Shelf-coastal seamless Mediterranean-Black sea model nested in Atlantic Ocean

I. Federico, I. Barletta, G. Verri,
S. Causio, F. Montagna, G. Coppini, N. Pinardi

CMCC (EuroMediterranean Center on Climate Changes) Foundation,
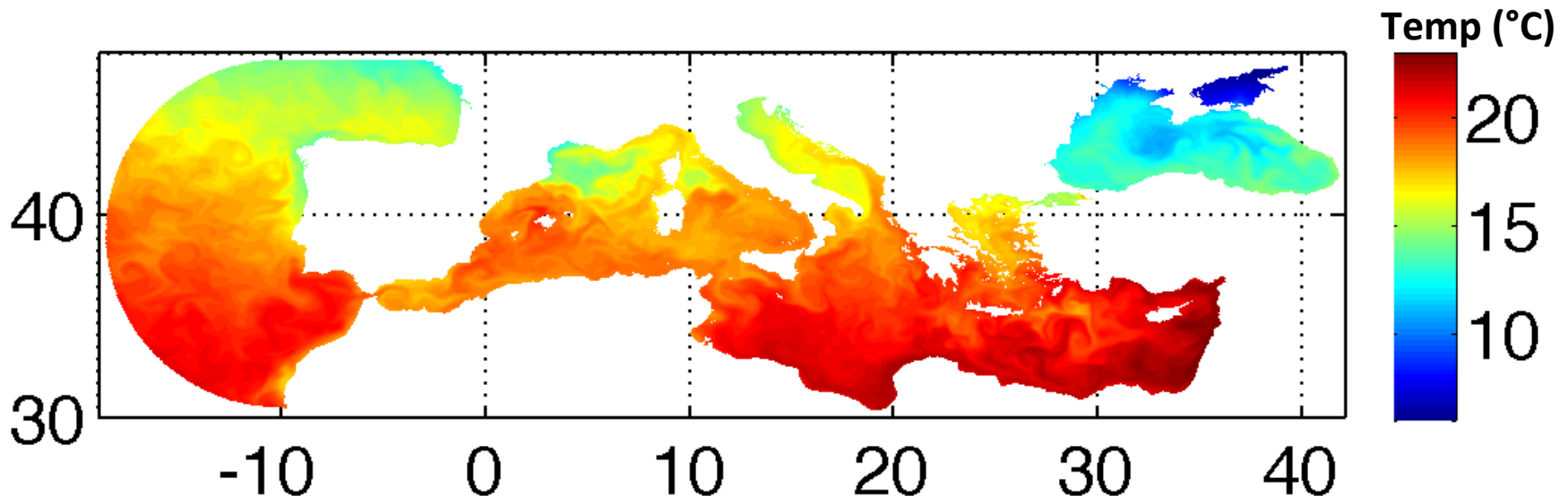OPA division (Ocean Predictions and Applications)

Florence, 17-19 October 2018
JONSMOD-2018

Keywords and goal:

- ## Seamless and cross-scale unstructured-grid modelling
  (inter-connected basins Atlantic, Mediterranean and Black Sea)

