

# Monitoring and predicting coastal dynamics for management, conservation and restoration: the MER Italian high-resolution modeling system

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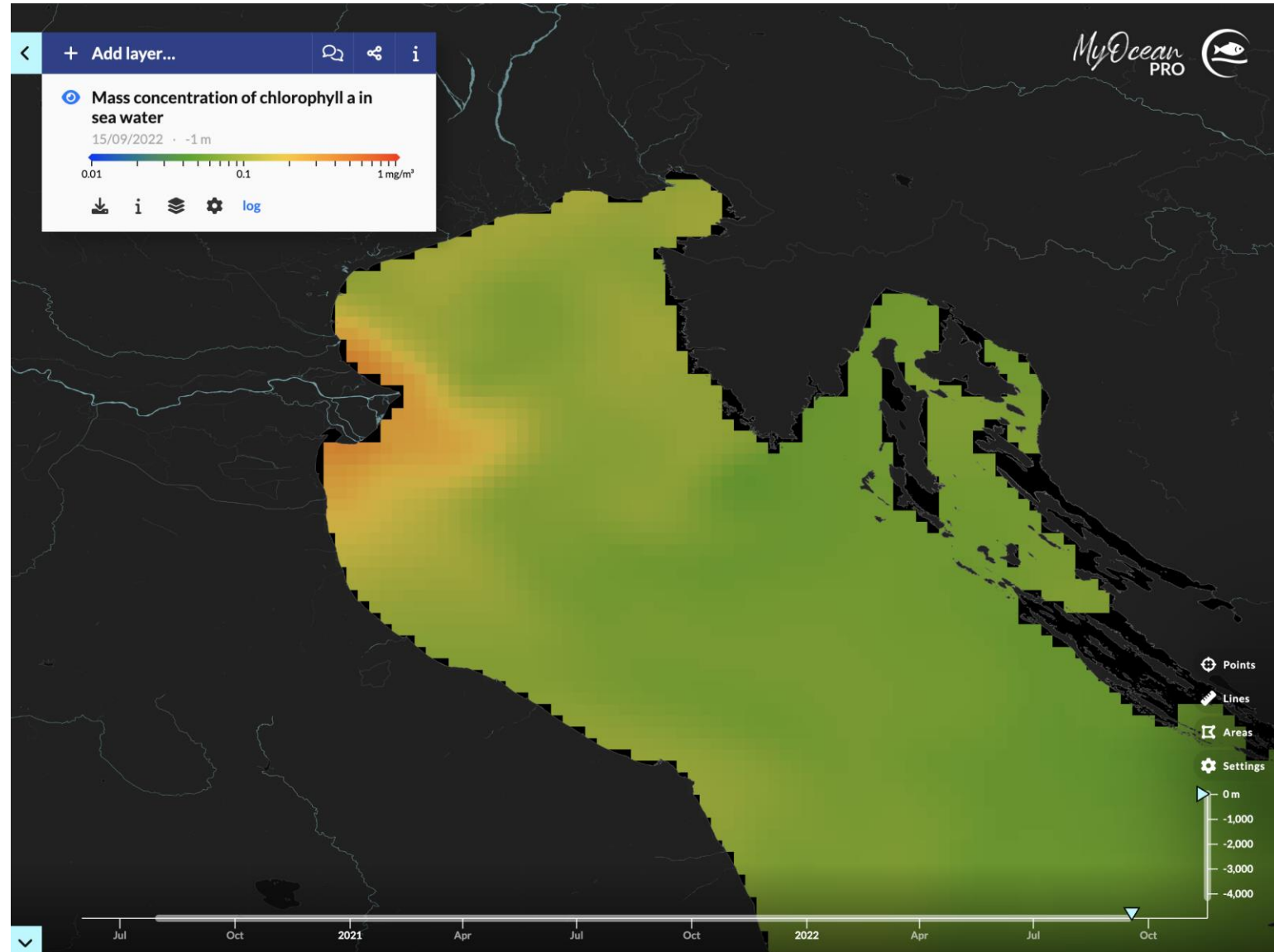
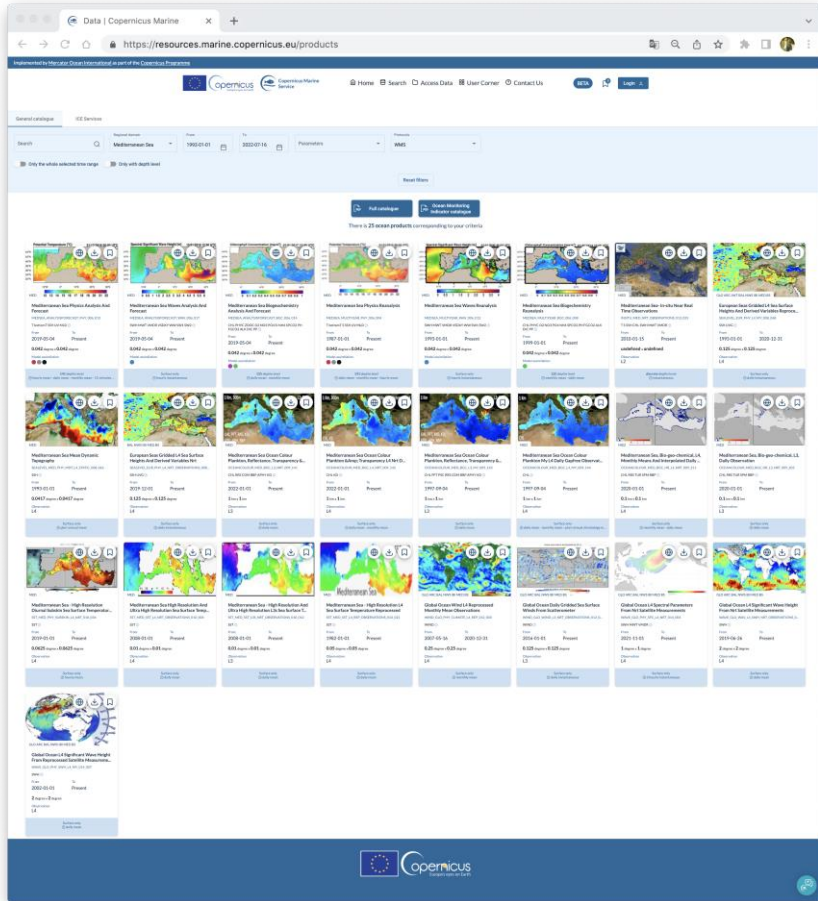
<sup>4</sup> CINECA (Consorzio Interuniversitario per il Calcolo Automatico dell'Italia Nord Orientale), Italy

<sup>5</sup> University of Trieste, Italy

- **MER (Marine Ecosystem Restoration)** project, funded by the **NextGenerationEU** program (investment M2C4 - I3.5) is the largest project on the sea in the context of the National Recovery and Resilience Plan;
- **ISPRA** is the implementing body / contracting authority and the **Ministry for the Environment and Energy Security** is the administration holder of the financing of **400 M€** for **2022-2026**;
- **37 actions**: from oysterground restoration, to measurement networks, to the acquisition of a new oceanographic naval unit;
- **actions B32 (biogeochemical modelling)** and **B35 (impact of sewage discharges – river / coastal outfalls)**
- **coastal areas**: highly dynamic environments with **physical** and **biogeochemical** processes interacting over multiple spatial and temporal **scales**;
- **monitoring** and **predicting** these processes for effective management, conservation and restoration of marine ecosystems;
- high-resolution regional **downscaling** tools need careful integration of various **products** (and their **dependencies**): open sea boundary conditions, river discharge, high-resolution atmospheric forcing, satellite observations and in situ coastal data (including wastewater treatment plant inputs);
- modelling system designed for **operational purposes** (five-day short-term forecasts);
- **10-year reanalysis** (2011-2020) and **5-year hindcast** (2021-2025) for the assessment of both coastal-open ocean dynamics and temporal variability at fine scales.

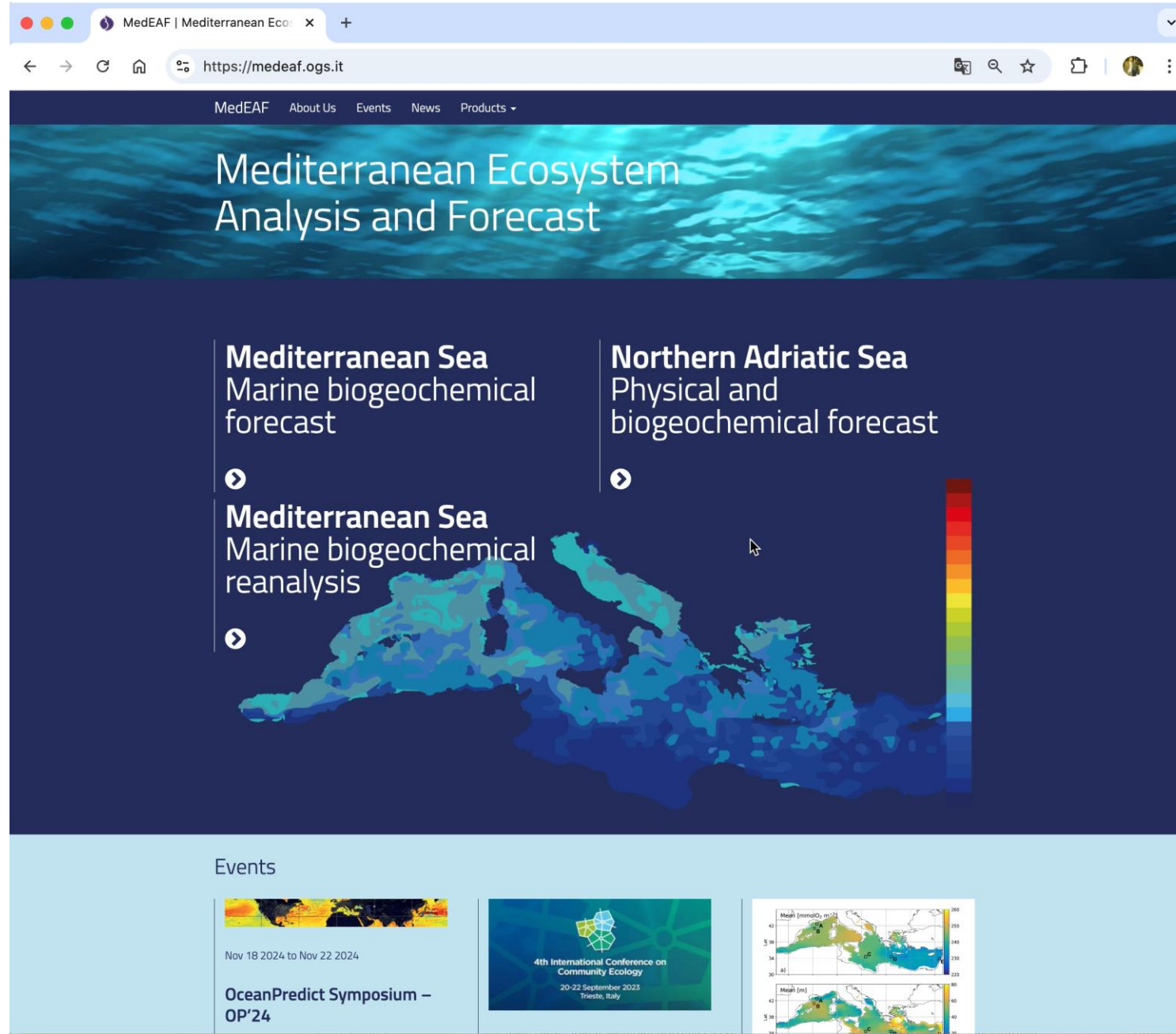
# Need for higher resolution systems

**CMEMS online catalogue**  
(**open** and **free**) of the products for  
the **physical** and **biogeochemical**  
variables and for **surface waves**



**PROBLEM:** for many coastal applications, the resolution ( $1/24^\circ$ ) is not enough...

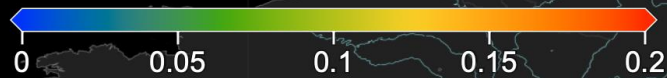
# MedEAF webpage: Med Sea products and downscaling on the northern Adriatic Sea



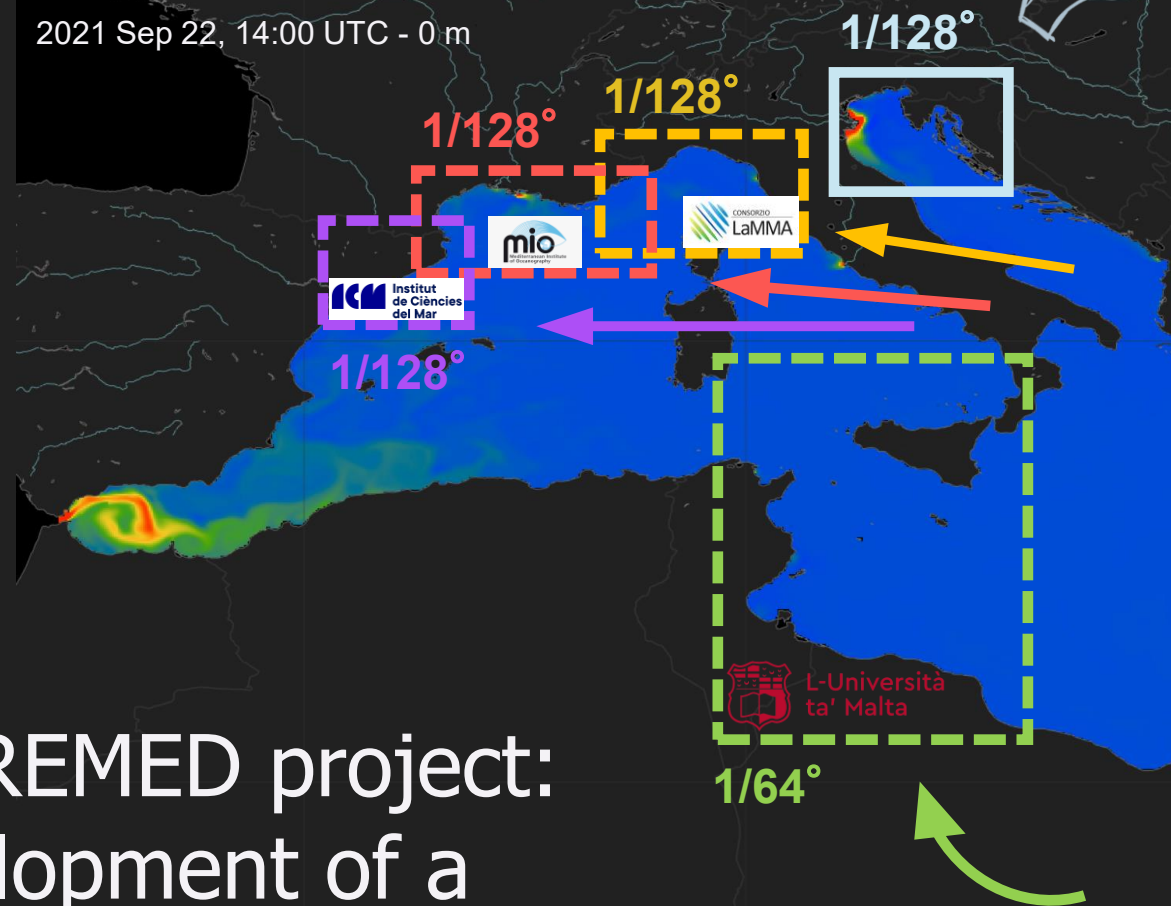
The screenshot displays the MedEAF website interface. The browser's address bar shows the URL <https://medeaf.ogs.it>. The website's navigation menu includes links for MedEAF, About Us, Events, News, and Products. The main header features the title "Mediterranean Ecosystem Analysis and Forecast" over a blue ocean background. Below this, there are three main sections: "Mediterranean Sea Marine biogeochemical forecast", "Northern Adriatic Sea Physical and biogeochemical forecast", and "Mediterranean Sea Marine biogeochemical reanalysis". Each section has a right-pointing arrow icon. A large map of the Mediterranean Sea is shown, with a color scale on the right ranging from blue (low values) to red (high values). The bottom section, titled "Events", lists upcoming conferences: "OceanPredict Symposium – OP'24" (Nov 18-22, 2024) and the "4th International Conference on Community Ecology" (20-22 September 2023, Trieste, Italy). Two small maps of the Mediterranean Sea are also visible in the bottom right corner.



