RIVIERADE

Kick-off meeting

Trieste 16-18 Feb 2026

WP6: Building basin-scale to coastal risks and developing areas climate services for ocean health, blue economy and coastal solutions for specific use cases

[Work Package Leader Organization: METU]

This project has received funding from Horizon Europe RIA under Grant Number 101181983

WP6 contributors

Contributions to RIVIERADE SOs

The contribution of WP6 to the project specific objectives:

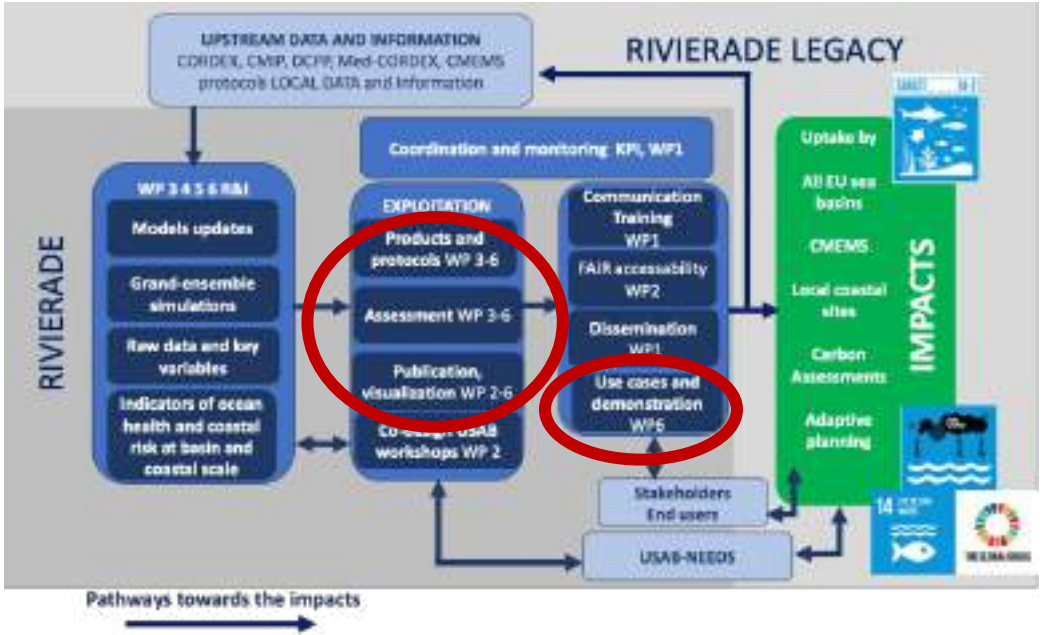
Table 1.1. RIVIERADE specific objectives.

SO#	Specific Objective [means of verification] and WPs
SO1	Improve ocean and regional climate modelling capabilities to produce climate change impact assessment in European seas (BAL, BLK, MED) and their coastal area by: i) sharing, integrating and merging existing capabilities to improve the representation of ocean and marine ecosystem processes and dynamic into climate models, and ii) developing a common framework and protocol for multi-model multi-sea evaluation to assess the representativeness of the model ensemble against available observations and to quantify its uncertainties [number of coupled atmosphere-ocean-biogeochemical modelling systems used in the ensemble; number of coupled model simulation runs; reports on protocols and on model evaluation; and open peer-review publications] (WP3, WP4, WP5)
SO2	Delivering a coherent ocean dataset of a first-of-its-kind coordinated ensemble of high-resolution, multi-model, multi-sea, decadal to multi-decadal climate simulations for quality assessed indicators on ocean status and health at basin scale for the three *target seas*, including uncertainty quantification [reports on protocols, on model development, production of ESGF-ready datasets (raw data)] (WP3, WP4, WP5)
SO3	Delivering coherent ocean data sets of dynamically downscaled very-high-resolution, multi-model, multi-sea, climate simulations for indicators on extreme sea level and coastal risk along all coasts and of relevant physical and biogeochemical indicators at selected *coastal regions* [Adriatic Sea, Swedish Coast, Marmara Sea, Southern Black Sea] at the decadal to multi-decadal temporal scale. [scientific publications; FAIR data and information (key variables and indicators), open documents (e.g. protocols, reports on Zenodo, peer-review publications) and codes (models, codes, tools on GitHub repository)] (WP6)
SO4	Delivery of regional ocean climate impact/risk services and of regional ocean climate services supporting blue economy (aquaculture, fishery, tourism) in 4 *local selected coastal sites* to be chosen and co-designed with end-users and stakeholders board. [use cases documentation, fact sheets] (WP1, WP2, WP5, WP6)
SO5	Delivery of a RIVIERADE catalogue produced in compliance with Open Science recommendation and FAIR principles, including key variables data sets, indicators, documents and codes, to support future studies and further climate services, and in order to favour the integration of project products and results into the digital perspective and the Digital Twin Ocean activities [digital catalogue] (WP2, WP3, WP4, WP5, WP6)

WP in the project context and overall architecture

The role of the WP within the overall project architecture

Its position along the chain:
modelling → indicators → services → users → impacts



WP6 in the project workflow

Inputs:
Physical decadal predictions from WP3
Physical multi-decadal projections from WP4
Physical multi-decadal projections from WP5

Outputs:
Basin-scale BGC indicators
ETWL projections & coastal hazard forcing
Climate change impact assessment

Core activities:

- Develop Basin scale indicators for ocean status, health, sustainable blue economy, coastal risks
- Develop Local scale climate risk services in coastal areas
- Develop climate services in coastal areas supporting blue economy

Users:

- Collaboration with WP2 → co-designed demonstrators
- USAB; end-users

WP6 interactions with other WPs

Interactions with with WP3,4,5

Exchange of: biogeochemical variables, SLR, ETWL projections

Joint design of: indicators, coastal risks, ocean health, sustainable blue economy

Iterative development: tuning outputs to services needs

Interactions with with WP2

Joint design of: indicators, coastal risks, ocean health, sustainable blue economy
 based on users feedback

