iFADO
INNOVATION IN THE FRAMEWORK OF THE ATLANTIC DEEP OCEAN

Numerical Model Evolution and Improvement in the Atlantic Area

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Interreg Atlantic Area
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What are the numerical models?

Numerical ocean models are **mathematical representations** of the natural marine environment, in which the processes describing the ocean hydrodynamics (e.g. sea level, currents, and turbulence) are described by a set of **PDE**s and are parameterized according to our best understanding of the system.

$$\frac{\partial u}{\partial t} - fv + \vec{v}\cdot\nabla u = -\frac{\partial \phi}{\partial x} - \left(\frac{g\rho}{\rho_o}\right)\frac{\partial z}{\partial x} - g\frac{\partial \zeta}{\partial x} + \frac{1}{H_z}\frac{\partial}{\partial \sigma}\left[\frac{(K_m+\nu)}{H_z}\frac{\partial u}{\partial \sigma}\right] + \mathcal{F}_u + \mathcal{D}_u$$

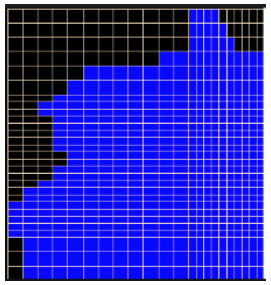
$$\frac{\partial v}{\partial t} \quad \left(\frac{g\rho}{\rho_o}\right)\frac{\partial z}{\partial y} \quad \frac{\partial v}{\partial \sigma}\right] + \mathcal{F}_v + \mathcal{D}_v$$

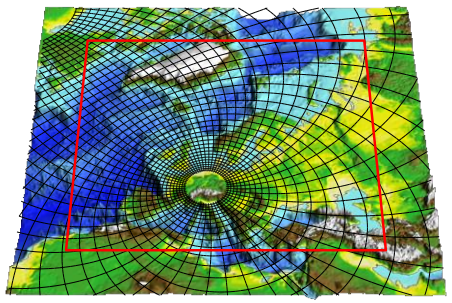
$$\frac{\partial C}{\partial t} \quad -\nu)\frac{\partial C}{\partial \sigma}$$

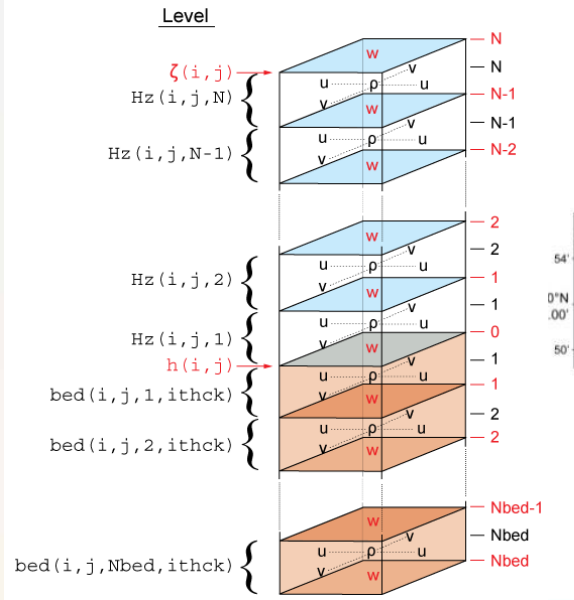
$$\rho =$$

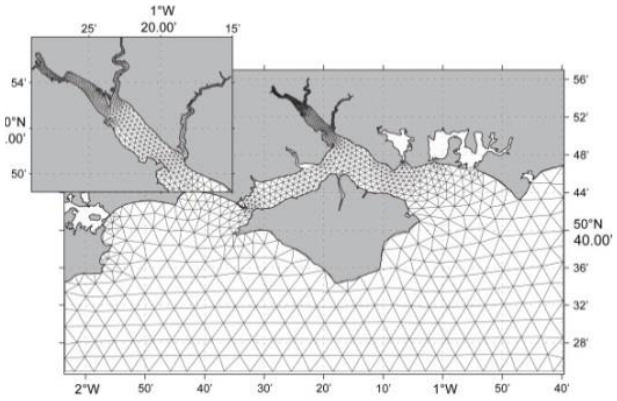
$$\frac{\partial \phi}{\partial \sigma}$$

$$\frac{\partial H_z}{\partial t} + \frac{\partial (H_z u)}{\partial x} + \frac{\partial (H_z v)}{\partial y} + \frac{\partial (H_z \Omega)}{\partial \sigma} = 0$$









How do we solve these equations?

- They do not have analytical solution. We approximate the solution using so called **numerical methods**
- We use supercomputers
- For example to produce a 3-day forecast for Irish ocean these equations must be solved ~233 billion times

What processes are included?