- ## Fully baroclinic

- ## (Pre-)Operational Forecasting

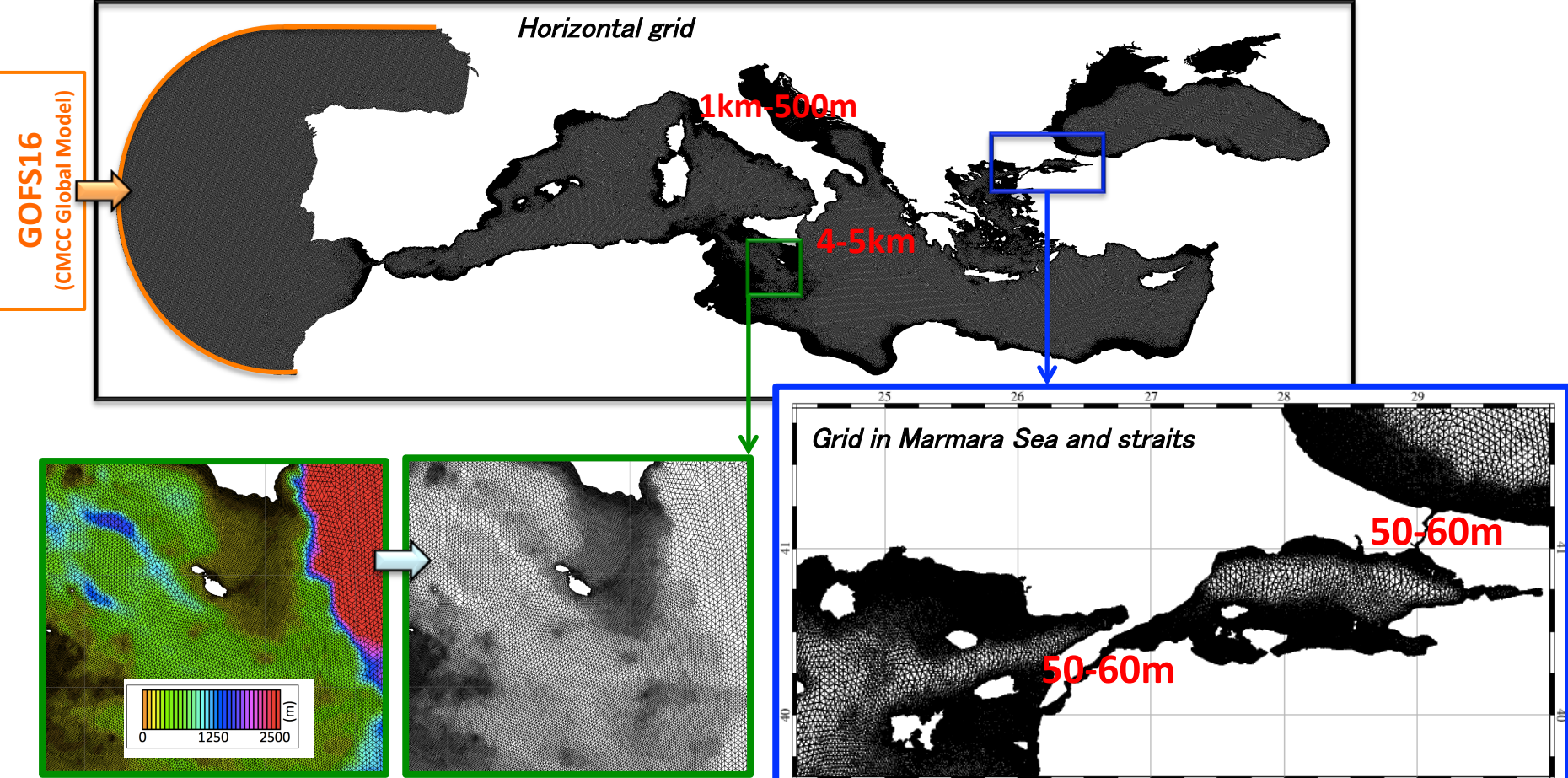*uMEDBS (Unstructured-grid MEDiterranean and Black Sea system)*

Shelf-coastal seamless Mediterranean-Black sea model nested in Atlantic Ocean

uMEDBS (Unstructured-grid MEDiterranean and Black Sea system)

○ Covering the entire Mediterranean and Black Sea with the a unique-continuum-seamless grid,

○ Solving with appropriate variable resolution different oceanographic scales, with detailed focus on the shelf-coastal scale,