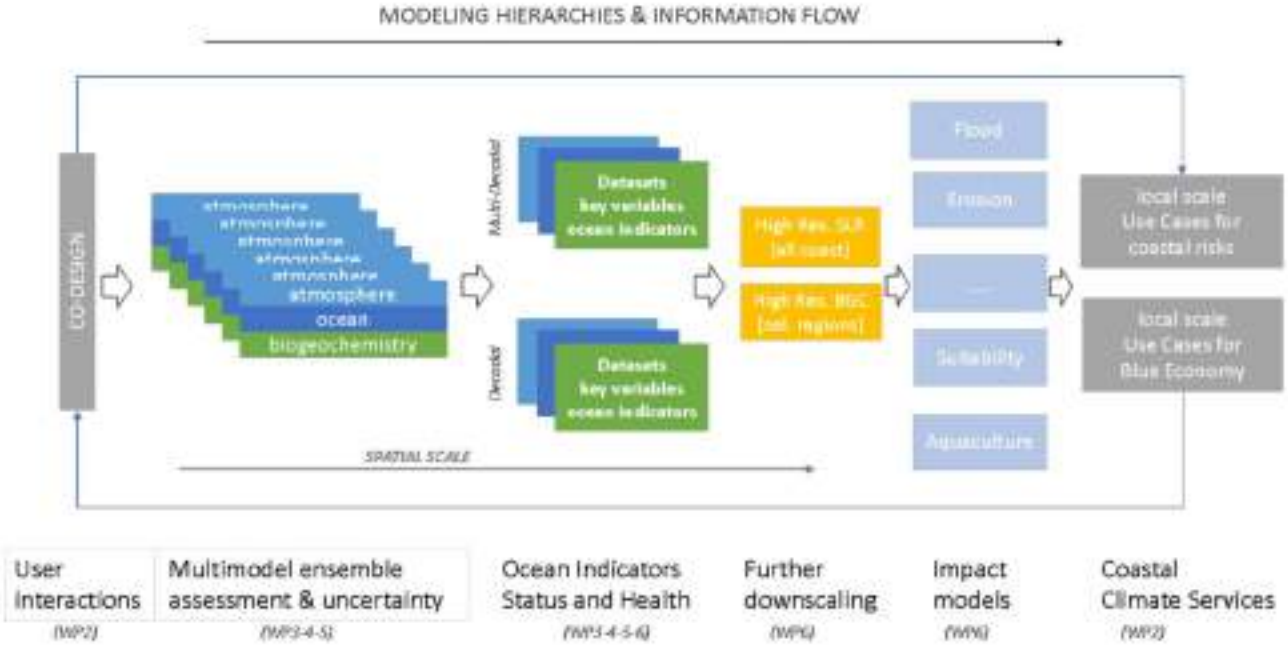
WP6 Objectives

1) Develop protocols for basin scale ocean-climate services to address coastal risks, ocean health, and sustainable blue economy, using decadal predictions and multi-decadal projections provided by WP3, WP4 and WP5.
2) Derive products and indicators for the three target seas.
3) Test and validate products and indicators for the demonstrators co-designed with stakeholders (with WP2).
4) Use cases of climate services will be developed for coastal risks and in support of blue economy at very high resolution (~10 km), showcasing them in 4 selected locations.

- This WP fulfils specific objectives SO3, SO4, SO5.

WP Methodologies

Development, production and publication of quality-assessed data and indicators based on model projections, as well as demonstrators of climate services for basin scale to coastal scale ocean status/health and of local scale climate services for coastal risk and in support to blue economy. All services include multiple scenarios and scientific assessment of their uncertainty and value in terms of climate change impacts (WP6).



WP Methodologies

The methodology is applied in three target European seas (BAL, BLK, MED), benchmarked with use cases selected with end-users to develop and demonstrate ocean climate services for basin scale, and for coastal climate risk services and sustainable blue economy, showcased in 4 locations (Fig. 1.1).

As for Global Framework for Climate Service (GFCS) definition, climate services are the provision and use of climate data, information and knowledge to assist decision-making.

OVERVIEW OVER TASKS IN WP6

Task 6.1 Development and production of basin scale indicators for ocean status, health, sustainable blue economy, and coastal risks [M6-M42] (SMHI, all PPs)

Task 6.2 Assessment and release of basin scale indicators [M24-M42] (CNRS-LEGOS, all PPs)

Task 6.3 Development of local scale climate risk services in coastal areas [M30-M42] (IHE Delft, ENEA)

Task 6.4 Development of climate services in coastal areas supporting the blue economy [M30-M48] (METU, all PPs)

Tasks in detail: TASK WP6.1

Task 6.1 Development and production of basin scale indicators for ocean status, health, sustainable blue economy, and coastal risks [M6-M42] (SMHI, all PPs)

6.1.1 - Ocean status, health and blue economy indicators: Identification and production of indicators (including keyvariables) to assess ocean status, health and to support the sustainable blue economy, at basin scale including basin coastal area at least at a 10 km resolution (input from WP3-4-5) for all considered SSPs for the three target seas. Indicators will be based on GCOS ECVs and CMEMS OMIs with additional ones based on users needs (WP2, Task 2.2).

6.1.2 - Coastal hazard products and associated coastal risk indicators: Produce 1 km resolution maps for the three basins, for years 2030, 2050 and 2100 of: 1) coastal flooding for a range of ETWL return periods (1, 5, 10, 20, 50, 100, 200, 500, and 1000 yr) using a process-based flood model (e.g. SFINCS, Leijnse et al., 2021) for all considered SSPs for the three target seas; 2) estimated annual number of people affected (EAPA) and estimated annual damage (EAD) at 1 km resolution; 3) chronic coastal erosion (i.e. shoreline retreat ~1 km alongshore resolution) for the sandy coasts in the target basins. Moreover, the task will explore the possibility of considering dynamic coupling of coastal flooding and erosion to develop EAPA and EAD indicators resulting from the compounding of the flood and erosion hazards, using IPCC-AR6 forcing and newly produced forcing (WP4).

Tasks in detail: TASK WP6.2

Task 6.2 Assessment and release of basin scale indicators [M24-M42] (CNRS-LEGOS, all PPs)

Assessment and release of indicators of ocean status, health and blue economy: Using the hindcast and historical simulations, key variables and selected indicators are validated against available data and information from CMEMS reanalysis and other sources. Moreover, sensitivity and uncertainty analysis will be performed to ensure the products reliability. Proof-of-concept will include the optimization of a workflow to be aligned with CMEMS-like products framework. First and final versions of RIVIERADE catalogue (to be shared with WP2) with selected indicators produced in Subtask 6.1.1.

Assessment and release of indicators of coastal hazard products and derived risk: Probabilistic ETWL results produced in task 6.1.2 for the historical baseline period will be used to produce coastal erosion estimates, coastal flood maps and estimates of EAD and EAPA, including their uncertainty, for the baseline period in the three target basins. Coastal erosion (i.e. shoreline retreat/progradation) estimates will be validated against global reference datasets based on satellite observations. Flood risk (EAPA/EAD) will be validated against existing global and regional hindcasts based on reanalysis datasets. Proof-of-concept will include the optimization of a workflow to be aligned with CMEMS-like products framework. First and final versions of RIVIERADE catalogue (to be shared with WP2) with selected indicators produced in Subtask 6.1.2.

Tasks in detail: TASK WP6.3

Task 6.3 Development of local scale climate risk services in coastal areas [M30-M42] (IHE Delft, ENEA)

A very high resolution (~ 10 m) assessment of coastal flood and erosion risk will be undertaken using physics based, yet fast, coastal impact models for selected sites. As boundary conditions for the wave and surge models that will be dynamically coupled with the coastal flooding/erosion models, we will use RSLR projections from Task 5.3 as well as other high-resolution outputs produced in WP4 (e.g wind and storm surge). Best available information on flood defences and coastal hardening will be used. Case studies for coastal erosion: a coastal strip about 50 km long between Grado and Rimini; for coastal flooding: Trieste Port. Exact model domains will be selected via stakeholder interactions.

Tasks in detail: TASK WP6.4

Task 6.4 Development of climate services in coastal areas supporting the blue economy [M30-M48] (METU, all PPs)

Relevant indicators for blue economy services in the coastal areas of the three target seas will be identified (see section 3.2). The indicators will be tailored to user needs and requirements (WP2), with data derived from high-resolution coastal models and biologically based models (WP3-4-5). Customization of models and post-processing tools will be done to align with site-specific conditions and user requests, and the analysis will include the examination of regime shifts and tipping points in environmental conditions and suitability. Case studies proposed are: Adriatic Sea, Black Sea, Marmara Sea, and the Swedish Coast. Details of the methodology and the approach for each region is given in detail in Section 1.2.1 (pillar 3.1). Results will be visualised based on the USAB needs.

Deliverables and Milestones

Deliverables

- **Deliverable D6.1 –** Report on development and assessment of basin scale climate indicators. M38
- **Deliverable D6.2 –** Report on use cases for climate service in coastal areas. M48

Milestones

No 16 First version of RIVIERADE catalogue for WP2 demonstrators. - CNRS - M36

No 17 Final version of RIVIERADE catalogue for WP2 demonstrators – CNRS – M40

No 18 Physical-biogeochemical downscaling runs in selected coastal areas completed. – METU – M40

Risks

Not receiving the inputs from WP’s 3, 4, 5 on time for WP6.

Work plan for the first year

Task 6.1 Development and production of basin scale indicators for ocean status, health, sustainable blue economy, and coastal risks [M6-M42] (SMHI, all PPs)

6.1.1 - Ocean status, health and blue economy indicators: Identification and production of indicators (including key variables) to assess ocean status, health and to support the sustainable blue economy, at basin scale including basin coastal area at least at a 10 km resolution (input from WP3-4-5) for all considered SSPs for the three target seas. Indicators will be based on GCOS ECVs and CMEMS OMIs with additional ones based on users needs (WP2, Task 2.2).

