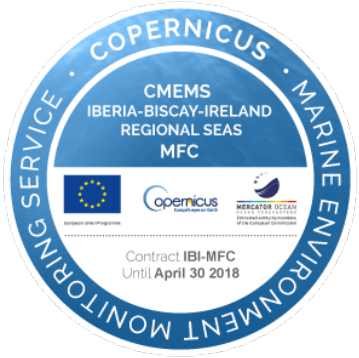
Predicting in a turbulent environment: The Iberian-Biscay-Ireland Copernicus Marine Forecasting System



ENRIQUE ALVAREZ FANJUL AND THE IBI-MFC TEAM

PUERTOS DEL ESTADO

About Puertos del Estado

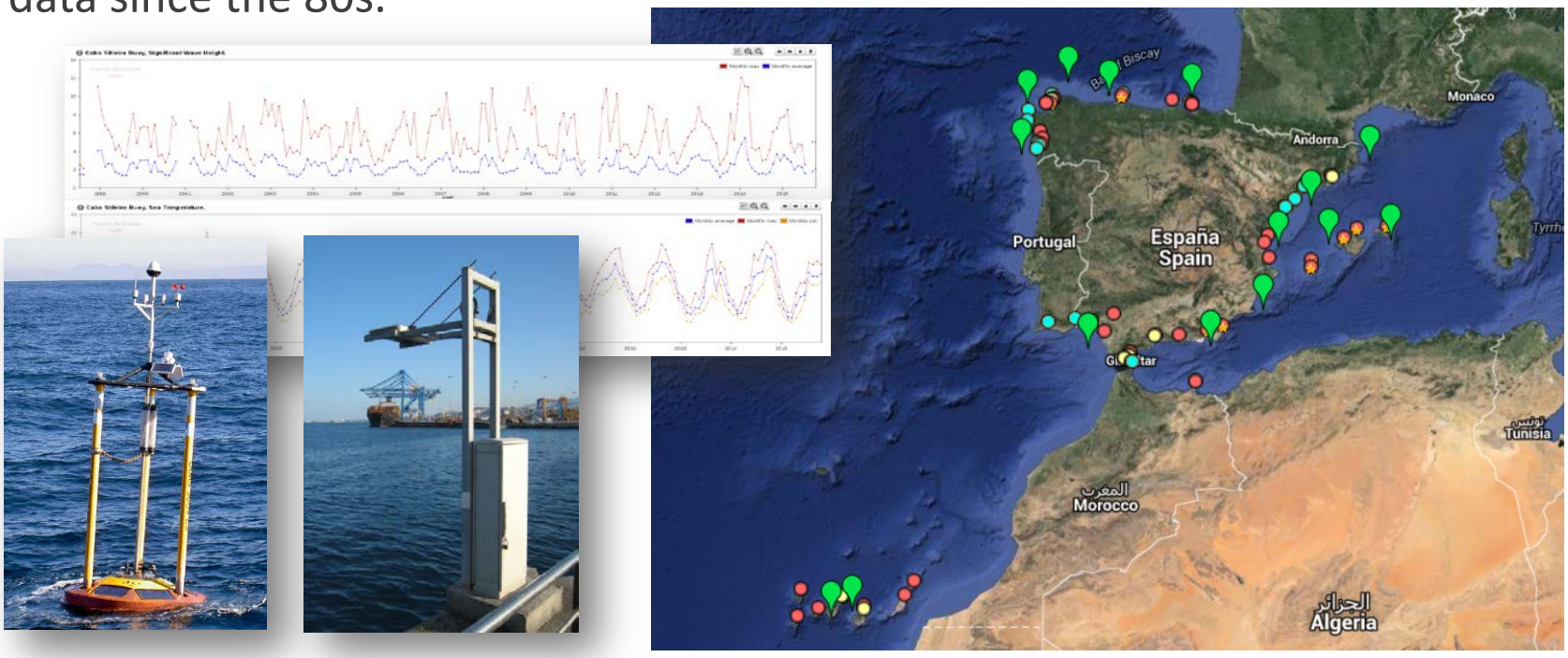
The State-owned Spanish Port System includes 46 ports of general interest, managed by 28 Port Authorities, whose coordination and efficiency control corresponds to the government agency Puertos del Estado (Ministry of Public Works)

Ports need climatic information

- Design phase
- Construction planning
- Operation projections

Puertos del Estado ocean related activities: climate observing networks

Puertos del Estado maintains and exploits a large ocean observing network: 25 Buoys, 39 tide gauges, 20 met stations, 8 HF radars with data since the 80s.



Puertos del Estado ocean related activities: climate studies

Puertos del Estado developed with AEMET and IMEDEA climate projection studies for the Spanish waters

Variables (mean and extreme):

- Waves, Sea level, SST, Currents, Salinity

Spatial resolution:

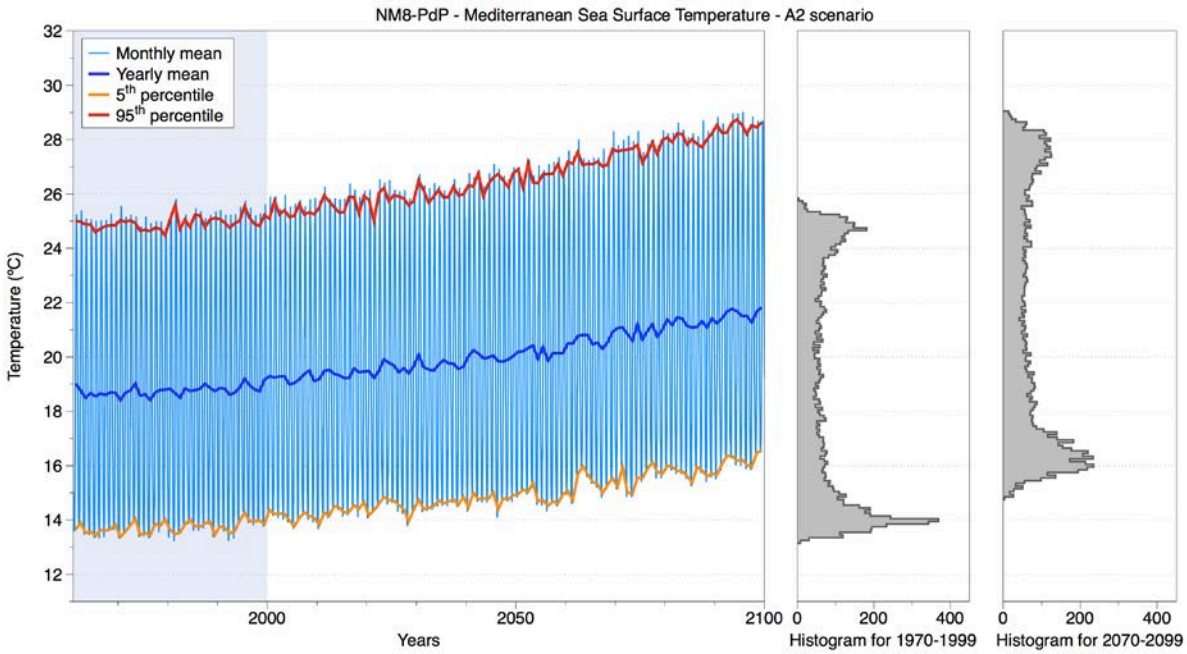
- Regional simulations

Temporal framework:

- XX and XXIcentury

Models employed

- WAM, NEMO, RCA, HAMSOM

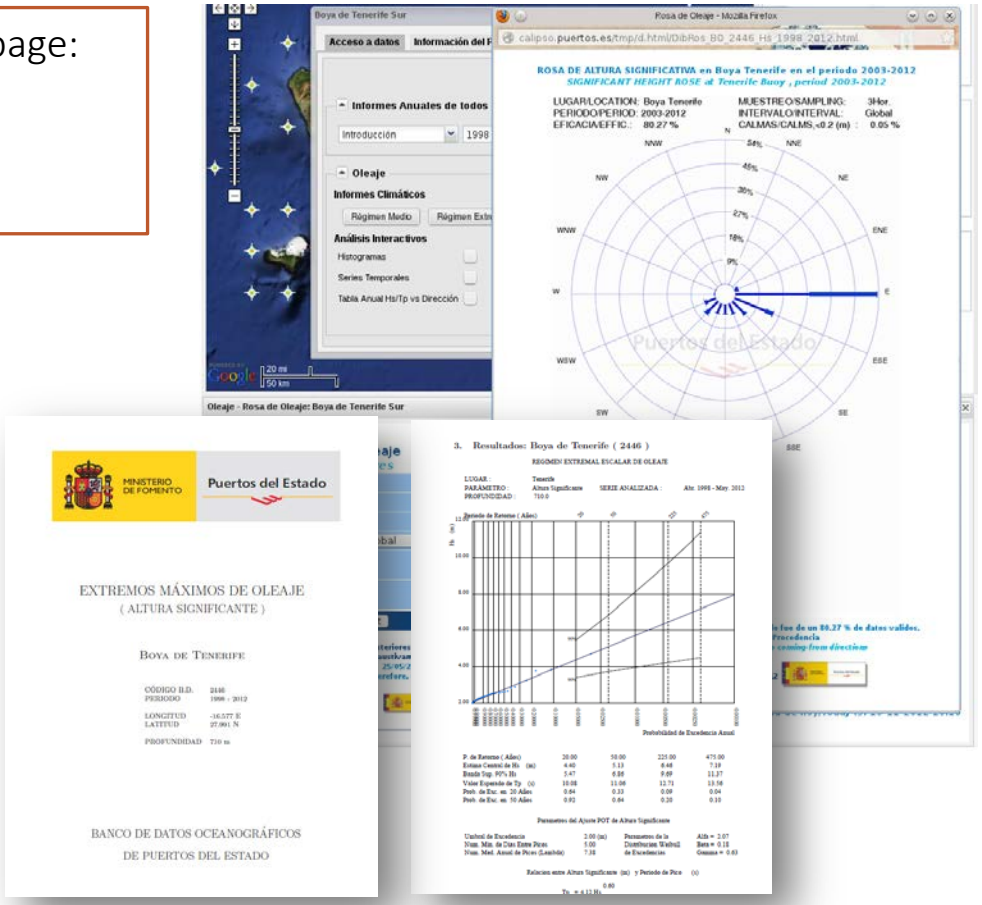


XXI century SST evolution in the Med. Sea

Puertos del Estado ocean related activities: source of climatic information

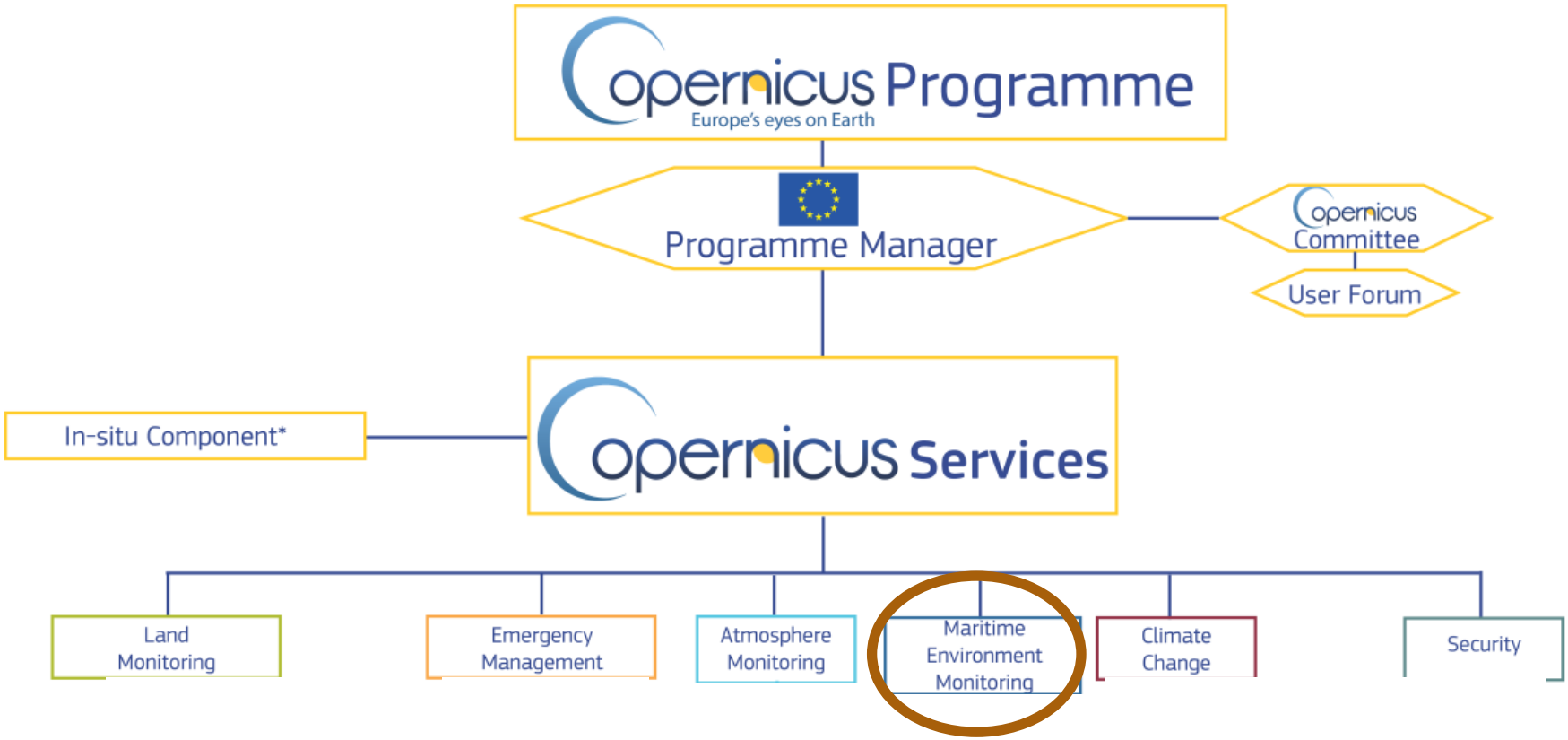
Puertos del Estado web page:
www.puertos.es

8K users daily



- ✓Information of all systems + Hindcasts converge into the database
- ✓Interactive tools to access information
- ✓All kind of reports
- ✓400 raw data requests per year for science and engineering

The Copernicus Programme: a European system for monitoring the Earth



The Marine Service (CMEMS):

The CMEMS provides regular and systematic **core reference information on the state of the physical oceans and regional seas**. The observations and forecasts produced by the service support all marine applications.

The European Union delegates to **Mercator Ocean** the role and responsibility of managing the EU budget for delivering the CMEMS on 2014-2020.

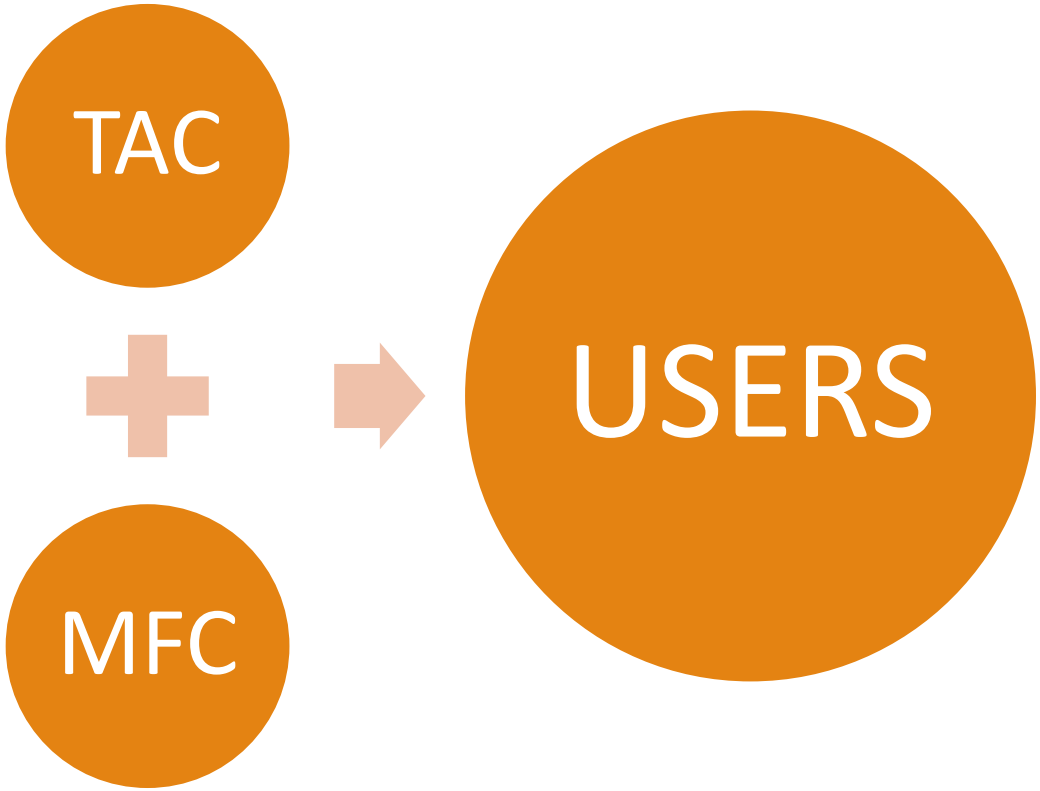
Mercator distributed CMEMS tasks via competitive open bidding. Puertos succeed in two consortiums two for IBI (Iberian-Biscay Ireland) area (data and models)

- Science
- Maritime engineering
- Environment protection
- Fisheries
- Marine energy
- Ports and transport
- Climate change
- Search and rescue
- Oil pollution fight
- Sustainable development.
- Tourism

