

# Advancing Black Sea Research and Innovation to Co-Develop Blue Growth within Resilient Ecosystems – BRIDGE-BS



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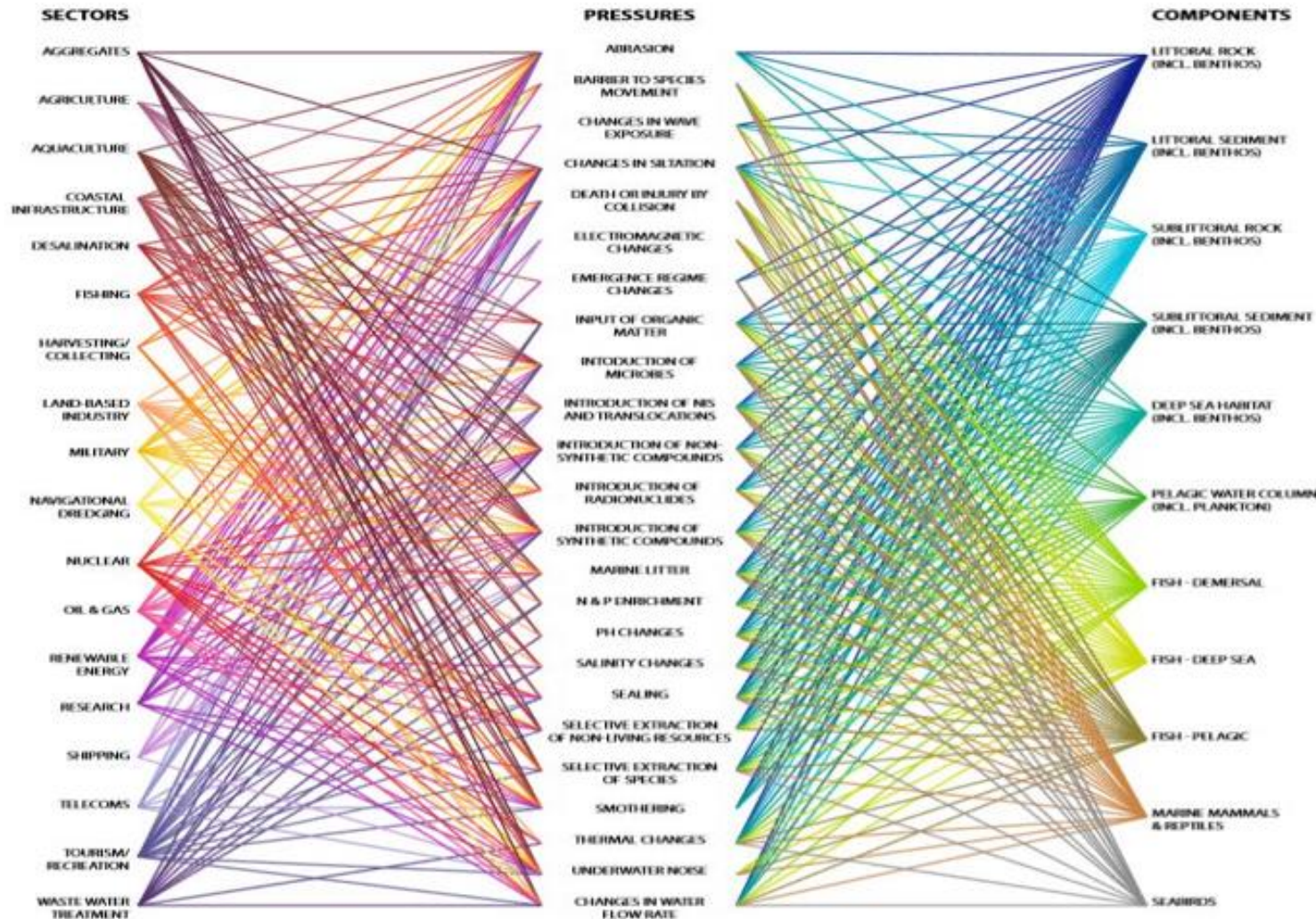
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**METU Institute of Marine Sciences**

- Planetary Boundries and Digital Twins of the Ocean
- Black Sea and BRIDGE-BS Approach to DTO Demonstrator
  - Node 1 Ecosystem Services link to DTO (Data, Modelling Framework Decision Support Tools and Resilience Analyses)
  - Node 2 Blue Growth Incubators link to DTO (Smart Observations Living Labs and Socioeconomic Analyses)
  - Black Sea DTO portal demonstrator



# BACKGROUND: MARINE MANAGEMENT



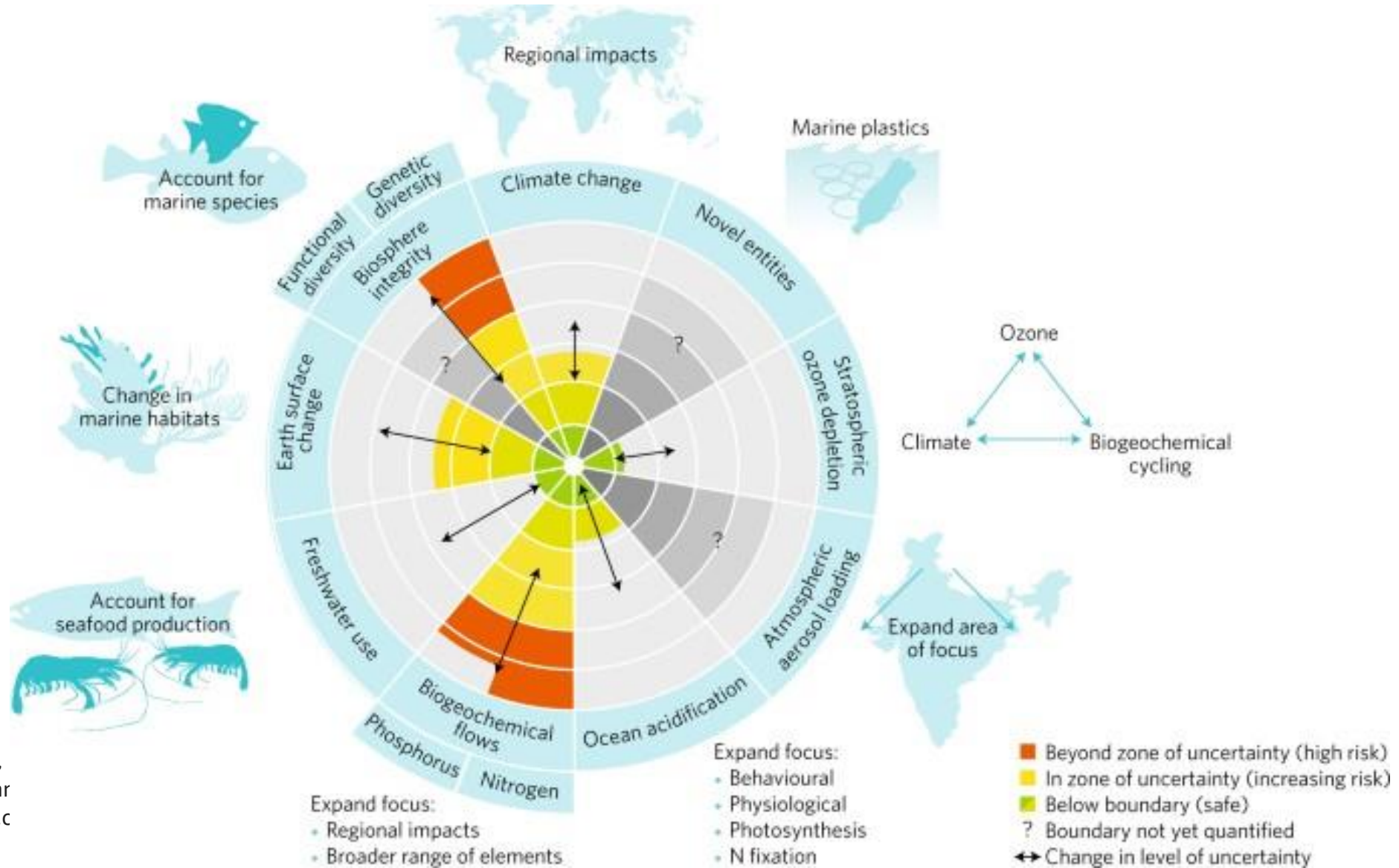
## CHALLENGES

- Economic and Social Benefits
- Sustainable Use of Resources
- Protecting Marine Ecosystems
- Climate Change Mitigation



Complex Interactions:  
Ecosystems Human  
Activities

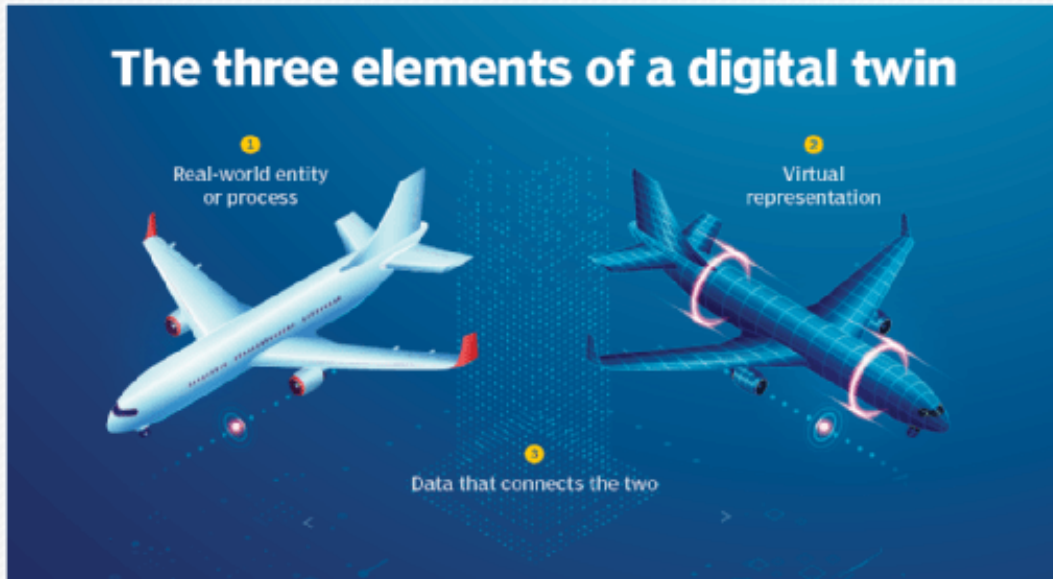
# PLANETARY BOUNDARIES FOR A BLUE PLANET





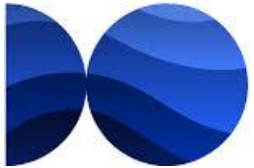
# WHAT IS A DIGITAL TWIN?