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WP6 Models NEMO-TURSEM Partner METU

Target basins: Black and Marmara Seas

Focus on co-designed indicators, improving our demonstrators developed for these seas and the production of basin scale indicators.

BRIDGE-BS

THE BLACK SEA

multi-stressors

overfishing

eutrophication

climate change

acidification

CO_2

noise pollution

oil spill

chemical pollution

industry

tourism

agriculture

urbanization

maritime transport

sea and land-based activities

deoxygenation

O_2

1990 excessive increase in 2024

human-induced pressures

invasive species

marine litter

physical, chemical and biological changes in the marine ecosystem

BRIDGE-BS DEKOSIM

Main Page

BRIDGE BLACK SEA
DIGITAL TWIN OCEAN DEMONSTRATOR

One of the First Examples of Digital Twin Ocean Demonstrators

Total Visits : 1,918

The Horizon 2020-funded **BRIDGE-BS (Advancing Black Sea Research and Innovation to Co-Develop Blue Growth within Resilient Ecosystems)** aims to advance the Black Sea's marine research and innovation to co-develop Blue Economy pathways under multi stressors for the sustainable utilization of the ecosystem services. The 4.5-year project started in 2021 and will end in November 2025.

BRIDGE-BS is designed to define a safe operating space for the Black Sea Blue Economy, ensuring that ecosystem boundaries are known and respected. To achieve this, the project has developed, for the first time in the region, an ensemble modeling framework that provides critical insights into the resilience of the Black Sea which has never been analyzed before. These models, supported by new ecosystem and socio-economic data, deliver results on ecosystem state under different climate and human-driven pressures. The outputs feed into AI emulators, cumulative effect assessment tools, and "what-if" scenarios, while also supporting the development of multi-stressor, multi-service Decision Support Tools and adaptive management strategies at both basin-wide and Pilot scales. Living Labs across different regions provide additional stakeholder-driven input, reinforcing the co-design of Digital Twin Ocean applications and enabling risk-based assessments that guide sustainable management of the Black Sea.

Black Sea DTO will be maintained by **DEKOSIM (The Center for Marine Ecosystems and Climate Research)** infrastructure hosted by Middle East Technical University beyond BRIDGE-BS.

Explore Physics & Biogeochemistry

Explore how the sea evolves under SSP future projections — visualize physical processes and

Higher Trophic Level & Plastics

Visualize fish biomass, yield, and marine plastics distribution.

Resilience Assessment

Assess ecosystem & community resilience through indicators.

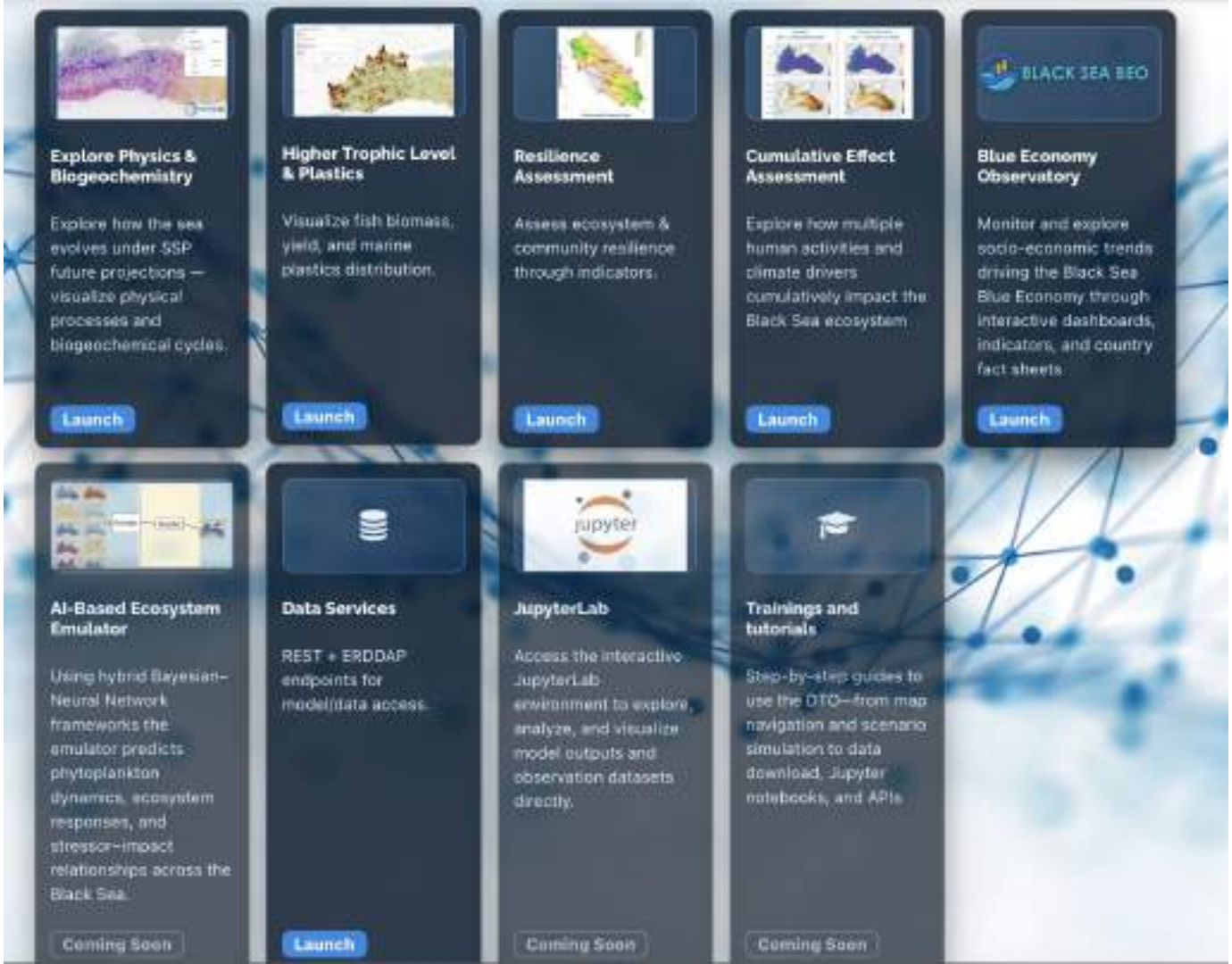
Cumulative Effect Assessment

Explore how multiple human activities and climate drivers cumulatively impact the Black Sea ecosystem

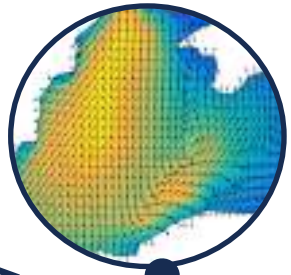
Blue Economy Observatory

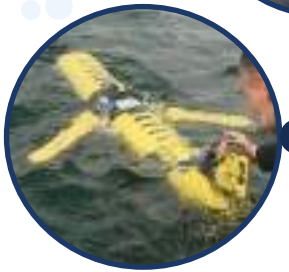
Monitor and explore socio-economic trends driving the Black Sea Blue Economy through interactive dashboards

Collaboration with MMU that is part of the Users and Stakeholders Advisory Board (USAB)