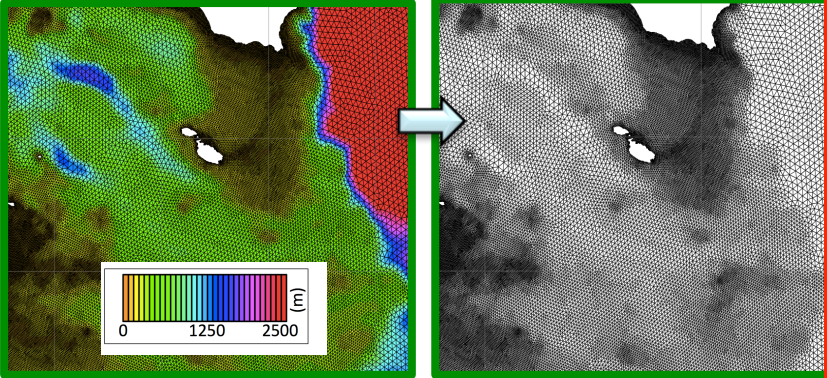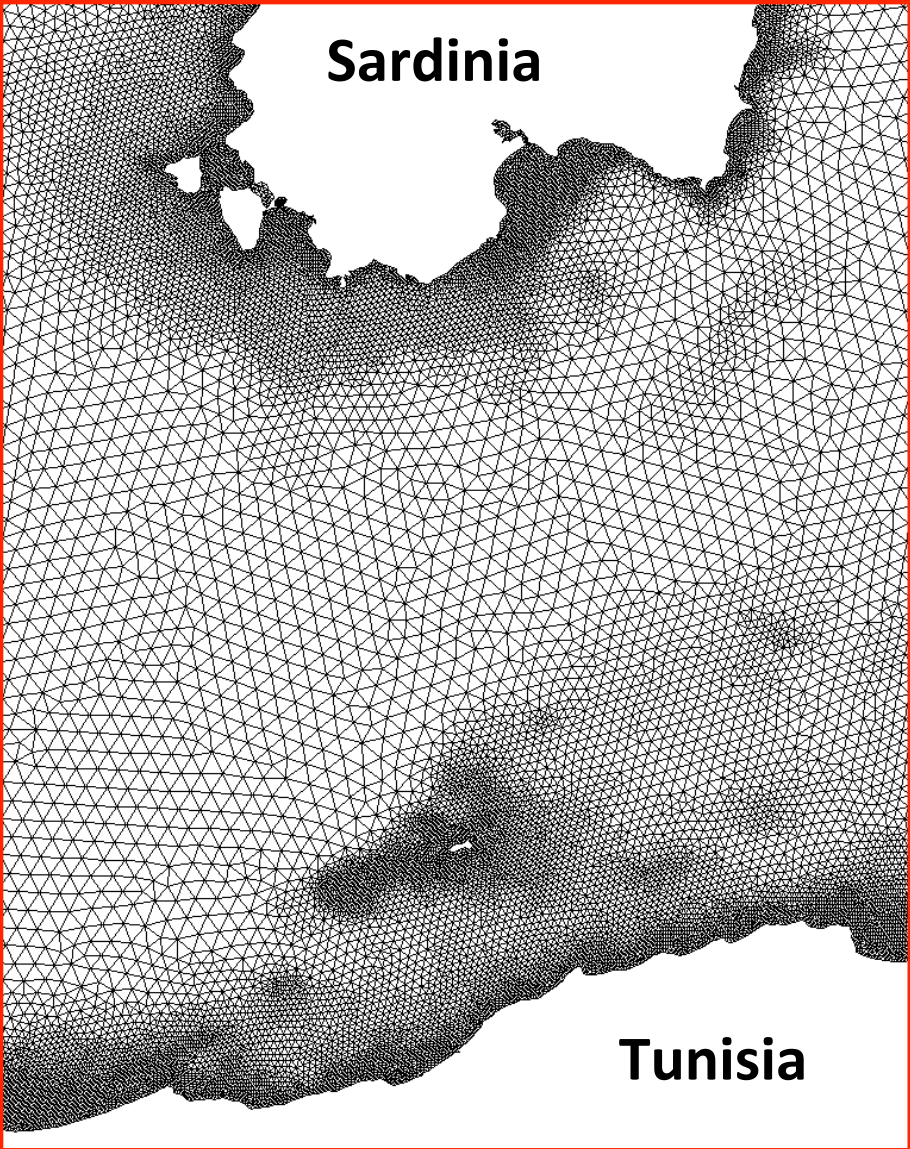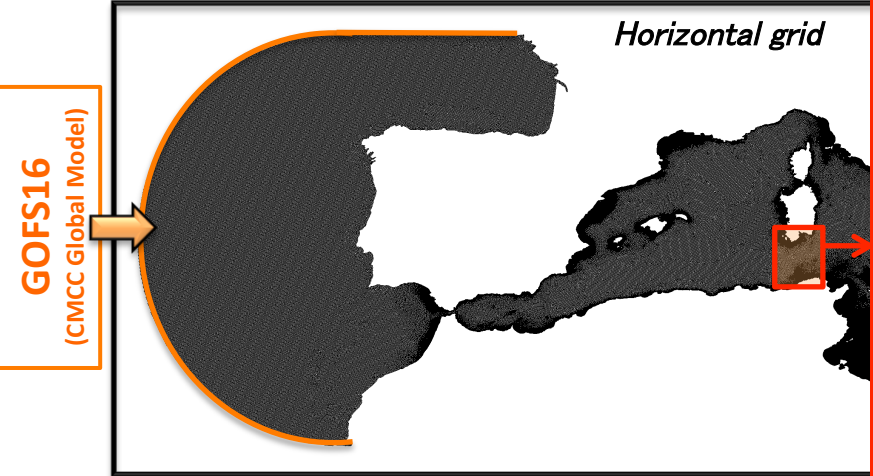○ Extending in a large Atlantic box with a lateral open boundary nested into Global Model.