A digital twin is a virtual representation of an object or system designed to reflect a physical object accurately. It spans the object's lifecycle, is updated from real-time data and uses simulation, machine learning and reasoning to help make decisions.





The Digital Twin Ocean will give governments, researchers, businesses, activists, and citizens alike the power to make **informed decisions**, backed by science and data, to restore marine and coastal habitats, support a sustainable blue economy and mitigate and adapt to climate change.



**EDITO INFRA** is 2-year project that will build the public **infrastructure backbone** for EDITO by integrating key data service components (among which Copernicus Marine Service and EMODnet), and by sharing cloud processing capabilities and software into a single digital framework



**EDITO Model Lab** is a 3-year project aiming to develop the **next generation of ocean models, combining artificial intelligence and high-performance computing**, to be integrated into the EDITO public infrastructure, providing access to focus applications and simulations of different what-if scenarios

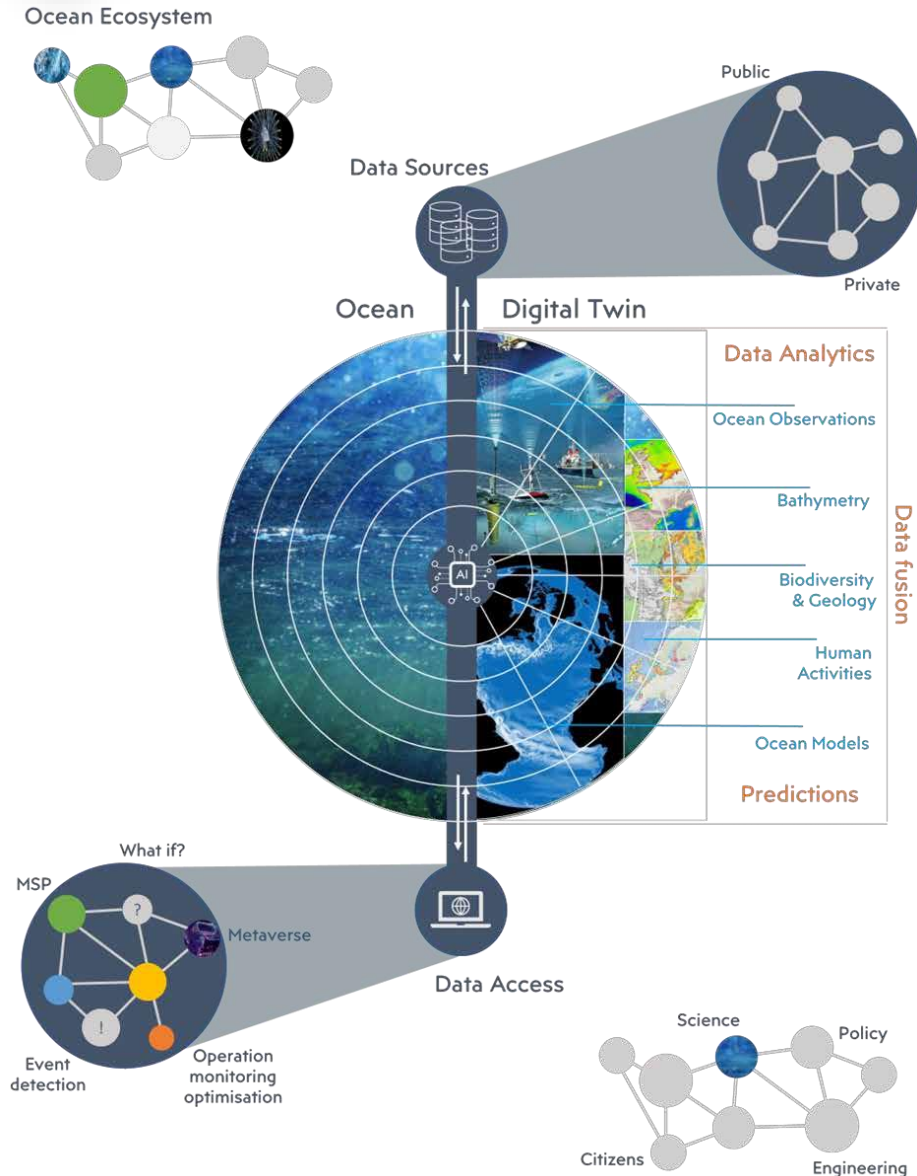


**DITTO**  
Digital Twins of the Ocean

**ILIAD** capitalises on the increasing **wealth of data and advanced computing infrastructures** by combining these diverse data in a semantically rich and data-agnostic approach allowing simultaneous communication with real-world systems and models.

The **DITTO** aims to support **ocean protection, governance, and a sustainable Blue Economy** through the use of DTOs. It seeks to develop a common understanding of DTOs, establish best practices, and create a digital framework to empower ocean professionals worldwide.

# GAME CHANGER: DIGITAL TWINS OF THE OCEAN



- **Virtual interaction between physical, chemical and biological properties with assets and human activities**



- **Data contextualization**
  - Data Sources / Data lakes
  - Observations and data assimilation



- **Integrating AI-driven data science and analytics**

- **New ways of interacting with and presentation of data**

- **Interoperability / Standardization**

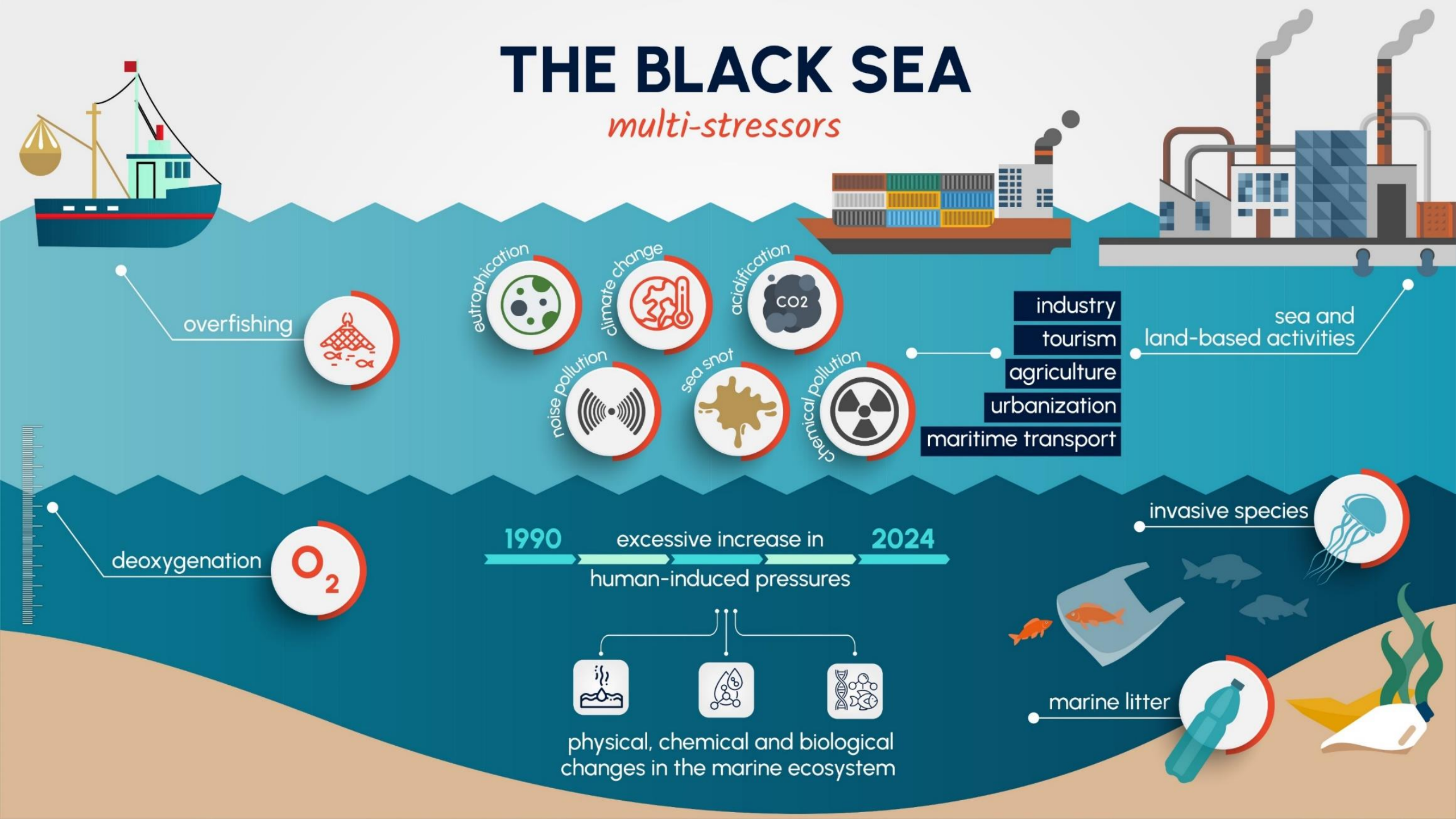
- **Modelling "what-if" scenarios for decision making**





