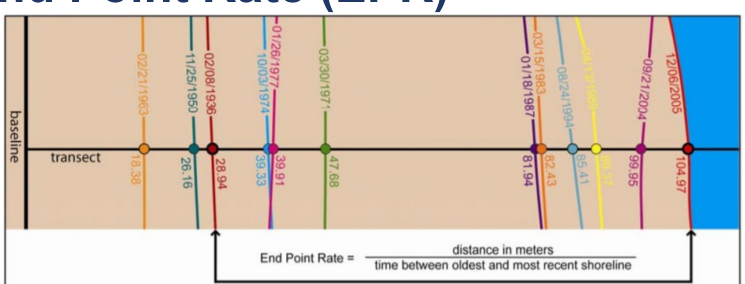
Shoreline Change Envelope (SCE)



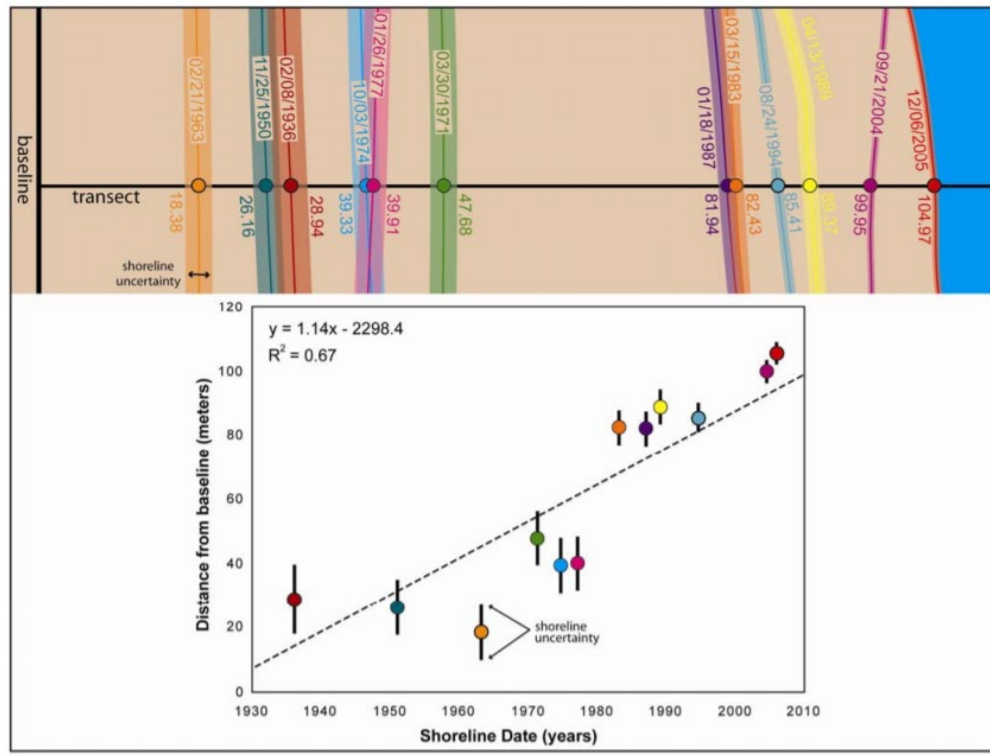
Net Shoreline Movement (NSM)



End Point Rate (EPR)



Weighted Linear Regression (WLR)



Methodology in steps - ArcMap & DSAS

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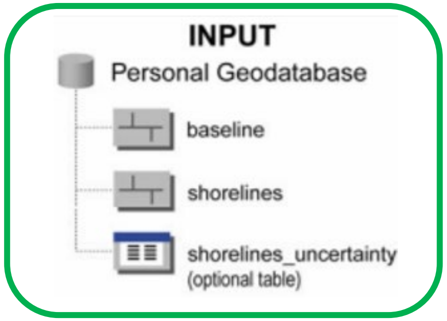
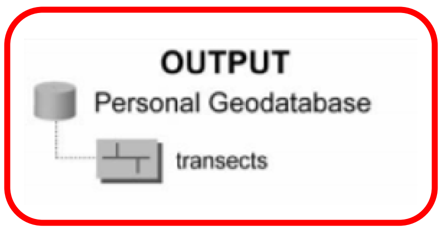
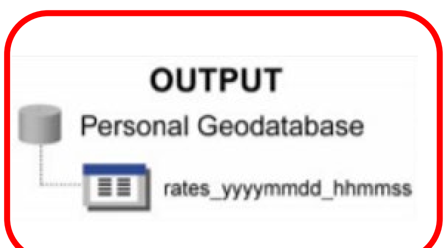






Step 1st : Import the shorelines In ArcMap

Step 2nd : Design a **baseline**

Step 3rd : Create a new **Personal Geodatadase (. mdb)**

Step 4th : Define the technical characteristics of the vertical **Transects** in DSAS toolbox

Step 5th : Edit **Transects**

Step 6th : Select the **Statistical Parameters**

Step 7th : **DSAS calculates and export** the results

Step 8th : Visualization of the results

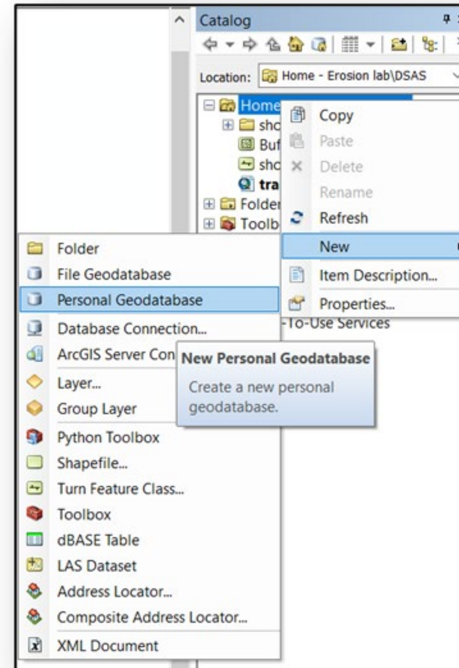
Step 9th : Post- processing of the results

Create a new Personal Geodatabase

ODYSSEA

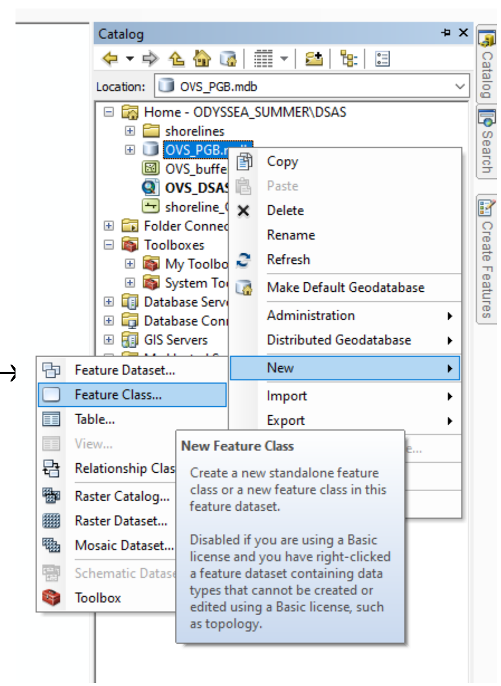
1. Create a new Personal Geodatabase

- **Catalog → New Personal Geodatabase**
- **Rename → OVS_PGB.mdb**



2. Create 2 Feature Classes (shoreline & baseline)

- **OVS_PGB.mdb** (Right click) → **New → Feature class…**



Create new Feature Classes for shorelines and baseline

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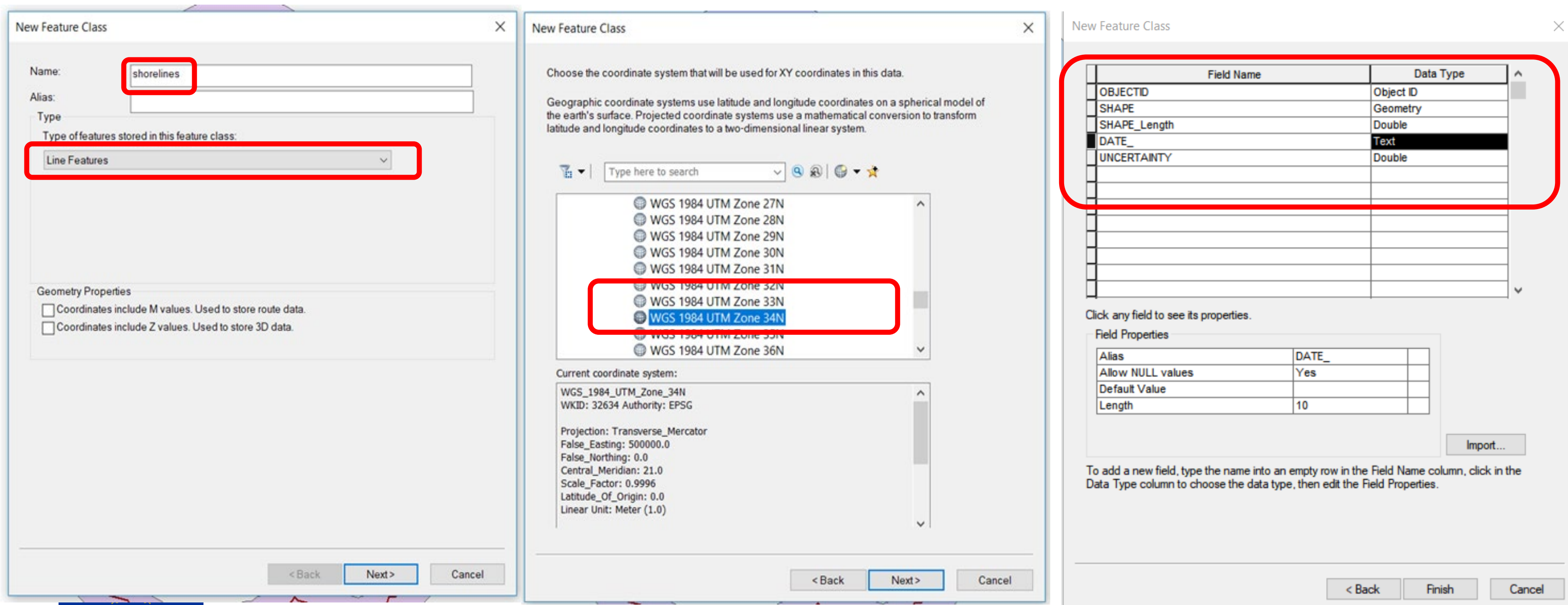
- In the Tab **Catalog** → **OVS_PGB.mdb** (right click) → **New** → **Feature class…**