Horizontal grid

1km-500m

4-5km

GOFS16 (CMCC Global Model)

Grid in Marmara Sea and straits

50-60m

50-60m

Bathymetry constraint

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uMEDBS (Unstructured-grid MEDiterranean and Black Sea system)

o Covering the entire Mediterranean and Black Sea with t

o Solving with appropriate variable resolution different

   shelf-coastal scale,

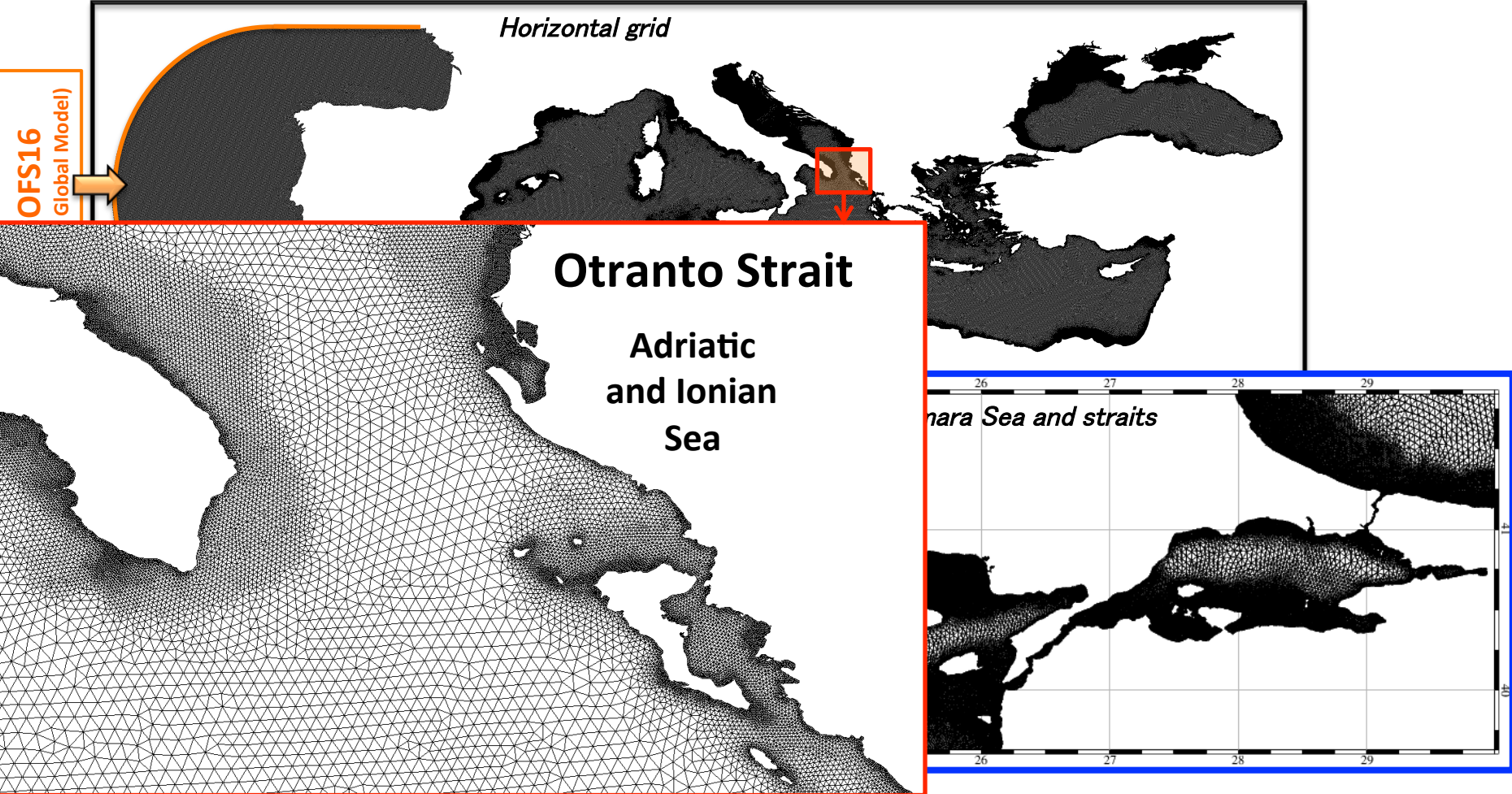o Extending in a large Atlantic box with a lateral open bou

Horizontal grid

GOFS16
(CMCC Global Model)