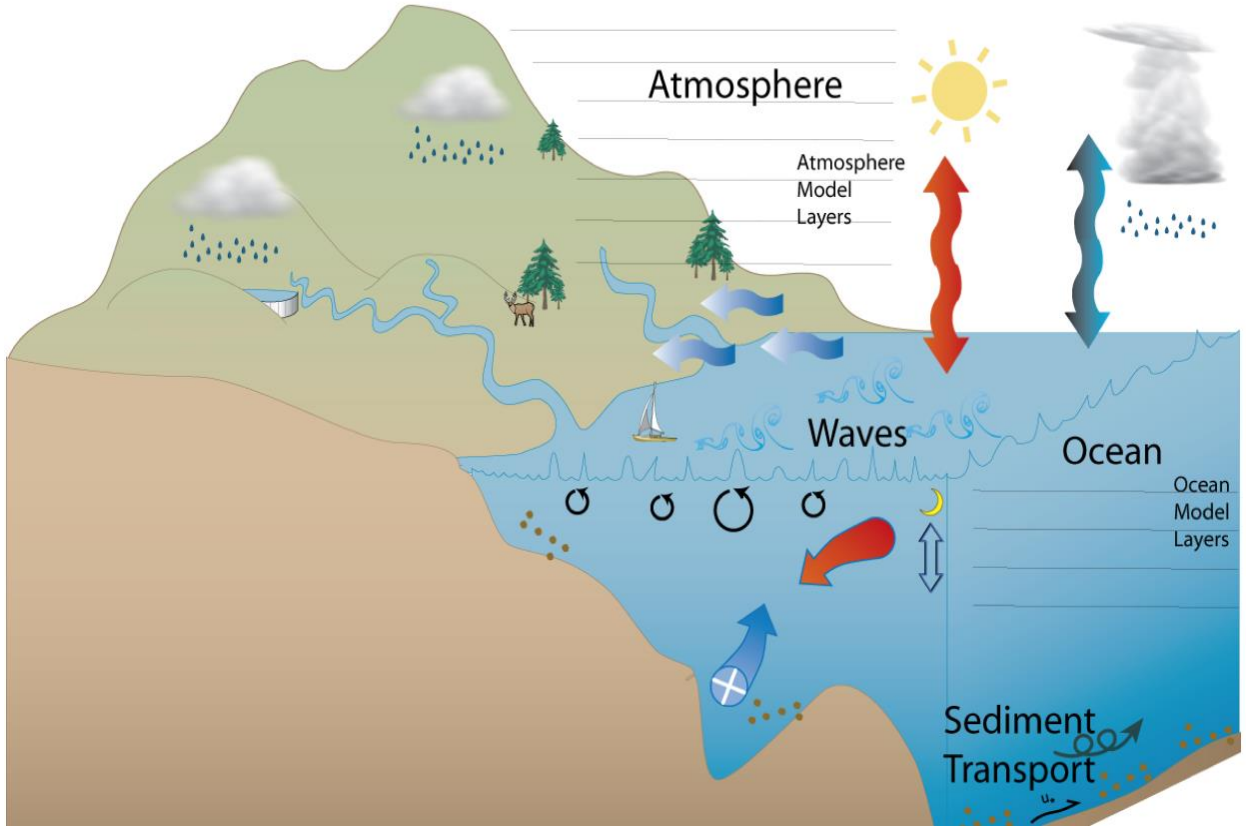


Figure from:
https://www.usgs.gov/centers/whcmsc/science/coawst-coupled-ocean-atmosphere-wave-sediment-transport-modeling-system

In addition to physics, **biogeochemical** models are commonly set-up. These simulate lower trophic level: cycling of **nutrients in a dissolved form and in phytoplankton, zooplankton and detritus.**

Objectives

- Downscaling for coastal systems to build the bridge between the Copernicus Marine Service and the Land Service. This is important because there is no service in these coastal areas

- Developed new model grids (spacing, vertical levels) and upgraded existing models, e.g. freshwaters flow sources (near-real-time-flows).

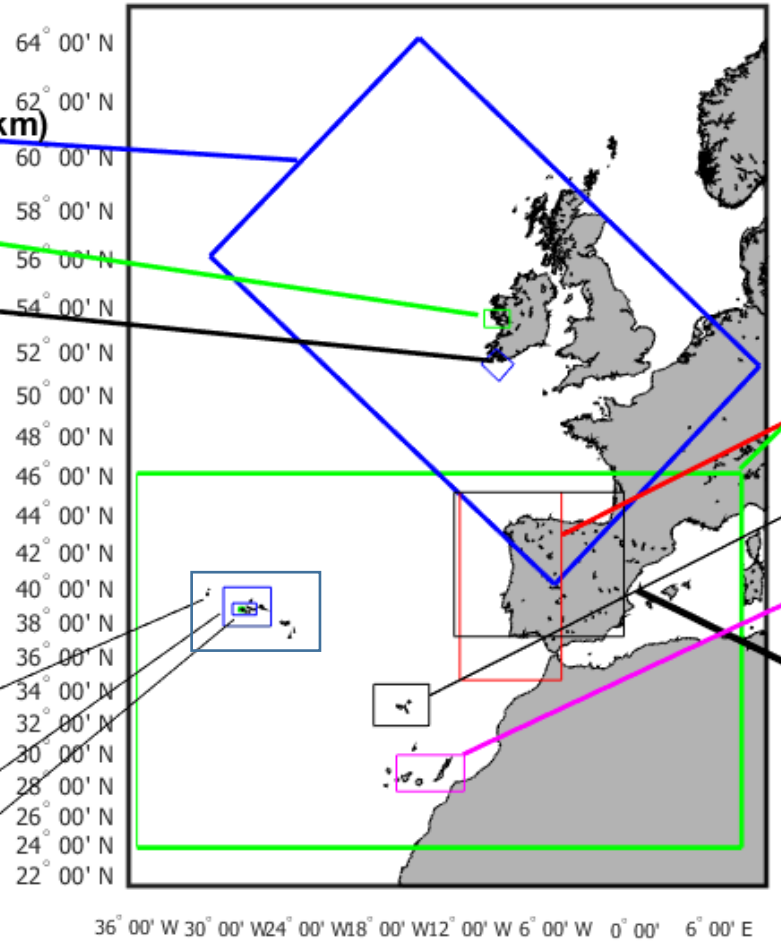
- The modelling results were validated with the in situ and remote sensing data made available during the iFADO project.

- The model outputs are processed to derive MSFD indicators

Models

(IMI)

- North East ATLANTIC (1.1km – 2.4km)
- Connemara (200 meters)
- Bantry Bay (200 meters)



(AZORES)

- Azores Central Group (3.6 km)
- Triangle Islands (1.2 km)
- Pico-Faial channel (80 meters)

(IST)