Mole concentration of phosphate in sea water [mmol/m<sup>3</sup>]



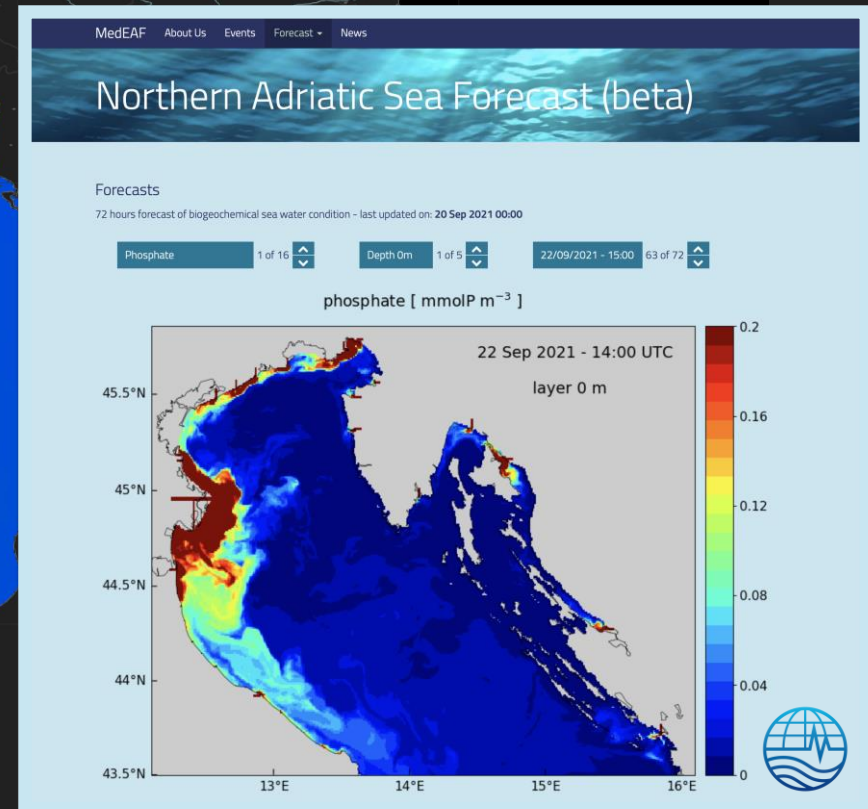
2021 Sep 22, 14:00 UTC - 0 m



background image credit:

*My Ocean*  
by Copernicus Marine Service

SHAREMED project:  
development of a  
relocatable short-term  
forecasting system  
for coastal areas



Interreg  
Mediterranean



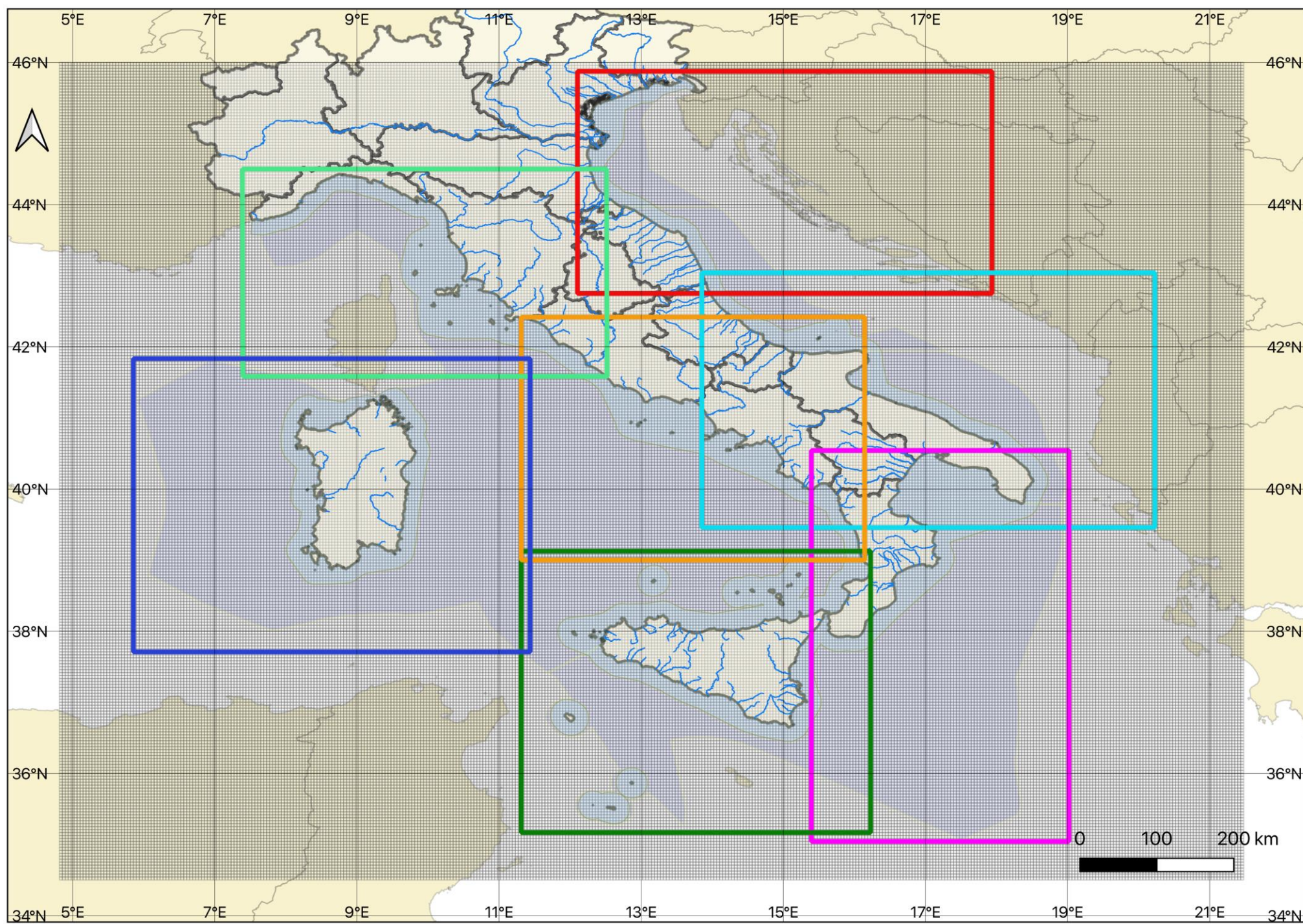
SHAREMED



OGS

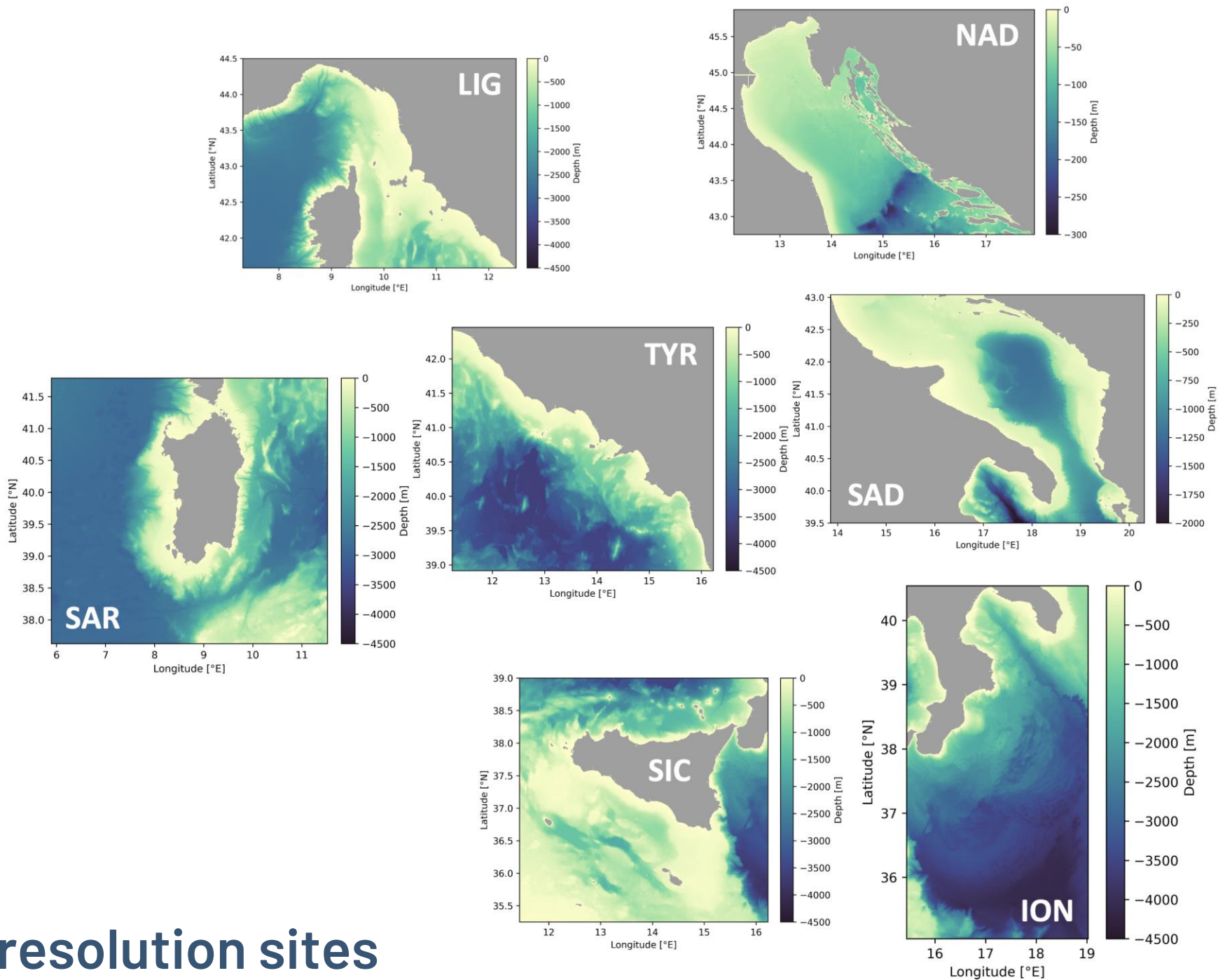


# Model domains (500 m res.)





# Model domains (500 m res.)



+ 10 high-resolution sites

## SUBCONTRACTS

**Lot 1** - Adaptation and quality control of the **satellite products** of Ocean Color and Sea Surface Temperature of the Marine Copernicus service for the coastal strip of the Italian seas.

**Lot 2** - Contribution to **optimization and validation** for the implementation of the biogeochemical modeling system at the national scale at a resolution of 500 m.

**Lot 3** - Support for the implementation of the oceanographic modeling system at the scale of **high-resolution sites** (sites of extension not less than 400 km<sup>2</sup> with grid elements not greater than 100 m).



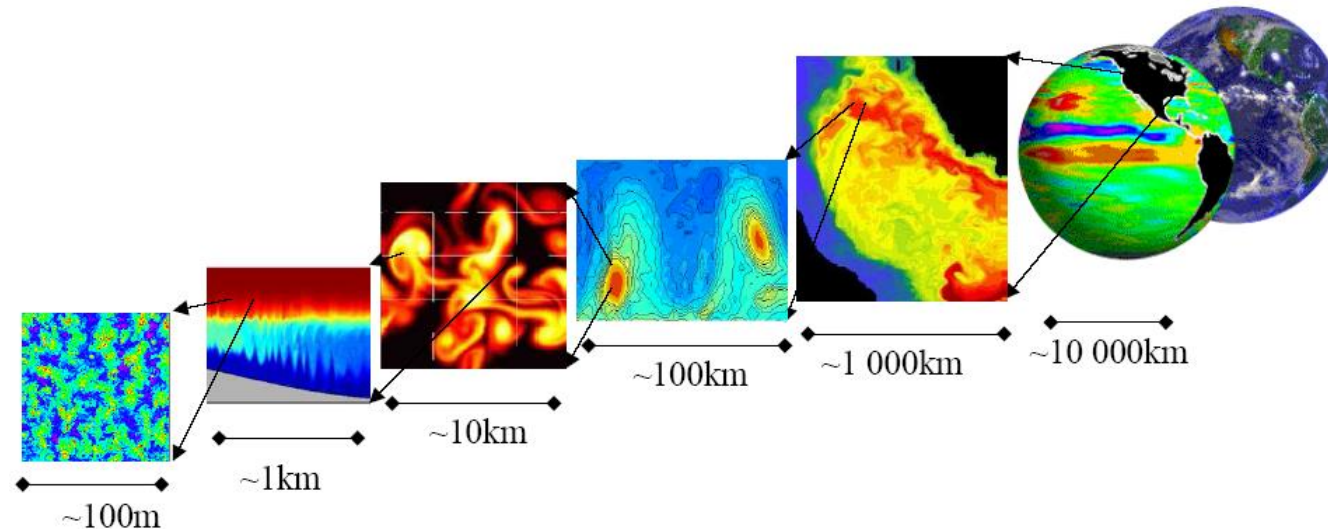


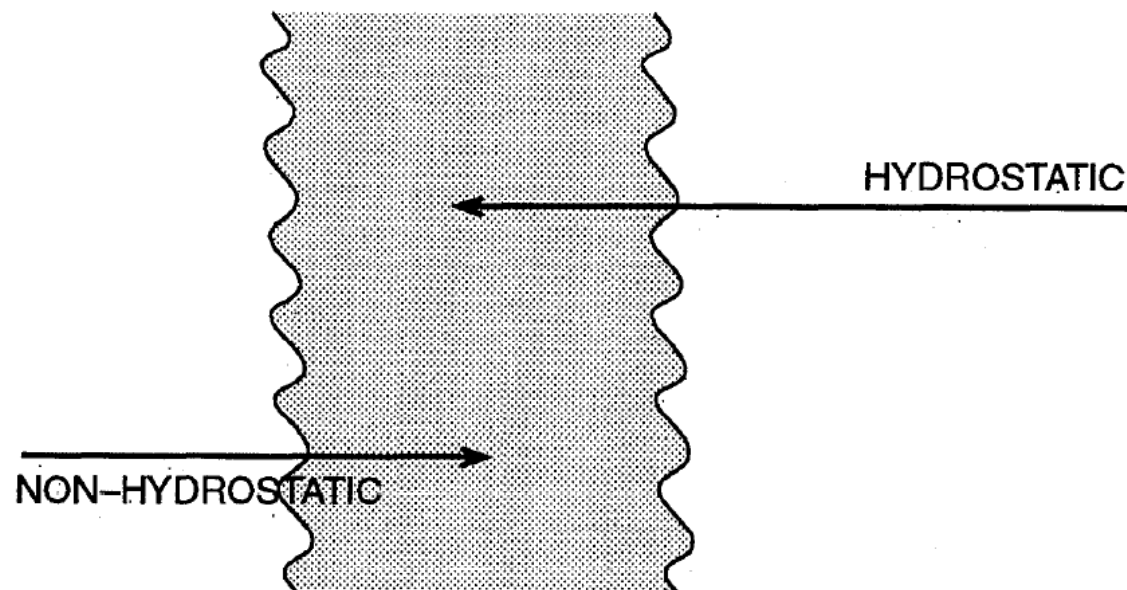
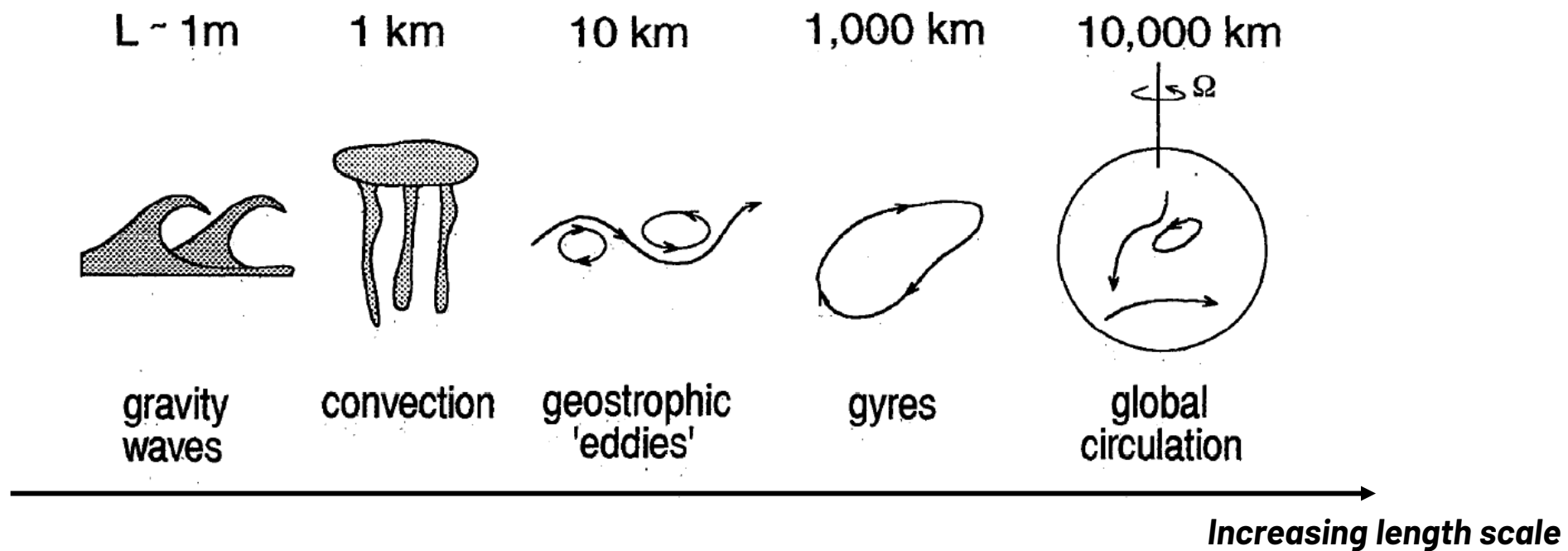
**3Dvar - NUDGING:** assimilation of sea surface chl/temperature and coastal data of nutrients

MITgcm Ocean General Circulation Model [*Marshall et al., 1997*]

MITgcm main features:

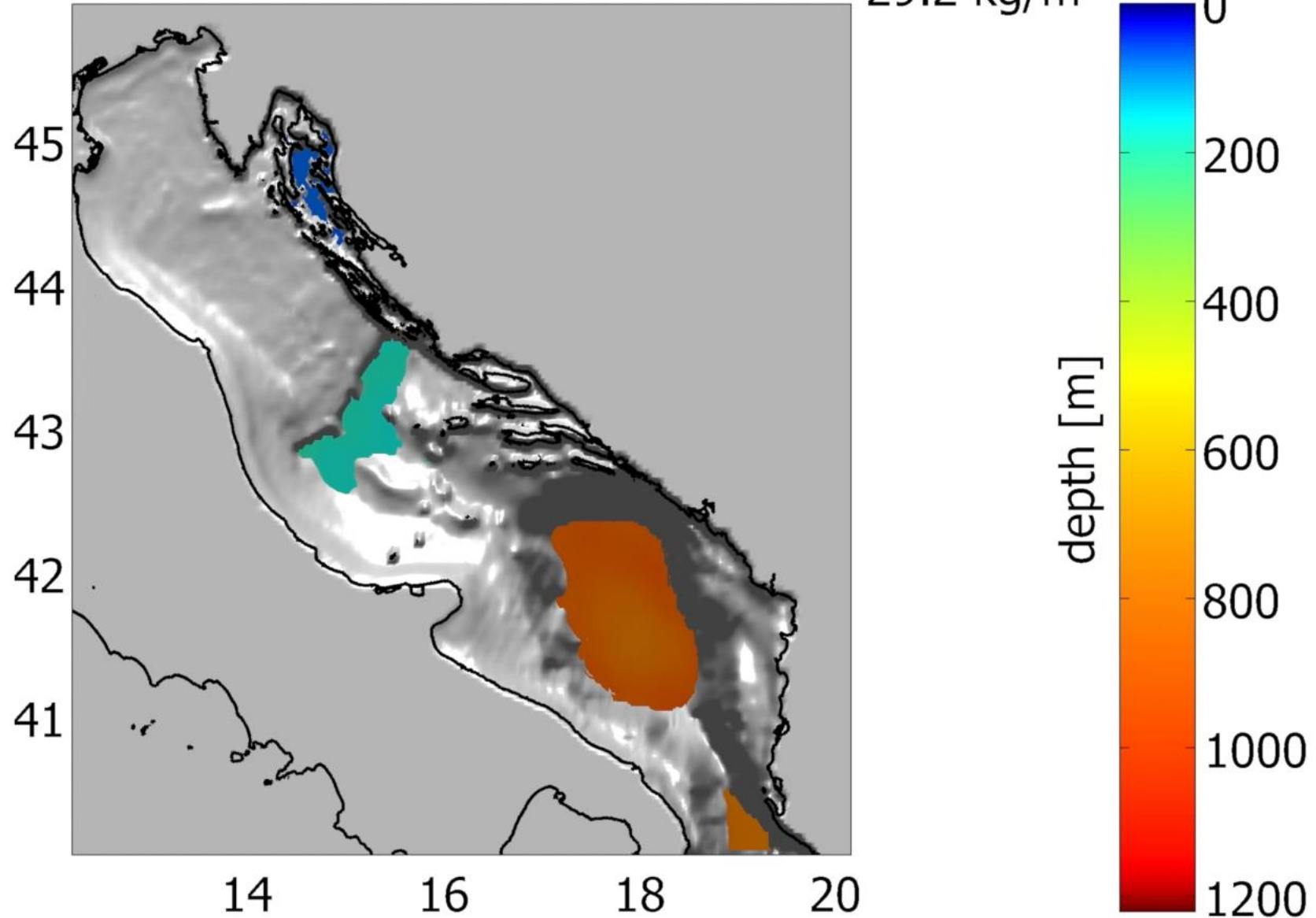
- designed to study both atmospheric and oceanic phenomena
- includes non-hydrostatic capability
- adopts the KPP or GGL90 vertical turbulence parametrization
- adopts a finite volume technique
- developed to perform efficiently on a wide variety of computational platforms including MPI parallelizing directive





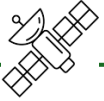
01/11/2011

potential density  
 $29.2 \text{ kg/m}^3$





# MER B32-B35 forecast and reanalysis components



**Remote sensing** data integration  
of **sea surface temperature** and  
**chlorophyll**



EIONET-SOE **in-situ** data integration



**MITgcm-BFM**  
modeling system

**Atmospheric forcing**

**ICON / COSMO** forecasts

**SPHERA** reanalysis

~2.2 km horiz. res., 1 hour freq.