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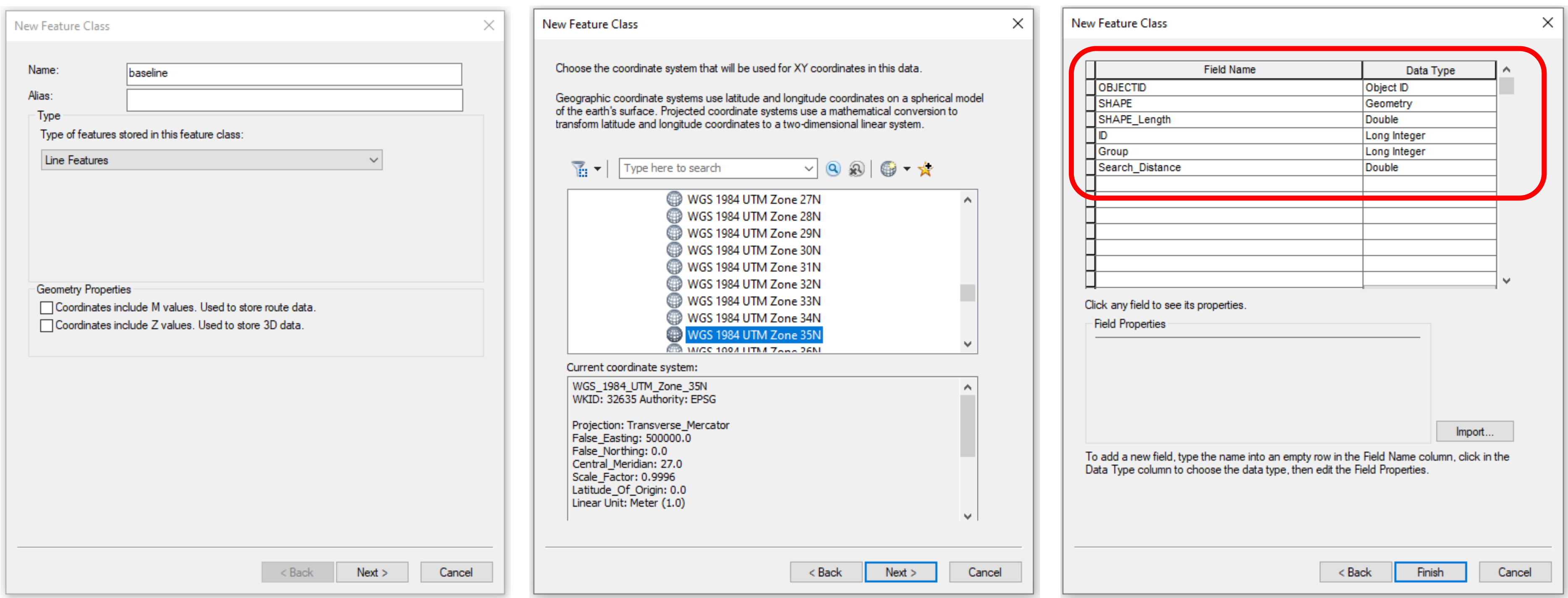

New Feature Class
Name: baseline
Alias:
Type
Type of features stored in this feature class:
Line Features
Geometry Properties
Coordinates include M values. Used to store route data.
Coordinates include Z values. Used to store 3D data.
< Back
Next >
Cancel
New Feature Class
Choose the coordinate system that will be used for XY coordinates in this data.
Geographic coordinate systems use latitude and longitude coordinates on a spherical model of the earth's surface. Projected coordinate systems use a mathematical conversion to transform latitude and longitude coordinates to a two-dimensional linear system.
Type here to search
WGS 1984 UTM Zone 27N
WGS 1984 UTM Zone 28N
WGS 1984 UTM Zone 29N
WGS 1984 UTM Zone 30N
WGS 1984 UTM Zone 31N
WGS 1984 UTM Zone 32N
WGS 1984 UTM Zone 33N
WGS 1984 UTM Zone 34N
WGS 1984 UTM Zone 35N
Current coordinate system:
WGS_1984_UTM_Zone_35N
WKID: 32635 Authority: EPSG
Projection: Transverse_Mercator
False_Easting: 500000.0
False_Northing: 0.0
Central_Meridian: 27.0
Scale_Factor: 0.9996
Latitude_Of_Origin: 0.0
Linear Unit: Meter (1.0)
< Back
Next >
Cancel
New Feature Class
Field Name
Data Type
OBJECTID
Object ID
SHAPE
Geometry
SHAPE_Length
Double
ID
Long Integer
Group
Long Integer
Search_Distance
Double
Click any field to see its properties.
Field Properties
Import...
To add a new field, type the name into an empty row in the Field Name column, click in the Data Type column to choose the data type, then edit the Field Properties.
< Back
Finish
Cancel

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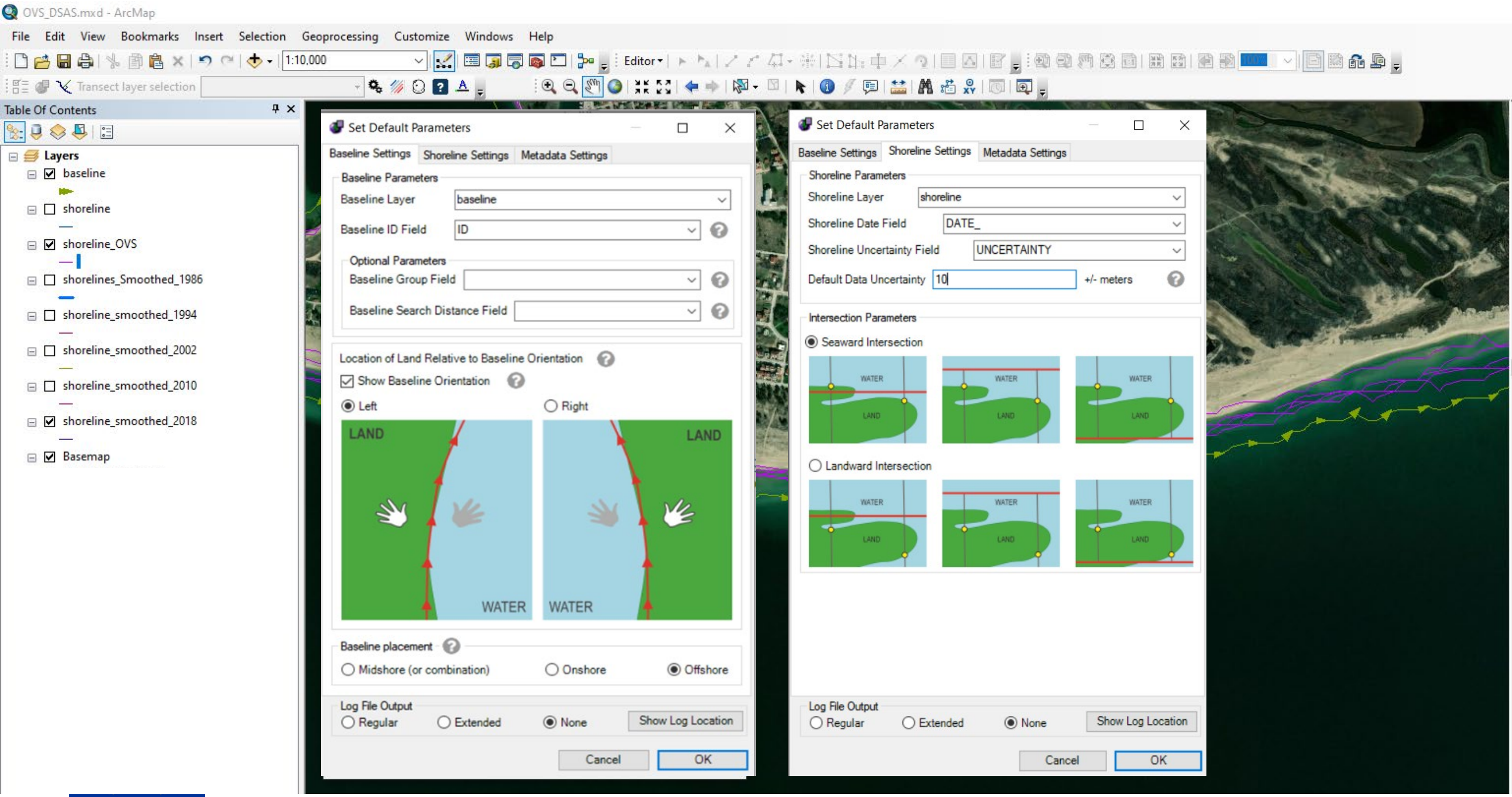

OVS_DSAS.mxd - ArcMap
File Edit View Bookmarks Insert Selection Geoprocessing Customize Windows Help
1:10,000
Editor
Transect layer selection
Table Of Contents
Layers
baseline
shoreline
shoreline_OVS
shorelines_Smoothed_1986
shoreline_smoothed_1994
shoreline_smoothed_2002
shoreline_smoothed_2010
shoreline_smoothed_2018
Basemap
Set Default Parameters
Baseline Settings
Shoreline Settings
Metadata Settings
Baseline Parameters
Baseline Layer
baseline
Baseline ID Field
ID
Optional Parameters
Baseline Group Field
Baseline Search Distance Field
Location of Land Relative to Baseline Orientation
Show Baseline Orientation
Left
Right
LAND
WATER
Baseline placement
Midshore (or combination)
Onshore
Offshore
Log File Output
Regular
Extended
None
Show Log Location
Cancel
OK
Shoreline Parameters
Shoreline Layer
shoreline
Shoreline Date Field
DATE_
Shoreline Uncertainty Field
UNCERTAINTY
Default Data Uncertainty
10
+/- meters
Intersection Parameters
Seaward Intersection
Landward Intersection