Hydrodynamical and biogeochemical models

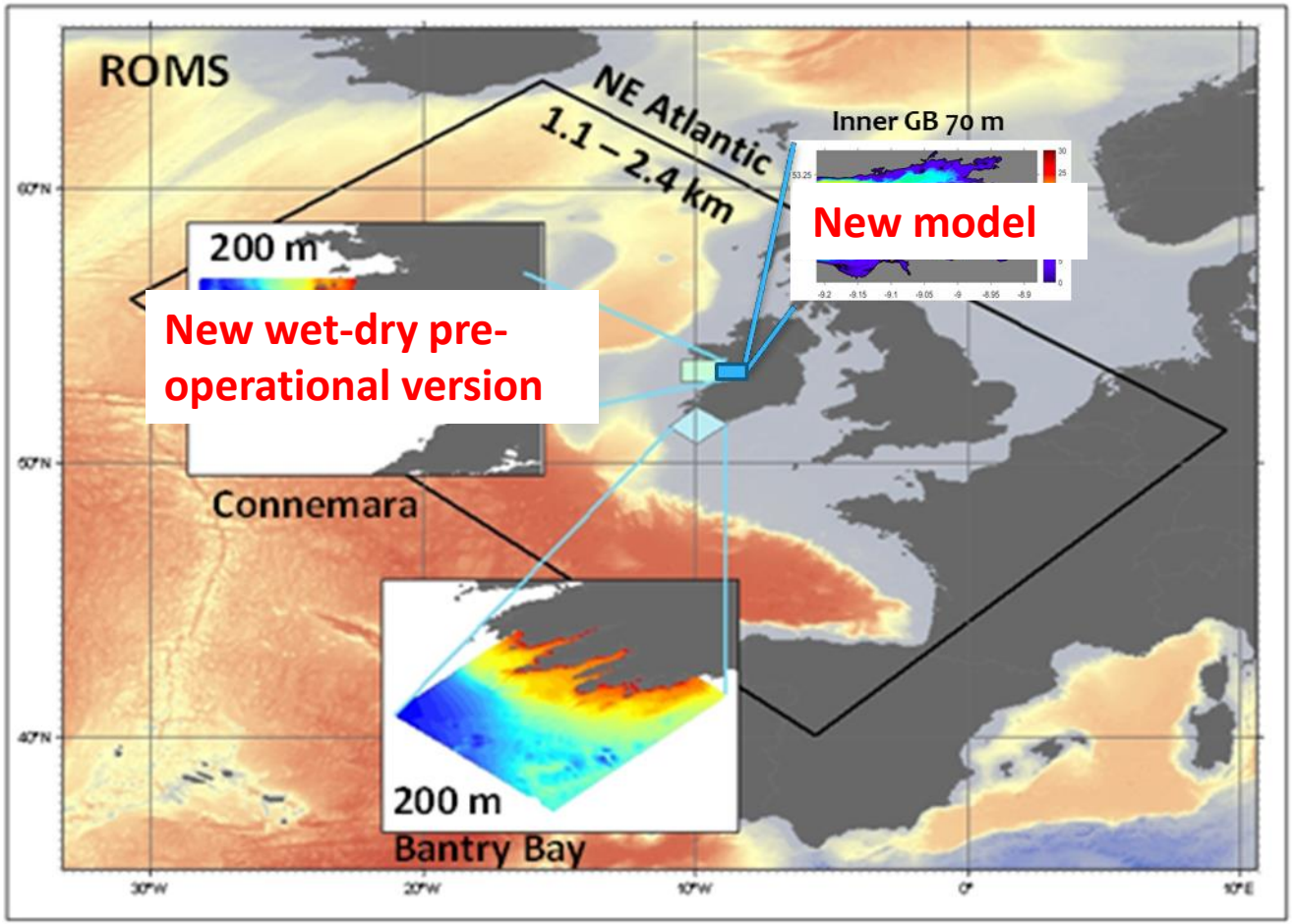
- LUSITANIA (0.08°)
- PCOMS (0.06°)
- Madeira (0.06-0.02°)
- MARPOCS Canarias (0.02°)

(IEO)

Hydrodynamical & Biogiochemical Model

W and NW Iberia (3.5 km)

Marine Institute's operational forecasting models



Bathymetry	GEBCO & INFOMAR
Forcing	• 1-Hourly ECMWF 0.1° • Copernicus global ocean 1/12° • TPXO8 tides 1/30° • River climatologies, Corrib operational
Forecast Period	+3 days (daily)
Hindcast Period	-7 days (weekly)
Output	• 3D velocities, ssh, stresses @ 1 hourly • T, S @ 3 hrs spatially • 2265 stations @ 10 mins
Nested Domains (operational)	• Connemara (200m) • Bantry Bay (200m) • Inner Galway Bay (70 m)
Other Domains (non-op)	Clew Bay (80m), Berthraghboy Bay (50m), Kenmare Bay (120m), Kilmakilloge Harbour (40m), SW Ireland (1 km)

Under dev:
- Celtic Sea

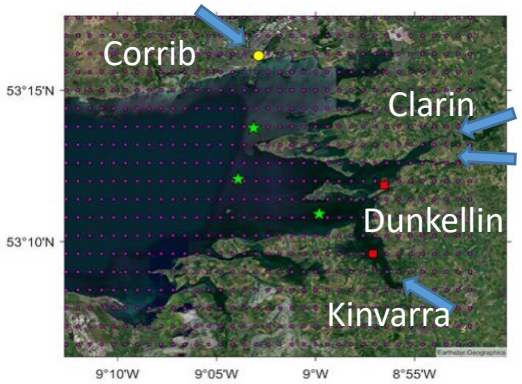
Future:
- Dublin Bay, main fisheries harbours

