Coastal Digital Twins: building knowledge through numerical models and IT tools

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Outline

- Context
- Coastal Digital Twins:
  - concept
  - a vision for all uses and all users
- Data challenges and their role in digital twins
- The role of on-demand forecast services
- OPENCoastS+ service:
  - A new paradigm in coastal forecasting to empower users
  - Navigating in the 3 pillars: configuration assistant, forecast manager, viewer
- Challenges ahead: the road for reliable, accurate and user-friendly Digital Twins

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Societal needs

- Anticipate contamination events and support emergency actions
- Support water economy daily tasks and leisure & recreation
- Guide management to minimize risks and address conflicting uses in coastal areas

Coastal Digital Twins:
user-centered, on-demand framework for decentralized ocean-to-coast knowledge creation through modeling, forecasting, data analysis and service provisioning

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Coastal digital twins: the concept

- Forecast systems/platforms (even with data assimilation) are not digital twins!
- Multiple automatic services are needed: forecasting, scenario evaluation, information creation and sharing

- 3 “thematic” pillars: data, models, users!
- 3 enabling pillars: coastal researchers, IT experts and infrastructures resources

- Integrating data and simulations
- Allowing for user interaction, sharing and creating knowledge
- Platform for collaborative coastal management

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Coastal digital twins: LNEC's vision

Managers

Companies

Researchers

Public

....

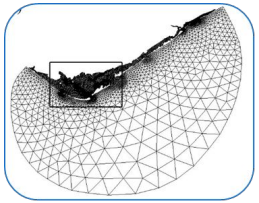
Addressing societal needs

Digital infrastructures

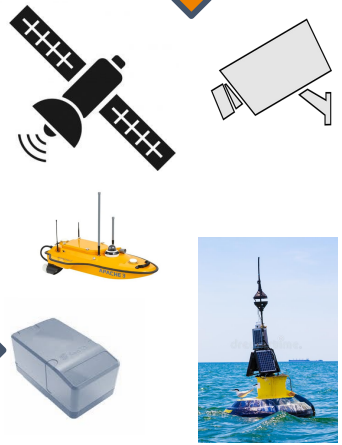
OPENCoastS

WORSICA

User-centered services



Models



Data sources

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2021 2030 United Nations Decade of Ocean Science for Sustainable Development

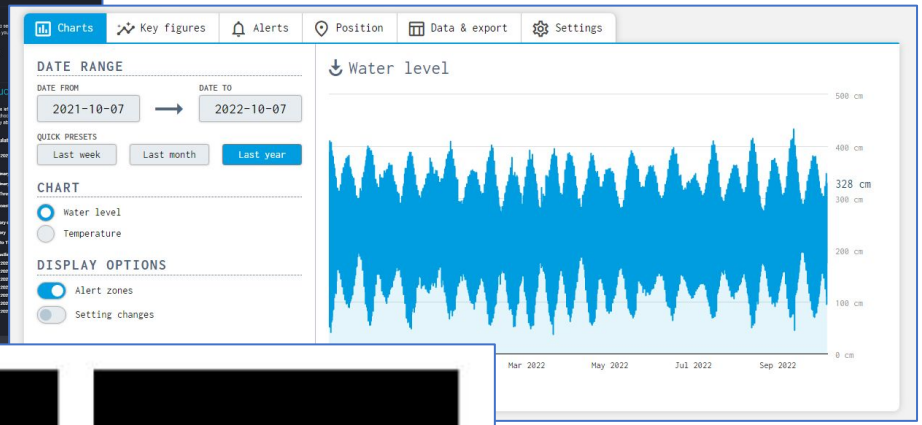
ESMF

Challenge of managing and combining multiple, large streams of data

- Huge online volume of data streams provided by satellites, IoT sensing and many real time surveillance platforms

Worsica service: Satellite data processing

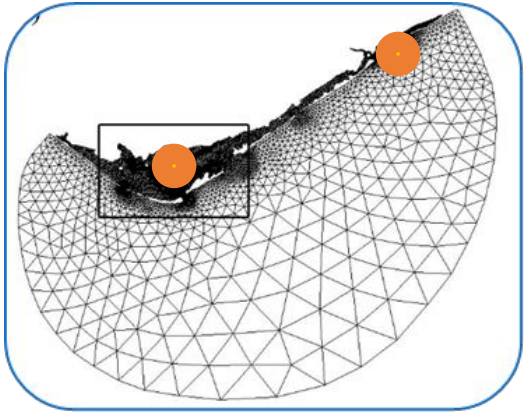
Low cost sensors data



Low cost camera data processing

How to go from data to knowledge creation?

