Towards a coastal ocean forecasting system in the Mediterranean Sea.

The pilot implementation of the Southern Adriatic Northern Ionian seas.

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ClimaSouth Regional Workshop on
Methods and Tools for Vulnerability Assessment

Milan, 3-4-5 February 2016

ClimaSouth

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sui Cambiamenti Climatici

Overview

① Ocean Modelling and Downscaling

- From Global Ocean …
- .. to Regional Scale …
- … to sub-regional and coastal zones

① The unstructured-grid modelling

- SHYFEM. 3D model for hydrodynamics and tracers
- The SANIFS operational system

① Operational Activities and Applications

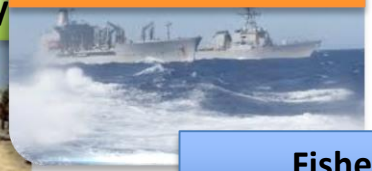
- Forecasting System
- Decision Support Systems

Sea Situational Awareness User-centered Services
Why? For whom?

Safety of navigation

Search & Rescue

Law enforcement & civil protection



Coastal protection & erosion

Pollution emergency

Fishery & aquaculture

Climate Change

Ocean-Lab cmcc

Harbours

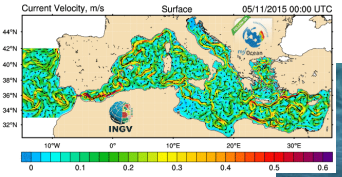
Renewable energy

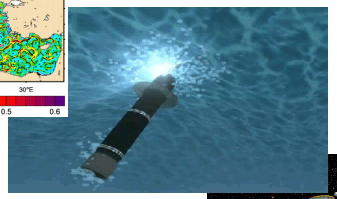
Protection & management of marine ecosystems

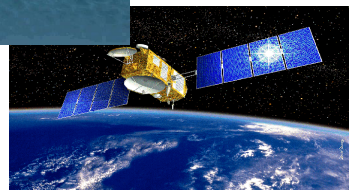
Tourism

Offshore activities

Sea Situational Awareness Services: how we produce them



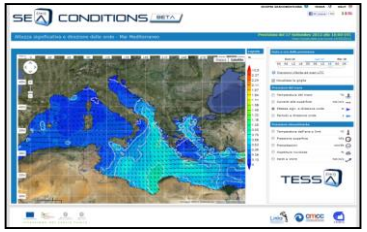




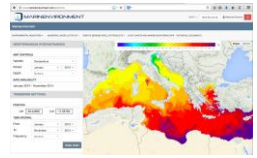
Upstream information

Copernicus Marine Service, Meteo, Observations

Informations and applications for end-users



Sea Conditions

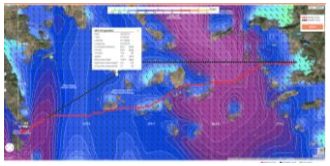


Marine Environment

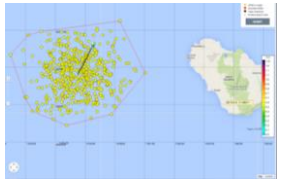
Sea level forecast

Downscaling

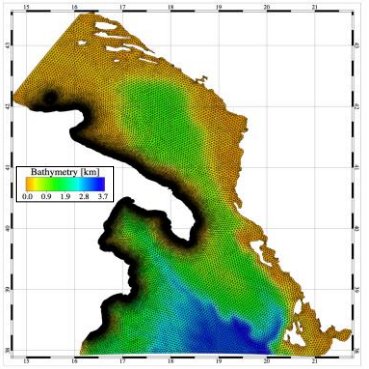
High Resolution Analysis and Forecast

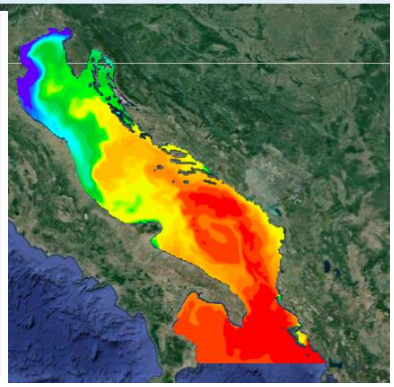


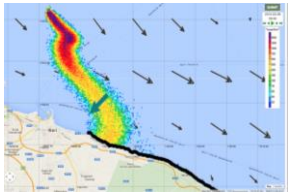
Ship Routing



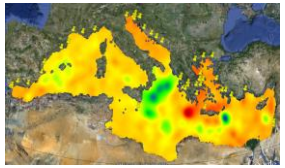
Search & Rescue







Oil Spill



Climate Indicators

harbour ------- coastal ---------- shelf ---------- open-sea -------- global ocean

SANIFS unstructured grid system (3km-50m)

(CMCC)

MED-MFC (1/16°)

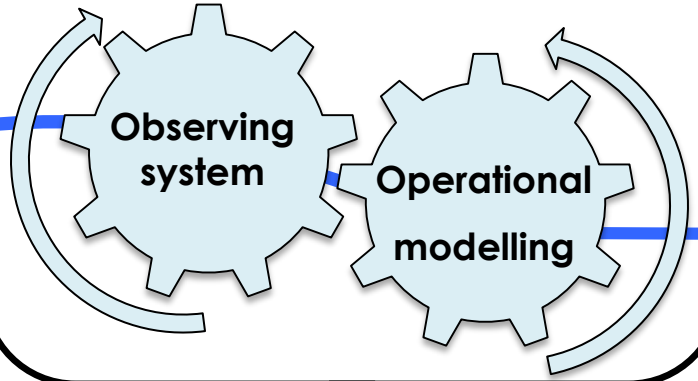
(INGV)

GLO-MFC (1/12°)

(Mercator-Ocean)

Coastal Situational Awareness (CSA)

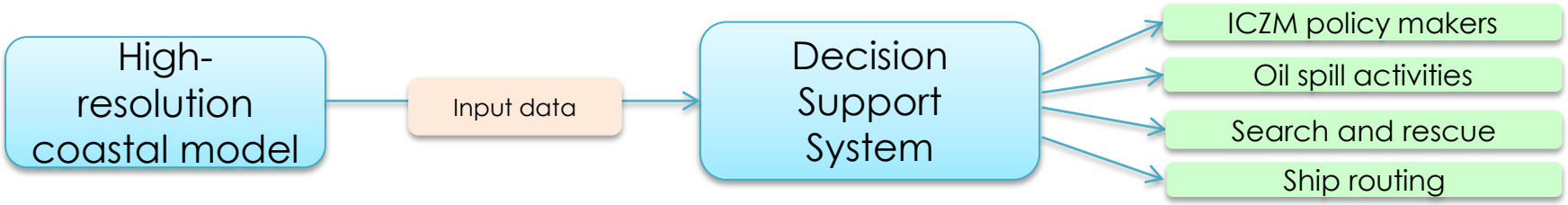
Improve the ***awareness*** (and the knowledge) of coastal environment integrating the **observing systems** (also in real time) with the **operational modelling**.

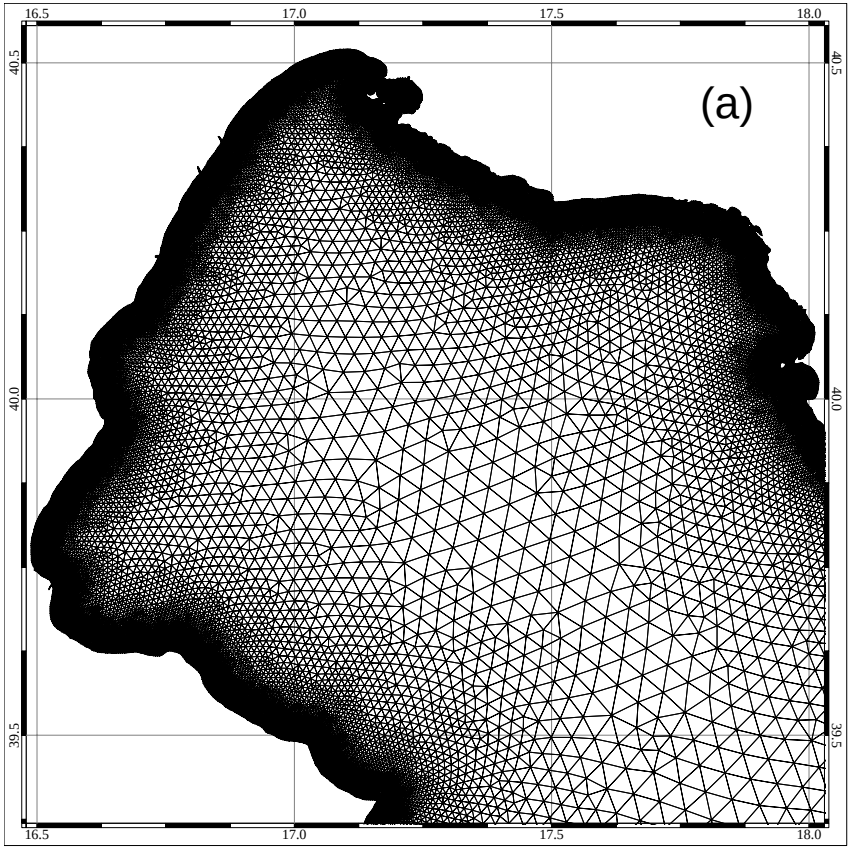


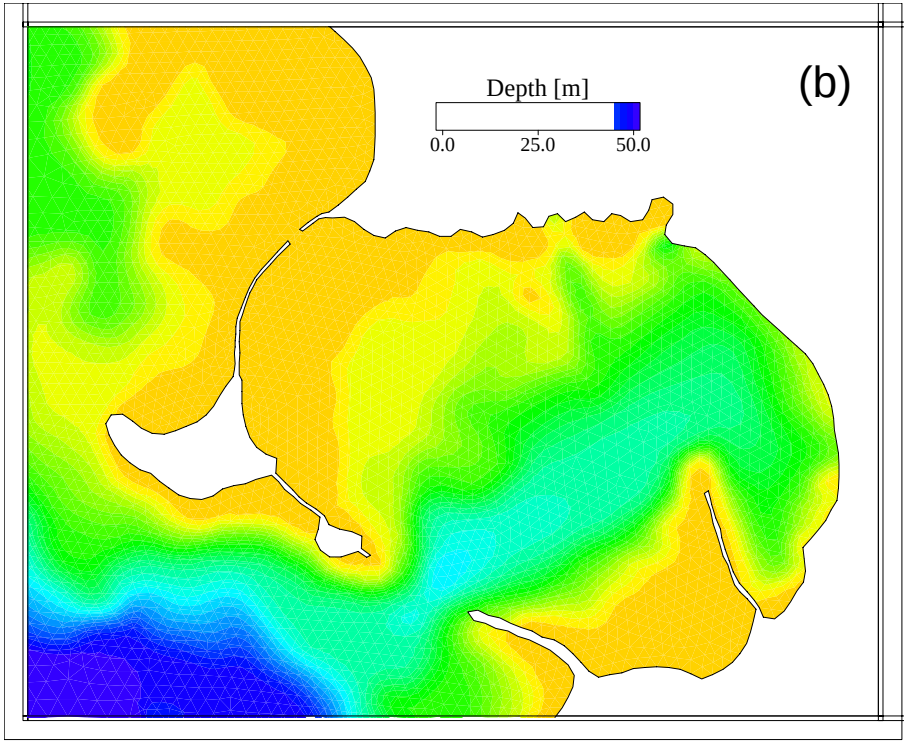
Products and services to provide:

- **Early warning** and **rapid mapping** of extreme events (e.g. **storm surge**)
- **Coastal erosion and flooding** indicators
- Support an integrated **management of harbor** areas

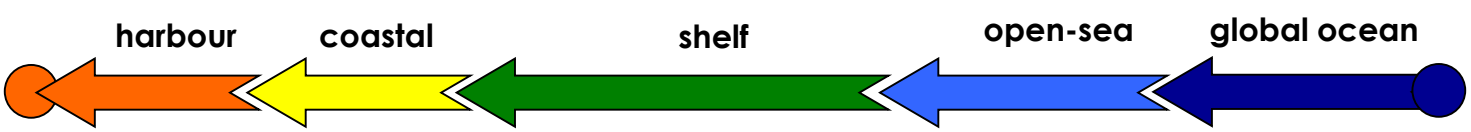
Decision-makers, stakeholders and users needs in coastal areas