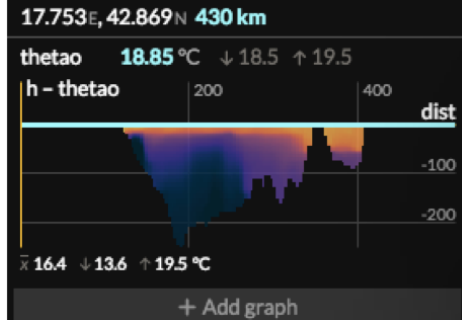


**Atmospheric nutrient deposition**

**Model** results (~25 km horiz. resolution)  
+ bias correction based  
on **observations**



**Initial and southern**  
**boundary conditions**  
for PHY and BGC  
variables



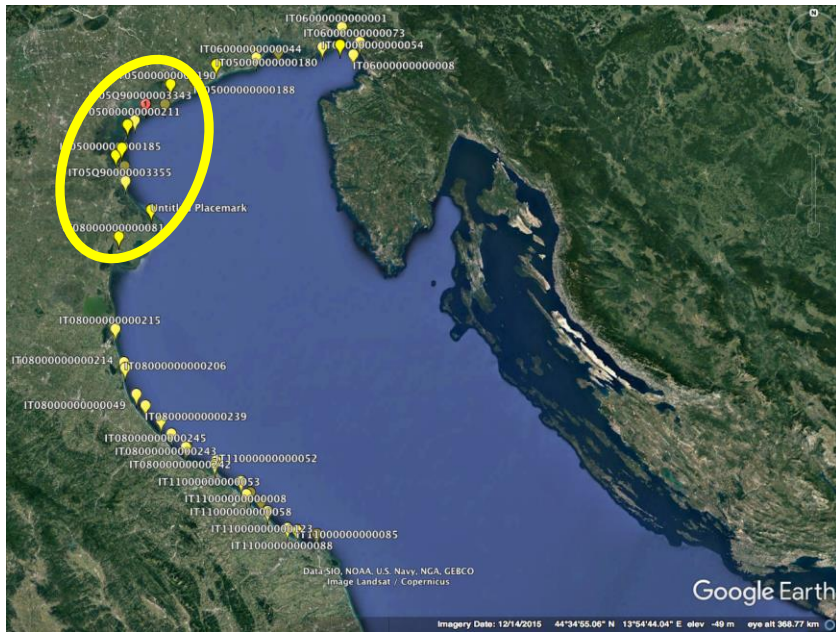
**River discharges and BGC loads**

**Observations** and  
hydrological **model data**  
(~1.5 km horiz. res.)



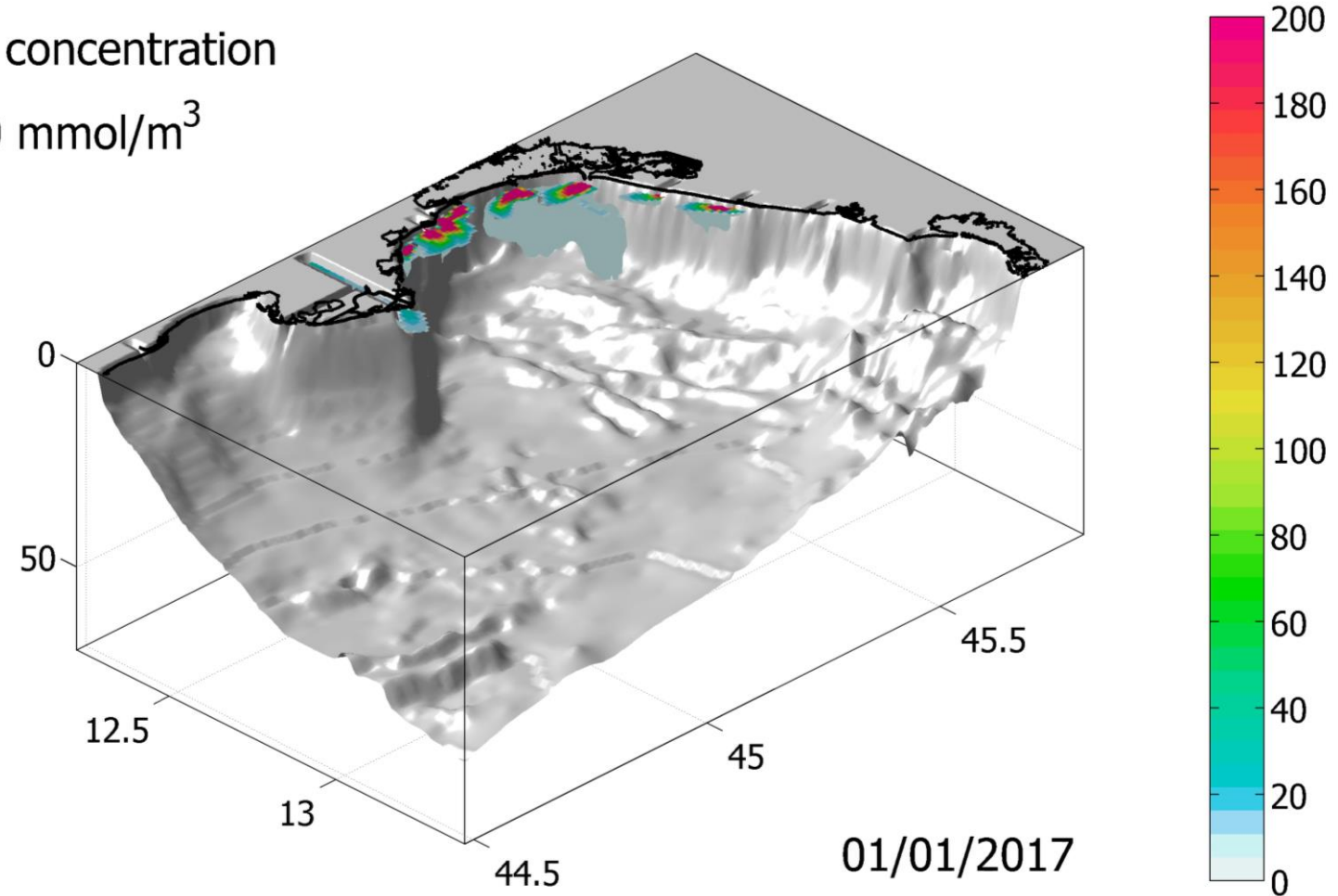
# Action B35: simulation of bottom sewage discharges

**Bottom discharges**, 3D case study  
(municipality of Chioggia):  
12 sources of pollutant  
(proxy of e. coli)



Coastal discharges (ISPRA dataset)

tracer concentration  
 $10 \text{ mmol/m}^3$



first order decay law [Chan et al., 2013]

$$k(z, t) = (k_b + k_s S(z, t)) \theta^{T-20} + k_I I(t) e^{-e_t z}$$

$z$  (depth),  $t$  (time),  $k_b=0.8$ ,  $k_s=0.017$ ,  $k_I=0.086$ ,  $e_t=0.5$  (higher transparency),  $\theta=1.07$

# exact lab

Solutions for the digital revolution

**Client:**



**ISPRA**

Istituto Superiore per la Protezione  
e la Ricerca Ambientale



Sistema Nazionale  
per la Protezione  
dell'Ambiente

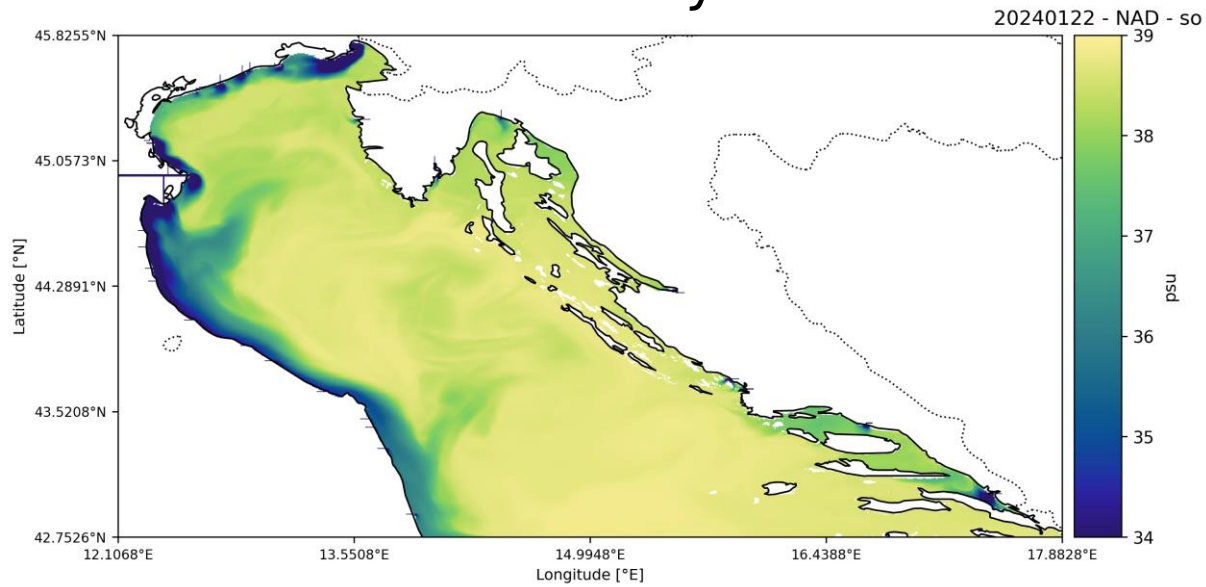
**Case study: MER**  
**Biogeochemical operational chain  
engineering**