Bathymetry constraint

Regional shelf-coastal scales

Sardinia

Tunisia

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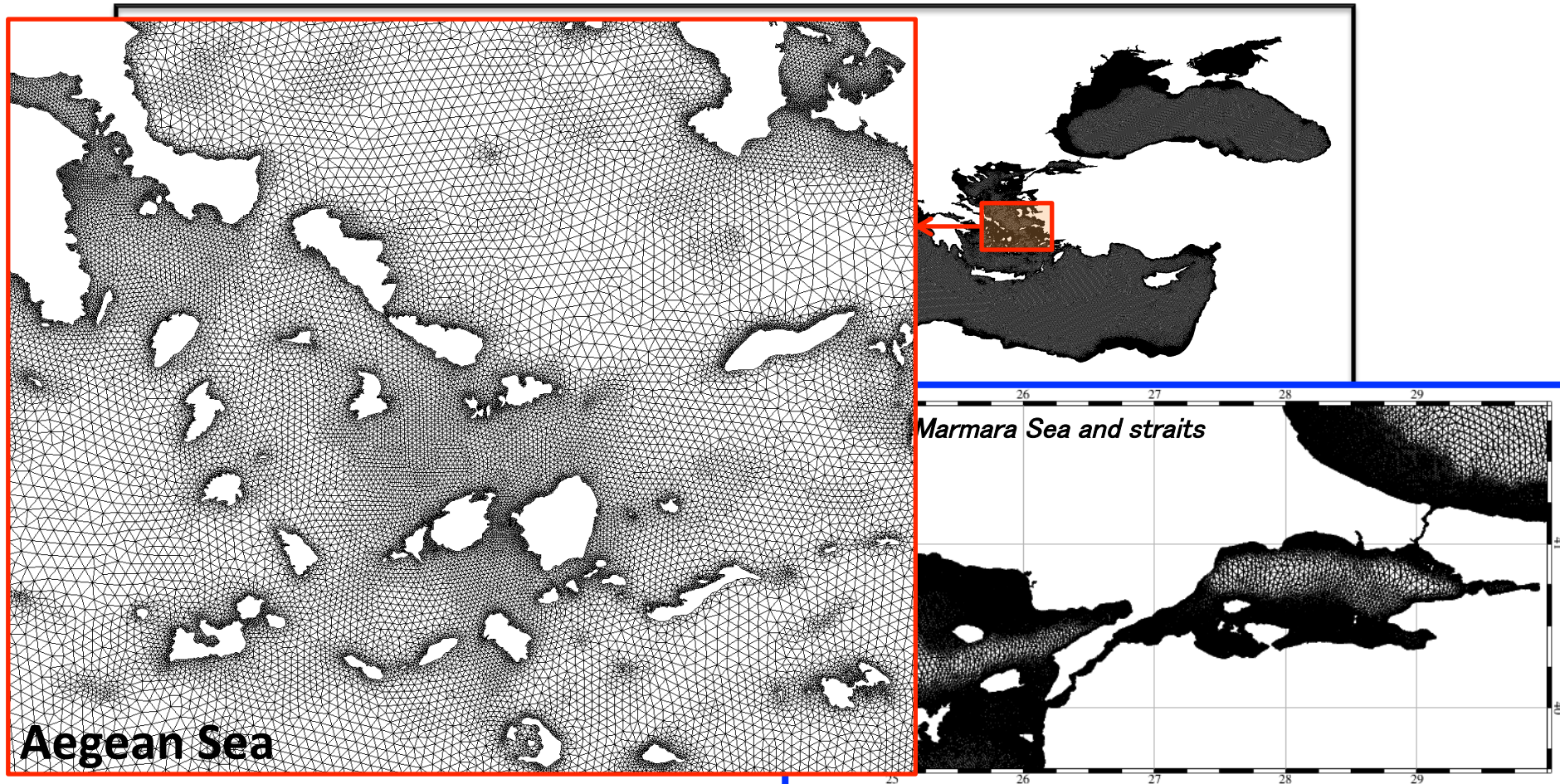o Extending in a large Atlantic box with a lateral open boundary nested into Global Model.

Horizontal grid

OFS16 (Global Model)

Otranto Strait

Adriatic and Ionian Sea

nara Sea and straits

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Marmara Sea and straits

Aegean Sea

uMEDBS (Unstructured-grid MEDiterranean and Black Sea system)

- o Cover... ...nless grid,
- o Solvin... ...detailed focus on the shelf-c...
- o Exten... ...del.

GOFS16
(CMCC Global Model)

Kerch Strait

Black Sea and Azov Sea

...and straits

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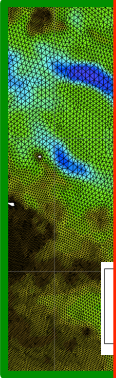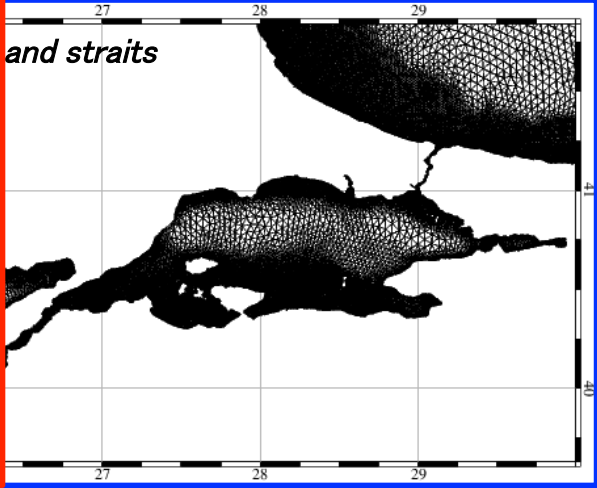## uMEDBS (Unstructured-grid MEDiterranean and Black Sea system)