Transects creation in DSAS tool

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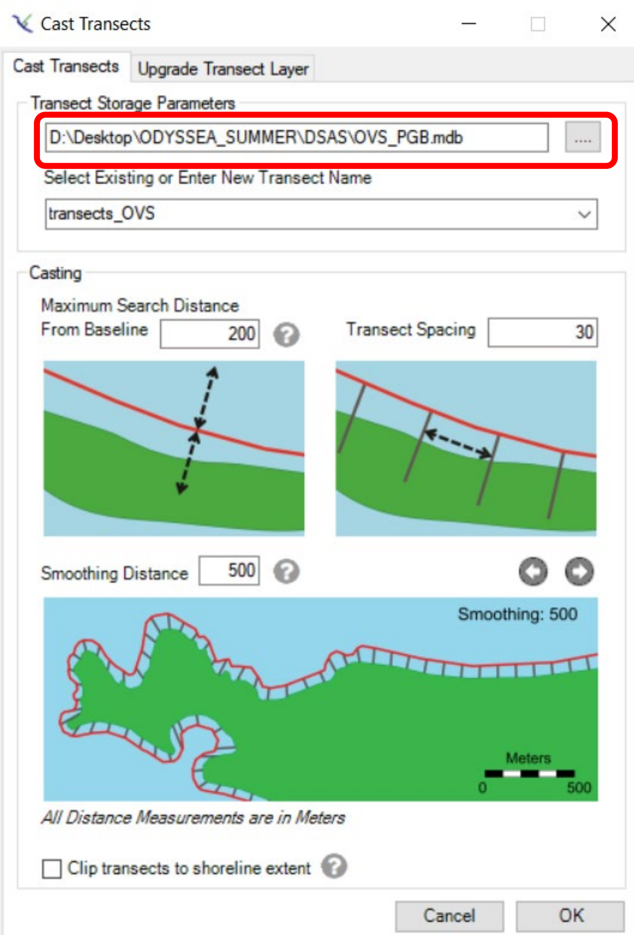
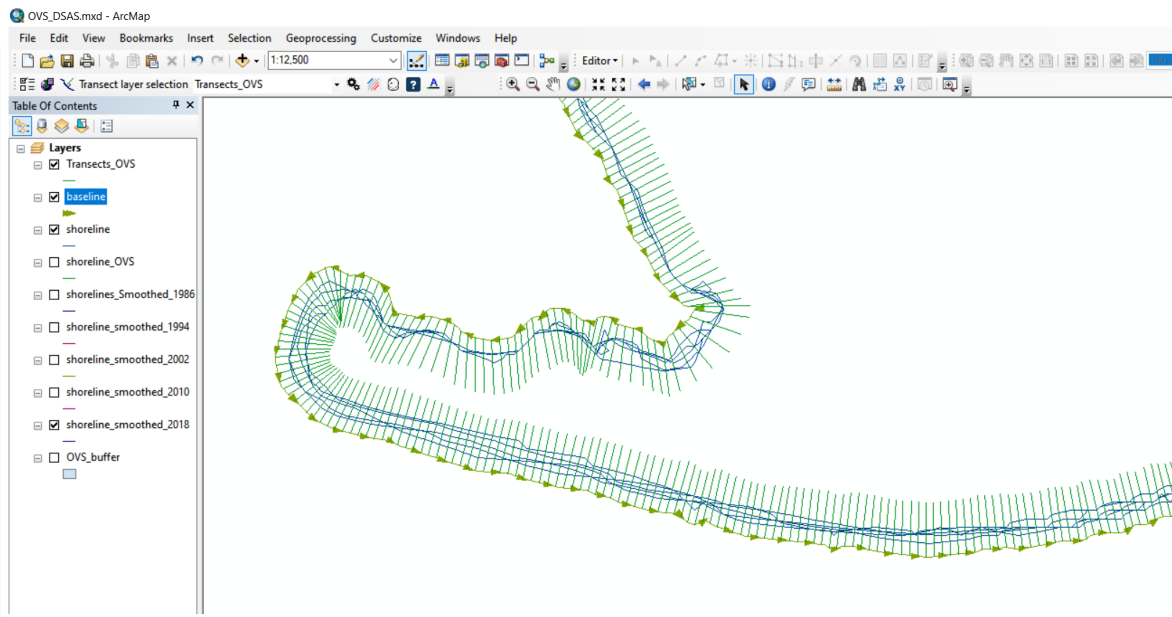
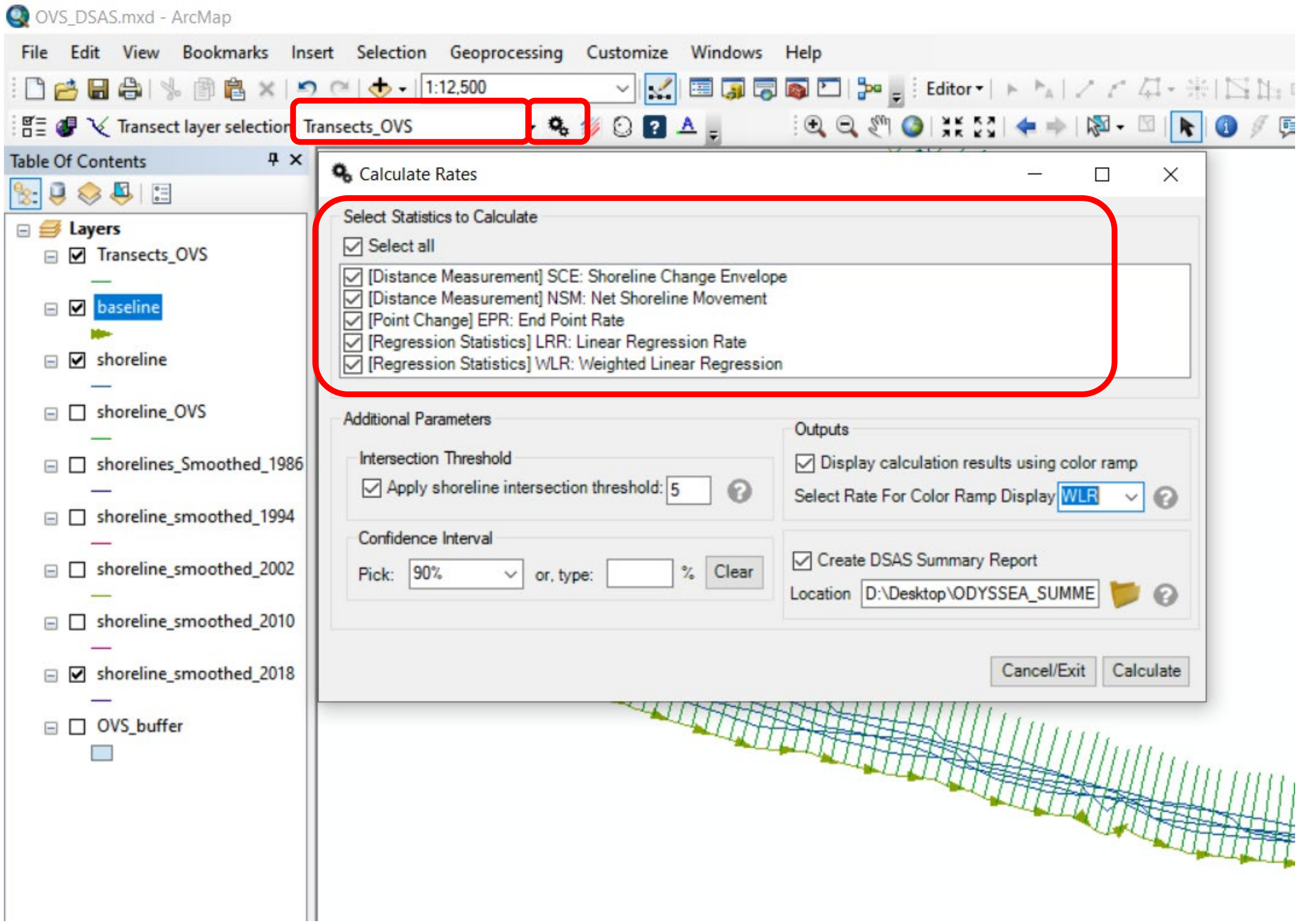




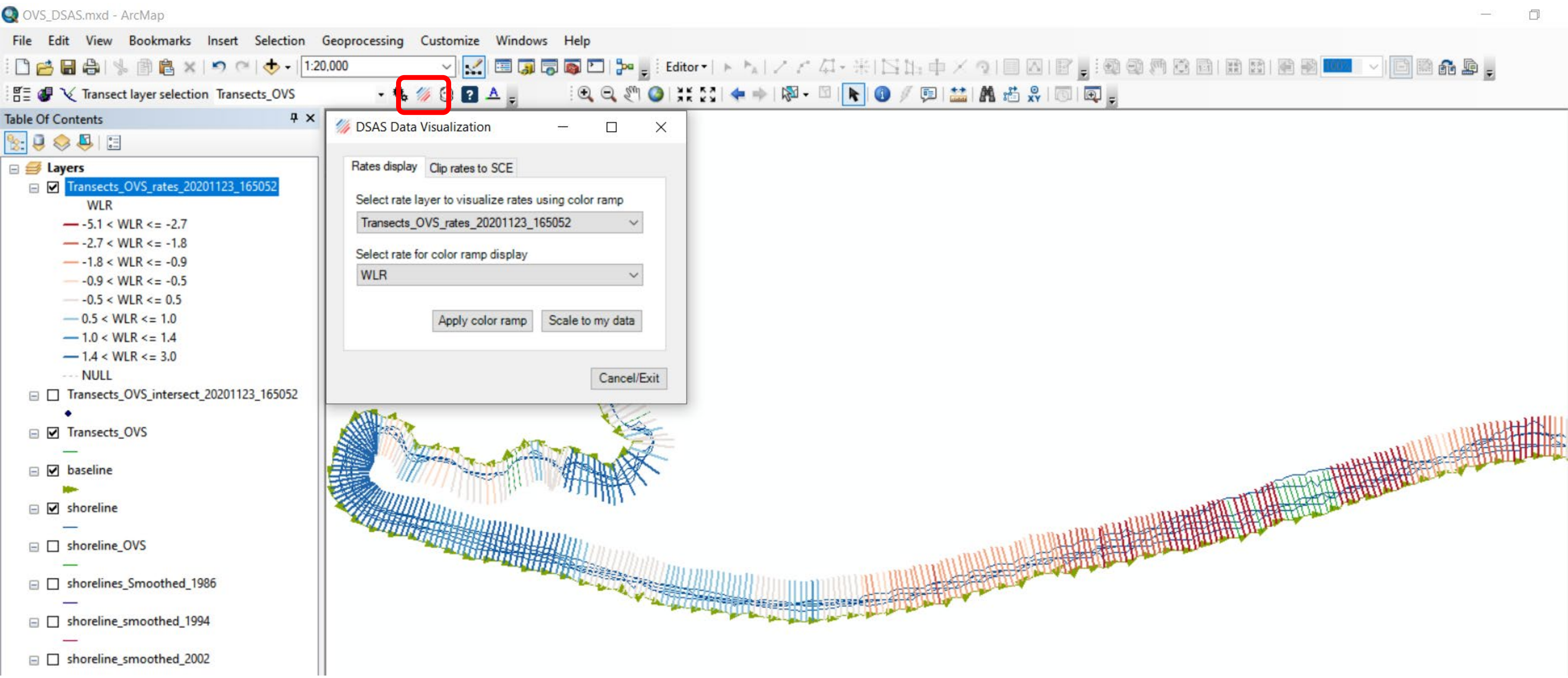
<u>We can edit **transects**:</u>

- Delete
- Add new transect
- Rotate or move in space

Calculation of Statistical parameters in DSAS tool



Visualization of the DSAS analysis results in ArcGIS



ODYSSEA

Table

Transects_OVS_rates_20201123_165052

object identifier *	geometry *	TransectID	BaselineID	GroupID	TransOrder	Azimuth	ShrCount	TCD	SHAPE_Length	SCE	NSM	EPR	EPRunc	LRR	LR2	LSE	LCI90	WLR	WR2	WSE	WCI90
1	Polyline	2	1	<Null>	2	43.2	5	30	200	27.48	-27.48	-0.85	1.32	-0.82	0.91	3.72	0.34	-0.82	0.91	0.12	0.34
2	Polyline	3	1	<Null>	3	42.78	5	60	200	31.84	-31.84	-0.99	1.32	-0.92	0.94	3.36	0.31	-0.92	0.94	0.11	0.31
3	Polyline	4	1	<Null>	4	44.6	5	90	200	29.92	-29.92	-0.93	1.32	-0.99	0.9	4.91	0.45	-0.99	0.9	0.16	0.45
4	Polyline	5	1	<Null>	5	46.14	5	120	200	21.22	-21.22	-0.66	1.32	-0.77	0.75	6.61	0.61	-0.77	0.75	0.22	0.61
5	Polyline	6	1	<Null>	6	47.45	5	150	200	26.14	-26.14	-0.81	1.32	-0.77	0.66	8.01	0.74	-0.77	0.66	0.27	0.74
6	Polyline	7	1	<Null>	7	47.9	5	180	200	36.54	-36.54	-1.14	1.32	-0.92	0.68	9.18	0.85	-0.92	0.68	0.31	0.85
7	Polyline	8	1	<Null>	8	47.36	5	210	200	42.46	-42.46	-1.32	1.32	-1.19	0.9	5.9	0.55	-1.19	0.9	0.2	0.55
8	Polyline	9	1	<Null>	9	46.09	5	240	200	42.43	-42.43	-1.32	1.32	-1.31	0.9	6.45	0.6	-1.31	0.9	0.22	0.6
9	Polyline	10	1	<Null>	10	44.26	5	270	200	33.28	-33.28	-1.03	1.32	-1.08	0.9	5.33	0.49	-1.08	0.9	0.18	0.49
10	Polyline	11	1	<Null>	11	43.75	5	300	200	9.84	-9.84	-0.31	1.32	-0.32	0.72	2.93	0.27	-0.32	0.72	0.1	0.27
11	Polyline	12	1	<Null>	12	43.75	5	330	200	12.67	8.34	0.26	1.32	0.31	0.49	4.64	0.43	0.31	0.49	0.15	0.43
12	Polyline	13	1	<Null>	13	44.49	5	360	200	22.38	22.38	0.7	1.32	0.82	0.78	6.46	0.6	0.82	0.78	0.22	0.6
13	Polyline	14	1	<Null>	14	46.17	5	390	200	32.39	32.39	1.01	1.32	1.07	0.94	4.13	0.38	1.07	0.94	0.14	0.38
14	Polyline	15	1	<Null>	15	47.28	5	420	200	42.35	42.35	1.32	1.32	1.32	0.86	7.71	0.71	1.32	0.86	0.26	0.71
15	Polyline	16	1	<Null>	16	47.5	5	450	200	39.55	39.55	1.23	1.32	1.25	0.79	9.47	0.88	1.25	0.79	0.32	0.88
16	Polyline	17	1	<Null>	17	47.5	5	480	200	29.96	29.96	0.93	1.32	1.01	0.8	7.43	0.69	1.01	0.8	0.25	0.69
17	Polyline	18	1	<Null>	18	47.78	5	510	200	21.24	21.24	0.66	1.32	0.79	0.75	6.72	0.62	0.79	0.75	0.22	0.62

1 (0 out of 1341 Selected)