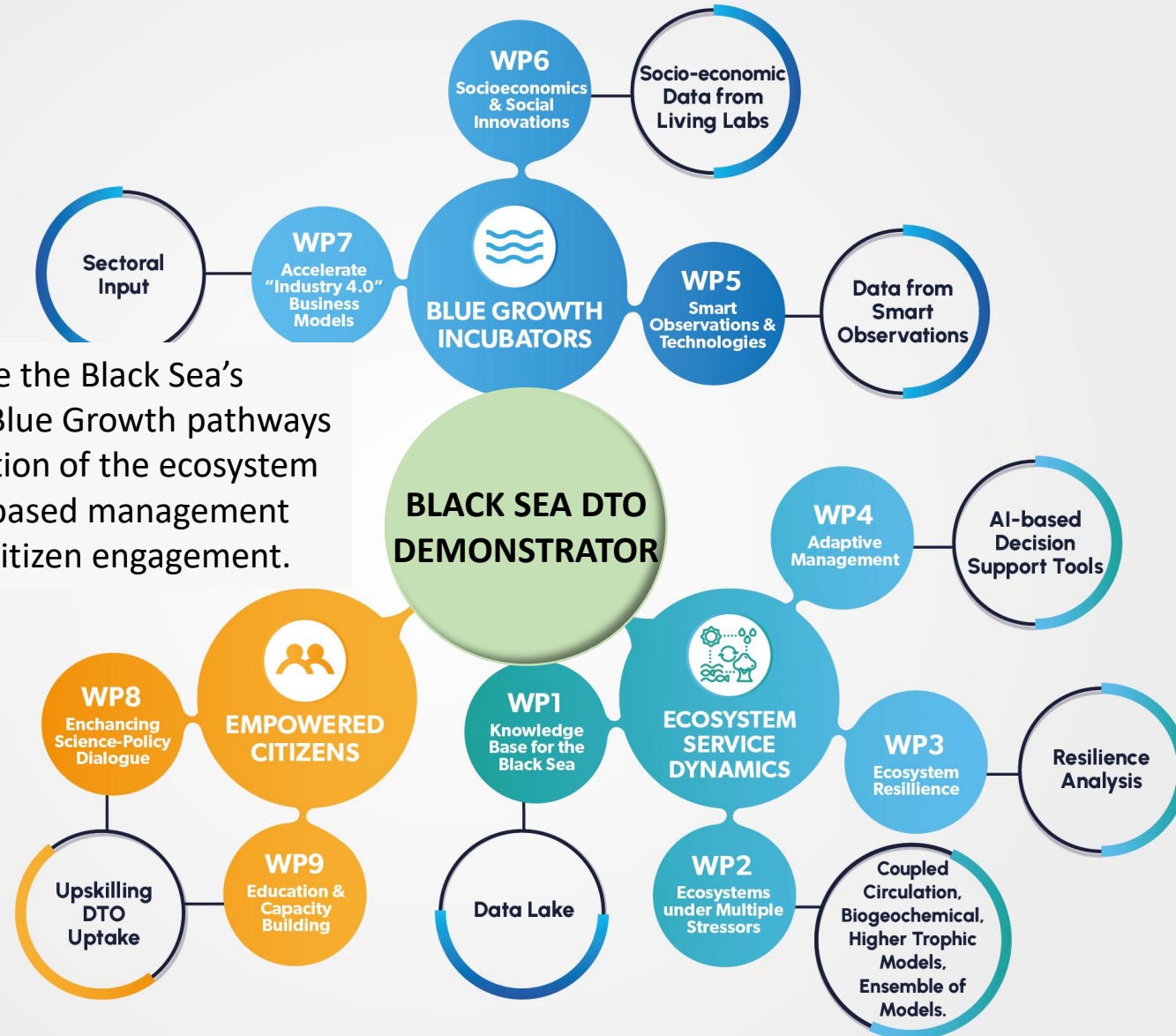
# THE BLACK SEA

*multi-stressors*





# BRIDGE-BS APPROACH TOWARDS BLACK SEA DTO DEMONSTRATOR



The overall objective of BRIDGE-BS is to advance the Black Sea's marine research and innovation to co-develop Blue Growth pathways under multi-stressors for the sustainable utilization of the ecosystem services. To do so it will develop an ecosystem-based management framework to enable policy uptake and foster citizen engagement.

virtual representation of  
a physical object or system

# DIGITAL TWIN

digitally simulates a real asset  
through data and models

*What is it?*

## 3D INTEGRATED MODELLING SYSTEM

recently applied also in the field of **oceanography**

### dynamic structure

simultaneously affected by  
physical and ecological changes  
and learns through data



### extensive research

facilitates extensive digital  
research by conducting studies  
unfeasible on physical objects



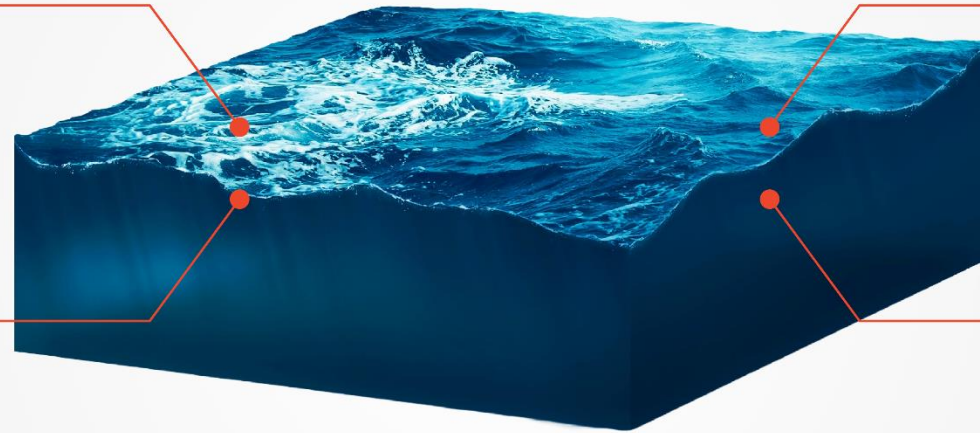
### predictive capacity

learns through historical and  
current data to make strong  
predictions



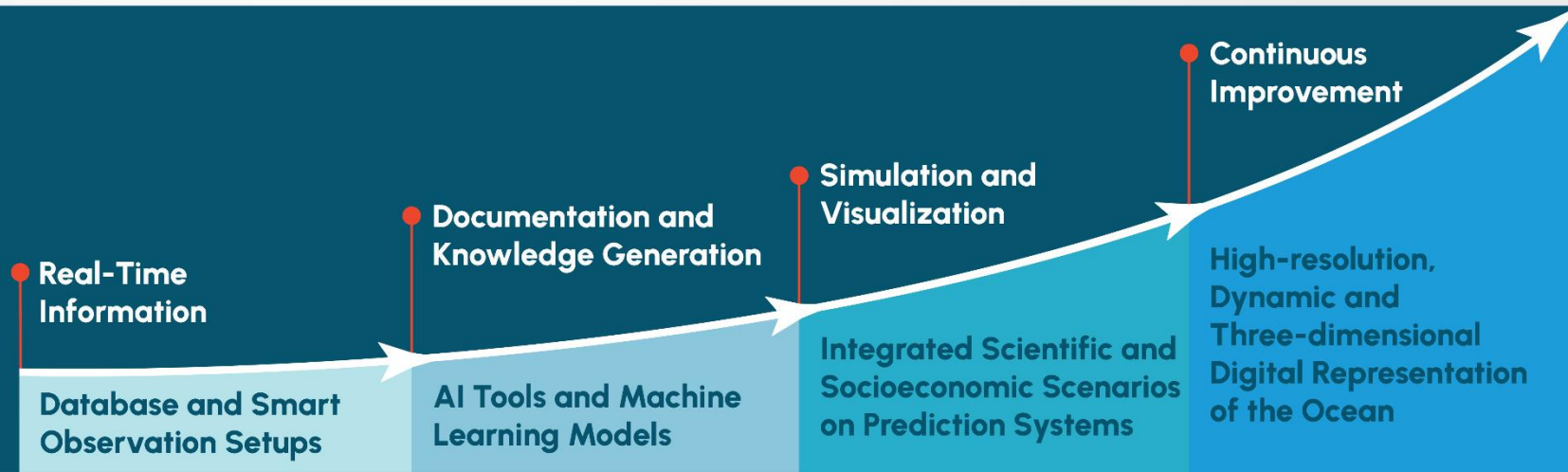
### real-time

changes the analysis and  
results in parallel with  
real-time data



## How do digital twins work as **ocean demonstrators**?

They utilize real-time data from databases and smart observation systems, employing dynamic, high-resolution, fully coupled models of sea and watershed with AI tools. These Digital Twins enhance comprehension of regional sea ecosystems, predict their states amid climate changes, and assess socio-economic scenarios for decision-making.