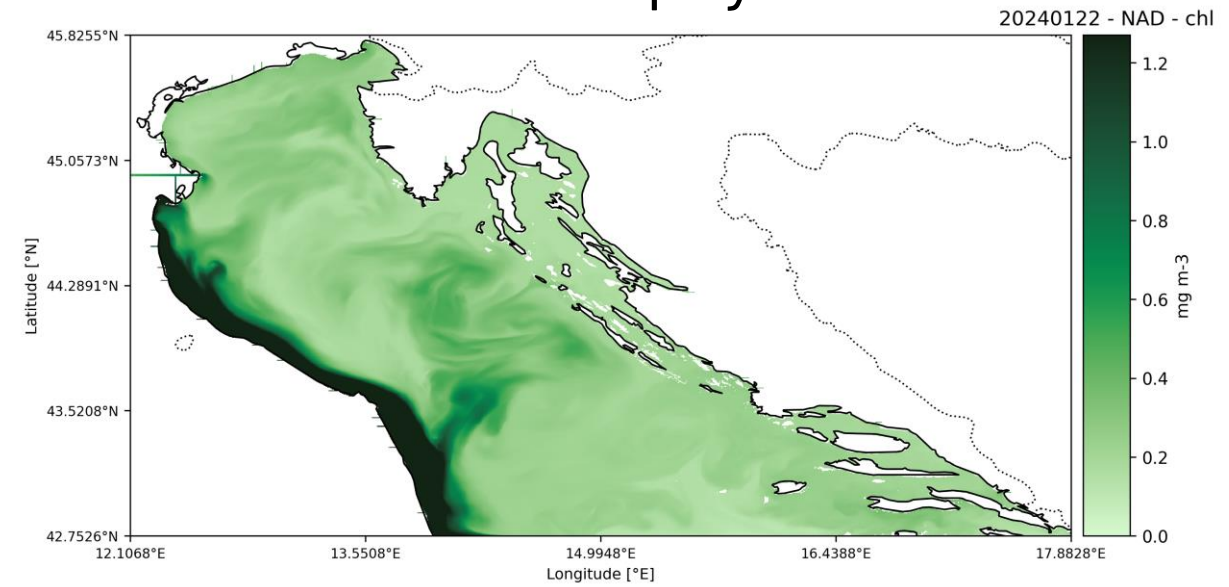
# Model results – yearly run – NAD

## WINTER 2024

salinity



chlorophyll

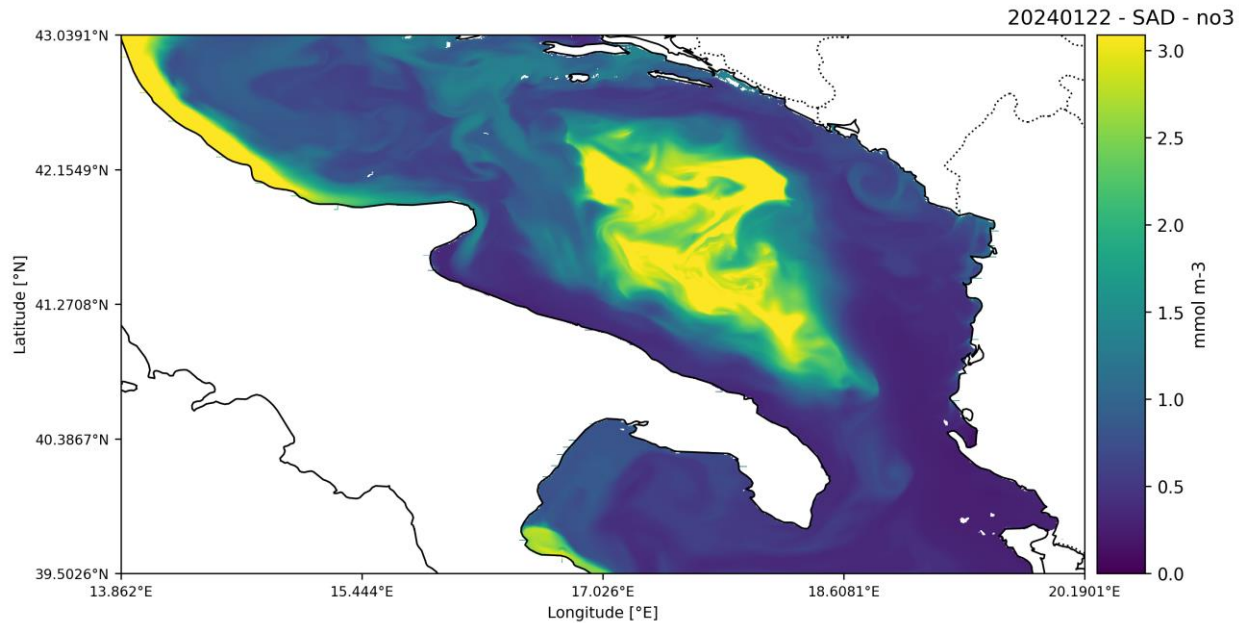




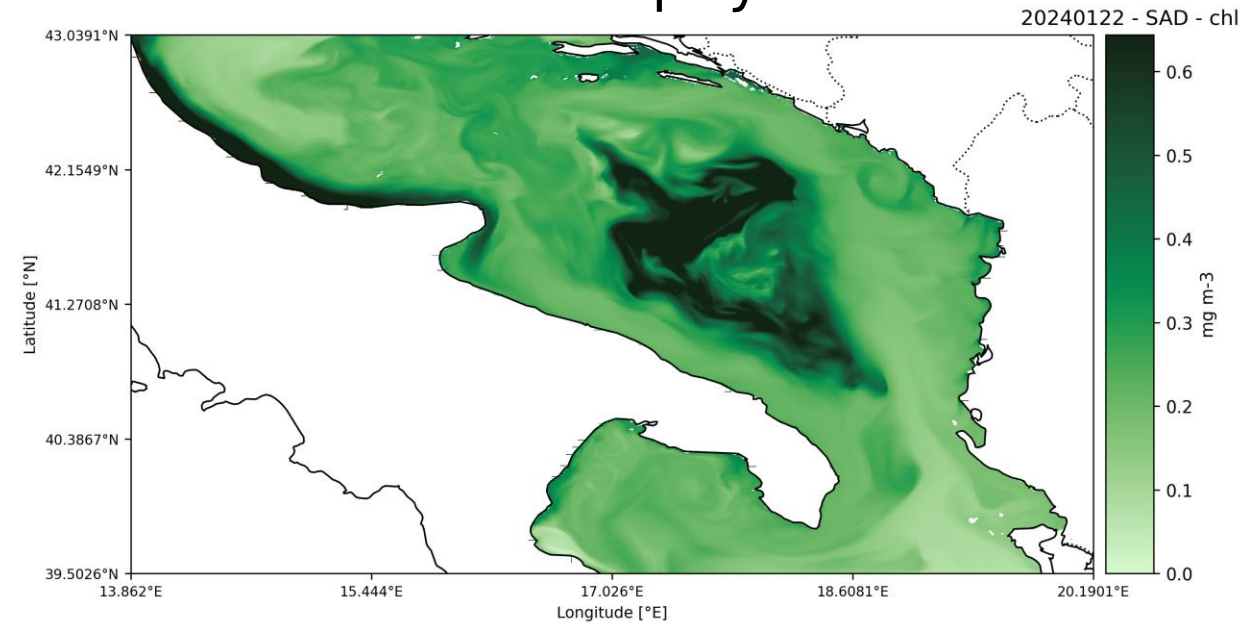
# Model results – yearly run – SAD

## WINTER 2024

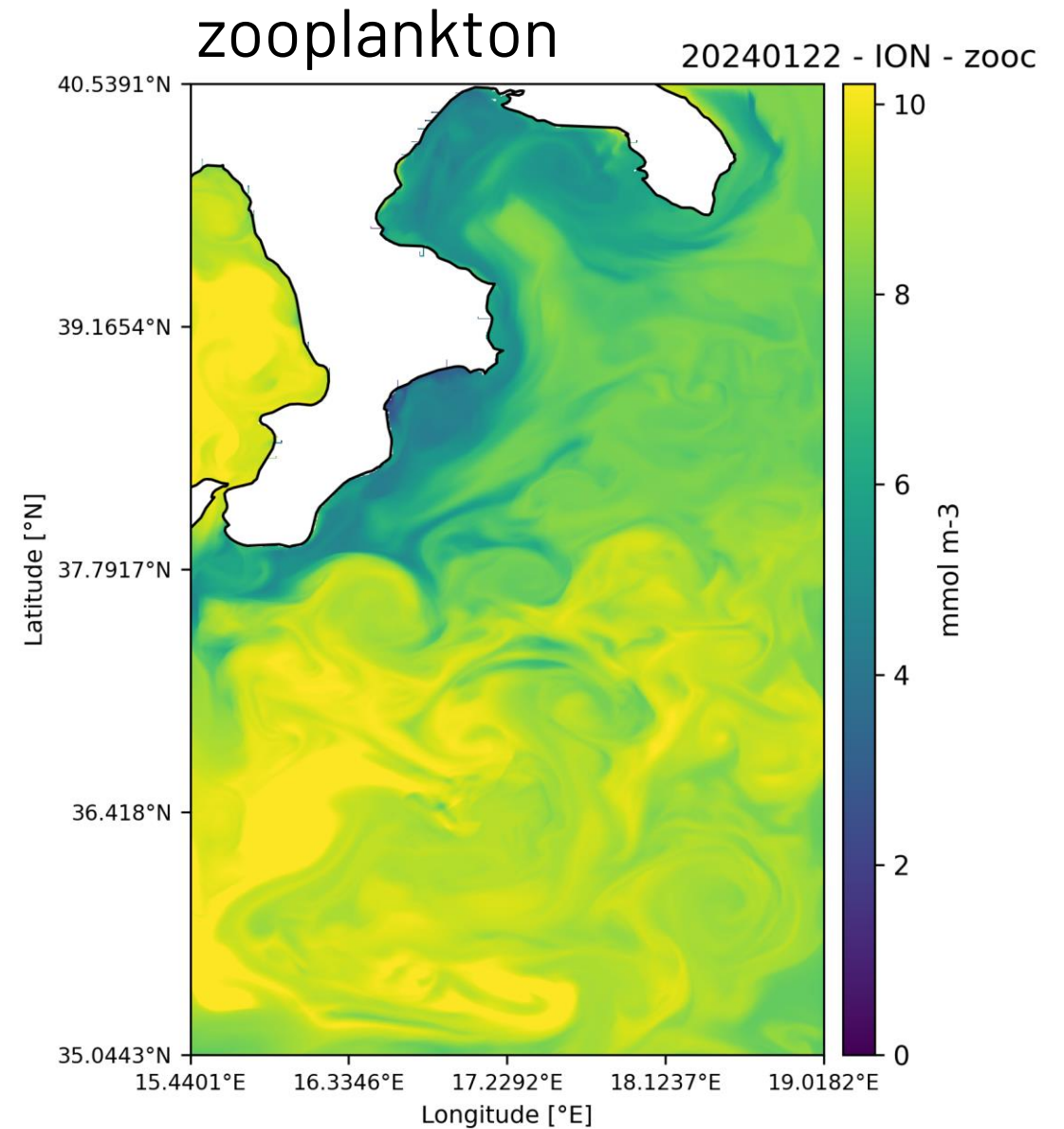
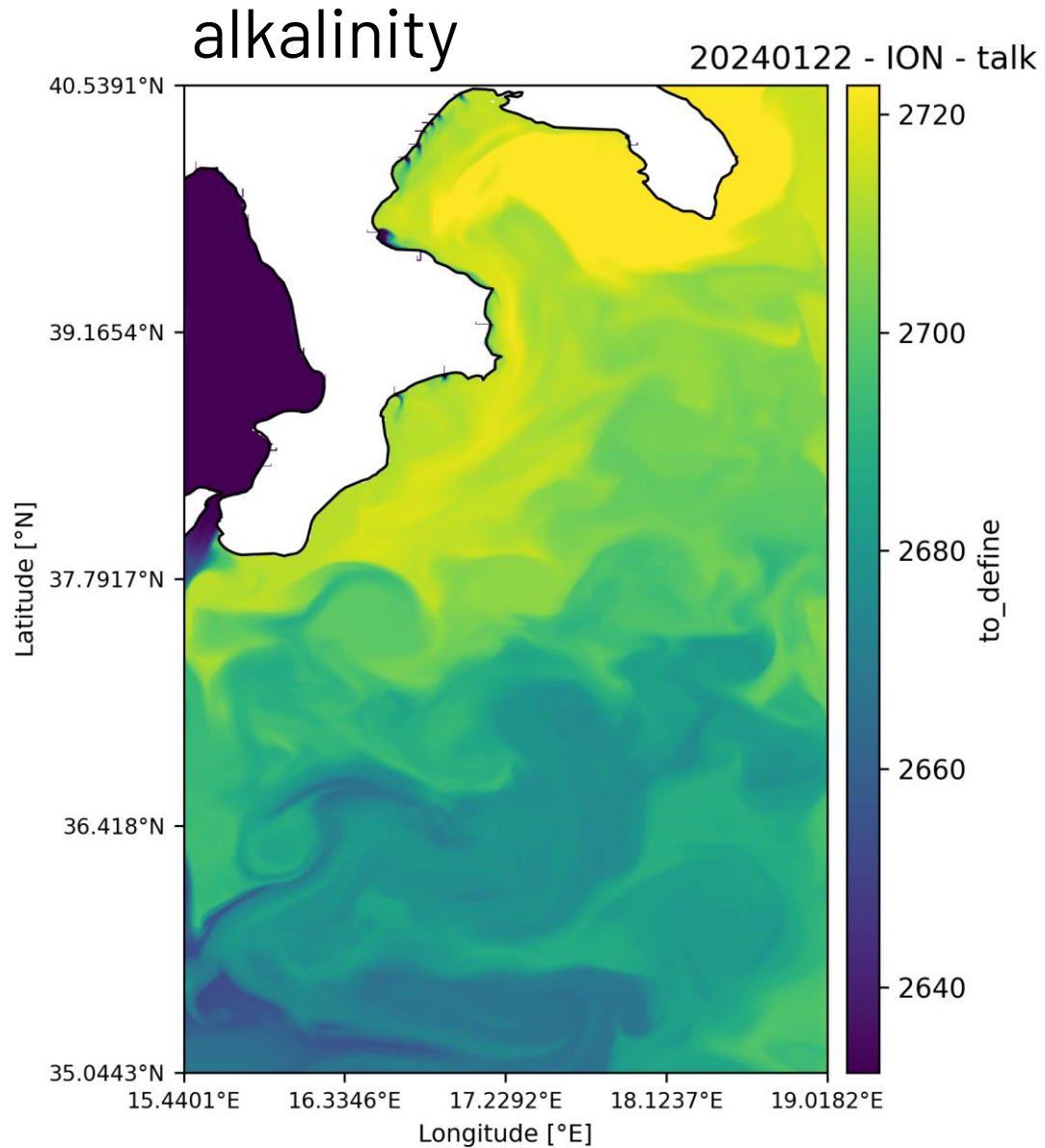
nitrate