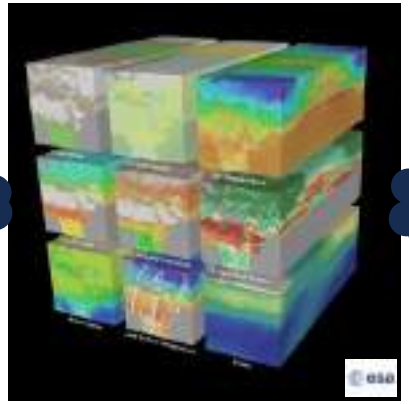


System of Systems



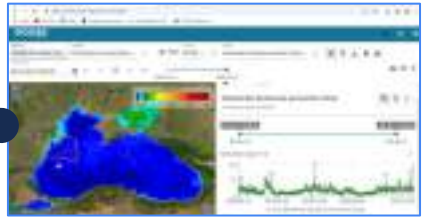


Cloud based data store
Multivariate analysis



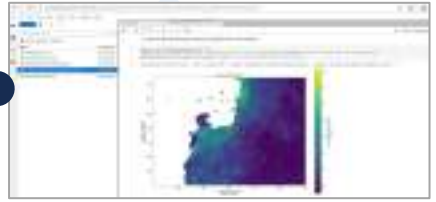
XCubeTechnology & GeoDB

Data Visualisation & Interaction

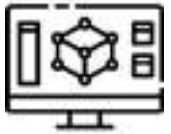


The Data Viewer

The DOORS Dashboard



The Jupyter Lab Notebook



Future: Direct integration into existing platforms

THE SEA OF MARMARA

multi-stressors

overfishing

eutrophication

climate change

acidification

CO_2

noise pollution

spill shot

chemical pollution

industry

tourism

agriculture

urbanization

maritime transport

sea and land-based activities

deoxygenation

O_2

600 m

1990 excessive increase in 2024

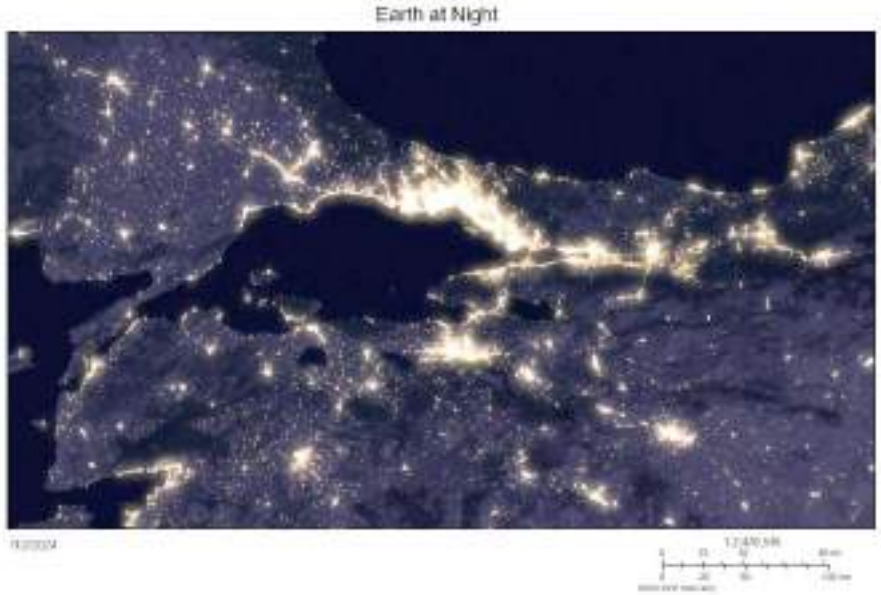
human-induced pressures

physical, chemical and biological changes in the marine ecosystem

invasive species

marine litter

HUMAN PRESSURE

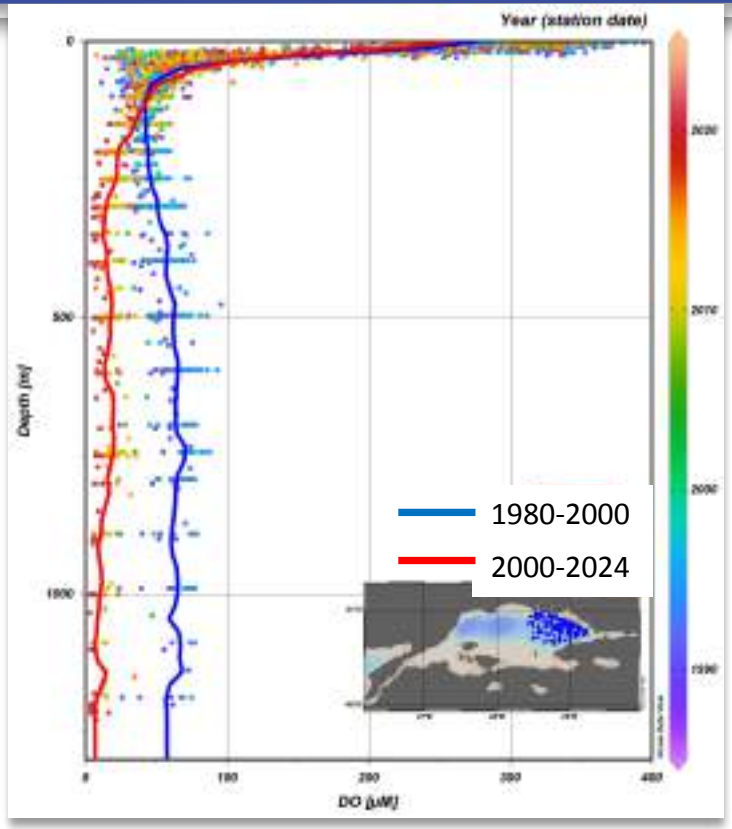


A nighttime satellite image of the Marmara Region

2021 Mucilage event

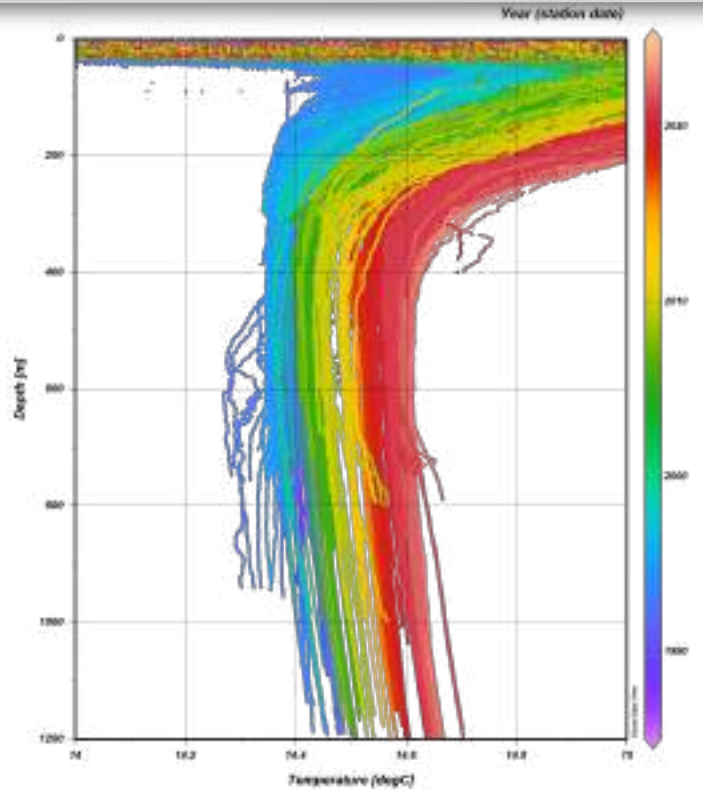
THE CURRENT SYSTEM OF THE TURKISH STRAITS SYSTEM

MAIN OUTPUTS - OXYGEN LEVELS



Oxygen depletion in deep basin

O_2



Increase in water temperature in deep basin

Collaboration with MMU that is part of the Users and Stakeholders Advisory Board (USAB)

6.4 Black Sea And Marmara test Cases

- In the coastal **Southern Black Sea** use case, a high-resolution coupled physical-biogeochemical model (horizontal resolution 3 km) including a representation of higher trophic levels to investigate the impact of climate change on the coastal zone which is an important area for tourism, fishing and cultural heritage.