Wetting-drying and high resolution

<u>Context</u>

Inner Galway Bay **subtidal** area **10,352 ha**

Inner Galway Bay **intertidal** area **2,111 ha**

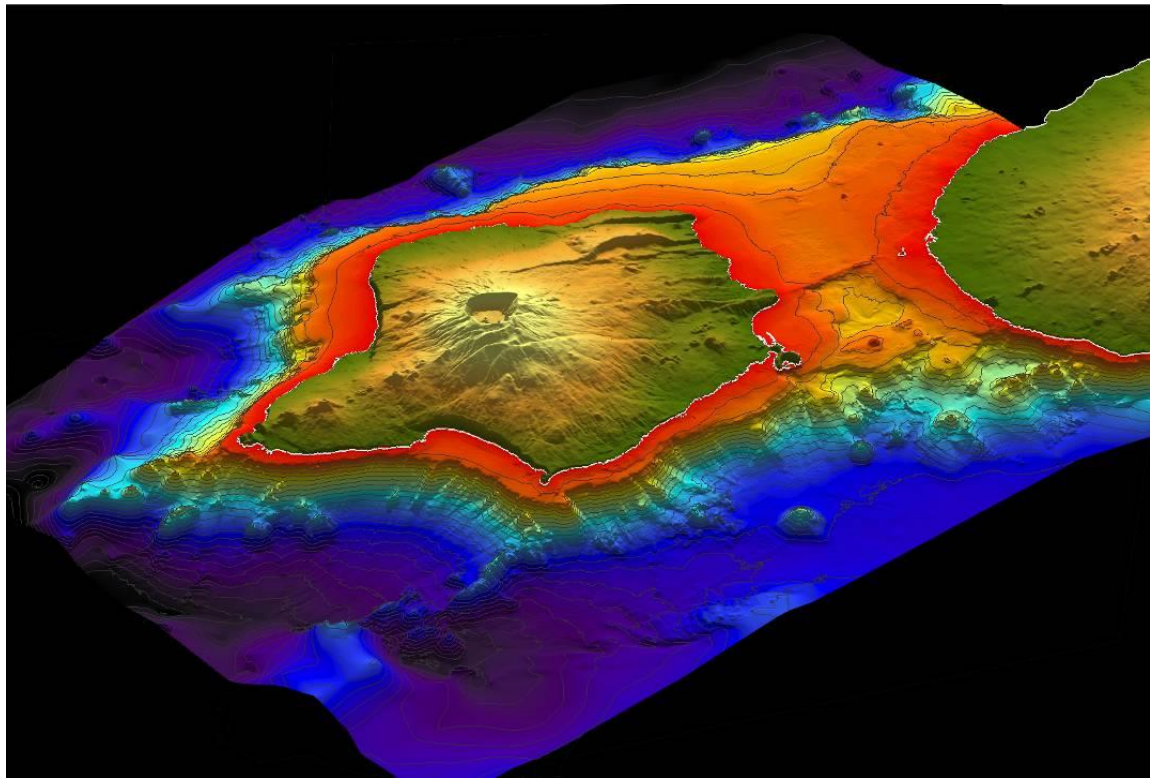


	200 m				200 m				70 m			
	CONNEMARA OPERATIONAL				CONNEMARA WET & DRY				GALWAY BAY			
	CORR	RMSE	STDN	ARMAE	CORR	RMSE	STDN	ARMAE	CORR	RMSE	STDN	ARMAE
ADCP A (u)	0.955	0.031	1.097	0.182	0.956	0.028	1.027	0.160	0.962	0.026	0.974	0.127
ADCP A (v)	0.757	0.031	2.194	0.973	0.714	0.035	2.328	1.155	0.771	0.027	1.966	0.732
ADCP B (u)	0.951	0.031	1.060	0.186	0.944	0.032	0.924	0.182	0.951	0.030	0.971	0.173
ADCP B (v)	0.066	0.029	0.329	0.583	0.292	0.027	0.218	0.522	0.289	0.027	0.369	0.519
ADCP C (u)	0.930	0.066	1.356	0.443	0.939	0.099	1.707	0.748	0.963	0.036	1.105	0.191
ADCP C (v)	-0.222	0.031	1.537	1.186	-0.036	0.035	1.950	1.340	-0.115	0.026	1.247	0.856