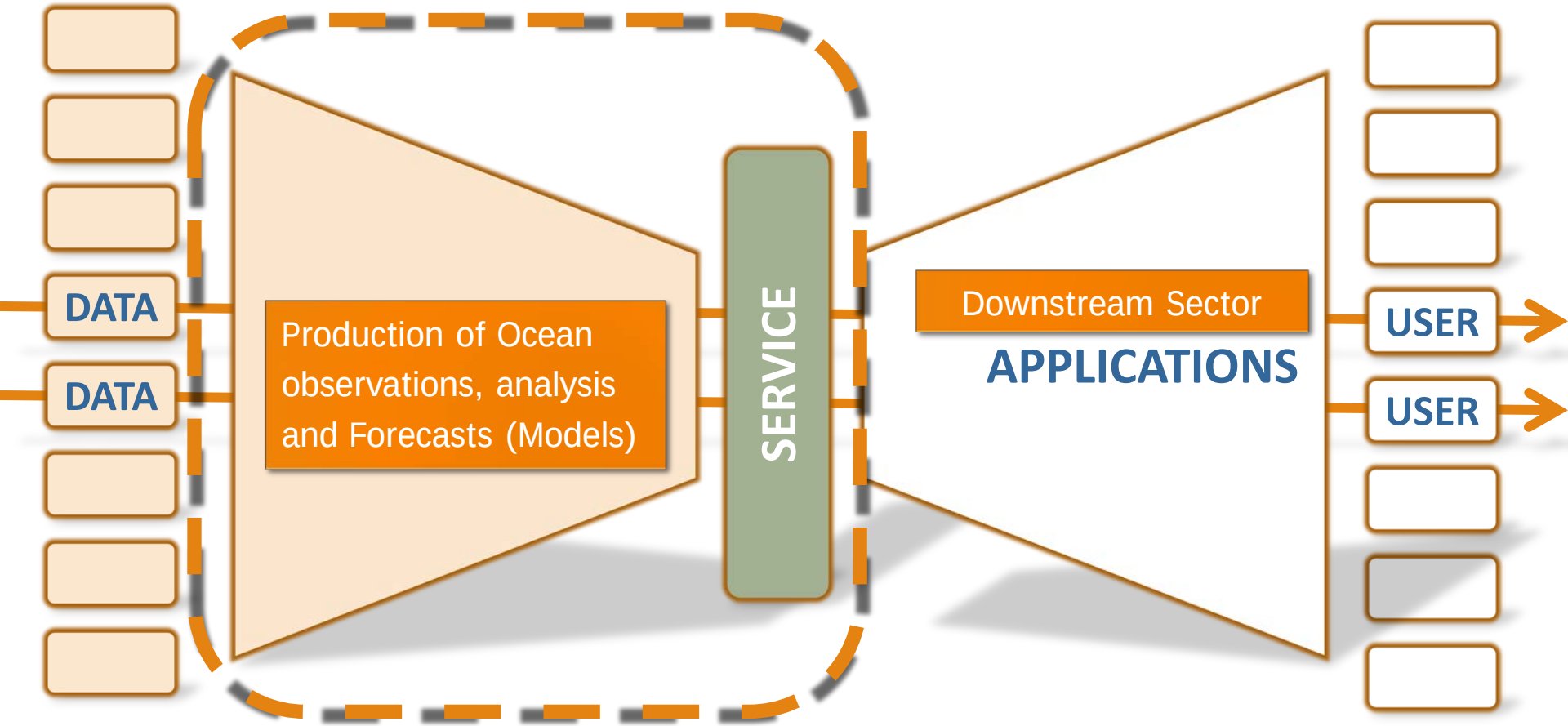
CMEMS structure: models and data

- TAC: **Thematic assembly Center**. Compiles and coordinates measurements

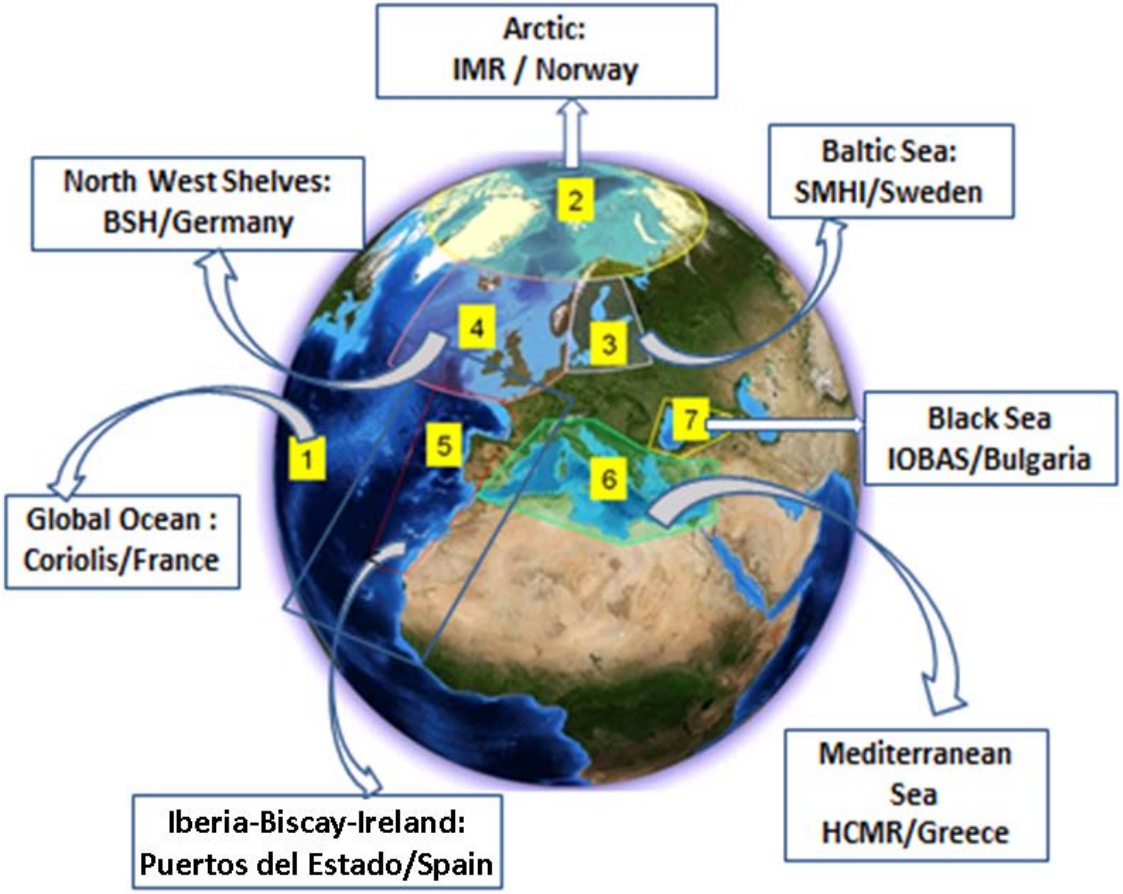
- MFC: **Marine Forecasting Center**. Forcasts of ocean state.



The Marine Service (CMEMS): A European Core service

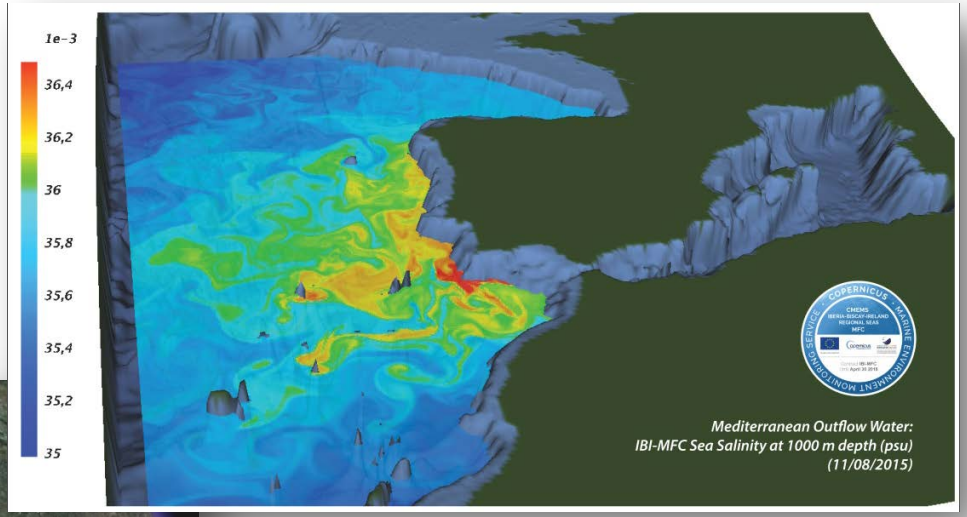


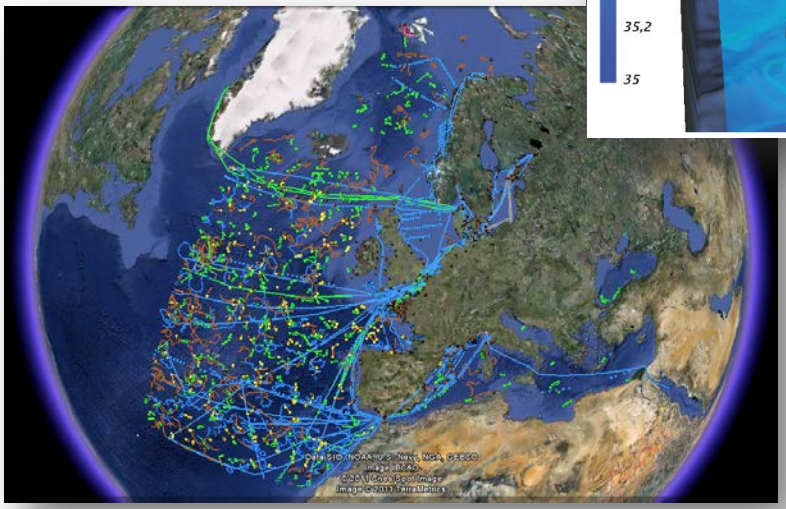
CMEMS Geographical regions



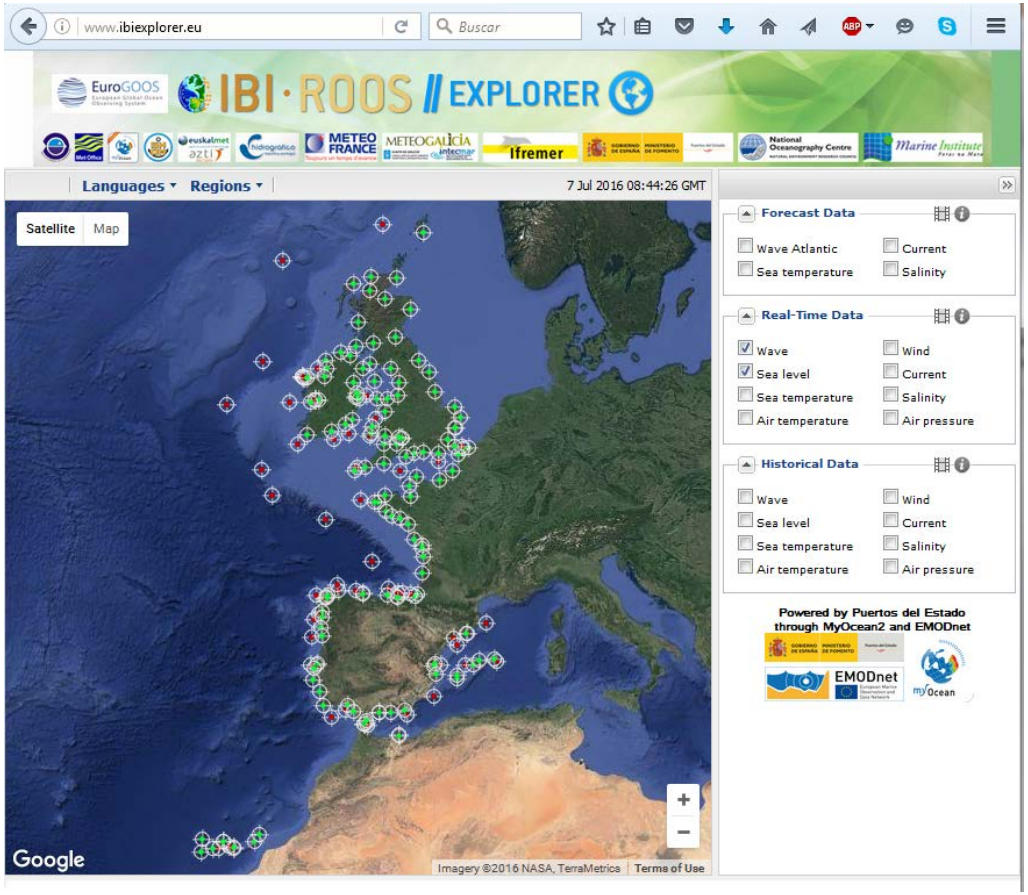
Puertos del Estado Copernicus related activities: CMEMS

Puertos del Estado operates for Mercator Ocean (entrusted entity for CMEMS) two important service elements for the IBI (Iberian-Biscay-Irish) area : the IBI-MFC component (monitoring and forecasting centre) and the IBI-in situ TAC component (thematic assembly centre for in situ data).



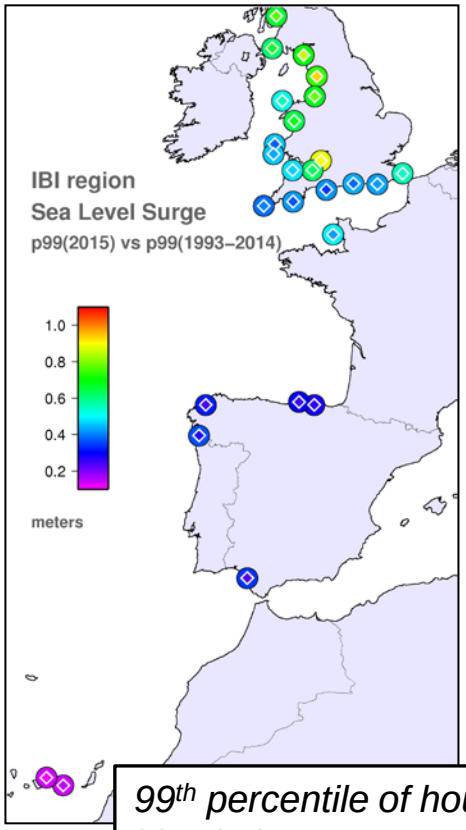


CMEMS IBI region in-situ TAC

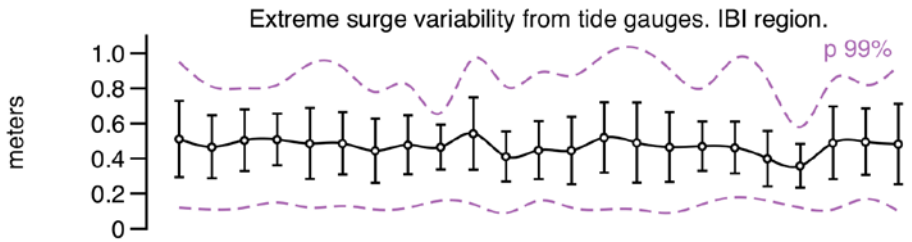


- 1124 sensors from 12 institutions integrated in real time!!!
- All data is received, quality controlled and distributed in unified format.
- Puertos is distributing the data by means of the IBIROOS-explorer and other more technical methods

In-situ TAC: a data set for science and operations



99th percentile of hourly storm surge:
big circles: mean value at each station period 1993-2014,
inner smaller diamonds: 99th percentile for 2015



Evolution of the 99th (top) annual percentile levels of hourly surge data averaged for all the stations in the IBI region: black lines: averaged value and standard deviation for each year; magenta lines: maximum and minimum values in the whole region for each year.