Transects_OVS_rates_20201123_165052

Table

Transects_OVS_intersect_20201123_165052

object identifier *	geometry *	TransectID	TransOrder	BaselineID	ShorelineID	Distance	IntersectX	IntersectY	Uncertainty
1	Point	2	2	1	06/05/1986	-53.028553	297938.838749	4529817.322503	30
2	Point	2	2	1	06/05/1994	-59.281586	297943.119035	4529821.880965	30
3	Point	2	2	1	06/06/2002	-59.281586	297943.119035	4529821.880965	30
4	Point	2	2	1	06/06/2010	-69.89344	297950.382991	4529829.617009	30
5	Point	2	2	1	07/07/2018	-80.505293	297957.646948	4529837.353052	30
6	Point	3	3	1	06/05/1986	-50.037492	297956.706169	4529793.293831	30
7	Point	3	3	1	06/05/1994	-60.652059	297963.915458	4529801.084542	30
8	Point	3	3	1	06/06/2002	-60.652059	297963.915458	4529801.084542	30
9	Point	3	3	1	06/06/2010	-71.266625	297971.124747	4529808.875253	30
10	Point	3	3	1	07/07/2018	-81.881192	297978.334036	4529816.665964	30
11	Point	4	4	1	06/05/1986	-51.498687	297980.368208	4529772.315896	30
12	Point	4	4	1	06/05/1994	-60.207549	297986.483584	4529778.516416	30
13	Point	4	4	1	06/06/2002	-60.207549	297986.483584	4529778.516416	30
14	Point	4	4	1	06/06/2010	-79.718604	298000.184279	4529792.407861	30

1 (0 out of *2000 Selected)

Transects_OVS_intersect_20201123_165052

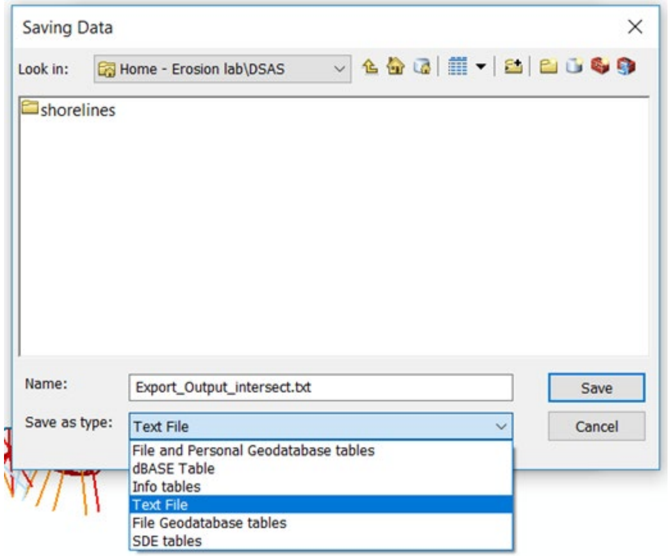
Saving data

The parameters estimated from DSAS are:

- **TRANSECT INTERSECT** (data of the transect position)
- **TRANSECT RATES** (results of the **Statistical Analysis** for each transect)

Save the file as .txt:

Table of Contents → **List by source** → **transects_intersects** (right click) → **Data** → **Export** → **Save**



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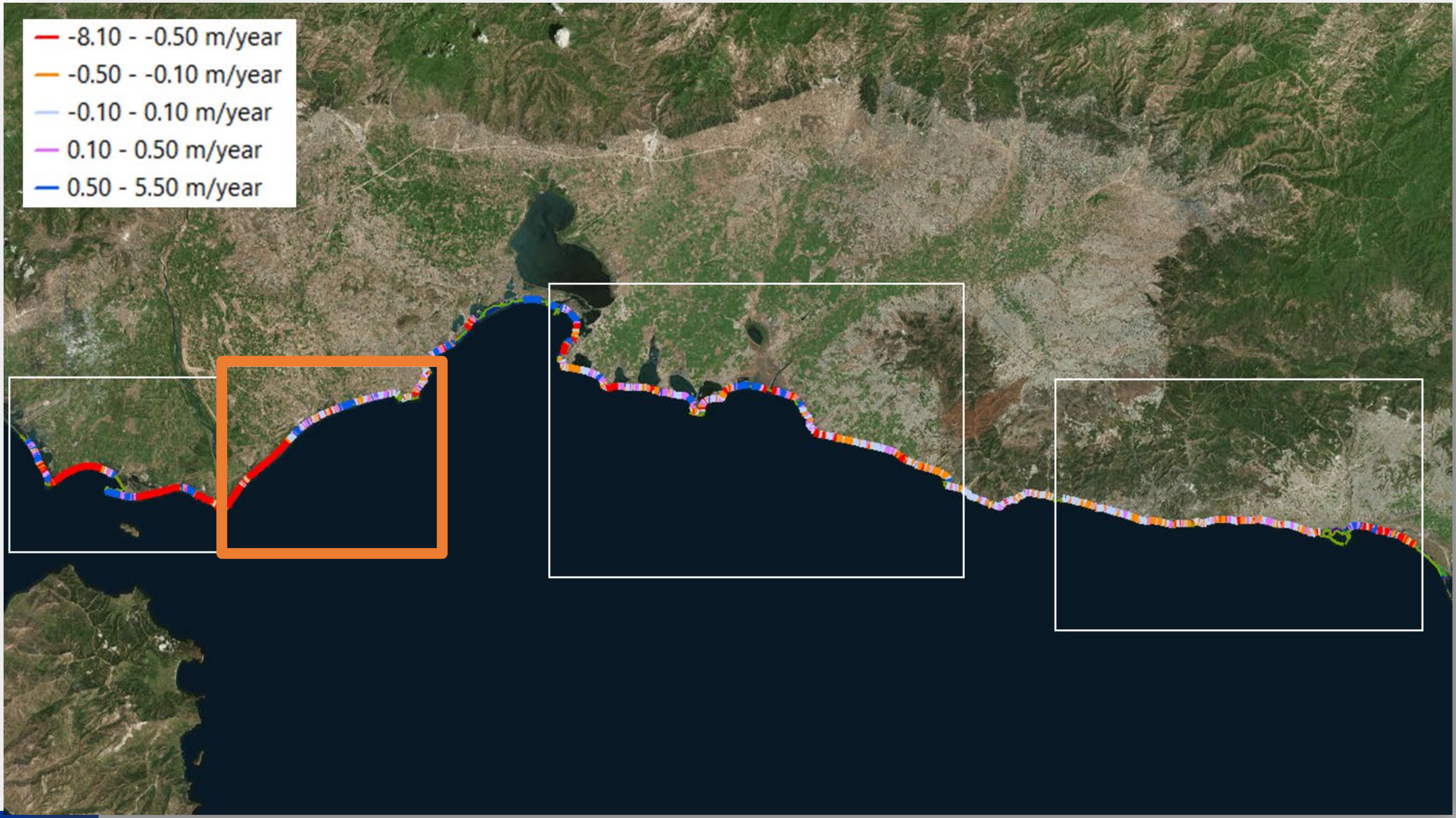
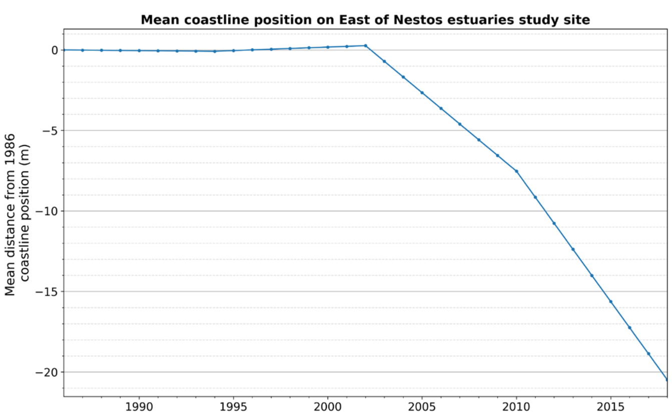
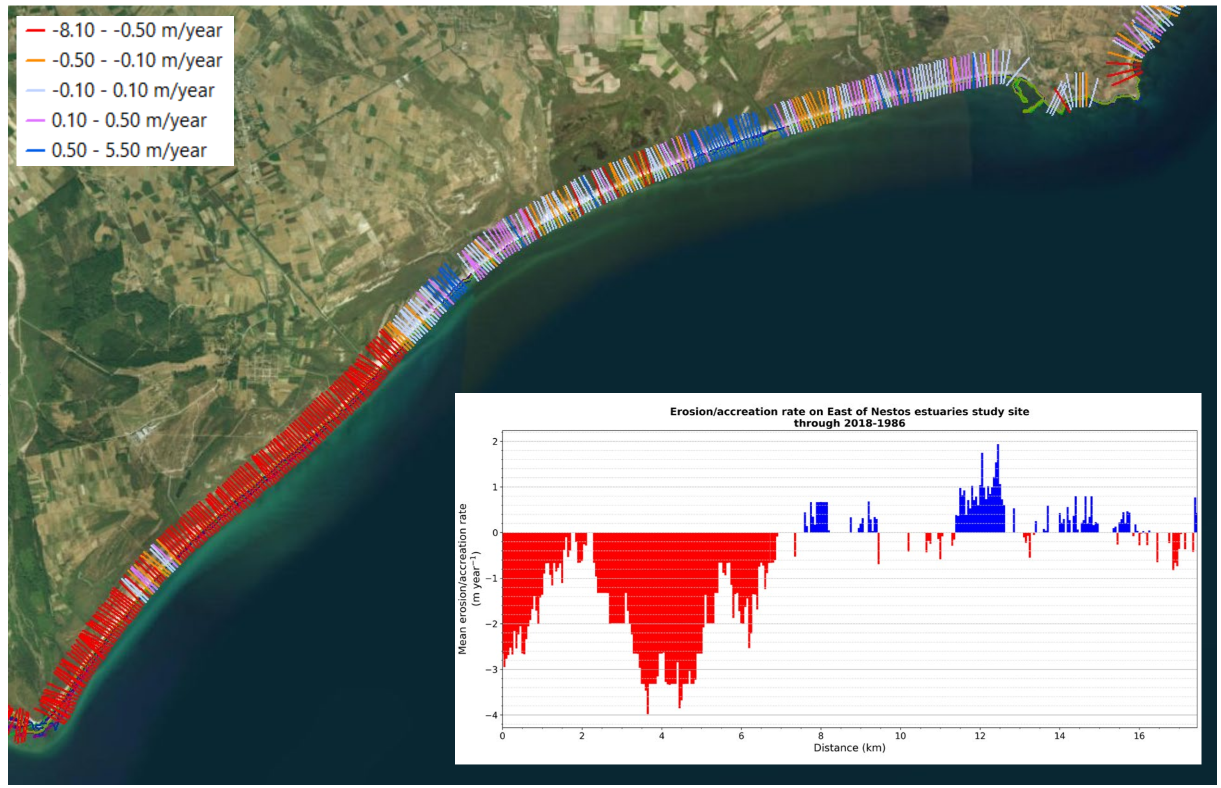


-8.10 - -0.50 m/year
-0.50 - -0.10 m/year
-0.10 - 0.10 m/year
0.10 - 0.50 m/year
0.50 - 5.50 m/year

	Value	Units
Average rate	-0.70	m/year
max accretic	1.93	m/year
max erosion	-3.78	m/year
Average Erro	0.35	m





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Satellite images:

- Earth Explorer: https://earthexplorer.usgs.gov/
- Copernicus Hub: https://scihub.copernicus.eu/dhus/
- Planet Explorer: https://www.planet.com/explorer/

Plug-ins

- SCP plug in: https://plugins.qgis.org/plugins/SemiAutomaticClassificationPlugin/
- DSAS tool: https://www.usgs.gov/centers/whcmsc/science/digital-shoreline-analysis-system-dsas?qt-science_center_objects=0#qt-science_center_objects

GIS Links

- QGIS: https://qgis.org/en/site/forusers/download.html
- ArcMap: https://pro.arcgis.com/en/pro-app/get-started/install-and-sign-in-to-arcgis-pro.htm

