Framework for improving land boundary conditions in regional ocean products.

Results from the CMEMS SE LAMBDA project

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Project funded by
CMEMS SE2

Main Objective

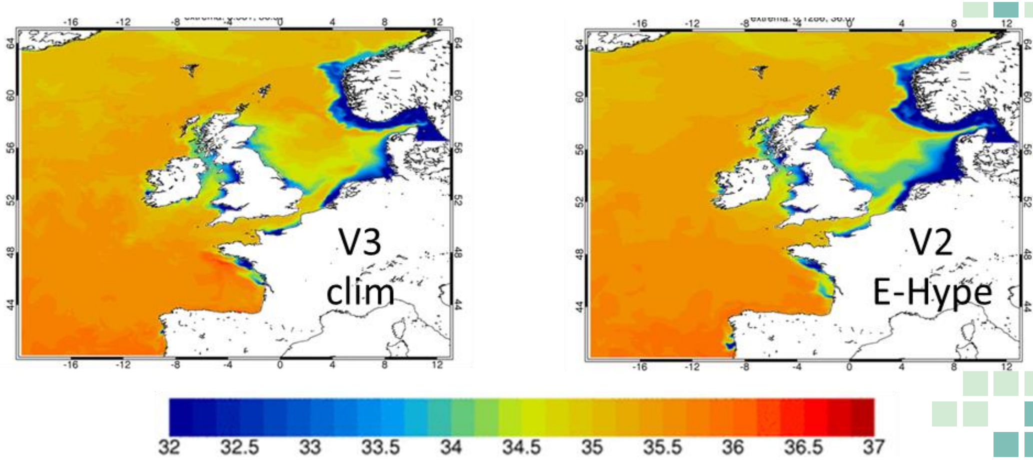
to improve the CMEMS MFCs thermohaline circulation in coastal areas by a better characterisation of the land-marine boundary conditions

Relation with CMEMS objectives

- The LAMBDA project implementation aim to contribute to the following short- and mid-term objectives:
  - Improved and standardised inputs of freshwater flows and associated river inputs of particulate and dissolved matter and homogenised river forcing approaches in global, regional and coastal models;
  - Comprehensive impact studies of CMEMS boundary conditions on coastal systems (physics, biology) and their applications (e.g. MSFD);
- And to the following longer-term objectives:
  - Adoption of robust standards to ensure compatibility between CMEMS and downstream systems;
  - Connection and coupling with land hydrology models.

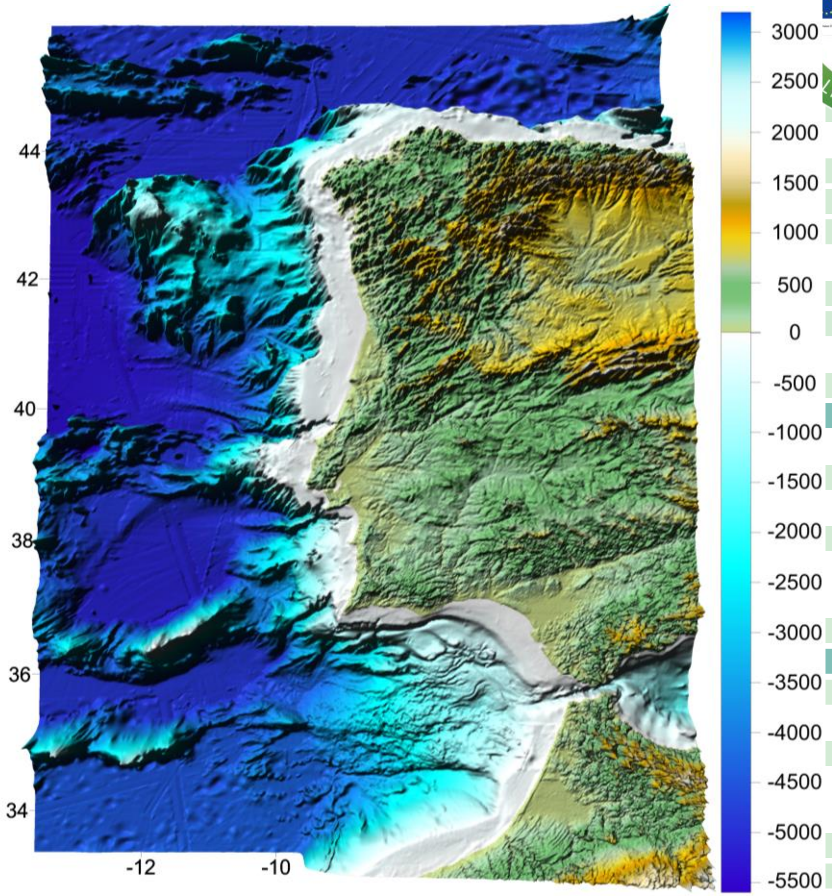
Meeting CMEMS MFCs requirements

- IBI MFC: sea surface salinity was the least accurate property among the twelve modelled variables Aznar *et al.* (2016).
- NWS MFC: V3 version moving back to climatological flows due to significant excess of fresh water, i.e. in the German Bight region

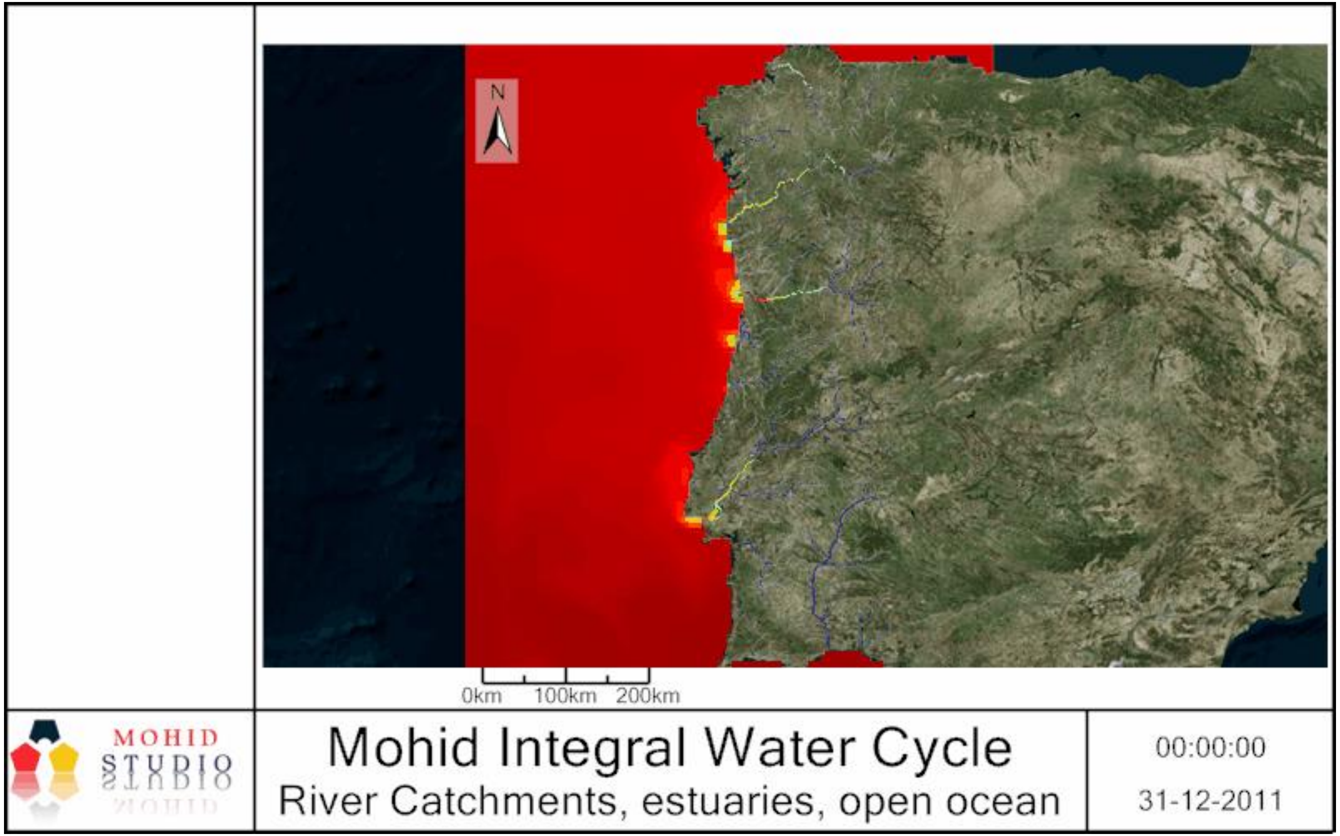


Integrated water cycle approach – A paradigm shift:

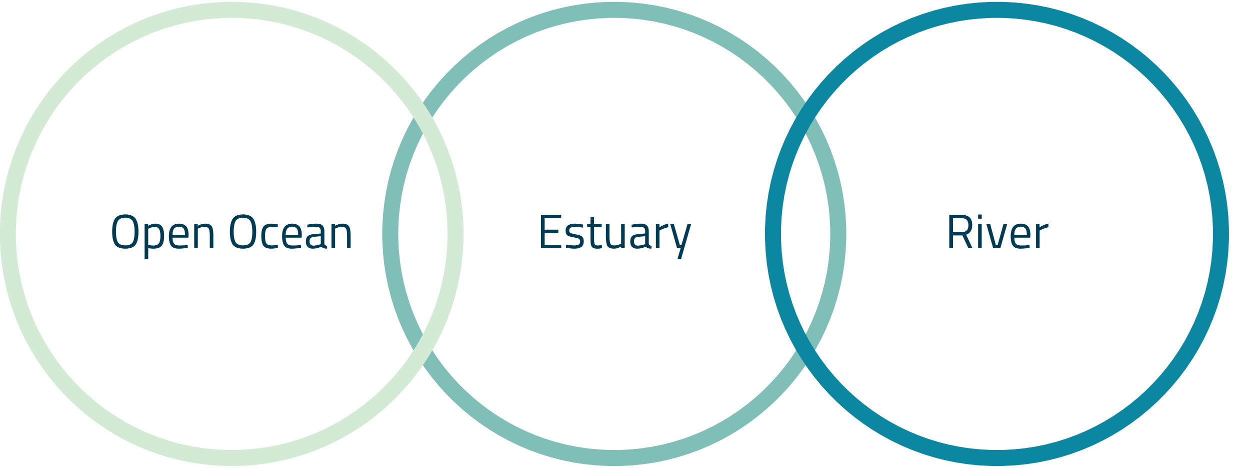
- The main objective of the present research was to explore a novel methodology and to evaluate the capacity to improve the thermohaline circulation in regional ocean model applications by a better characterisation of the land-ocean boundary conditions able to represent the salinity features.
- Main Challenges:
  - Obtain data near the river mouth;
  - How to impose those inputs in regional ocean models;
  - How to validate the results.



The big objective is to integrate the water continuum



LAMBDA project conceptual dyagram: Coping with Water continuum interfaces



Complete description at:
Campuzano F (2018). Coupling watersheds, estuaries and regional seas through numerical modelling for Western Iberia. PhD Thesis, Instituto Superior Técnico, Universidade de Lisboa, Portugal.

The LAMBDA project:

- generated freshwater products flows and associated water properties;
- enhanced satellite salinity products development;
- evaluated the capacity of hydrological models;
- integrated the different time scales of river outflow by flexible interfaces;
- benefited from local and regional knowledge.

The LAMBDA project rely on three pillars:

- A wide consortium with excellence on their respective area;
- Model, software and EO products developers connected with local experts and CMEMS MFCs operators;
- Communication activities to enhance partner interaction.

Consortium:
Full partners

- MARETEC-IST (PT)
- Bentley Systems (USA)
- Barcelona Expert Centre (ES)
- ETT (IT)

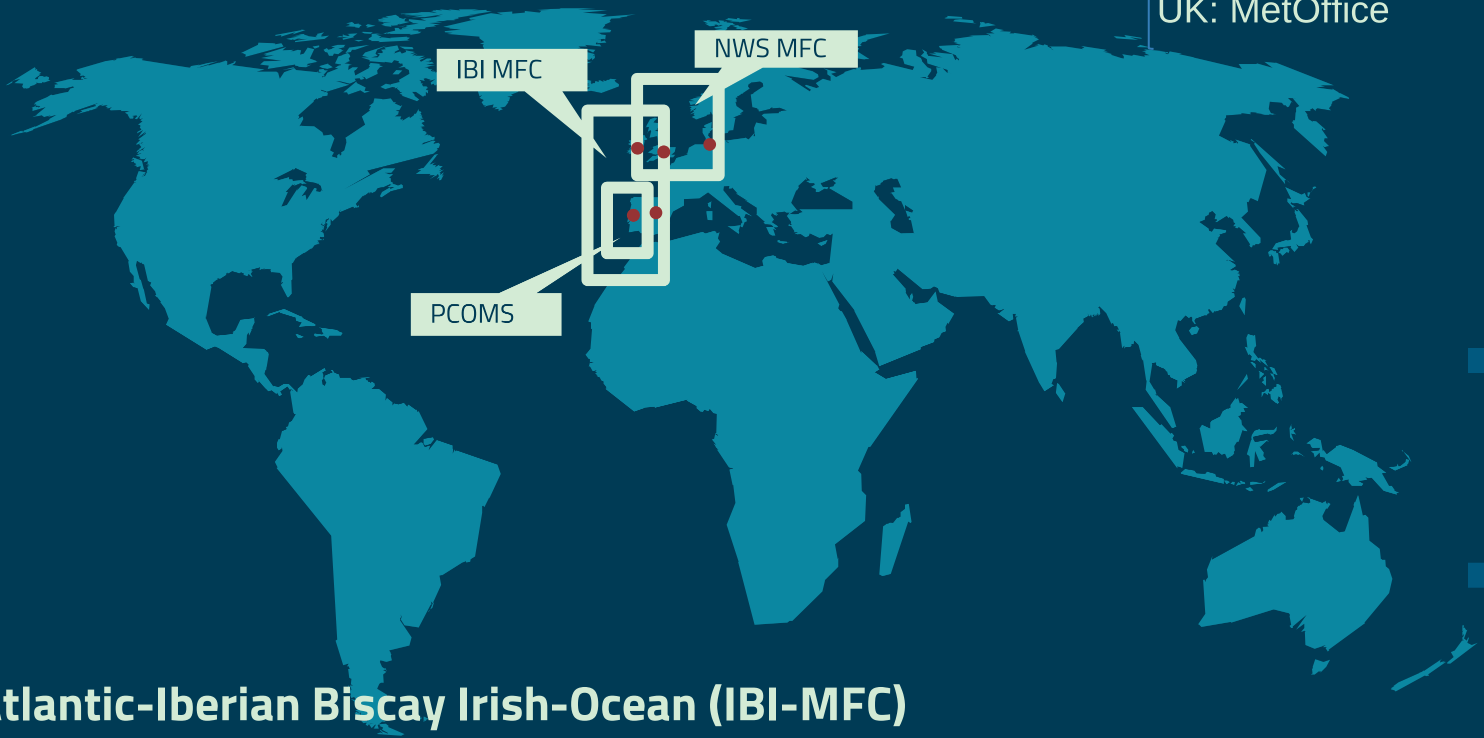
Consortium: Associated Partners

- Met Office (UK)
- Puertos del Estado (PdE,ES)
- Marine Institute (MI, IE)
- Helmholtz-Zentrum Geesthacht (HZG, DE)

Study Areas

Local Experts

- Germany: HGZ
- Ireland: MI
- Portugal: MARETEC-IST
- Spain: Puertos del Estado
- UK: MetOffice



Atlantic-Iberian Biscay Irish-Ocean (IBI-MFC)
Atlantic-European North West Shelf (NWS-MFC)
Portuguese Coast Operational Modelling System (PCOMS)

Numerical modelling:

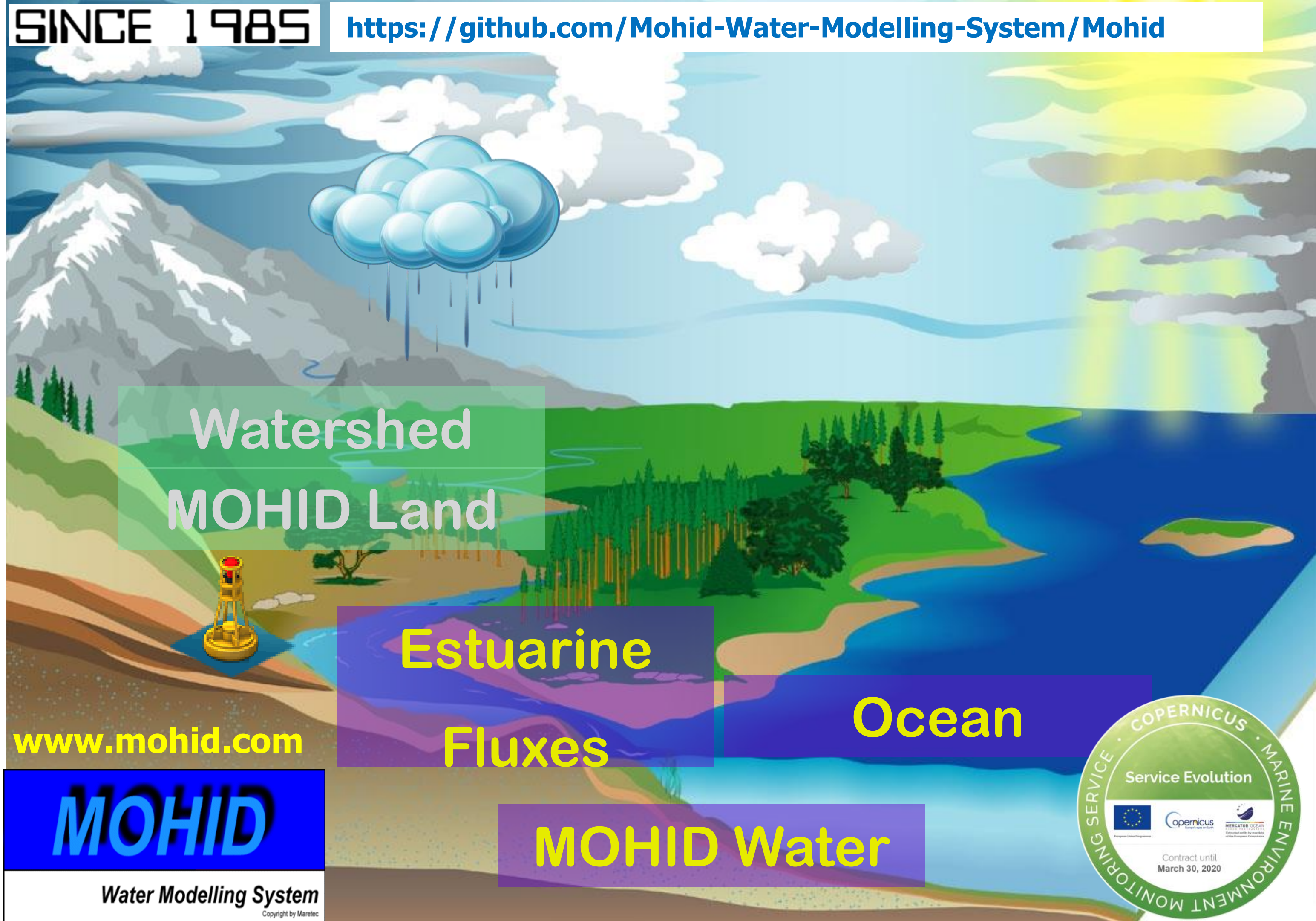
Numerical modelling activities included:

1. Watershed modelling (using MOHID Land)
2. Estuarine proxy (using MOHID Water)
3. Regional ocean models:
    1. PCOMS regional ocean model for Western Iberia (using MOHID Water)
    2. IBI MFC (LAMBDA watershed V1 product being currently tested by Puertos del Estado)
    3. HZG has also performed tests in the German Bight Area
    4. MI is planning testing the LAMBDA watershed V1 product in a coastala area

Results from PdE and HZG are not shown in this presentation

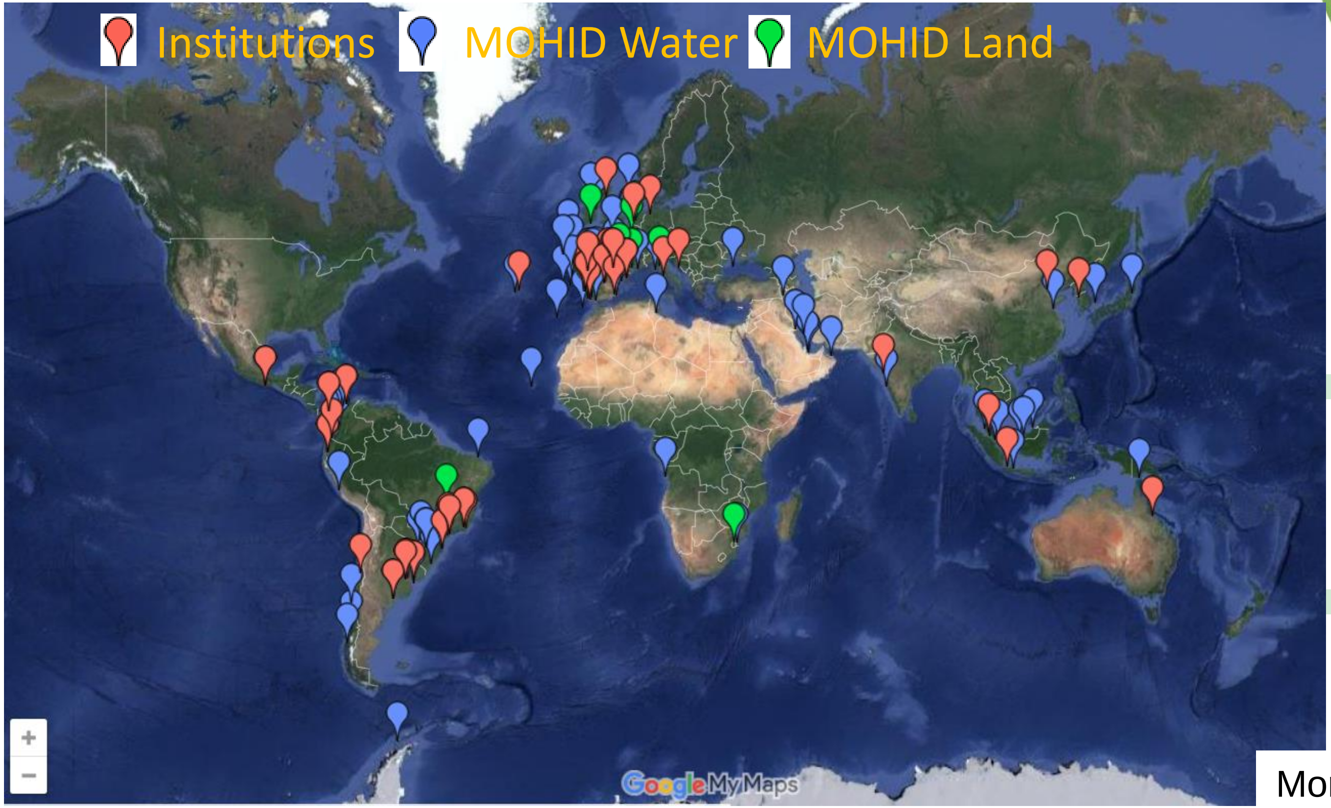
Numerical modelling using MOHID Water Modelling System– an open source model with two main components:

- MOHID Land for watersheds and crop production
- MOHID Water used for estuaries, coastal areas and open ocean



MOHID community: a globally established model

Map of a non-exhaustive collection of institutions and model applications

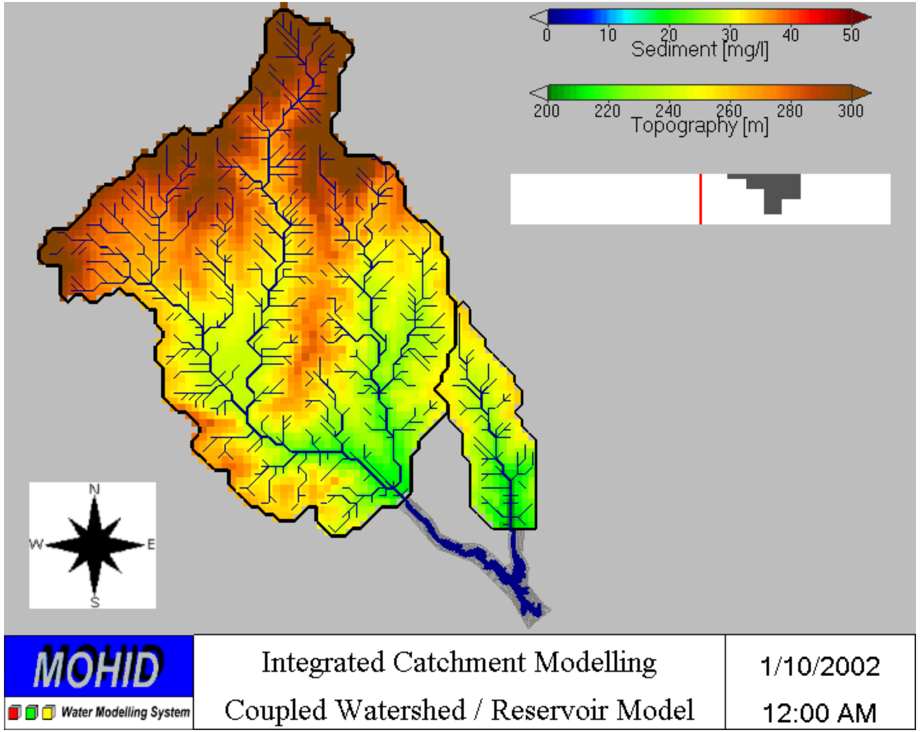


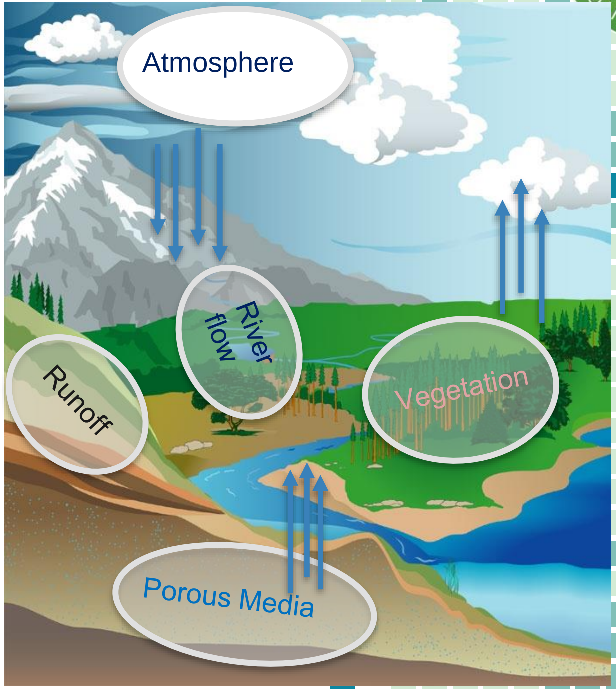
COPERNICUS MARINE ENVIRONMENT MONITORING SERVICE
Service Evolution
Contract until March 30, 2020

More info at
www.mohid.com

Watershed modelling:

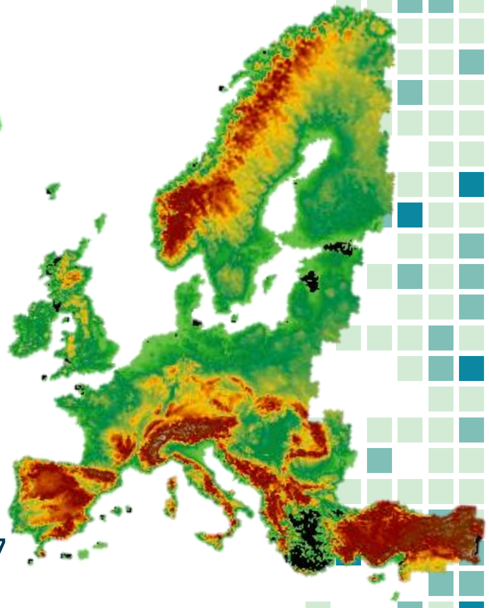
MOHID Watershed modelling: water pathways





Watershed modelling details

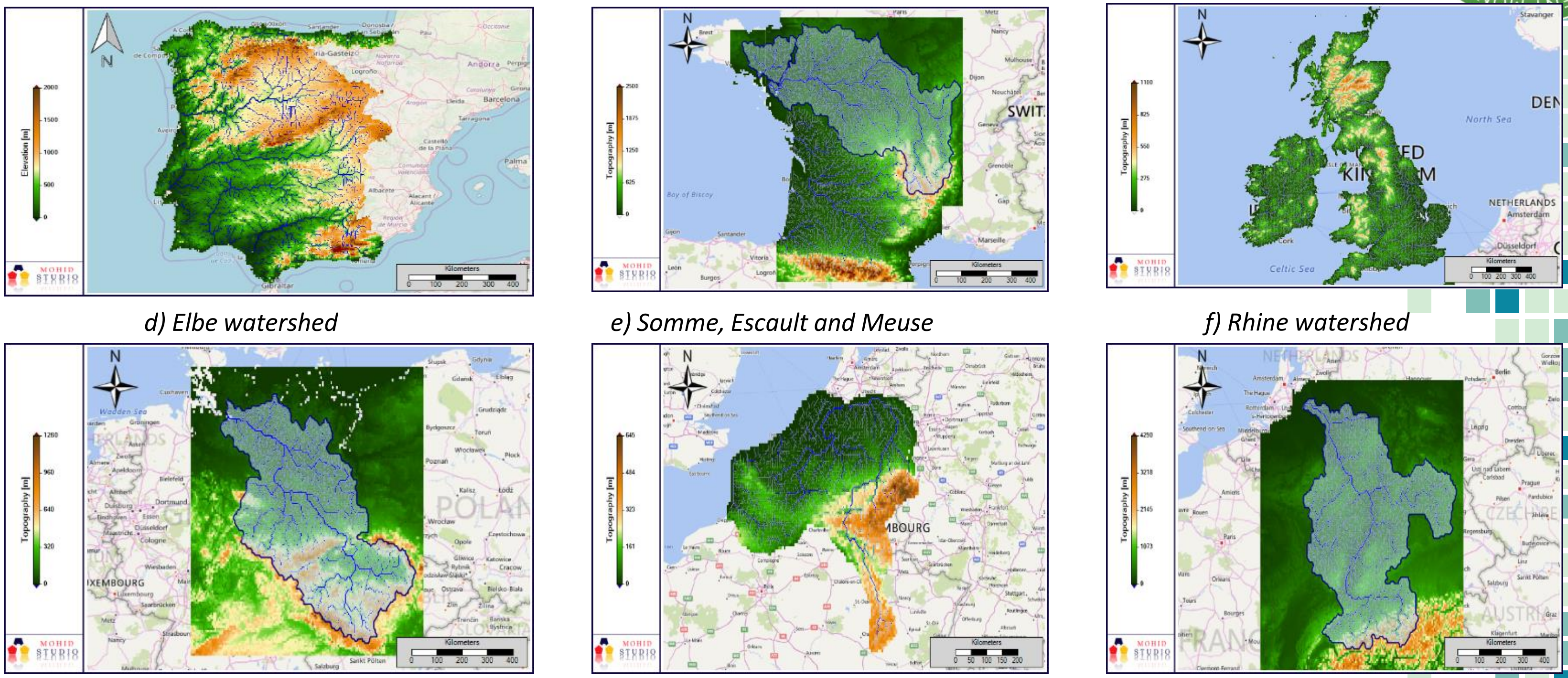
- The main goal was estimating the amount of freshwater entering the coastal areas of the North Sea/Atlantic Ocean.
- The LAMBDA project divided the study area into ten numerical modelling domains
- Simulated period: 01/01/2008 – 01/01/2019
- 5 km x 5 km grid, except for for Loire and Severn rivers
- ERA5 meteorological model (ECMWF) except for Ems and Weser watersheds were meteorological stations produced better results
- EU-DEM (resolution: 30 m)
- River Cross Sections from Andreadis *et al.*, 2013
- 2012 Corine Land Cover from Copernicus Land Monitoring Service
- 3D soil hydraulic database (resolution: 250 m) from Tóth *et al.* 2017



Watershed modelling domains

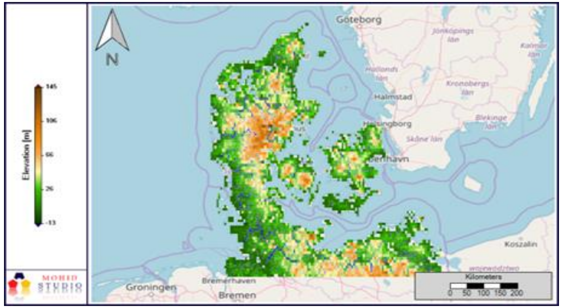
a) Western Iberian Peninsula
b) Western France
c) United Kingdom and Ireland

d) Elbe watershed
e) Somme, Escault and Meuse
f) Rhine watershed

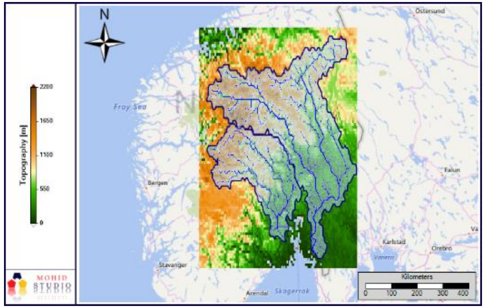


Watershed modelling domains

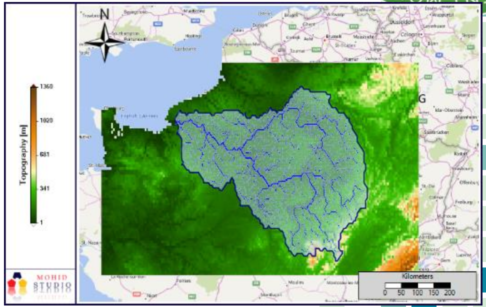
g) Denmark domain



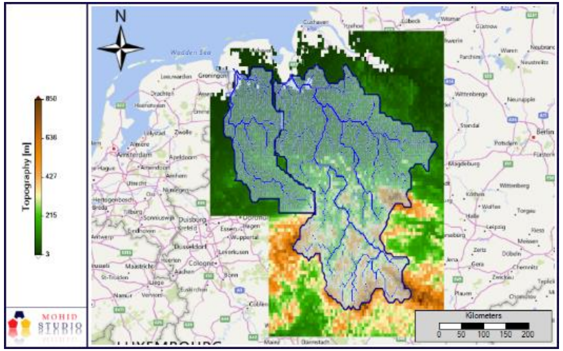
h) Glomma and Drammen



i) Seine watershed



j) Ems and Weser watersheds



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54 main Rivers*

* 70 and 364 extra rivers were produced for Western Iberia and Ireland-UK domains respectively

Modelling results quality indicators:

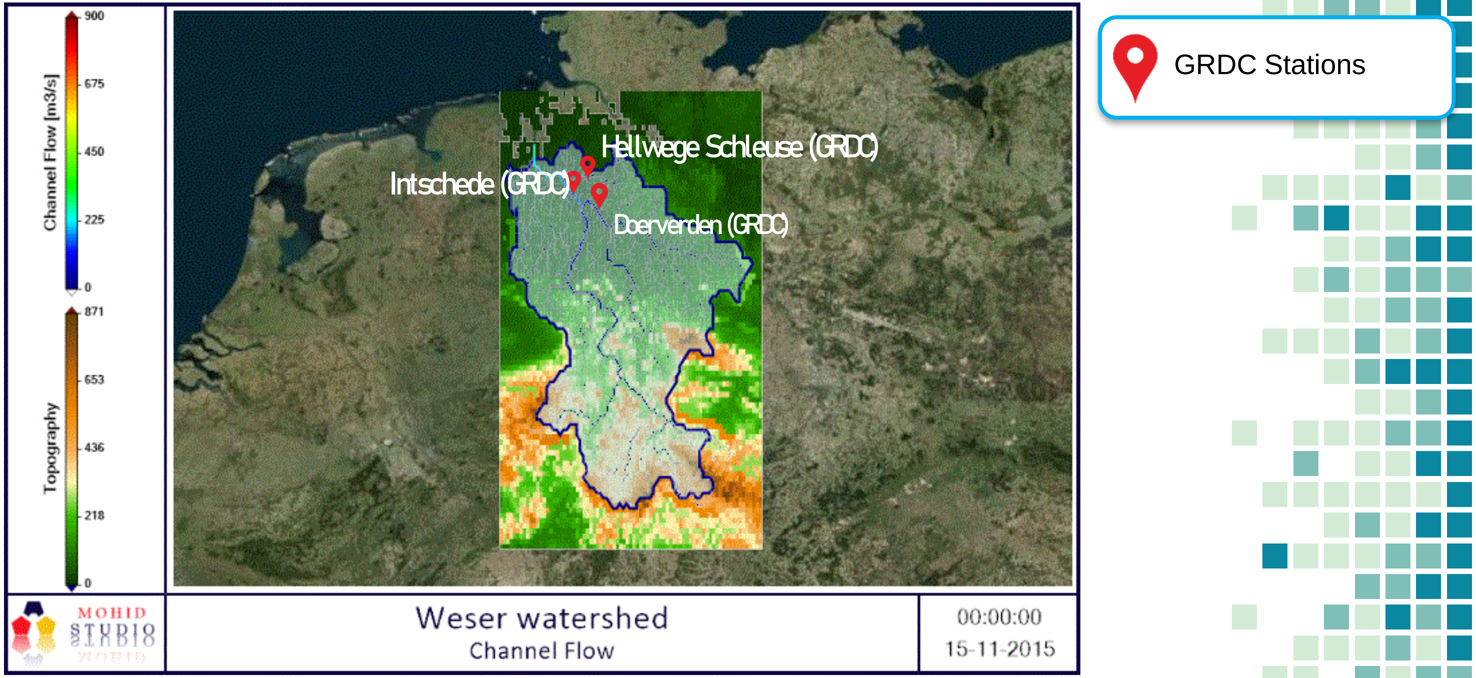
- Watershed modelling results were evaluated using:
  - Coefficient of determination (R^2)
  - Kling Gupta Efficiency, values range from -∞ (worst quality) to 1 (best quality). See formula below

$$KGE = 1 - \sqrt{(r-1)^2 + (\beta - 1)^2 + (\gamma - 1)^2}$$

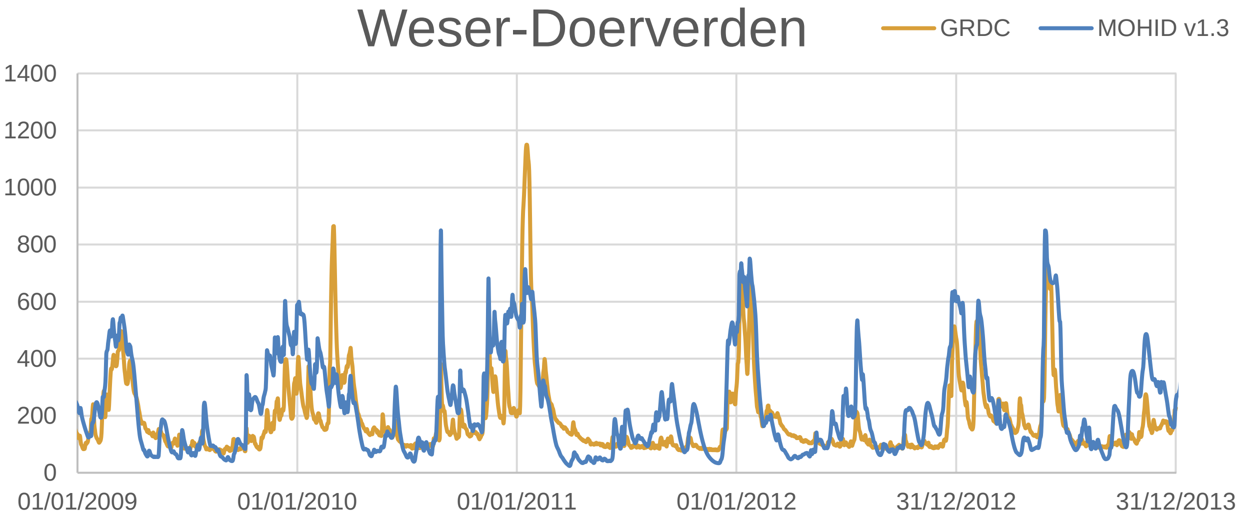
from $-\infty$ to 1

$$\beta = \frac{\mu_{sim}}{\mu_{obs}} \qquad \gamma = \frac{Cv_{sim}}{Cv_{obs}} = \frac{\sigma_{sim}/\mu_{sim}}{\sigma_{obs}/\mu_{obs}}$$

Calibration steps (Weser example)



Weser Calibration Process:



	R^2	KGE
V0	039.3	-0.187
V1.0	0.348	-0.293
v1.1	0.467	0.141
v1.2	0.507	0.308
v1.3	0.537	0.638

Simulated (MOHID) vs Observed (GRDC) channel flow in m³/s between 1/1/2009 and 1/1/2014 in GRDC Station Doerverden.

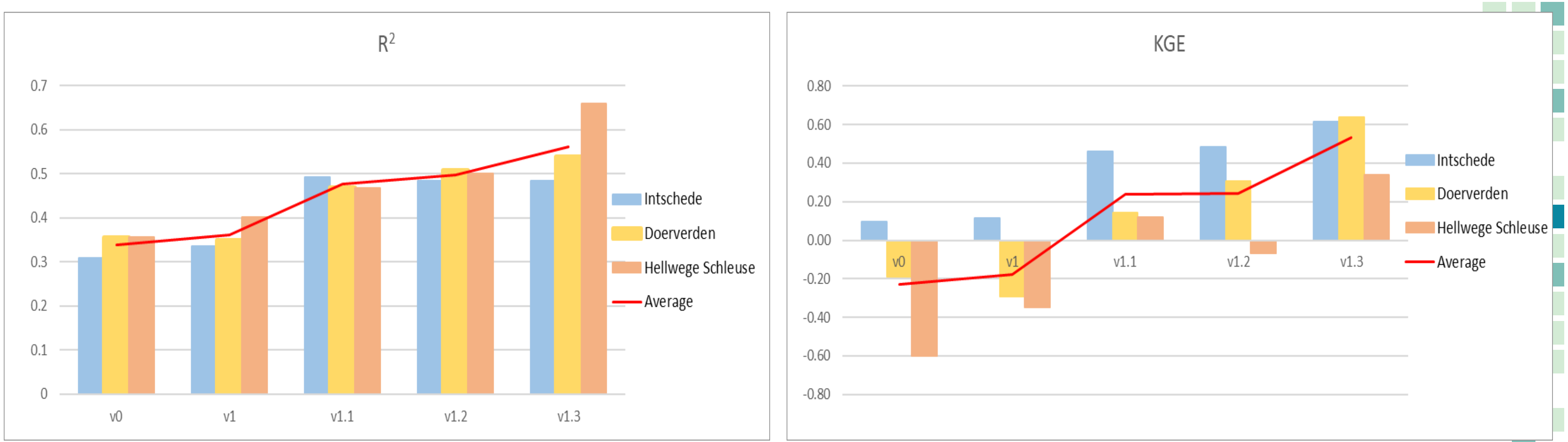
V1.0 Add Evergreen properties to Pine, bushes and forest vegetation.

V.1.1Substantially increase K_{sat} on the top soil layer.

V1.2 Substantially increase K_{sat} on the middle soil layer.

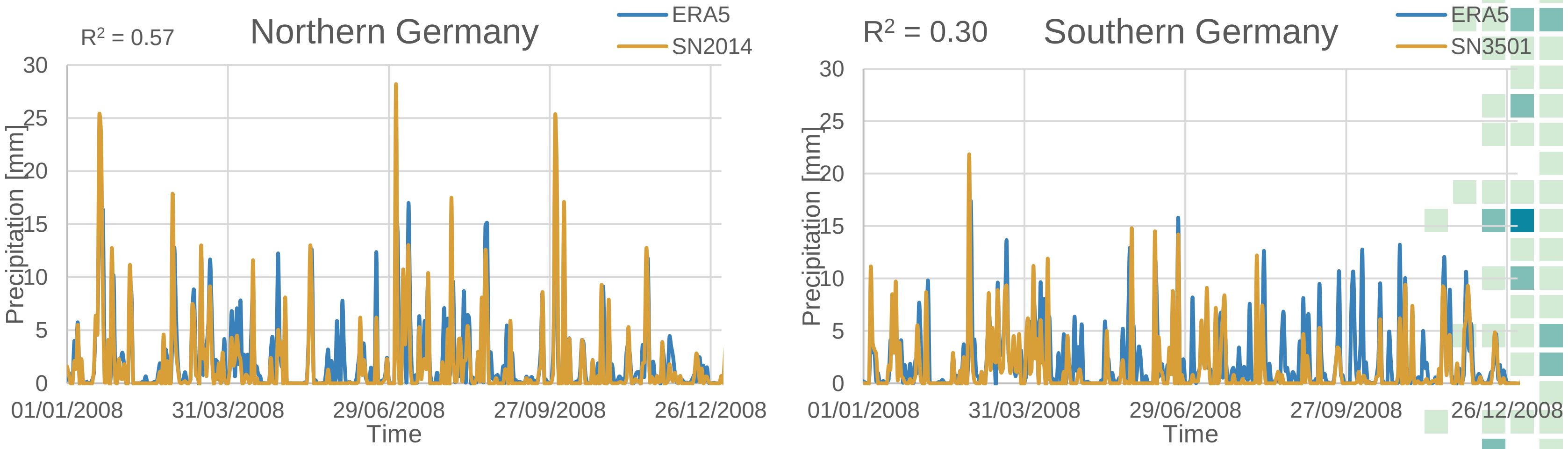
V1.3 Precipitation from observed stations.

Weser Calibration Process:



Statistical Indicators (R^2 in the left, KGE in the right) of Weser channel flow in the 3 chosen GRDC observed data stations: Intschede, Doerverden and Hellwege Schleuse. Red line represents the resulted average value of the three stations' indicators.

The Meteorological Problem:



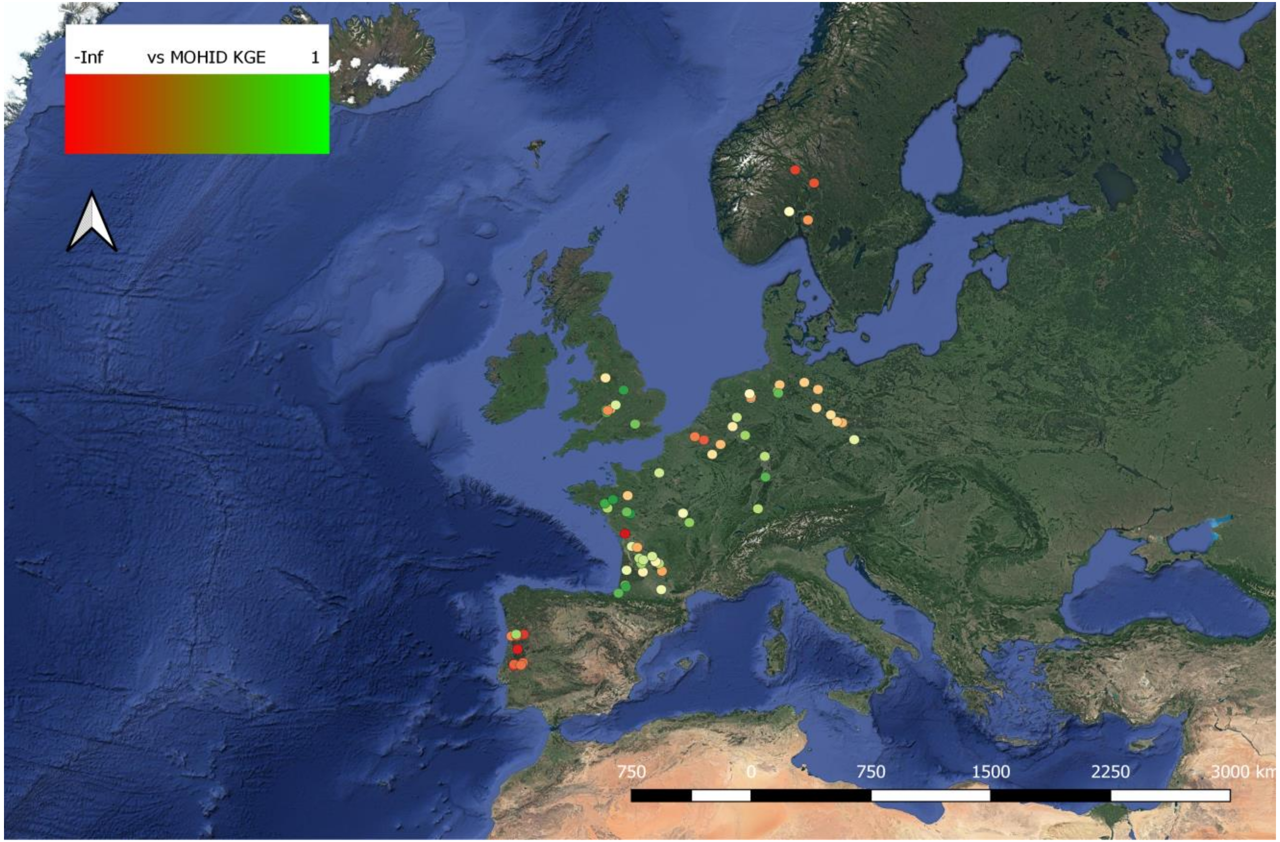
Accumulated daily precipitation [mm] in the year 2008, compared between observed data in meteorological stations (SN2014 in the Northern Germany and SN3501 in the Southern Germany) and ERA5 meteorological model.

Summary of results for LAMBDA V1 product:

NAME	Longitude	Latitude	R2 final	KGE final	NOTES
Adour	-1.548584	43.530264	0.538	0.651	---
Avon (Beth)	-2.991306	51.170599	NA	NA	---
Bann	-6.769782	55.166999	NA	NA	---
Barrow	-6.978576	52.269855	NA	NA	---
Blackwater (Munster)	-7.711302	52.090599	NA	NA	---
Canche	1.5887	50.5412	NA	NA	---
Charente	-0.936476	45.937072	0.334	0.400	---
Corrib	-9.071301	53.330598	NA	NA	---
Courant-de-Contis	-1.278728	44.069976	NA	NA	---
Dordogne	-0.486716	44.992576	0.576	0.535	---
Douro	-8.4775	41.0809	0.573	0.073	---
Drammen	10.1949445	59.739984	0.245	0.427	---
Eden	-3.271306	54.930596	NA	NA	---
Elbe	10.0837	53.4581	0.411	0.364	---
Ems	7.39336255	53.265673	0.564	0.379	Meterological forcing from observed precipitation
Erne	-8.2169341	54.504228	NA	NA	---
Escaut	4.0887	51.3412	0.137	-0.012	---
Eyre	-1.053848	44.654664	0.254	0.483	---
Garonne	-0.559112	44.969496	0.437	0.381	---
Glomma	11.1241195	59.391023	0.076	-0.041	---
Great Ouse	0.32869	52.730598	NA	NA	---
Guadiana	-7.4339	37.2957	NA	NA	---
Gudena	10.1246	56.4696	NA	NA	---
Liffey	-6.271303	53.330598	NA	NA	---

NAME	Longitude	Latitude	R2 final	KGE final	NOTES
Loire	-0.9823	47.3946	0.607	0.556	3km resolution grid
Mersey	-3.03131	53.4106	0.500	0.379	---
Meuse	4.8387	51.6912	0.426	0.368	---
Minho	-8.7726	41.9437	NA	NA	---
Mondego	-8.6002	40.1931	0.253	-0.987	---
Moy	-9.1513	54.1306	NA	NA	---
Nene	0.08869	52.8106	NA	NA	---
Palue	-1.36868	43.93505	NA	NA	---
Rhine	5.664499	51.89981	0.451	0.583	---
Ribe	8.7746	55.3196	NA	NA	---
Sado	-8.6275	38.4375	NA	NA	---
Seine	0.42914	49.46728	0.566	0.532	---
Severn	-2.2553	51.88833	0.619	0.450	1km resolution grid
Sévre-Niortaise	-0.98145	46.34186	0.467	-2.966	---
Shannon	-8.63628	52.6618	NA	NA	---
Skjern	8.6246	55.9196	NA	NA	---
Somme	1.6387	50.1912	NA	NA	---
Spey	-3.09615	57.67075	NA	NA	---
Tagus	-8.9222	38.9483	0.306	-0.124	---
Tay	-3.28874	56.3543	NA	NA	---
Tees	-1.23131	54.6106	NA	NA	---
Thames	0.020399	51.4965	0.626	0.631	---
The Haven	-0.15131	52.9706	NA	NA	---
Trent	-0.69796	53.69329	0.527	0.721	---
Tweed	-2.00717	55.76665	NA	NA	---
Tyne	-1.55131	54.9706	NA	NA	---
Ulla	-8.7175	42.6675	NA	NA	---
Vilaine	-2.27406	47.53264	0.610	0.670	---
Weser	8.486693	53.29315	0.561	0.531	Meterological forcing from observed precipitation

KGE value at validation stations



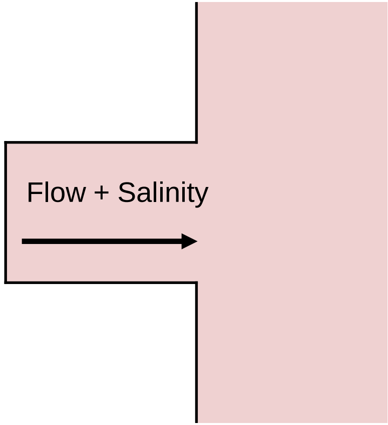
Conclusions from watershed modelling:

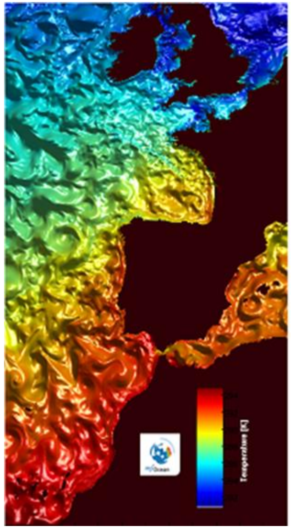
- Best results are obtained from higher resolution and single watershed domains.
- Meteorological forcing from ERA5 is inadequate in Germany, but adequate everywhere else.
- Calibration was the most effective through changes in Toth *et al*. (2017) van Genuchten parameters.
- Rivers without available observations can not be further calibrated.
- Better results for rivers less affected by human intervention