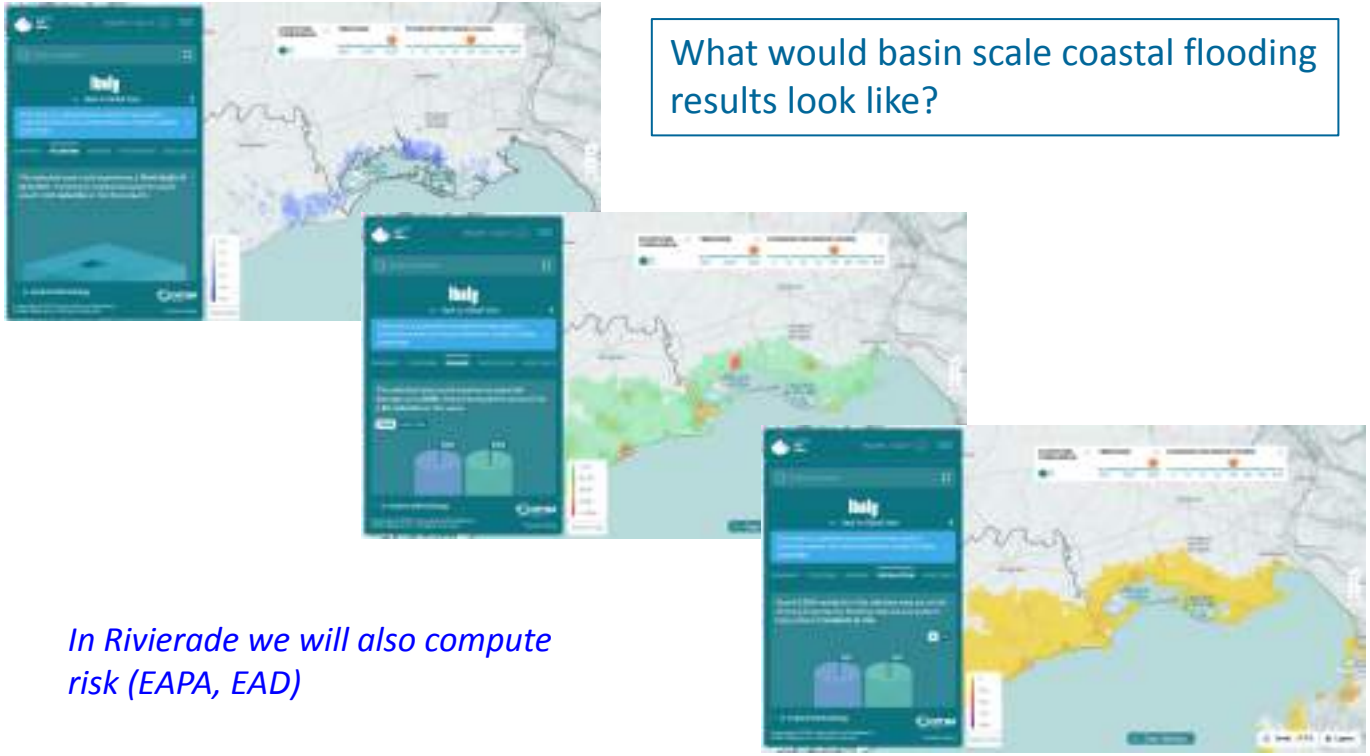
 A scenario analysis will focus on projecting the impact of climate change on relevant Blue Economy sectors, by assessing warming, water quality and threats related to increasing eutrophication, jelly blooms, and acidification. (Maybe also fish recruitment.)

- As for the use case in **Marmara Sea**, we will set up a high-resolution coupled physical-biogeochemical model (horizontal resolution 1 to 2 km) to investigate the impact of climate change on the coastal zone, which is an important area for tourism, fishing, and maritime activities
- Biodiversity changes. A scenario analysis will focus on calculating the impact of climate change and nutrients input on Blue Economy, such as on warming and heat waves, water quality, including threats due to increasing seasonal deoxygenation as a result of eutrophication and biodiversity changes.

Rivierade WP6 – IHE Delft contribution

Activity	Inputs Reqd	Deliverable	Start	End
Basin scale				
Coastal flooding projections in 3 basins due to ESL2_P (same RPs, DEM res 10-30m)	Copernicus+DeltaDEM, ESL2_P, Maintain same flood defense RPs	SFINCS derived flood maps at 1km res for 3 basins for all RPs using ESL2-P, for 2030, 2050, 2100, SSPs 1-2.6 and 3-7.0	M42	M44
Coastal Flooding EAD and EAPA in 3 basins	Coastal flood maps (1km res) for all RPs (hindcast/baseline) and projections), pop, GDP data	EAD and EAPA for 3 basins for baseline, 2030, 2050, 2100	M45	M47
Shoreline change in 3 basins due to RSLR2-P and ambient using V2020 model (1km res GCC, SSP1-2.6, 3-7.0)	Updated ambient change and RSLR2_P, Coastal hardening from Nawarat et al (2024)	Shoreline change projection maps at 1km res for 3 basins for 2030, 2050, 2100	M39	M41
Local scale				
High res shoreline change risk (EAD and EAPA) in Grado-Rimini area (PCR, XX alongshore res), SSP1-2.6, 3-7.0	Local DEM or Copernicus+DeltaDEM, RSLR2_P, Downscaled Surge and Waves, Local Defenses, property value and Population density	Erosion EAD and EAPA for 2030, 2050, 2100	M37	M40
High res coastal flood risk (EAPA and EAD) in Trieste Port area (10m overland res), SSP1-2.6, 3-7.0	Local DEM or Copernicus+DeltaDEM, ESL2_P, Local Defenses, property value and Population density, DD curves	Flooding EAD and EAPA for 2030, 2050, 2100	M42	M44

Rivierade WP6 – IHE Delft contribution



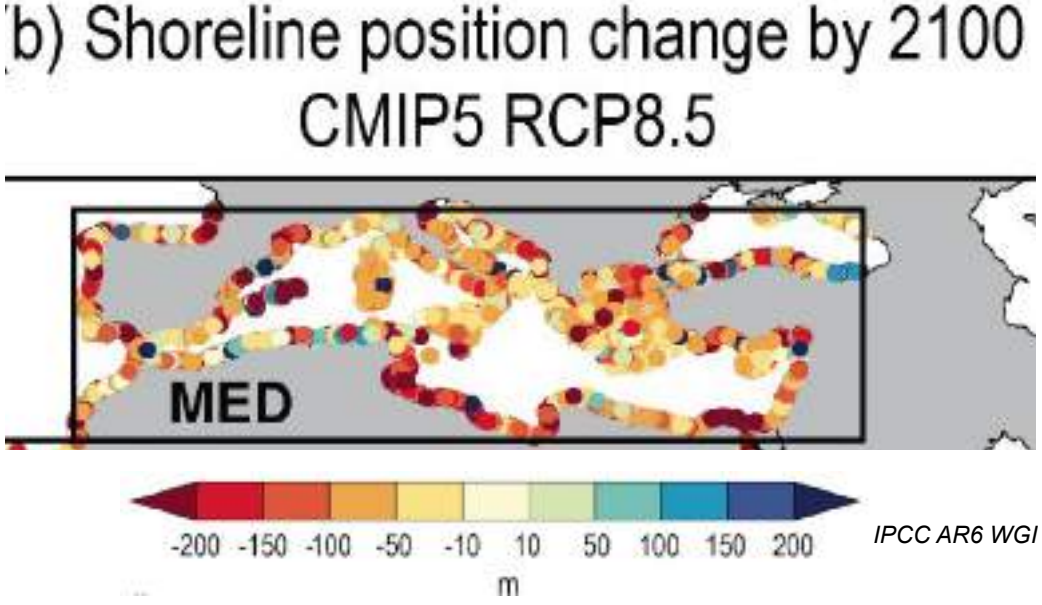
What would basin scale coastal flooding results look like?

In Rivierade we will also compute risk (EAPA, EAD)

https://coastalriskindex.com/

Rivierade WP6 – IHE Delft contribution

What would basin scale shoreline retreat results look like?