Excellent
Good
Reasonable
Poor
Bad

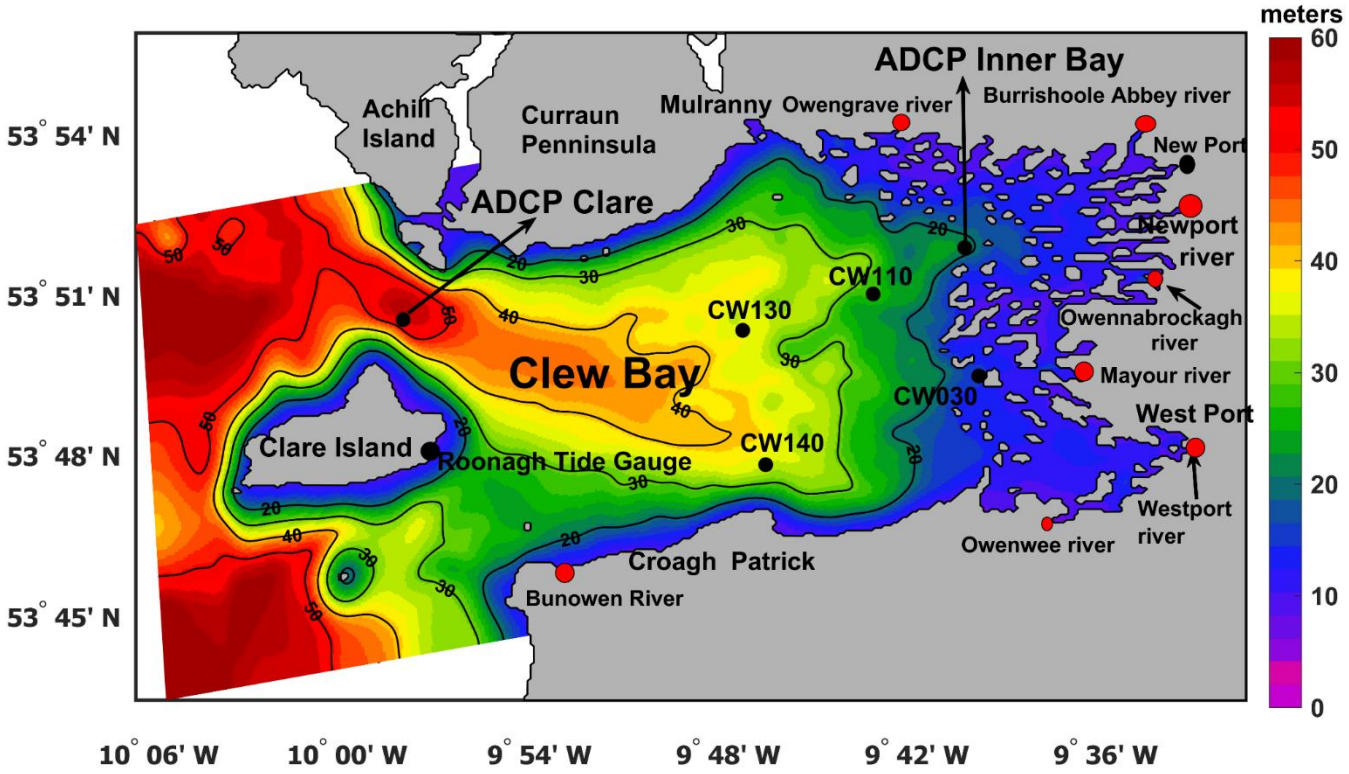
High resolution

Azores - Pico-Faial channel



Credits: Fernando Tempera

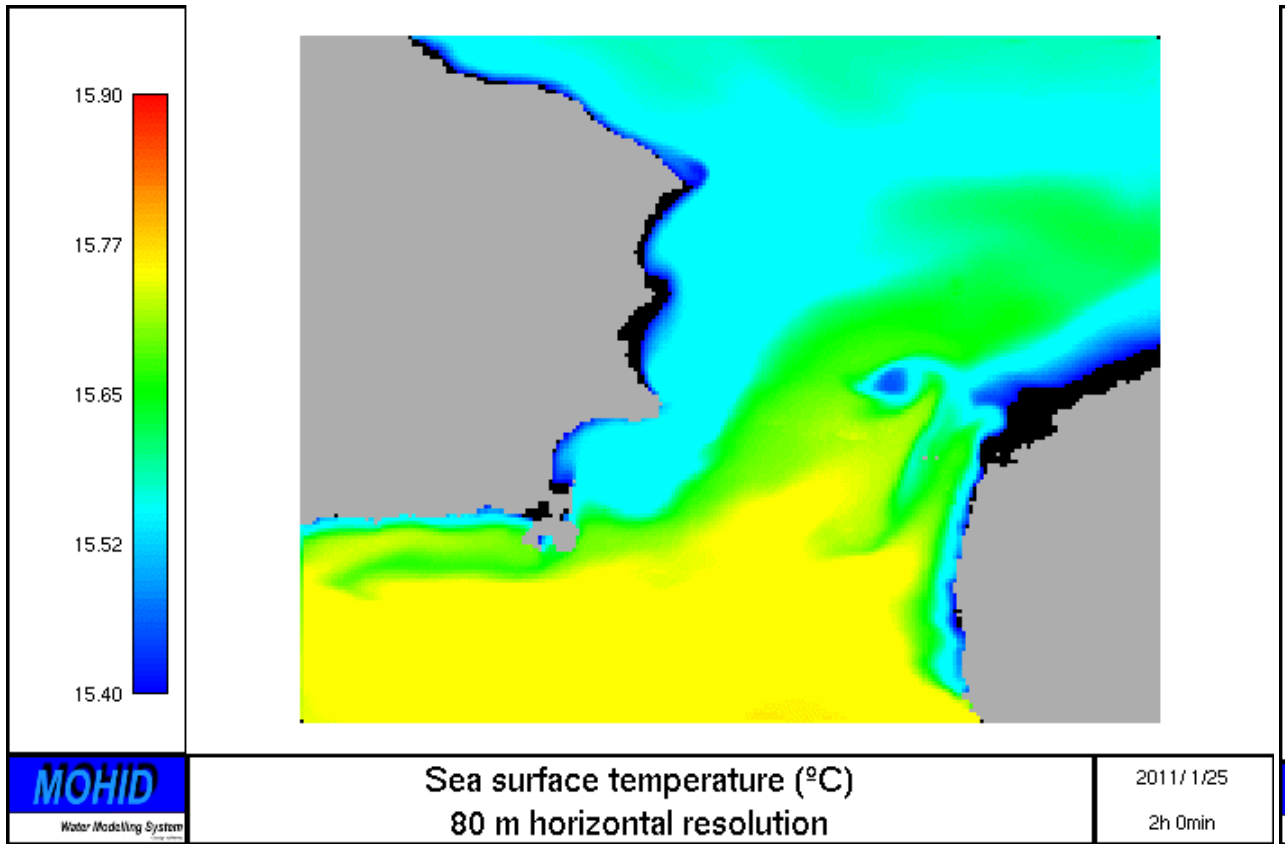
Ireland – Clew Bay

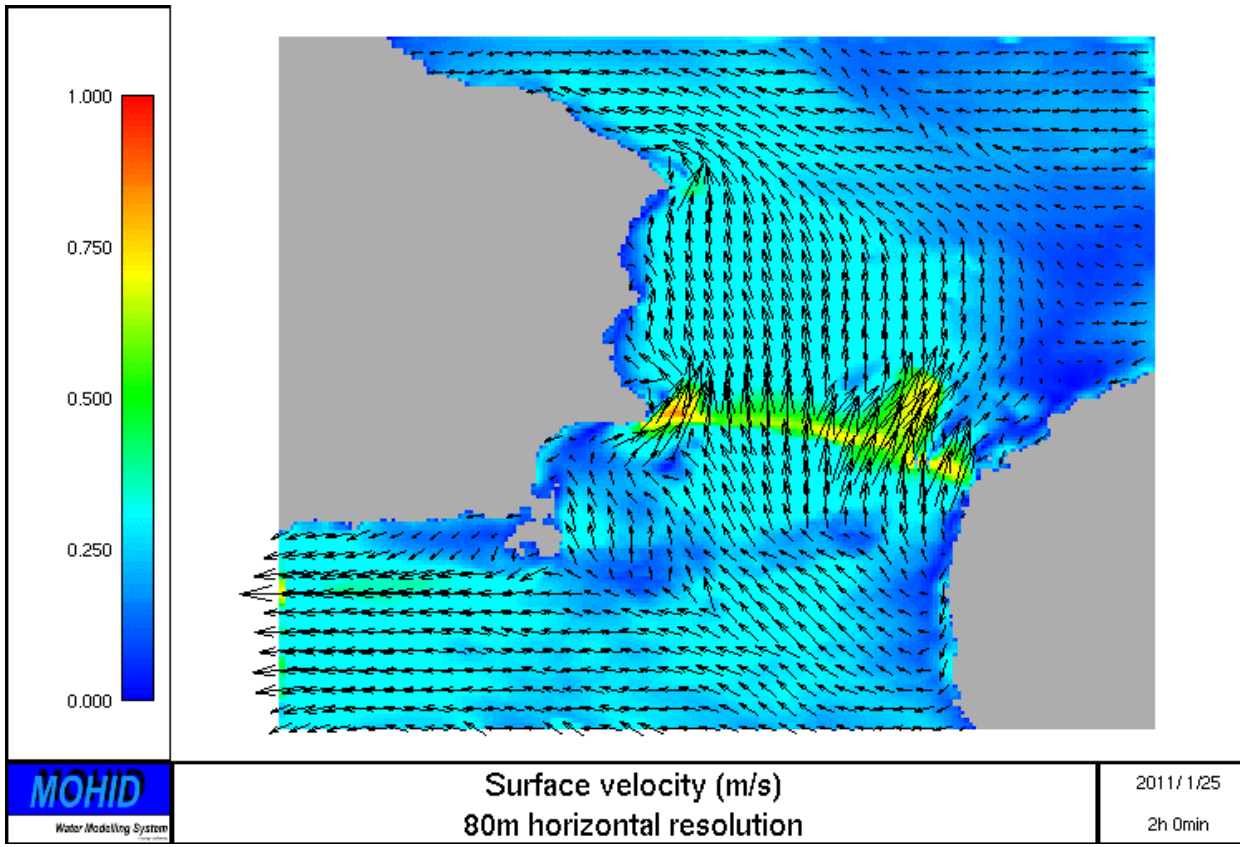


Nagy et al., 2023

High resolution

Level 5 – Pico – Faial channel – 80 m resolution





Manuela Juliano – U Azores

Improved freshwater inputs

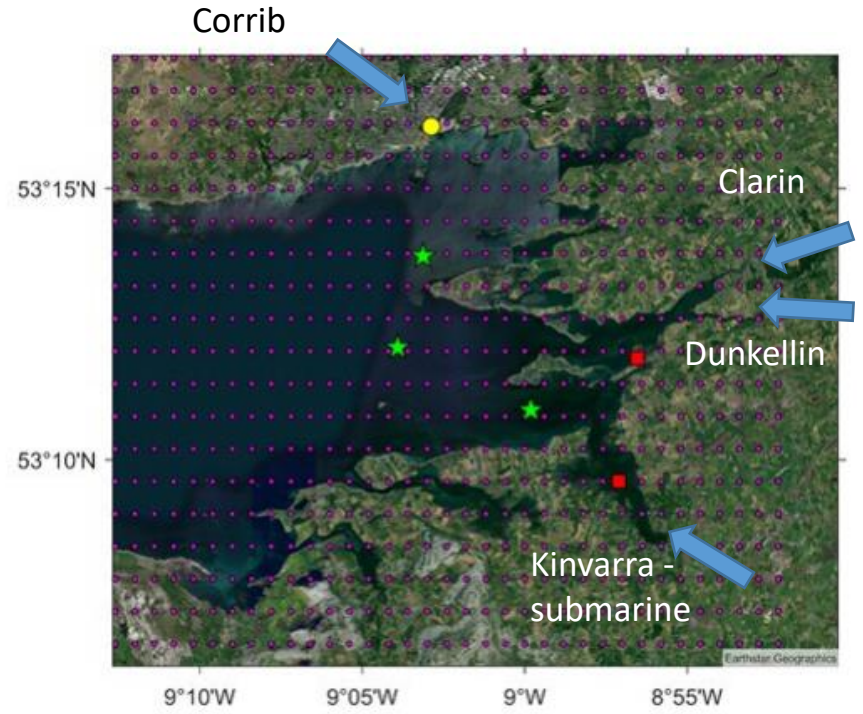
- Daily climatologies were used until recently