- Handling multiple data sources: the challenge of data assimilation procedures and methods in the coastal zone
- FAIR compliance and adhering to standards: need to provide training to researchers and data generators; need to establish easy-to-use FAIR assessment softwares (EOSC-Synergy)
- Linking data and model information: handling different scales and resolutions
- Data quality:
  - dealing with multiple types of faults (outliers, drifts, …) from multiple sources (sensors, transmission, integration in data lake,...)
  - Fault detection and correction in real time in an automatic way



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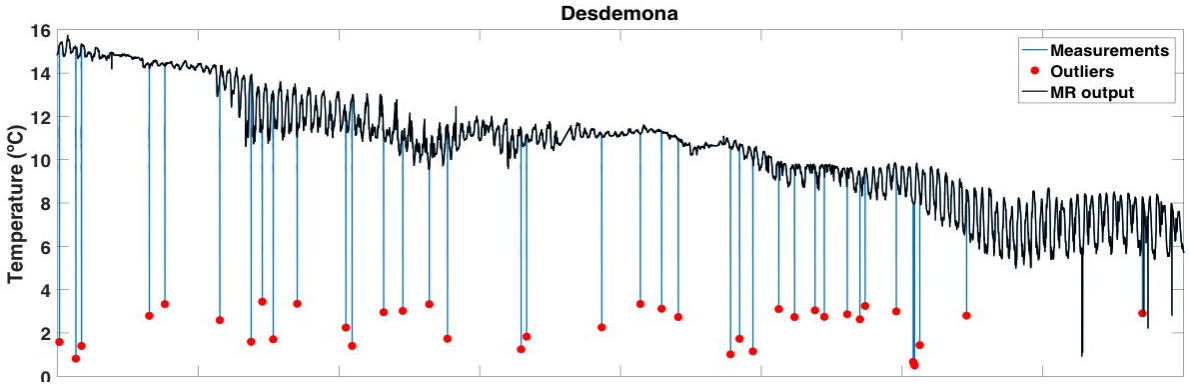
Automatic data quality assessment and reliability

- On-the-fly detection of outliers, drifts and other faults
- Jesus et al (2021) dependability framework using multi sensor fusion for aquatic monitoring systems: use of machine learning on top of data and model results



From Jesus et al., 2021

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The role of relocatable (applicable anywhere) forecast systems in CDT

- Capacity to anticipate coastal system dynamics for circulation, sediment dynamics, water quality, biogeochemistry
- High resolution information in space and time
- Facility to address “what-if”, CC and management scenarios
- Continuous increase in coastal knowledge, numerical modeling and computational resources has produced very accurate and reliable tools

  However:
- Forecast systems are complex to maintain and improve
- Concept of on-demand forecasting as a service - **OPENCoastS**
  - to centralize development, execution and maintenance of forecast systems
  - Make forecast system building available to all

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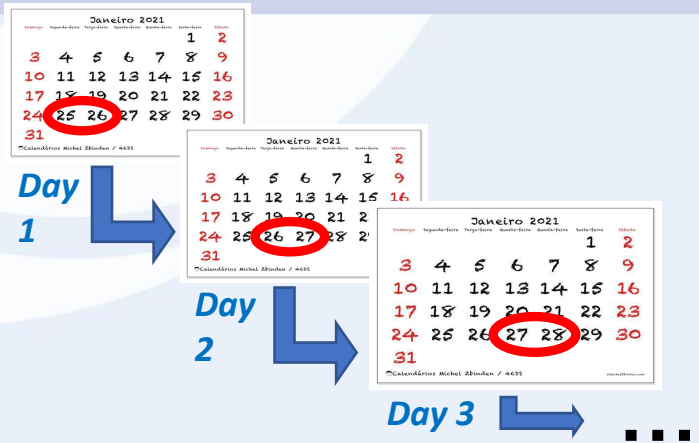
Forecast systems @ the core of Coastal Digital Twins