a digital model of the  
real-world conditions,  
processes and dynamics

# DIGITAL TWIN OCEAN DEMONSTRATOR

one of the first examples  
of digital twin ocean  
demonstrators

1960

2030

*for a healthier Black Sea*

blue economy  
sector analyses

smart  
observations

Past  
Data

Current  
Data

Future  
Data

living lab  
experiences

stakeholder  
input

AN EXTENSIVE DATABASE ON  
3D INTEGRATED MODELLING SYSTEM

better  
management  
recommendations

ensure safe  
operating  
space

enhance  
capacity  
building

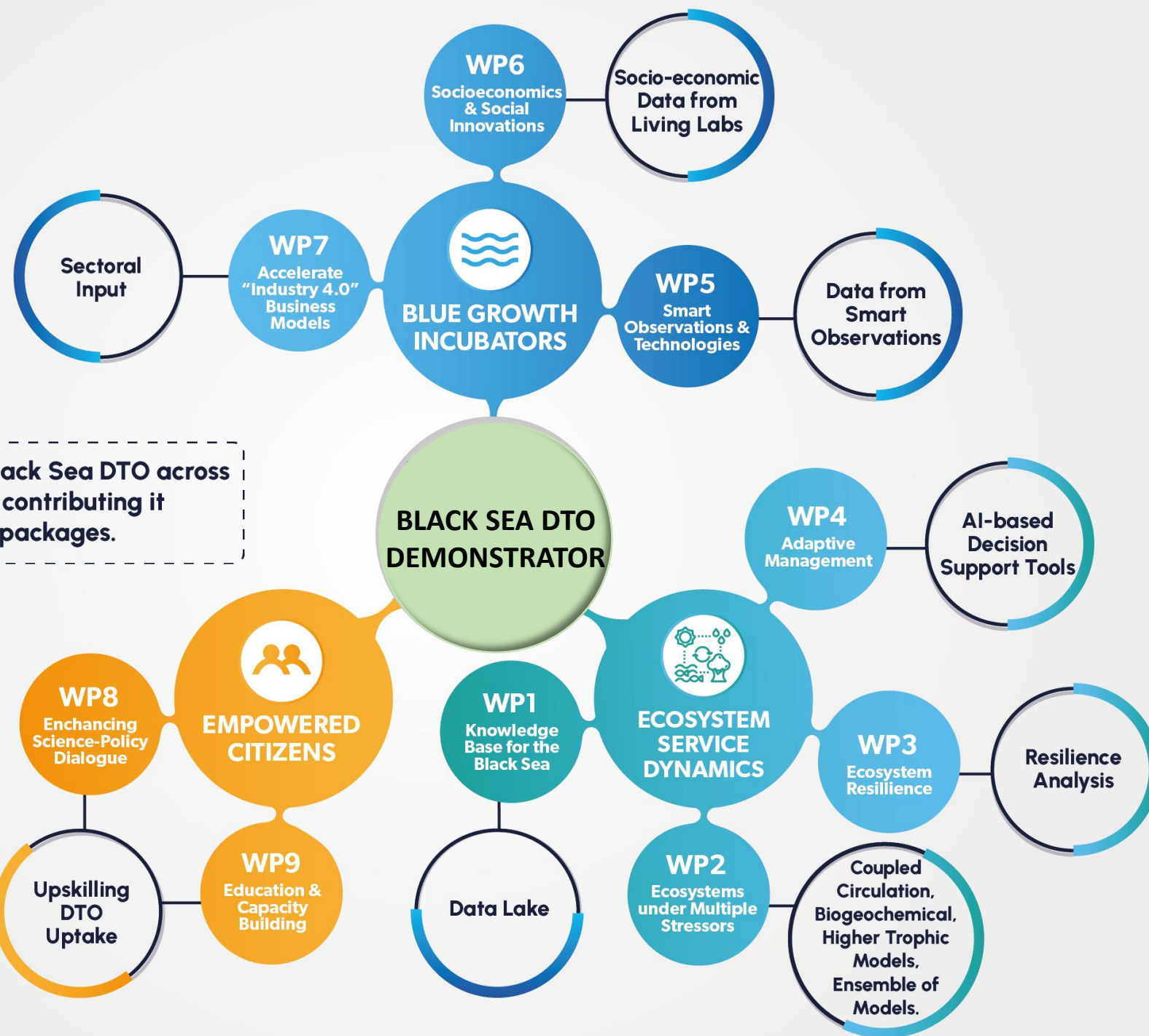
test  
various  
scenarios

prediction  
and early  
warning  
systems

optimize  
the data

Enhancing the **resilience** of the Black Sea **ecosystem** and surrounding **societies**, boosting **biodiversity** and safeguarding **benthic** and **pelagic** fauna









# BRIDGE-BS OCEANOGRAPHIC AND ECOSYSTEM MODELS: ENSEMBLE APPROACH

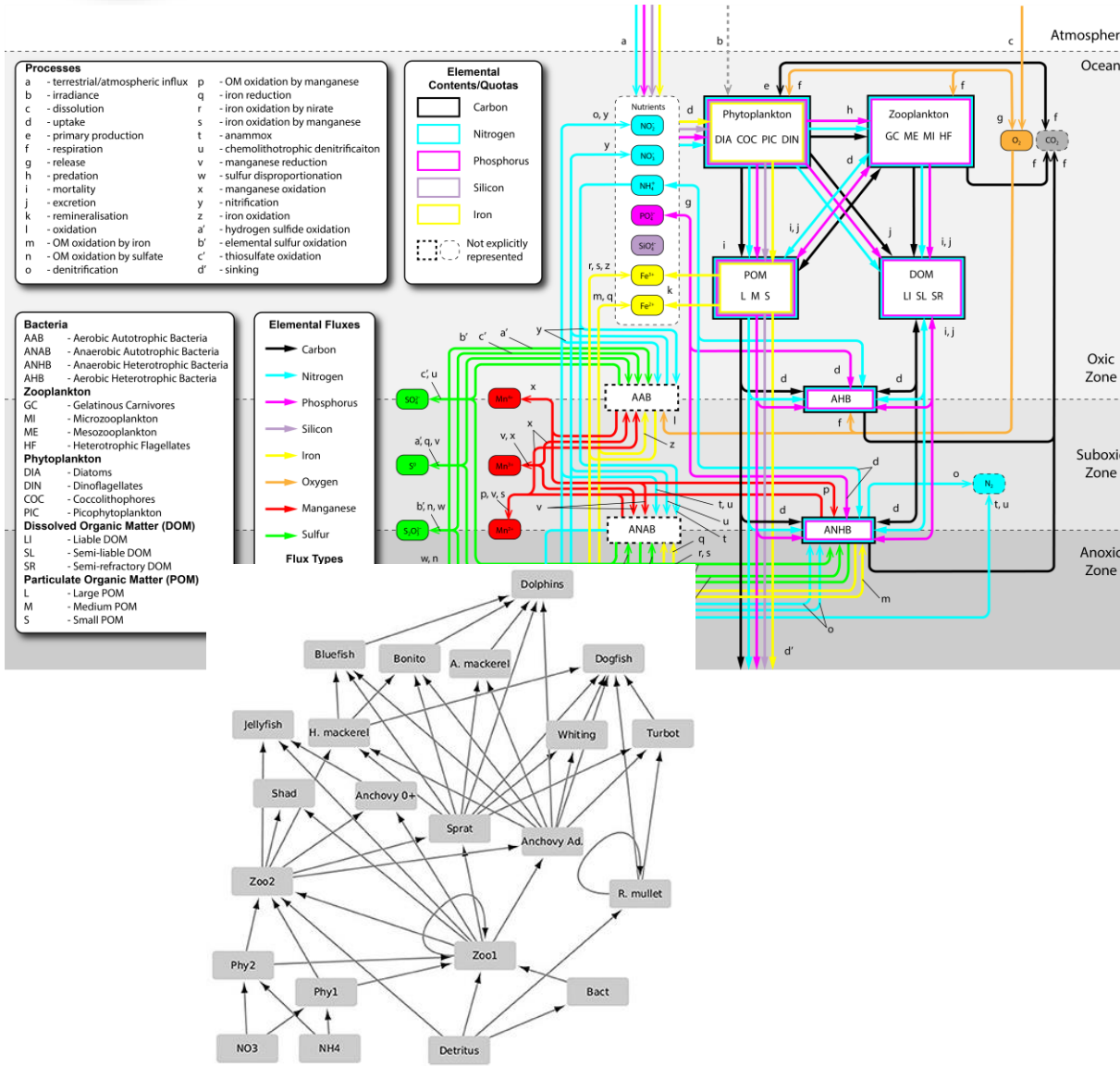
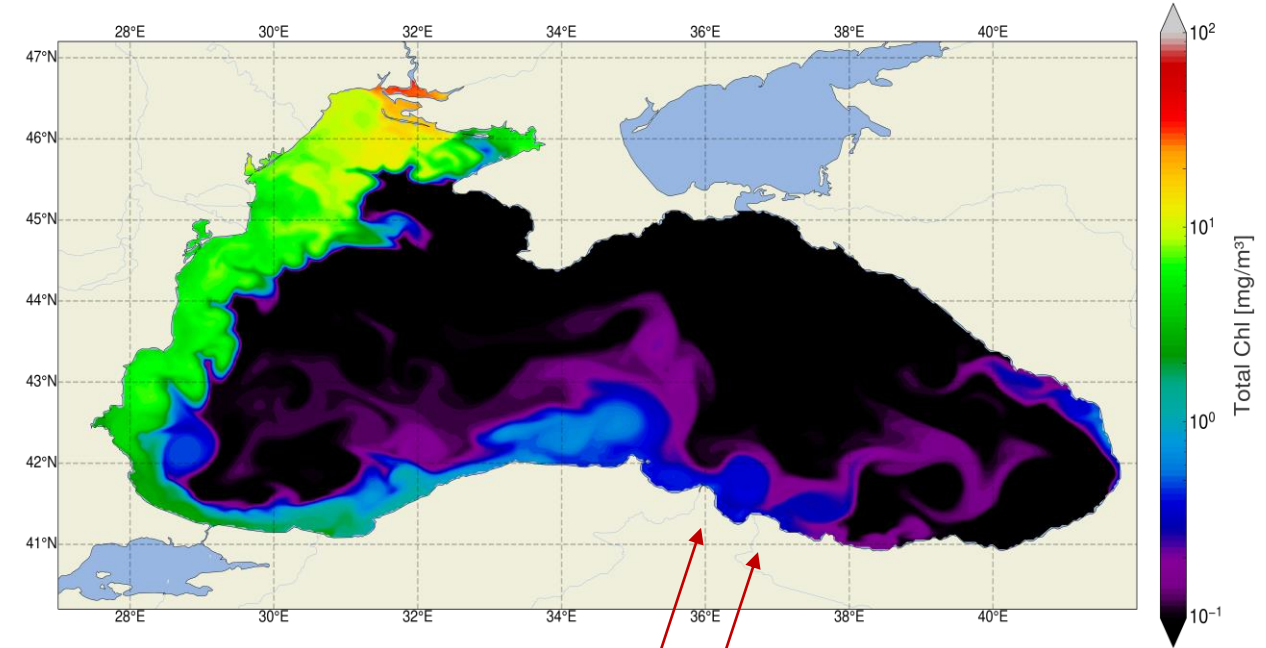
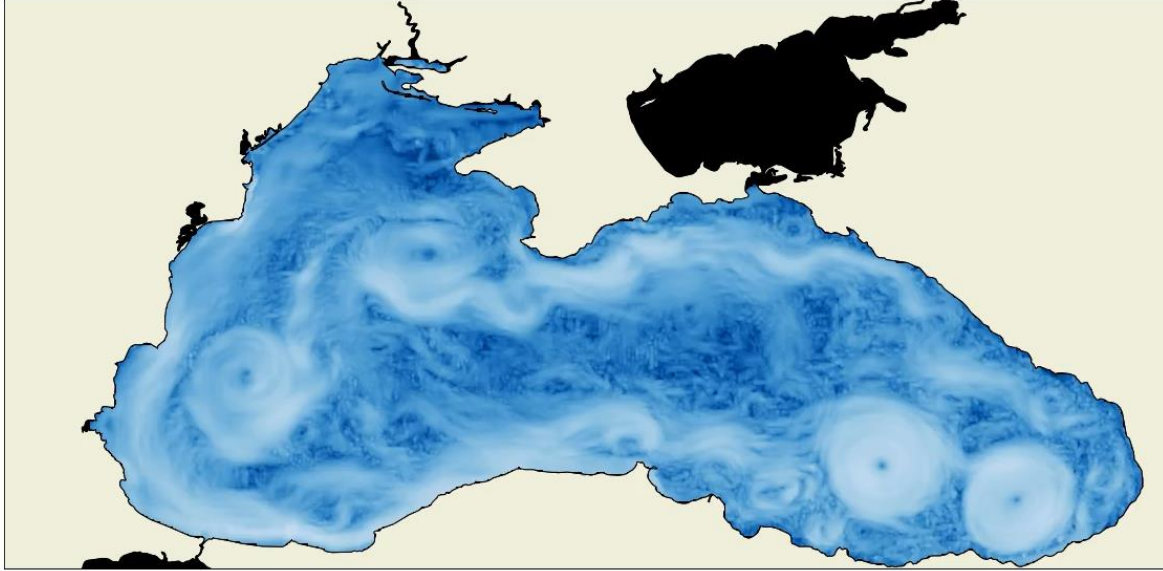