Estuarine Modelling:

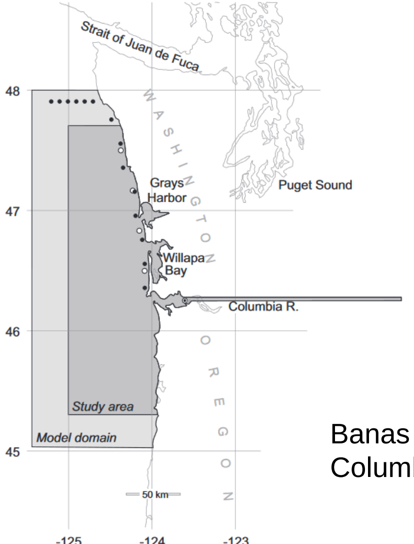
Traditional River input methods

- Direct Discharge
  - Initial dilution through single inlet (Flow + constant salinity) such as the CMEMS IBI MFC





- Integrated estuary
  - Varying horizontal resolution
  - Good approach for single estuary studies



Banas *et al.* 2009
Columbia River

LAMBDA Georeferred Estuarine Proxy

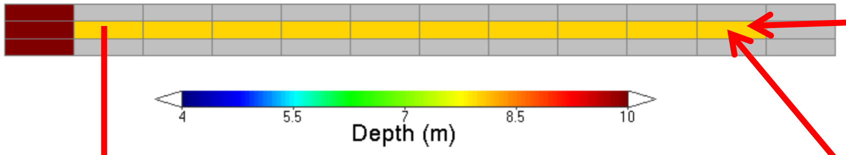
Ocean Inputs

MOHID
Water Modelling System

Land Inputs

FES2014

PCOMS



MOHID Land

Modelled flow +
Modelled Temperature

Observations

Observed flow +
Modelled Temperature

Outputs

- Proxy consist on basic 2D MOHID Water configuration with 10x3 cells domain
- 4 basic configurations defined with mouth towards North, South, East and West
- Inputs forced in the innermost cell and outputs obtained at the last estuarine cell : Volume, velocity (u or v), salinity and temperature

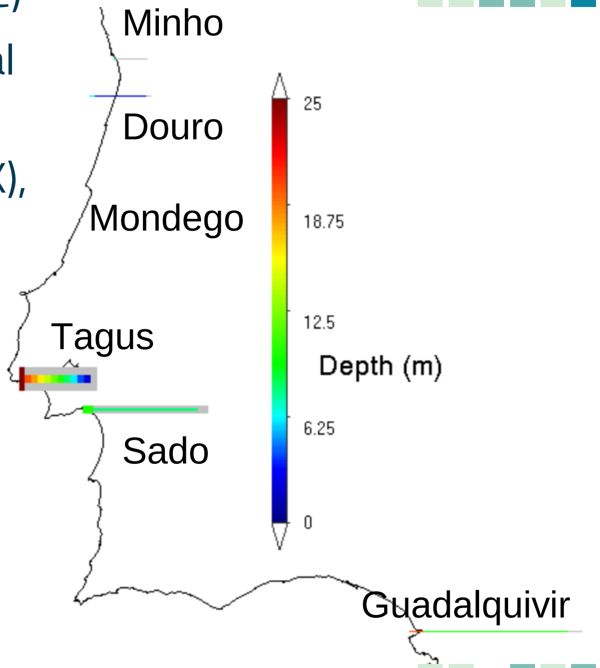
EMODnet

NRT river flow data

Example of estuarine configurations

- Inputs needed to configure the proxy domain: Average Depth, Depth at the mouth, Total Length, Average Width, Water properties at the near ocean, Location of the mouth (latitude and longitude)
- The following 6 estuaries were configured to force the Regional Ocean Model PCOMS for the LAMBDA project
- Configurations are also available for Guadiana (ES), Humber (UK), Ria de Arousa (ES), Scheldt (BE-NL), Thames (UK), Weser (DE).

Estuary	Cell Length (Degrees)	Cell Width (Degrees)	Depth Mouth (m)	Depth Estuary (m)	Longitude Mouth	Latitude Mouth
Douro	0.022	0.00272	8.2	8.2	-8.7	41.14
Guadalquivir	0.11	0.00475	20	10	-6.44	36.785
Minho	0.04	0.00575	6	2	-8.885	41.86
Mondego	0.0015	0.045	6	2	-8.88	40.143
Sado	0.08	0.02	10	8	-8.93	38.47
Tagus	0.05	0.062	25	20-2	-9.42	38.62

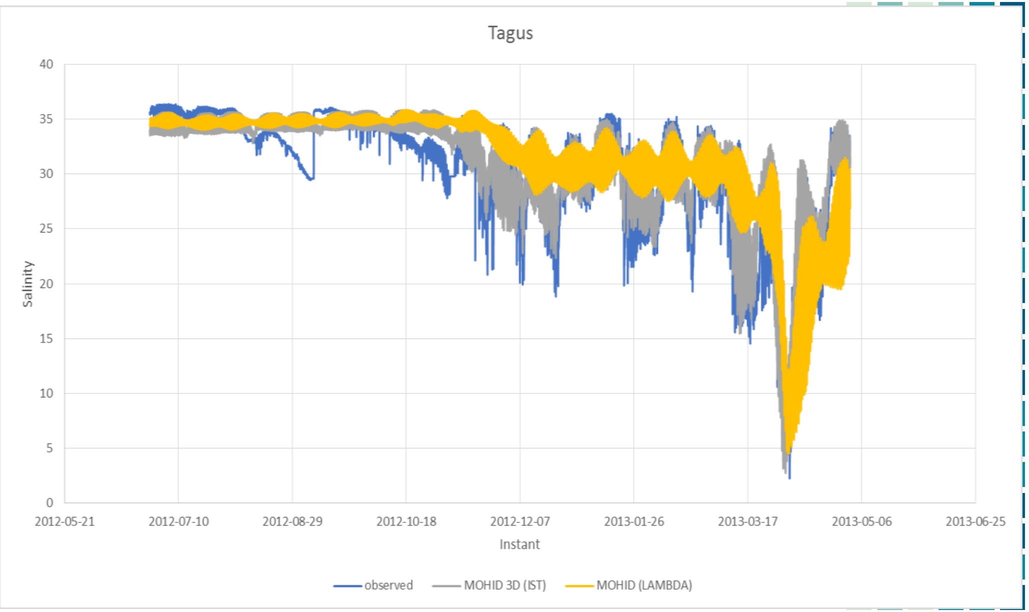


Proxy salinity results at Tagus estuary mouth

Salinity obtained at the mouth of the Tagus estuary using a 3D estuary model (Grey line) and using the 2D LAMBDA estuary proxy (Yellow line) for the period June 2012- April 2013.

The period was selected due to the availability of observations at the estuarine mouth (Blue line).

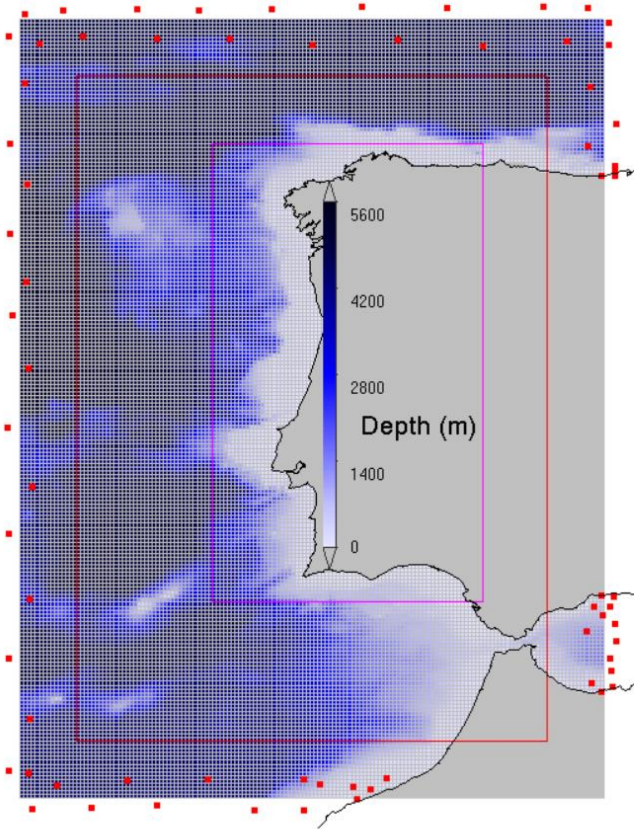
Stats MOHID 3D (IST) vs observed: v R^2 = 0.83, RMSE = 2.36, MAE = 1.80.
Stats MOHID 2D estuary proxy (LAMBDA) vs observed: R^2 = 0.65, RMSE = 3.50,, MAE = 2.60.



Observations kindly provided by Águas do Tejo Atlântico Grupo Águas de Portugal

Regional ocean modelling:

Portuguese Coast Operational Modelling System (PCOMS)



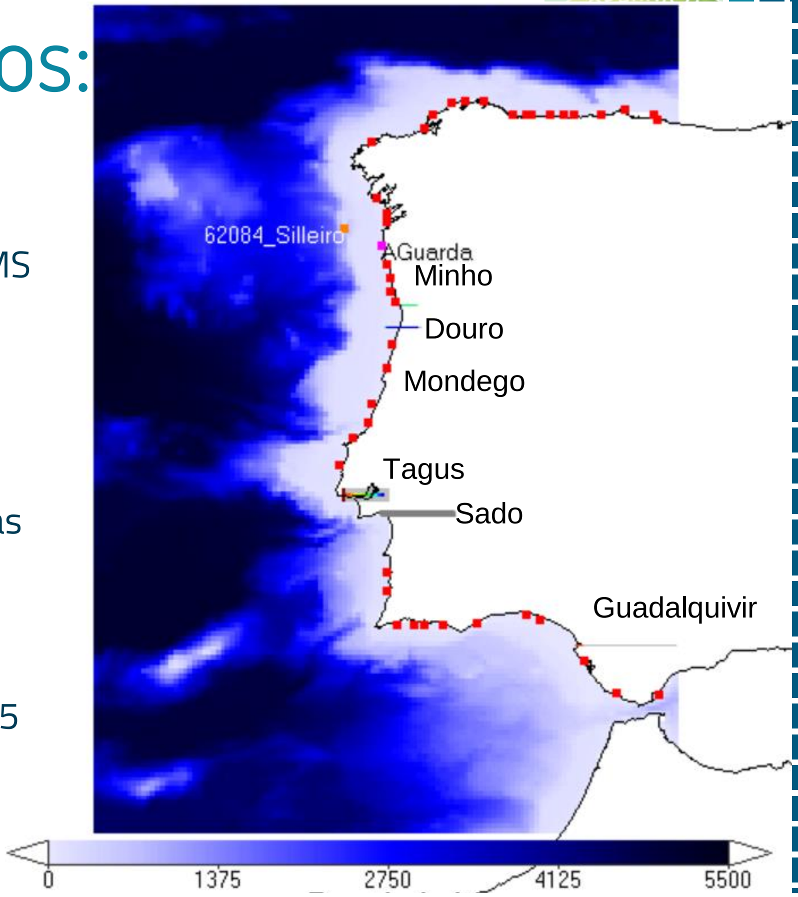
- Based on the MOHID Water model
- Downscalled from CMEMS GLOBAL_ANALYSIS_FORECAST_PHY_001_024
- Tides from FES2014
- Two nested domains (0.06° ≈ 6 km):
    - 2D WestIberia domain: 208x155 cells
    - 3D Portugal domain: 177x125 cells
- Hybrid vertical configuration corresponding to 7 Sigma layers on top of 43 Cartesian layers
- NPZD biogeochemical model forced with nitrate, phosphate, oxygen and phytoplankton from CMEMS GLOBAL_ANALYSIS_FORECAST_BIO_001_02
- Meteorological forcing from MM5 Model application

LAMBDA scenario testing rationale

- The LAMBDA boundary products were implemented first as proof of concept (PoC) in the Portuguese Coast Operational Modelling System (hereafter referred as PCOMS, Mateus *et al.*, 2012; Campuzano, 2018) for the year 2018 as test case.
- Land inputs influence was analysed by the extension of the Western Iberia Buoyant Plume (WIBP): a low salinity water lens present all year round and generated by several river plumes in Northwest Iberia (Peliz et al., 2002). During extreme events, WIBP can be detected eventually in Puertos del Estado Silleiro Buoy 50 km offshore (Campuzano, 2018).
- Next slides describe the LAMBDA boundary conditions and show some results from the different scenarios during the month of February and an extreme event in late March 2018.

LAMBDA project scenarios:

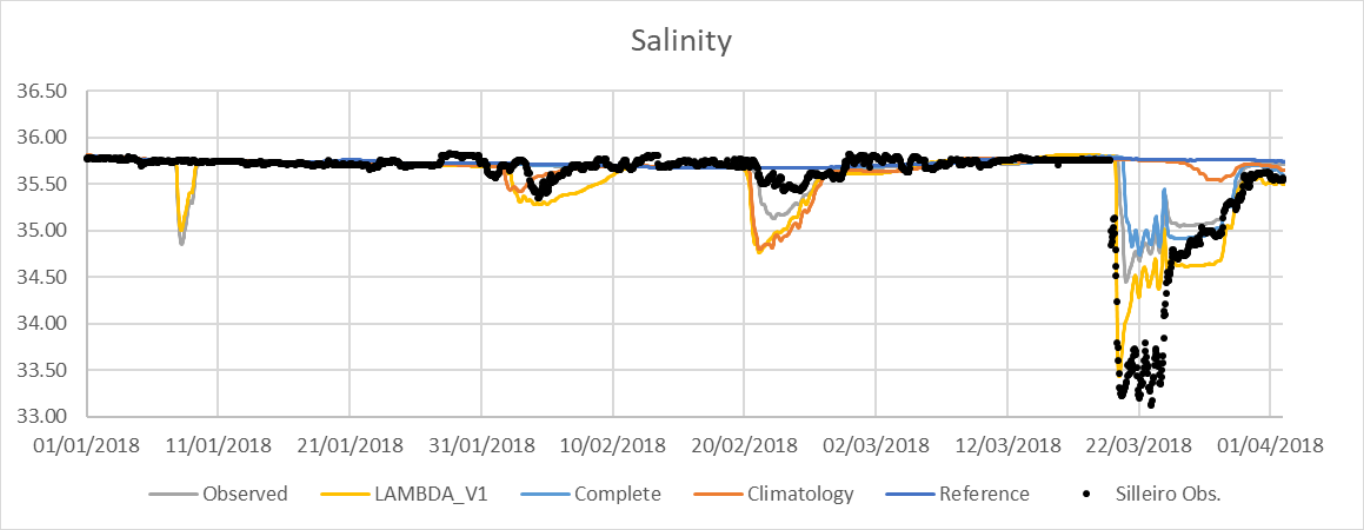
- **Reference**: CMEMS relaxation at the open boundary, no river discharge
- **Climatology**: flow and temperature river climatology for CMEMS included river in the PCOMS domain (Douro, Guadiana, Guadalquivir, Minho, Mondego, Tagus);
- **LAMBDA V1**: Best LAMBDA flow and temperature for same rivers as **Climatology** scenario
- **Observed**: observed flow from *in situ* stations for same rivers as **Climatology** scenario. Temperature from **LAMBDA watershed V1 product**;
- **Complete**: best forcing conditions: Observed data corrected by estuarine proxy at 6 estuaries. Forcing completed with other 45 direct discharges with modelled temperature and constant salinity of 25.
- **Biogeochemical**: Complete scenario plus constant phosphate and oxygen and nitrate monthly climatology.



Red dots indicate the extra 45 discharges location in **Complete** scenario. Silleiro and A Guarda locations also shown

Silleiro Buoy Salinity

- January and February salinity drop overrepresented in the direct discharge scenarios (Observed, LAMBDA_V1 and Climatology). However during the large event LAMBDA_V1 seems to match well as salinity drops in time and intensity.
- The complete scenario performs satisfactorily though it lacks some fresh water. It may be due to the 25 constant salinity imposed in the rest of the rivers. Some relation with the salinity of neighbour estuaries could improve the results.



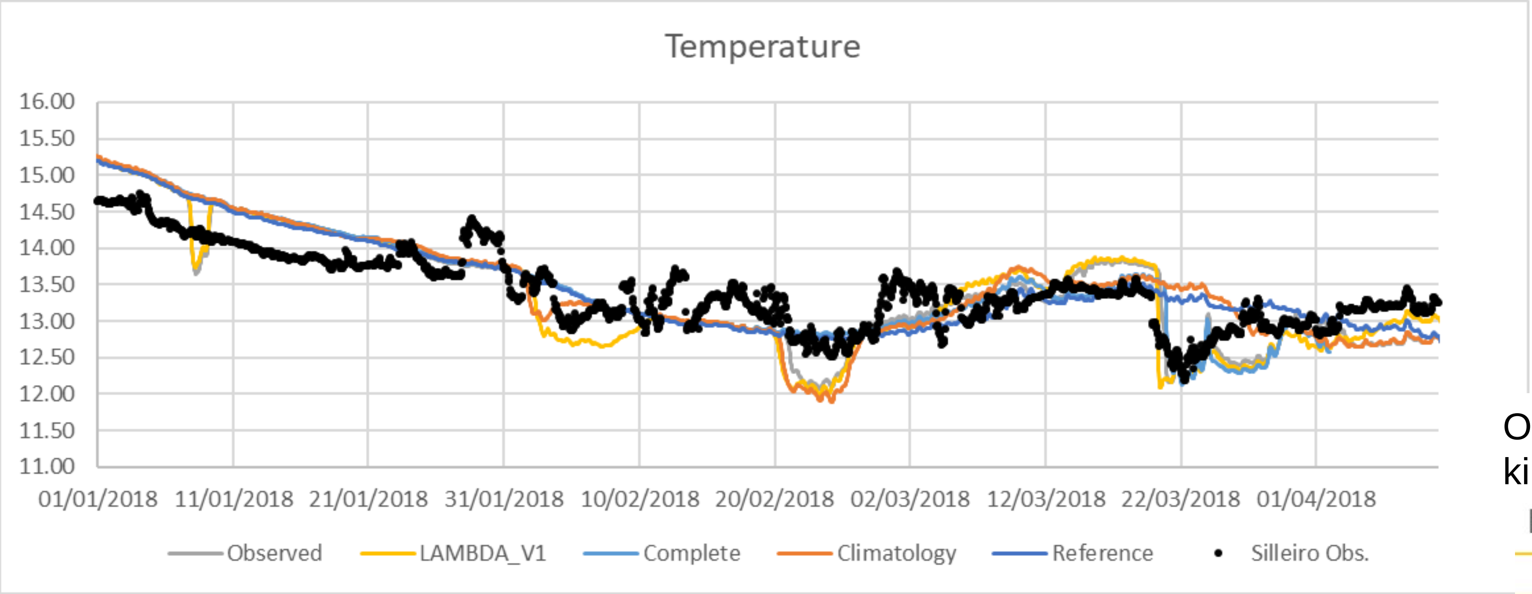
Observations kindly provided by

Puertos del Estado

GOBIERNO DE ESPAÑA MINISTERIO DE FOMENTO

Silleiro Buoy Temperature

Same situation for temperature, January and February temperature drops in excess in the direct discharge scenarios (Observed, LAMBDA_V1 and Climatology). During the extreme event all scenarios seems to perform relative well. The complete scenario is the one that recovers better the temperature while other scenarios are lower than observations.