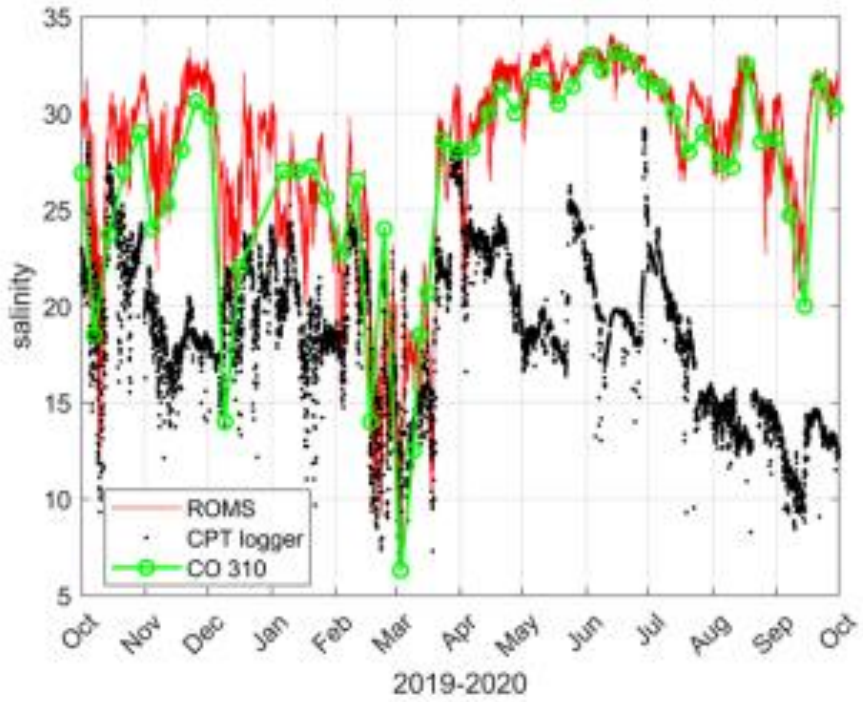
- Recent upgrades include specification of near-real-time flows for Irish rivers. Sources:
  - https://waterlevel.ie/ - flows are published there operationally. For one river we apply a rating curve to convert stage to a flow.
  - Electrical Supply Board (ESB) - provide daily/hourly hydrometric information for each of the hydro schemes managed by ESB. Published in PDF format – we read the flow from PDF

  Flows are then fixed for a duration of the forecast and updated next day.