Mar Grande (Taranto, Puglia).
Commercial and industrial port



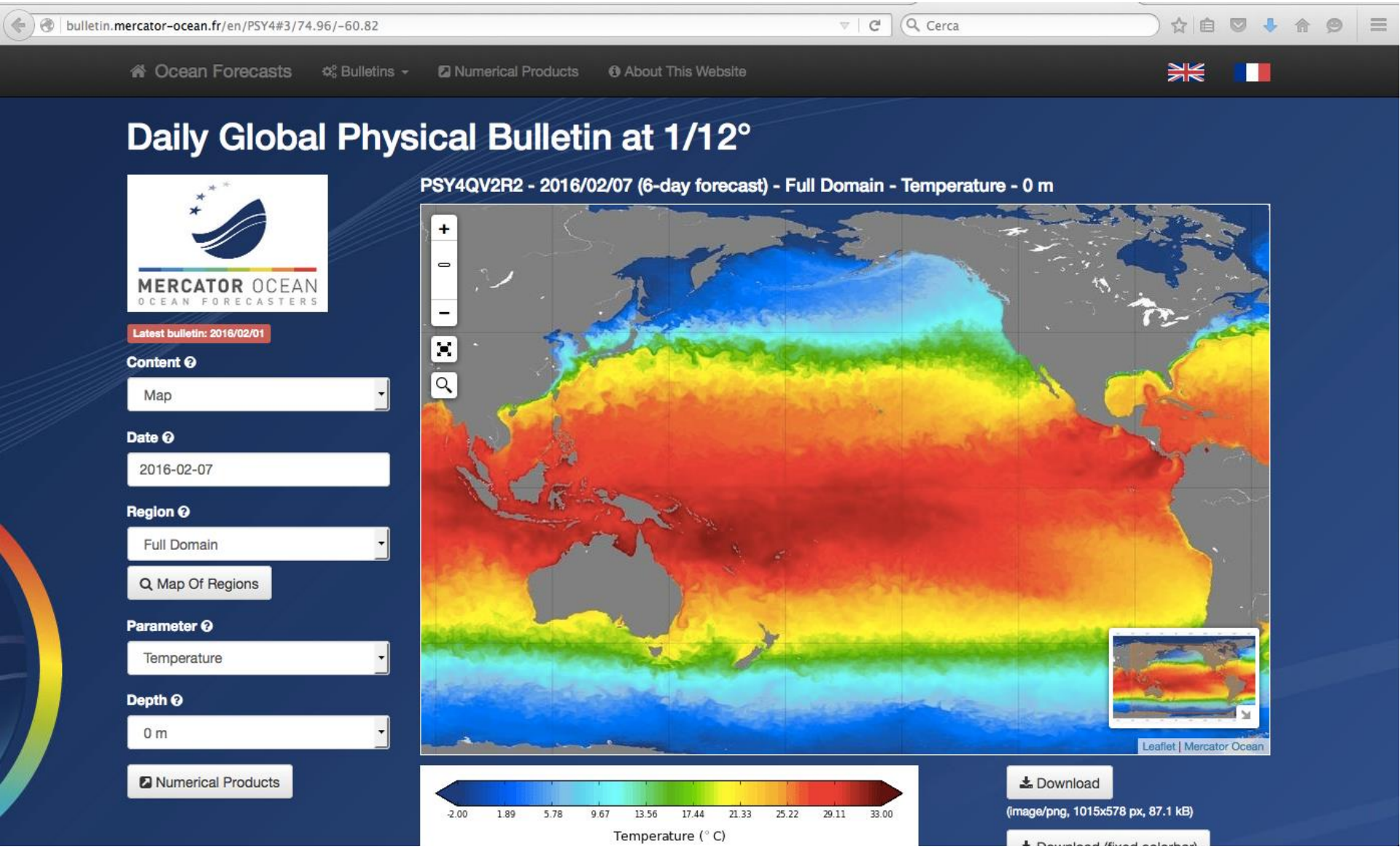
From Global Ocean

… to Regional Scale …

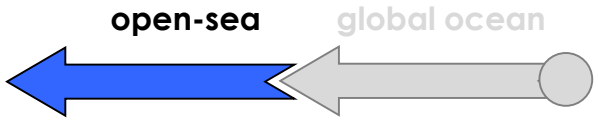
… to sub-regional and coastal zones

global ocean

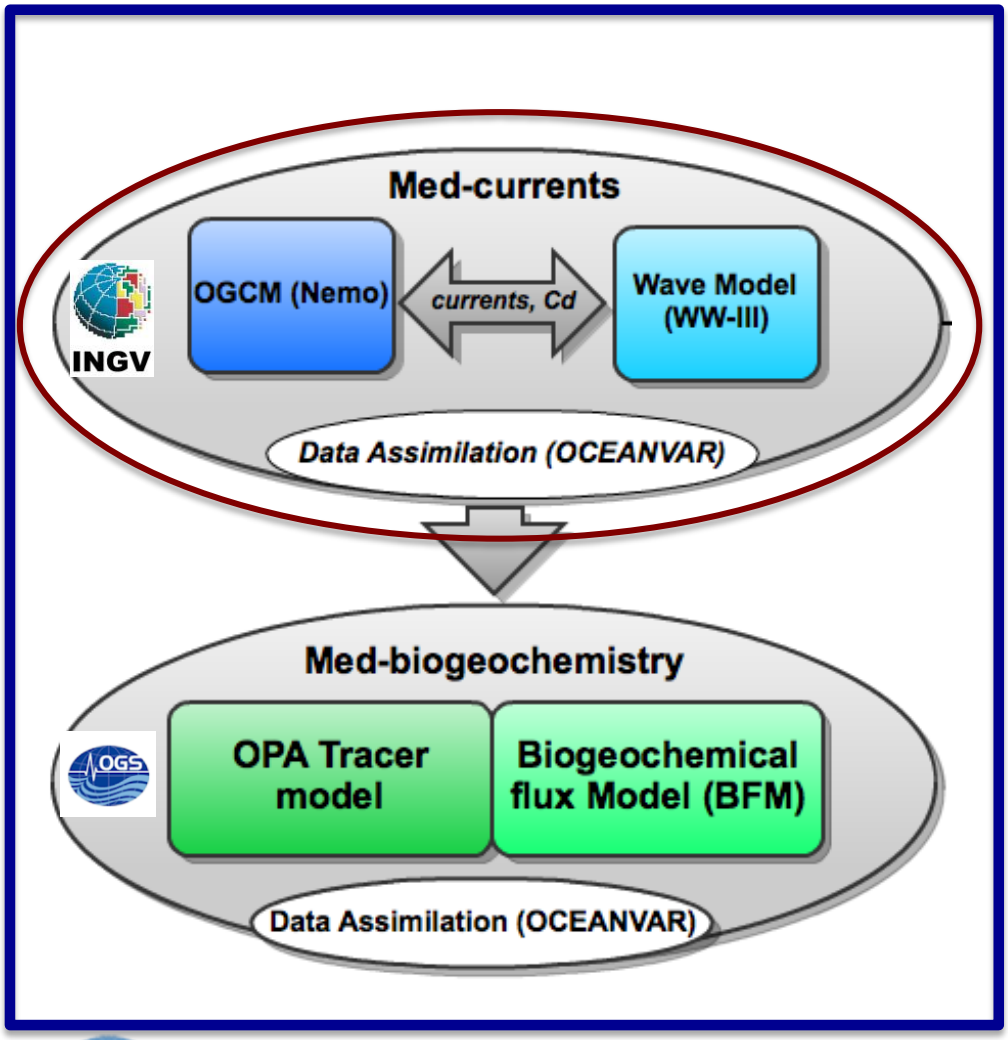
CMEMS GLO-MFC, Mercator-Ocean products



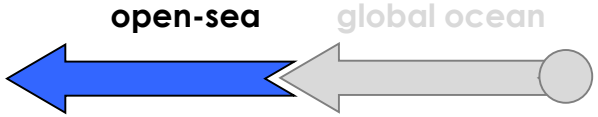
Slide from web, Mercator Ocean

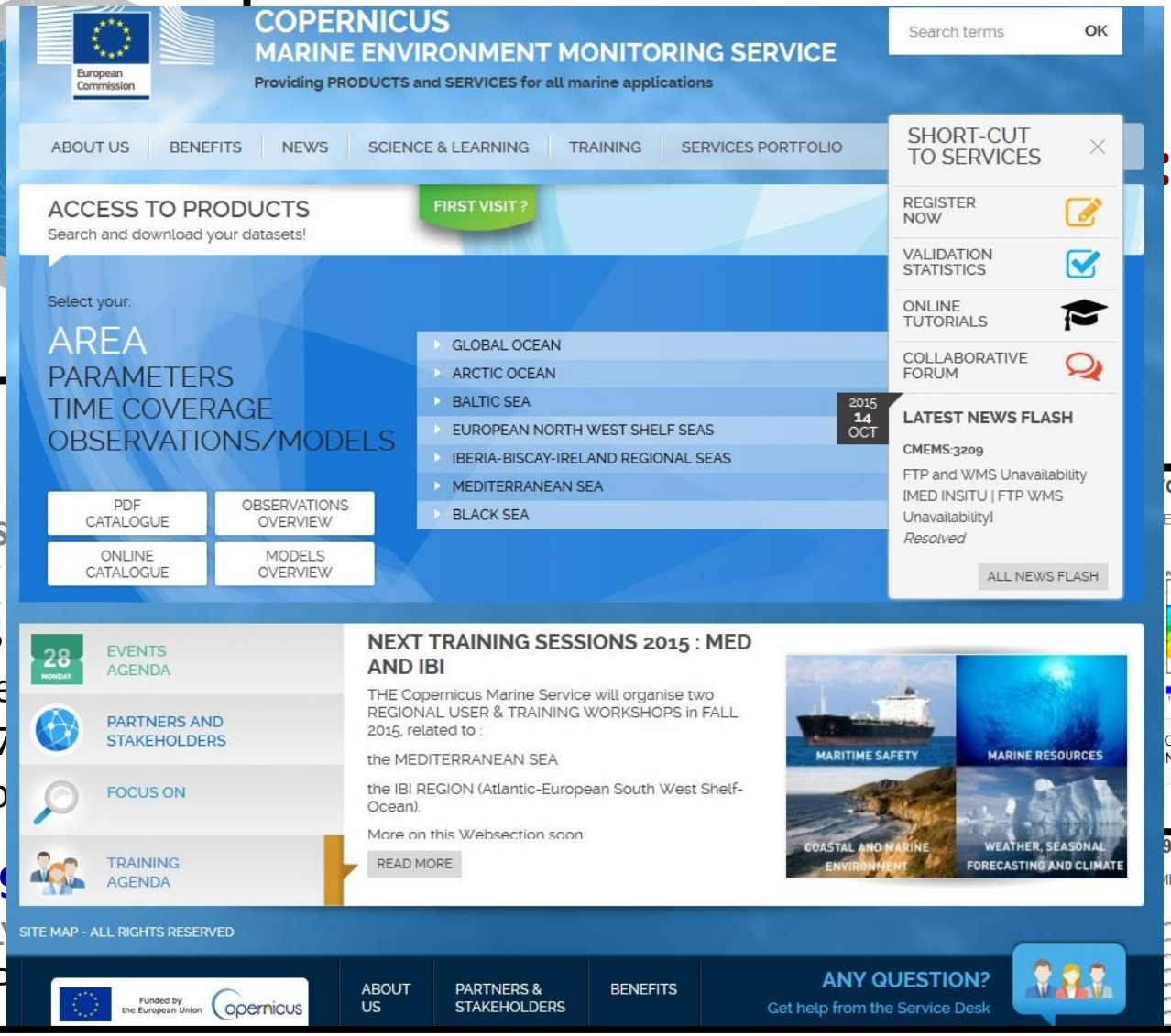


CMEMS Med-MFC



Courtesy of E. Clementi, INGV





Analyses and

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  Currents, SS
  Wavenumbe
- Res: 1/16°, 7
- Daily and ho

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- 4 variables (F

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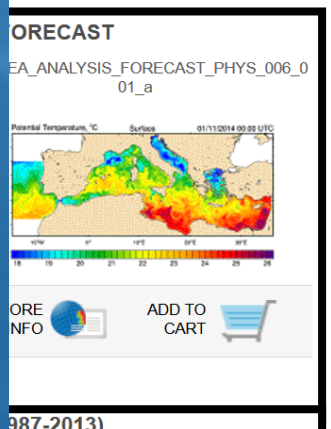
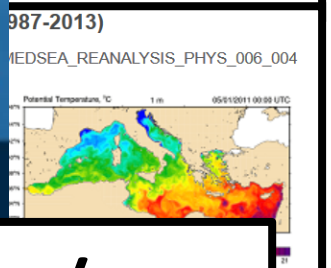
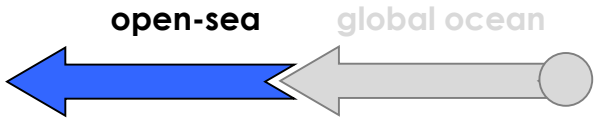


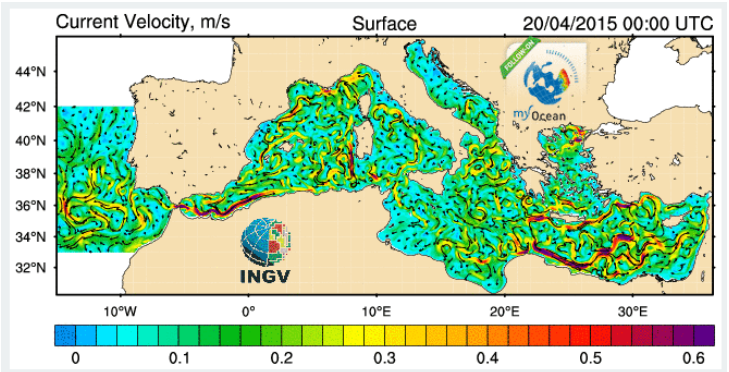


http://marine.copernicus.eu/



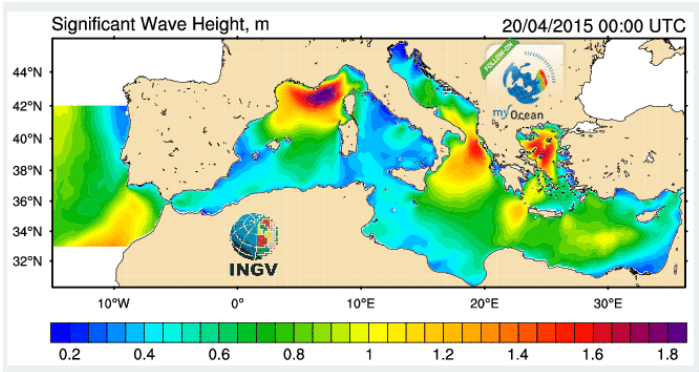
Med-MFC Physics: analysis and forecast numerical model

Ocean General Circulation Model (OGCM) based on NEMO code v3.4

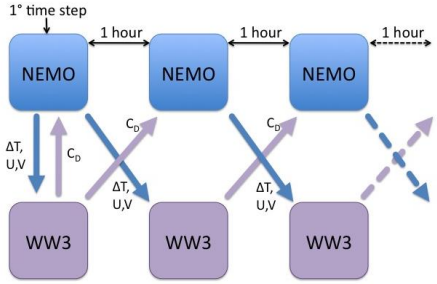


2-way hourly coupling

Wave model WaweWatch-III (WW3) v3.14



Hor. Res. = 1/16º (~6 km)
Vert. Res. = 72 z-levels
partial cells

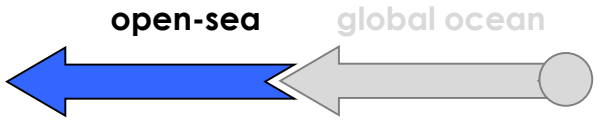


Hor. Res. = 1/16º (~6 km)
Spectral discretization:
* 30 freq. bins (0.05-0.79 Hz)
* 24 directional bins

The two-way coupling consists of inputting currents to the wave model (for wave refraction) and air-sea temperature difference (for wind speed correction) and computing the wind stress drag coefficient from waves information to force the momentum flux in NEMO

Courtesy of E. Clementi, INGV

Med-MFC Physics: analysis and forecast Atmo/Land forcings/OBC



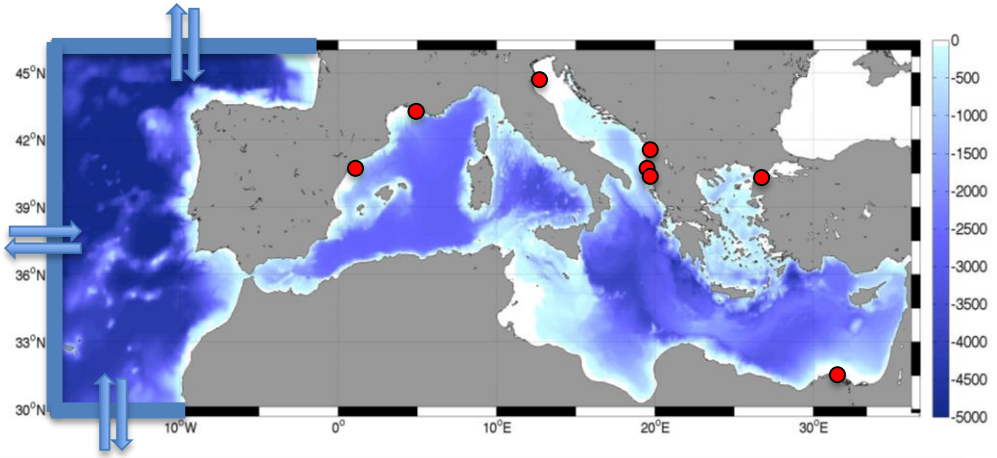
The external forcings to the model are:

ECMWF 1/8º atmospheric fields:
- mean sea level pressure (MSLP)
- cloud cover
- 2m relative humidity
- 2m air temperature
- 10m zonal and meridional winds components

Temporal resolution:
For forecasts: 3hr time resolution for the first 3 days and 6 hours time resolution fields for the remaining 7 days
For analysis: 6 hours time resolution

CMAP precipitations: monthly mean climatology

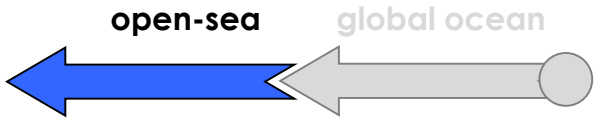
The land river runoff: vertical boundary condition for 7 major rivers:
Ebro, Rhone, Po, Vjosë, Seman, Buna-Bojana, Nile (climatological monthly mean seasonal cycle values)
The Dardanelles inflow is also parameterized also as a river



Boundary conditions in the Atlantic daily real time analyses and forecasts from Global Ocean Forecasting System (GLO-MFC) @ 1/12° horizontal resolution, 50 vertical levels

Courtesy of E. Clementi, INGV

Med-MFC Physics: analysis and forecast Data Assimilation model



Model solutions are corrected by the data assimilation

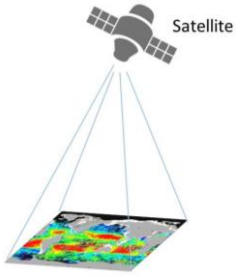
The real time data assimilation system is the **3D variational scheme** adapted to the oceanic assimilation problem.

The assimilation cycle is daily, using a background error correlation matrix varying seasonally and in different sub-regions of the Mediterranean Sea.

The assimilated data are:

Along track Sea Level Anomaly from Copernicus MSL-TAC, for all available satellites:

- Jason 2
- Cryosat2
- Saral/AltiKa

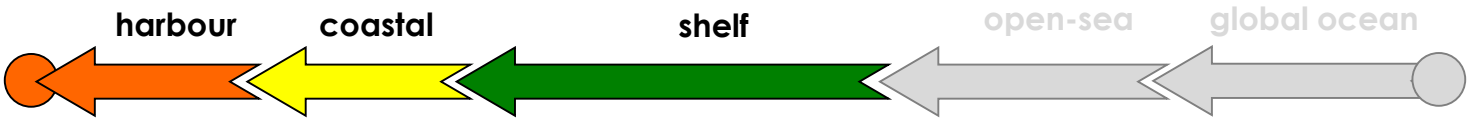


Vertical profiles of Temperature and Salinity from Copernicus InSitu TAC:

Argo XBT Gliders

Non-solar heat flux correction is achieved through satellite SST nudging

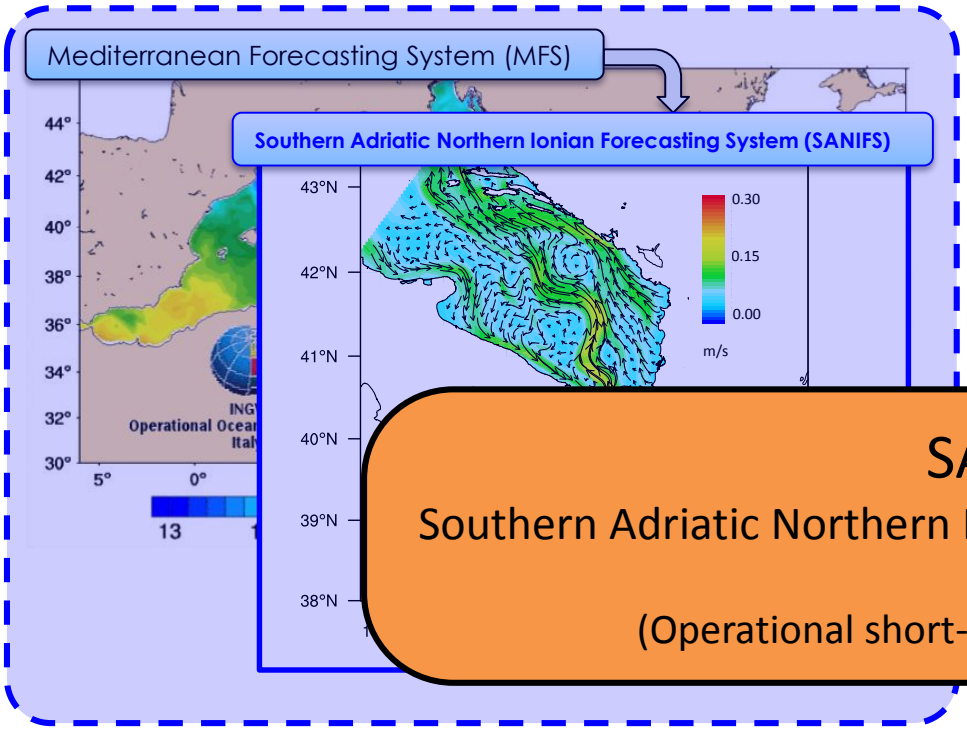
Courtesy of E. Clementi, INGV

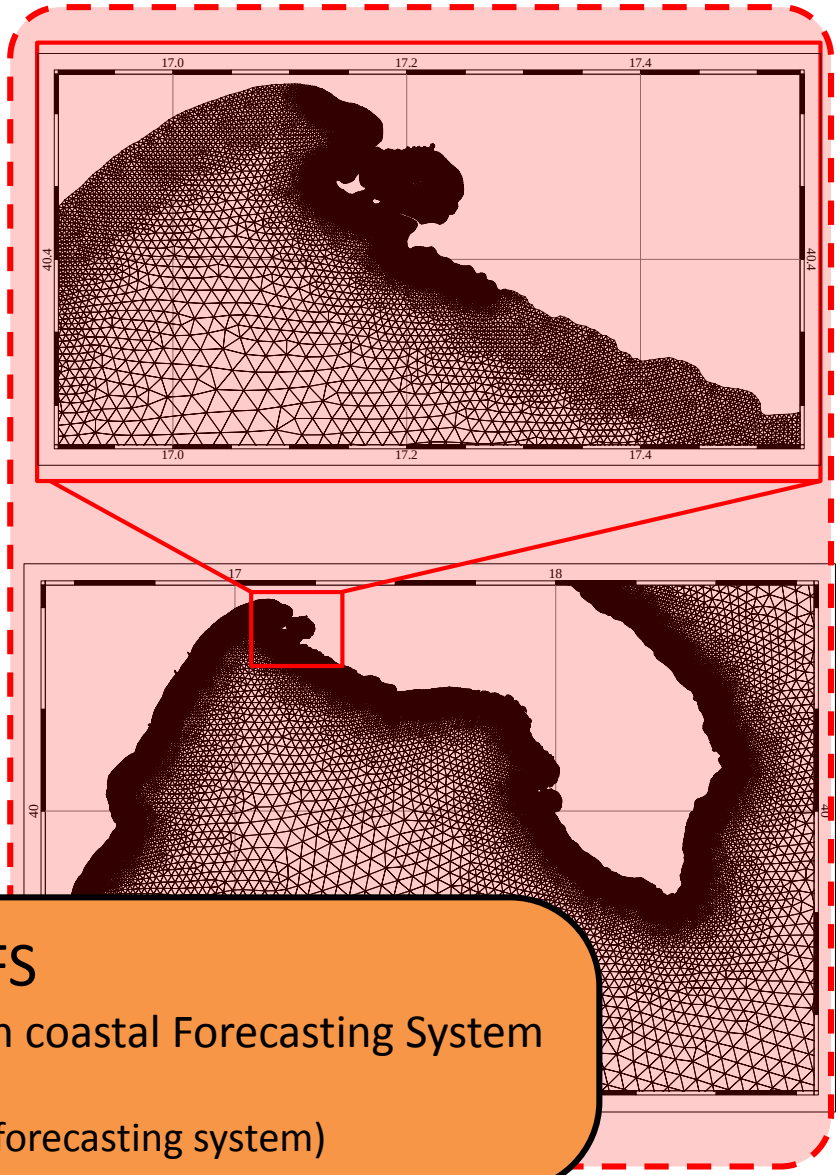


- Mediterranean sea (Southern Eastern Italian coasts)
- Coastal modelling and forecasts
  - SANI area (Apulia, Calabria, Basilicata)
- Linking open-sea to shelves to coasts

  1) New Generation Modelling

  2) Downscaling approach

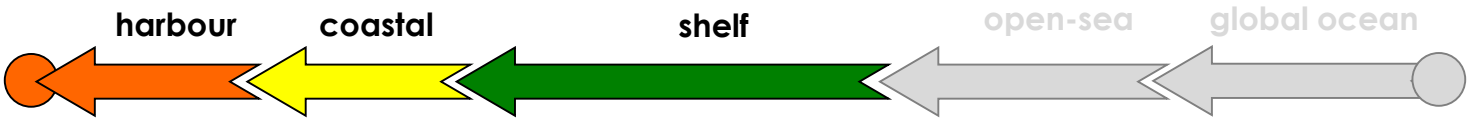




SANIFS

Southern Adriatic Northern Ionian coastal Forecasting System

(Operational short-term forecasting system)