chlorophyll



# Model results – yearly run – ION

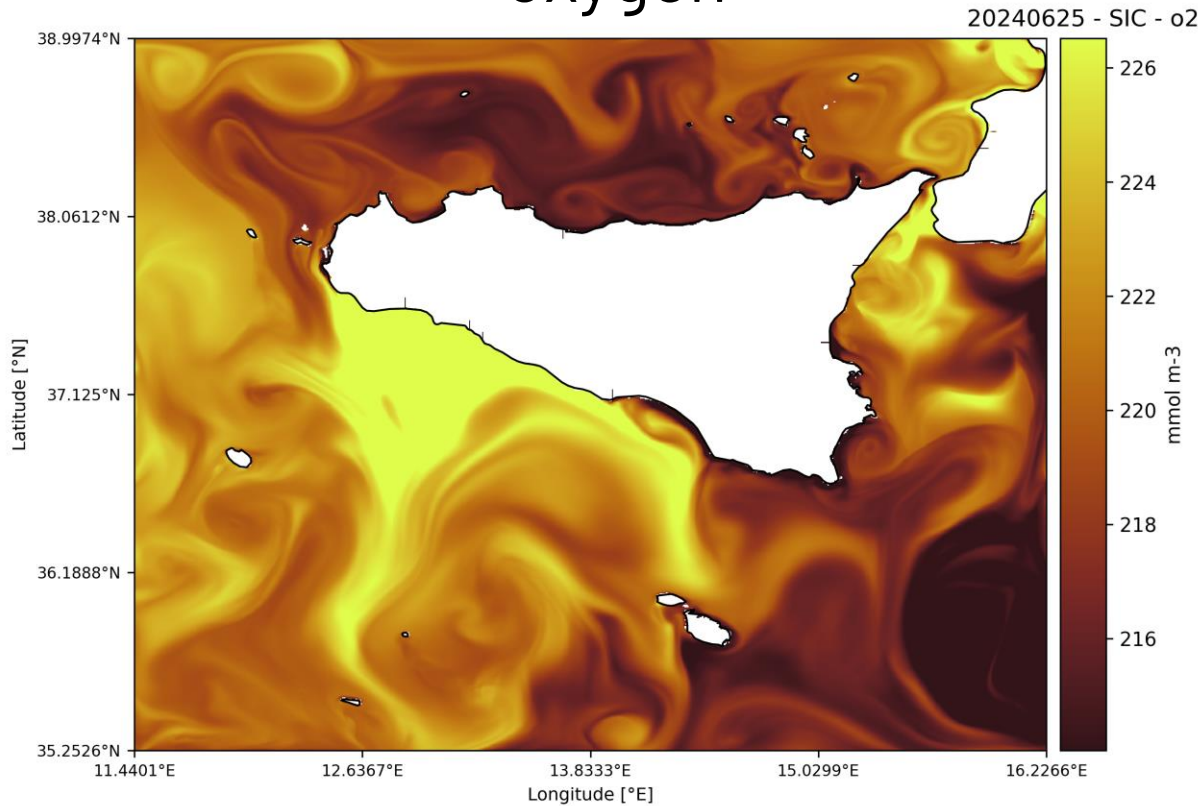


**WINTER 2024**

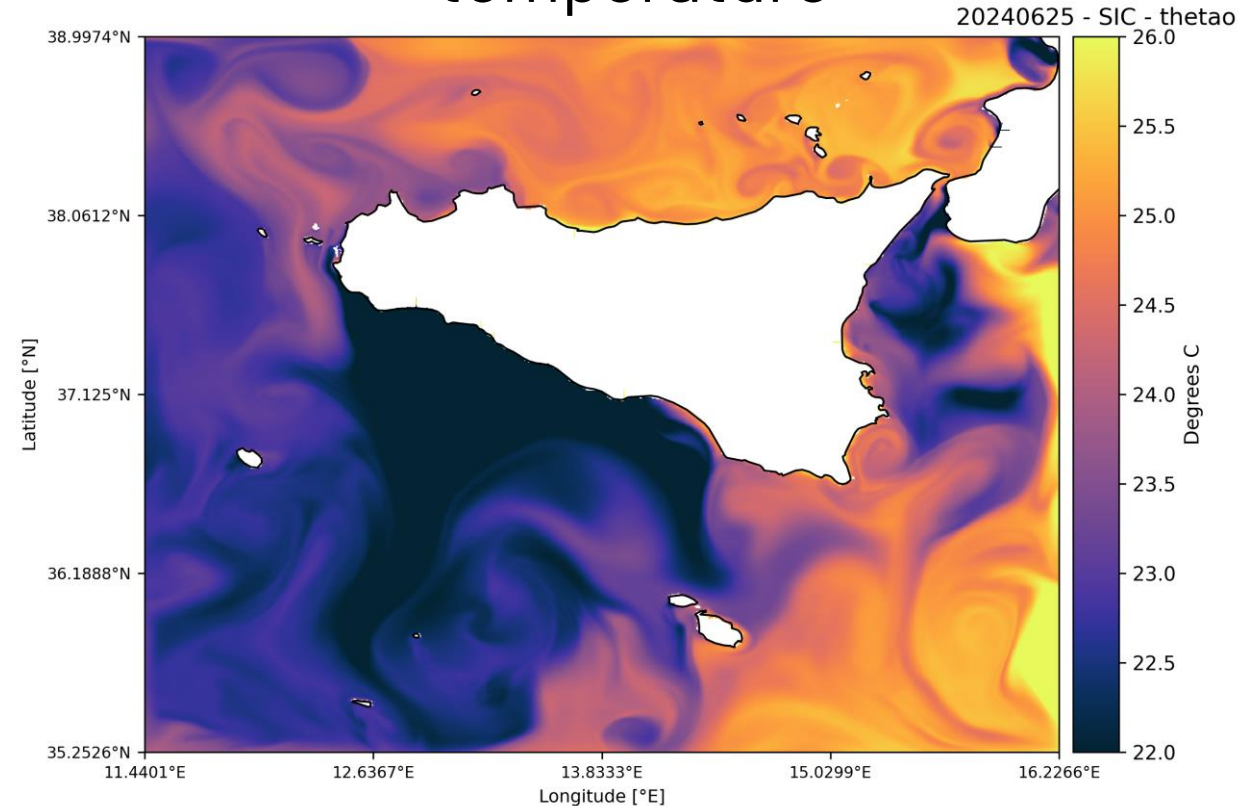
# Model results – yearly run – SIC

## SUMMER 2024

oxygen



temperature



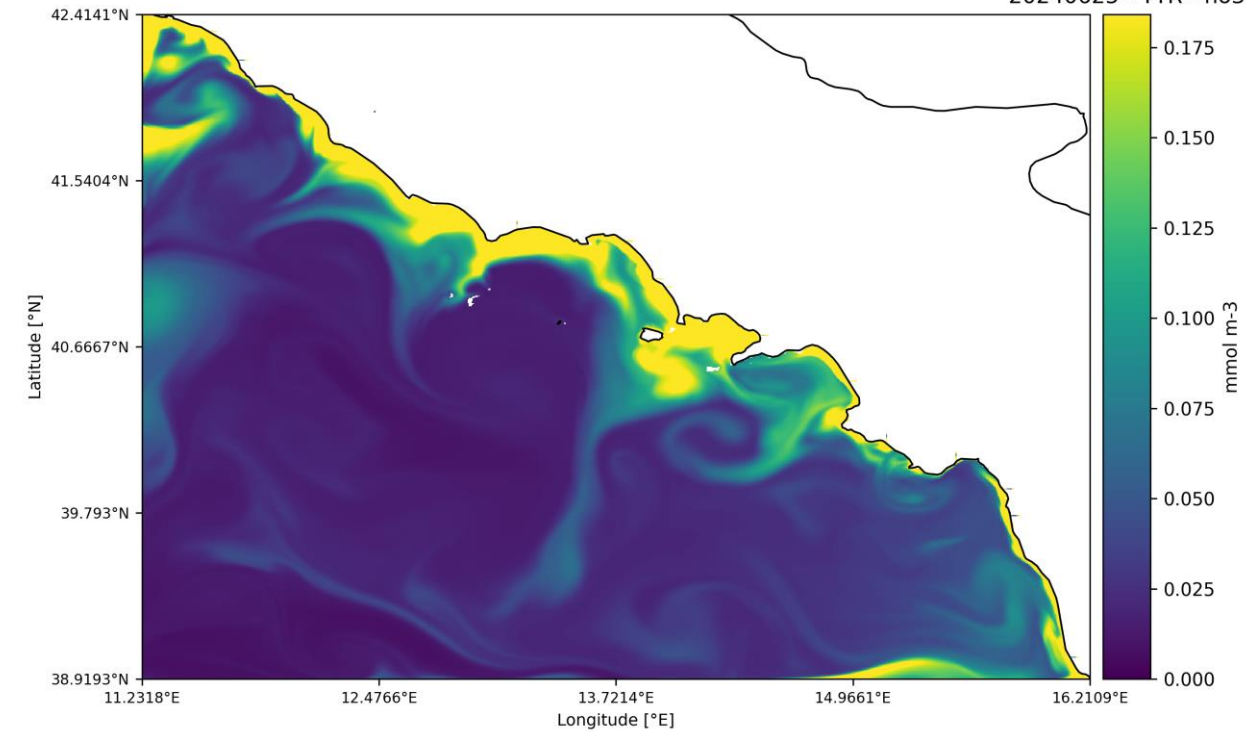


# Model results – yearly run – TYR

## SUMMER 2024

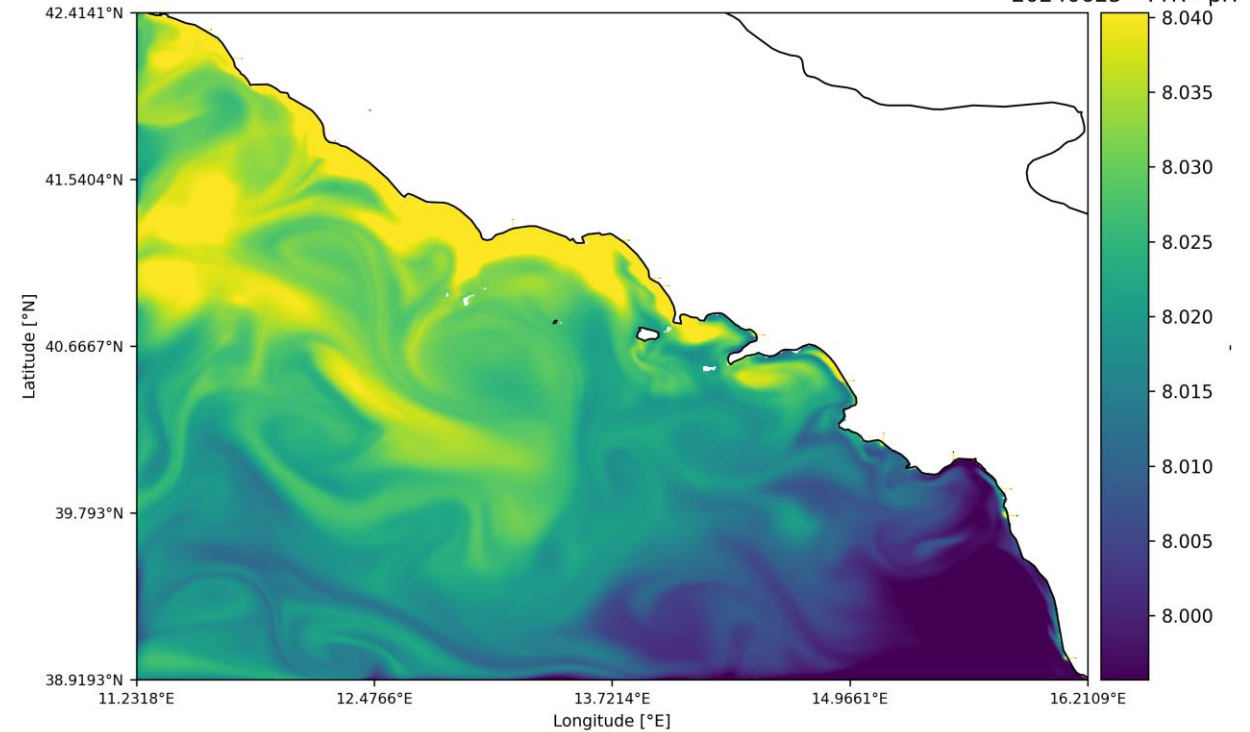
nitrate

20240625 - TYR - no3



pH

20240625 - TYR - pH

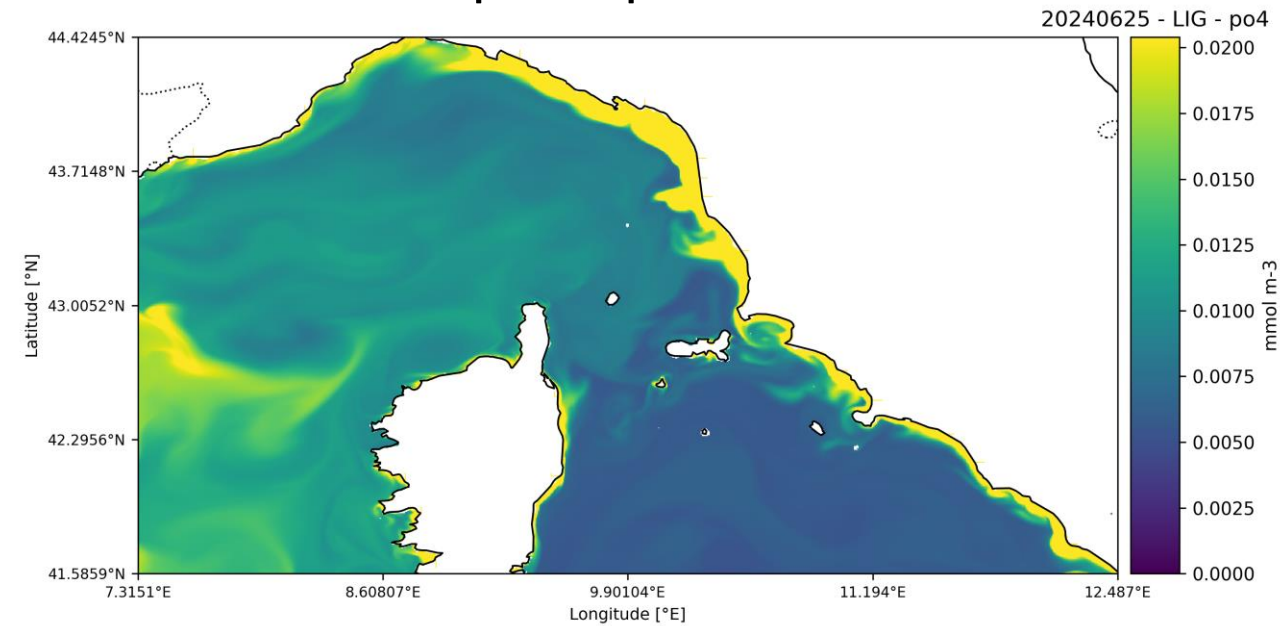




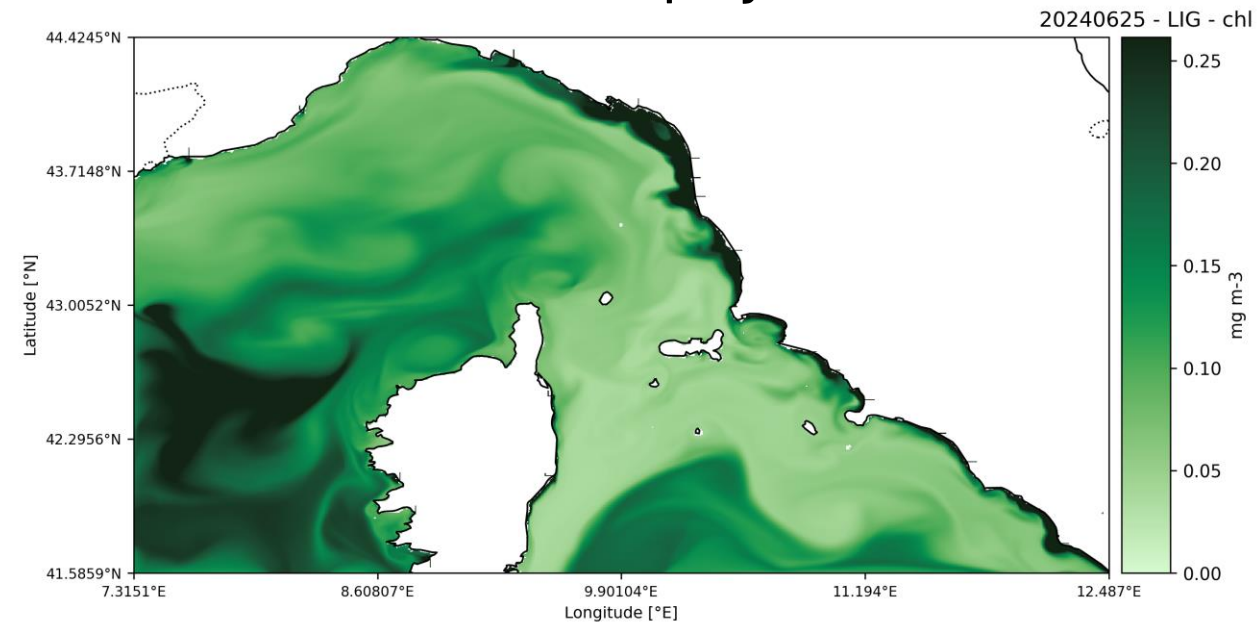
# Model results – yearly run – LIG

## SUMMER 2024

### phosphate



### chlorophyll

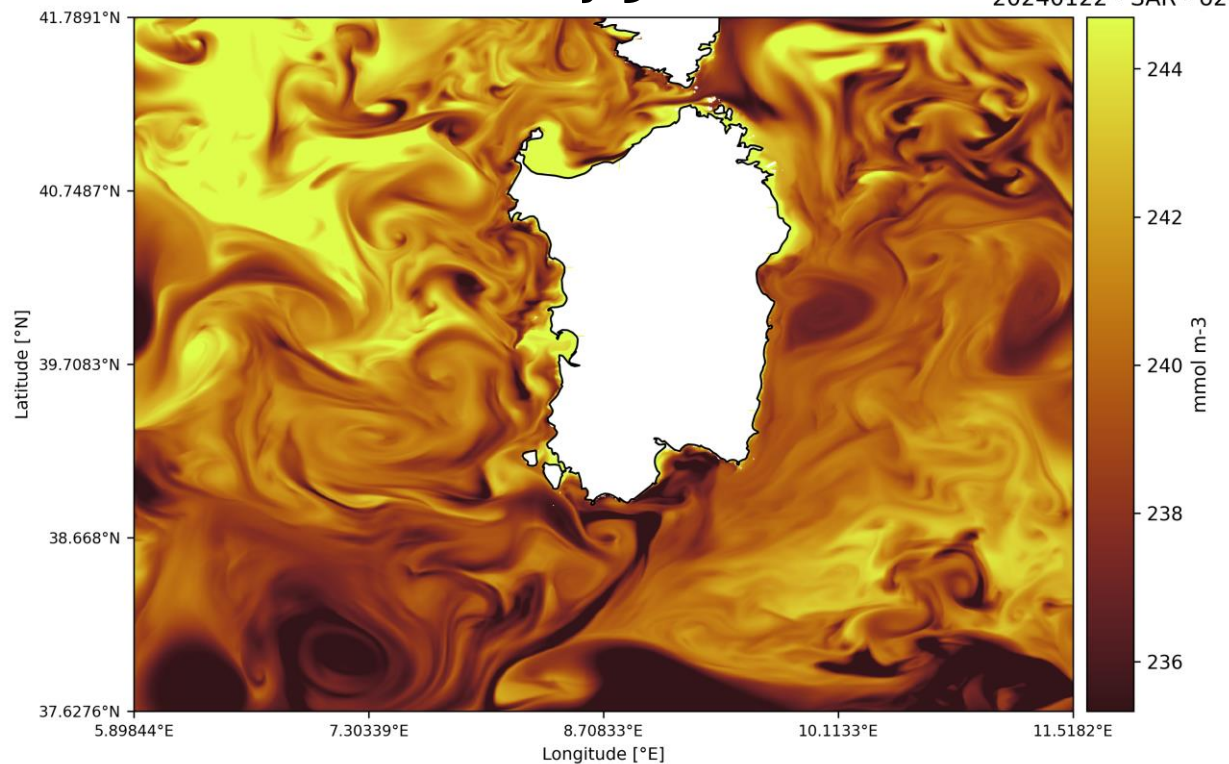


# Model results – yearly run – SAR

## WINTER 2024

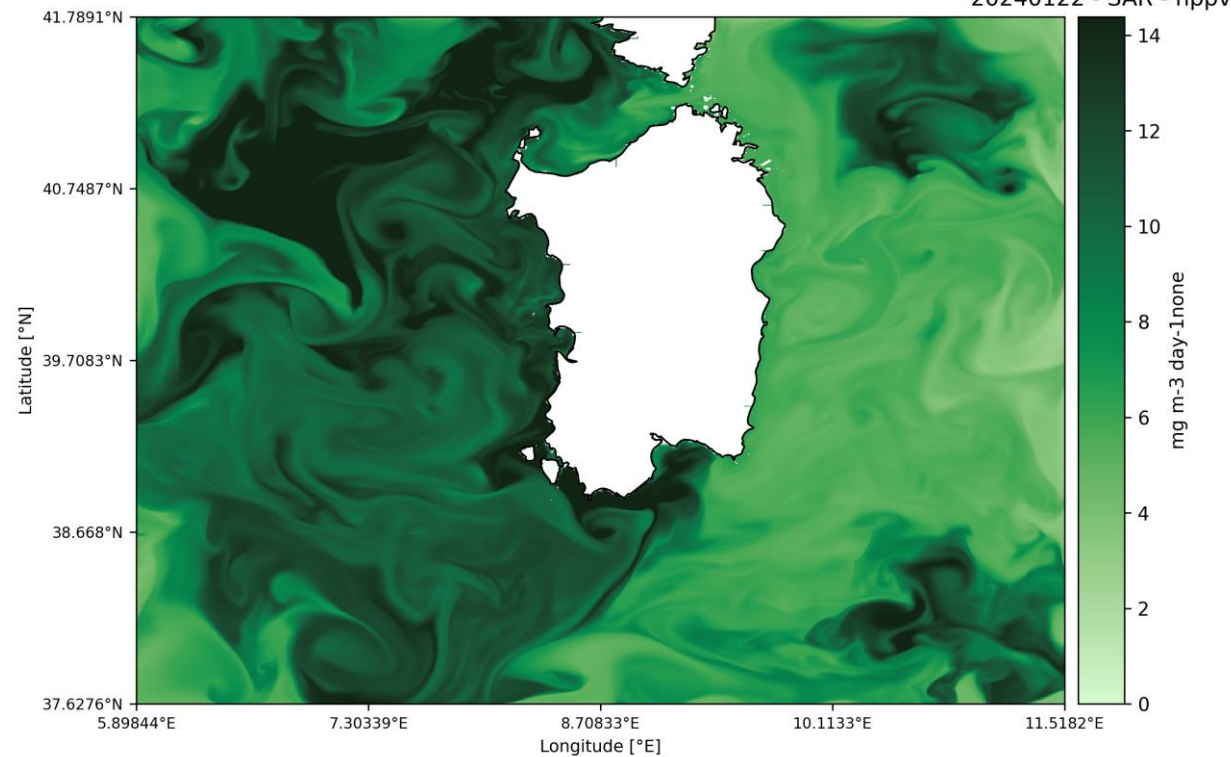
oxygen

20240122 - SAR - o2



net primary prod.

20240122 - SAR - nppv



# Wrap up...

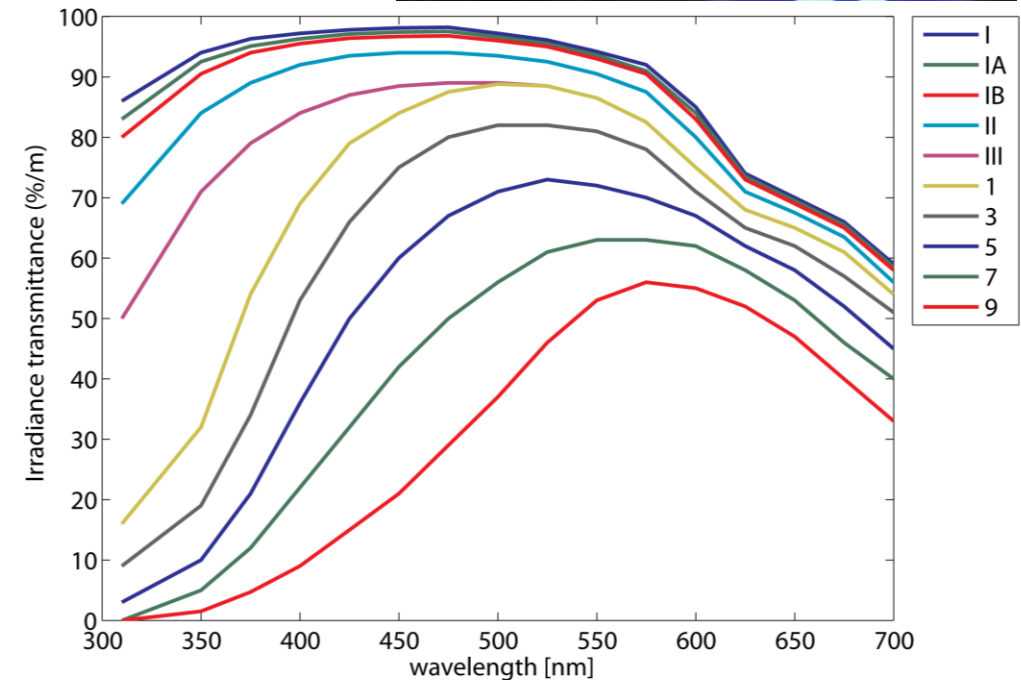
- for coastal applications high **resolution** and high level of **detail** are needed
- **regional downscaling tools** need careful **integration** of various products (and their dependencies): open sea boundary conditions, river discharge, high-resolution atmospheric forcing, satellite observations and in situ coastal data;
- technological advancements and potential benefits of the **MER relocatable forecasting system**;
- preliminary results of the physical and biogeochemical hindcast simulations for the Italian coastal waters.