Creating products and knowledge
for the Mediterranean

EUTROPHICATION INDICES IN MARINOMICA

ODYSSEA Virtual School – Oceanography from Space

Lőrinc Mészáros

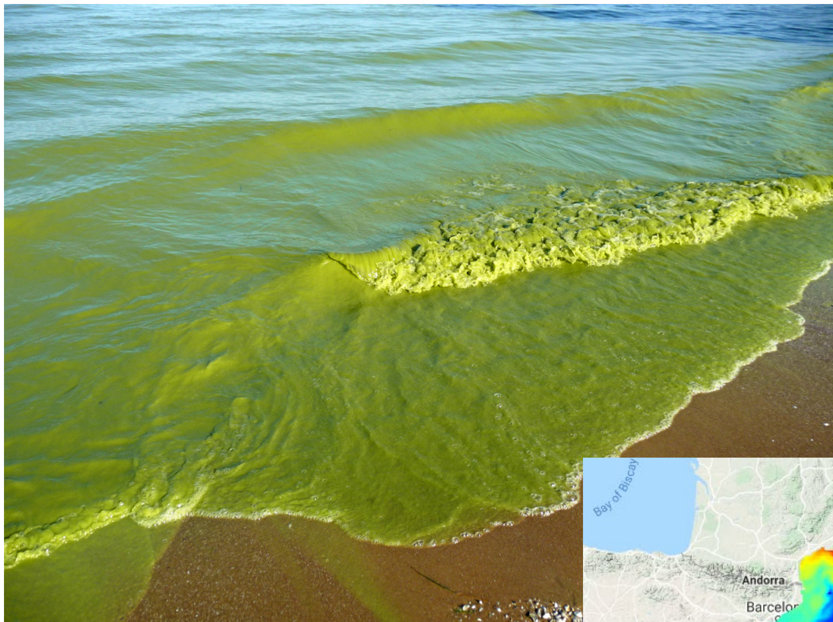
Deltares

lorinc.meszaros@deltares.nl

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 727277

Eutrophication indices

ODYSSEA



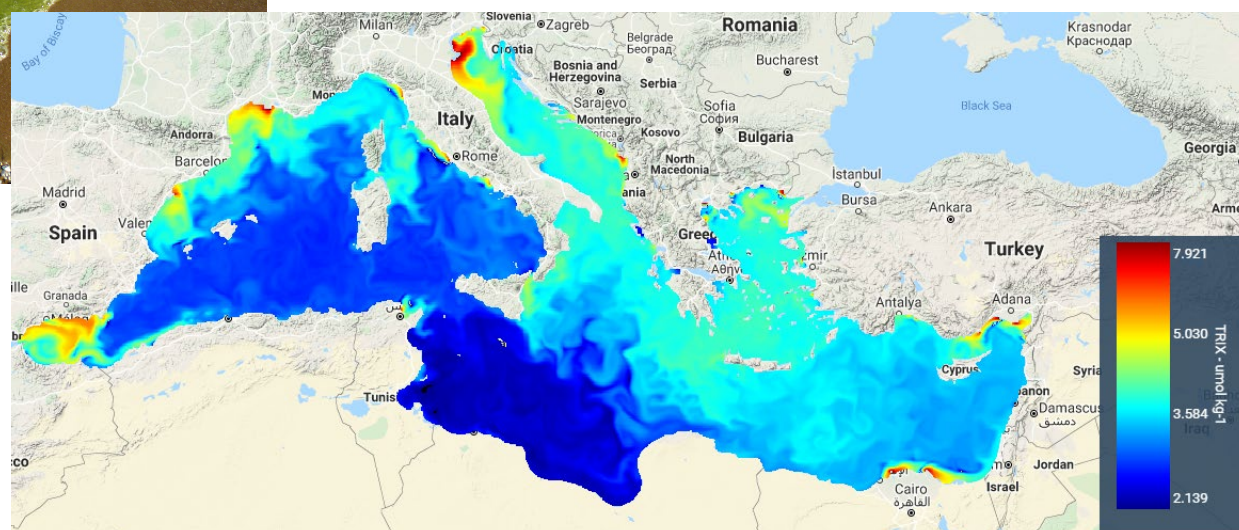
eutrophos (Greek) = well-nourished

⬇

excessive growth of algae

⬇

oxygen depletion



Is it a problem in the Med?

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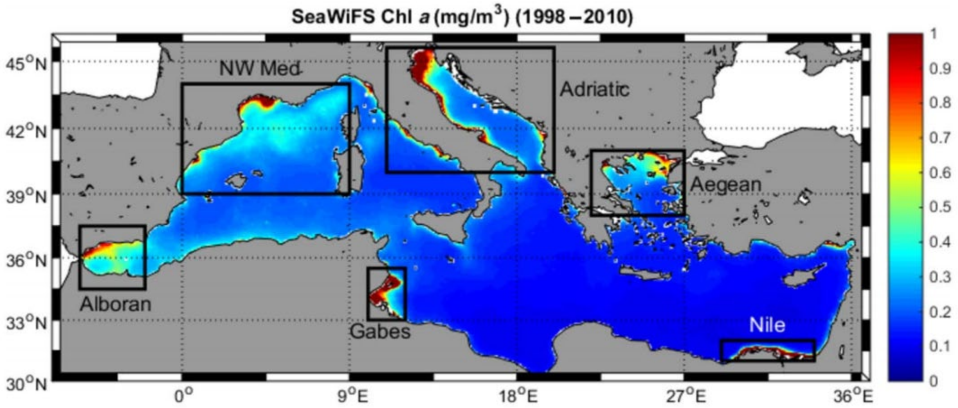
Pinterest: BYOjet

Mostly not, but there are problem areas…



Macias, D., Garcia-Gorriz, E. and Stips, A. (2018), Major fertilization sources and mechanisms for Mediterranean Sea coastal ecosystems. Limnol. Oceanogr., 63: 897-914. https://doi.org/10.1002/lno.10677

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Eutrophication in international policies

Sustainable Development Goals

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Target 14.1: preventing every form of marine pollution including nutrient pollution leading to eutrophication

Intergovernmental Oceanographic Commission

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United Nations Educational, Scientific and Cultural Organization

Intergovernmental Oceanographic Commission

- Link: http://www.ioc-unesco.org/

- Objective:

*"to promote **international cooperation** and to coordinate programmes in research, **services and capacity-building**, in order to learn more about the nature and **resources of the ocean and coastal areas** and to apply that knowledge for the improvement of management, sustainable development, the protection of the marine environment, and the decision-making processes of its Member States."*

- High level Objectives:
  1. **Ecosystem Health**
  2. **Marine Hazards**
  3. **Climate Change**
  4. **Enhanced Scientific Knowledge**

EU Marine Strategy Framework Directive

- Link: http://ec.europa.eu/environment/marine/eu-coast-and-marine-policy/marine-strategy-framework-directive/index_en.htm
- Objective:

*"The Marine Directive aims to achieve **Good Environmental Status (GES)** of the EU's marine waters by 2020 and to protect the resource base upon which marine-related economic and social activities depend."*

Source: ec.europa.eu

MSFD Descriptors

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Descriptor 1	BIOLOGICAL DIVERSITY
Descriptor 2	NON-INDIGENOUS SPECIES
Descriptor 3	COMMERCIAL FISH
Descriptor 4	FOOD WEBS
Descriptor 5	EUTROPHICATION
Descriptor 6	SEA-FLOOR INTEGRITY
Descriptor 7	HYDROGRAPHICAL CONDITIONS
Descriptor 8	CONTAMINANTS AND POLLUTION EFFECTS.
Descriptor 9	CONTAMINANTS IN FISH AND OTHER SEAFOOD
Descriptor 10	MARINE LITTER
Descriptor 11	UNDERWATER NOISE/ENERGY

OSPAR Convention

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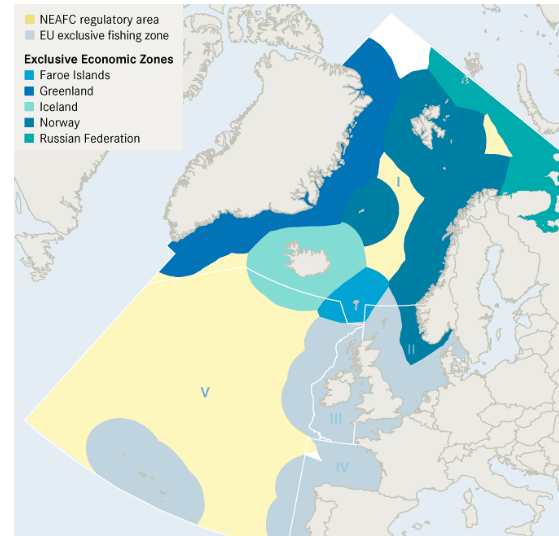
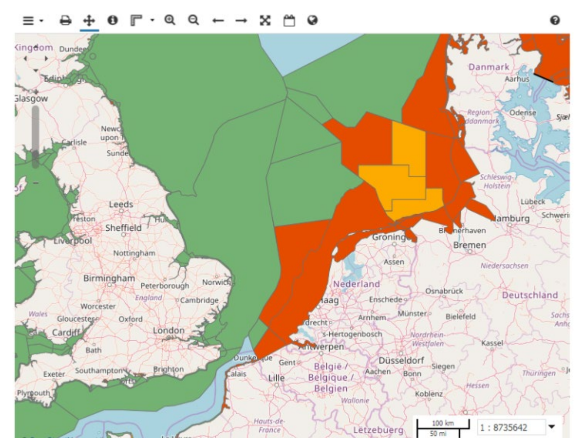
- Link: https://www.ospar.org/convention
- *[OSPAR Convention = Convention for the Protection of the Marine Environment of the North-East Atlantic]*
- Entered into force on 25 March 1998
- Specific OSPAR Areas:
    - ❖ **Prevention and elimination** of:
        - pollution from land-based sources;
        - pollution by dumping or incineration;
        - pollution from offshore sources;
    - ❖ **Assessment** of the quality of the marine environment;
    - ❖ **protection and conservation** of the ecosystems and biological diversity of the maritime area.



Source: https://qsr2010.ospar.org



Data on Eutrophication status

OSPAR COMMISSION

Eutrophication indices in Marinomica

So far…

Primary VS derived

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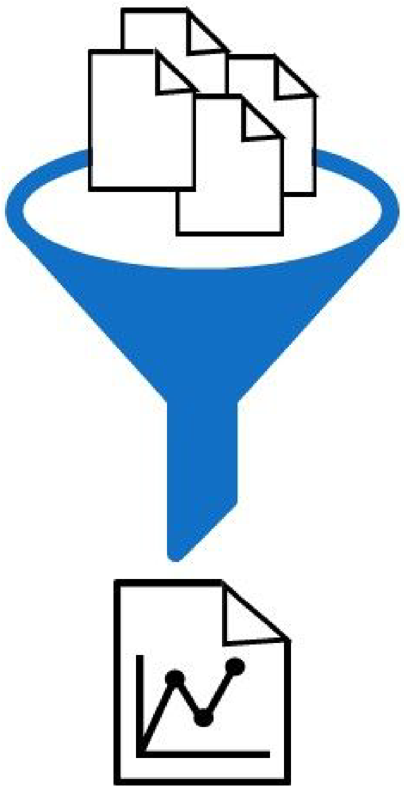
Primary variables

- Nutrients (phosphate and nitrate)
- Dissolved oxygen
- Chlorophyll-a concentration

Secondary (derived) indices

- Eutrophication Index in sea water
- TRophic IndeX in sea water
- UNscaled TRophic IndeX in sea water
- Efficiency Coefficient in sea water

Primary variables

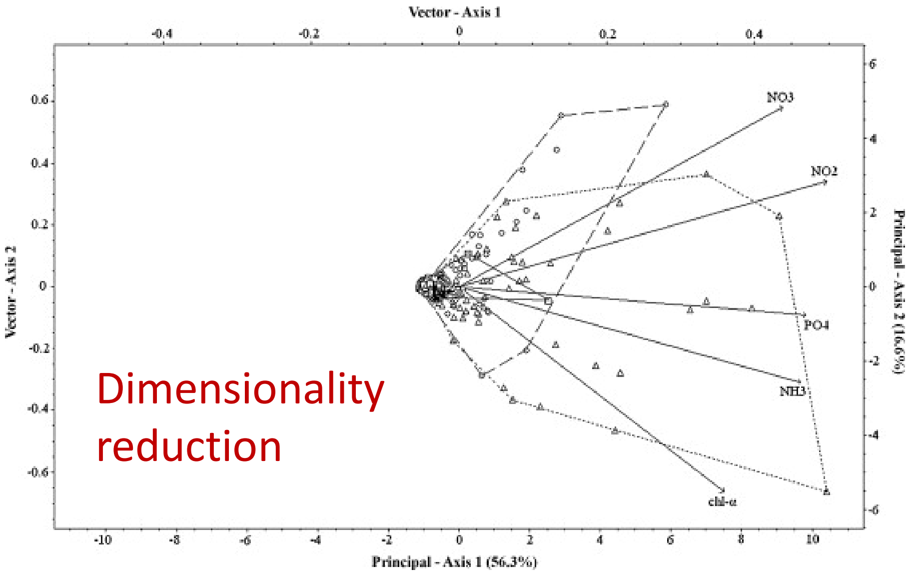


Derived indices

Eutrophication Index in sea water

Description

- computed through the **Principal component analysis** of a combination of five parameters: **chlorophyll-a (Chl)**, **nitrate (NO_3)**, nitrite (NO_2), ammonia (NH_3), and **phosphate (PO_4)**.
- the first principal component is considered as the eutrophication index



Primpas, I., Tsirtsis, G., Karydis, M., Kokkoris, G.D., D., 2010. Principal component analysis: development of a multivariate index for assessing eutrophication according to the European water framework directive. Ecol. Indic. 10, 178–183.