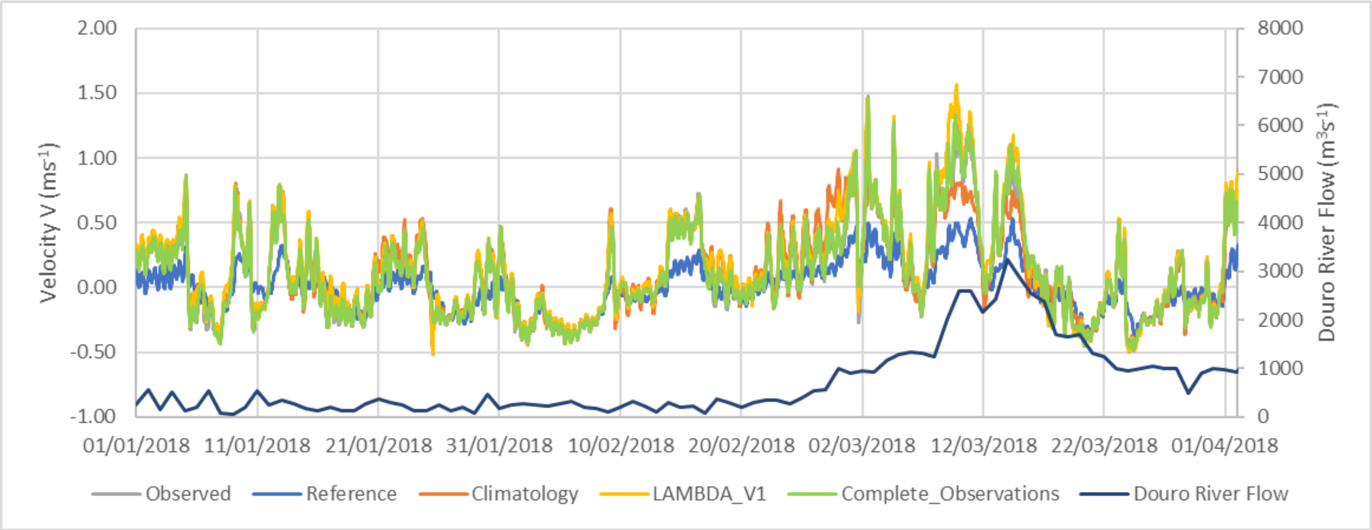


Observations kindly provided by Puertos del Estado

GOBIERNO DE ESPAÑA MINISTERIO DE FOMENTO

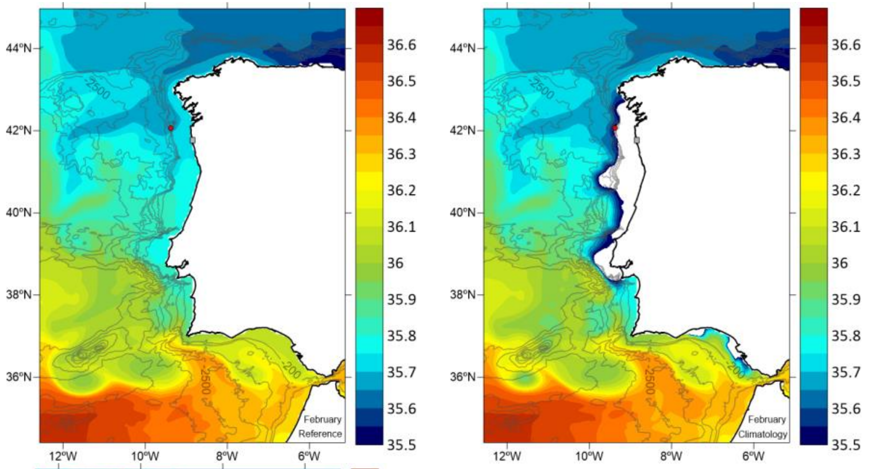
A Guarda Meridional velocity

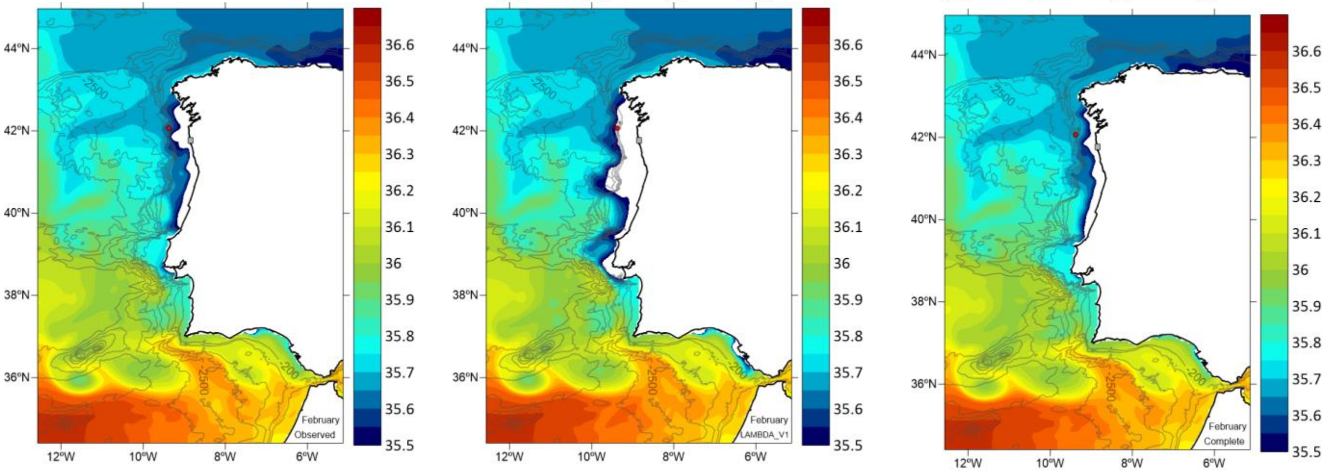
To highlight the impact of discharges in the hydrodynamics of the coastal area current velocities simulated were compared for the coastal location of A Guarda. Scenarios with high discharges can affect the velocity up to three times compared with velocities without river inputs. During the highest peak of velocities: the reference scenario reached values of 0.5 ms^{-1} while climatology stayed below 1 ms^{-1} and more realistic scenarios reached values of 1.5 ms^{-1}.



Salinity average for February 2018

During the month of February it can be observed that **Climatology** and **LAMBDA_V1 scenarios** have the highest extension of the WIBP. While in the **observed** and **complete** scenarios the impact seems is more reduced.

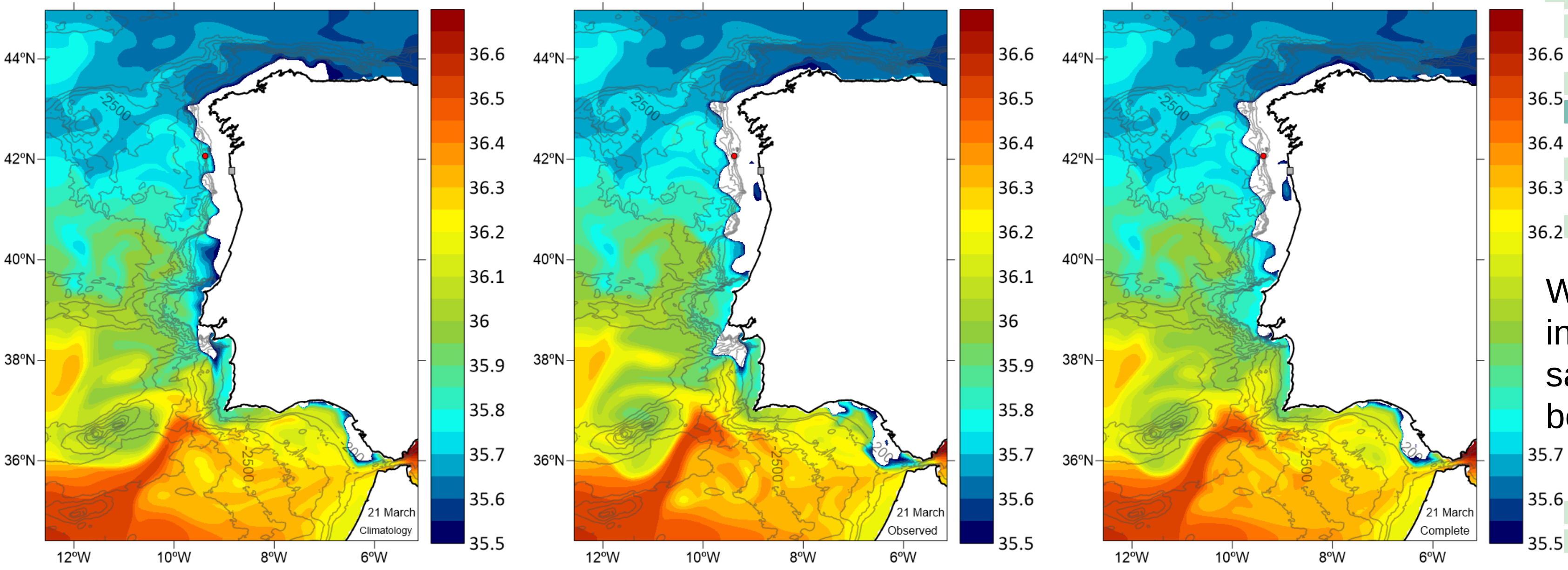




White areas indicates salinity below 35.5

Late March 2018 Extreme Event

During the peak of the extreme event, spatial pattens were different between simulated scenarios: **Climatology** (left) plume extends further to the north. The effect of the estuary proxy effect can be seen in the Tagus ROFI: **Observed** scenario where the Tagus discharge is direct (centre) has a larger plume when compared with the scenario including the estuarine proxy (**Complete** scenario right)

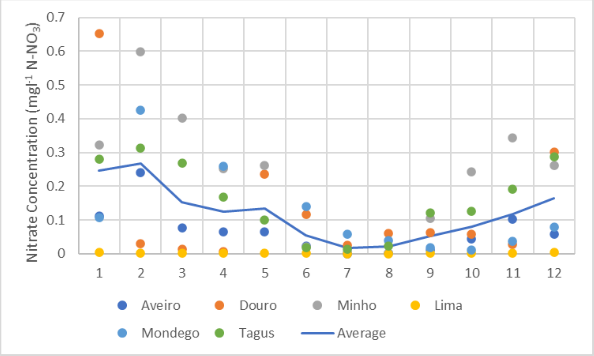


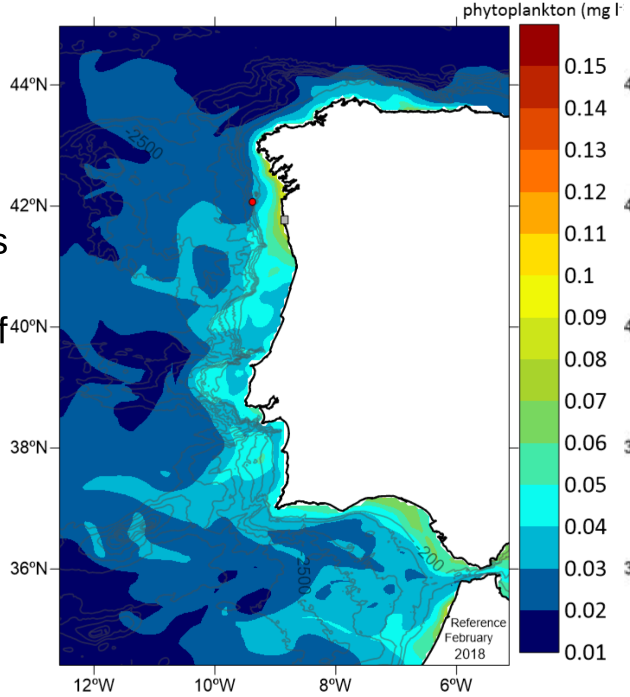
White areas indicates salinity below 35.5

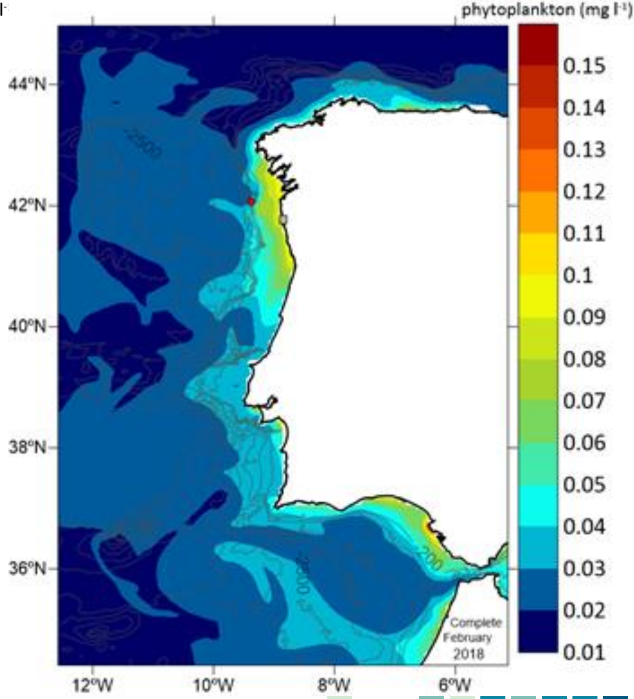
Impact on biogeochemistry

A monthly climatology for nitrate concentration were obtained from six modelled estuaries (Image below; Campuzano, 2018) and imposed in the land boundary conditions.

Phytoplankton surface concentrations during the wet season were higher in the northwest Iberia and in the Gulf of Cadis (right) compared with a non-discharge scenario (left).







Conclusions Numerical Modelling:

- A novel methodology for calculating the overall inputs to the coastal area, simulate its evolution in the estuary continuum and inserting the volume and properties dynamics in a regional model was developed and tested successfully.
- Numerical modelling is currently the only tool able to represent and estimate the temporal and spatial scale of the WIBP and other estuarine plumes.
- The present methodology can complete temporally, spatially and cover the data gaps provided by monitoring equipment and field surveys in fresh water, estuarine and ocean environment to produce forecasts.
- The set of numerical tools implemented in the LAMBDA project significantly improve salinity fields and aid to the delimitation of region of freshwater influence and salinity fronts which are relevant to coastal activities management.
- The estuarine proxy is a versatile tool that allows to estimate in a simple way the estuarine mixing and the contributions to the open ocean. The number of included estuaries is not limited, and their horizontal resolution is independent from the receiving model.
- The developed methodology is generic and could be set for any region using open source data and models.

Lambda SMOS SSS products

Three different SMOS SSS products have been considered in the project:

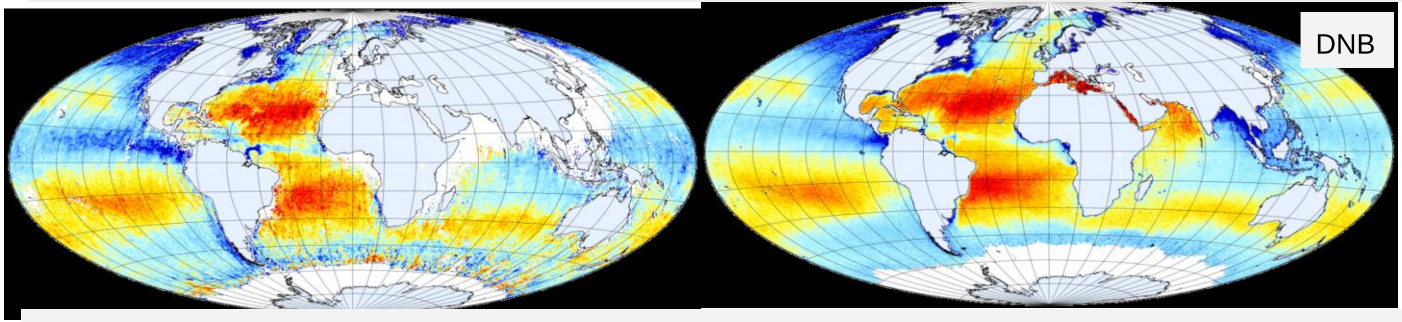
- **V0**: Product generated through ESA SMOS+MED project, it was the starting point of Lambda. Time coverage:2011-2016; spatial coverage: North Atlantic and Western Mediterranean; spatial resolution: 0.25ºx0.25º (Level 3) and 0.05ºx0.05º (Level 4)

- **V1**: We have generated a global SMOS SSS product addressing main issues in v0. Time coverage is 2011-2018; spatial coverage: global; spatial resolution 0.25ºx0.25º (Level 3).