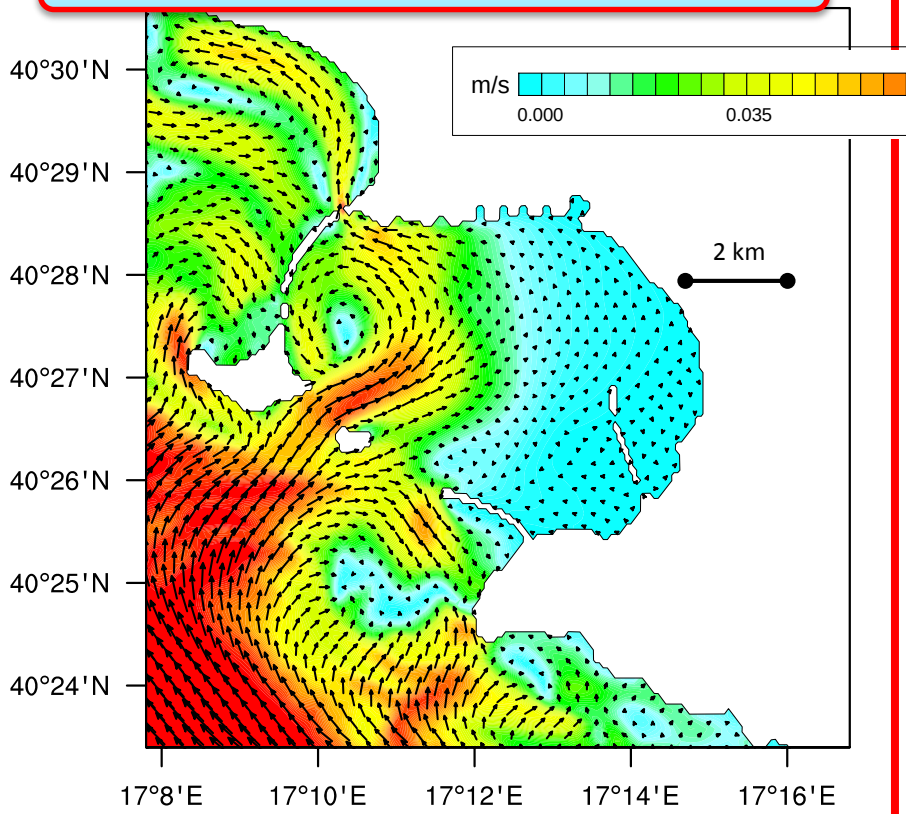
High-resolution coastal model

Input data

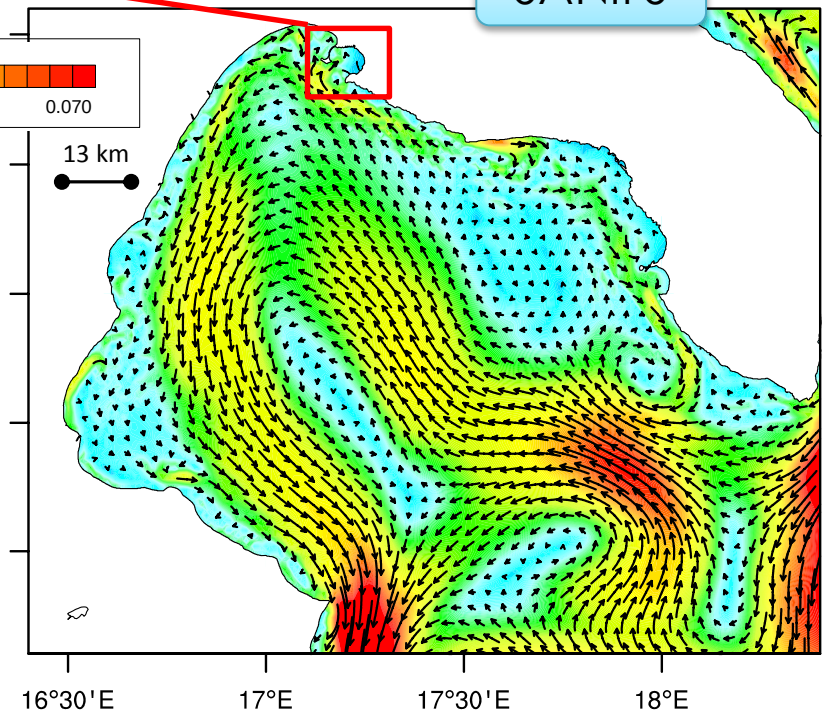
Decision Support System

- ICZM policy maker
- Oil spill activities
- Search and rescue
- Ship routing

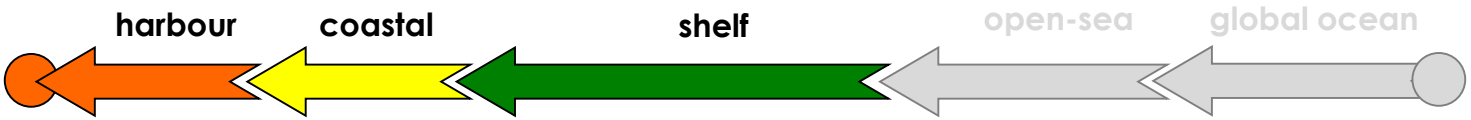
SANIFS – Mar Grande, Taranto



SANIFS



Mar Grande (Taranto, Puglia): commercial and industrial port



High-resolution coastal model

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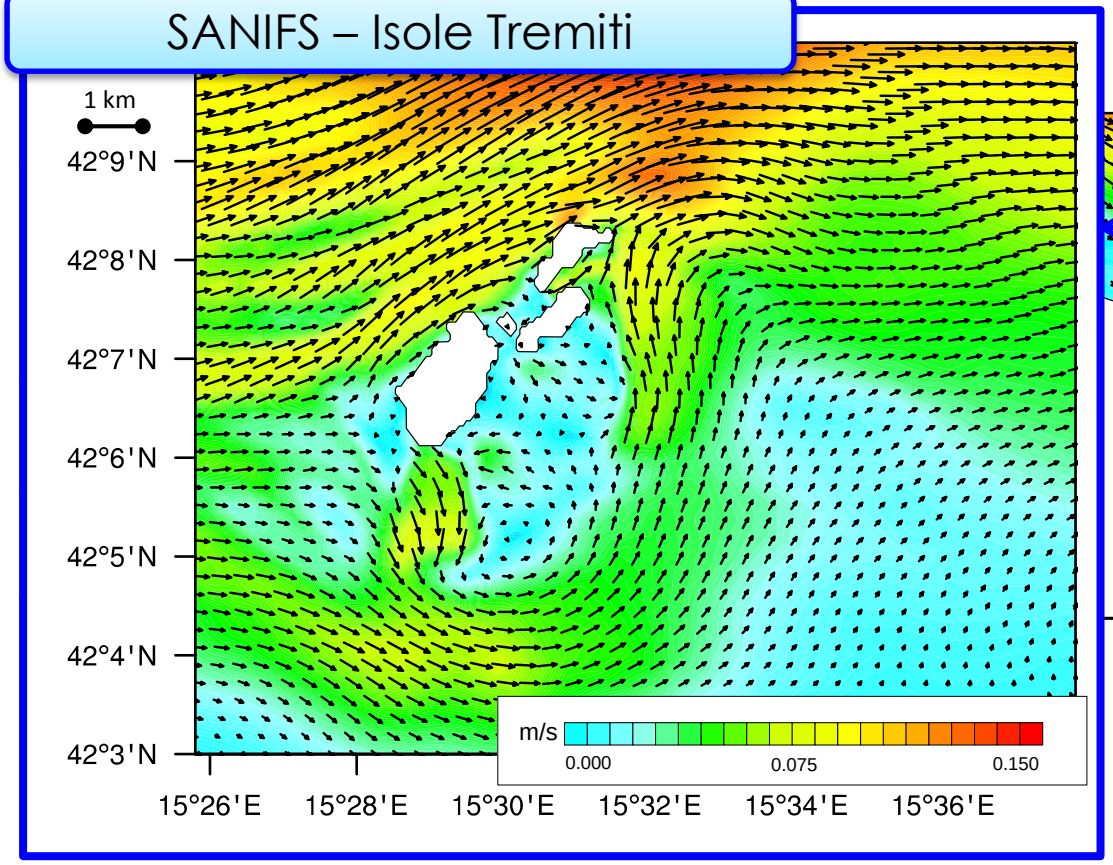
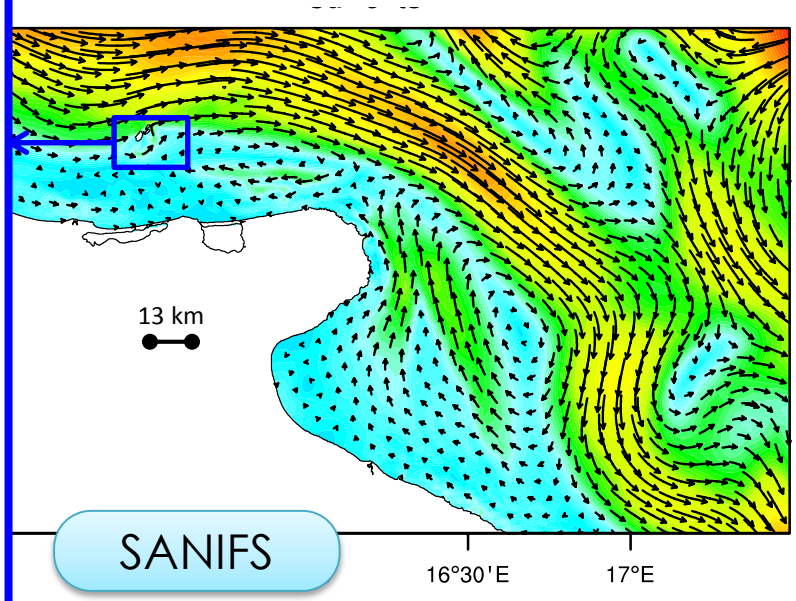
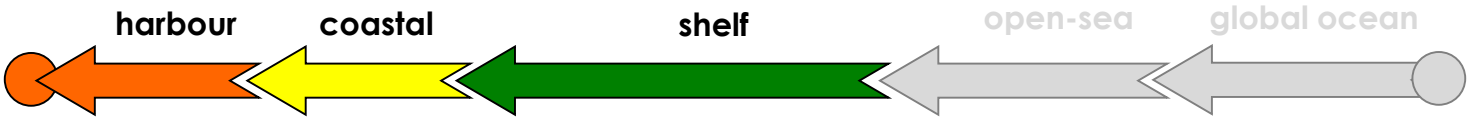
SANIFS – Isole Tremiti



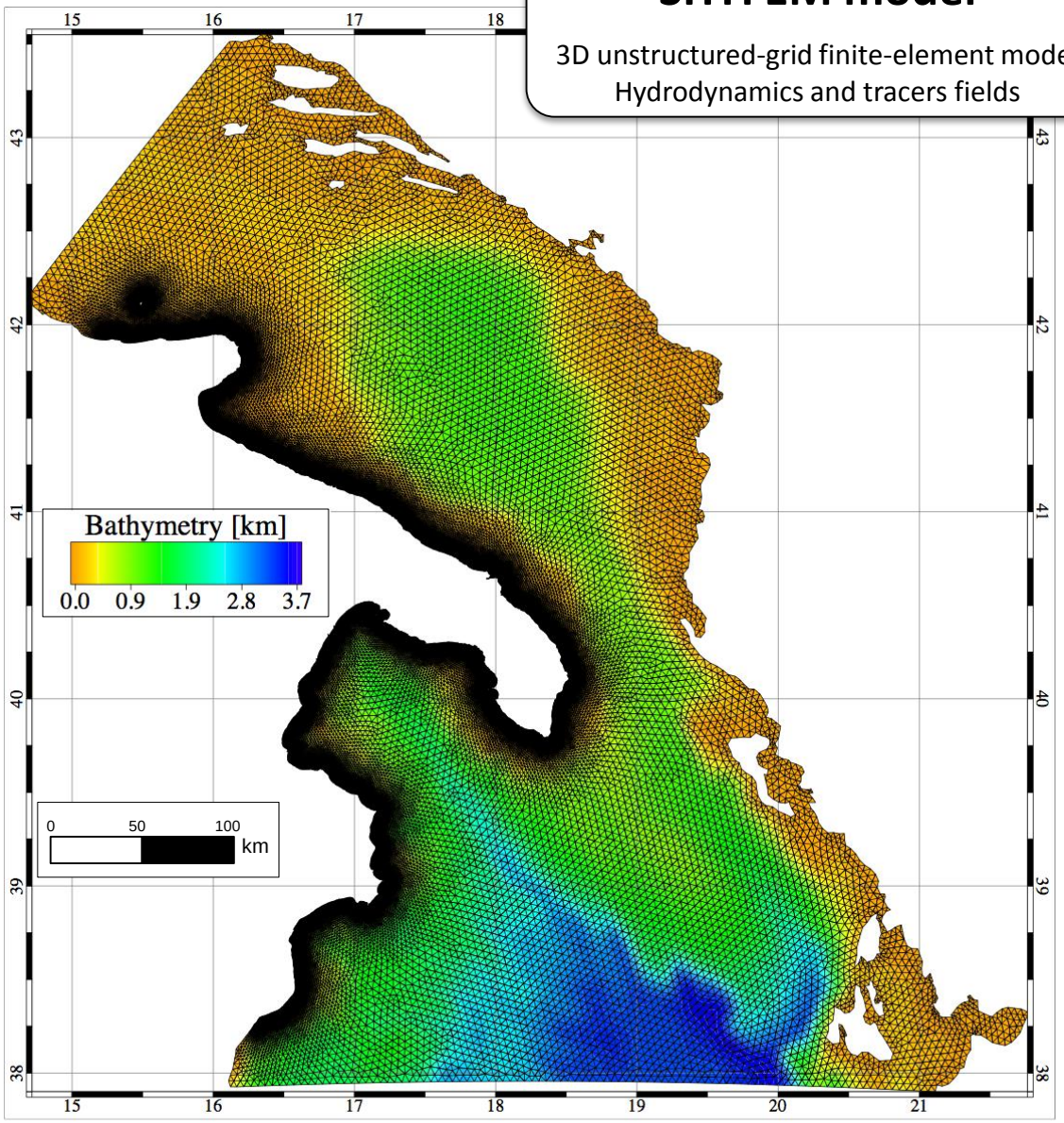


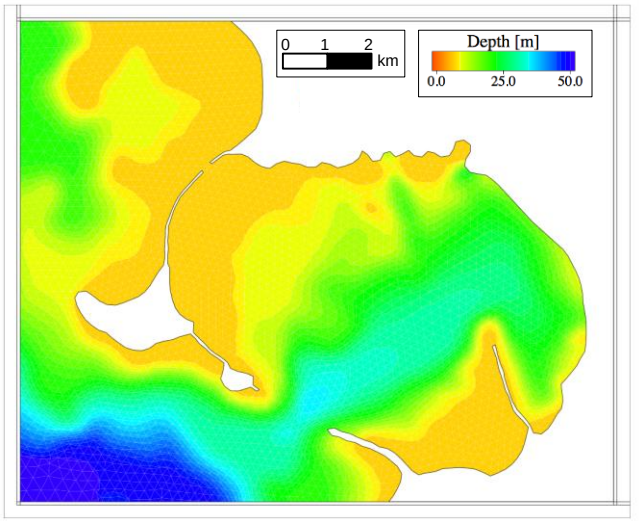
Tremiti islands (Gargano, Puglia): touristic area

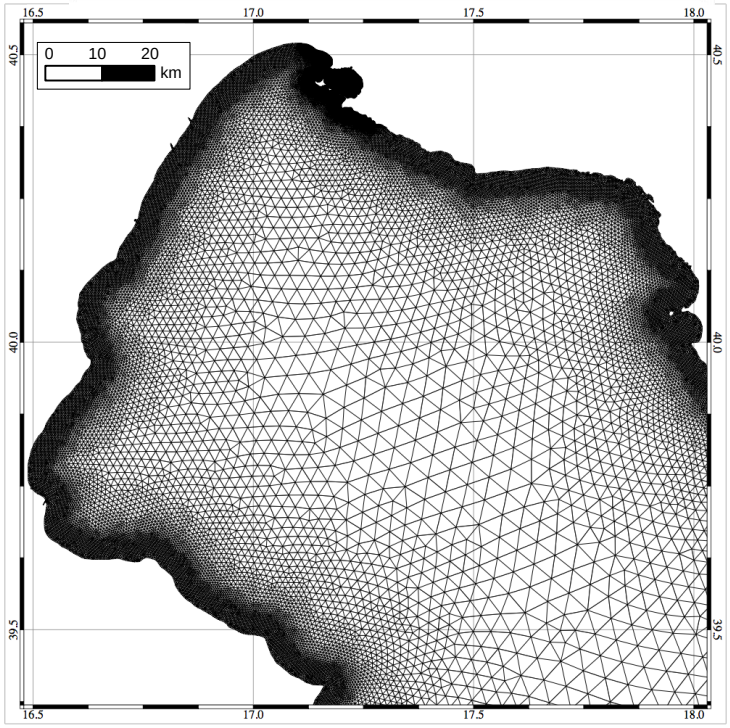


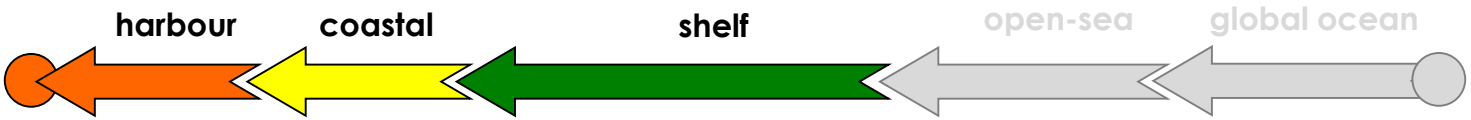
SHYFEM model

3D unstructured-grid finite-element model
Hydrodynamics and tracers fields



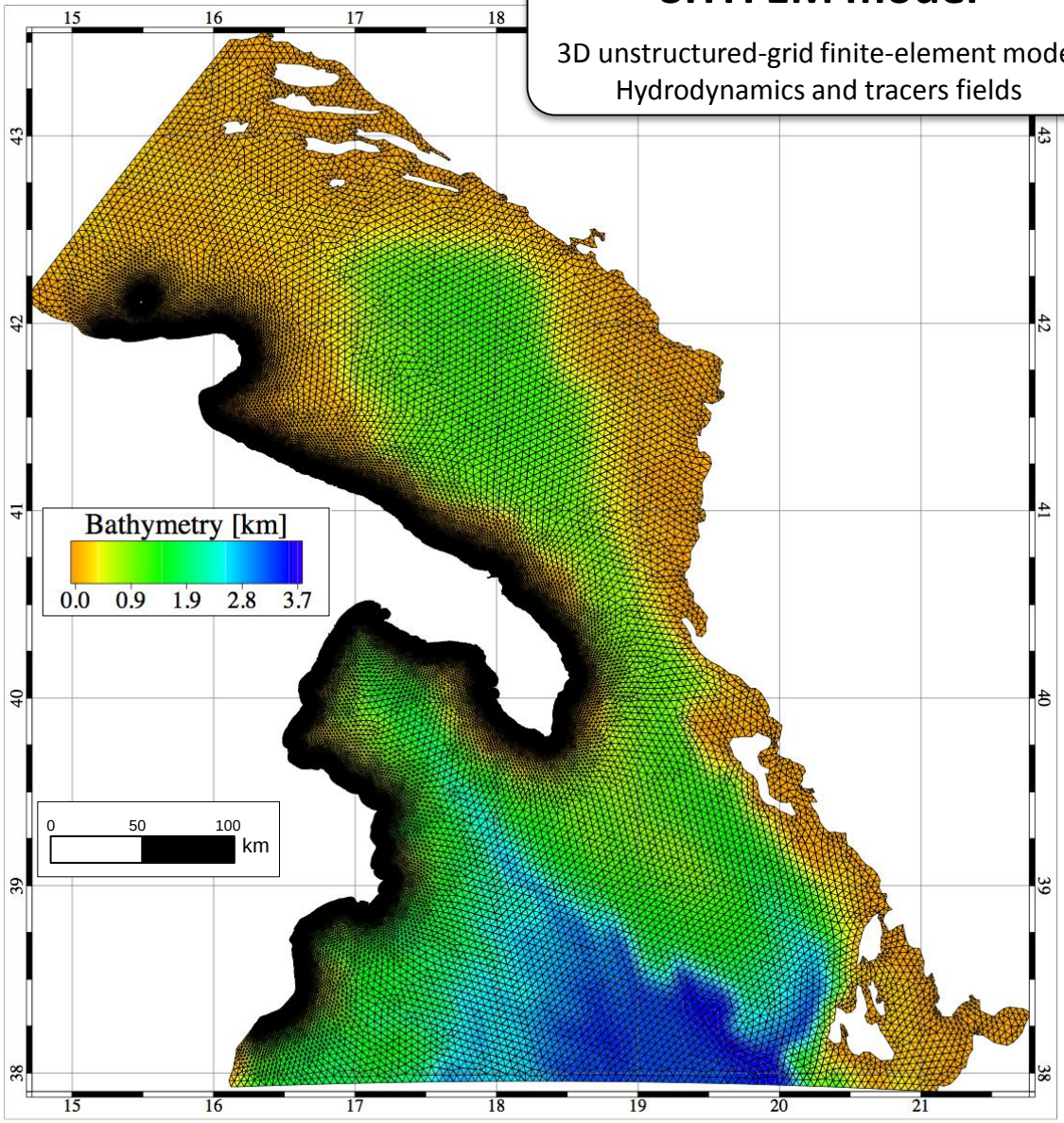






SHYFEM model

3D unstructured-grid finite-element model
Hydrodynamics and tracers fields



Resolution:

Horizontal → coastal 50-500 m; open-sea 3 km
Vertical → 91 z-levels

Turbulence scheme:

Local Richardson number dependent formulation
(Pacanowski and Philander, 1981; Lermusiaux, 2011)

Surface boundary conditions:

ECMWF vs COSMOME

- **Temperature:** air-sea parametrization with bulk formulae (Petenuzzo et al., 2010)
- **Momentum**: surface wind stress computed with drag coefficient parametrization (Hellerman and Rosenstein, 1983)
- **Free surface**: water flux = E-P-R
- **Salinity**: turbulent salt flux set to the product of water flux and surface salinity

harbour coastal shelf open-sea global ocean

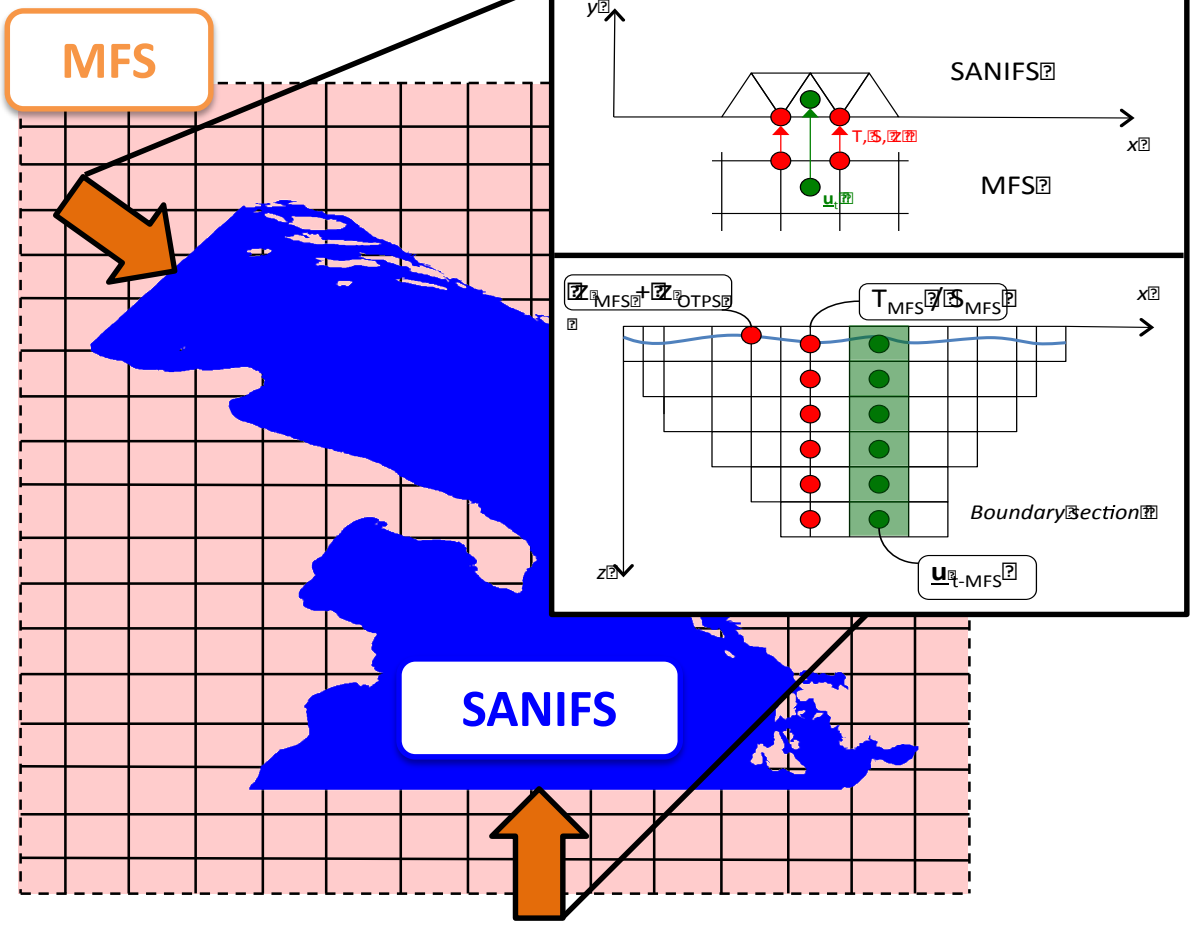
Downscaling is accepted as the preferred methodology to propagate the large scale dynamics into Coastal Ocean Forecasting Systems, through **lateral open boundary conditions** from Large scale Ocean Forecasting Systems

Parent Model (MFS)

MFS is based on **NEMO** finite-difference code with a **horizontal resolution of 1/16°** (**6-7 km** approximately) and **72 unevenly spaced vertical levels**.
The forecasting system is provided by a **data assimilation** system based on the 3DVAR scheme developed by Dobricic and Pinardi (2008).

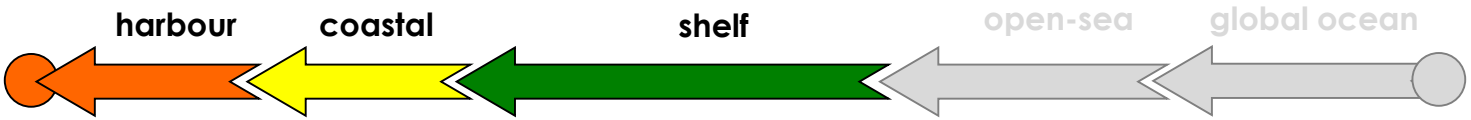
Downscaled model (SANIFS)

To simulate correctly the water masses properties and circulation characteristics propagating from open ocean to coastal zones, downscaling approach needs to be supported by an **appropriate (high) open-sea resolution (also) in nested model**.

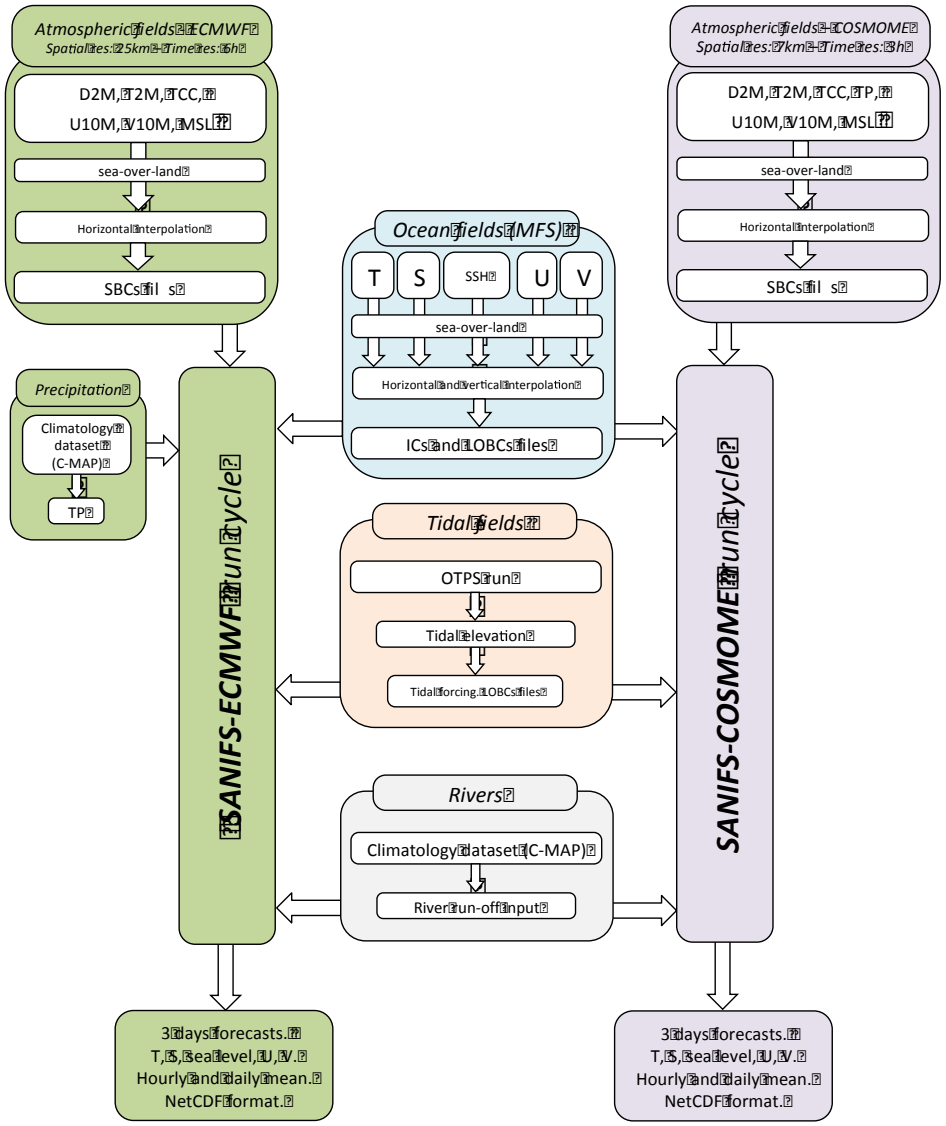


MFS fields (temperature, salinity, non-tidal sea surface height and total velocities) are imposed at SANIFS lateral open boundary conditions.

For the barotropic field, the tidal free surface components are taken from the **OTPS** tidal model.



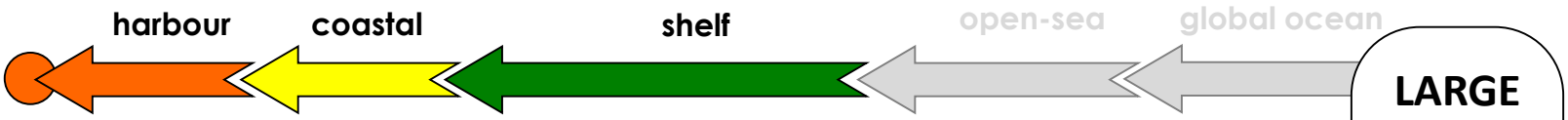
The operational chain



The operational chain provides 3-day forecasts and is based on two configurations:

(i) SANIFS-ECMWF forced via ECMWF atmospheric data (12.5 km space resolution);

(ii) SANIFS-COSMOME forced via COSMOME atmospheric data (6.5 km space resolution).



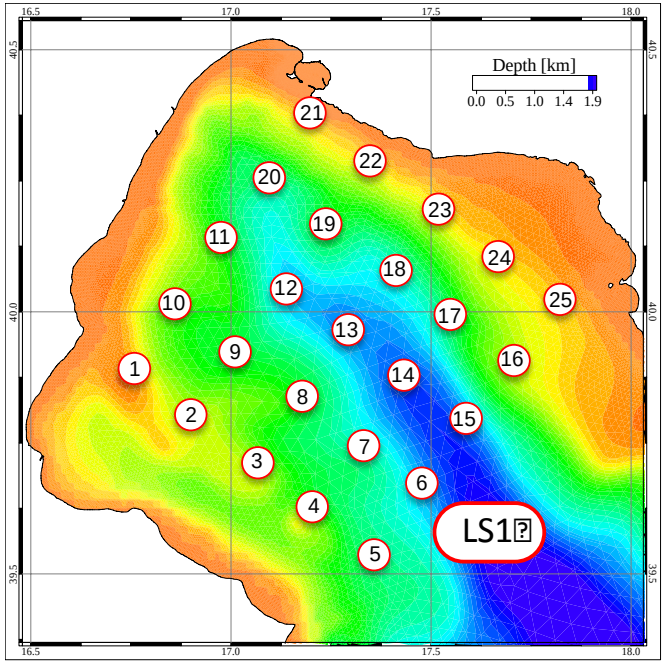
LARGE scale

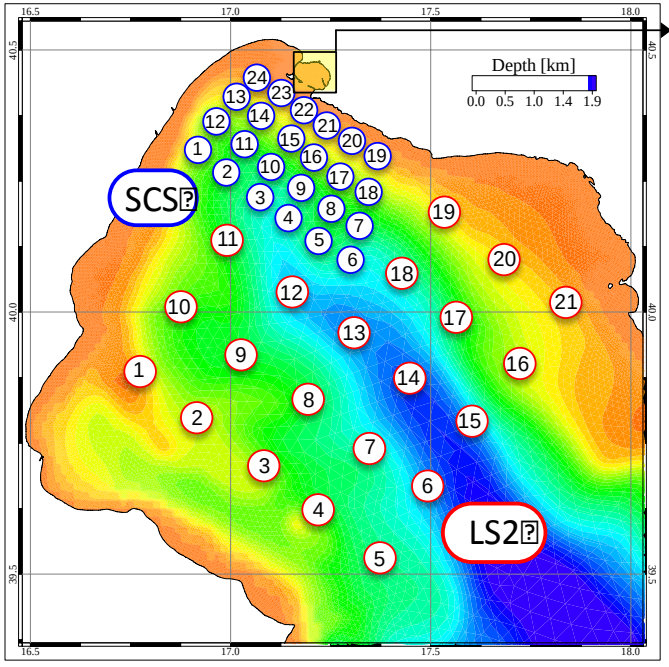
The MREA14 experiment in Gulf of Taranto and Mar Grande

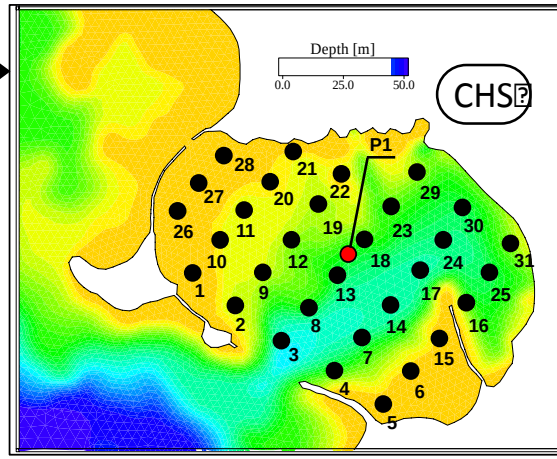
- The MREA14 **multi-scale sampling strategy**, which is designed to cover **three scales** (**large**, **shelf-coastal** and **coastal-harbour**), is perfectly tailored to assess the capabilities of the downscaling methodology and to validate the SANIFS forecasts at the three scales.
- **Three cruises** were organized together with data acquisition in the Gulf of Taranto and Mar Grande

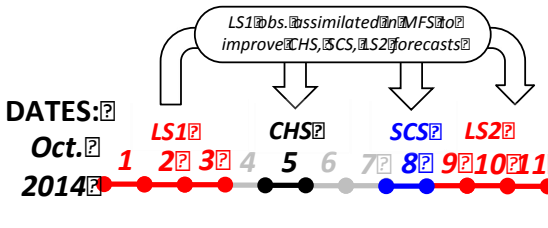
SHELF COASTAL scale

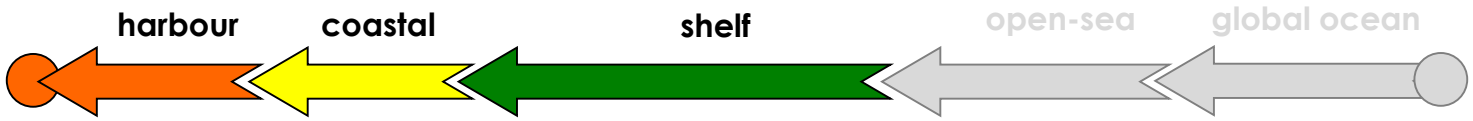
COASTAL HARBOUR scale





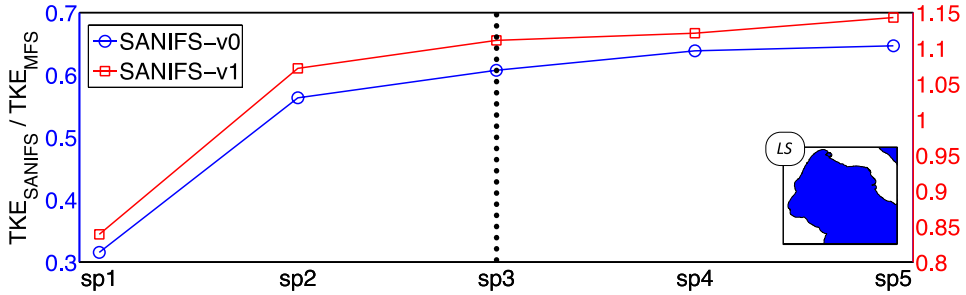






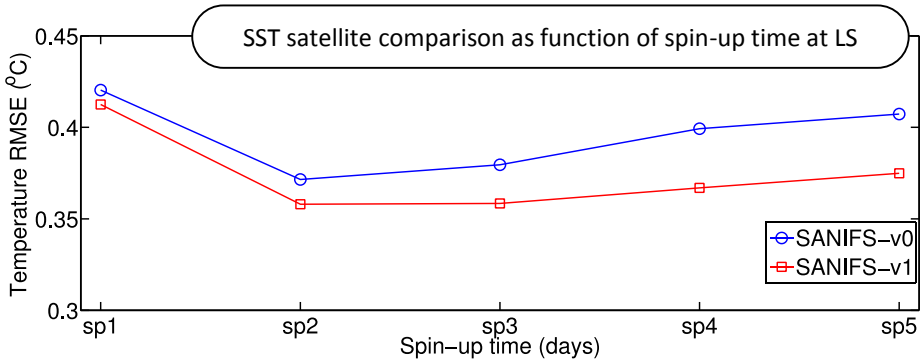
DOWNSCALING procedures: INITIALIZATION and SPIN-UP PROCEDURES

- SANIFS methodology is based on the high resolution **model re-initialization** every day, similarly to the **short term limited area** atmospheric **modelling** practice (Mesinger et al., 1988)
- Limited area ocean models may require a **spin-up time** to produce dynamically adjusted fields after initialization from the interpolation of coarser ocean model fields (Simoncelli et al., 2011).