IPCC AR6 WGI Ch 12- Fig 12.5

In Rivierade we could also compute impact (assets at risk, pop at risk), EAPA, EAD (prob small numbers) and optionally assess the extent of the coastline that would be "perceived" to be unsafe

Rivierade WP6 – IHE Delft contribution

What would local scale high resolution coastal flood and erosion risk maps look like?

Erosion risk at a Sydney Beach by 2100; SSP5-8.5

Flood risk at a Cantho city (Vietnam) by 2050; SSP5-8.5

RIVIERADE

Kick-off meeting

Trieste 16-18 Feb 2026

WP6

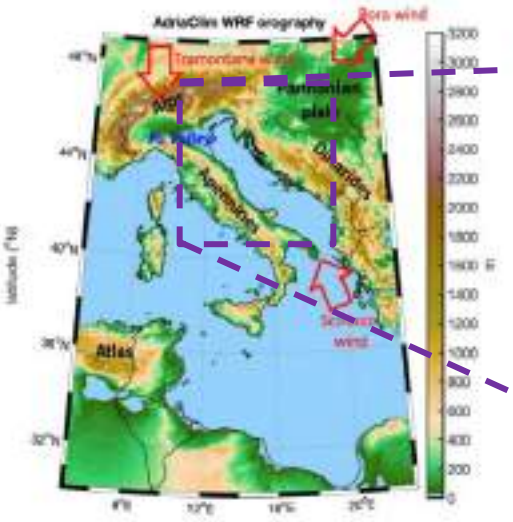
[CMCC Giorgia Verri]

This project has received funding from Horizon Europe RIA under Grant Number 101181983

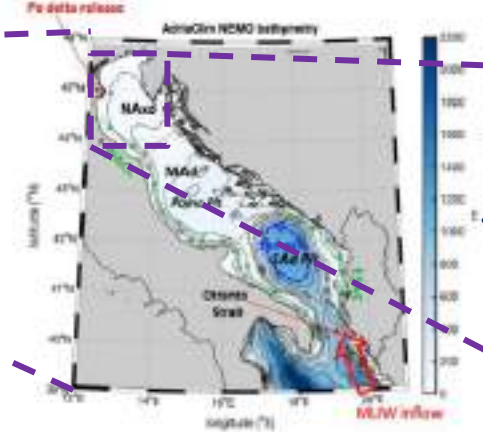
Coastal and Estuarine Climate Downscaling

Phase 1: Coastal Downscaling

Coupled multimodel atm+hydro+ocean
for subregional Earth system



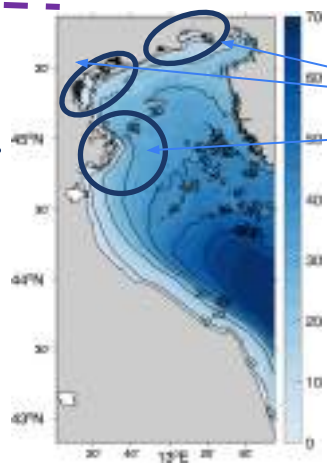
WRF(6km, 6h)+WRFHYDRO (600m, 1h)



NEMO+BFM+WWIII (2km, 3h-daily)

Coastal dynamical downscaling

2way nesting



NEMO (500m, 3h-daily)

Transitional areas of interest: lagoons and ROFIs

120-year simulation:
Atm+hydro (576 cores): ~95 days, ~35 TB
Ocean NEMO (288 cores) : ~30 days, ~5 TB

✓historical: 1980-2014
✓Projection SSP2-4.5 and SSP5-8.5: 2015-2100

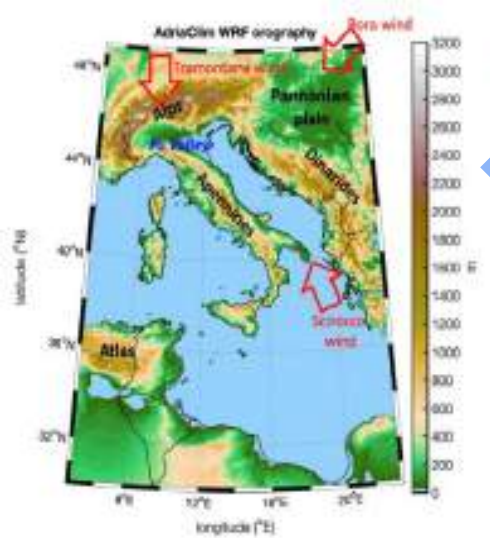
Downscaled climate projections under SSP2 and SSP5 over 1985-2100

Northern Adriatic changing dynamics, trends and extremes

Coastal and Estuarine Climate Downscaling

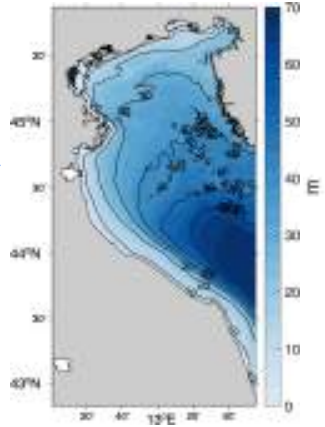
Phase 2: Estuarine Downscaling

Subregional to coastal multimodel earth system (Phase1)



WRFHYDRO (600m, 1h)

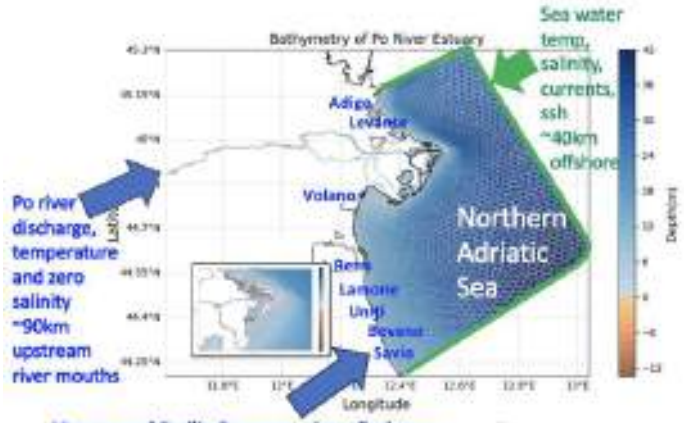
2way nesting



NEMO (500m, 3h-daily)

1way nesting

Estuarine dynamical downscaling



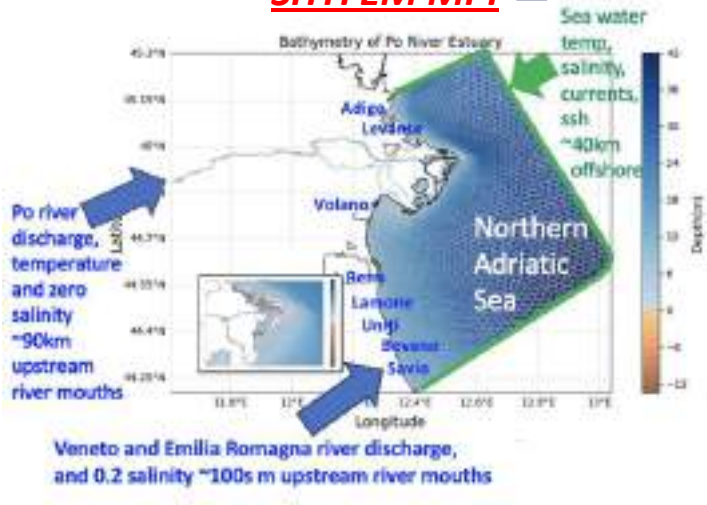
3D FEM SHYFEM (up to 10m , 1h)