TRophic Inde**X** in sea water

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Description

- computed as a **linear combination of four state variables**: chlorophyll (Chl), oxygen saturation (dissolved oxygen - DO), mineral and total nitrogen (dissolved inorganic nitrogen - DIN), and phosphorus (total phosphorus - TP)
- Initially developed for northern Adriatic Sea
  - $0 < TRIX < 4$ High (Elevated) Trophic Status, Oligotrophic
  - $4 <= TRIX < 5$ Good Trophic Status, Mesotrophic
  - $5 <= TRIX < 6$ Medium Trophic Status
  - $6 <= TRIX < 8$ Low (Bad) trophic Status, Hyper-trophic

$$TRIX = \frac{\log(Chl - \alpha \times aD\%O \times DIN \times TP) - (-1.5)}{1.2}$$

Vollenweider, R. A., Giovanardi, F., Montanari, G., & Rinaldi, A. (1998). Characterization of the trophic conditions of marine coastal waters with special reference to the NW Adriatic Sea: proposal for a trophic scale, turbidity and generalized water quality index. Environmetrics: The official journal of the International Environmetrics Society, 9(3), 329-357.

UNscaled TRophic IndeX in sea water

ODYSSEA

Description

- it is computed by the log of the product of four eutrophication-related parameters: chlorophyll-a (Chl), oxygen saturation (dissolved oxygen - DO), mineral and total nitrogen (dissolved inorganic nitrogen - DIN), and phosphorus (total phosphorus - TP)
- Unscaling TRIX!

$$TRIX = \frac{\log(Chl-\alpha \times aD\%O \times DIN \times TP) \cancel{-(-1.5)}}{\cancel{1.2}}$$

Remove −1.5 and 1.2 which are ***scale factors*** based on an extended dataset concerning the northern Adriatic Sea

$$\mathrm{UNTRIX} = \log(\mathrm{Chl}\text{-}a * \mathrm{aD\%O} * \mathrm{DIN} * \mathrm{TP})$$

Maurizio Pettine, Barbara Casentini, Stefano Fazi, Franco Giovanardi, Romano Pagnotta (2007), A revisitation of TRIX for trophic status assessment in the light of the European Water Framework Directive: Application to Italian coastal waters, Marine Pollution Bulletin, Volume 54, Issue 9

Efficiency Coefficient in sea water

ODYSSEA

Description

- defined as the logarithm of the ratio between the two aggregated main components of the TRIX index
- it is computed by the combination of four parameters: chlorophyll-a (Chl), oxygen saturation (dissolved oxygen - DO), mineral and total nitrogen (dissolved inorganic nitrogen - DIN), and phosphorus (total phosphorus - TP).
- **can be considered a supplementary index with which to evaluate the nutrient utilization of the system**.

$$TRIX = \frac{\log(Chl-\alpha \times aD\%O \times DIN \times TP) - (-1.5)}{1.2}$$

$$Eff.Coeff. = Log_{10} \frac{(Chl-a \times aD\%O)}{(DIN \times TP)}$$

GIOVANARDI, F., & Vollenweider, R. A. (2004). Trophic conditions of marine coastal waters: experience in applying the Trophic Index TRIX to two areas of the Adriatic and Tyrrhenian seas. Journal of Limnology, 63(2), 199-218

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Eutrophication data sources in Marinomica

Data sources

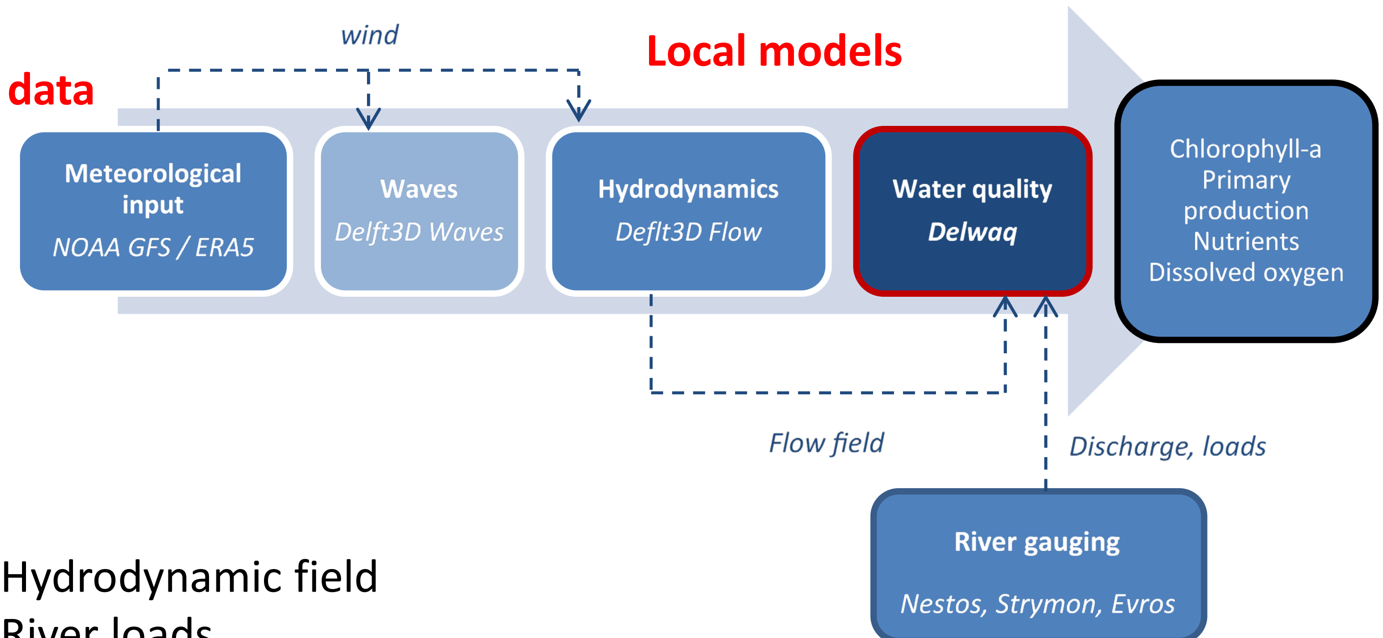
ODYSSEA

In-situ measurements	*e.g. gliders*
Local coastal models	*e.g. Delft3D*
External datasets (satellite/model)	*e.g. CMEMS*
Algorithms	*e.g. TRIX*

Delft3D Water quality (Delwaq)

ODYSSEA

External data



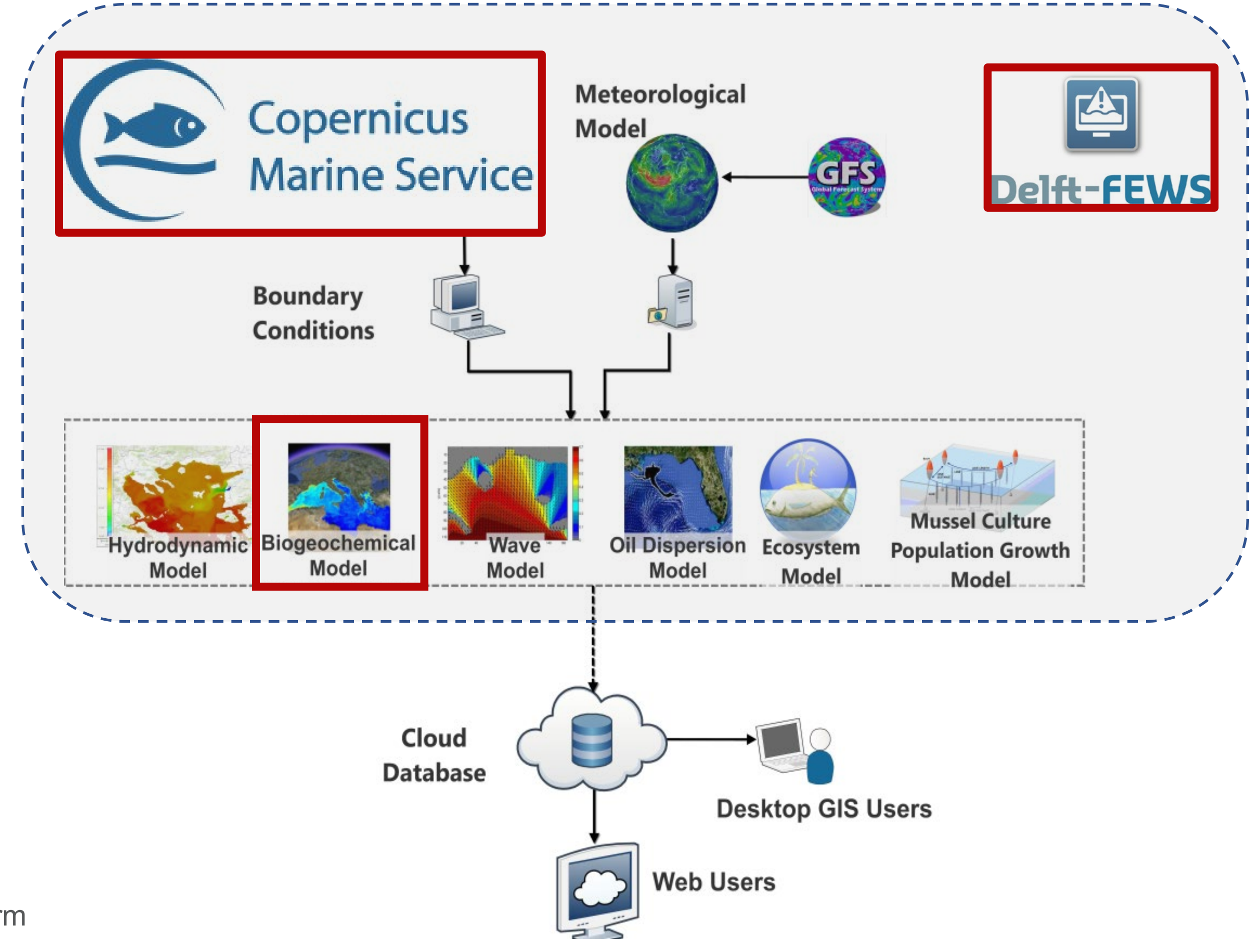
- Hydrodynamic field
- River loads

In-situ / external data/ algorithm

Downstream service for eutrophication

ODYSSEA

- From Copernicus Marine Service to local (high resolution) operational water quality simulation