IBI-MFC: description of the products

This talk

Forecast (available)

Reanalysis (available)

Circulation

BioGeochemical

Forecast (2017)

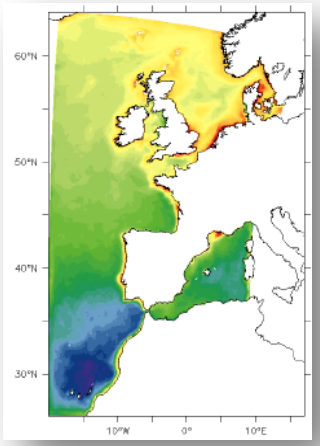
Reanalysis (available)

Forecast (2017)

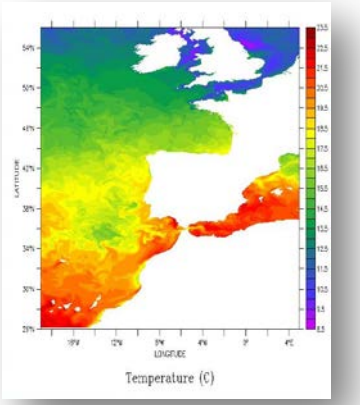
Reanalysis (2018)

Waves

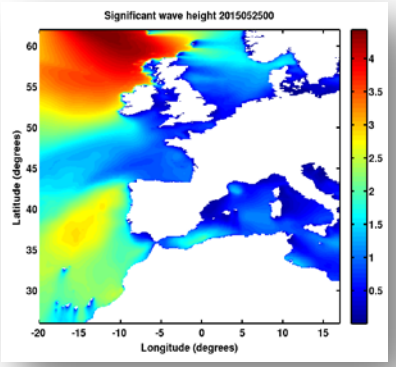
Pisces model



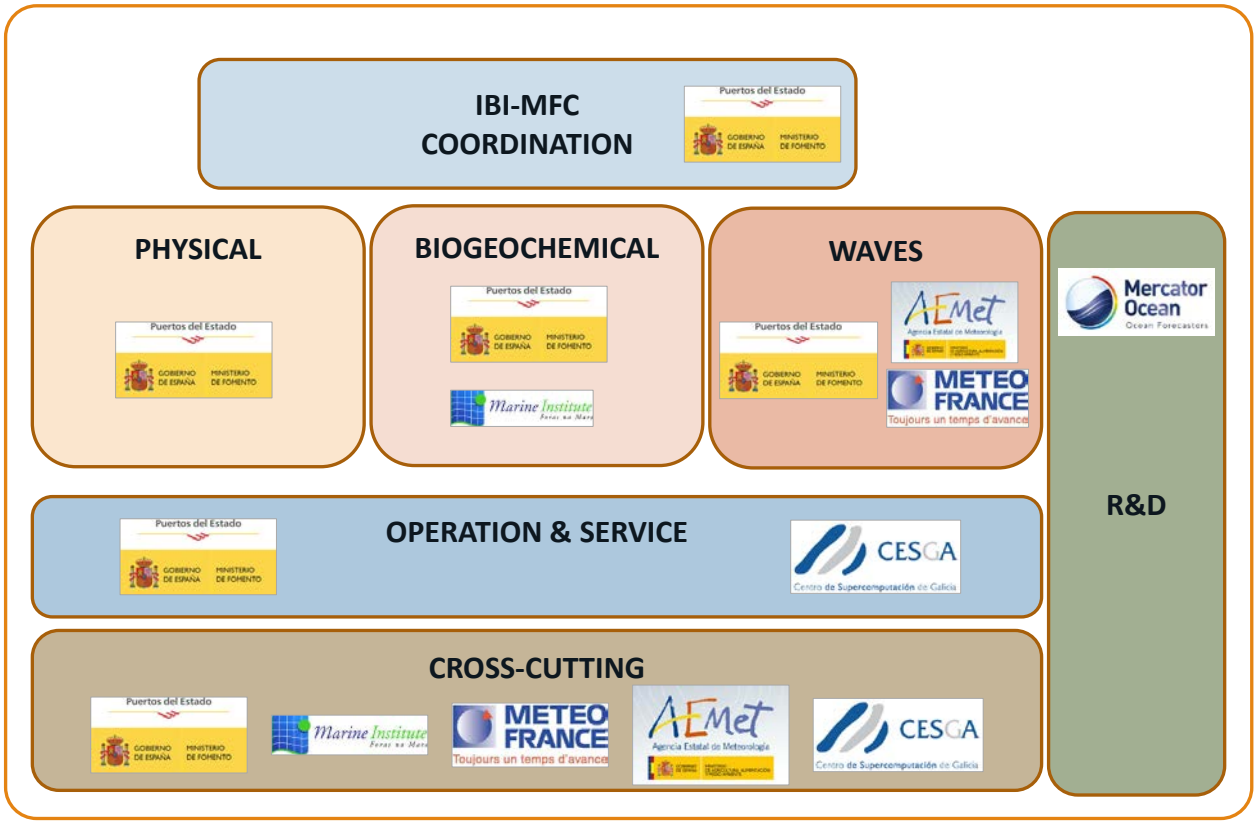
NEMO model



WAM model



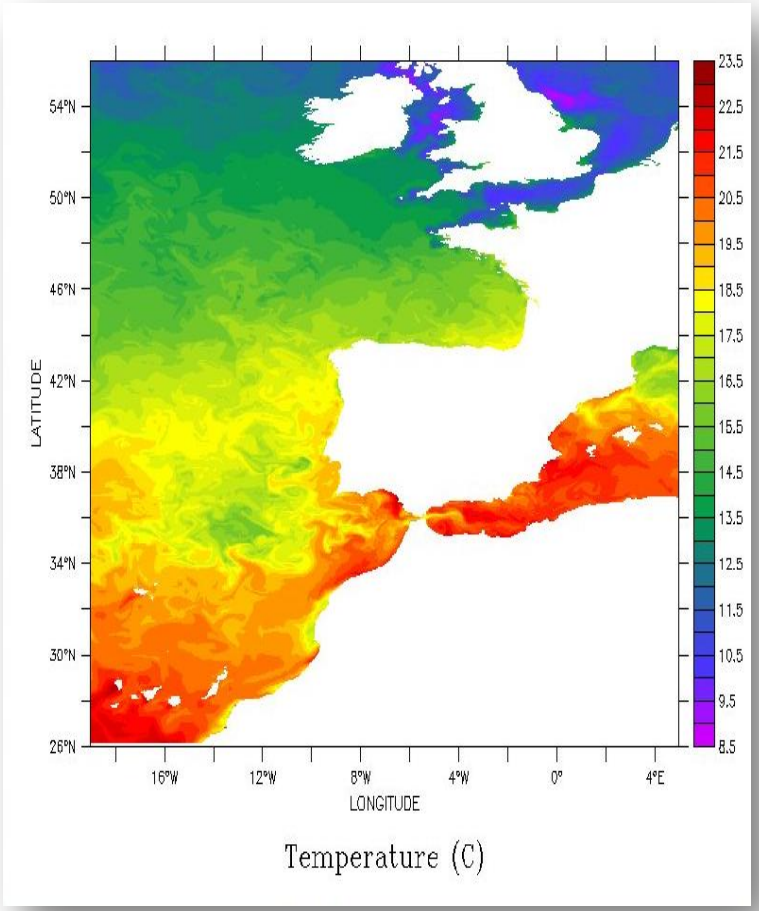
The IBI-MFC Team and structure



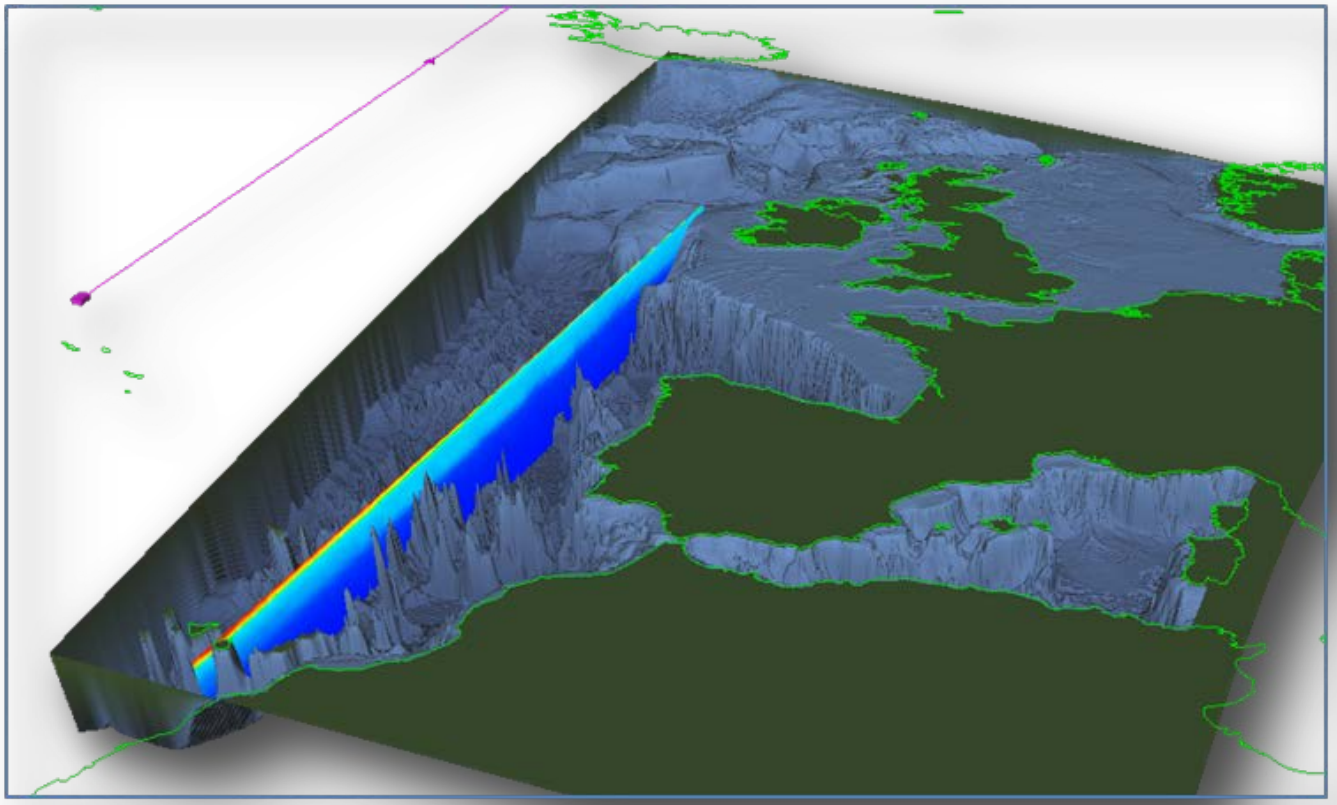
More than 30 experts in the IBI Team

IBI-MFC: description of the model

- 3D baroclinic NEMO model
  - Tides
  - ECMWF atmospheric forcing
  - Nested in Copernicus Global model
  - River discharge
- Daily forecast; 5 days forecast horizon
- 3 Km resolution; 75 levels
- 103 millions of points (1000 cores at CESGA)
- Spectral nudging to include data assimilation
- K-epsilon turbulence scheme