Temp (°C)
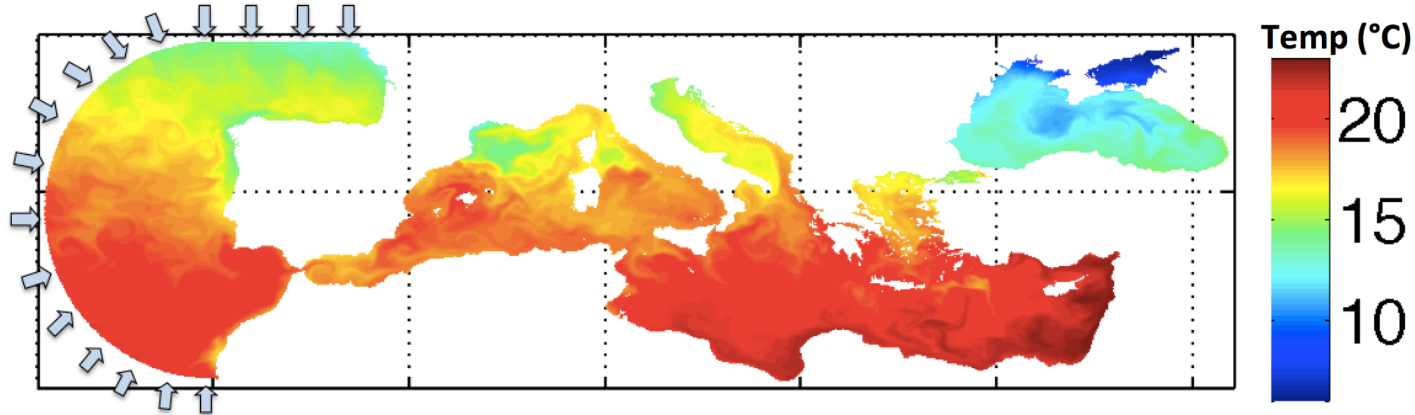
The MODEL SETTINGS:

- **Horizontal/vertical grid**: 4-5km to 1km-500m to 50-60m (n. 1.100k; **e. 2.100**k) / z-layer = 89 levels

- **Bathymetry**: EMODNET (1/8 arc-min) + TSS dataset (100÷50m, Aydogdu et al., 2018)

- **Initial Conditions**: T, S, velocity from GOFS16

- **Lateral Open Boundary Conditions**, in a large Atlantic Box (Oddo et al., 2009; and MFS-CMEMS):
  T, S, ssh, velocity from **GOFS16**, tides from OTPS

- **Surface Boundary Conditions**: ECMWF (0.125°) fields for:
  - heat flux: MFS-bulk-formulae (Pettenuzzo et al., 1998)
  - wind stress: Hellermann and Rosenstein (1983)

- **Tidal potential**: astronomical tidal model included (K_1, O_1, P_1, Q_1; M_2, N_2, S_2, K_2; Long period).

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uMEDBS *(Unstructured-grid MEDiterranean and Black Sea system)*