Coastal and Estuarine Climate Downscaling

Phase 2: Estuarine Downscaling

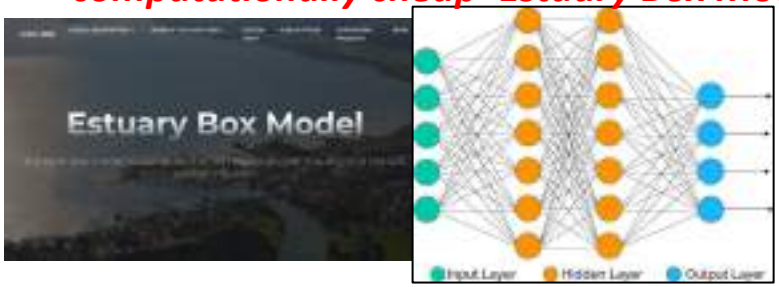
Merge dynamical and statistical estuarine downscaling

3D FINITE ELEMENT MODEL SHYFEM MPI



LEARNING DATA
to train ML algorithms

ESTUARY EMULATOR:
ML-based, physics-informed, computationally cheap Estuary Box Model



Downscaled climate projections under SSP2 and SSP5 over 1985-2100

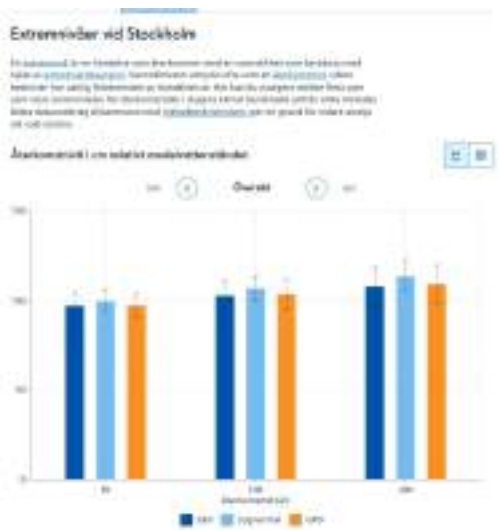
- *Along delta SWI length and salinity: process understanding (multi physics drivers, cross-scale feedbacks), trends and statistics of extremes*

WP6 Models SCZ & NEMO-Nordic-SCOBI Partner SMHI

Target basin: Baltic Sea

Focus for SMHI on co-designed indicators, our demonstrator and the production of basin scale indicators.

Ultimately our hope is that the work in this WP will contribute to make future climate services more comprehensive, better and more easily used than those we currently operate



RIVIERADE

Kick-off meeting

Trieste 16-18 Feb 2026

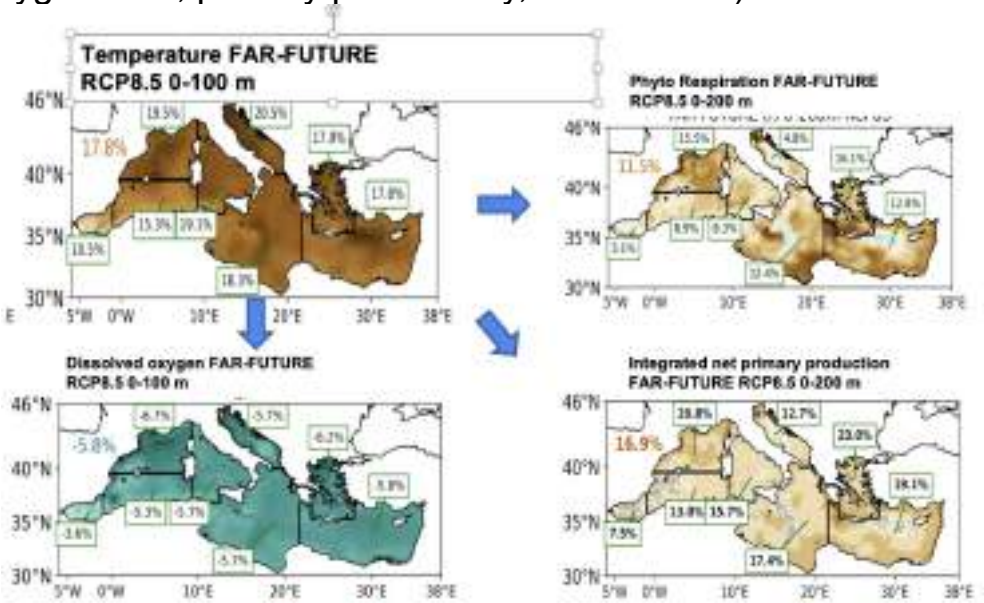
WP6

OGS

This project has received funding from Horizon Europe RIA under Grant Number 101181983

Basin scale indicators for ocean status, health and sustainable blue economy, and coastal risks

Contribute to the development of indicators to assess:
Ocean status for the Mediterranean Sea using the biogeochemical model variables combined with physical ones (i.e. OHI, deoxygenation, primary productivity, acidification)



Reale et al., 2022

Selection of indicators will be made with WP2 and WP5

Assessment and release of basin scale indicators

Assessment of selected indicators and uncertainty valuation

Other indicators meaningful for biodiversity, conservation and with impact on the blue economy:

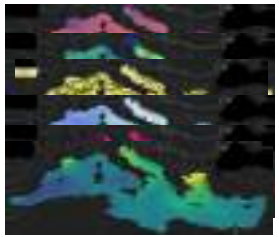
from climatic to species distribution projections