CMEMS to Delwaq

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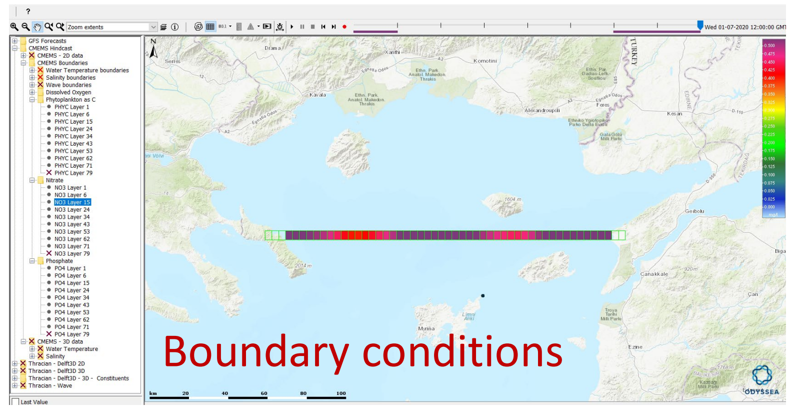
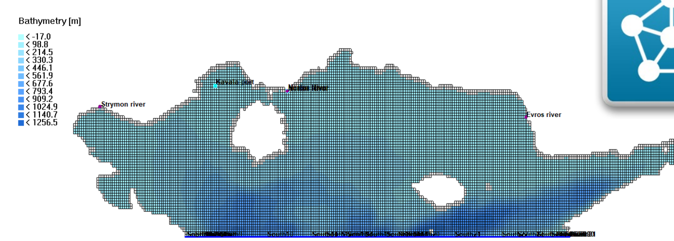
Copernicus Marine Service

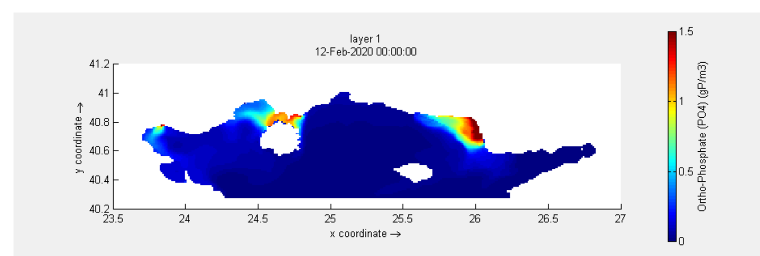
Delft-FEWS



Variable mapping

Delwaq state variable	CMEMS variable / constant
OXY	O2
NO3	NO3
PO4	PO4
Si	0.06008; from M.D. Krom et al, 2014
Opal	PHY * 0.5 * 0.125 * 28.08 / 12
POC1	PHY
PON1	PHY * 0.1196 * 14 / 12
POP1	PHY * 0.0085 * 30.97 / 12
MDIATOMS_E	0
MDIATOMS_N	PHY * 0.5
MDIATOMS_P	0
MFLAGELA_E	0
MFLAGELA_N	PHY * 0.5
MFLAGELA_P	0





Operational infrastructure

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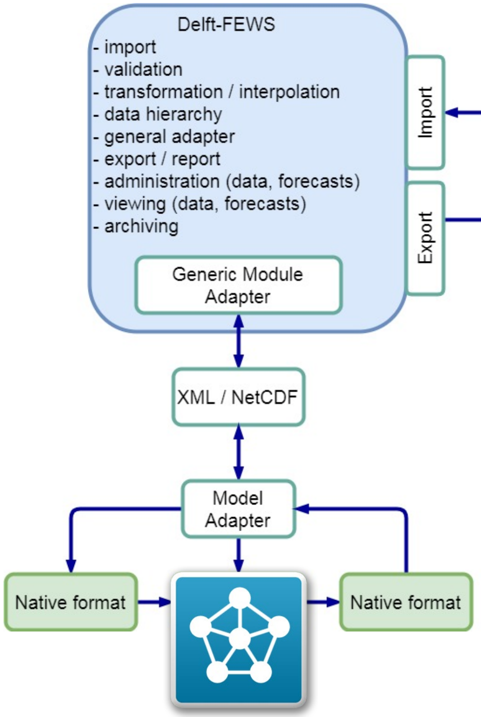
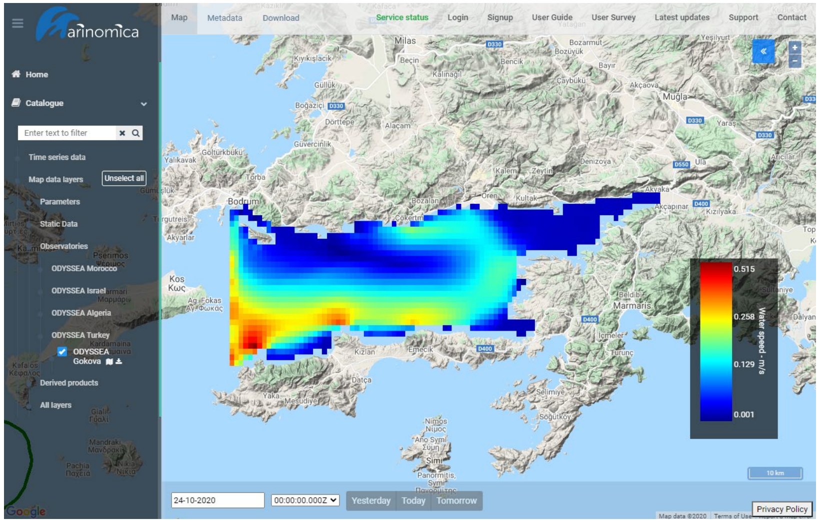
- Operational infrastructure using Delft-FEWS



Delft3D-FLOW + Delwaq



Applications

1) Historical assessment

2) Early warning: Real time and forecast (operational)

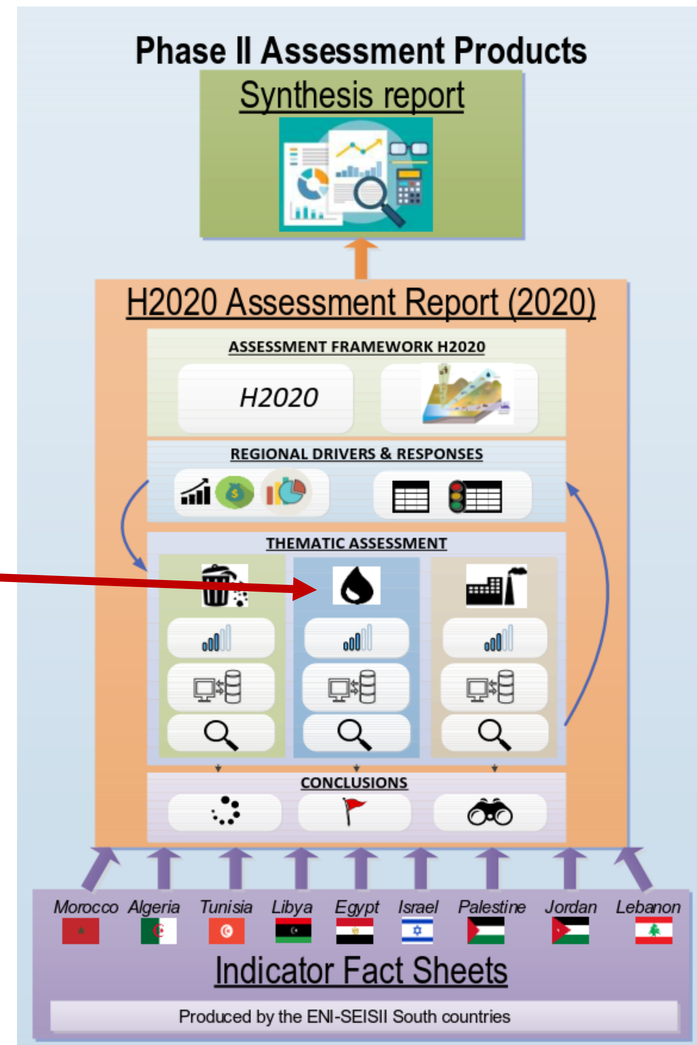
1) Historical assessment

ODYSSEA

- ENI-SEIS II:
  https://eni-seis.eionet.europa.eu/south
- Horizon 2020 Assessment Technical Med report (EEA)
  https://eni-seis.eionet.europa.eu/south/communication/news/eea-unep-map-launch-country-consultation-on-executive-summary-of-the-eea-unep-map-2nd-horizon-2020-indicator-based-assessment-report