Forcings

Prediction simulations

Post-processing, archiving and visualization

Comparison with real time data



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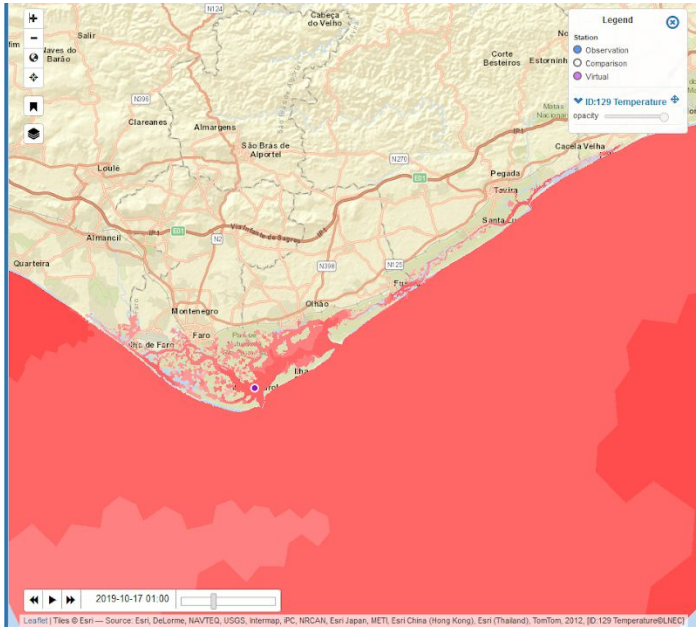
OPENCoastS in a nutshell

It assembles on-demand coastal forecast systems for selected coastal areas and generates daily forecasts of water levels, wave parameters, 2D and 3D velocities, and 3D salinities, temperatures and water quality variables over the region of interest for 48 hours, based on numerical simulations of all relevant physical and biogeochemical processes



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a new paradigm in coastal forecasting to empower users

A service to:

- Make the implementation of coastal forecasts fast and easy:

  build forecast systems for a location chosen by the user, using a browser-based user-friendly, interface
- Make the service flexible in its configuration:

  forcings, processes and model parameters
- Flexible IT architecture that can grow to additional processes
- Take advantage of the EOSC infrastructure and core-services to provide the required computational resources

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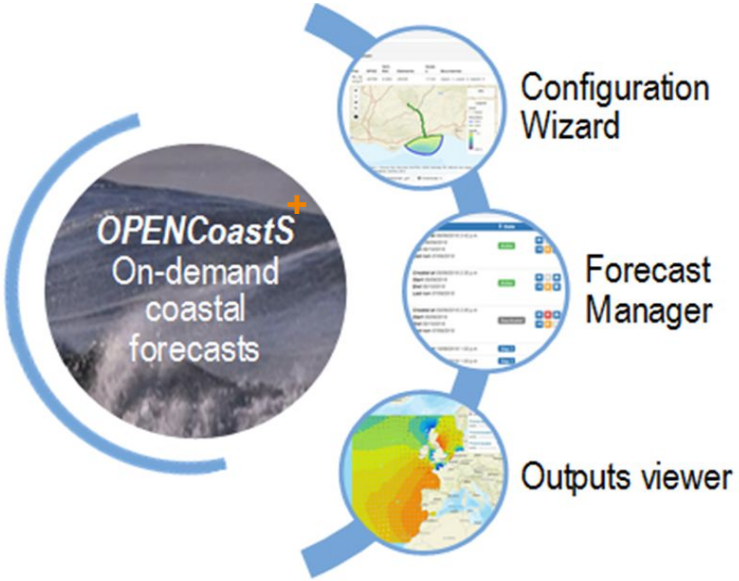
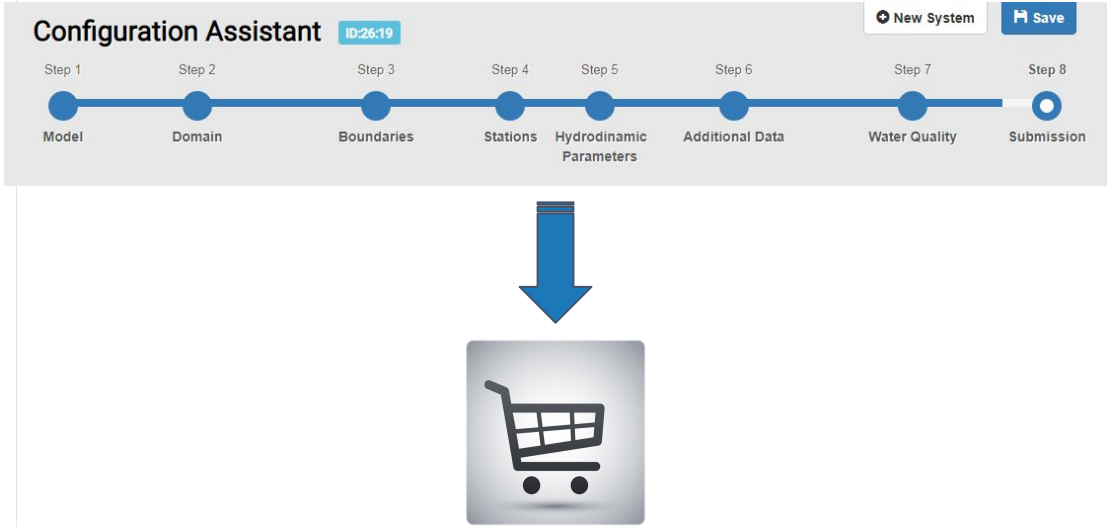
Navigating in the 3 pillars: user-centered approach