Table 2. Existing BRIDGE-BS models and their basin/regional scale horizontal resolution, lead partner. The selected Pilot Sites (PS) where downscaled regional simulations will run are also indicated.

Model Name	Basin scale resolution	Regional resolution, Pilot Site (PS)	Lead Partner
<b>3D coupled physical-biogeochemical models (Lower Trophic Level - LTL)</b>			
POM-ERSEM (Politikos, D. et al. 2015)	5 km	500 m (PS2, PS4, PS7)	HCMR
NEMO-ERSEM (DEKOSIM Project 2012-2021)	3 km	1 km (PS1, PS6, PS7)	METU
NEMO- BAMHBI (Grégoire et al. 2008, Capet et al. 2016)	3 km	600 m (PS2, PS3, PS4)	ULiege
ROMS	1km-500 m (curvilinear)	1km-500 m (curvilinear) (PS5)	SIO-RAS
NEMO/ BSAS12	7-8 km	7-8 km	SIO-RAS
<b>High Trophic Level (HTL) models</b>			
EwE Fortran (Akoglu et al., 2015), OSMOSE (Sombee Project, 2017-2018)	3 km	1 km (PS1, PS5, PS6, PS7)	METU
Life cycle models based on Individual Based models (Politikos, D., 2015)	5km	500 m (PS2, PS7)	HCMR
Habitat suitability models (Bioclim) (Albouy et al., 2013)	3 km	600m (PS2, PS4, PS6)	IFREMER
Food Web: Ecopath with Ecosim and Ecospace (EwE) (Daskalov G., 2013; 2015; 2020)	30 km	2 km (PS2)	IBER-BAS
<b>Specific Models to connect with BRIDGE-BS Ecosystem services, GES and selected Blue Growth Activities</b>			
Submodels of biogeochemical process in anoxic conditions	3-km (in 3D models)	600m (PS1, PS2, PS3)	CNR
Habitat suitability models (e.g. Maxent, GAM, Random Forest) (benthic) (Berov, D. et al. 2018)	Not applicable	10-600 m (PS3, PS4)	IBER-BAS, ULiege
Radiative Transfer Model (RADTRAN) for modelling optical properties (water clarity)	3km	600 m (PS1, PS2, PS3, PS4)	ULiege
Particle drift models (plastics) (Stamataki, N. et al., 2020)	5km	500m (PS2, PS3, PS4, PS7)	HCMR, DTU
1D demographic ctenophore interaction model embedded in a 3D model (MBD model) (Shiganova T., 2018)	1-2 km	1 km (PS5)	SIO-RAS
Jellyfish model (Shiganova et al., 2019)	1-2 km	10-100 m (PS5)	SIO-RAS
- Aquaculture- Fish (mass-balance budget) (Tsagaraki et al. 2011, Petihakis et al. 2014) - Mussel (Dynamic Energy Budget) (Hatzonikolakis et al., 2017)	5 km	500m (PS3, PS7)	HCMR
Harmful algal blooms (HABs)	3 km	600 m (PS3, PS7)	DTU



# BRIDGE-BS OCEANOGRAPHIC AND ECOSYSTEM MODELS: ENSEMBLE APPROACH MODELLING FRAMEWORK



- When setting up the model and tuning it a major influence on eutrophication in the simulations was found to be the input of nutrients through the rivers.
- Having a robust estimation of nutrient influx from rivers provided by the watershed model detailed above has been critical in achieving the eutrophication simulation.