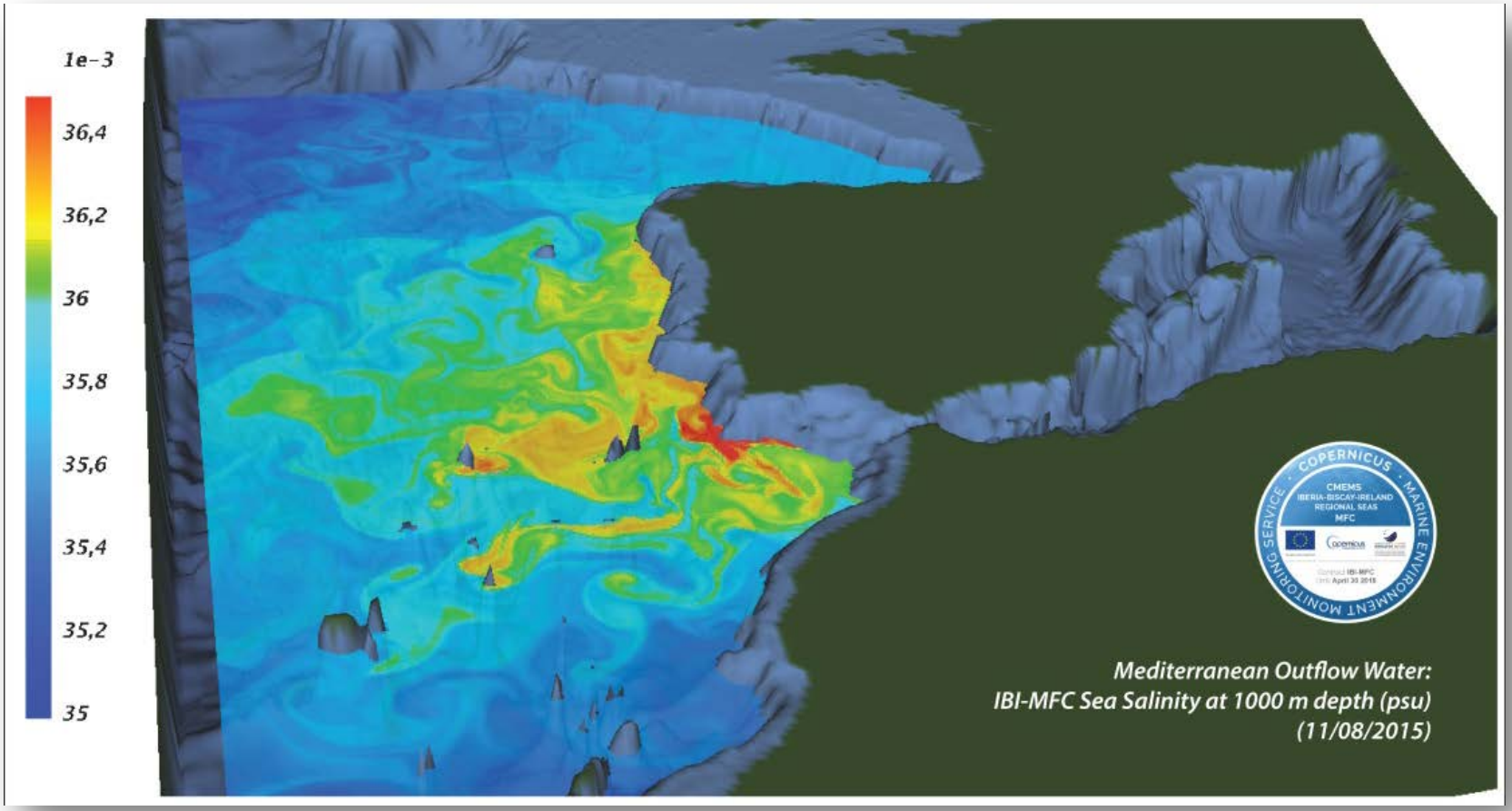
The IBI-MFC 3D domain



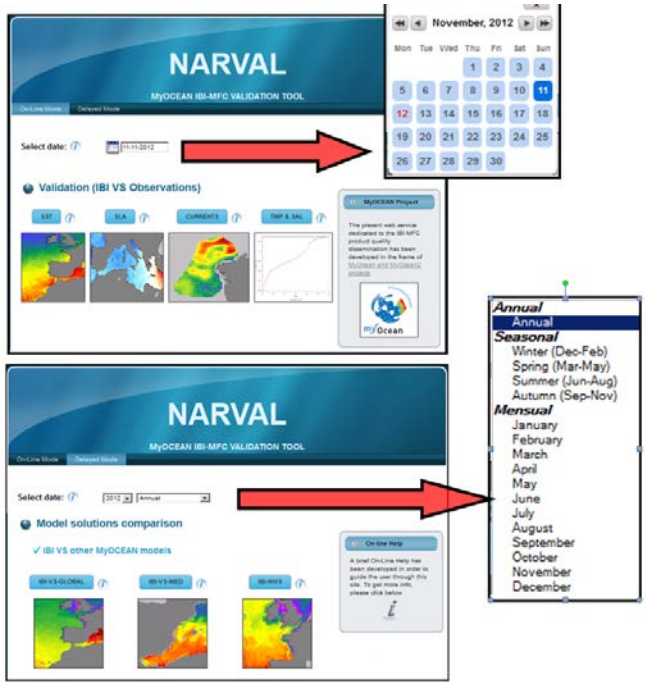
The IBI-MFC model output

The IBI-MFC tides and SSH

The IBI-MFC Physical processes: Spreading of Mediterranean water

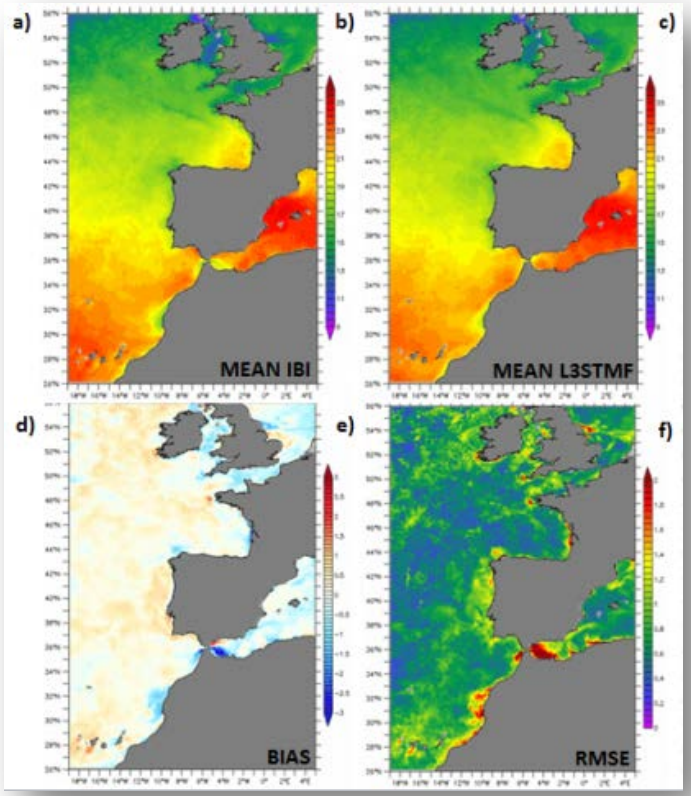


Real time validation of the model: Narval tool (North Atlantic Regional VALidation)

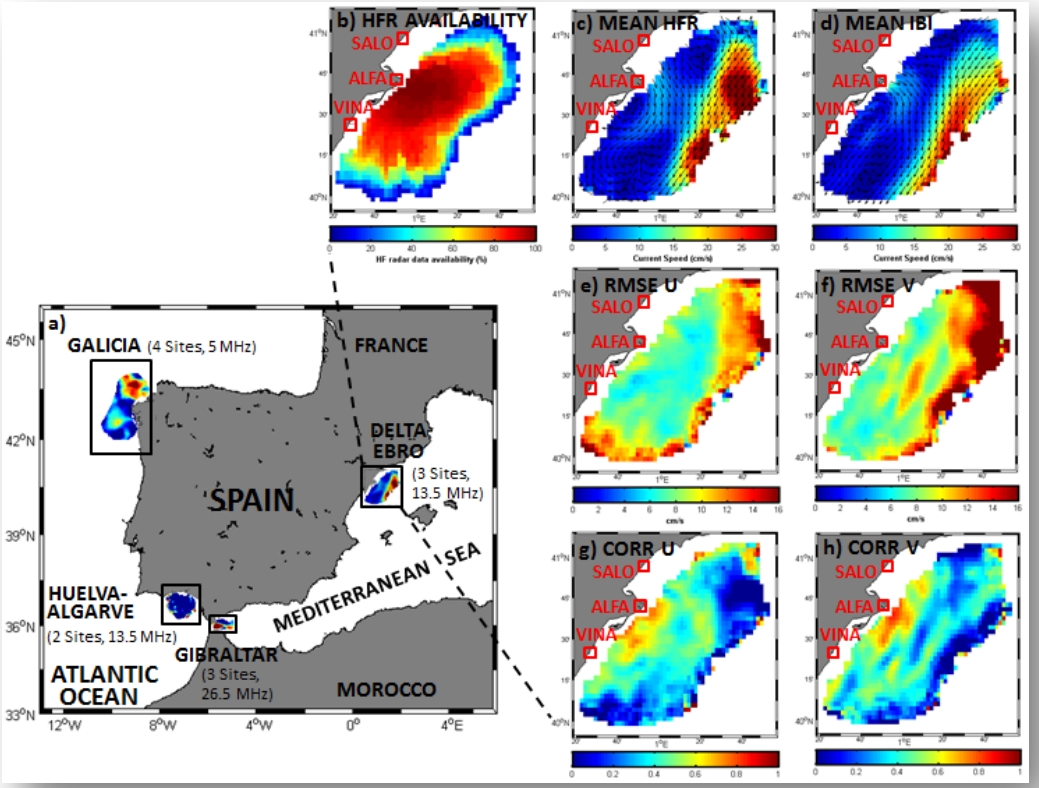


Comparison with...	Depth	Variable	Area	Source(s)
Observations	Surface	Temperature	IBISR + **REG**	L3STMF OSTIA(L4)
		Salinity	IBISR	SMOS
		Currents	GALICIA	HF RADARS
			GIBRALTAR	
			DELTA EBRO	
			HUELVA-ALGARVE	
	Levels (m) 0-5 5-200 200-600 600-1500	Temperature	IBISR + **REG**	ARGO FLOATS
		Salinity		
Other MyO Forecasting Services	Surface	Temperature	Overlapped areas + **REG**	MED NWS GLOBAL
		Salinity		
		Currents		