- **V2**: We have generated a global SMOS SSS product addressing some pending issues in V1 and the feedback provided by the users in the workshop. Time coverage: 2011-2019; spatial coverage: global (not appropriate for semi-enclosed seas); spatial resolution: 0.25ºx0.25º (Level 3) and 0.05ºx0.05º (Level 4)

LAMBDA SMOS SSS development

In the recent years enhanced data processing algorithms have significantly increased the quality of the SMOS SSS products



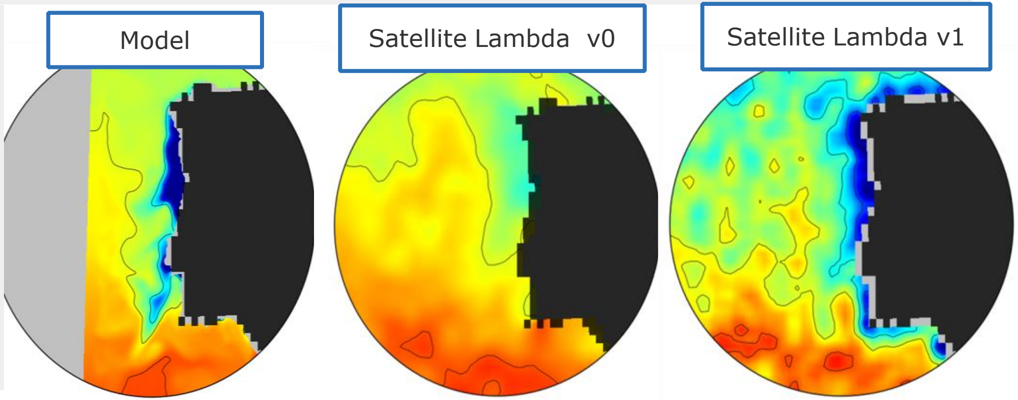
Debiased non-Bayesian salinity retrieval (DNB) (Olmedo, 2017, RSE) allows better coverage and lower error everywhere but especially close to the coast

	DNB	DINEOF	Filter	Improved interpolation	Corrected latitudinal seasonal bias	Corrected Coastal bias	Downscaling
V0	YES	YES	NO	NO	NO	NO	YES
V1	YES	NO	YES	YES	YES	NO	NO
V2	YES	NO	YES	YES	YES	YES	YES

LAMBDA SMOS SSS development (V1)

LAMBDA SMOS SSS V0 (Olmedo 2018, RS) provided good performances in the large scale, but close to the coast it displayed low variability.

LAMBDA SMOS SSS v1: filtering criteria according to geophysical variability and removed smooth interpolation schemes

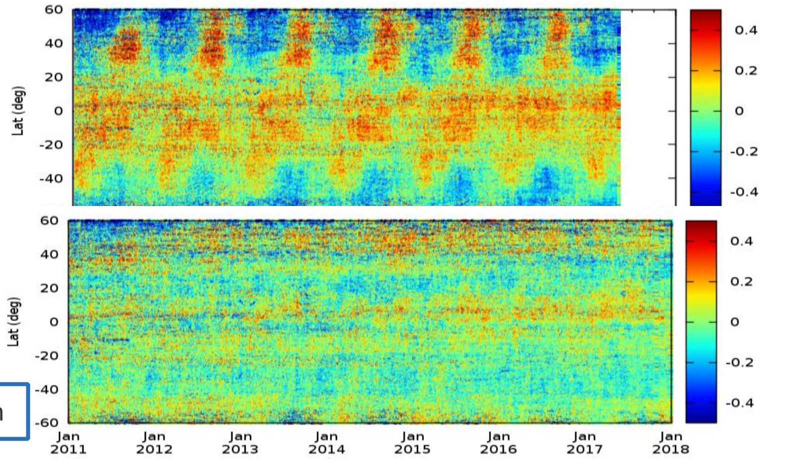


	DNB	DINEOF	Filter	Improved interpolation	Corrected latitudinal seasonal bias	Corrected Coastal bias	Downscalin g
V0	YES	YES	NO	NO	NO	NO	YES
V1	YES	NO	YES	YES	YES	NO	NO
V2	YES	NO	YES	YES	YES	YES	YES

LAMBDA SMOS SSS development (V1)

LAMBDA SMOS SSS V1: All the satellite SSS products are affected by latitudinal and seasonal bias. We have characterized and empirically corrected this bias (Olmedo,2019,IGARSS)

Hovmoller diagrams: SMOS SSS - Argo salinity

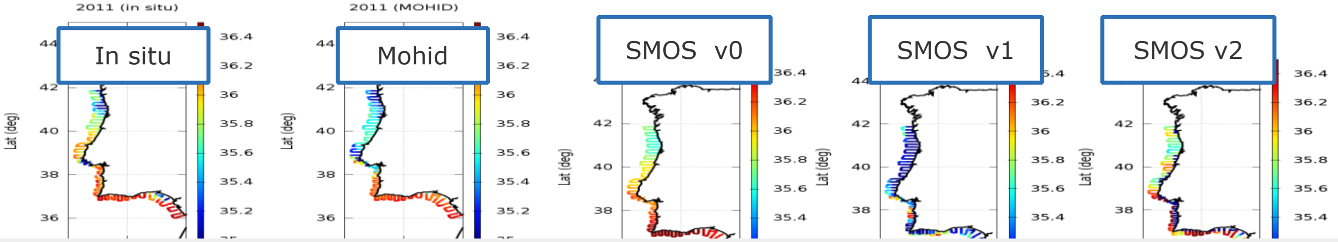


After correction

	DNB	DINEOF	Filter	Improved interpolation	Corrected latitudinal seasonal bias	Corrected Coastal bias	Downscaling
V0	YES	YES	NO	NO	NO	NO	YES
V1	YES	NO	YES	YES	YES	NO	NO
V2	YES	NO	YES	YES	YES	YES	YES

LAMBDA SMOS SSS development (V2)

LAMBDA SMOS SSS V1 shows more salinity variability close to the coast than V0 does, but also a larger bias in the pixels closest to the coast

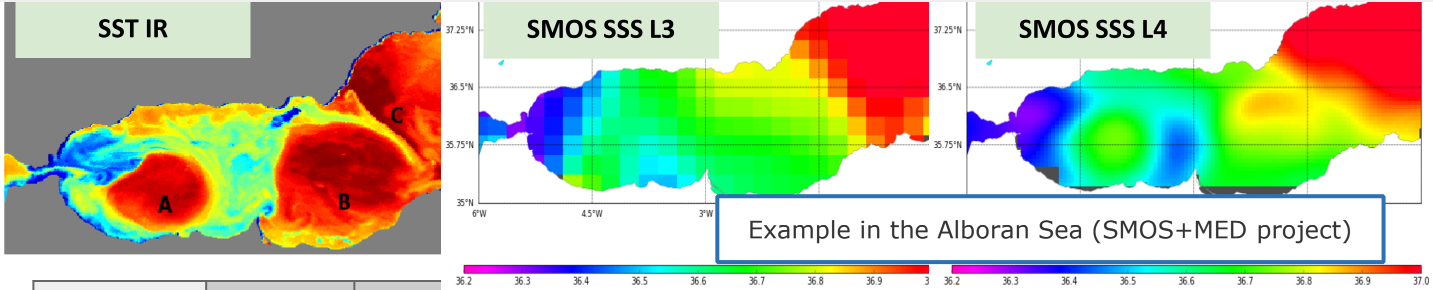


The large bias in those pixels closest to coasts is due to a poor characterization of the systematic biases in regions of larger salinity variability. **We have characterized and corrected these biases in LAMBDA SMOS SSS V2**

	DNB	DINEOF	Filter	Improved interpolation	Corrected latitudinal seasonal bias	Corrected Coastal bias	Downscaling
V0	YES	YES	NO	NO	NO	NO	YES
V1	YES	NO	YES	YES	YES	NO	NO
V2	YES	NO	YES	YES	YES	YES	YES

LAMBDA SMOS SSS development (V2)

Increasing the spatial resolution was a requirement pointed out at the Lambda project user workshop. We have addressed it using fusion techniques to merge SMOS SSS at 0.25ºx0.25º with OSTIA SST at 0.05ºx0.05º.These techniques have been demonstrated in the ESA SMOS+ MED project (Olmedo, 2018, RS) and globally (Olmedo, 2016, RSE).



Example in the Alboran Sea (SMOS+MED project)

	DNB	DINEOF	Filter	Improved interpolation	Corrected Latitudinal seasonal bias	Corrected coastal bias	Downscalin g
V0	YES	YES	NO	NO	NO	NO	YES
V1	YES	NO	YES	YES	YES	NO	NO
V2	YES	NO	YES	YES	YES	YES	YES

Global quality assessment

We have considered the year 2016 and we have compared our SSS product with:

- Argo floats
- Satellite products: SMOS CATDS (v3), SMAP REMSS (v3-40km), SMAP JPL (v4.2)
- CMEMS: ARMOR3D NRT CMEMS V4

Methods for validation:

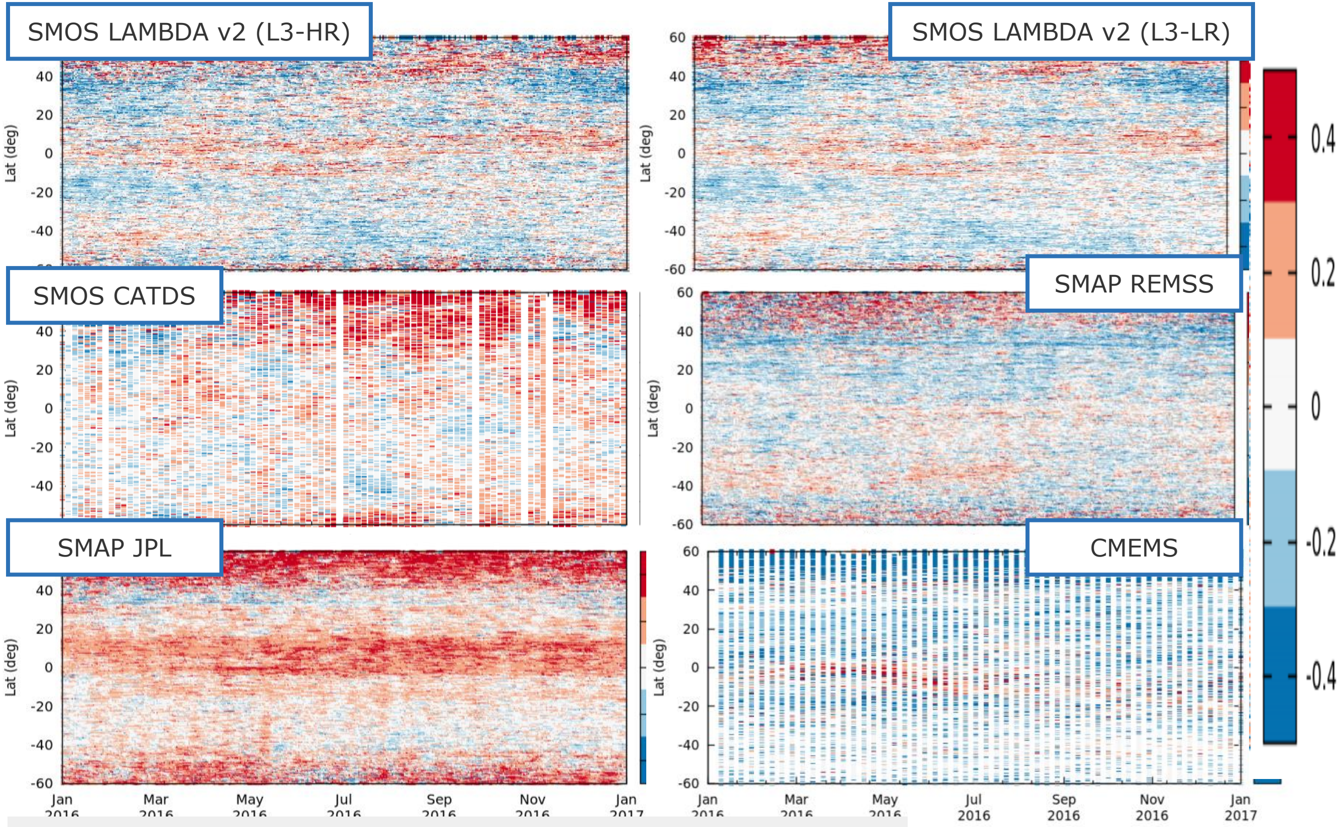
- Self consistency statistics
- **Statistics wrt Argo floats**
- Power spectra
- Singularity analysis
- **Triple collocation**

We are preparing a paper to be submitted to Earth System Science Data

We compare the two L3 SMOS SSS fields generated:

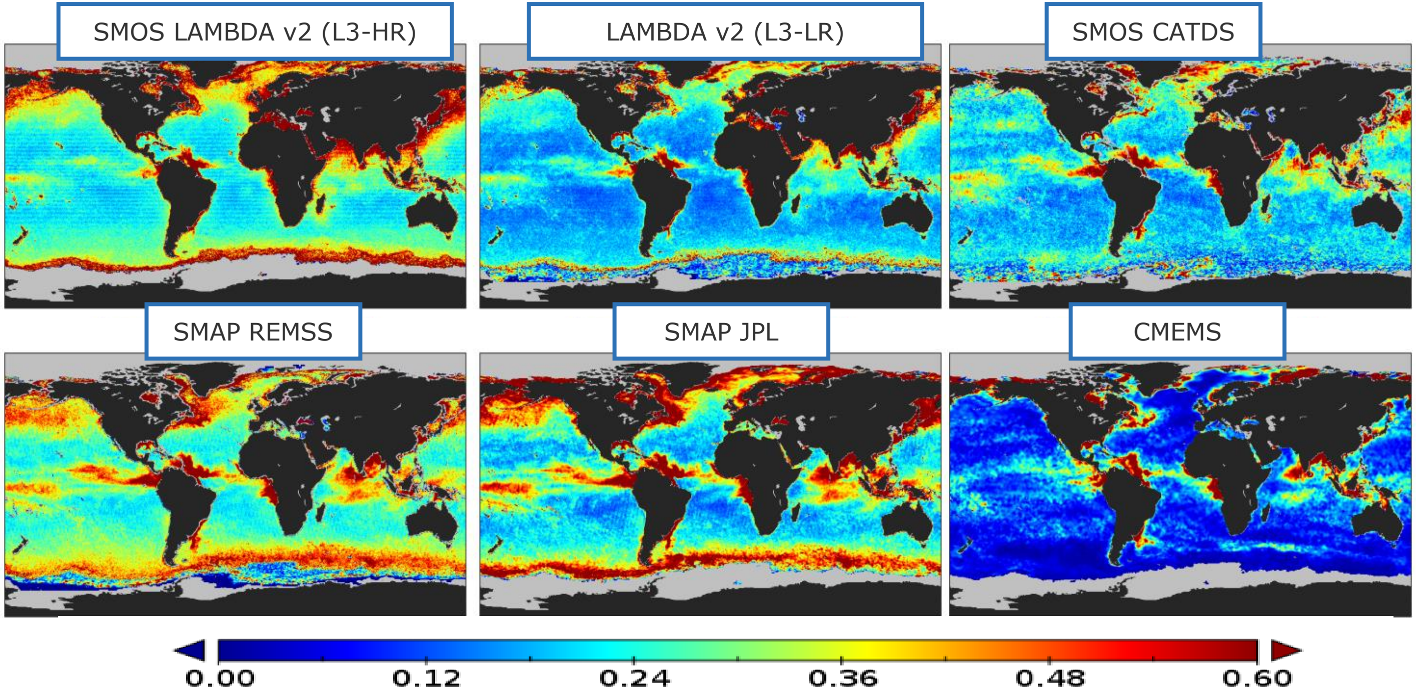
- SMOS LAMBDA v2 (L3-HR): weighted average binning
- SMOS LAMBDA v2 (L3-LR): low pass filter of radius 50km

Global Latitudinal bias: average of product-Argo salinity in 0.25º latitude bands



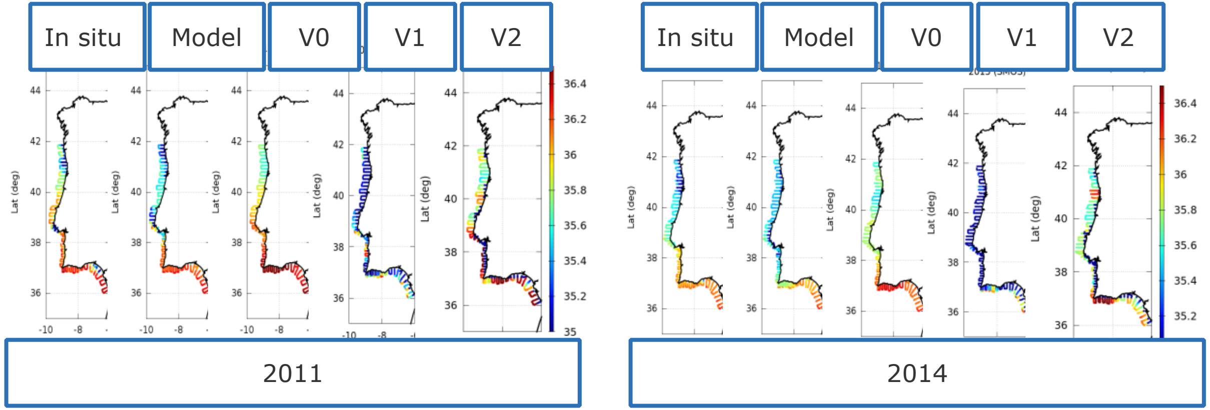
Good performance in terms of biases w.r.t Argo floats.

Triple collocation: SSS uncertainty estimation



We use a new triple collocation technique that allows having two correlated error sources (González-Gambau,RSE, submitted).
Good performance in terms of estimated uncertainty salinity error.