- One-stop-shop for all forecast activities
- Optional choices on every step

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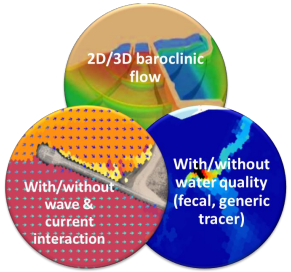
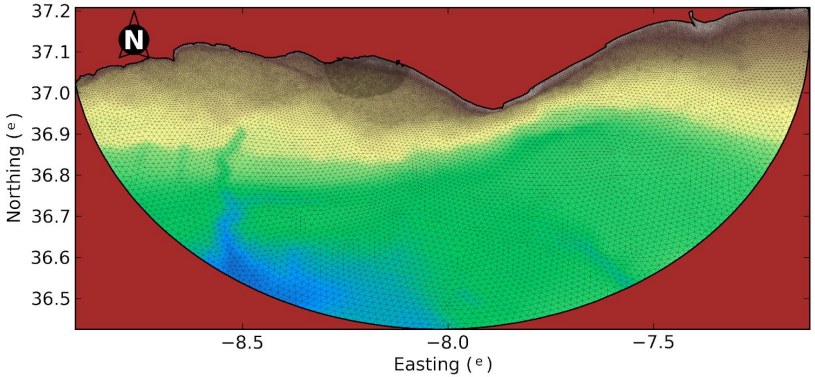
Navigating in the 3 pillars: configuration assistant



SCHISM

2D/3D/
W&C/quality



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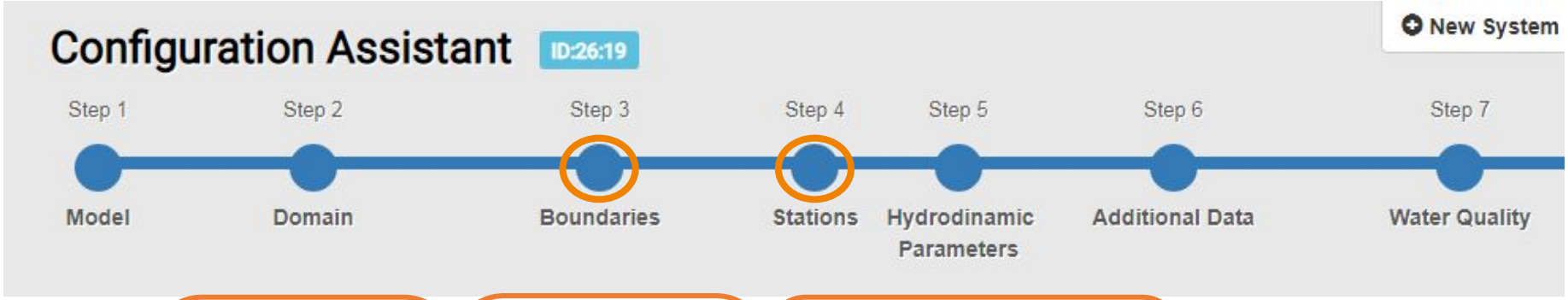
Navigating in the 3 pillars: configuration assistant



meteogalicia

METEO FRANCE

GFS Global Forecast System

FES2014 TIDE

Copernicus Marine Service

WAVEWATCH III

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EMODnet European Marine Observation and Data Network