Real time validation of the model: Narval tool (North Atlantic Regional VALidation)



Vs. Satellite

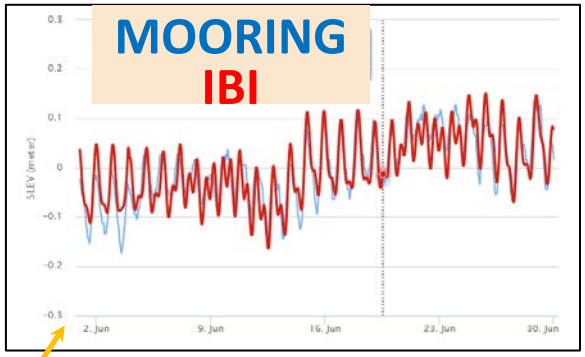


Vs. HF radar

Real time validation of the model: Narval tool (North Atlantic Regional VALidation)

Link with in-situ TAC

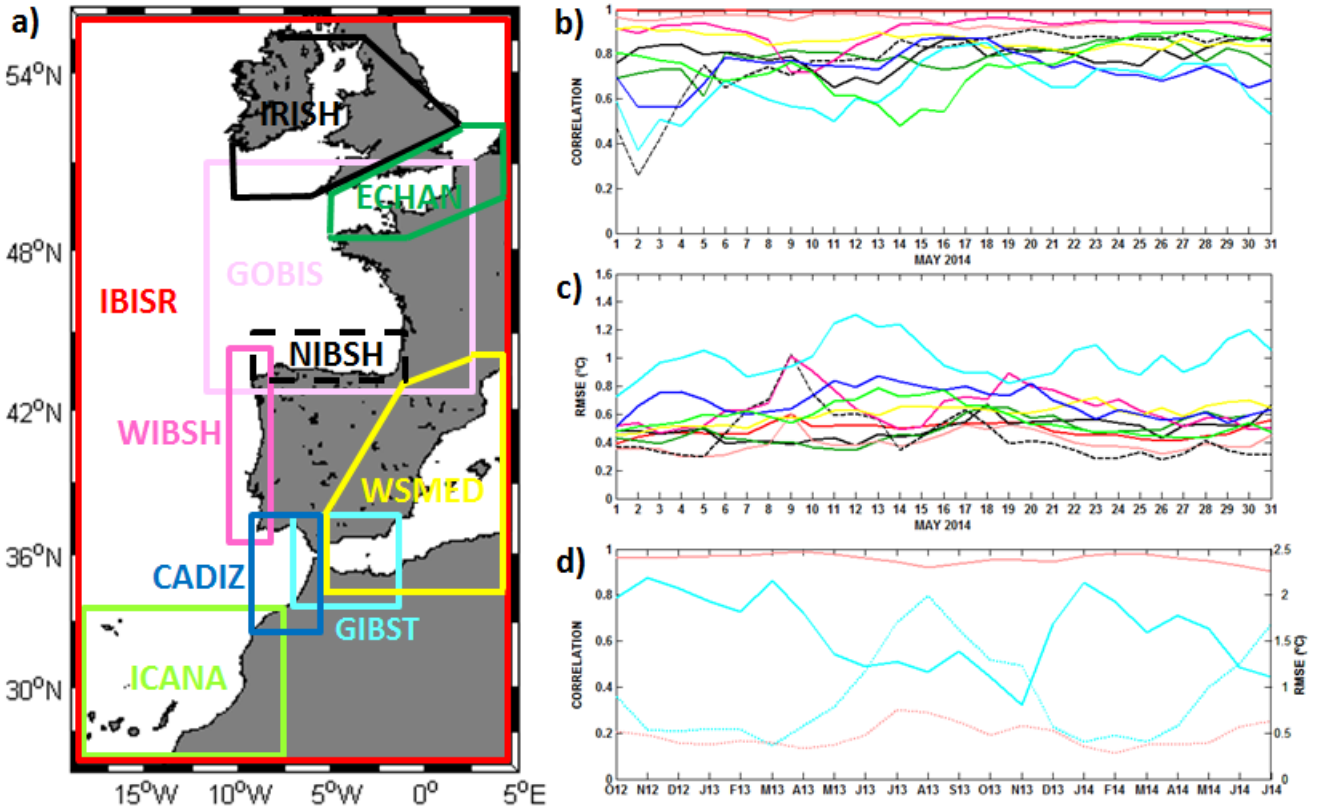
Select Date:



FORMENTERA: JUNE 2014

METRICS:
N = 697 hourly data
RMSE = 3.38 cm
Correlation = 0.88

Real time validation of the model: Narval tool (North Atlantic Regional VALidation)



*(a) IBI spatial coverage domain split into **sub-regions***

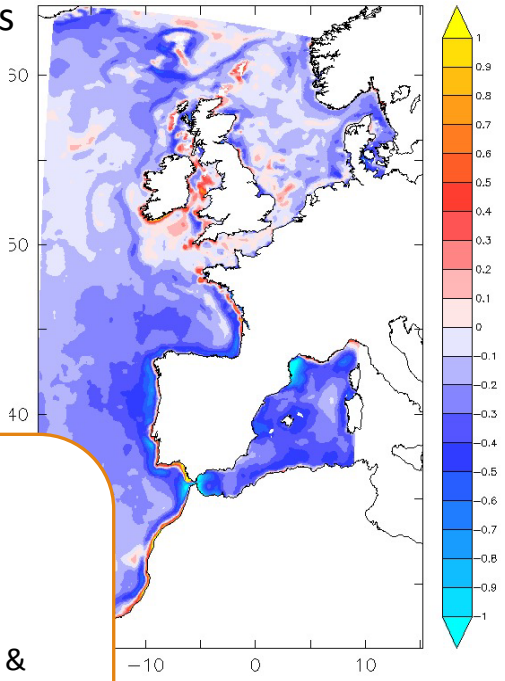
***(b-c) SST comparison between IBI and OSTIA** satellite-derived product: daily evolution of spatial correlation and RMSE, respectively, during **May 2014** for each IBI sub-region*

***(d)** Evolution of monthly metrics during the period **October 2012 – July 2014** for the **Strait of Gibraltar** (**GIBST**, cyan line) and **Gulf of Biscay** (GOBIS, light pink line). Averaged time correlation and RMSE are denoted by solid and dotted lines, respectively.*

Reanalysis of circulation, including data assimilation (2002-2014)

- Nemo Model 1/12 degrees over same domain
- Initial conditions from CMEMS Global reanalysis 3D outputs.
- Atmospheric forcing from ERA-INTERIM
- Open boundary conditions: Temperature, salinity, velocities and SSH from CMEMS Global reanalysis.
- 33 rivers freshwater discharge
- 11 tidal harmonics (M2, S2, N2, K1, O1, Q1, M4, K2, P1, Mf, Mm).
- Vertical mixing: K-ε mod

Mean SST differences AVHRR-IBI SST data . 2002-2014 averages.

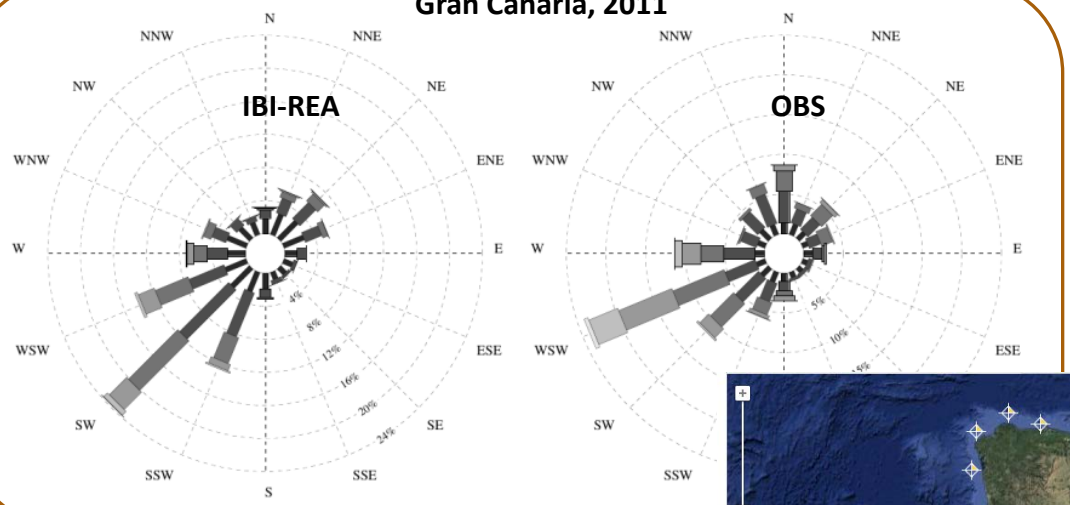


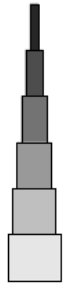
Data assimilation:

- SEEK (Kalman filter).
  - T, S from Argo floats.
  - SST from multisatellite & AVHRR.
  - SLA from radar altimeter (JASON, ENVISAT, TOPEX, GFO, ERS).