# ECOSYSTEM SERVICES UNDER INTERACTING MULTISTRESSORS AND BLUE GROWTH SCENARIOS

## PILOT SITES ECOSYSTEM SERVICE - SECTOR SPECIFIC SCENARIO

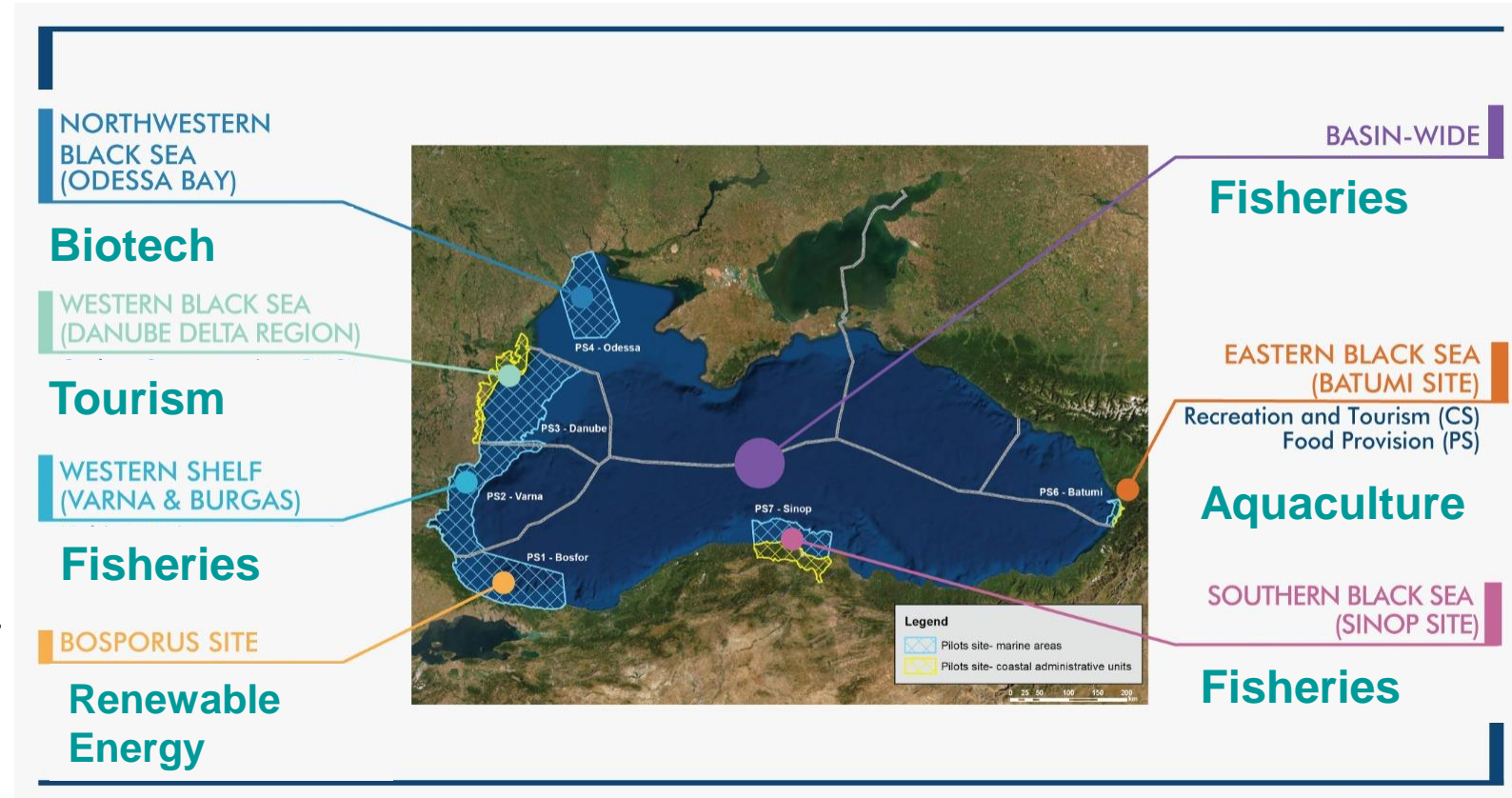
### Sectors

- Climate regulation (carbon sequestration, GHG emission)
- Recreational (plastics, eutrophication)
- Food provisioning (fisheries, aquaculture)

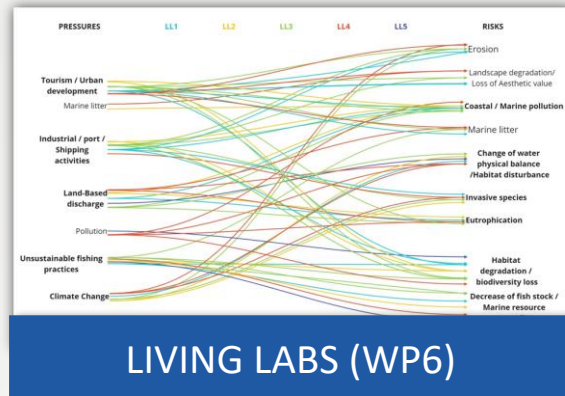
### Socio-Economic Scenarios

SSP1-2.6, (SSP2-4.5), SSP5

1. River nutrients
2. Fishing pressure (PS2, PS6, PS7 +basin)
3. Plastic delivery (PS2, PS6, PS7 +basin)
4. Aquaculture (PS2, PS6, PS7 +basin)