Automatic detection of stations inside domain

Setup of virtual stations

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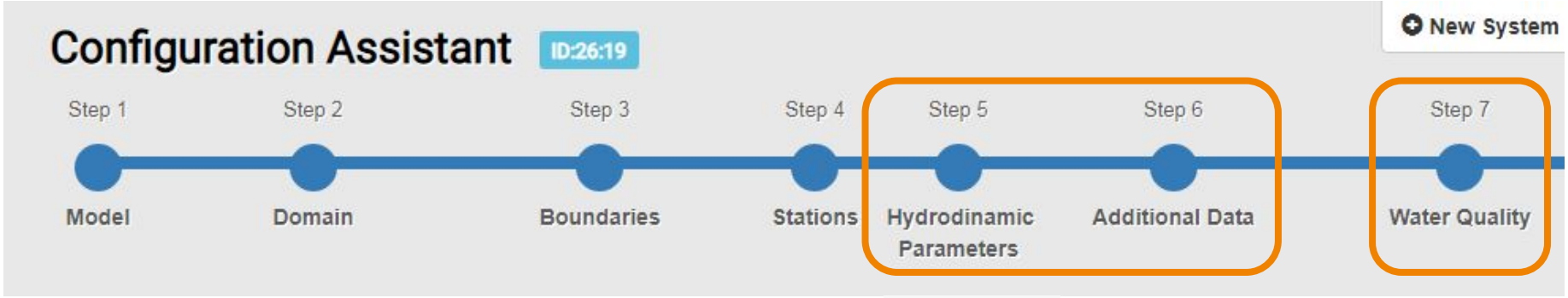
Automatic retrieval on open information repositories

Navigating in the 3 pillars: configuration assistant




pre-defined


user-selected

- fecal contamination /user-selected generic
- Constant rate/selection of formulations
- Sediment-related decay

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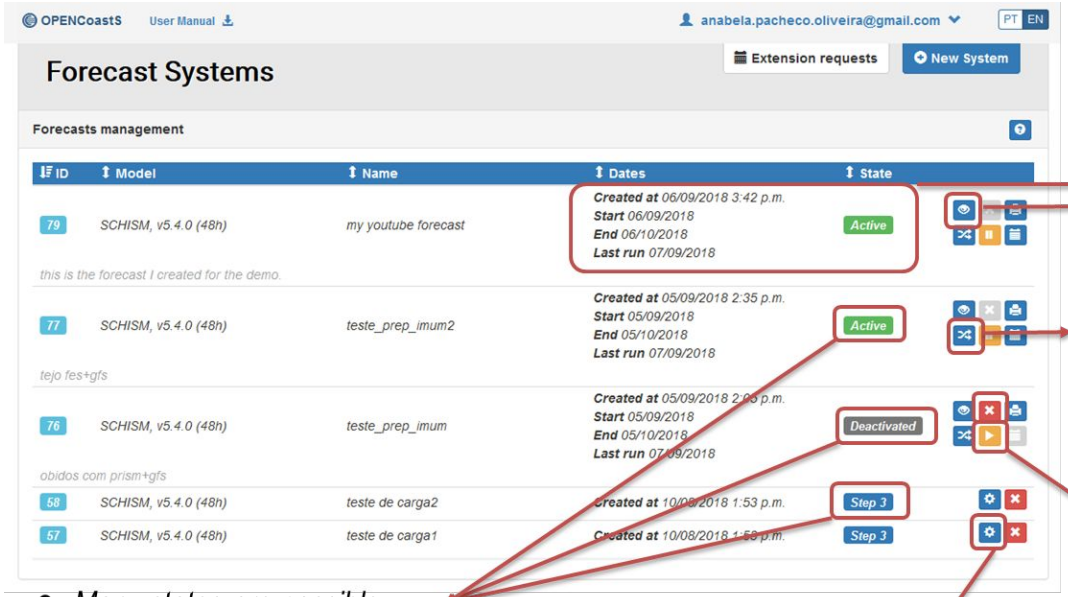
Navigating in the 3 pillars: Forecast manager



- *Checking the status and the settings of my runs*
- *Clone it – duplicate to change: b.c., parameters, outputs*
- *Re-activate a deactivated system or eliminate it*
- *Return to Conf. Assist. to continue to setup my forecast*
- *<u>Many states are possible</u>:*
  - *"step k" – in construction, we can continue later or just eliminate it*
  - *Active – we can deactivate, clone it, check it,…*
  - *Deactivated – we can activate it again or eliminate it*