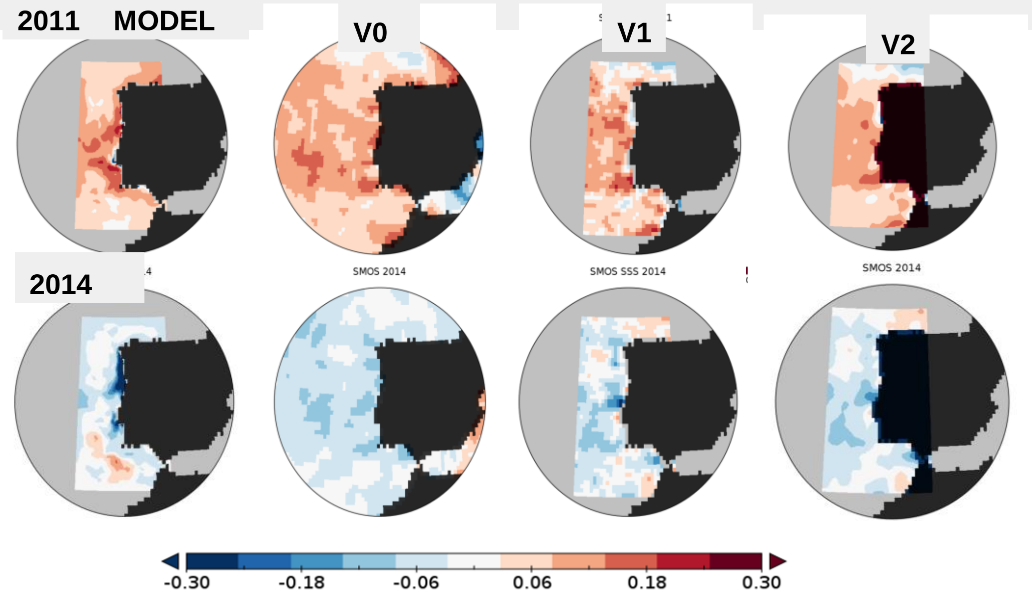
Coastal assessment: Comparison with *in situ* data



	2011			2014		
	Mean	std	cor.	Mean	std	cor.
Model	-0.04	0.69	0.50	-0.10	0.35	0.63
V0	0.31	0.69	0.46	0.20	0.33	0.68
V1	-0.11	2.07	0.32	-0.15	0.79	0.42
V2	0.28	0.69	0.46	0.21	0.48	0.32

Coastal quality assessment: Inter annual variability

Annual Sea Surface Salinity anomaly: positive (negative) salinity anomaly values indicate saltier (fresher) values with respect the mean value in period 2011-2015.

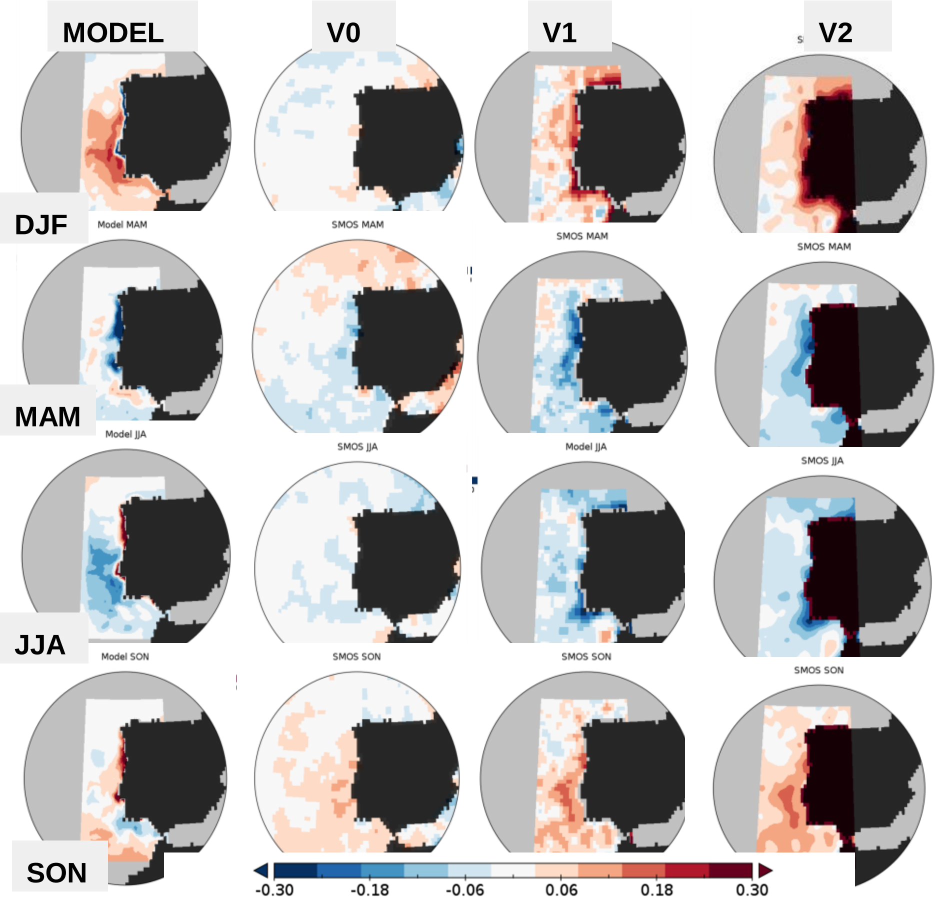


Sea surface salinity anomaly values show inter annual consistency with model.

Coastal quality assessment: Seasonal variability

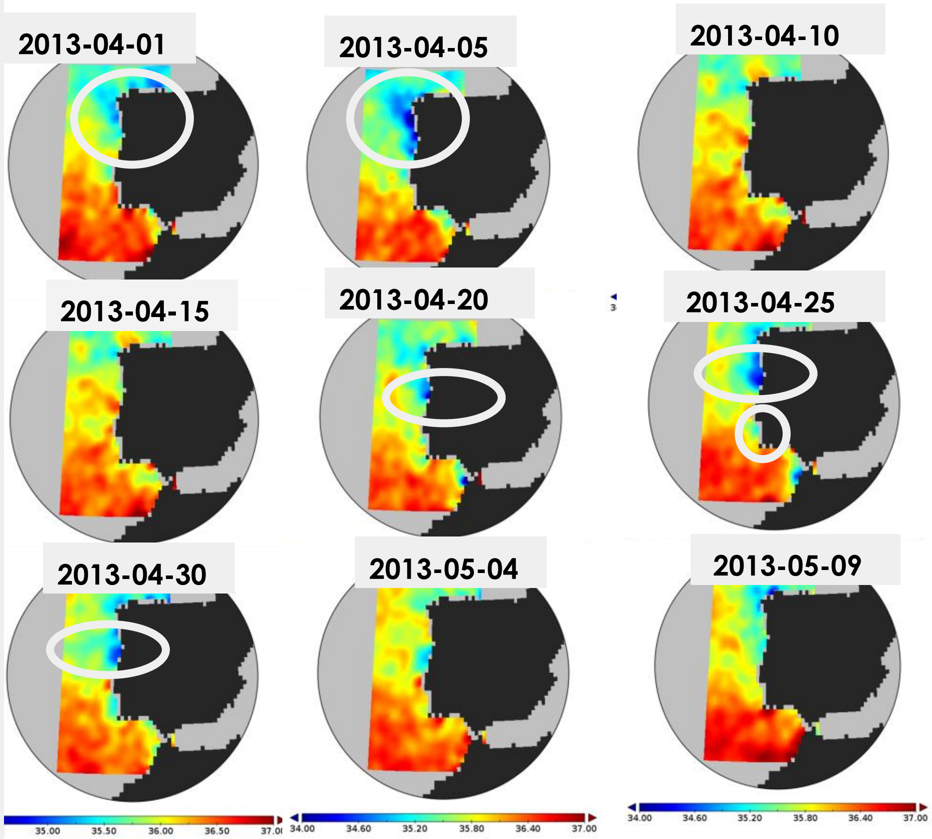
Seasonal Sea Surface Salinity anomaly using the period 2011-2015

The seasonal variations of the salinity are consistent with the model: in spring (MAM) close to the Douro mouth a fresh salinity anomaly is observed corresponding to the Douro plume and the corresponding water dispersion.



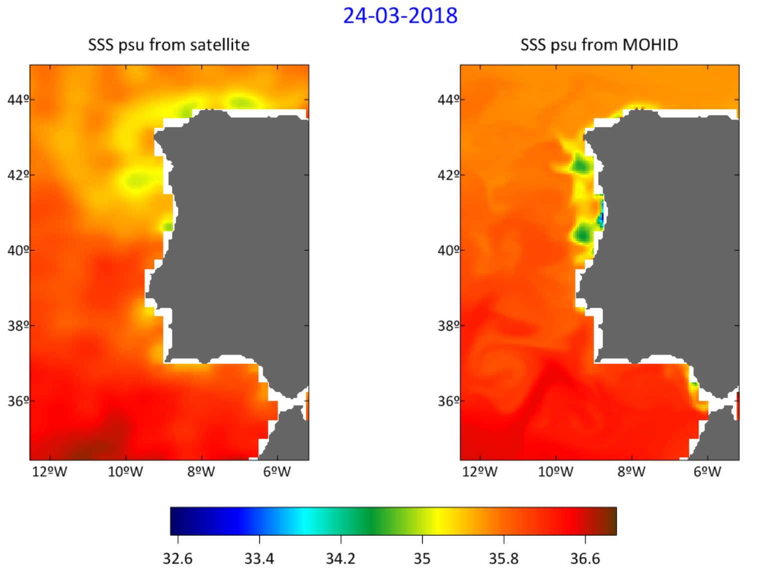
Coastal quality assessment: extreme event (V2)

On early spring of 2013, a severe rain event affected the Western Iberian territory.
The first days of April, the northern part of the basin appear fresher values of salinity.
The 20th of April the plume of the Douro starts growing and reaches its maximum the 25th.
Also fresher salinity values appear in the Tagus mouth but with saltier values of salinity than in the case of the Douro River



LAMBDA EO & Modelling Comparison

Finally, modelling results were compared with EO salinity derived products developed in the context of the LAMBDA project. The results obtained during the extreme event of late March 2018 indicate that both methods, EO and numerical modelling, present similar spatial structures and intensities which is an important advance since validation with EO salinity was uncommon in coastal areas.



Conclusions – LAMBDA EO

We have generated **9 years of a new SMOS SSS global product (2011-2019):**

- **Global assessment of the product** shows that the new product has good performances in comparison with Argo floats and other satellite products
- The **coastal assessment** shows that:
  - The residual bias in the coastal pixel present in V1 has been significantly mitigated in V2
  - **Better description of coastal salinity dynamics** in v2 than in v0
    - Seasonal and annual anomalies are consistent with modelling results
    - new satellite product seems to better describe the plumes of the main rivers of the basin

Future work:

Improving fusion techniques by using Sentinel images for increasing the spatial resolution of the EO satellite products close to the coasts

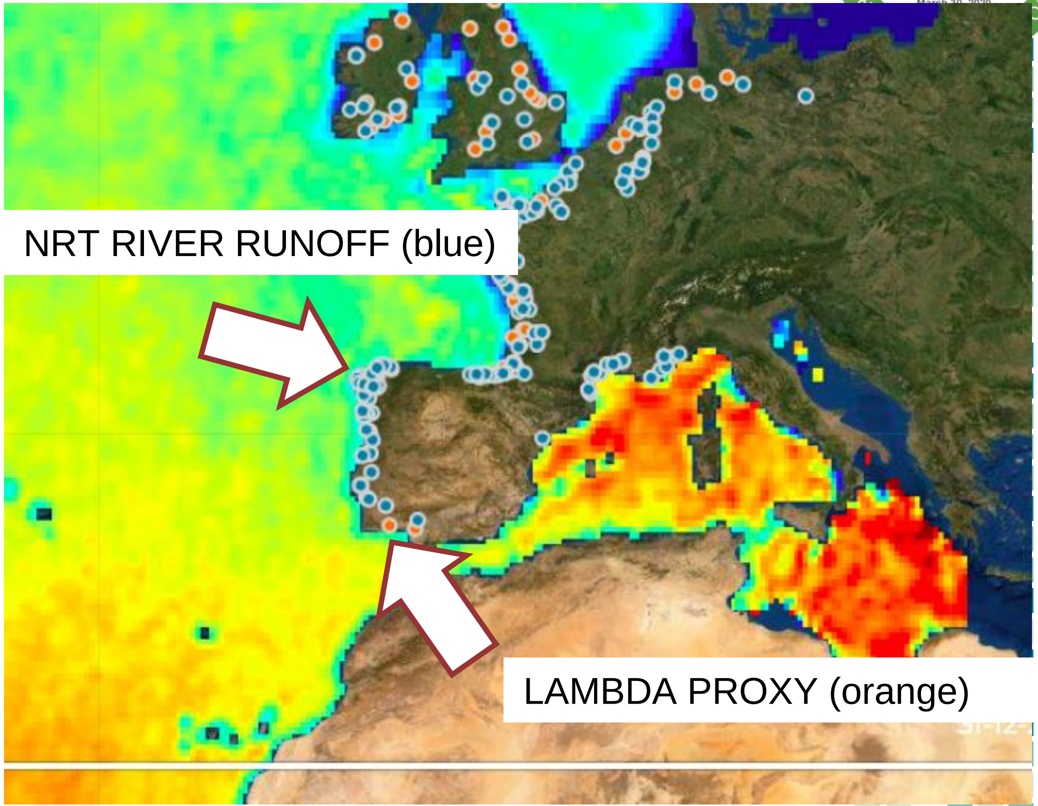
LAMBDA Map Viewer Service

LAMBDA Map V.2.0 http://www.cmems-lambda.eu/mapviewer

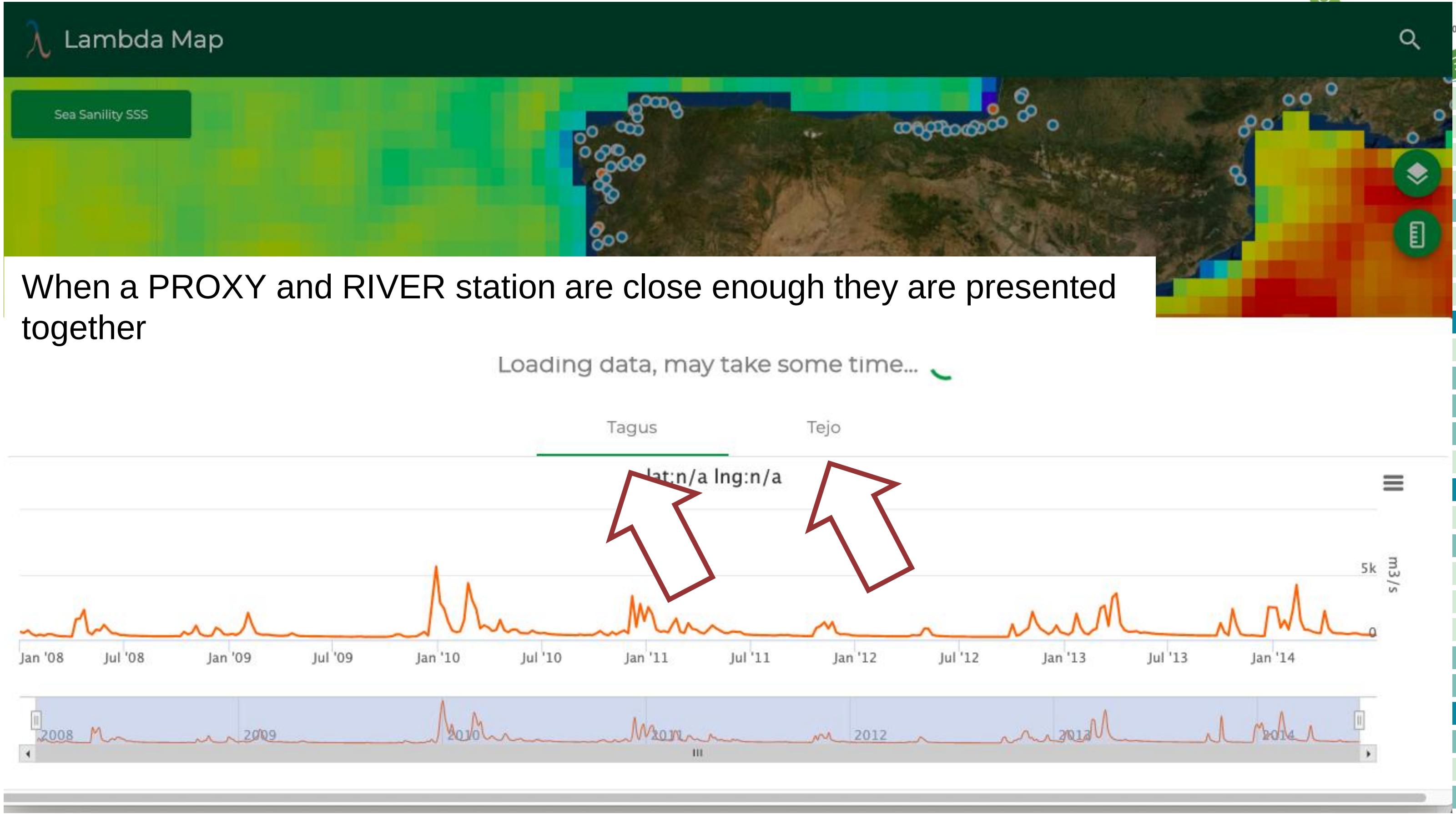
- Single point of access to the developed products and user interface to work and interact with the products
- Default view with LAMBDA SSS (SMOS), LAMBDA PROXY V.1.0, NRT RIVER RUNOFF
- Available products:
  - lambda proxy v.1.0,
  - *in situ* NRT river runoff
  - LAMBDA SSS (SMOS)
  - *in situ* psal
  - CMEMS IBI reanalysis phys 005 002

LAMBDA Map Viewer Service

The LAMBDA project map viewer allows to explore and compare the modelling and EO products generated during the project with existing *in situ* data along the water continuum (river flow, salinity observations, etc) and other CMEMS modelling products (i.e. IBI). Some features can be seen in next slides.