Regional shelf-coastal scales
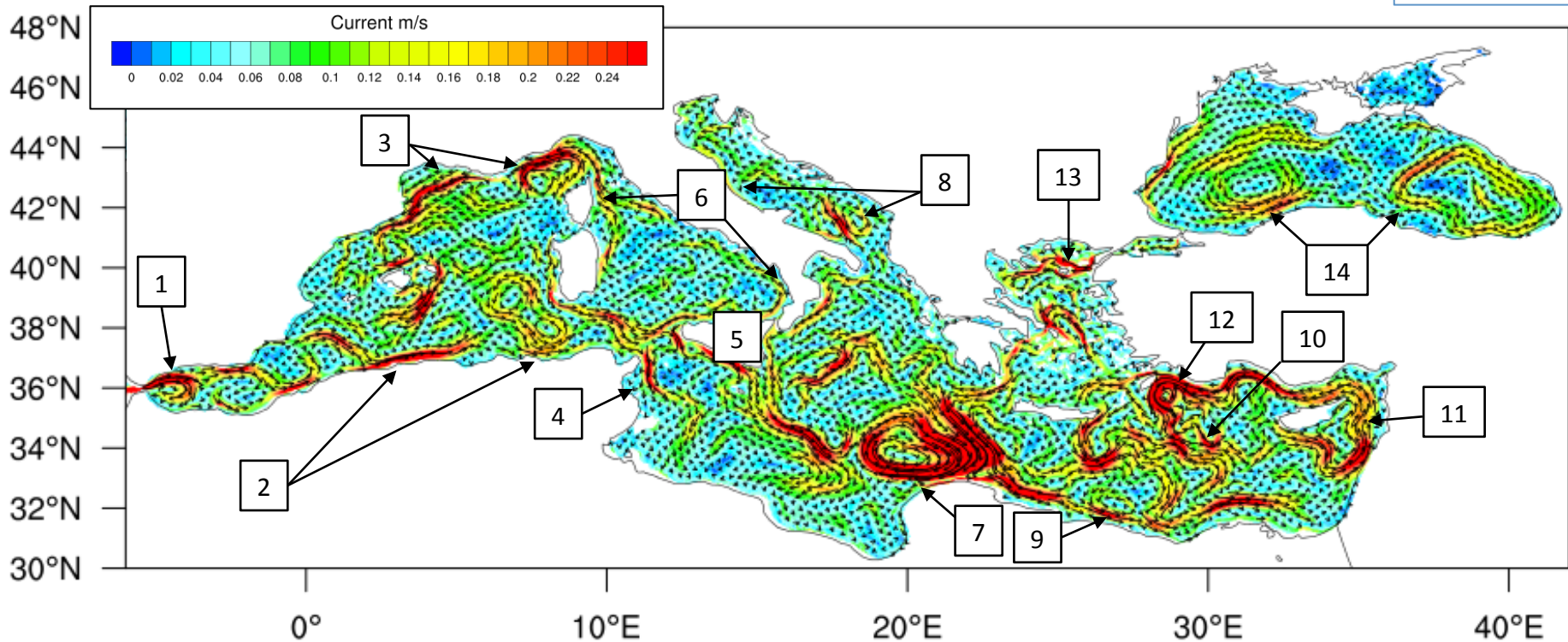
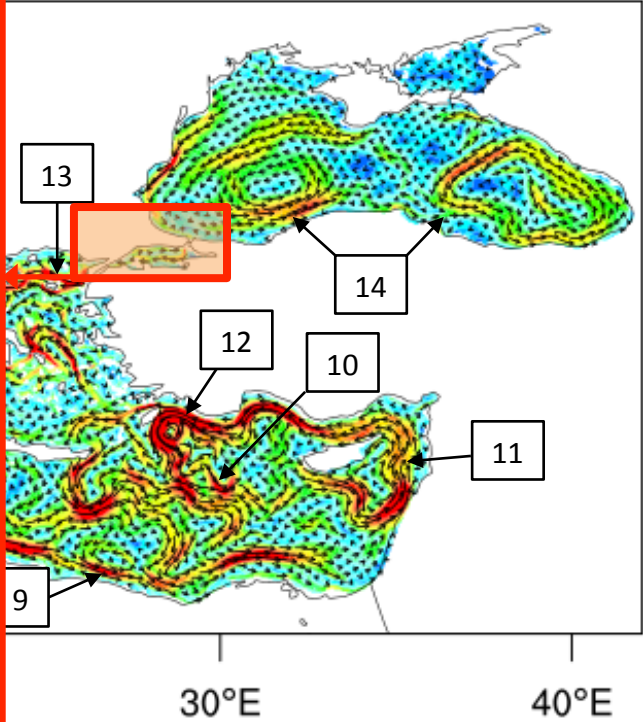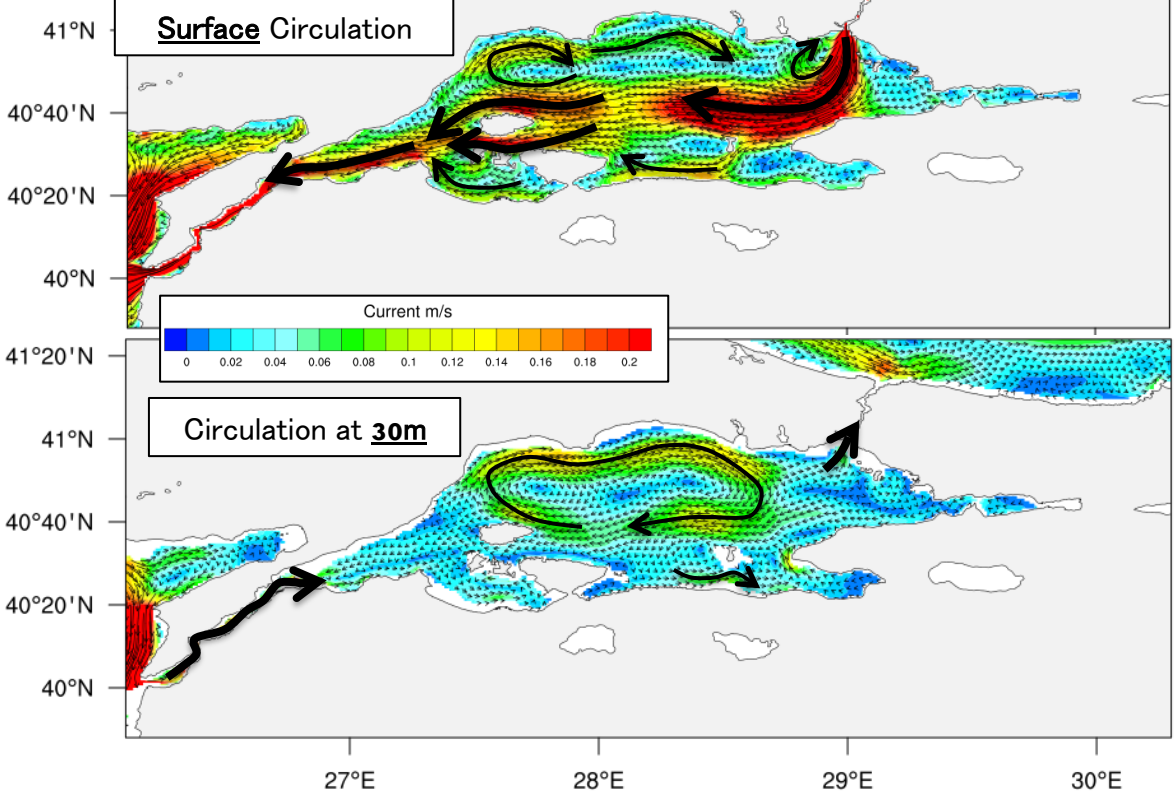**Evidence of general circulation in Mediterranean and Black Sea:**