Marinomica

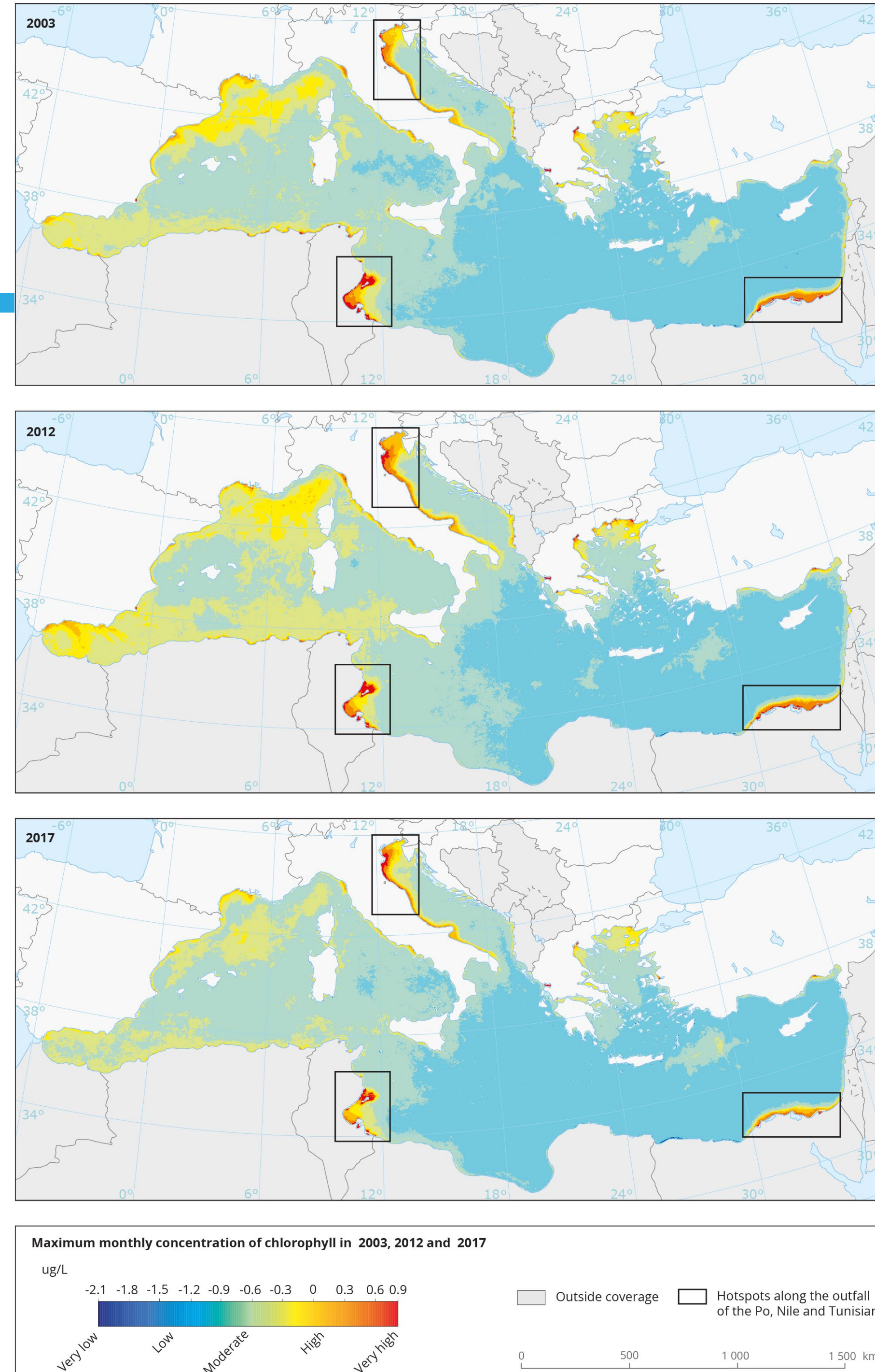
Coastal waters



European Environment Agency

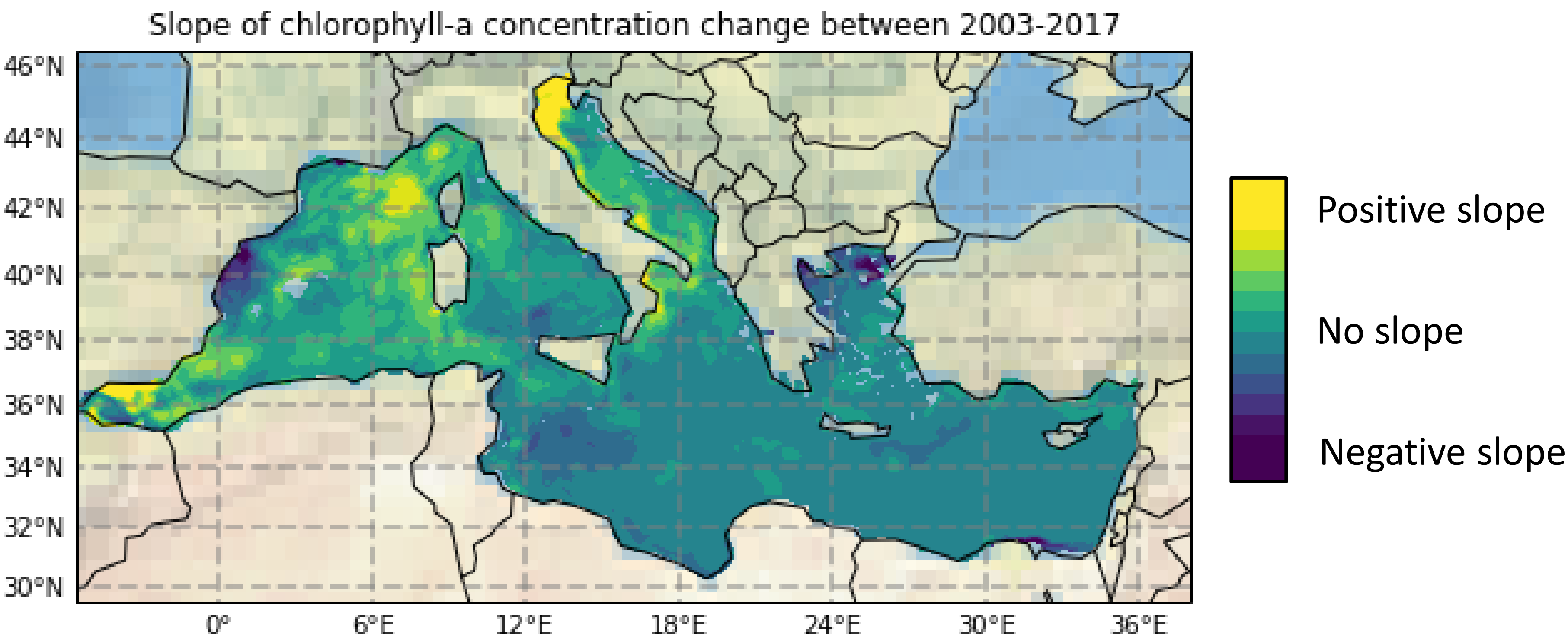
Identification of hotspots

Using satellite data..



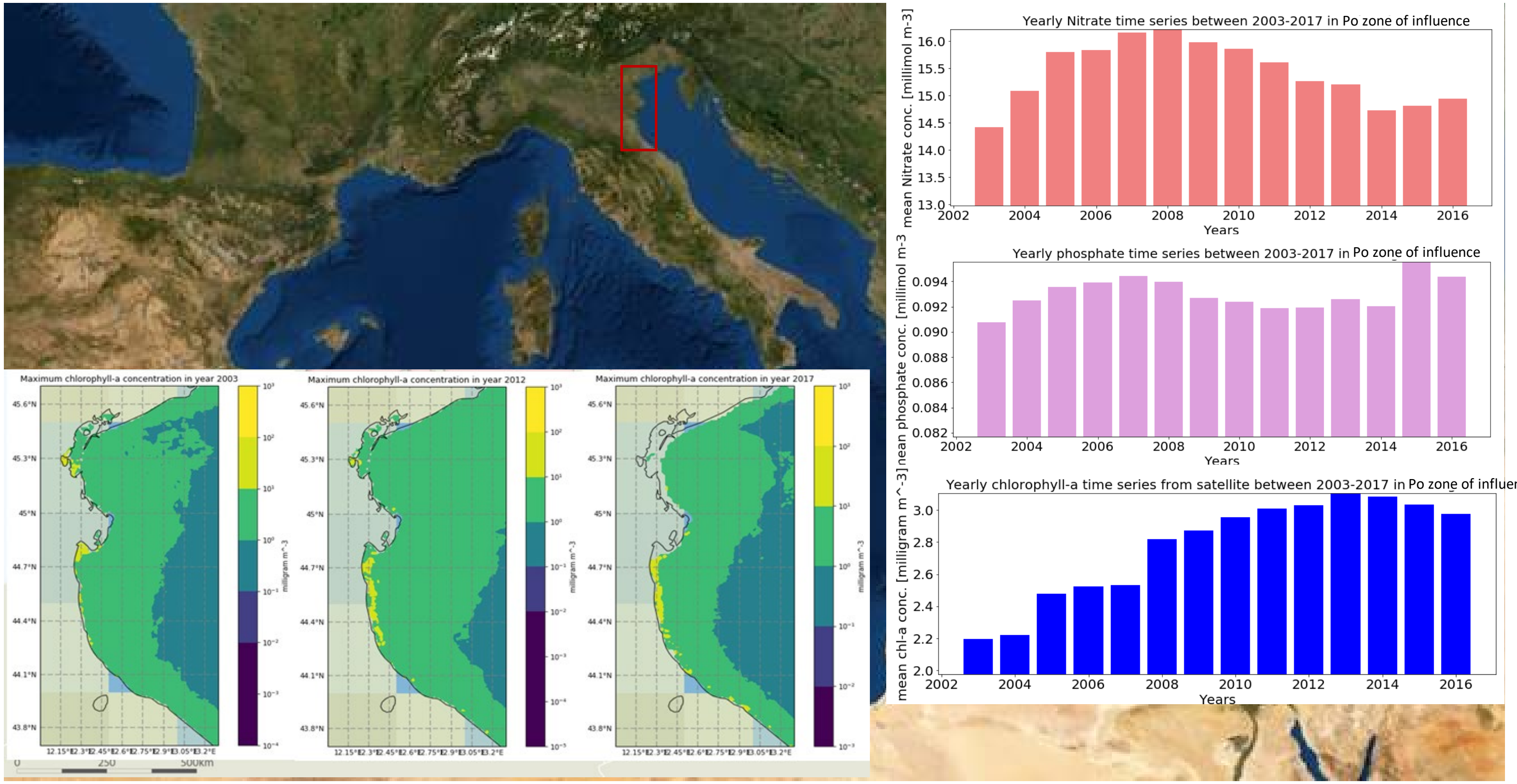
Trends

Using model data..



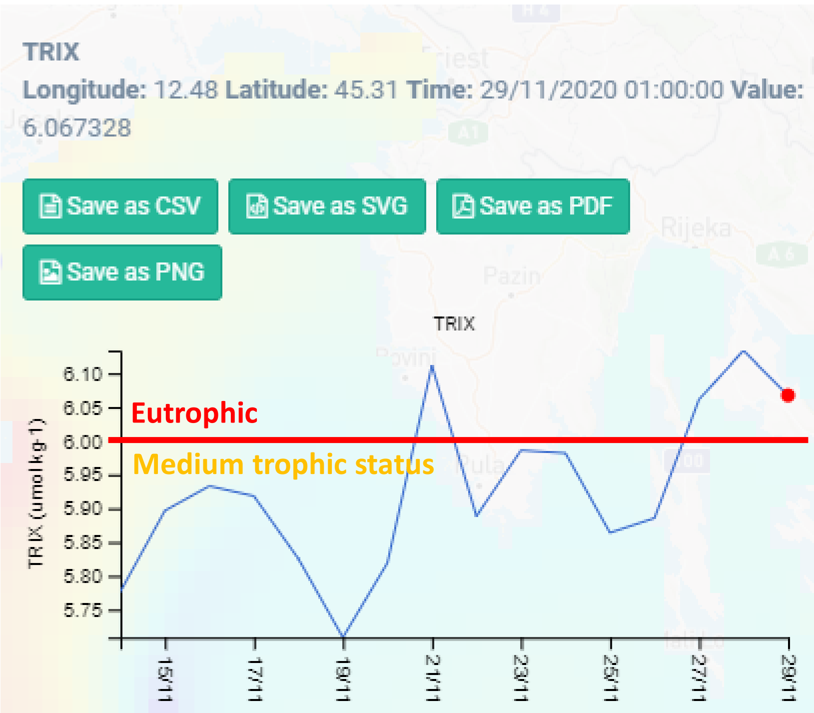
Regional analysis

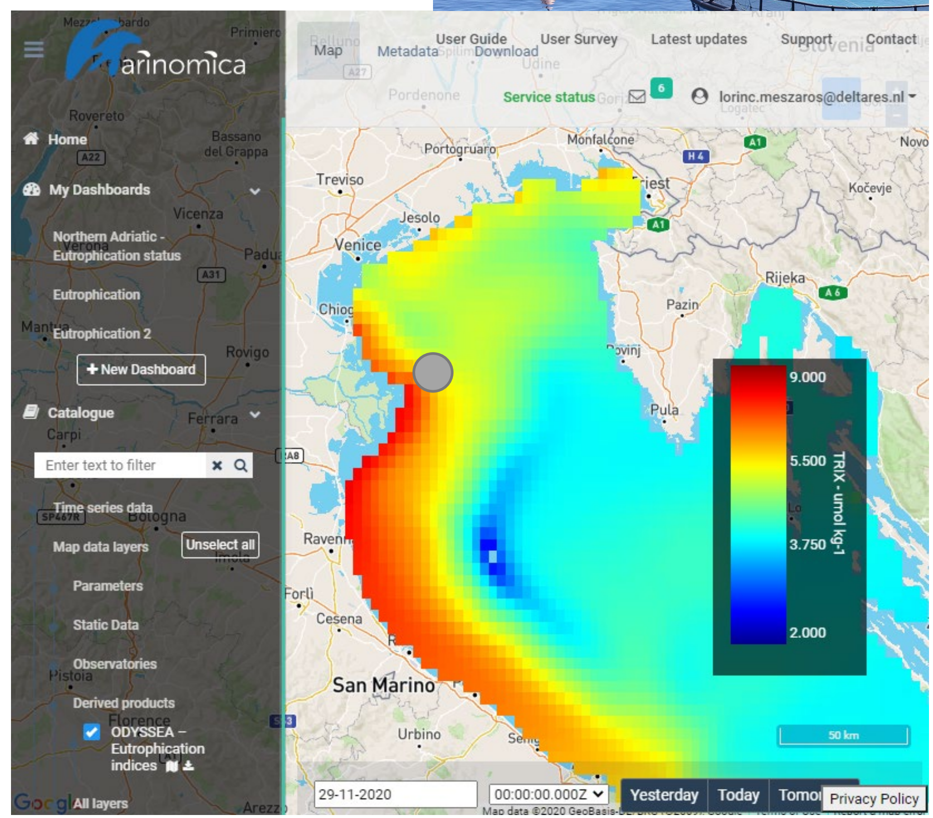
Using model data…



2) Early warning: Real time and forecast

ODYSSEA





ODYSSEA

Exercises

Eutrophication exercise

- **Export TRIX as csv and plot in Excel**

https://marinomica.com/

- **Export chlorophyll-a as netcdf and post-process in Jupyter notebook:**

https://mybinder.org/v2/gh/lorincmeszaros/chl_analysis/aaff984ad682d994d29653649f1661f8b76bcfd7

- **Create Eutrophication dashboard**

Test your shareable dashboard here:

http://www.csgnetwork.com/htmlcodetest.html