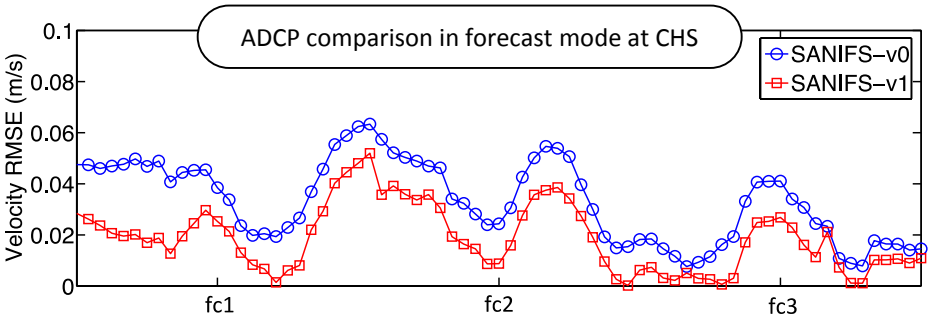
Spin-up time assessment → **3 days**

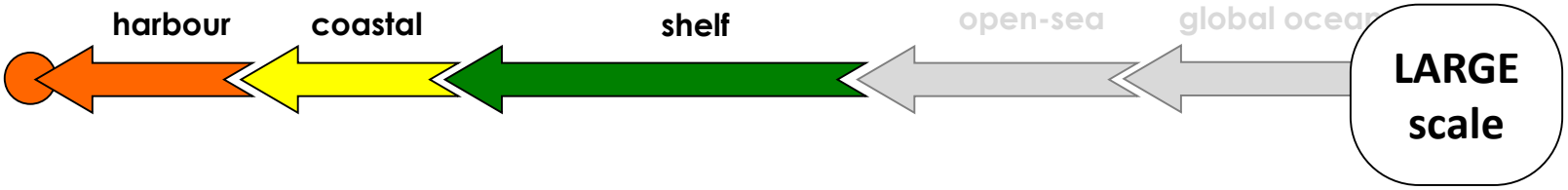
- Experiments are started at different times in the past with respect to a target initial forecast time. The number of days in the past with respect to the **target initial forecast day** is called the spin-up time and our aim was to test **how long the spin-up need to be.** Indicator: TKE ratio.
- 3 days of spin-up confirmed by literature on coastal modelling focused on short term forecast in slave mode (Rolinski and Umgiesser, 2007; Cucco et al., 2012)

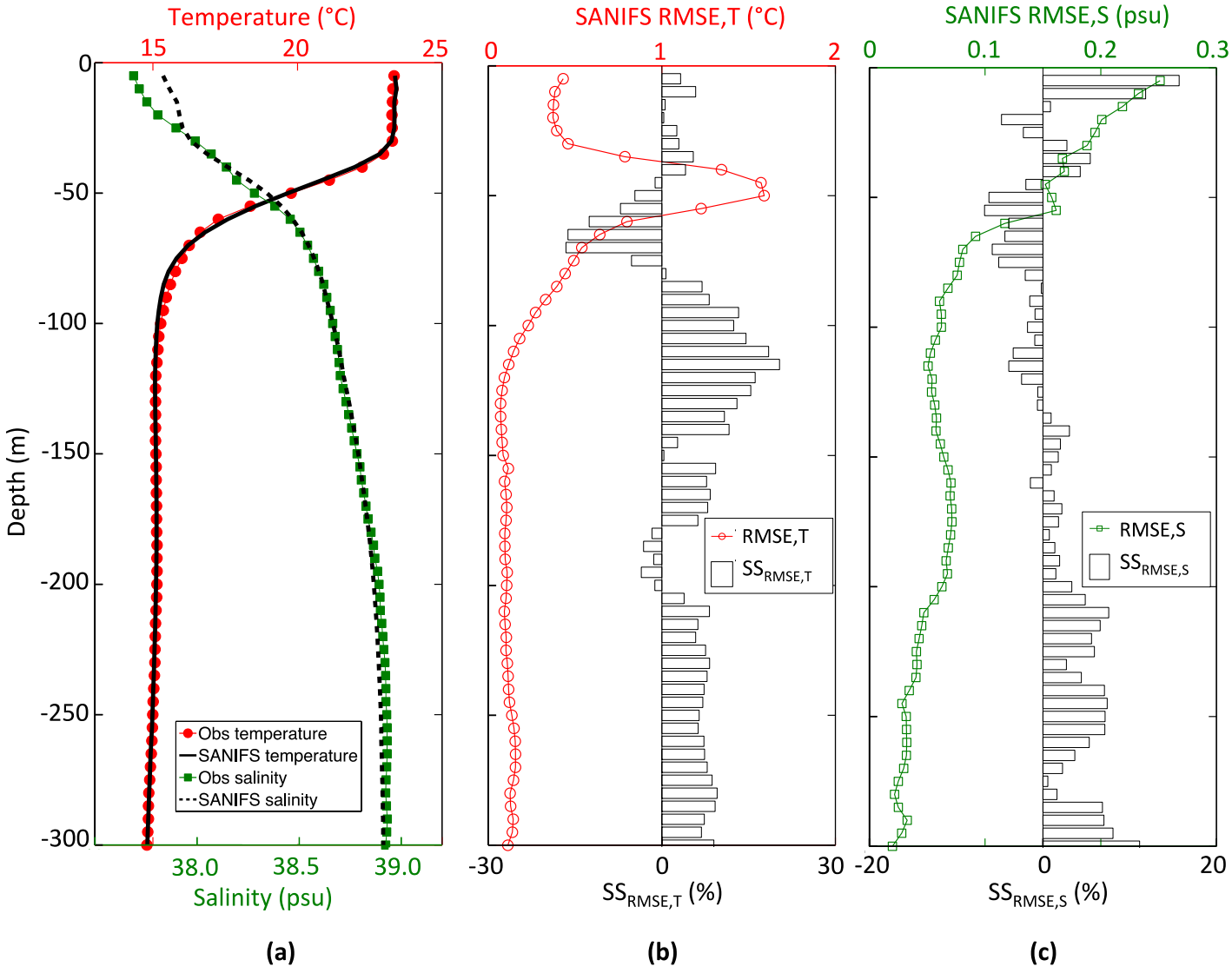


Sensitivity on types/number of initialization fields → **SANIFS-v1**

- Sensitivity of the **initialization to a different number of dynamical fields** (SANIFS-v0 vs. SANIFS-v1) in order to assess the configuration closer to the observations.
- SANIFS-v0 → initialized with T+S
- SANIFS-v1 → initialized with T+S+uv+ssh





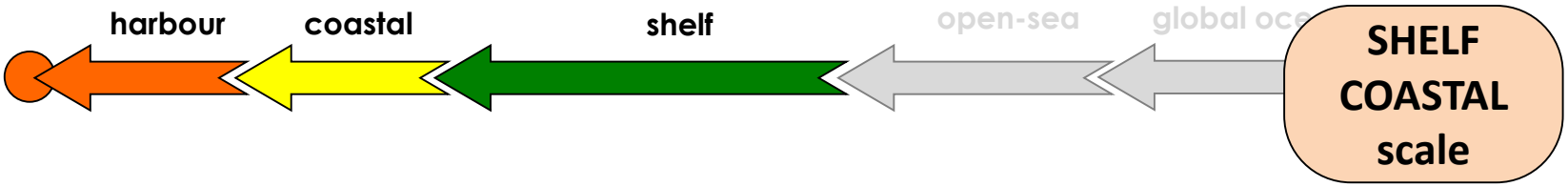


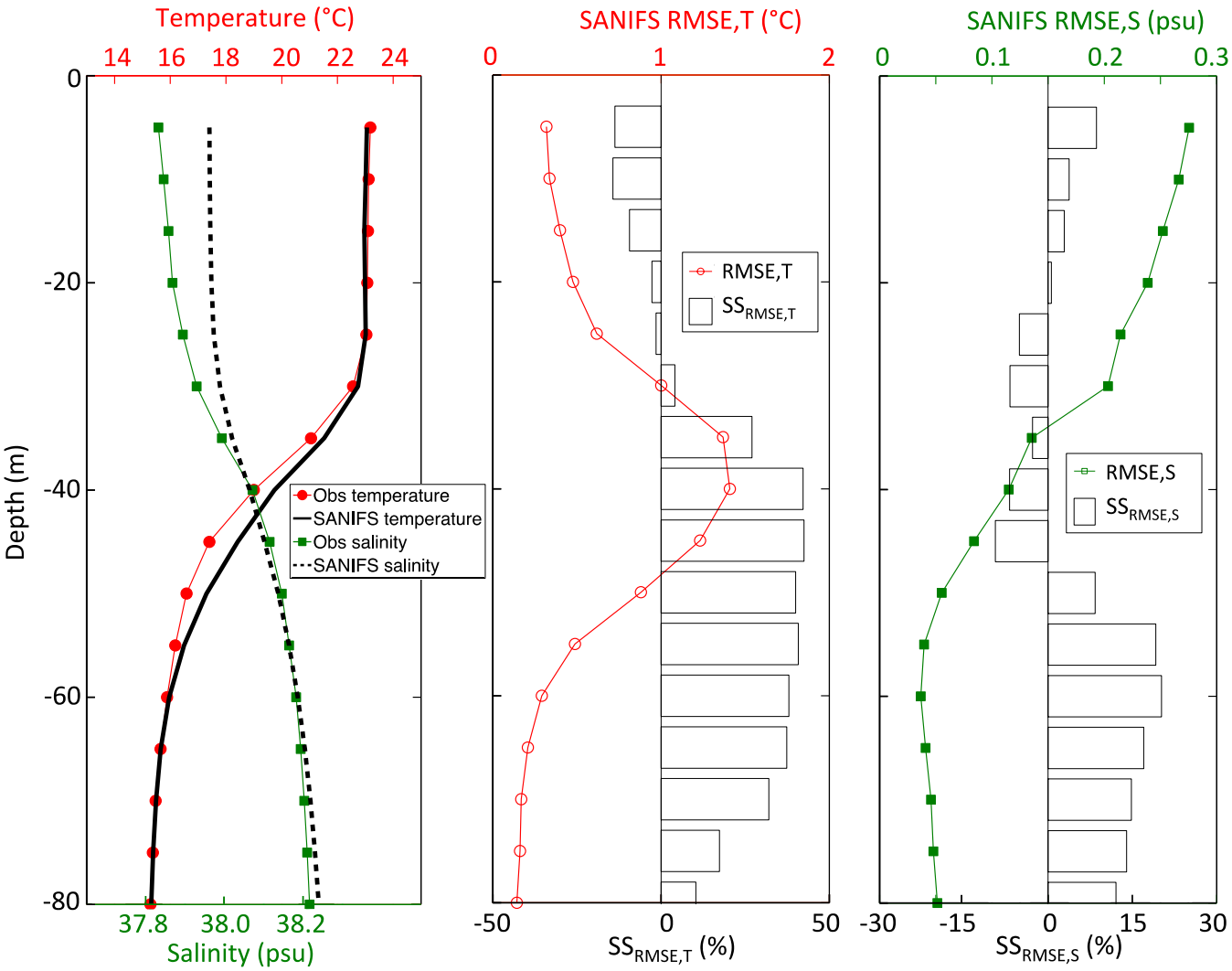
The representative profile of temperature and salinity, obtained by averaging all the model results and observation data in all the stations.

Comparison with reference model MFS

Sk. Sc. on temperature and salinity:

$$SS_{RMSE} = \frac{RMSE_{MFS} - RMSE_{SANIFS}}{RMSE_{MFS}}$$





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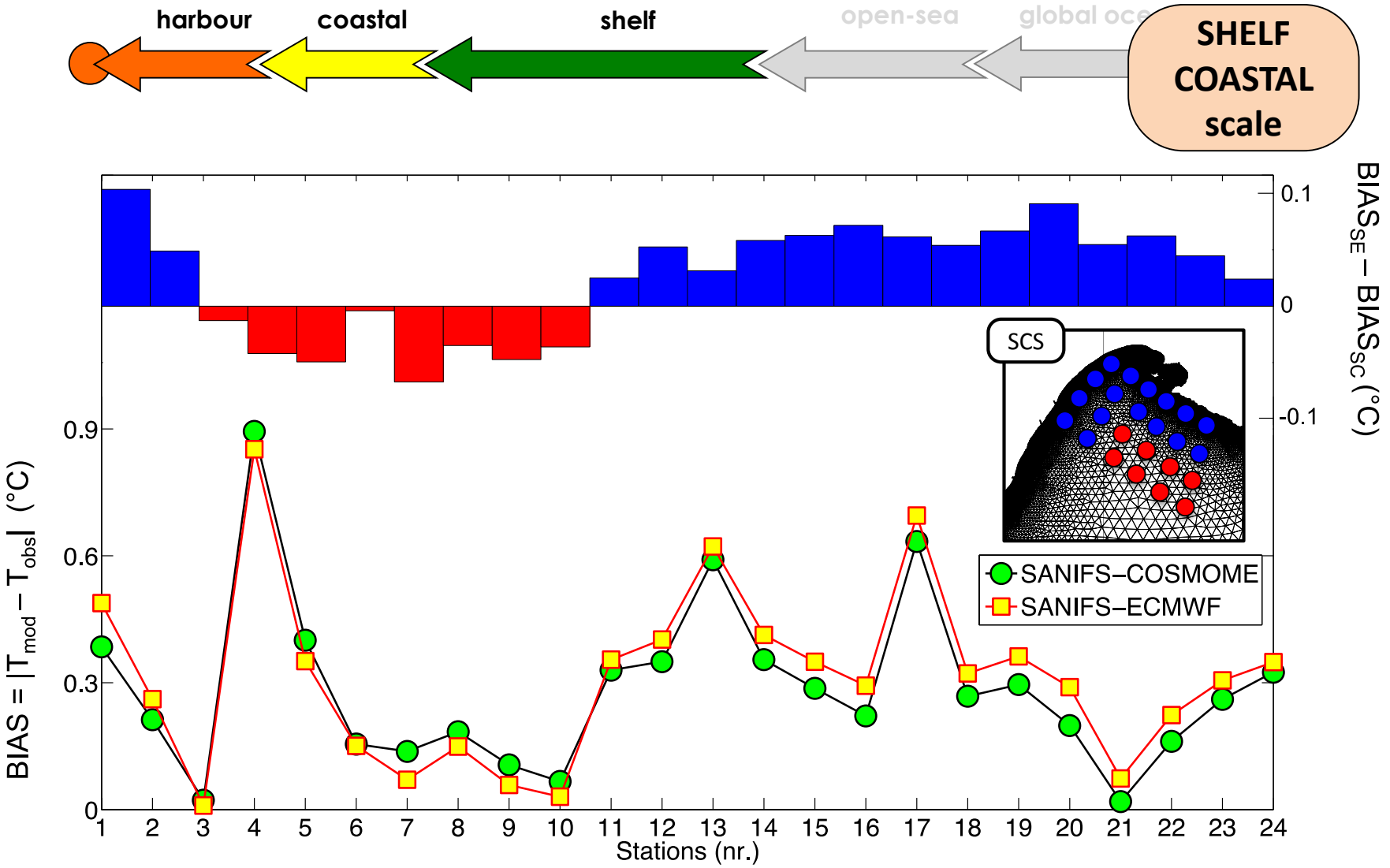
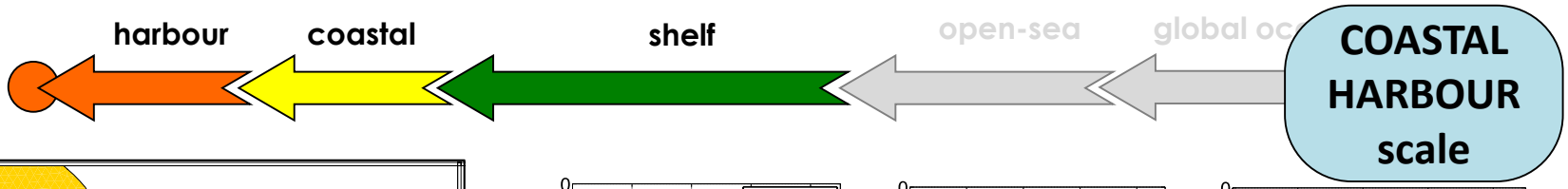
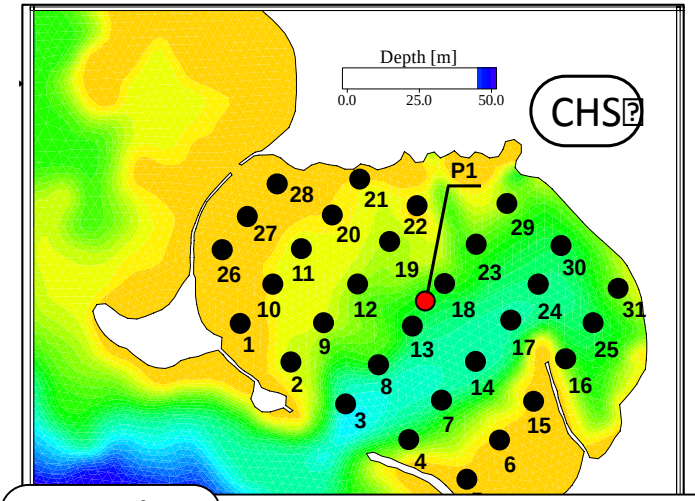
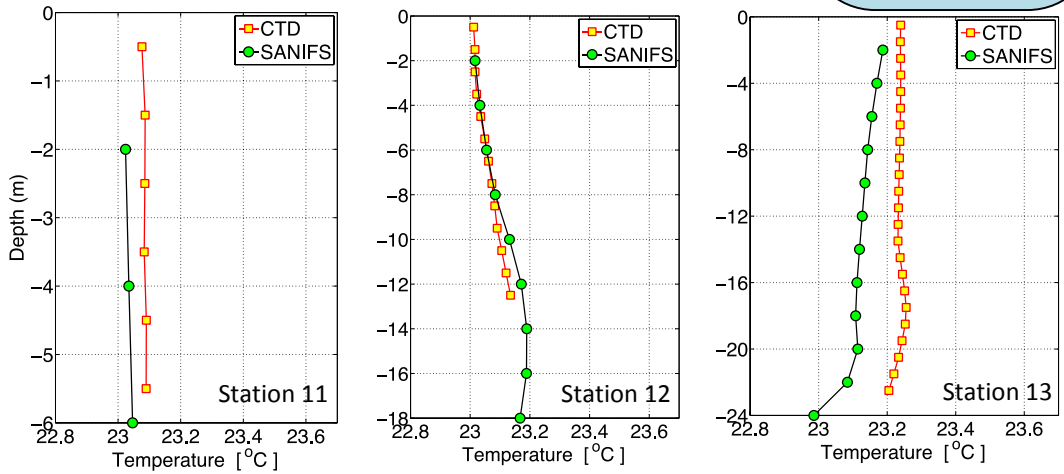


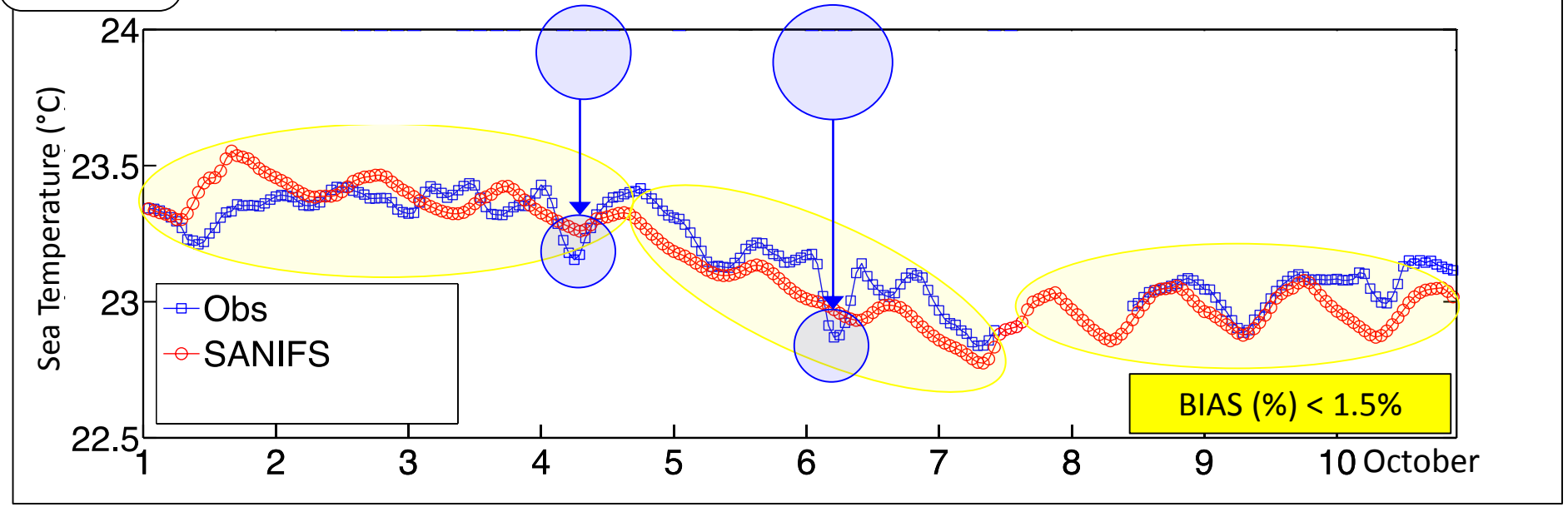
- A sensitivity study carried out using the **two alternative atmospheric forcings** (COSMOME and ECMWF).
- SANIFS-**ECMWF** produces **more accurate forecasts** than SANIFS-**COSMOME** for the eight **most open-sea stations** of the SCS campaign (red histograms) thus confirming the higher reliability of ECMWF as large-scale general circulation model (25 km resolution).
- The skills of SANIFS forced by the **higher-resolution (6 km) atmospheric limited area model COSMOME** are slightly greater in the remaining stations, **closer to the coasts** (blue histograms).