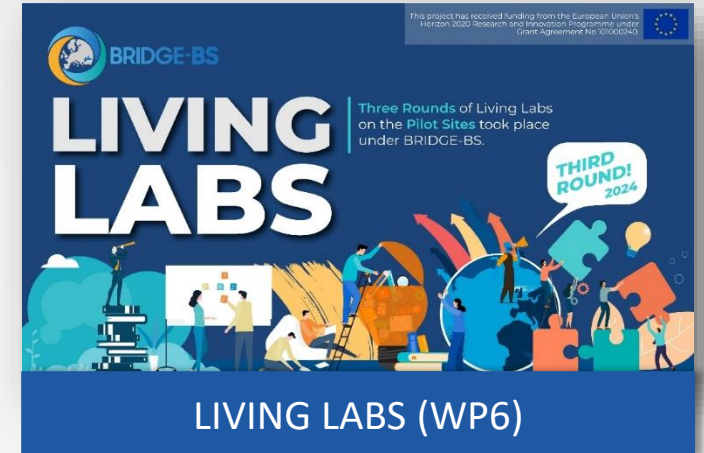






**WP6**  
Socioeconomics  
& Social  
Innovations

**Socio-economic  
Data from  
Living Labs**



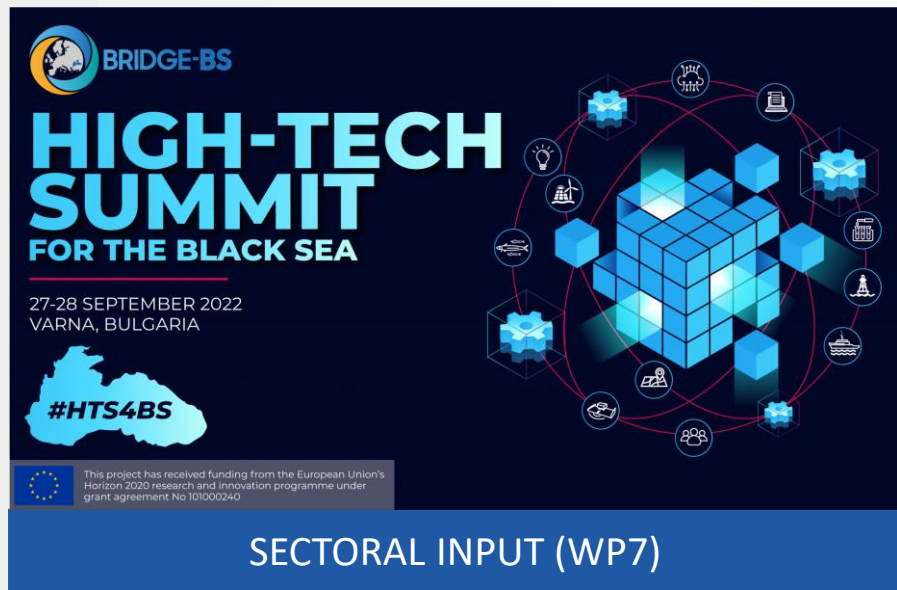
**Sectoral  
Input**

**WP7**  
Accelerate  
"Industry 4.0"  
Business  
Models

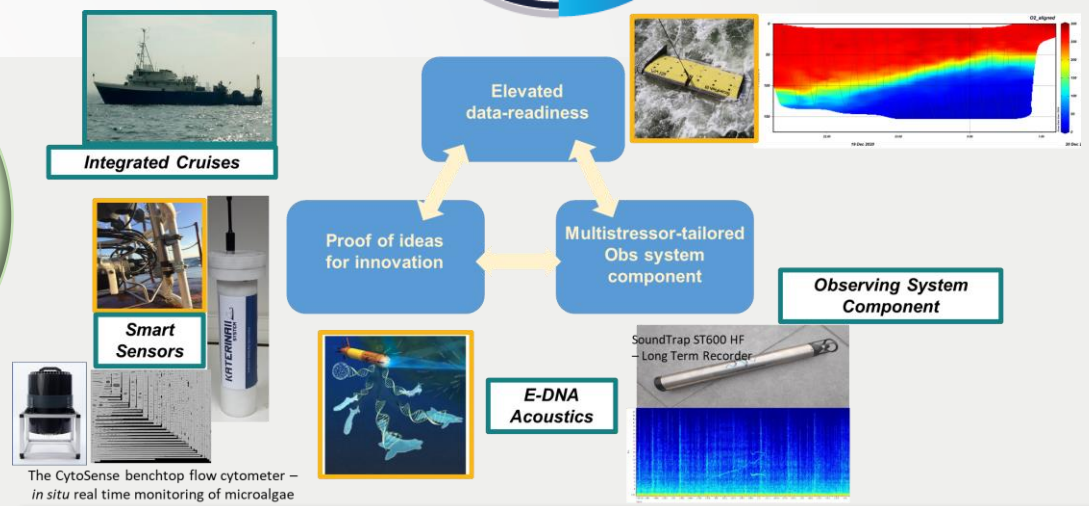
**BLUE GROWTH  
INCUBATORS**

**WP5**  
Smart  
Observations &  
Technologies

**Data from  
Smart  
Observations**

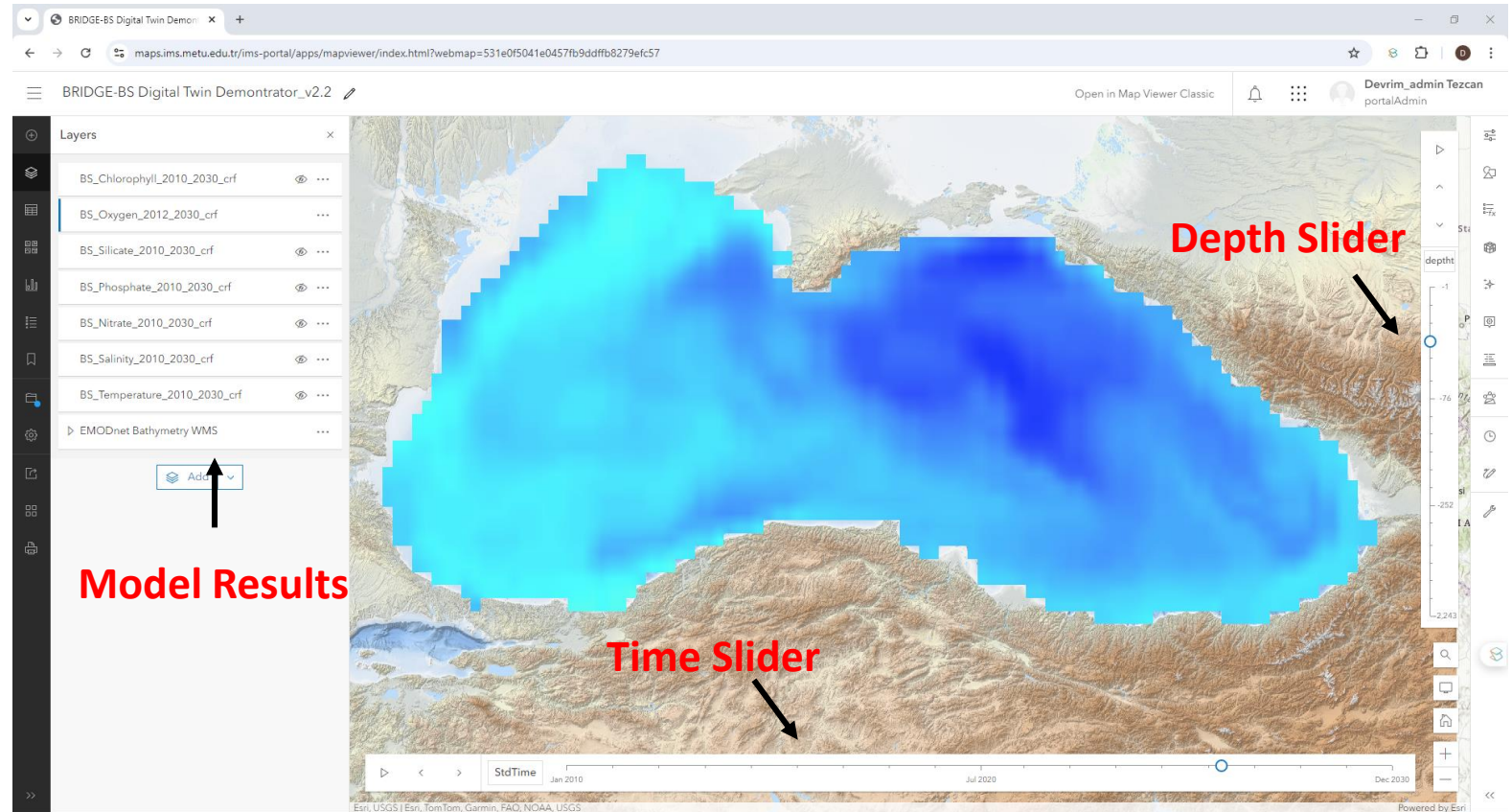


**BLACK SEA DTO  
DEMONSTRATOR**





- METU has educational organization license for ESRI ArcGIS Enterprise that includes ArcGIS Server, ArcGIS Portal, Data Store.
- All the data (in situ, satellite, model results, etc) in BRIDGE-BS project can be stored in METU ArcGIS Enterprise and can be published as web services
- These web services can be used by Map Viewer in ArcGIS Enterprise & ArcGIS Online or the other GIS applications to create a Web Map.



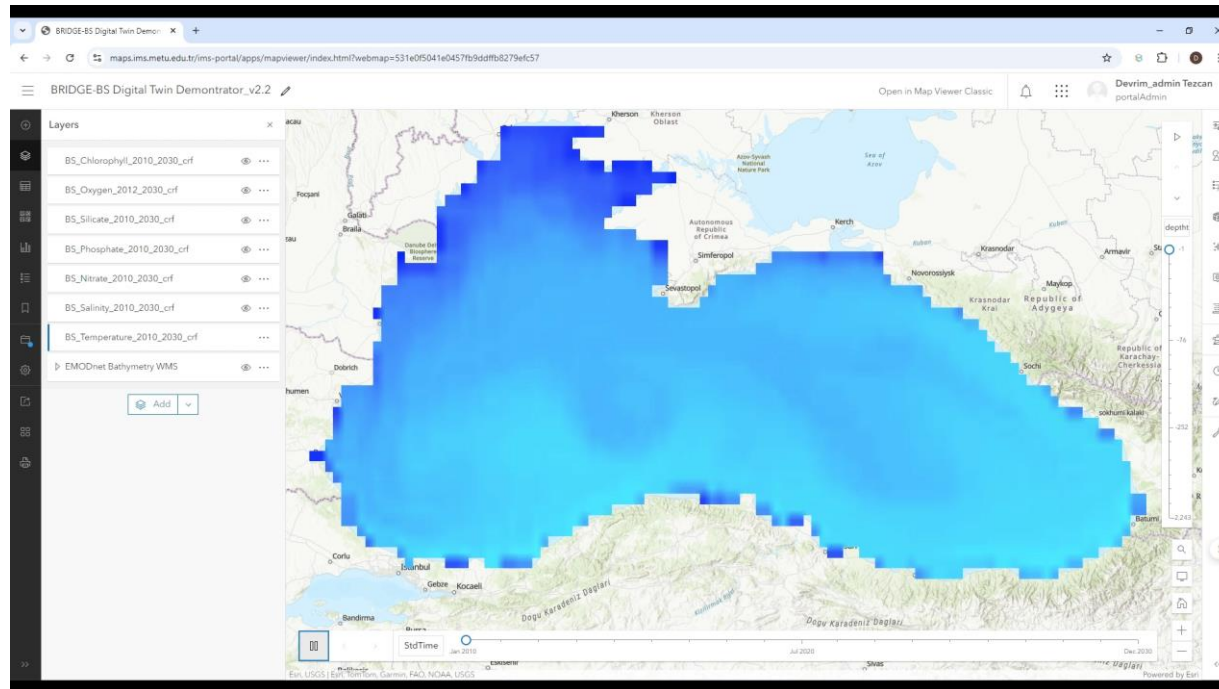
BRIDGE-BS Digital Twin Demonstration Tool Web Map

- ArcGIS Enterprise has a dashboard app to show Serial charts, Pie charts, Lists, Tables and Web maps in a dashboard.
- The data can be
  - Model Results,
  - In situ data,
  - Real time data
  - Environmental data
  - Demographic data
  - Economic data
  - ...

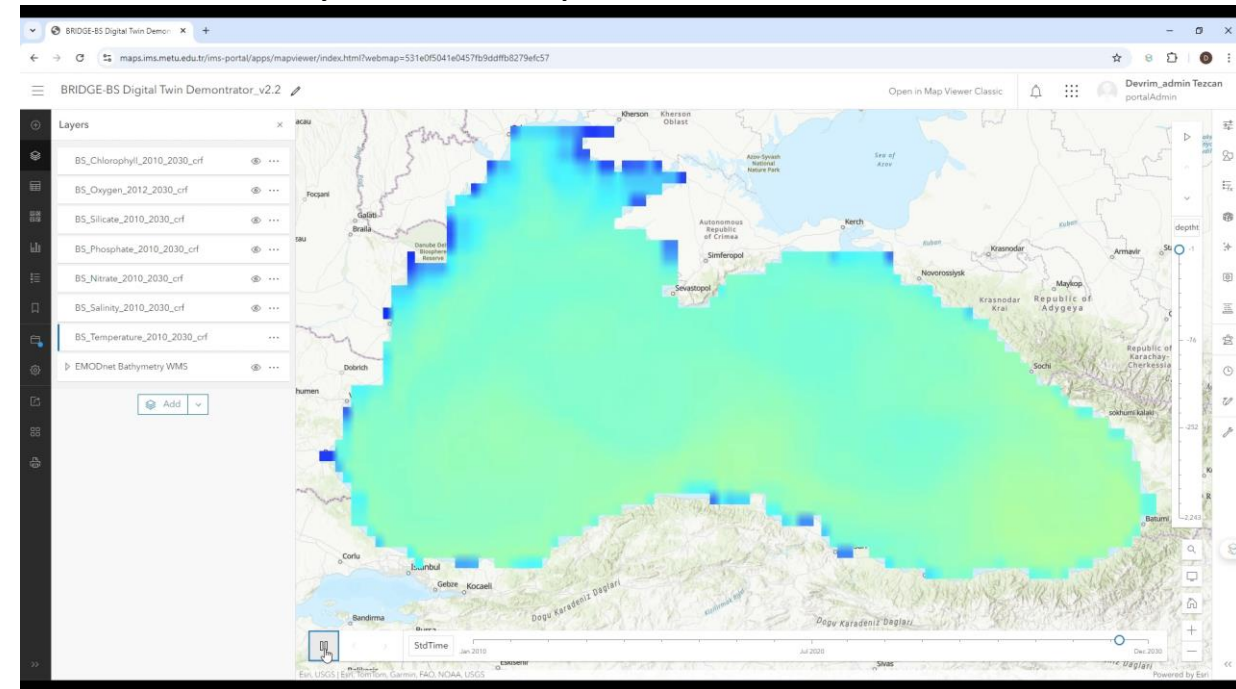


A Dashboard sample in ArcGIS Enterprise

## Monthly Mean Temperature at surface in 2010



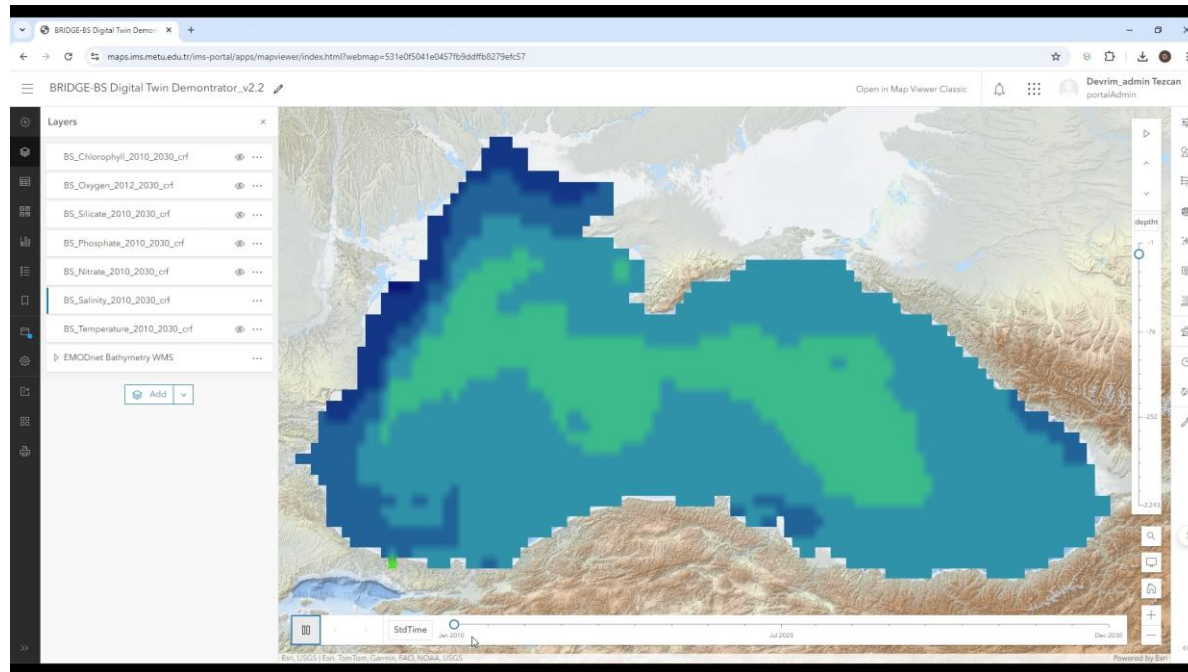
## Monthly Mean Temperature at surface in 2030