NATIVE, HABITAT FORMING SPECIES

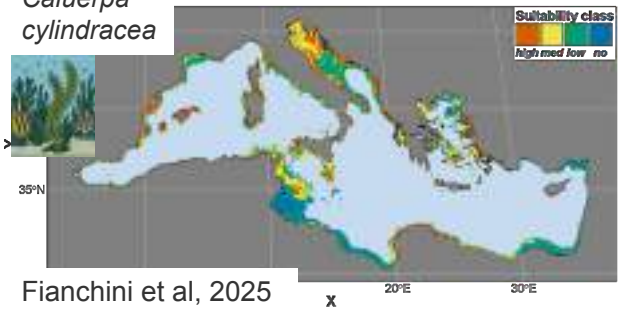
Posidonia oceanica

Cymodocea nodosa

Baldan et al, 2024



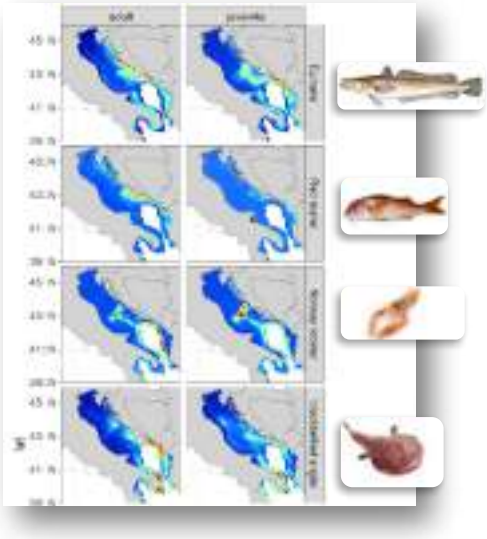
Caluerpa cylindracea



Fianchini et al, 2025

ALIEN INVASIVE SPECIES

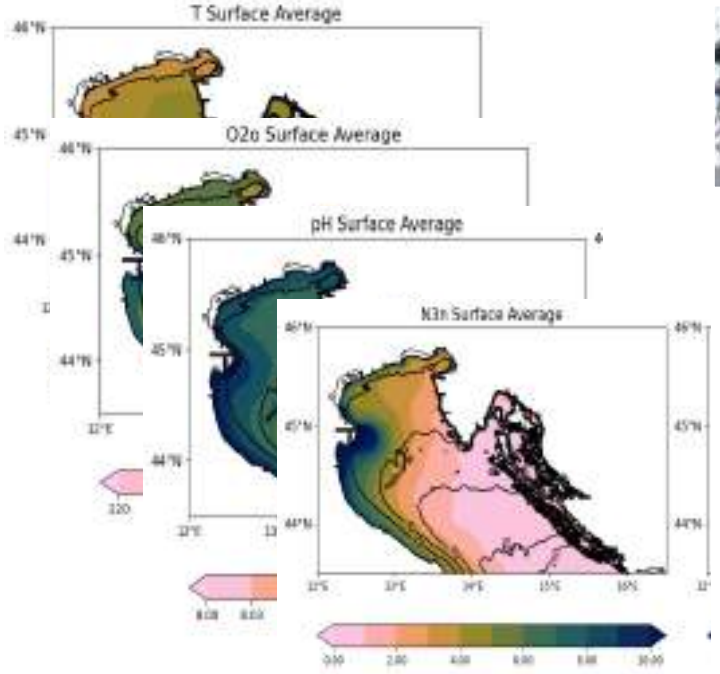
KEY DEMERSAL SPECIES



Panzeri et al, 2023

Selection of indicators will be made with WP2 and WP5

Development of climate services in coastal areas supporting blue economy

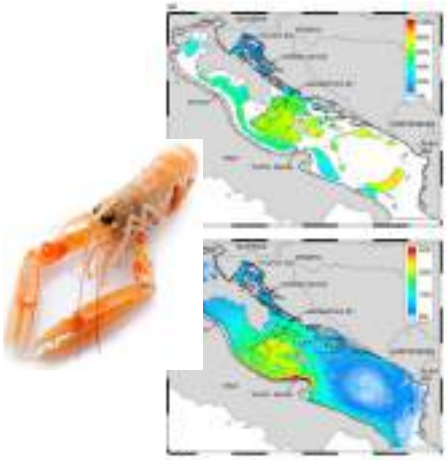


Clams **Mussels**

Melaku Canu et al., 2010

Ostrea edulis

Carratù et al., 2025



Nephrops norvegicus

Melaku Canu et al., 202

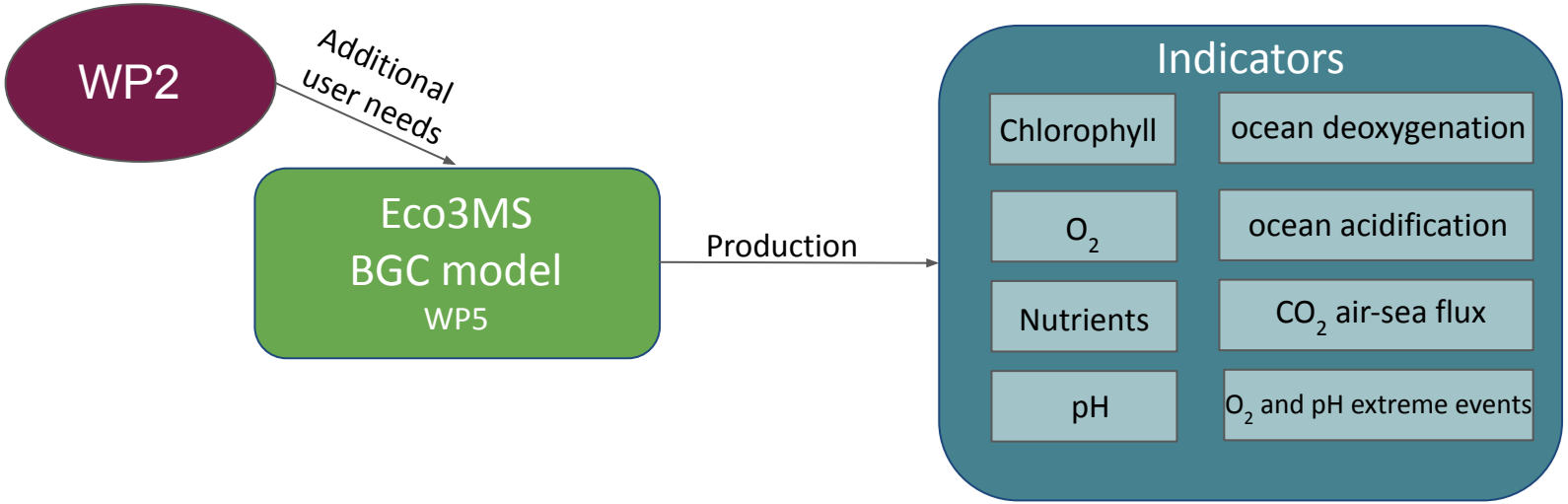
Downscaled physical and biogechemical properties → **Suitability, Connectivity** → **Ecosystem services, nature based solutions** → **Fishers, aqualcultures, coastal protection**

Targets selection will be made with WP2 and WP5

CNRS-LEGOS contributions to WP6

- Involved in T 6.1 indicators for ocean status, health, sustainable blue economy, and coastal risks

Development and production of basin scale biogeochemical-based indicators based on the Eco3MS model

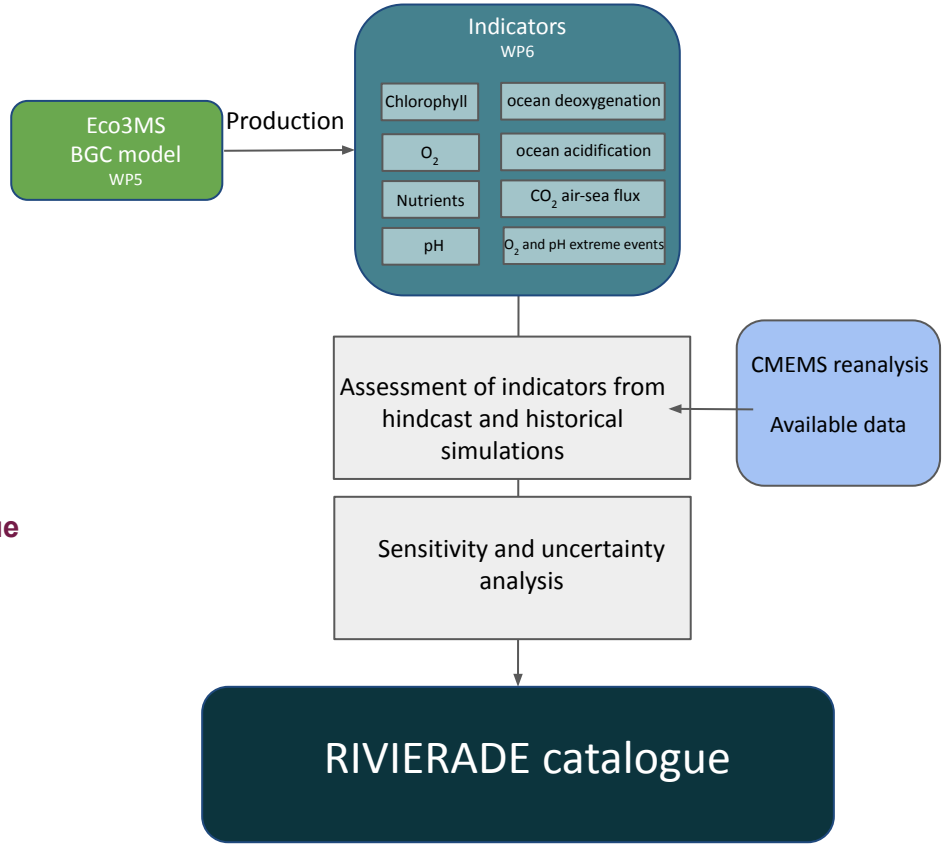


CNRS-LEGOS contributions to WP6

- Lead of T6.2: Assessment and release of basin scale indicators

  - Assessment and release of indicators of ocean health
  - Sensitivity and uncertainty analysis will be performed to ensure the products reliability.
  - Assessment and release of indicators of coastal hazard products and derived risk: coastal erosion estimates, coastal flood maps and estimates of EAD and EAPA, including their uncertainty.

⇒ **Deliverable 6.1: First and final versions of RIVIERADE catalogue**



Questions?

RIVIERADE

Partners