# Thank you!

## 1. Jerlov water type

**Jerlov** [1976] discretized his observations into a set of five typical **oceanic** spectra and nine typical **coastal** spectra

Jerlov Water Type	Examples
I	Open Pacific
IA	Eastern Mediterranean, Indian Ocean
IB	Western Mediterranean, Open Atlantic
II	Coastal waters, Azores
III	Coastal waters, North Sea
1	Skagerrak Strait
3	Baltic
5	Black Sea
7	Coastal waters, dark



## 2. Choice of the **albedo**

## 3. **Direct/diffuse** short wave radiation from atmospheric models: **same standard?**

## 4. **Spectral models** of light absorption

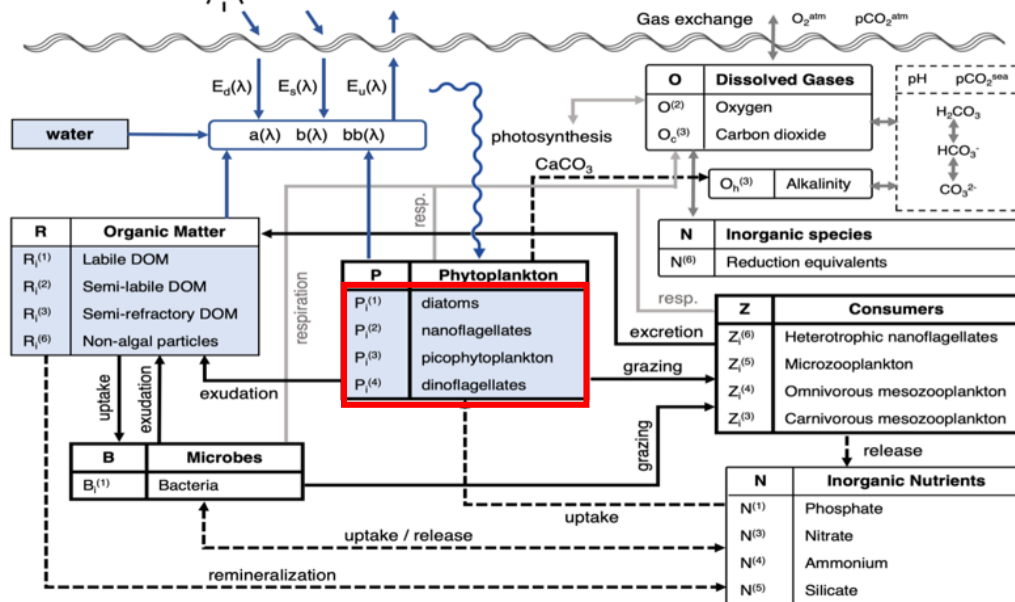
## 5. **Feedback** from **biogeochemical models**



# 3DVAR assimilation in MITgcm-BFM system for chlorophyll

MITgcm-BFM 3D physical-biogeochemical model

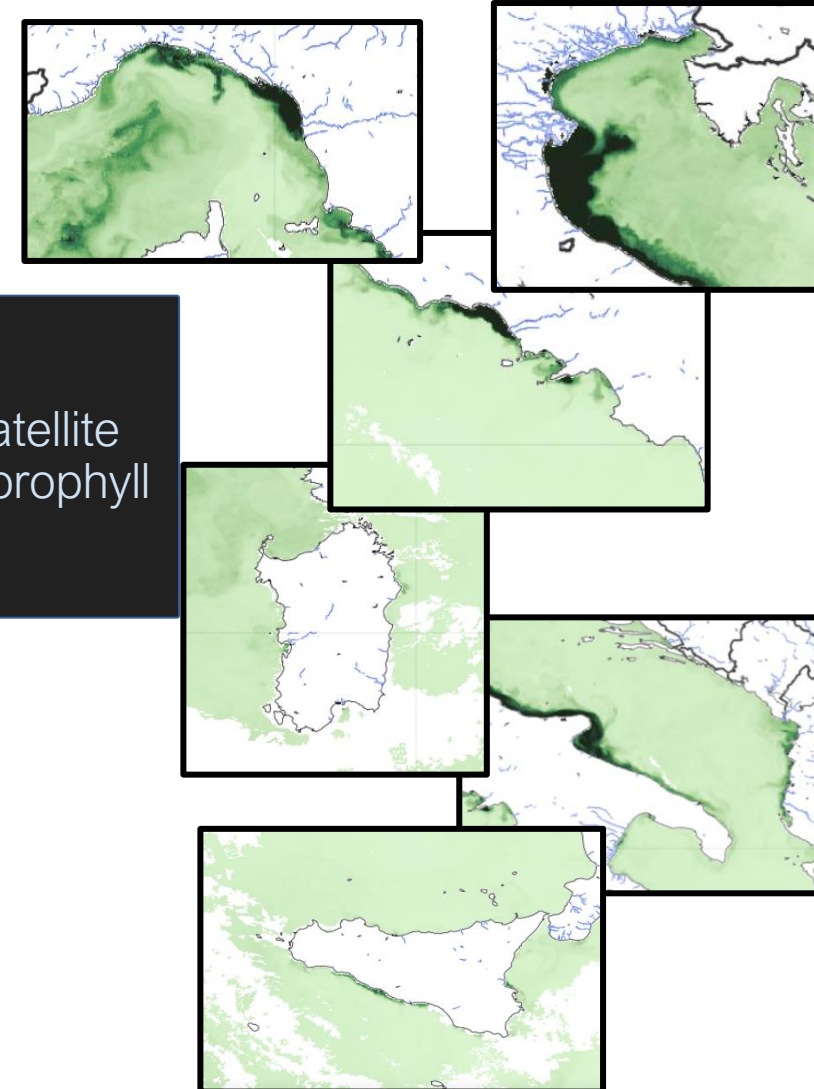
Biogeochemical Model



Variational data assimilation

Satellite chlorophyll

L3 OCTAC chlorophyll from CMEMS

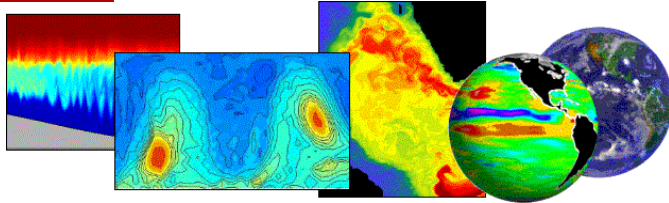


Every week assimilation of 1 week of observations

# Assimilation in MITgcm-BFM of SST and in-situ nutrients

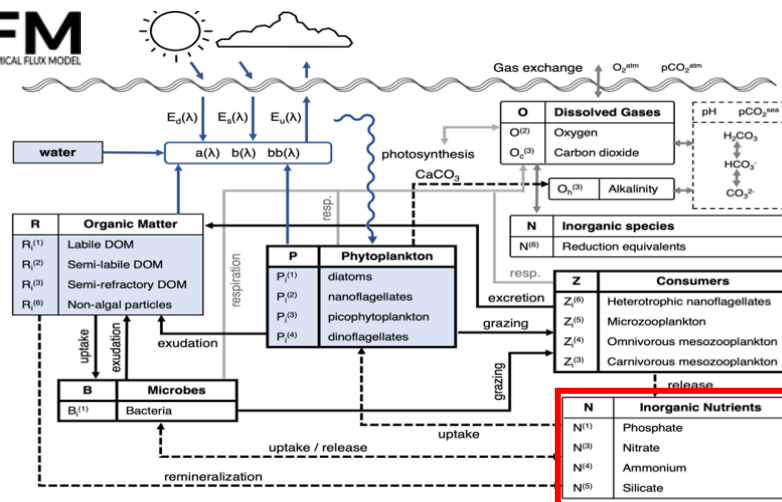
## MITgcm-BFM 3D physical-biogeochemical model

MITgcm hydrodynamic model



Temperature  
Salinity  
 $U, V, W$

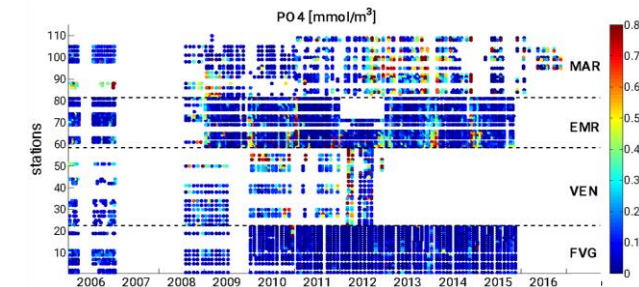
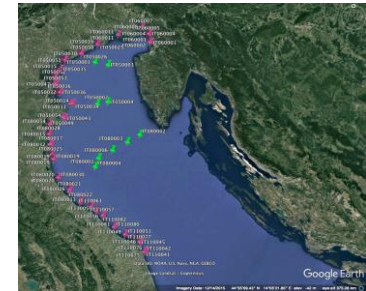
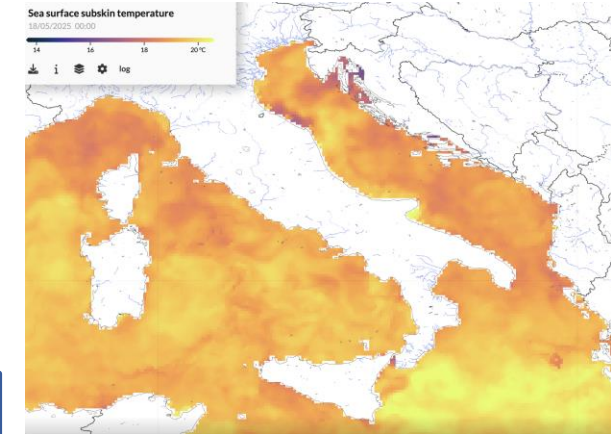
BFM  
BIOGEOCHEMICAL FLUX MODEL



nudging  
scheme

$$\frac{N(st,r)_{x,y} \cdot (C(x,y,t) - C_{st})}{\tau}$$

SST  
and in  
situ  
data

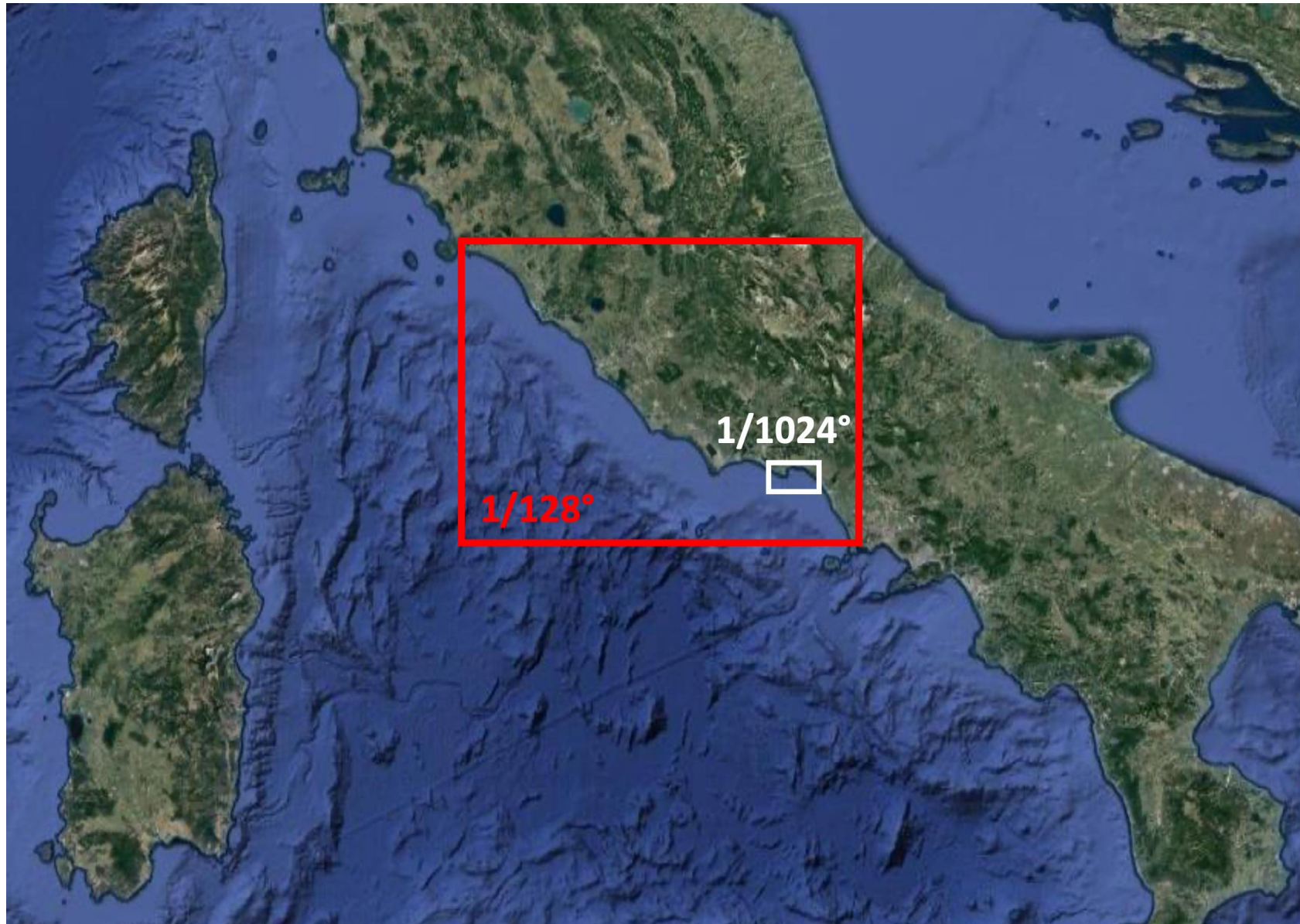


Daily relaxation for SST and **monthly** relaxation for in-situ nutrient data  
CMEMS SST and EIONET-SOE dataset



# Identification of allocated zones for aquaculture (AZA) – Lazio Region

Model domains: regional and local scale



$1/128^\circ \cong 750 \text{ m}$

$1/1024^\circ \cong 95 \text{ m}$

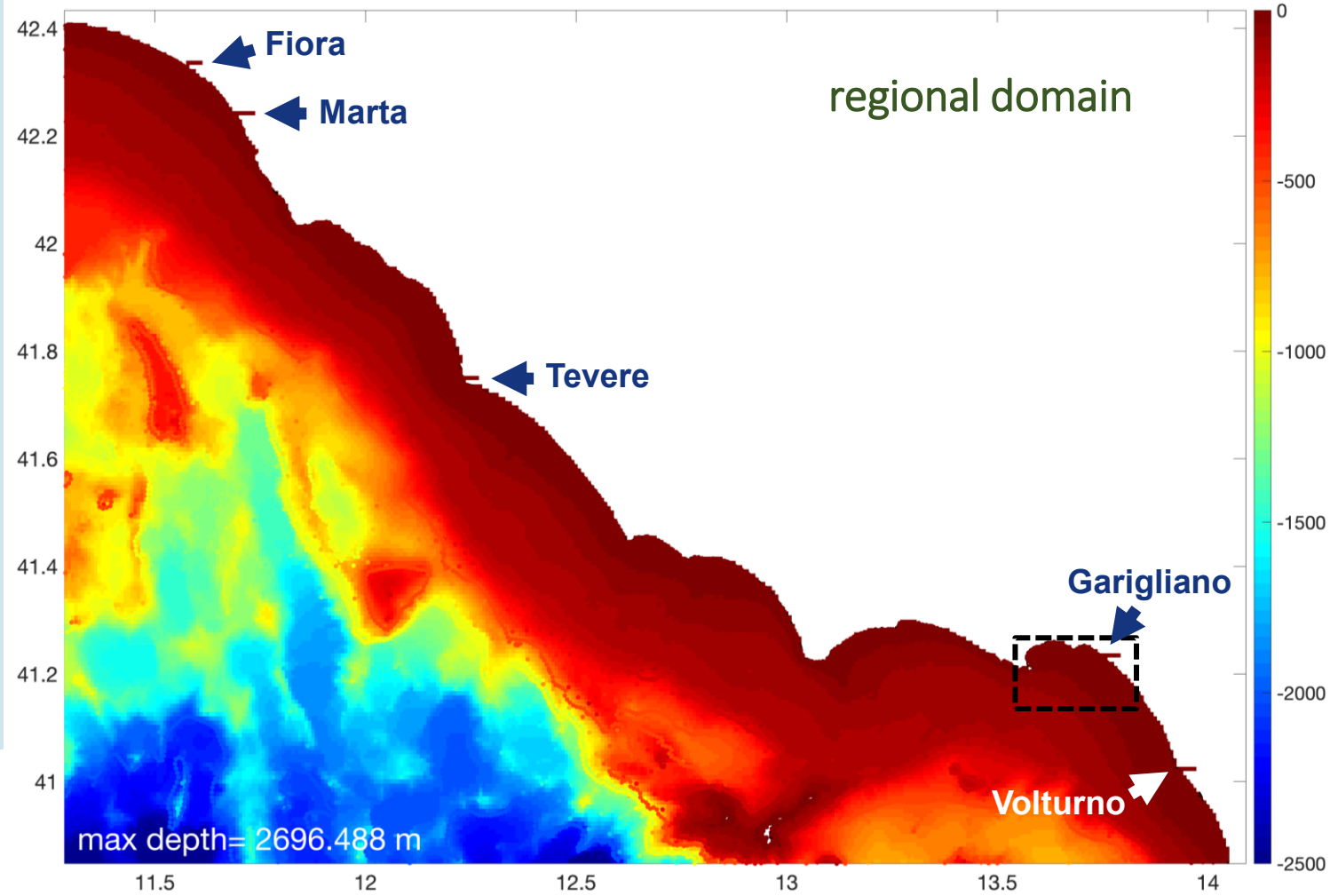


AZAlazio  
Assegnazione di zone marine per l'aquacoltura

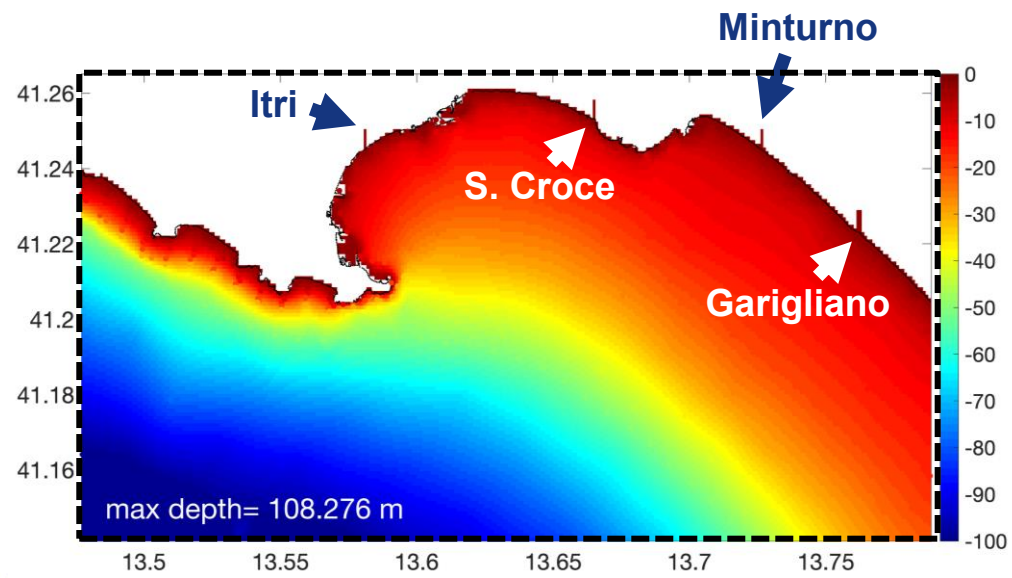


NER MARINE ECOSYSTEM  
RESTORATION

# Model domains: bathymetries



high resolution domain  
(from S. Agostino to Garigliano)





# Copernicus EU EFAS river discharges



The screenshot shows the Copernicus Early Warning Data Store (EWDS) interface. At the top, there are logos for the European Union, Copernicus, and the Emergency Management Service. A navigation bar includes links to 'Datasets', 'Documentation', 'Live', 'About CEMS', and 'Background'. A banner message dated 26 Sep 2024 welcomes users to the new EWDS and mentions ongoing enhancements. The search results section shows a search for 'efas river discharges' with 10 results found. Two results are highlighted with green and purple boxes. The first result, 'River discharge and related historical data from the European Flood Awareness System', is updated today and provides gridded modelled sub-daily and daily hydrological time series. The second result, 'River discharge and related forecasted data by the European Flood Awareness System', is updated 5 days ago and provides gridded modelled hydrological time series forced with medium-range meteorological forecasts. Both results include a map of Europe and a list of tags: Reanalysis, Copernicus CEMS, Europe, Past, and Land (hydrology).