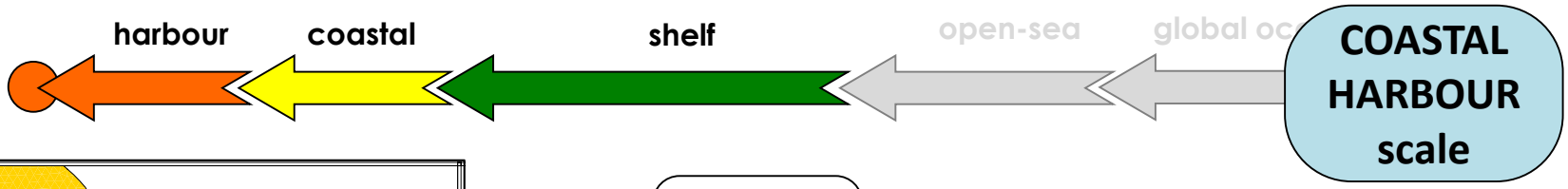


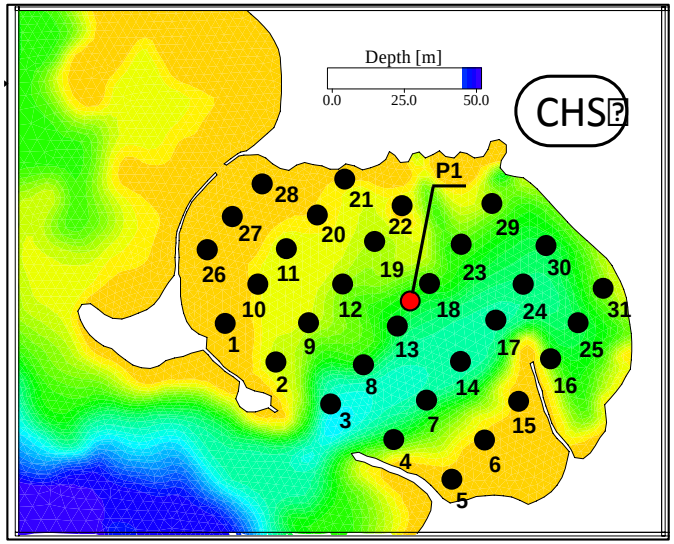


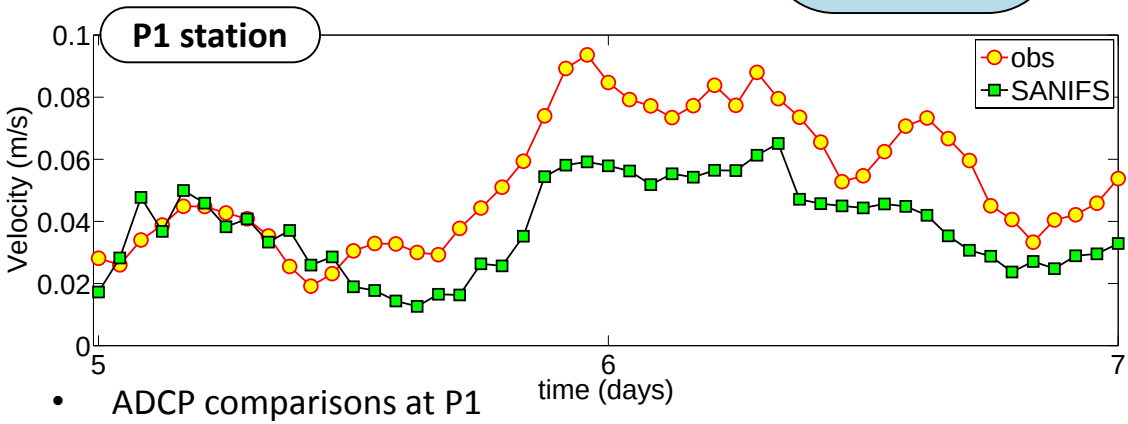
P1 station



- Modelled hourly time-series of sea temperatures at a 5 m of depth from the surface compared with the measured series.
- The two local minimum peaks of temperature in observations may be due to the **effect of total precipitation** since the maximum events of rainfall match with two local minimum temperatures. This suggests the need to introduce the temperature effects of rain.

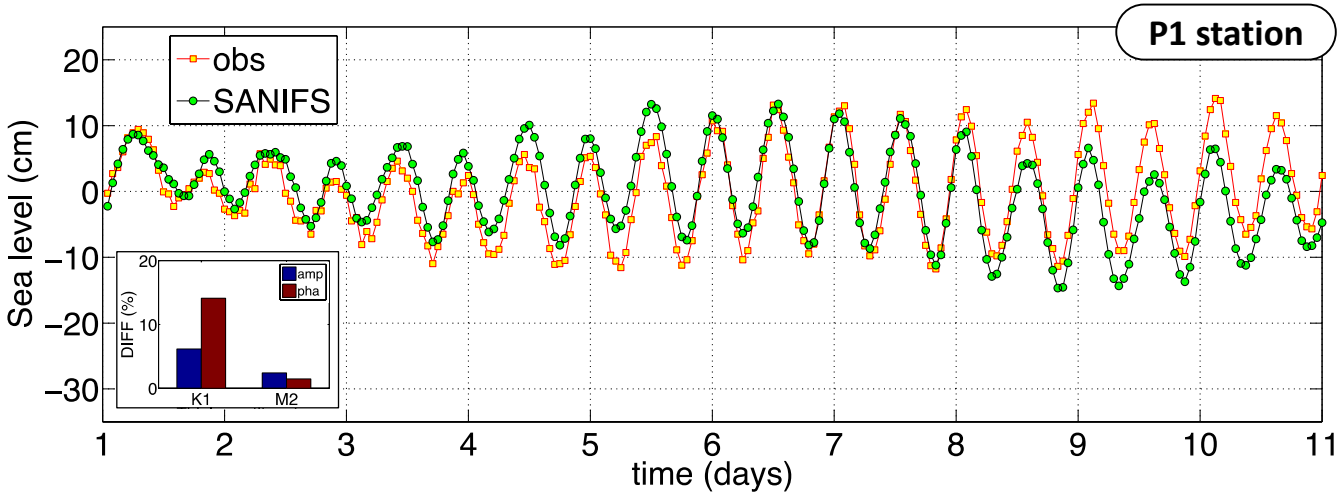




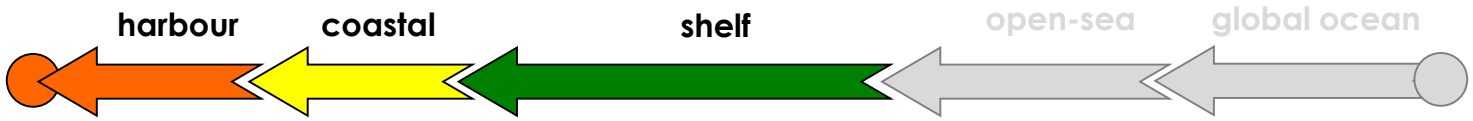


- ADCP comparisons at P1
- Consistent model agreement with observations in terms of velocity direction
- Underestimation of the velocity magnitude.

Comparison between modeled and observed sea level at the tidegauge station at P1

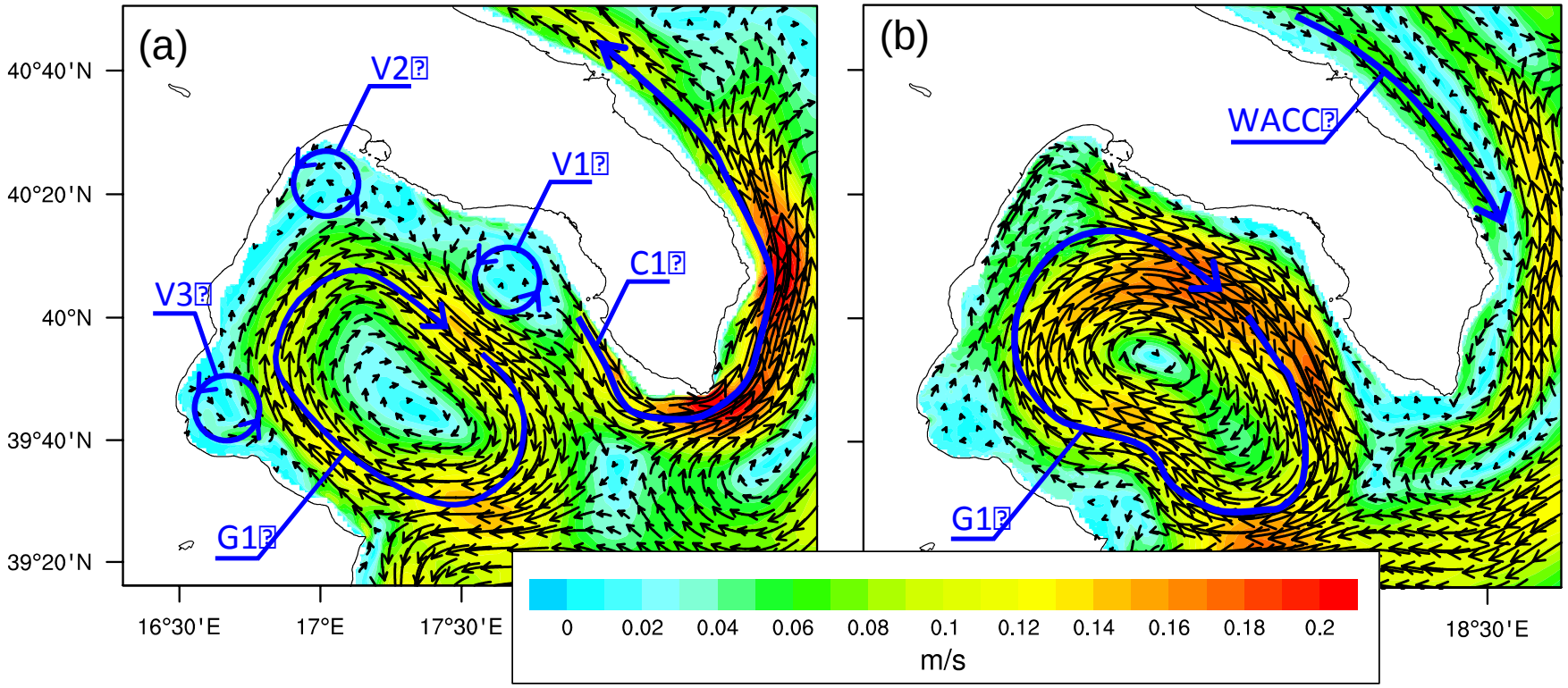


- Results for the most important semidiurnal and diurnal constituents (M2, K1).
- The tidal analysis reports errors of 6.2% and 14.1% for amplitude and phase of K1 component, and errors of 2.4% and 1.5% for amplitude and phase of M2 component.



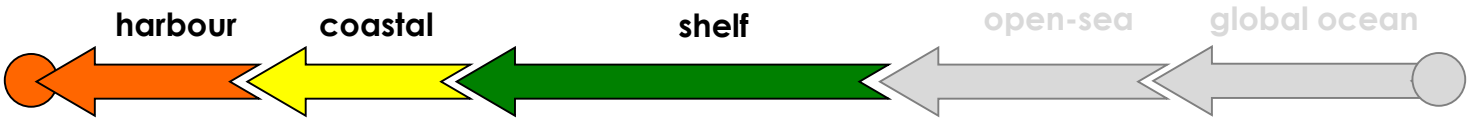
LS1: 1-3 October 2014

LS2: 8-10 October 2014

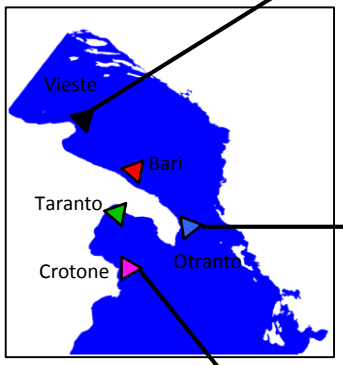


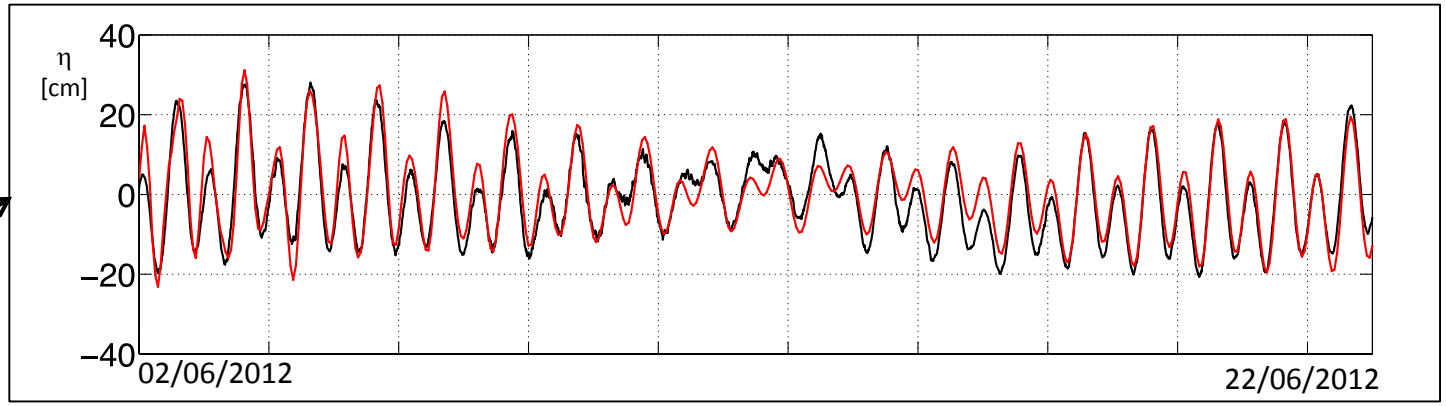
- Large scale circulation characterized mainly by an anticyclonic structure (G1).
- **LS1:** weak cyclonically-oriented vortices in shelf-coastal areas (V1, V2 and V3)
- Intense coastal current (C1) impacting on the Adriatic coastal circulation
- **LS2**: Intensification of large-scale anticyclonic gyre (G1) causing the three cyclonic vortices to vanish.

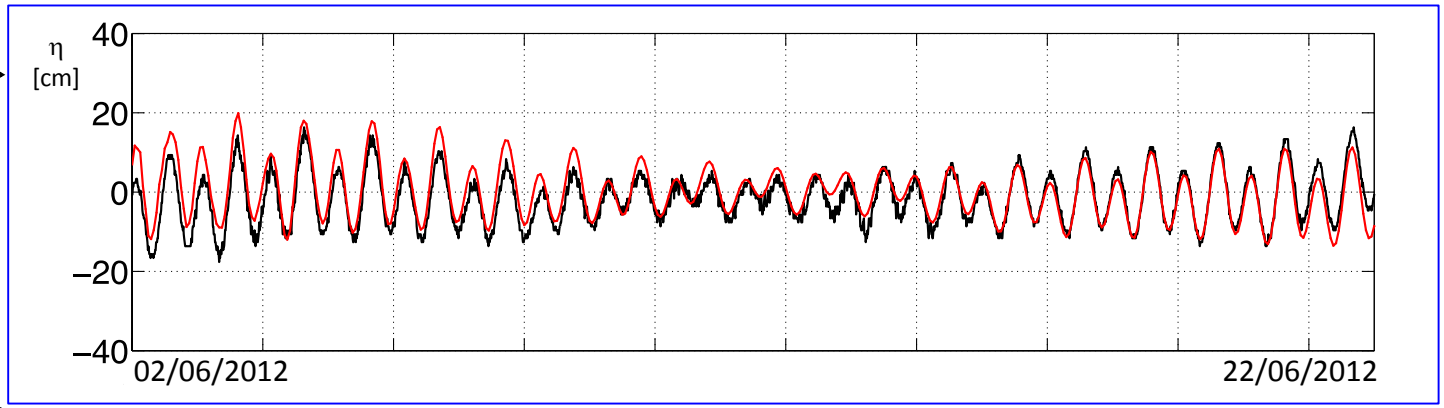
The Gulf of Taranto circulation structure affects the WACC entrance in the Gulf and along the Apulia coasts.
Weaker G1 → WACC reversed. Stronger G1 → southward oriented WACC

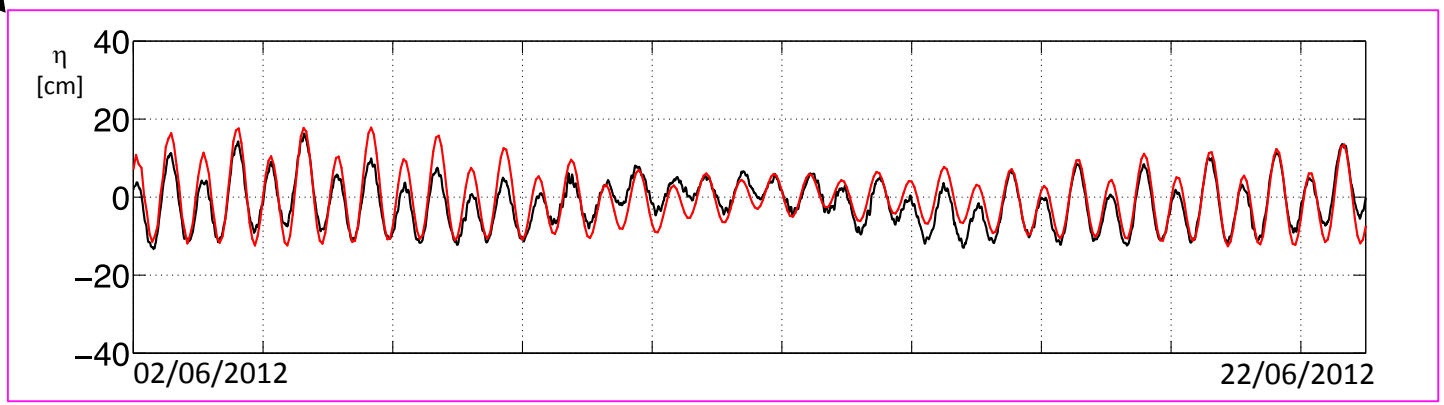


Time-series comparisons between the simulated sea level and the observed height at the Italian tide-gauges stations have been performed.