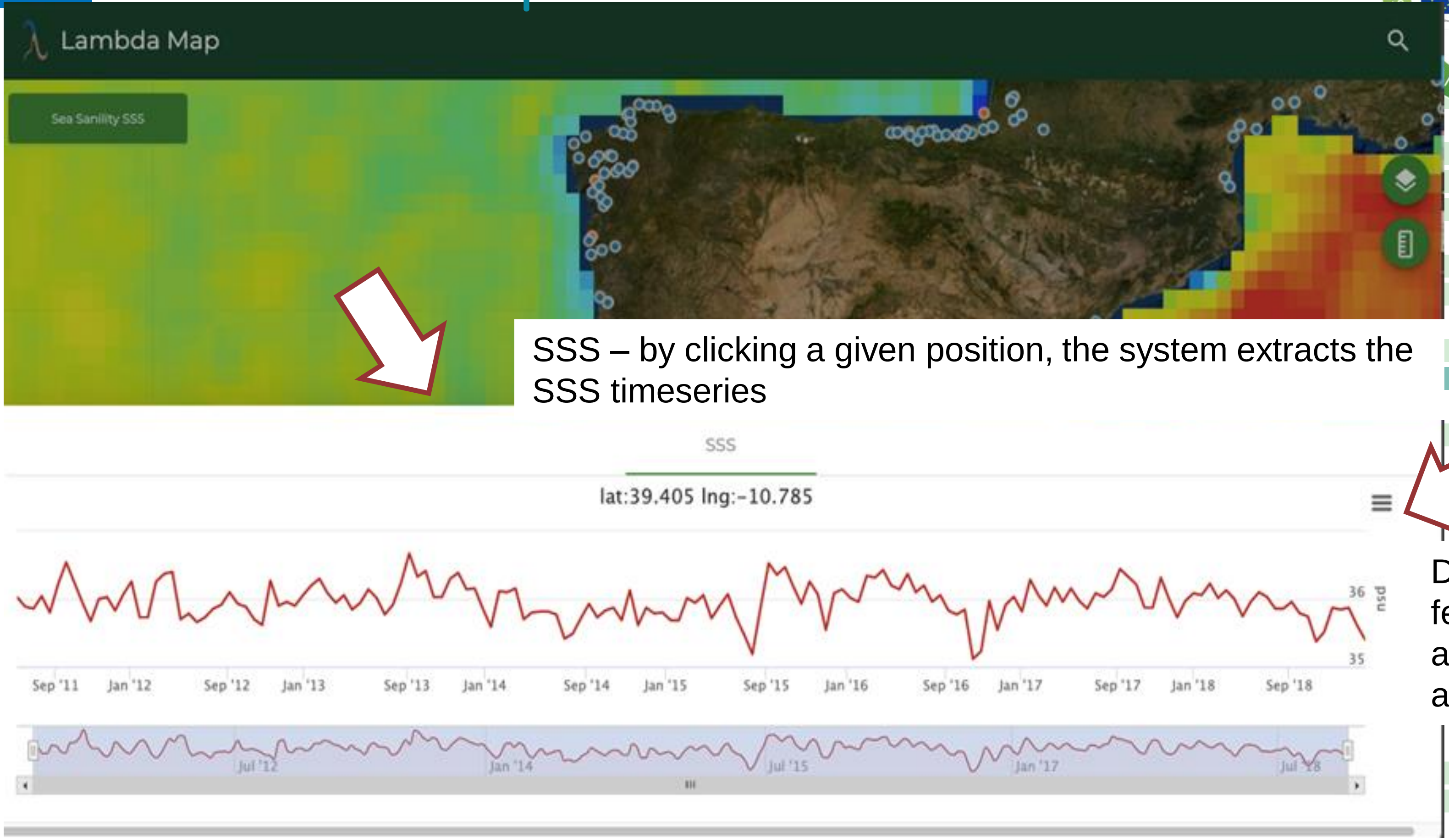


LAMBDA Map Viewer Service



When a PROXY and RIVER station are close enough they are presented together

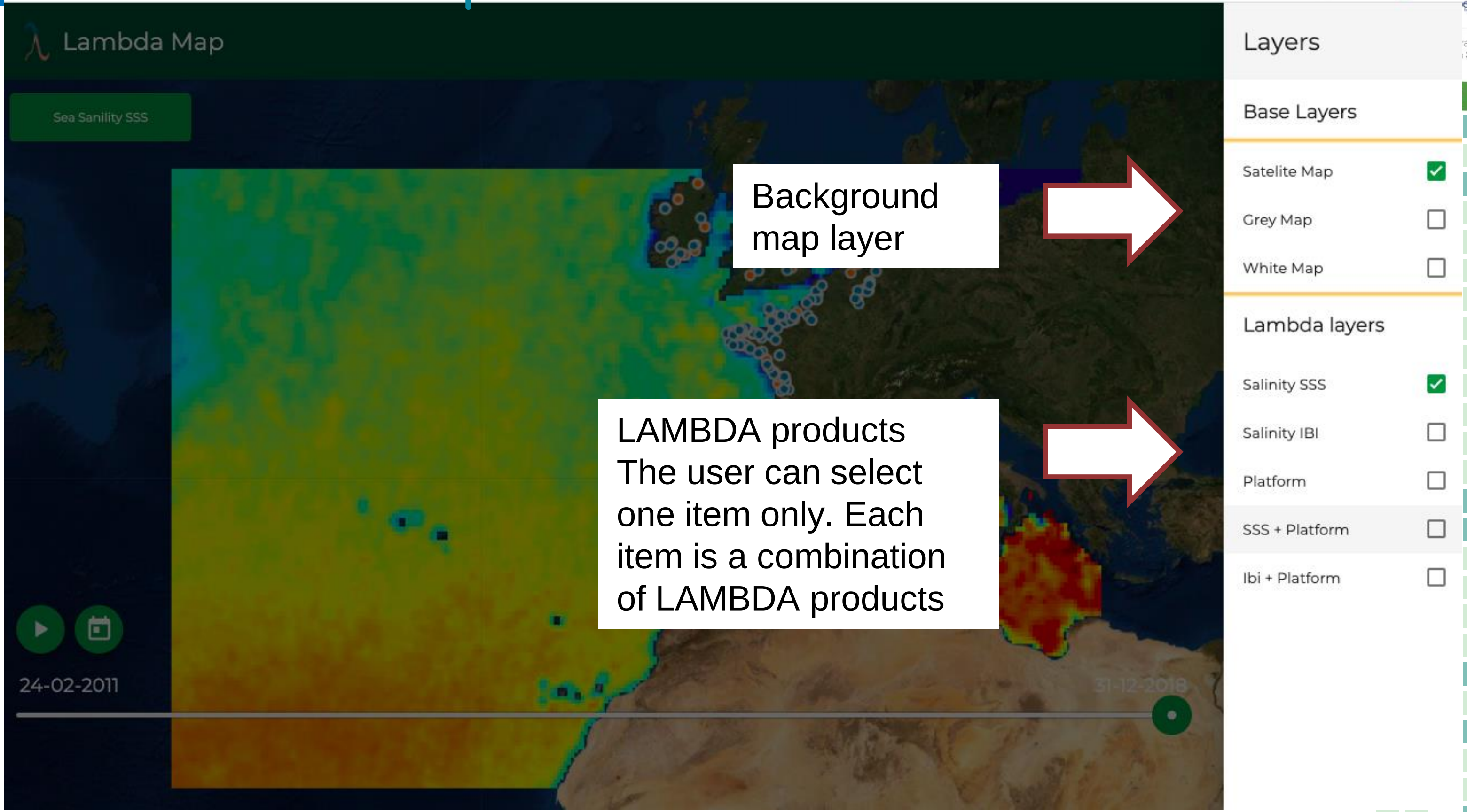
LAMBDA Map Viewer Service

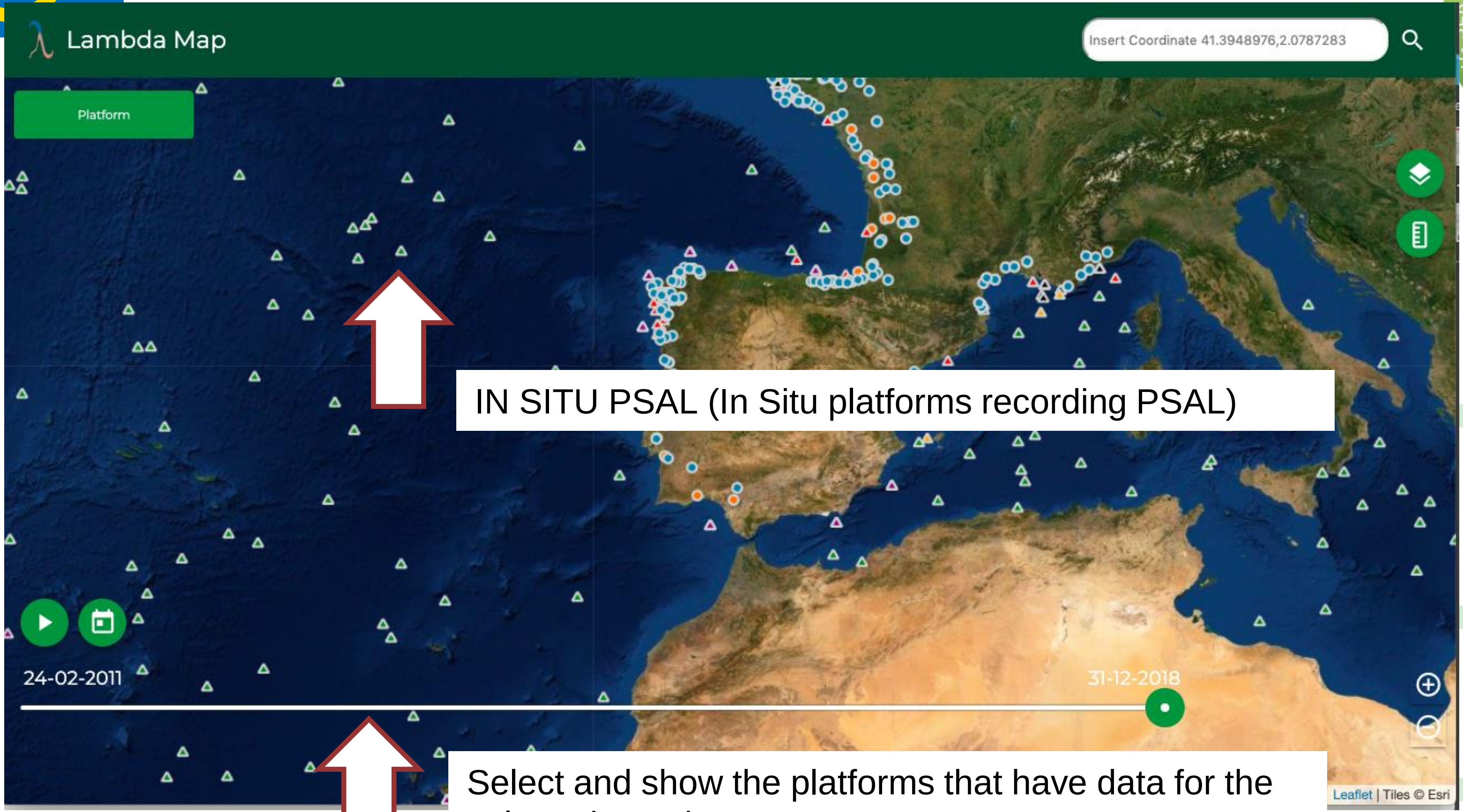


SSS – by clicking a given position, the system extracts the SSS timeseries

Download features always avaialble

LAMBDA Map Viewer Service

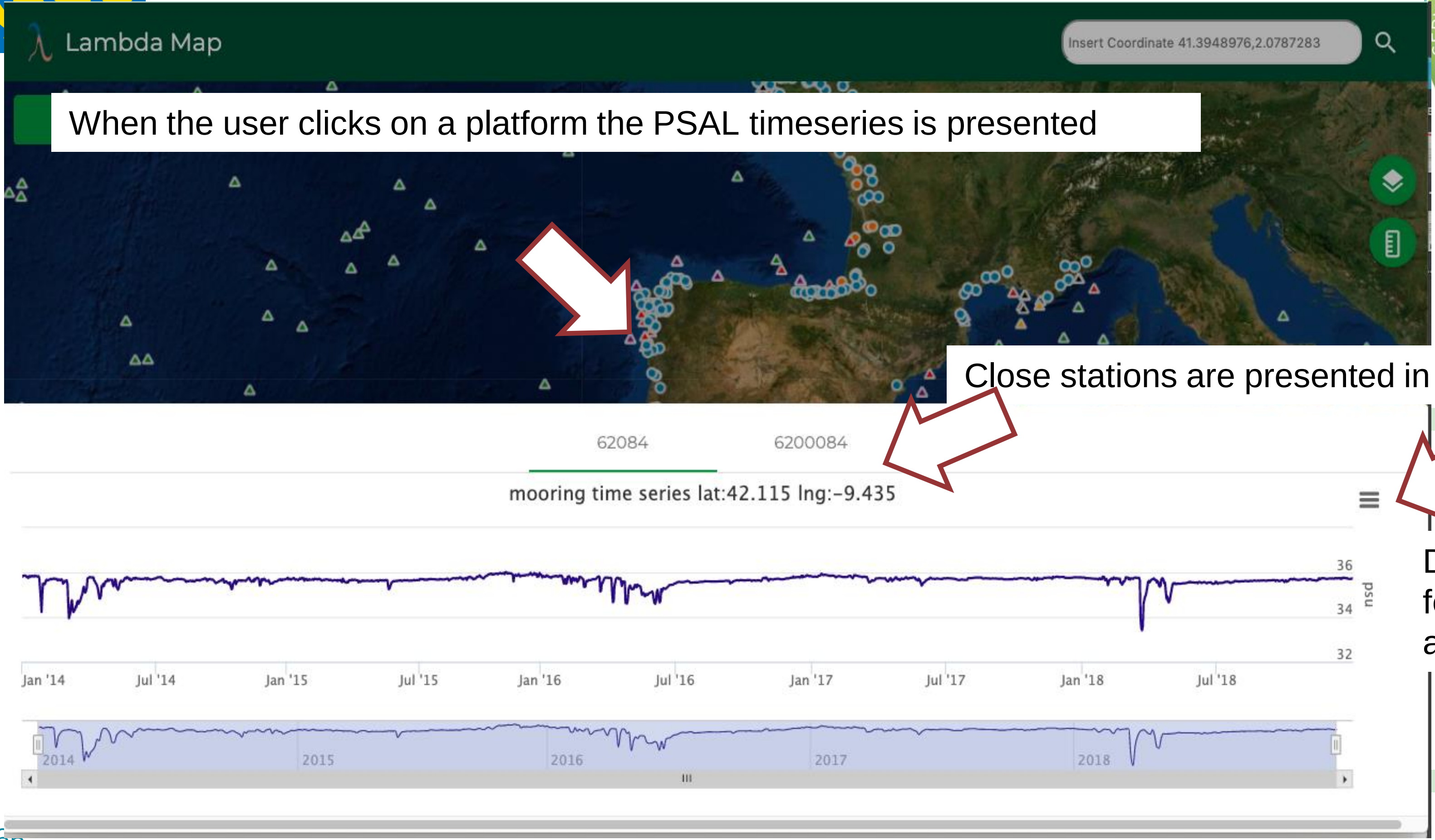




IN SITU PSAL (In Situ platforms recording PSAL)

Select and show the platforms that have data for the selected month

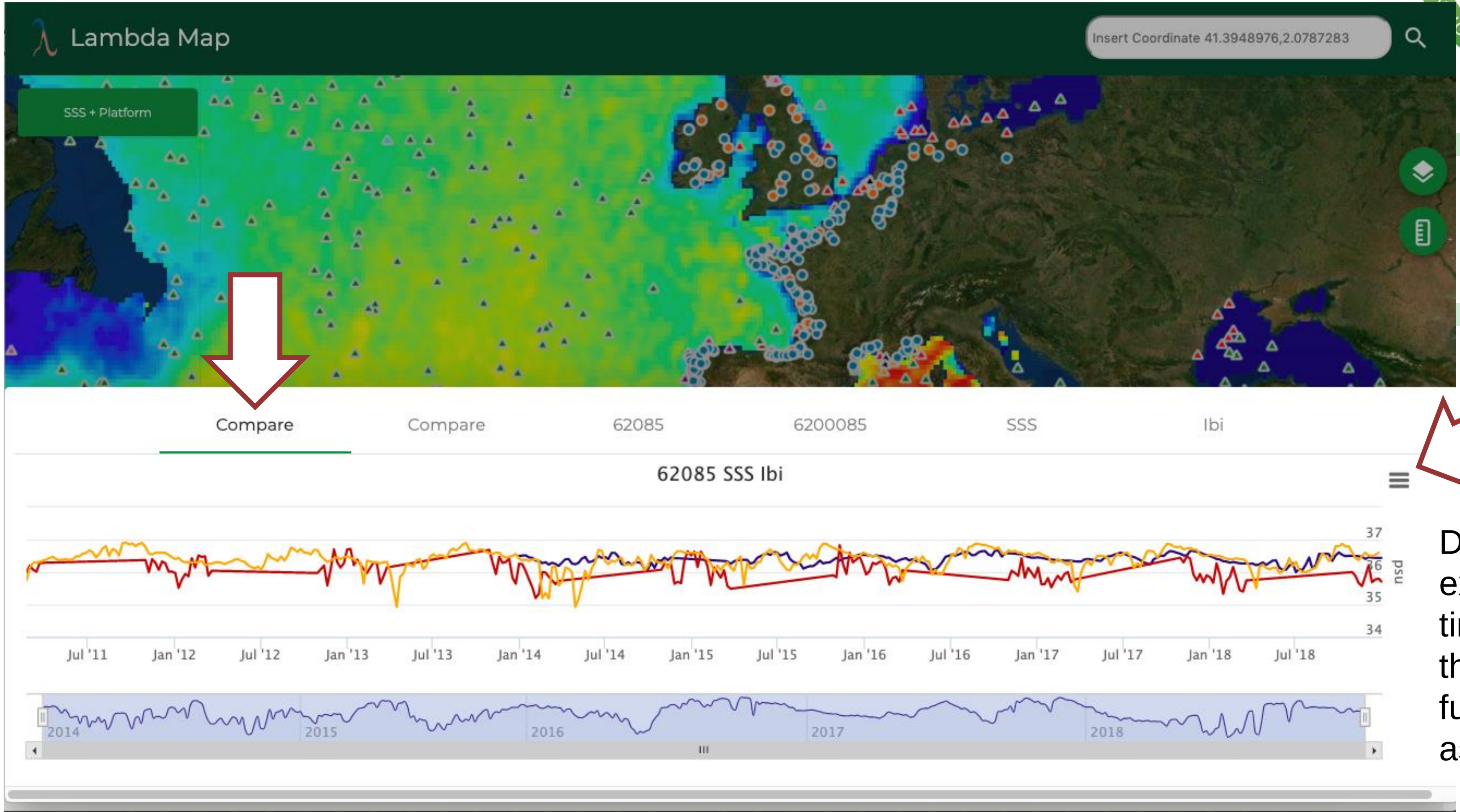
When the user clicks on a platform the PSAL timeseries is presented



Close stations are presented in tabs

Download features always avaialble

Products comparison



Download let to export all the timeseries in the panel for further assessments

THANKS!

Any questions?

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