Total LTA discharge from Irish rivers = 806.9 m3/s

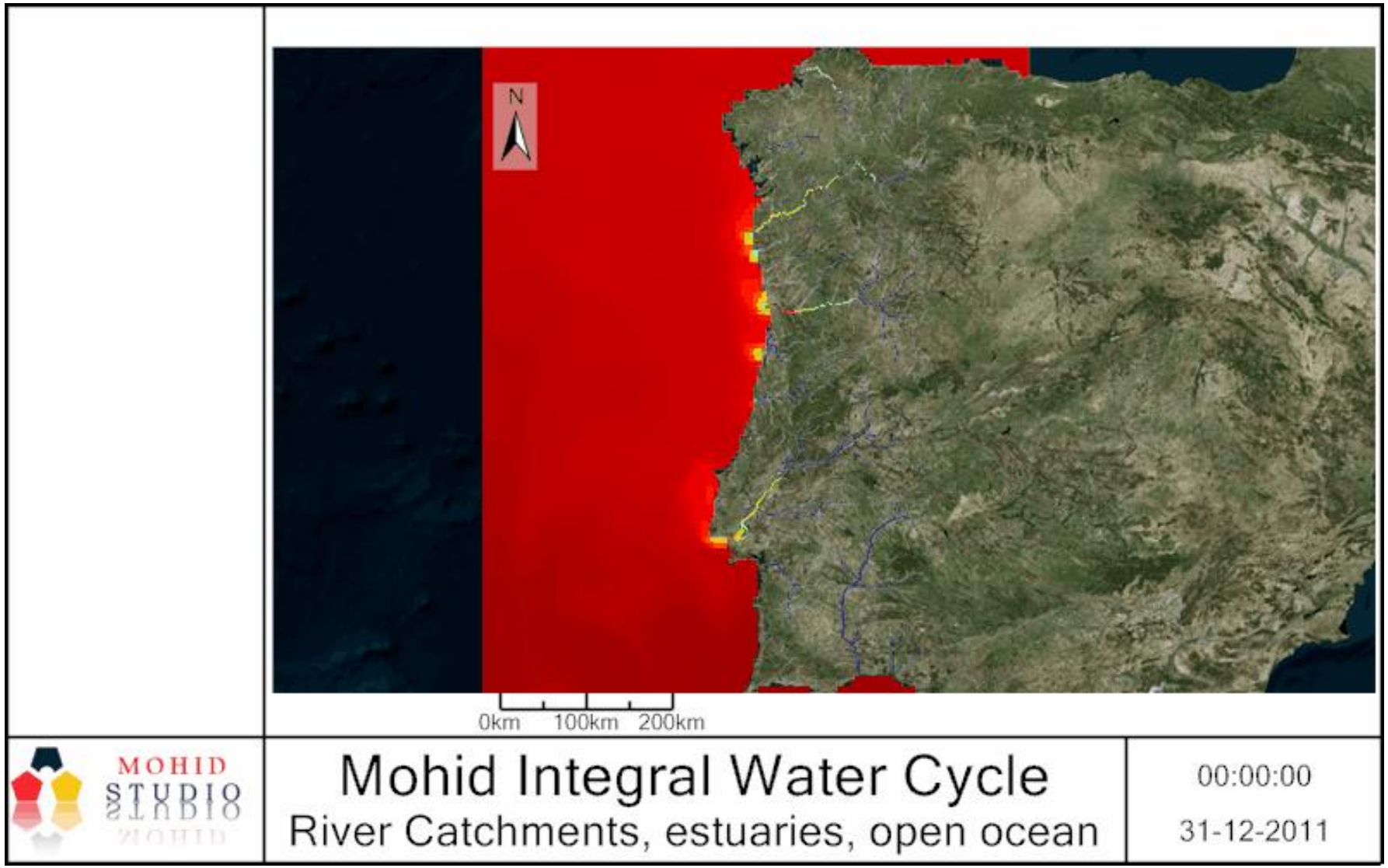
Freshwater inputs – Galway Bay





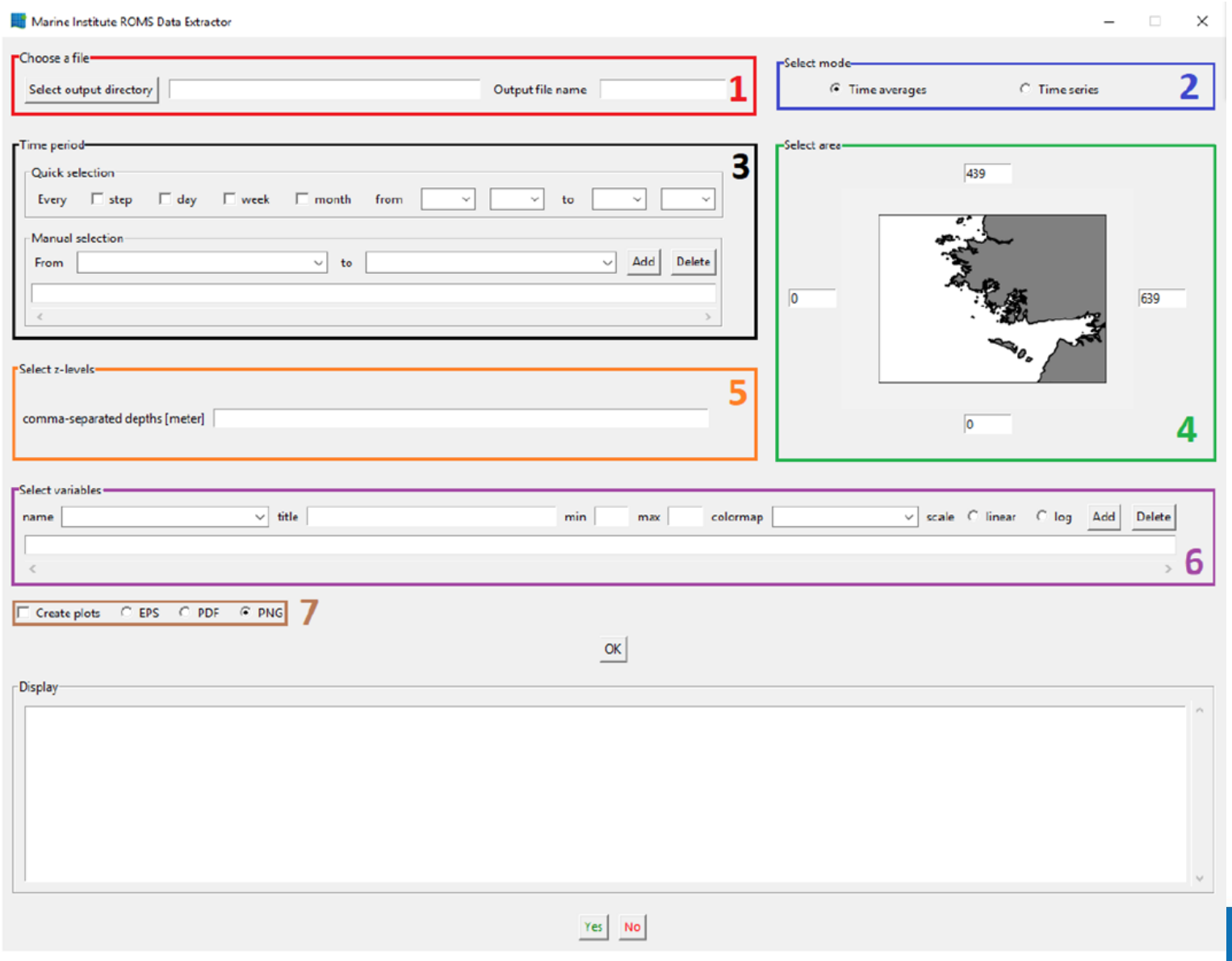
All inputs are near-real-time from the rating curves.