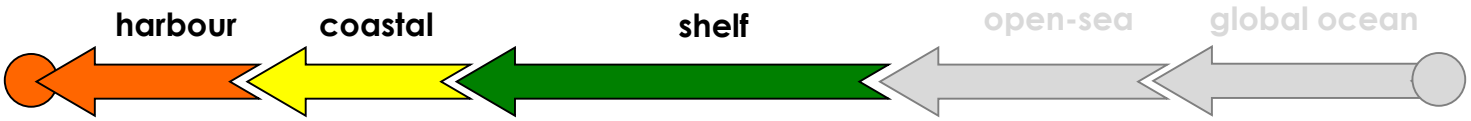






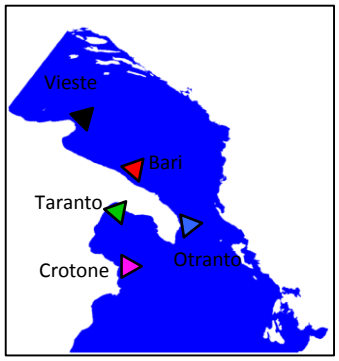


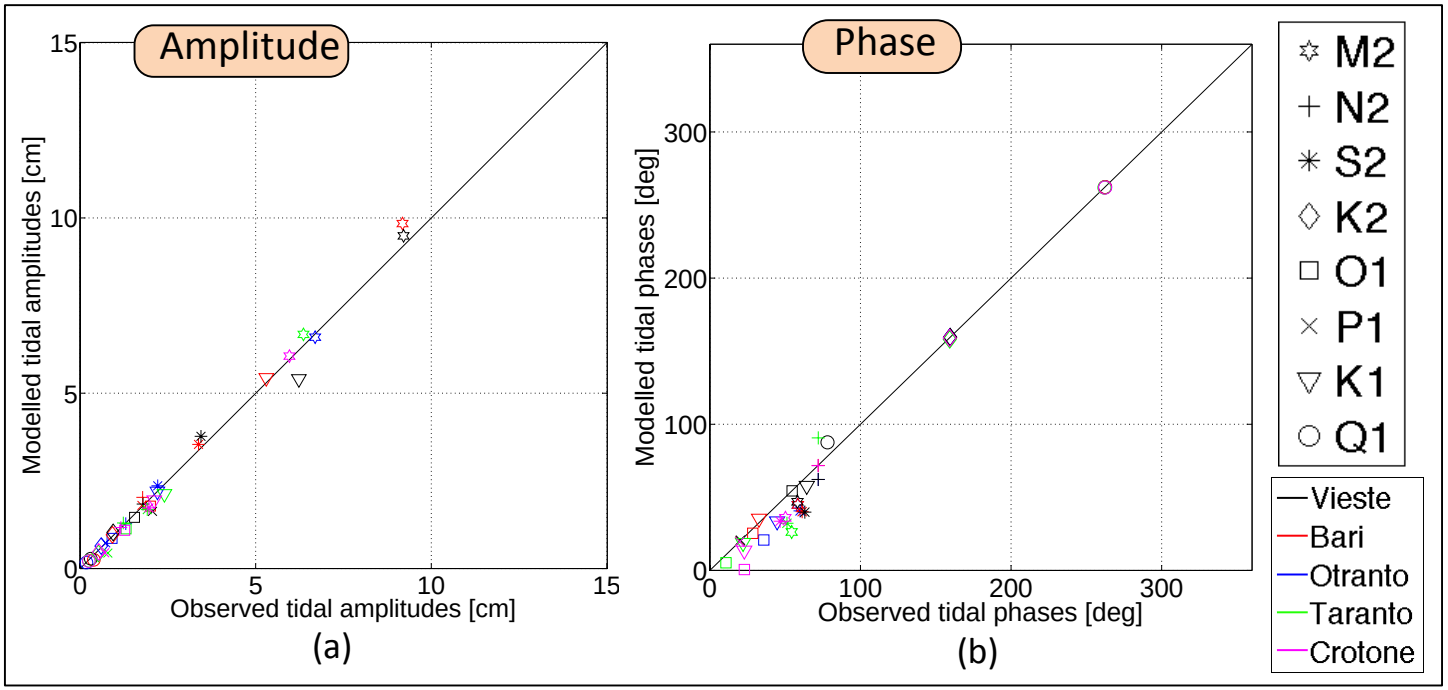
Obs: **Italian tigegauges** service provided by **ISPRA** (*Istituto Superiore per la Protezione e la Ricerca Ambientale*, the Italian Institute for Environmental Protection and Research)**.**



Tidal Analysis.
(TAPpy python toolbox)

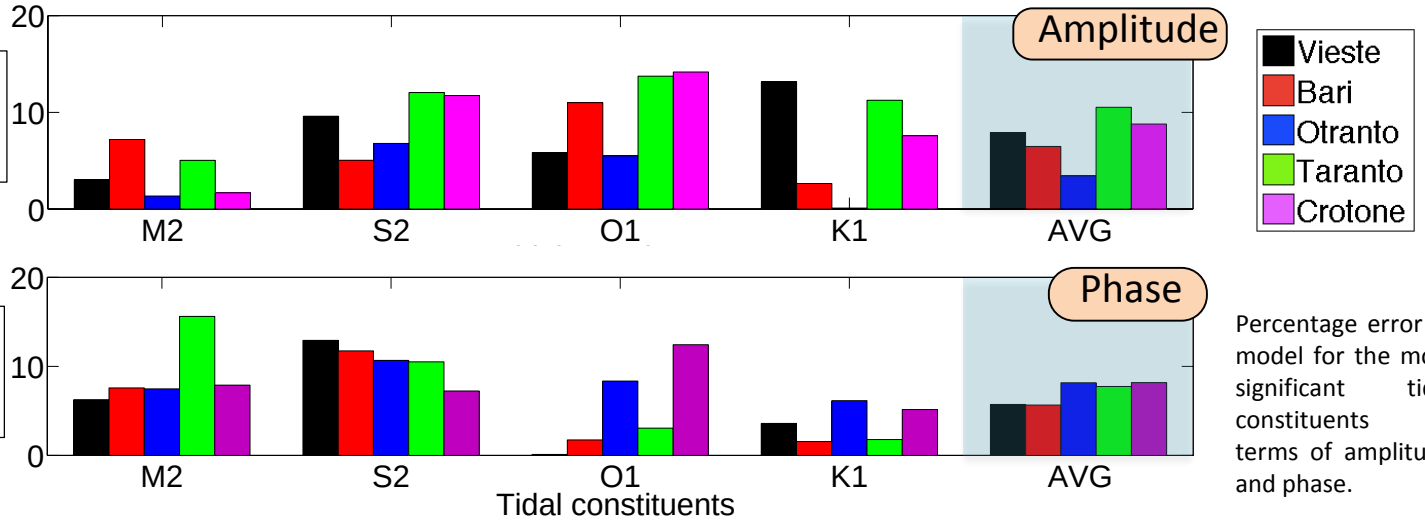
Scatter plots of observed and modeled (semidiurnal and diurnal) tidal constituents in terms of (a) amplitude [cm] and (b) phase [deg] at the 5 coastal stations in SANI domain.



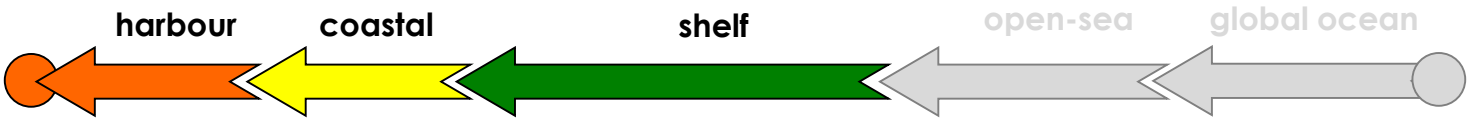


$$\mathrm{DIFF}^{amp}_{\%} = 100 \left| \frac{A^o - A^m}{A^o} \right|$$

$$\mathrm{DIFF}^{pha}_{\%} = 100 \left| \frac{P^o - P^m}{180} \right|$$



Percentage error of model for the most significant tidal constituents in terms of amplitude and phase.



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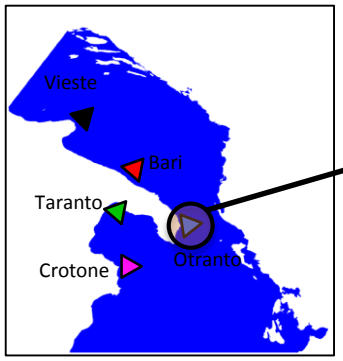
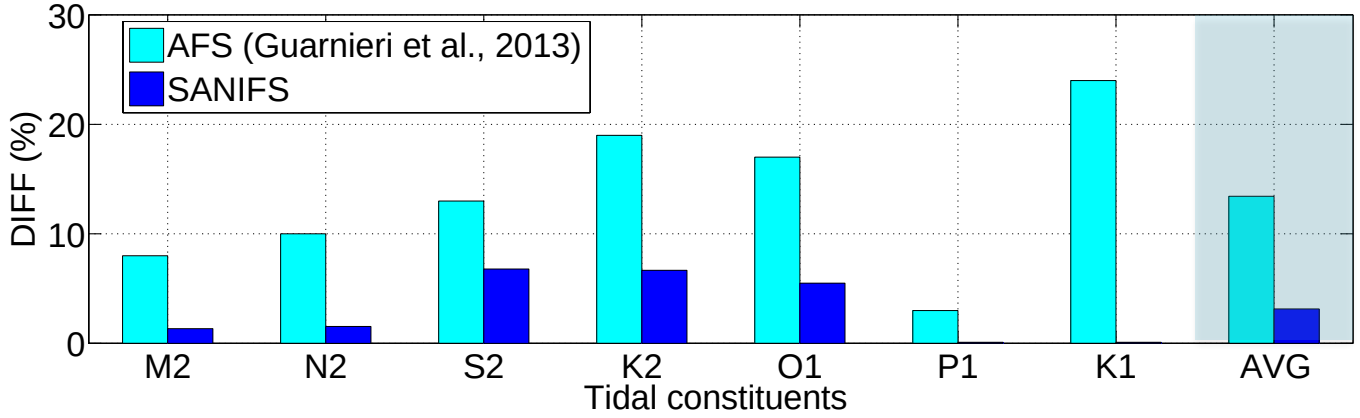
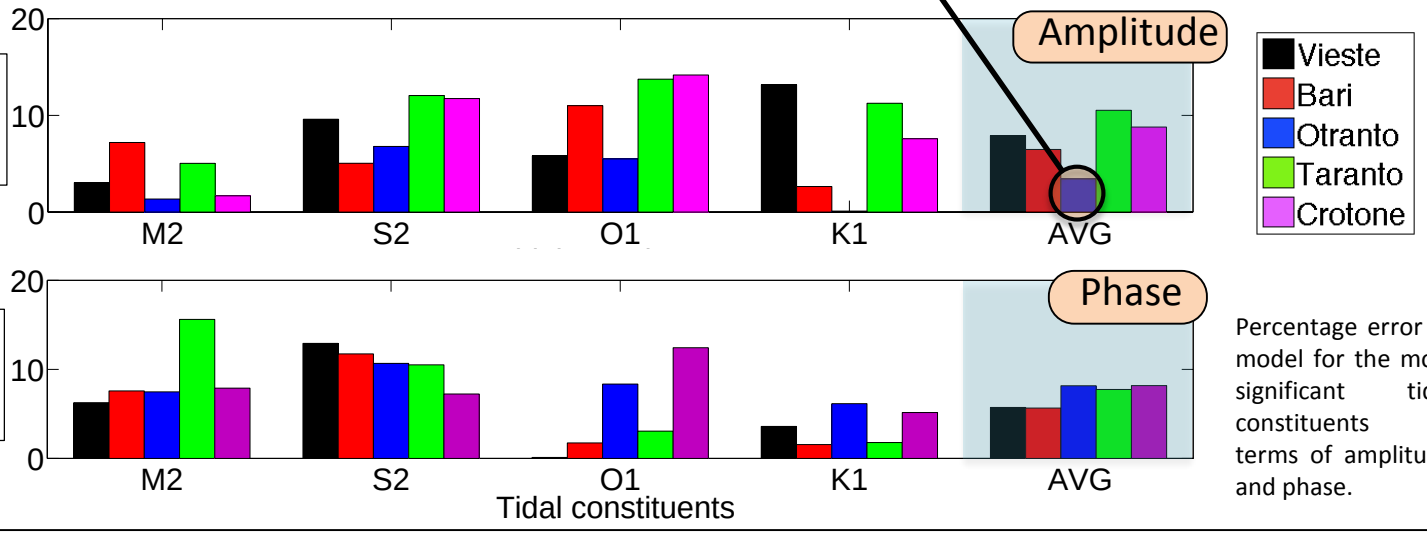




Comparison with AFS (POM-based) model for Otranto tidegauge.

$$DIFF^{amp}_{\%} = 100 \left| \frac{A^o - A^m}{A^o} \right|$$

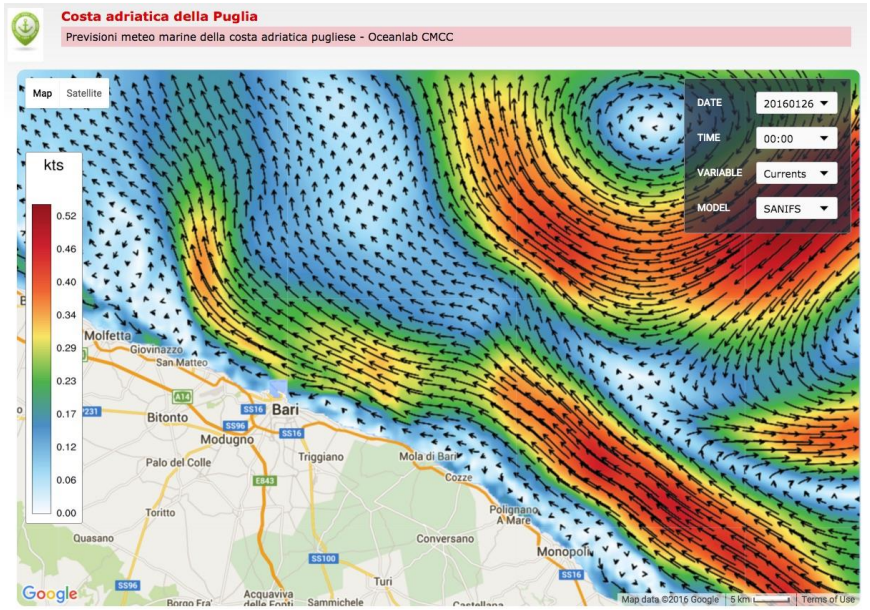
$$DIFF^{pha}_{\%} = 100 \left| \frac{P^o - P^m}{180} \right|$$

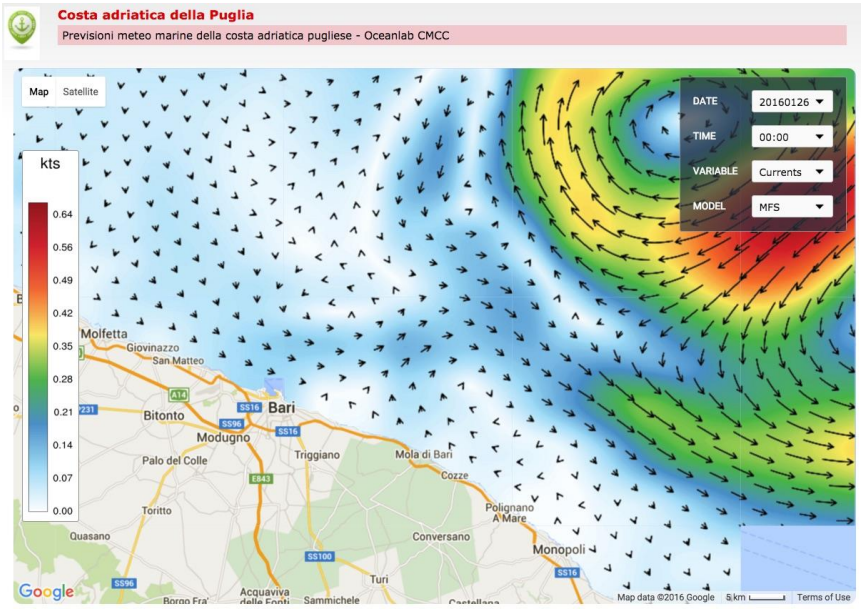


Percentage error of model for the most significant tidal constituents in terms of amplitude and phase.

ARGES
Passengers and logistics information Exchange System

European Territorial Cooperation Programme
Greece - Italy
2007-2013
INVESTING IN OUR FUTURE
Co-funded by the European Union (ERDF) and by National Funds of Greece & Italy





SANIFS

MFS

Mercoledì 9 Dicembre 2015

Autorità Portuale del Levante

MONOPOLI Dati al momento non disponibili

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Benvenuto,
Mannarini Gianandrea

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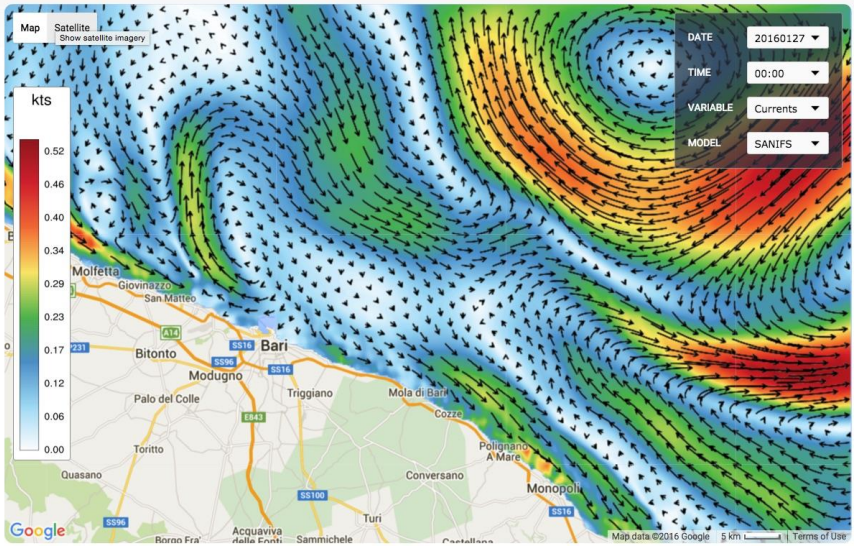
Report Meteo

Stazioni APL

Stazione: Bari **Tipo report:** Giornaliero Giorno: 9 Mese: Dicembre Anno: 2015

Costa adriatica della Puglia

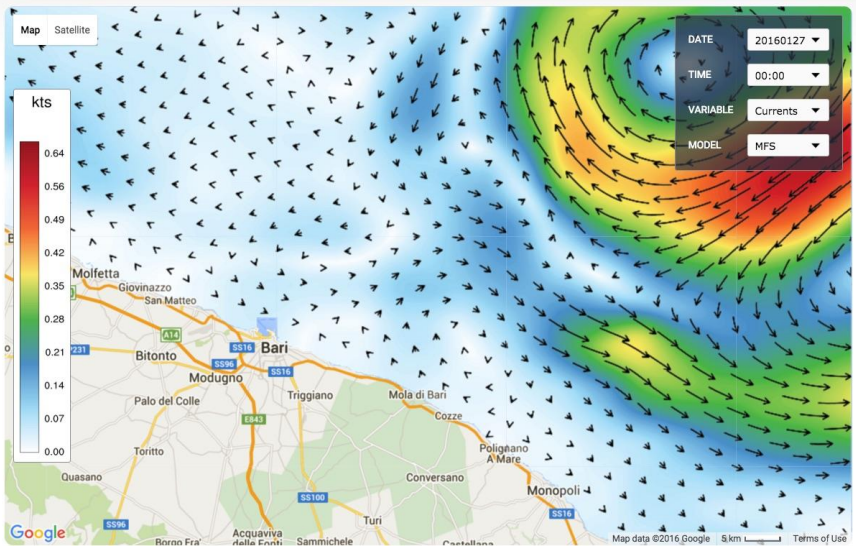
Previsioni meteo marine della costa adriatica pugliese - Oceanlab CMCC



SANIFS

Costa adriatica della Puglia

Previsioni meteo marine della costa adriatica pugliese - Oceanlab CMCC



MFS

Decision Support Systems (DSS)

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VISIR® is a commercial service providing optimized nautical routes in the Mediterranean Sea. The optimization regards total navigation time, taking into account safety of navigation.

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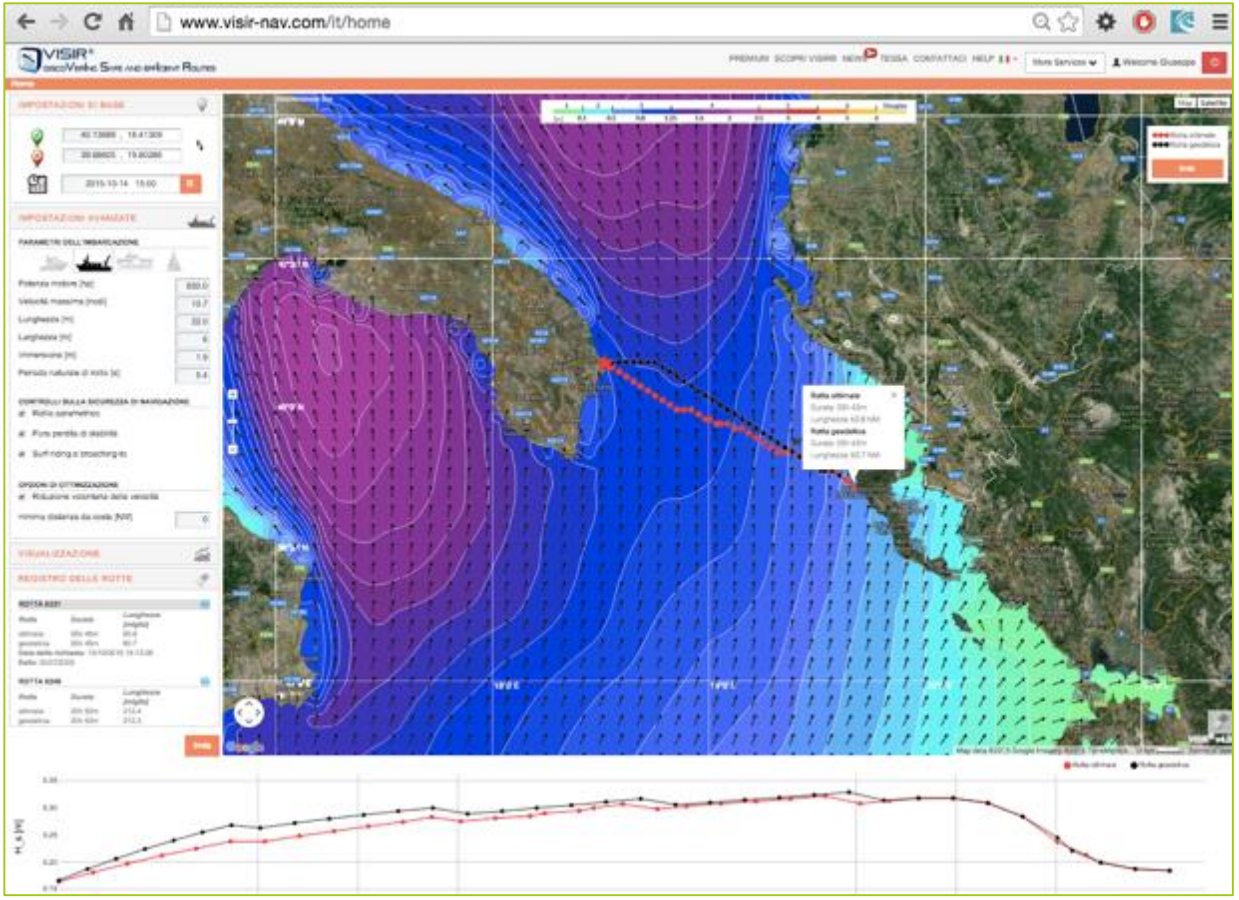

OCEAN-SAR - http://www.ocean-sar.com

OCEAN-SAR, the Maritime Search and Rescue Service in the Mediterranean Sea.