PROGRAMME OF THE EUROPEAN UNION

Copernicus

Emergency Management Service

Login - Register

CEMS Early Warning Data Store

Datasets Documentation Live About CEMS Background

Info 26 Sep 2024 Welcome to the New CEMS Early Warning Data Store (EWDS)! This new system is in its early days of full operations and still undergoing enhancements and fine tuning. Some disruptions are to be expected. Your feedback is key to improve the user experience on the new EWDS for the benefit of everyone. Thank you.

Search results

efas river discharges

Search

Filter by

Product type

Provider

Spatial coverage

Temporal coverage

Variable domain

Apply this search in CDS We found 2 results

Apply this search in ADS No results found

We found 10 results

Sort by: Relevance

River discharge and related historical data from the European Flood Awareness System Updated today

This dataset provides gridded modelled sub-daily and daily hydrological time series forced with meteorological observations. The data set is a consistent representation of the most important hydrological variables across the European Flood Awareness System (EFAS) domain. The temporal resolution is u...

Reanalysis Copernicus CEMS Europe Past Land (hydrology)

River discharge and related forecasted data by the European Flood Awareness System Updated 5 days ago

This dataset provides gridded modelled hydrological time series forced with medium-range meteorological forecasts. The data is a consistent representation of the most important hydrological variables across the European Flood Awareness System (EFAS) domain. The temporal resolution is sub-daily high...

Forecasts Copernicus CEMS Europe Past Land (hydrology)

EFAS v5 products (hydrological model with 1.5 km resolution) consisting of 6-h 2D maps of river discharge, divided in:

- **historical:** freely available, covering the **1992-present** time period;
- **forecast:** freely available, **since 2018-10-10** with 1 month delay, and **near-real-time** for **EFAS Third Party Partners** only.

**OGS** was appointed TPP by National Civil Protection Department and Copernicus Marine Service (one dataset on Med. scale), obtaining access to NRT data of **high-resolution ECMWF and DWD forecasts (10 and 7 days)** on a FTP server updated every 12h.

# River modelling (1/3)

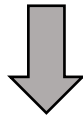
## EFAS DOMAIN

EFAS provides river discharge data within the **domain**:

longitude  $25.2^{\circ} \text{ W} \div 50.2^{\circ} \text{ E}$

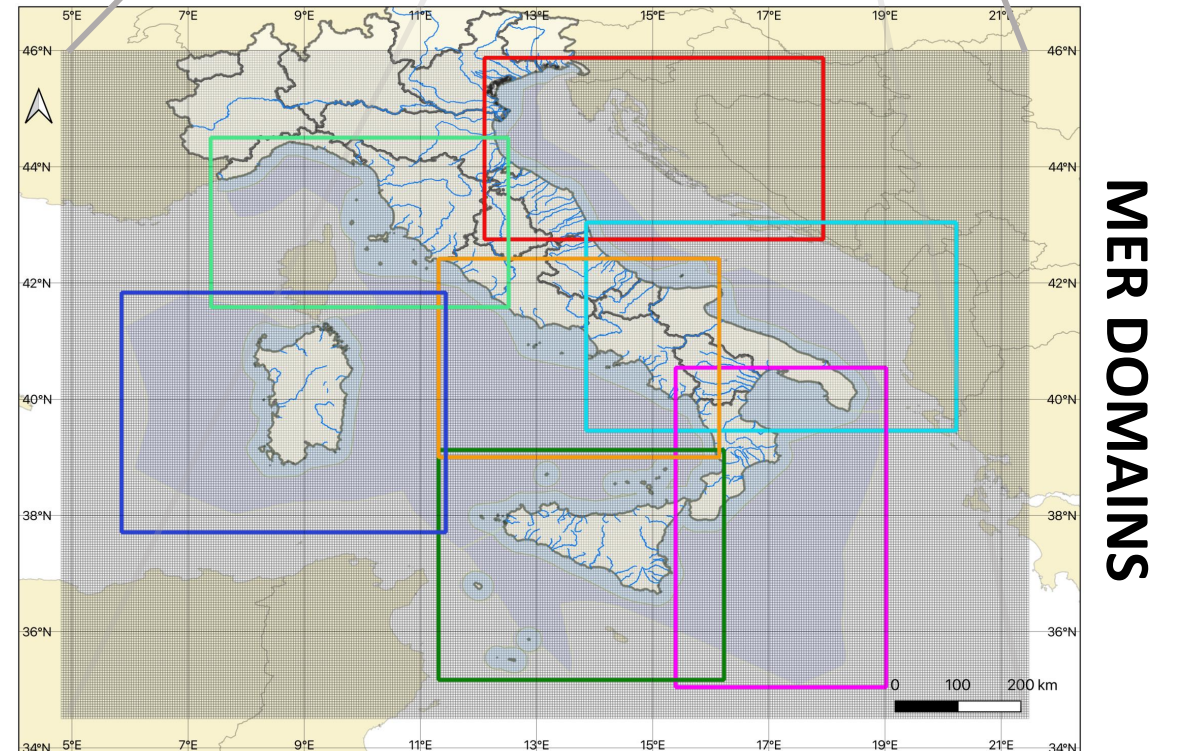
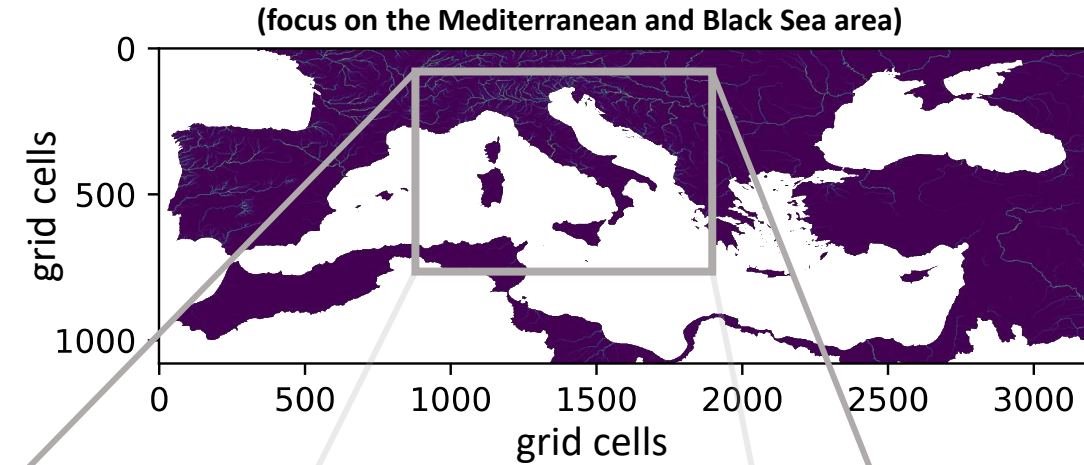
latitude  $22.8^{\circ} \text{ N} \div 72.2^{\circ} \text{ N}$

including the Mediterranean and Black Sea.



Rivers flowing into the **MER domains** were selected relying on:

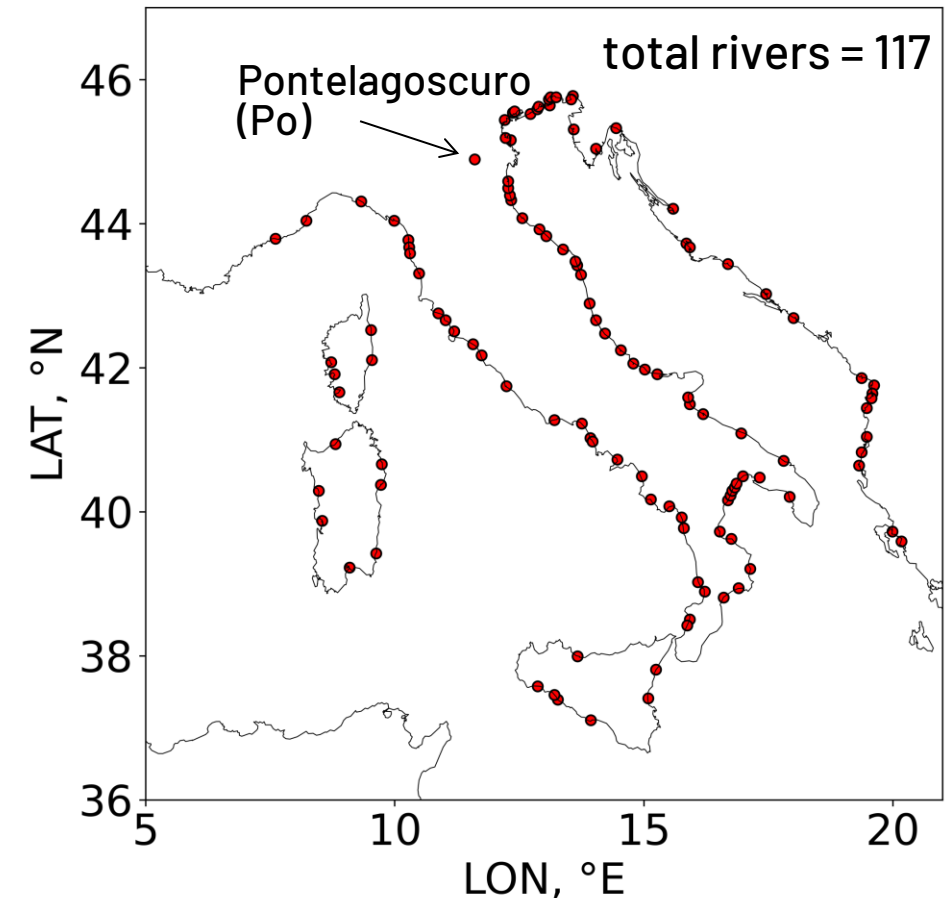
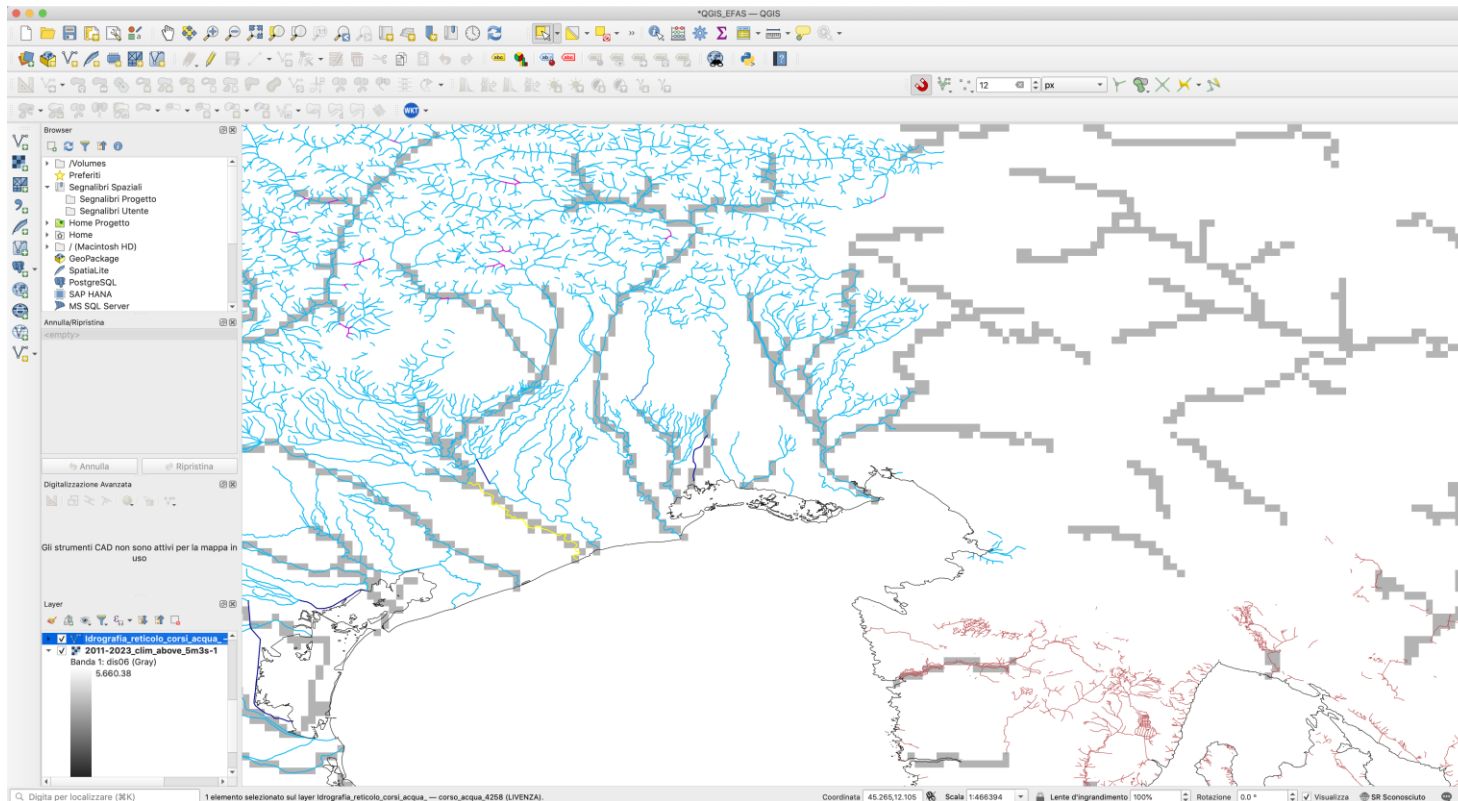
- **spatial criteria** (correspondence between areas);
- a **threshold** imposed on the EFAS climatological annual **discharges**, computed in the time period 2011-2023 (to identify “major rivers”).



# River modelling (2/3)

## 1) IDENTIFICATION OF RIVERS

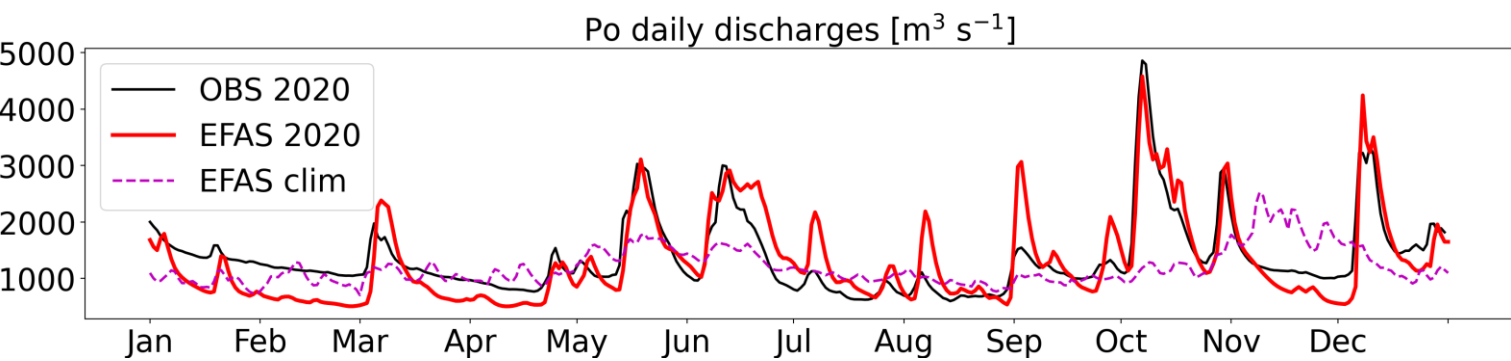
- We imposed a threshold of  $5 \text{ m}^3\text{s}^{-1}$  on climatological 2D EFAS maps of river discharge → EFAS river channels;
- QGIS overlapping of EFAS channel network and shapefiles of hydrographic networks from independent datasets;
- identification of nominal coordinates of river mouths (to be inserted in the bathymetry) and EFAS grid cells (to extract flow data).