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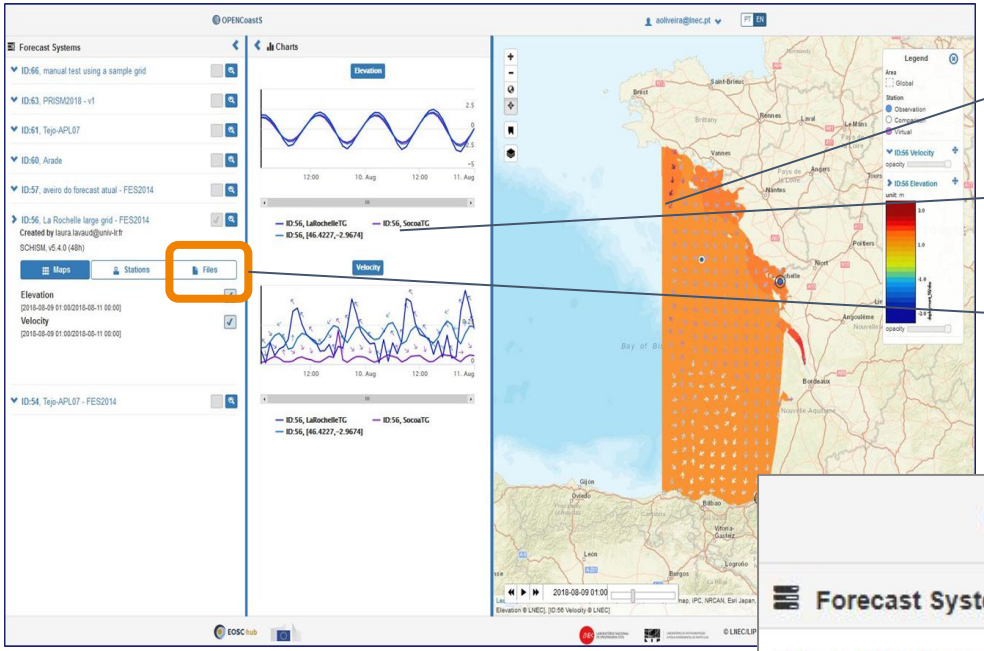
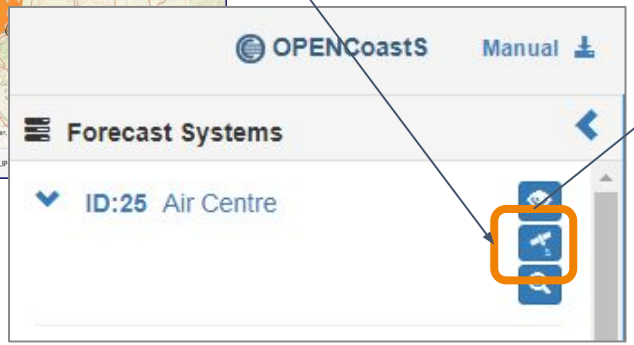
Navigating in the 3 pillars: Viewer



- Hydrodynamic and water quality maps
- Time series (pre-defined stations or stations defined on-the-fly)
- Download inputs and outputs
- View remote sensing water limits on top of predictions



WORSICA backend: Remote sensing: Sentinel 2

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Final considerations

- Following roadmap towards building society-centered, reliable, accurate and user-friendly coastal digital twins
- OPENCoastS^{+}, Worsica and other data related works are stepping stones in that roadmap
- As complexity and flexibility in user-centered services increases or as new services are built (e.g. the jUMP service to simulate on-demand underwater noise propagation for user-selected noise source and target), we need:
  - Large and robust computational resources
  - Large, reliable data lakes
- Next steps:
  - Build on-the-fly, on-demand, user friendly scenario generator
  - Link with other water compartments predictors - city, river,...
  - Include hybrid modeling (process-based+AI)

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Useful links

OPENCoastS+ PLATFORM	https://opencoasts.ncg.ingrid.pt/
Users Manual	http://opencoasts.lnec.pt/pdfs/Manual_opencoasts_v11.docx.pdf
Link to previous training events	http://opencoasts.lnec.pt/ Next session - Open training event in the 2nd MEDGU, Marrakech, Morocco

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Questions?

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Thank you for your attention!

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