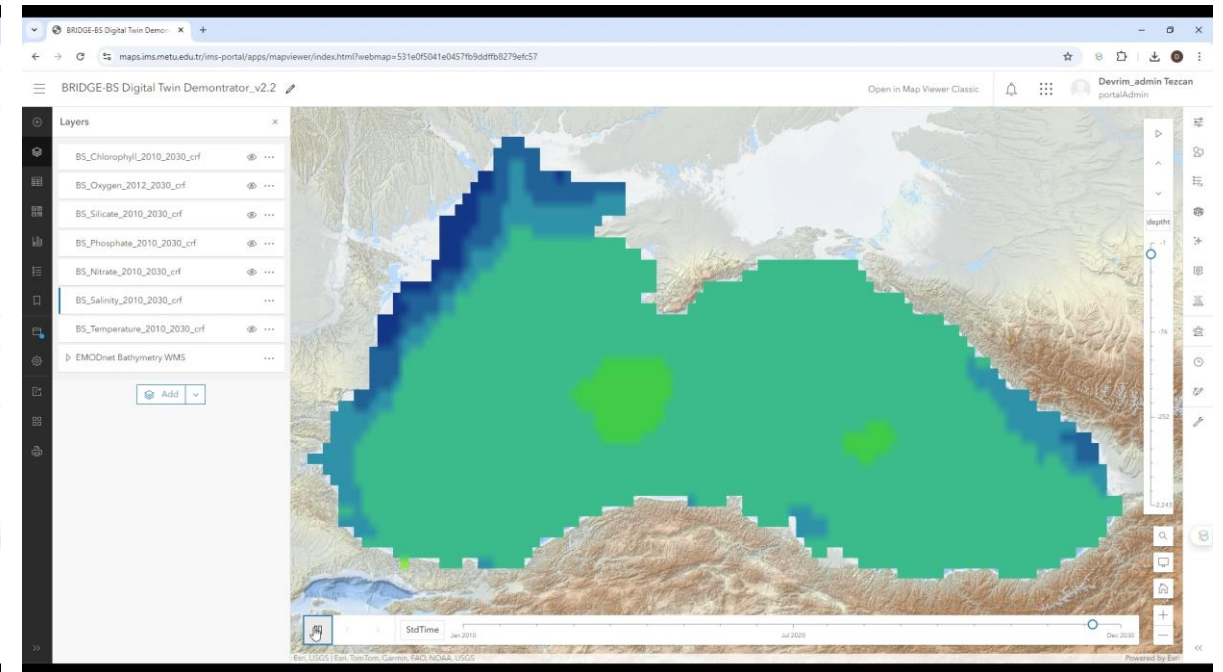
**Evidence of sea surface temperature warming within 20 years**



Monthly Mean Salinity at surface in 2010

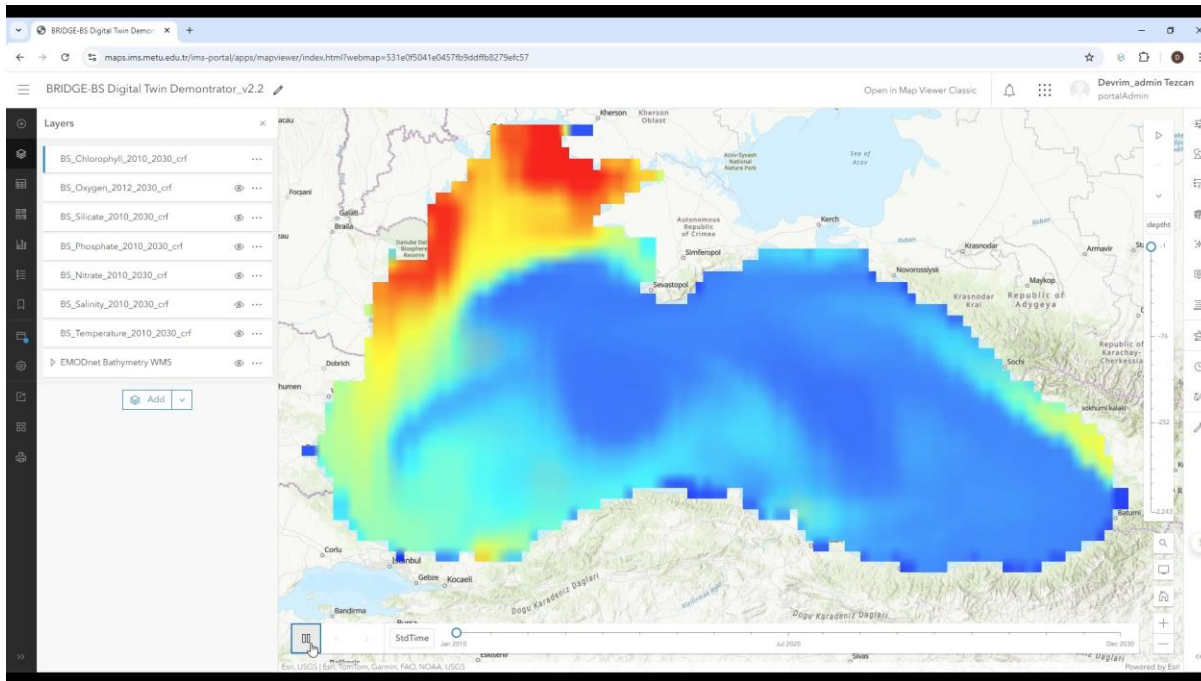


Monthly Mean Salinity at surface in 2030



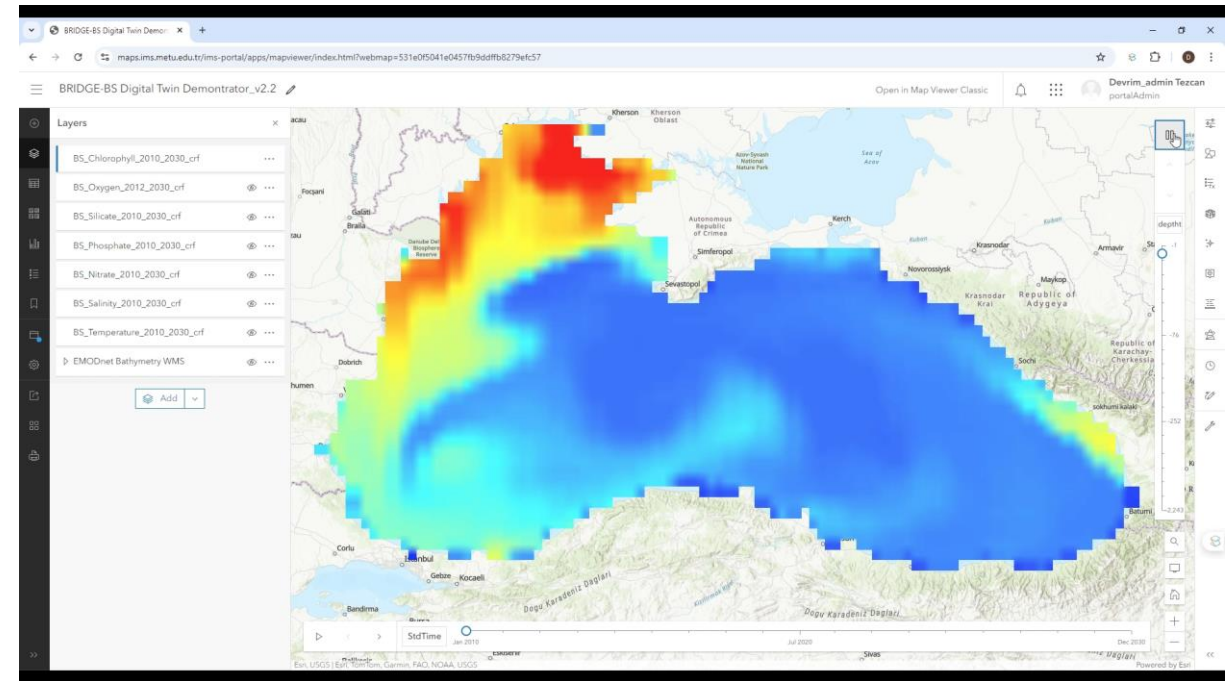
**Evidence of increase in salinity over 20 years**

Monthly Mean Chlorophyll at surface in 2010



**Strong winter bloom followed by spring bloom**

Monthly Mean Chlorophyll changes with depth in Jan 2010



**Deep chlorophyll maximum at depth**





# THANK YOU!

**STAY TUNED!**



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