Integrated Ocean - Watersheds

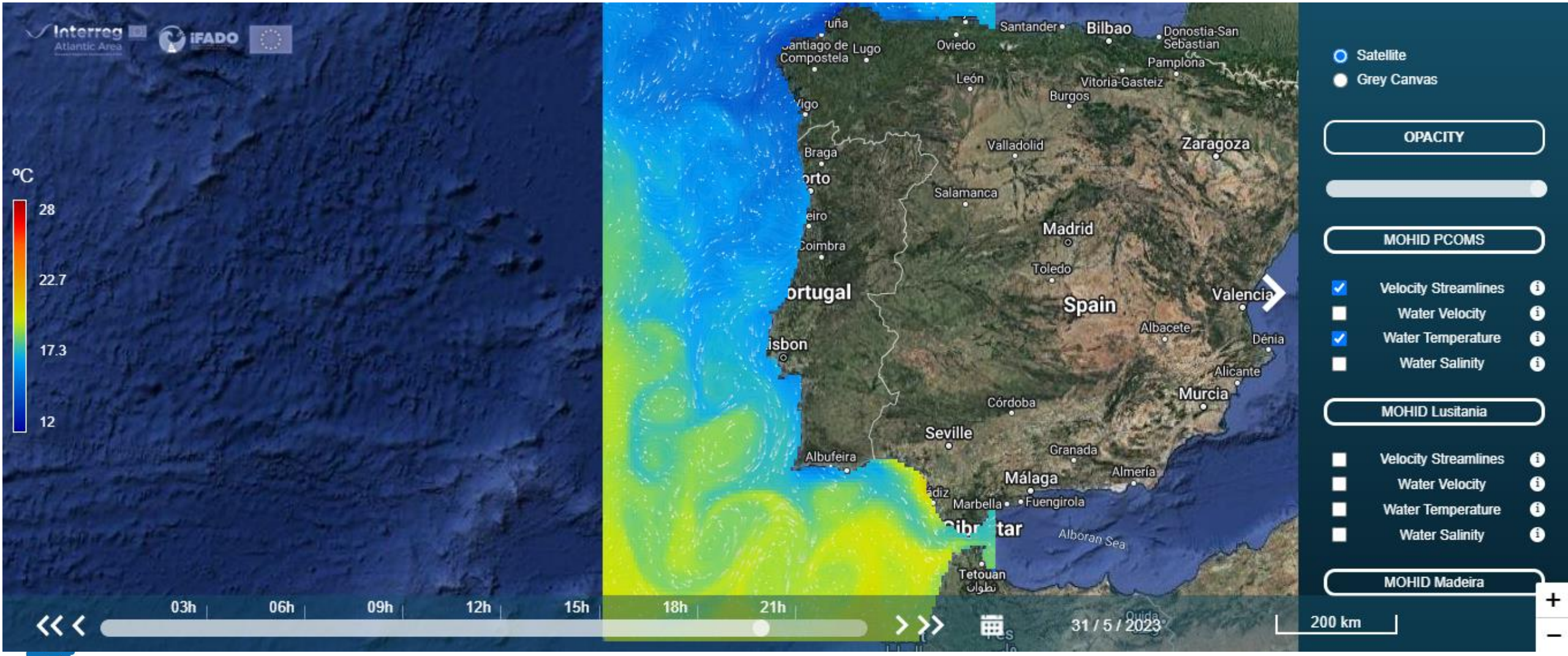


Integrated Ocean - Watersheds

Graphical User Interface (GUI) for extracting model outputs



Standardization of model outputs



Summary of achievements

- Downscaling is important as it provides more detailed products and services with higher accuracy
- Downscaled models can be used for “upscaling”, i.e. improving larger scale models accuracy in the coastal zone (presentation to follow)
- New coastal models have been developed as part of the iFADO project, e.g. Galway Bay, Clew Bay, and Connemara wet/dry, Pico-Faial,…
- New biogeochemical models were developed, e.g. CROCO-PISCES NE Atl model (developed by MI, Ireland)
- Existing models were operationalized, e.g. Lisbon and Sado Estuaries, Madeira, Azores, Galway Bay
- Model outputs were standardized. This enables ingestion of all model outputs by iFADO platform
- The models provide useful services to local stakeholders (e.g. coastal risks), support Blue Economy, support MSFD implementation, OSPAR assessments
- A Python-based Graphical User Interface (GUI) tool for computing MSFD from Regional Ocean Model (ROMS) outputs was developed

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THANK YOU!

Obrigado!

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