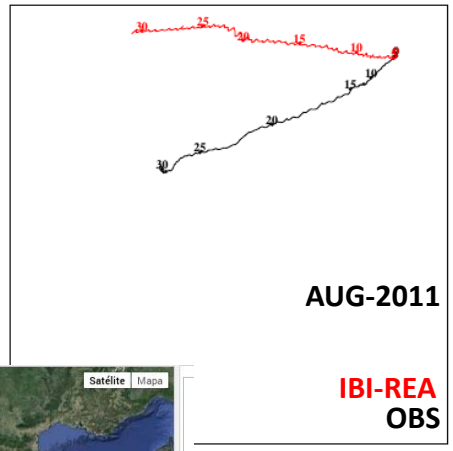
Validation of reanalysis: moorings current

Gran Canaria, 2011



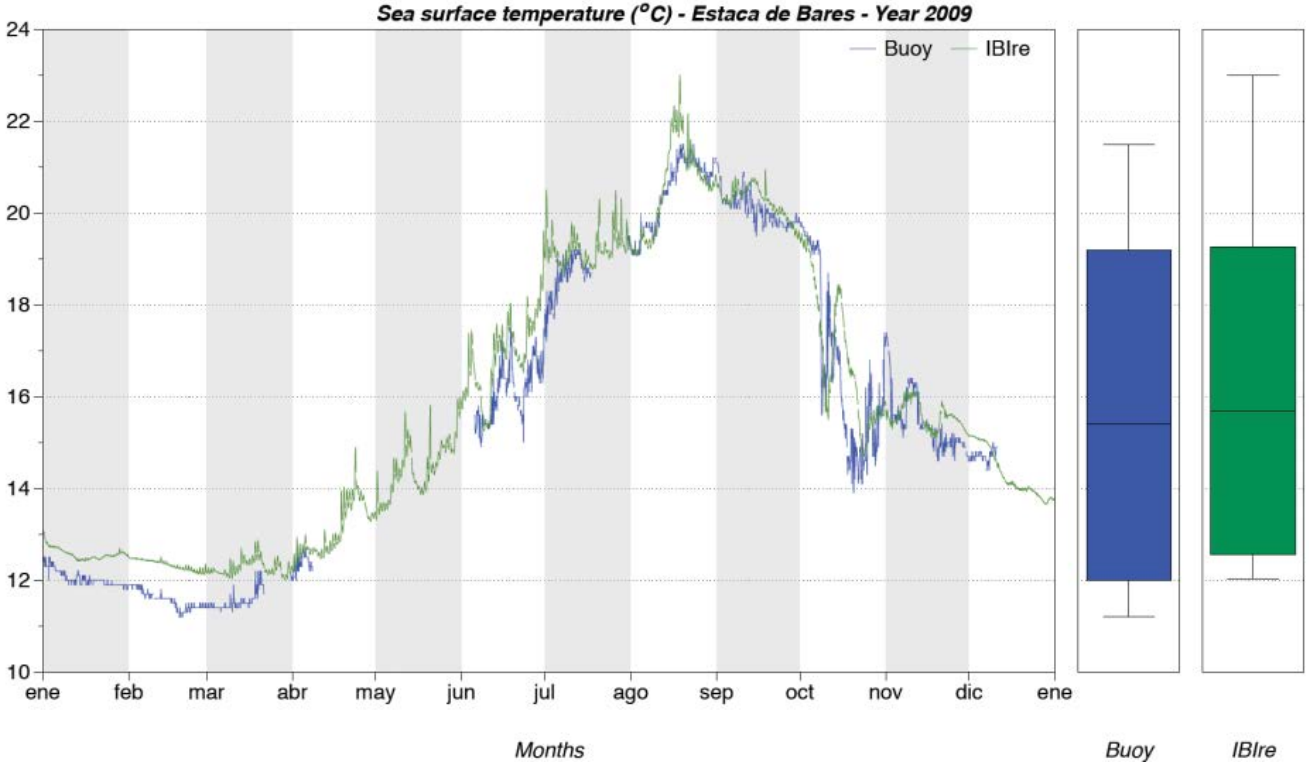


00 - 10
10 - 20
20 - 30
30 - 40
40 - 50
> 50

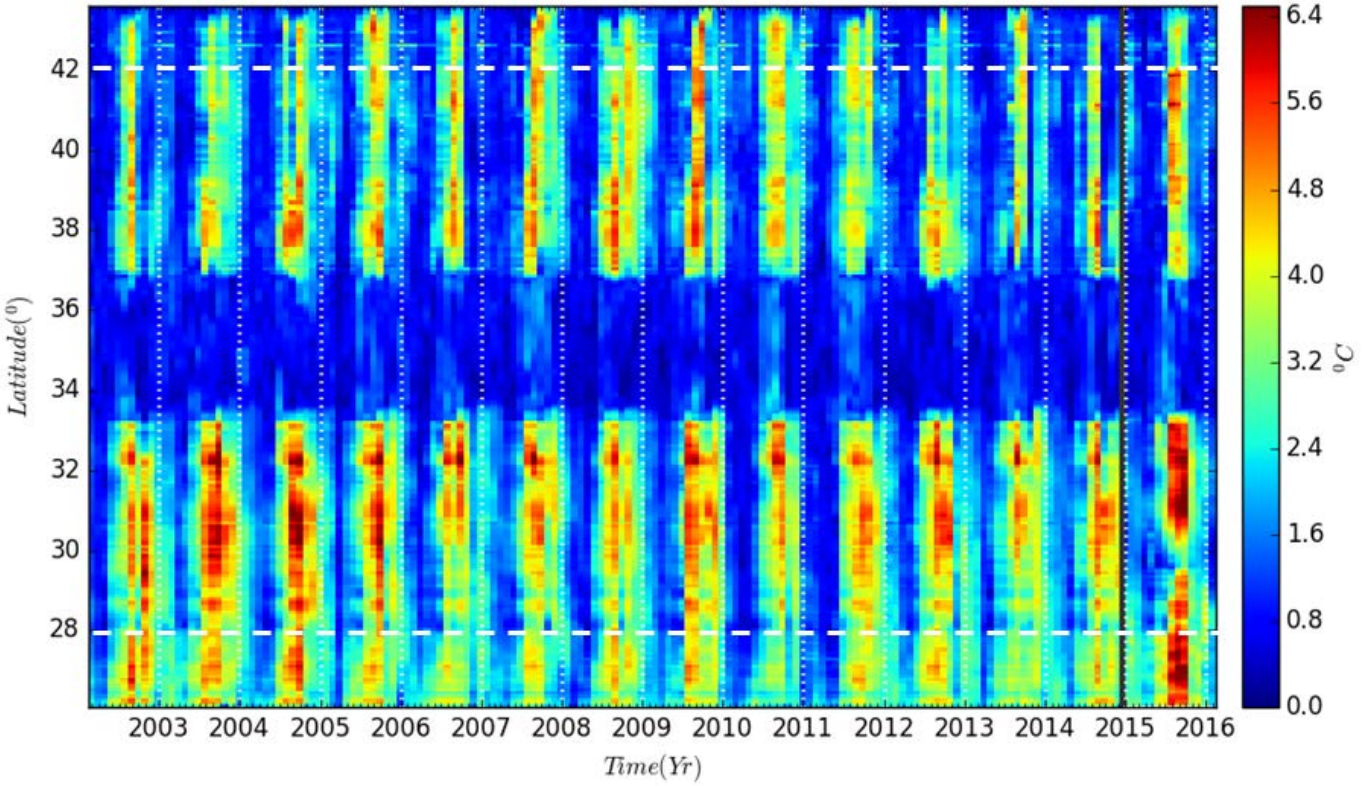


Progressive Vectors

Validation of reanalysis: moorings SST



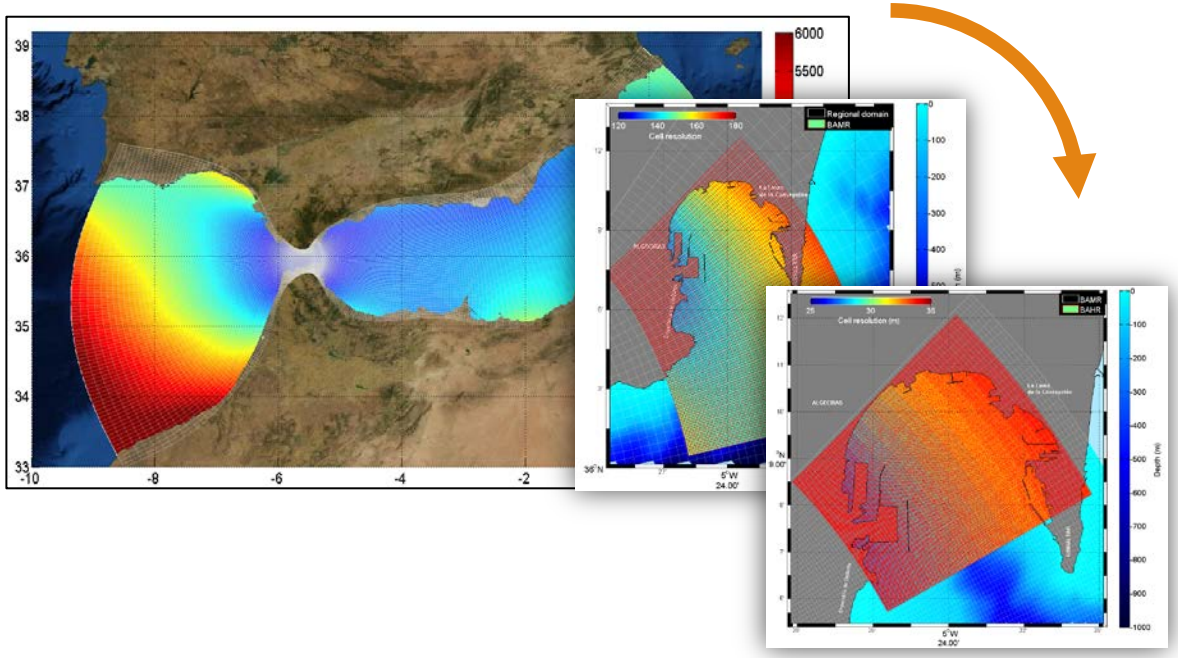
A data set for science: Upwelling index

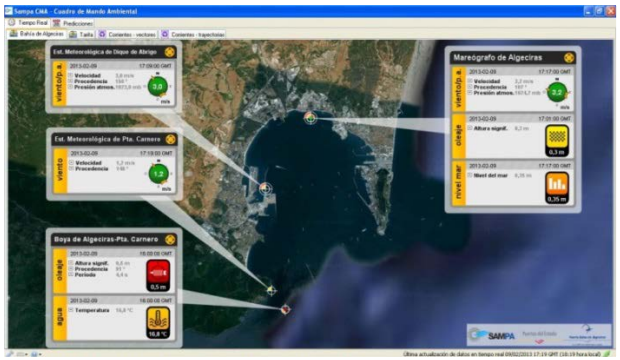


Upwelling indexes computed visa SST

Downstreaming IBI-MFC: SAMPA and SAMPA 2 projects

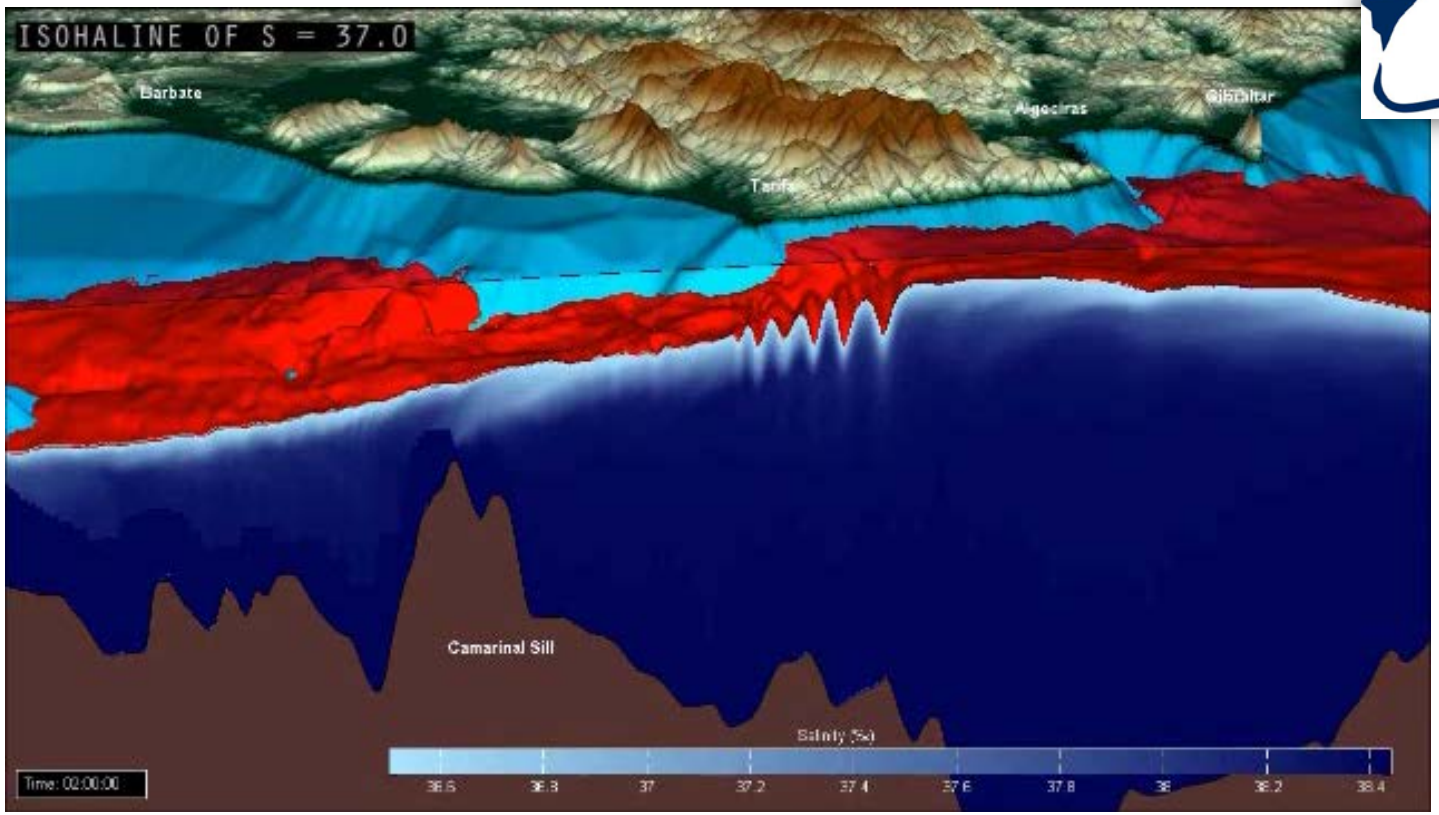
- MitCGM nested (3 levels down to 30 m) in IBI-MFC to provide service to the Algeciras Port
- MITGCM Model developed by UM. Operated at Puertos del Estado





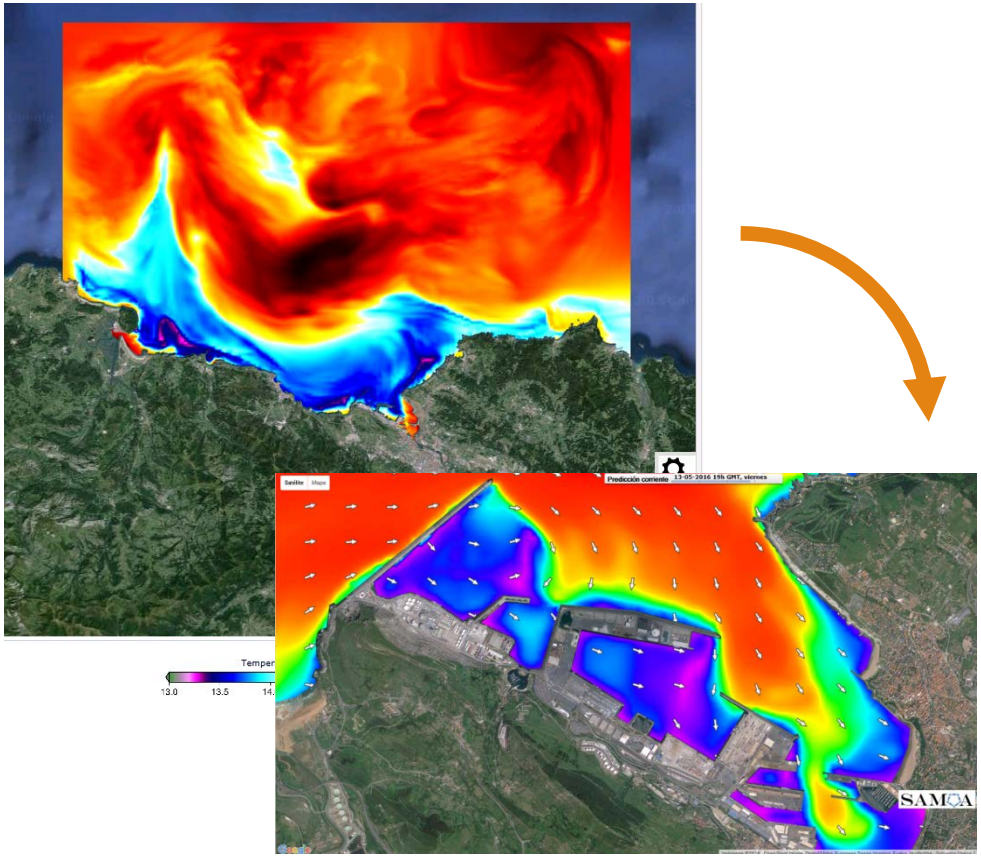
Downstream tools

Downstreaming IBI-MFC: SAMPA and SAMPA 2 projects

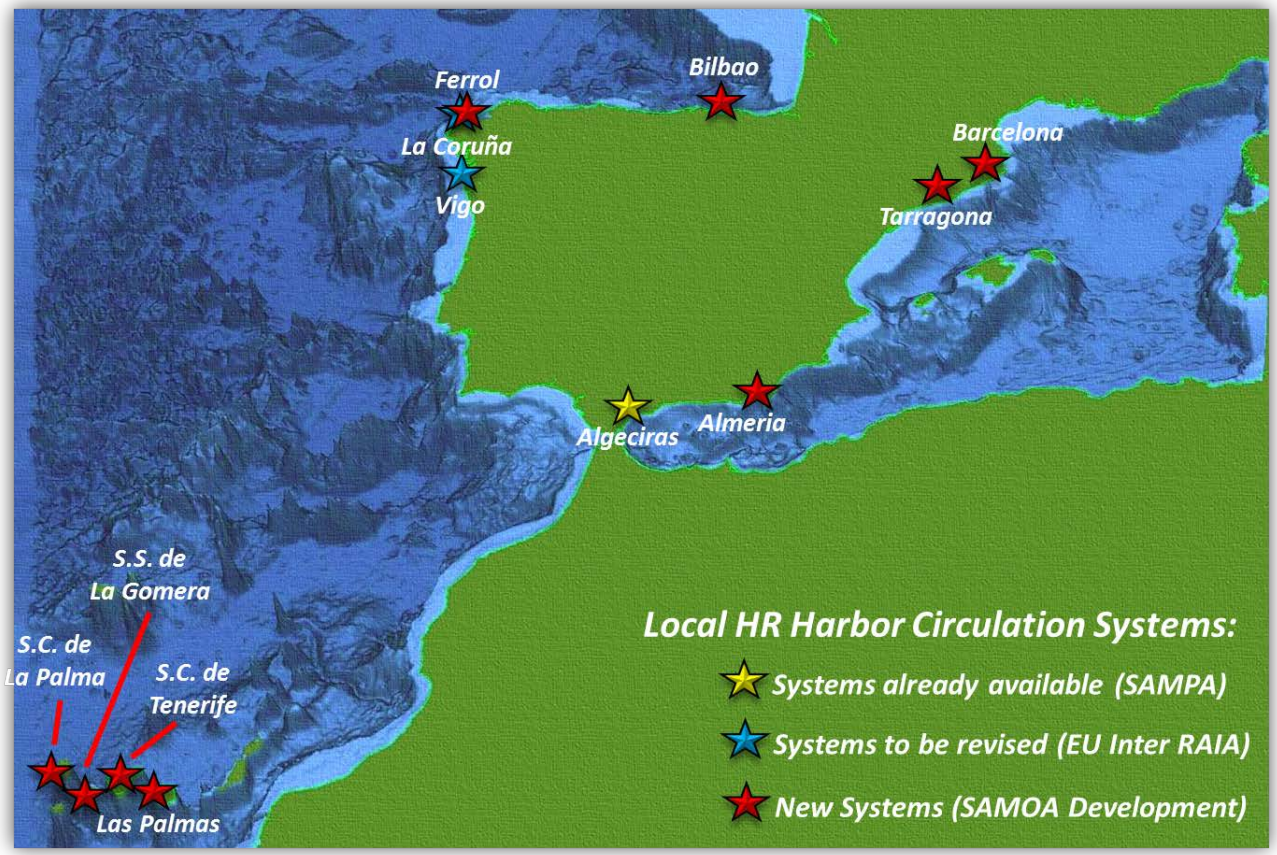


SAMOA: Towards information Services integrated in the Harbor operations

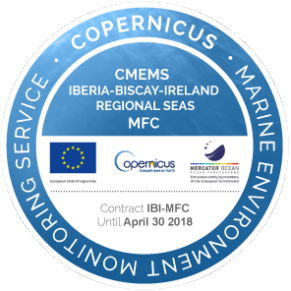
- New Paradigm in downstreaming Met-Ocean information Service
- Expanding SAMPA to other harbours
- SAMOA key services for decision making (info-based) at harbor authorities
- SAMOA co-developed by PdE & 18 Port Authorities (2015-2018)



SAMOA: Towards information Services integrated in the Harbor operations



Conclusions



- Copernicus stablishes an operational environment for OO at Europe
- The IBI-MFC + the nested downstream applications paves the way for forecasting in a turbulent environment
- IBI-MFC makes special focus on real time validation and evaluation
- The reanalysis data set is a valuable tool to describe present day climate
- Forecast still not always reliable enough. Needed improvements in many areas:
  - More data for data assimilation
  - Model numerics
  - Assimilation techniques