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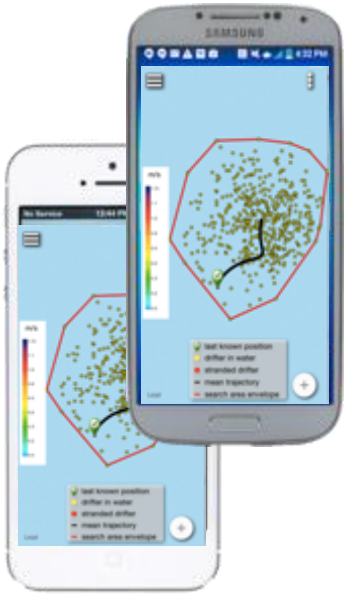
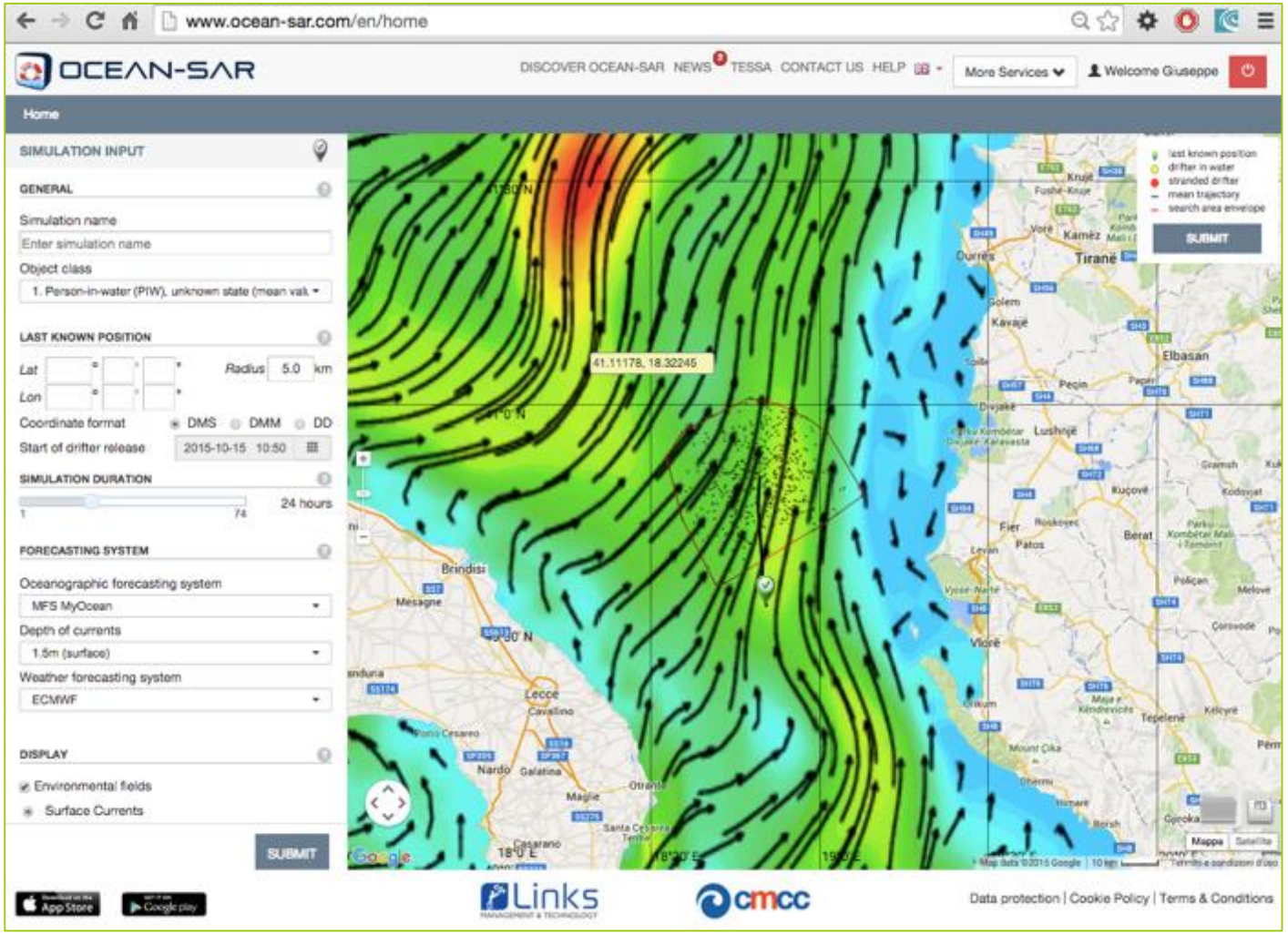
- Android
- iOS



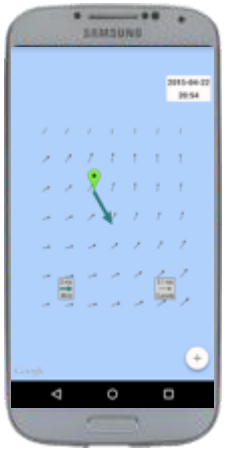


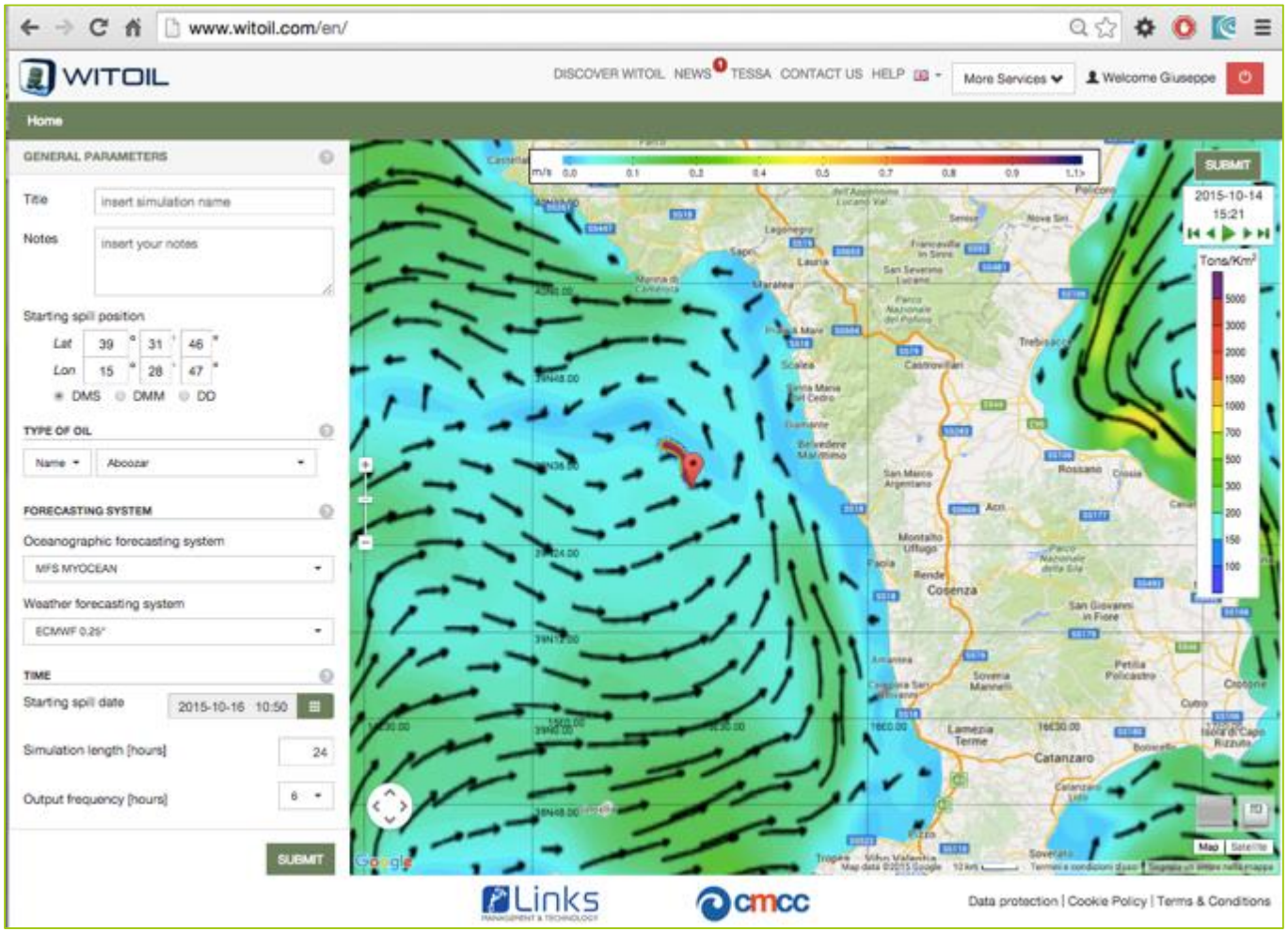
WITOIL - http://www.witoil.com

WITOIL, our service for predicting the fate and transport oil spills in the Mediterranean Sea.

Available for:

- Web
- Android



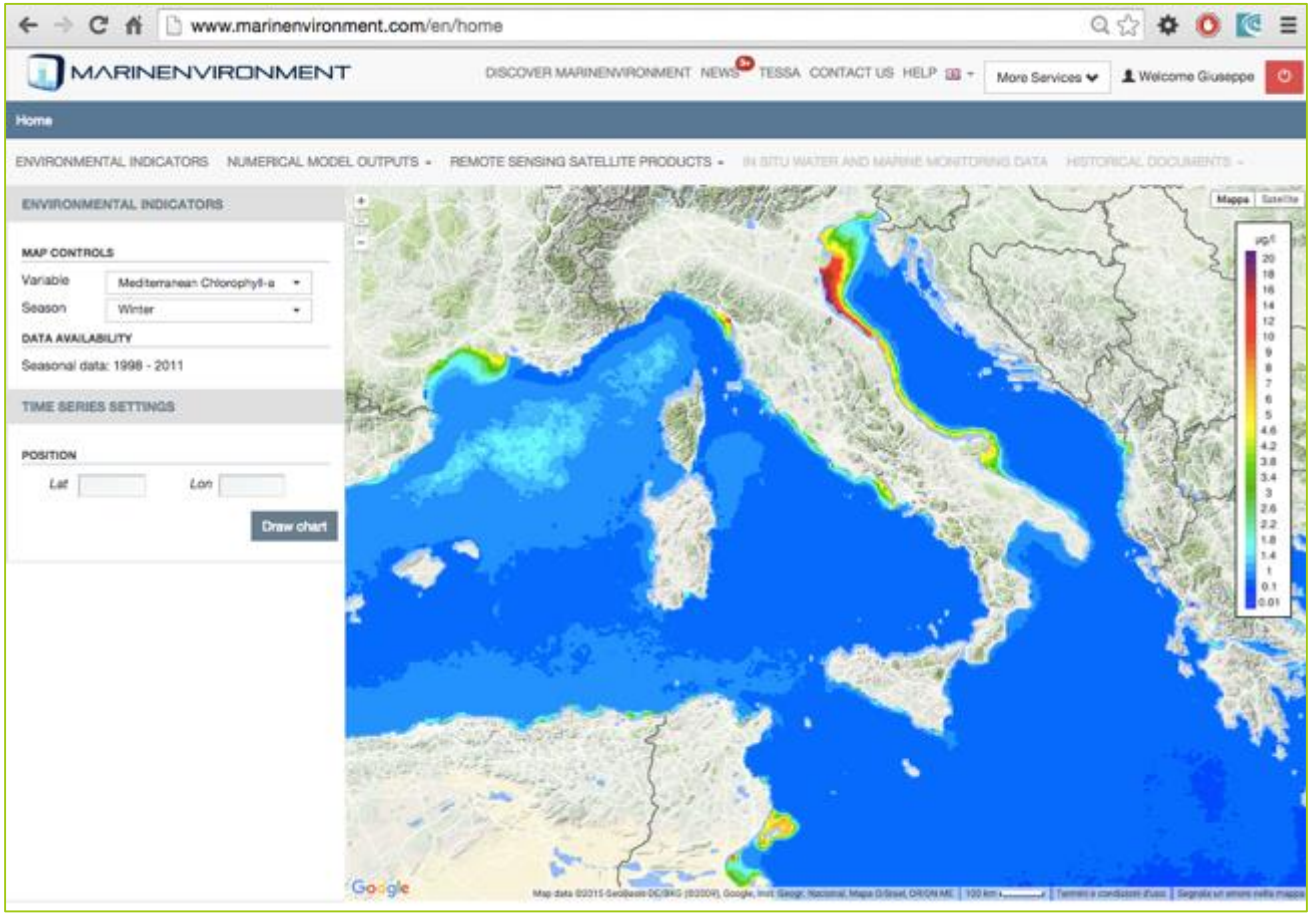


Marine Environment www.marinenvironment.com

MARINENVIRONMENT is a service to provide and display information on the environmental quality of the Mediterranean Sea.

Available for:

- Web
- Android
- iOS

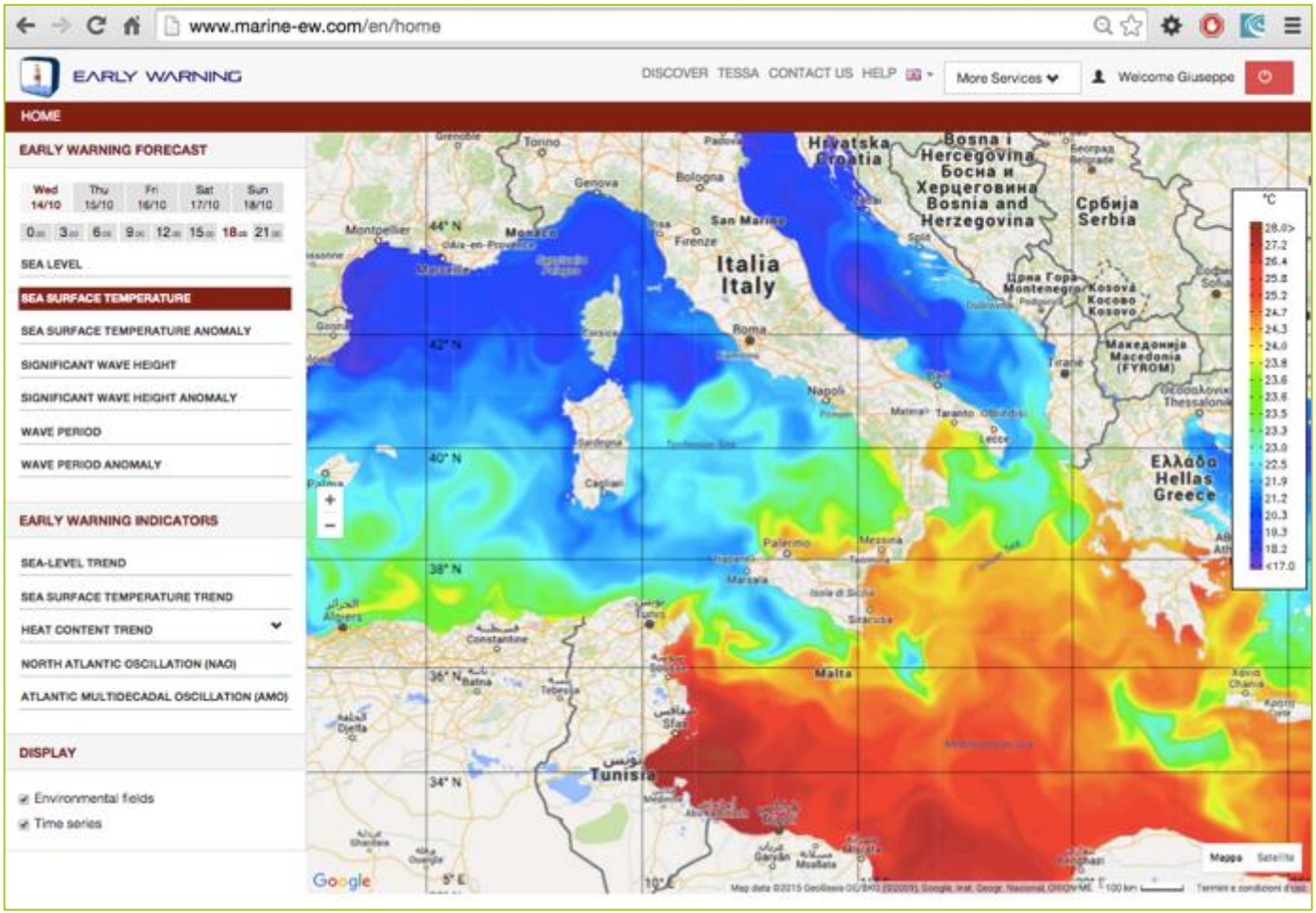


Early warning - www.marine-ew.com

Marine Early Warning is a service provided to decrease risk disaster at sea reducing loss of life and the economic and material impact.

Available for:

- Web
- Android
- iOS



Summarizing the methodology

- The coastal ocean circulation is driven by a combination of **local** (winds, atmospheric fluxes, tides, etc.) and **deep-ocean forcings** (along the shelf slope).

- Both of these influences must be included in Coastal Ocean Forecasting Systems (COFS).

- **Downscaling** is accepted as the preferred methodology to propagate the large scale dynamics into COFS, through boundary conditions from Large scale Ocean Forecasting Systems (LOFS) (Auclair et al. 2001; Dombrowsky et al. 2009, Kourafalou et al. 2015).

- To simulate correctly the water masses properties and circulation characteristics propagating from open ocean to coastal zones, downscaling approach needs to be supported by an **appropriate (high) open-sea resolution (also) in nested model**.

- COFS has been designed **also to provide accurate forecasts in open ocean**, exploiting high resolution horizontal e vertical discretization.

- Implementation (and validation) of techniques and parametrizazions **consolidated in classical regional model** (e.g. atmospheric bulk formulae, LOBC treatment, etc.) in **new modelling tools (unstructured-grdi models)**.

- Reduce parametrization tuning/calibration

Conclusion and Perspectives

- A methodology of downscaling from the Global Ocean to the Coastal-Harbour scale
- The pilot study of the Southern Adriatic Northern Ionian seas will be extended to the entire Mediterranean coastal seas
- Downscaling approach is integrated to the new modelling tools based on variable resolution (unstructured grid model)
- The modelling component is continuously run in operational mode to provide short-term forecast.
- The operational products can be exploited by several types of DSS (coastal erosion, risk mapping, oil spill, ship routing, search-and-rescue, etc.)

Thanks for your attention

cmcc

Centro Euro-Mediterraneo
sui Cambiamenti Climatici