# River modelling (3/3)

## 2) EXTRACTION OF DISCHARGES

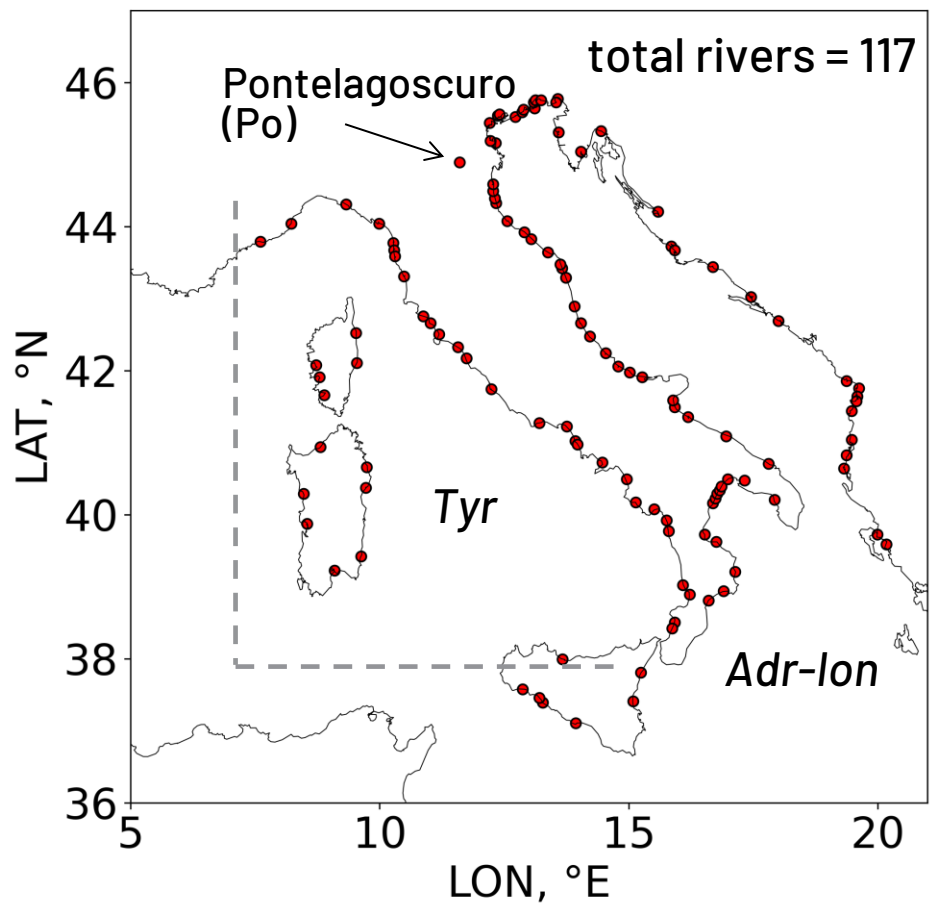


## 3) MODELLING OF BGC LOADS

load = daily discharge  $\times$  **conc.**  $\rightarrow$

*from up-to-date literature review*

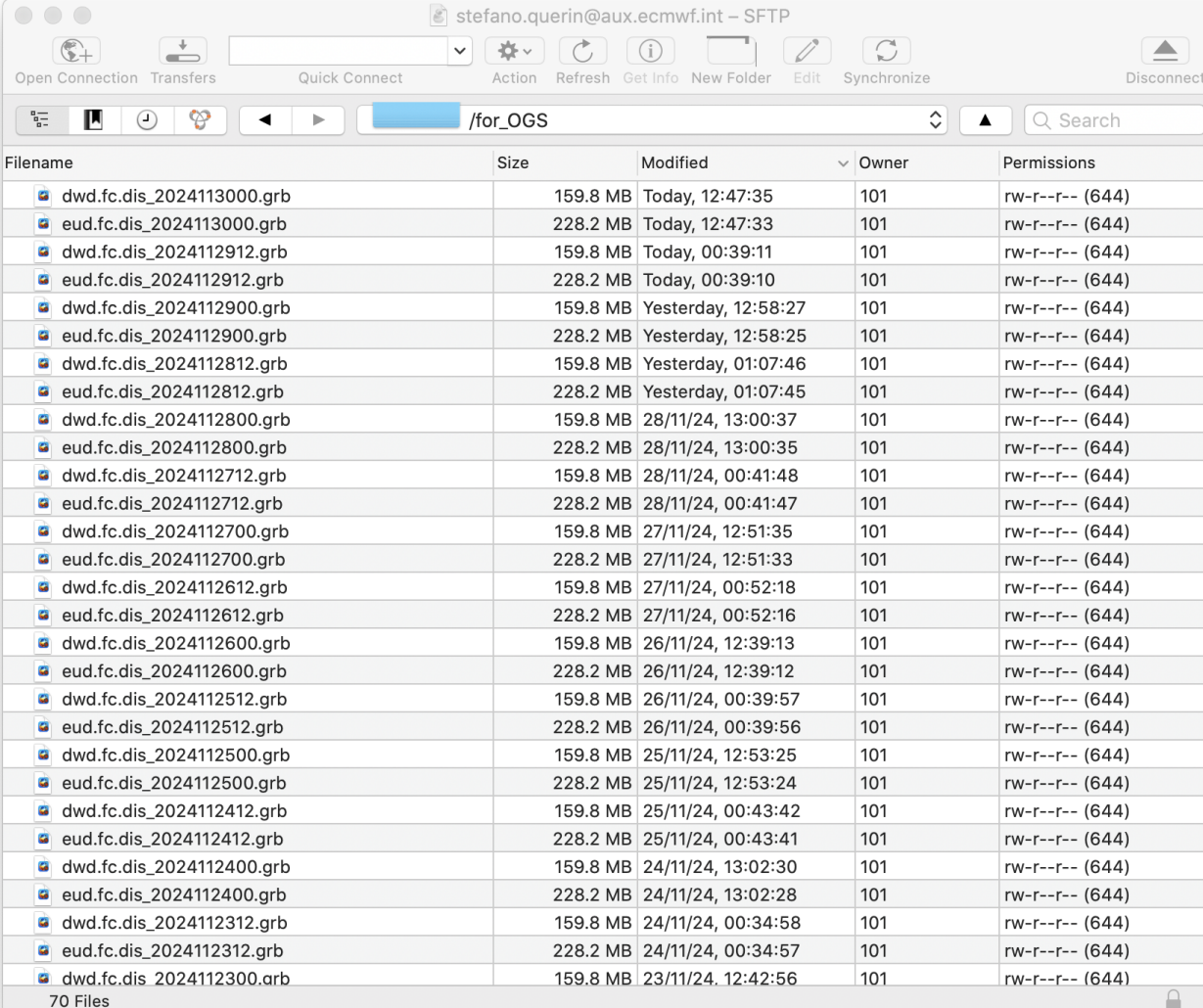
	Adr-lon	Tyr
Nitrate [ $\text{gN/m}^3$ ]	1,74	2,23
Phosphate [ $\text{gP/m}^3$ ]	0,059	0,283
DIC [ $\text{gC/m}^3$ ]	36,08	52,96
POC [ $\text{gC/m}^3$ ]	1,52	1,68
DOC [ $\text{gC/m}^3$ ]	2,29	3,24
Alkalinity [ $\text{mol/m}^3$ ]	3,01	5,16



# Recovery procedure of the RT forecasts in absence of EFAS forecast data

- 1) (*Base-level*) Use of daily river discharges from **EFAS daily climatology** [2011-2023];
- 2) (*Advanced*, if river daily observations are available) Discharges at point 1) **bias-corrected** by using daily observed discharges at measurement stations.

Example: for the **northern Adriatic** domain, we implement the recovery procedure 2) (*Advanced*) for a subset of EFAS rivers in the northern Adriatic area by using daily Po discharge rates measured at the Pontelagoscuro station.



The screenshot shows an SFTP client window titled 'stefano.querin@aux.ecmwf.int - SFTP'. The address bar displays '/for\_OGS'. The file list contains 70 files, alternating between 'dwd.fc.dis' and 'eud.fc.dis' for various dates in 2024. Each file entry includes its name, size (159.8 MB or 228.2 MB), modification time, owner (101), and permissions (rw-r--r-- (644)).

Filename	Size	Modified	Owner	Permissions
dwd.fc.dis_2024113000.grb	159.8 MB	Today, 12:47:35	101	rw-r--r-- (644)
eud.fc.dis_2024113000.grb	228.2 MB	Today, 12:47:33	101	rw-r--r-- (644)
dwd.fc.dis_2024112912.grb	159.8 MB	Today, 00:39:11	101	rw-r--r-- (644)
eud.fc.dis_2024112912.grb	228.2 MB	Today, 00:39:10	101	rw-r--r-- (644)
dwd.fc.dis_2024112900.grb	159.8 MB	Yesterday, 12:58:27	101	rw-r--r-- (644)
eud.fc.dis_2024112900.grb	228.2 MB	Yesterday, 12:58:25	101	rw-r--r-- (644)
dwd.fc.dis_2024112812.grb	159.8 MB	Yesterday, 01:07:46	101	rw-r--r-- (644)
eud.fc.dis_2024112812.grb	228.2 MB	Yesterday, 01:07:45	101	rw-r--r-- (644)
dwd.fc.dis_2024112800.grb	159.8 MB	28/11/24, 13:00:37	101	rw-r--r-- (644)
eud.fc.dis_2024112800.grb	228.2 MB	28/11/24, 13:00:35	101	rw-r--r-- (644)
dwd.fc.dis_2024112712.grb	159.8 MB	28/11/24, 00:41:48	101	rw-r--r-- (644)
eud.fc.dis_2024112712.grb	228.2 MB	28/11/24, 00:41:47	101	rw-r--r-- (644)
dwd.fc.dis_2024112700.grb	159.8 MB	27/11/24, 12:51:35	101	rw-r--r-- (644)
eud.fc.dis_2024112700.grb	228.2 MB	27/11/24, 12:51:33	101	rw-r--r-- (644)
dwd.fc.dis_2024112612.grb	159.8 MB	27/11/24, 00:52:18	101	rw-r--r-- (644)
eud.fc.dis_2024112612.grb	228.2 MB	27/11/24, 00:52:16	101	rw-r--r-- (644)
dwd.fc.dis_2024112600.grb	159.8 MB	26/11/24, 12:39:13	101	rw-r--r-- (644)
eud.fc.dis_2024112600.grb	228.2 MB	26/11/24, 12:39:12	101	rw-r--r-- (644)
dwd.fc.dis_2024112512.grb	159.8 MB	26/11/24, 00:39:57	101	rw-r--r-- (644)
eud.fc.dis_2024112512.grb	228.2 MB	26/11/24, 00:39:56	101	rw-r--r-- (644)
dwd.fc.dis_2024112500.grb	159.8 MB	25/11/24, 12:53:25	101	rw-r--r-- (644)
eud.fc.dis_2024112500.grb	228.2 MB	25/11/24, 12:53:24	101	rw-r--r-- (644)
dwd.fc.dis_2024112412.grb	159.8 MB	25/11/24, 00:43:42	101	rw-r--r-- (644)
eud.fc.dis_2024112412.grb	228.2 MB	25/11/24, 00:43:41	101	rw-r--r-- (644)
dwd.fc.dis_2024112400.grb	159.8 MB	24/11/24, 13:02:30	101	rw-r--r-- (644)
eud.fc.dis_2024112400.grb	228.2 MB	24/11/24, 13:02:28	101	rw-r--r-- (644)
dwd.fc.dis_2024112312.grb	159.8 MB	24/11/24, 00:34:58	101	rw-r--r-- (644)
eud.fc.dis_2024112312.grb	228.2 MB	24/11/24, 00:34:57	101	rw-r--r-- (644)
dwd.fc.dis_2024112300.grb	159.8 MB	23/11/24, 12:42:56	101	rw-r--r-- (644)

70 Files

Meteo-Hub: Mistral Meteo H... x +

https://metehub.mistralportal.it/app/requests

**MISTRAL METEO-HUB**

**REQUESTS**

Product	Submission date	End date	Size	Status
test_MER_all_variables	2024-11-22 04:17:26	2024-11-22 04:17:37	901 kB	SUCCESS
MER_all_variables	2024-11-22 04:17:15	2024-11-22 04:17:26	86.9 MB	SUCCESS

**Request Details**

Task ID: ca908b47-1d15-49a1-bf36-ea6754541443

Dataset(s)  
ICON\_2L\_all2km

Reference time  
2024-11-22 00:00 - 2024-11-22 00:00

Filter(s)  
level

- ✓ sfc Ground or water surface 0 0
- ✓ sfc Mean sea level 0 0
- ✓ sfc Specified height level above ground (m) 0 2
- ✓ sfc Specified height level above ground (m) 0 10

product

- ✓ Temperature (K)
- ✓ Dewpoint temperature (K)
- ✓ Total precipitation rate (kg m<sup>-2</sup> s<sup>-1</sup>)
- ✓ u-component of wind (m/s)
- ✓ v-component of wind (m/s)
- ✓ Pressure reduced to MSL (Pa)
- ✓ GRIB2(00080, 000, 004, 198, 015, 000)
- ✓ GRIB2(00080, 000, 004, 199, 015, 000)
- ✓ Downward long-wave radiation flux (W m<sup>-2</sup>)

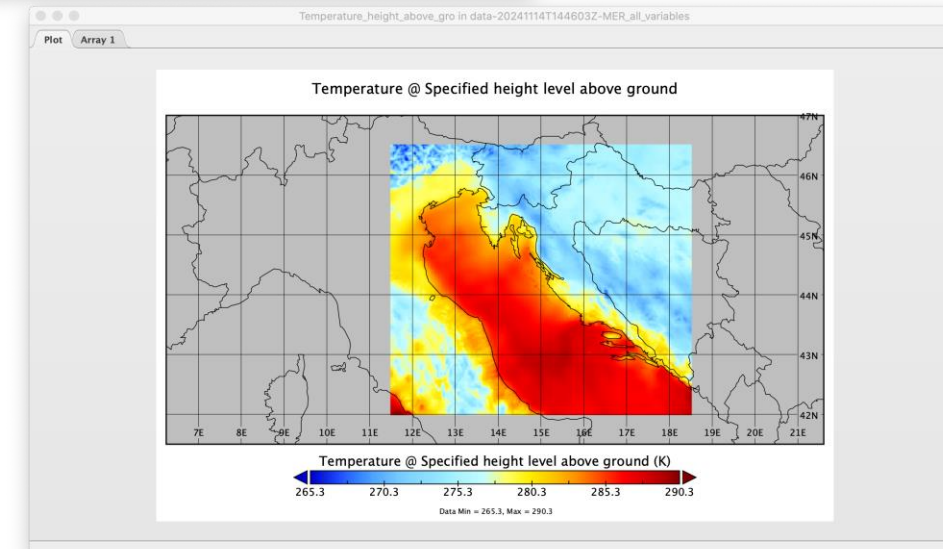
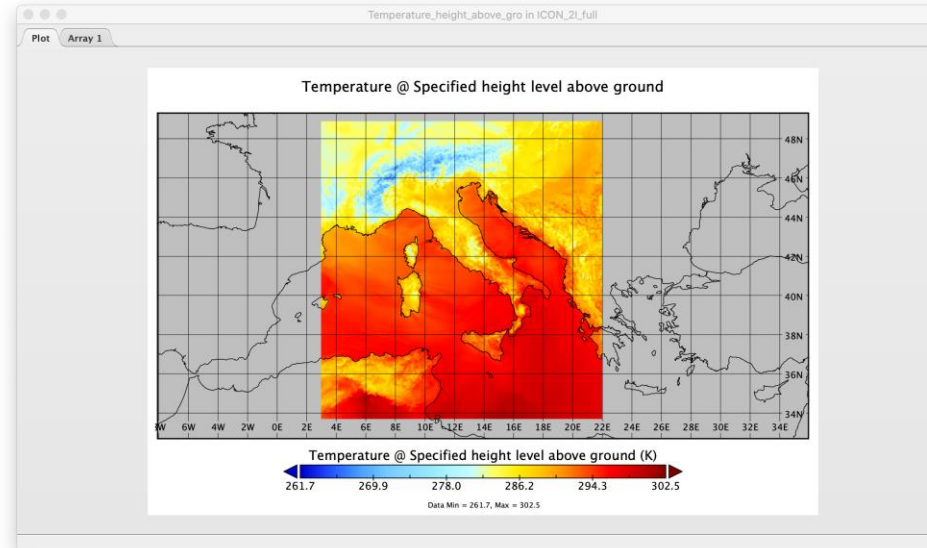
Post-Processing  
grid cropping

- ✓ coord = 11.500, 42.000, 18.500, 46.500

Product	Submission date	End date	Size	Status
MedEAF_all_variables	2024-11-22 04:17:04	2024-11-22 04:17:15	58.1 MB	SUCCESS
test_MER_all_variables	2024-11-21 20:43:47	2024-11-21 20:43:57	914 kB	SUCCESS
MER_all_variables	2024-11-21 20:43:37	2024-11-21 20:43:47	88.1 MB	SUCCESS
MedEAF_all_variables	2024-11-21 20:40:48	2024-11-21 20:43:37	58.9 MB	SUCCESS
test_MER_all_variables	2024-11-21 03:00:03	2024-11-21 03:00:15	893 kB	SUCCESS
MER_all_variables	2024-11-21 02:59:14	2024-11-21 02:59:28	86.9 MB	SUCCESS
MedEAF_all_variables	2024-11-21 02:58:10	2024-11-21 02:58:23	58.1 MB	SUCCESS
test_MER_all_variables	2024-11-20 15:15:09	2024-11-20 15:15:19	914 kB	SUCCESS
MER_all_variables	2024-11-20 15:14:58	2024-11-20 15:15:09	88.1 MB	SUCCESS

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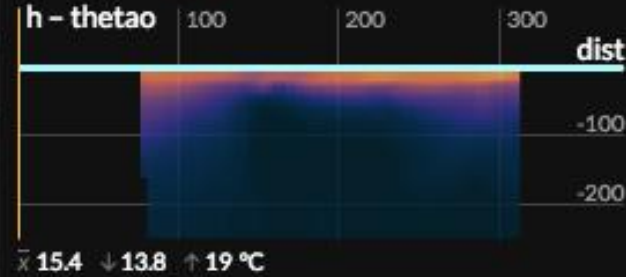


# Initial and open boundary conditions

MyOcean PRO

7.635E, 41.628N 316 km

thetao 18.54 °C ↓ 17.6 ↑ 19



+ Add graph

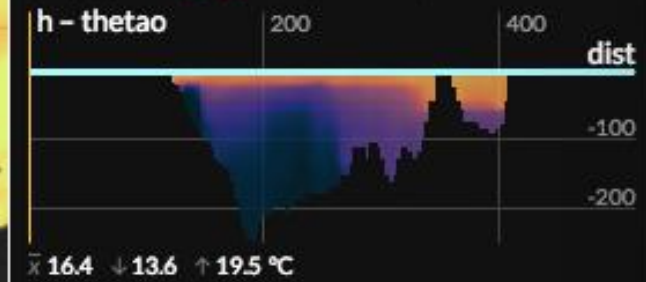
7.635E, 44.468N

12.473E, 42.911N

7.803E, 41.544N

17.753E, 42.869N 430 km

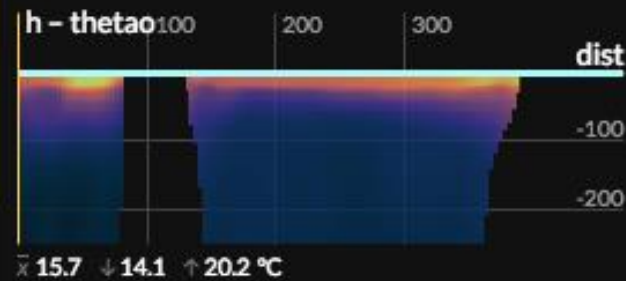
thetao 18.85 °C ↓ 18.5 ↑ 19.5



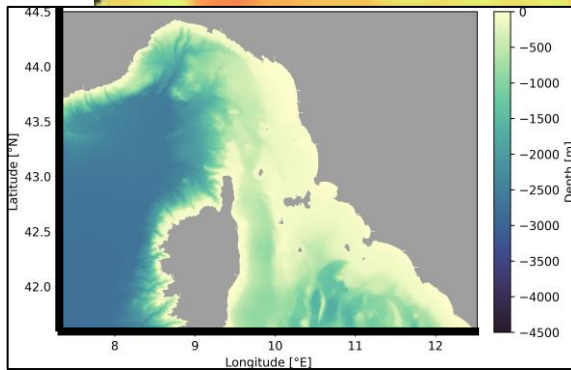
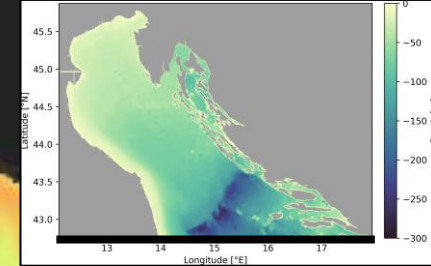
+ Add graph

12.494E, 41.544N 390 km

thetao 18.68 °C ↓ 17.8 ↑ 20.2



+ Add graph



- Points
- Lines
- Areas
- Import
- Settings

Reset

Apr Jul Oct 2024 Apr Jul Oct 2025 Apr

# Other forcings

- **surface deposition of nutrients (nitrate, phosphate)**
- **bottom fluxes of nutrients (nitrate, phosphate) and oxygen**
- **sewage discharges (from rivers and UWWTP outfalls)**