1. West Alboran Gyre
2. Algerian Current and Gyres
3. Liguro-Provencal-Catalan current (LPC)
4. Modified Atlantic Water (MAW)
5. Atlantic-Ionian stream
6. Tyrrhenian current and Eastern Corsica current
7. Sirte Gyre
8. Southern Adriatic Cyclonian Gyre and West Adriatic Current
9. Southern levantine current
10. Mid Mediteranean Jet
11. Asia Minor current
12. Rhodes gyre
13. Black Sea Water (BSW)
14. West and East winter Gyres in Black Sea

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uMEDBS *(Unstructured-grid MEDiterranean and Black Sea system)*

Marmara Sea and Straits

Surface Circulation

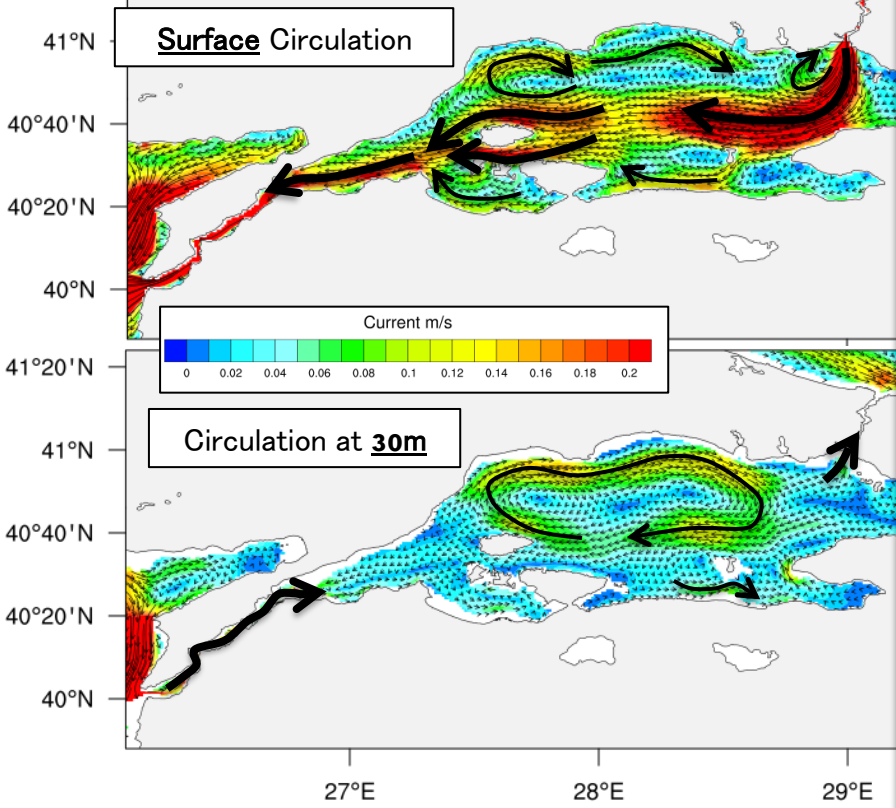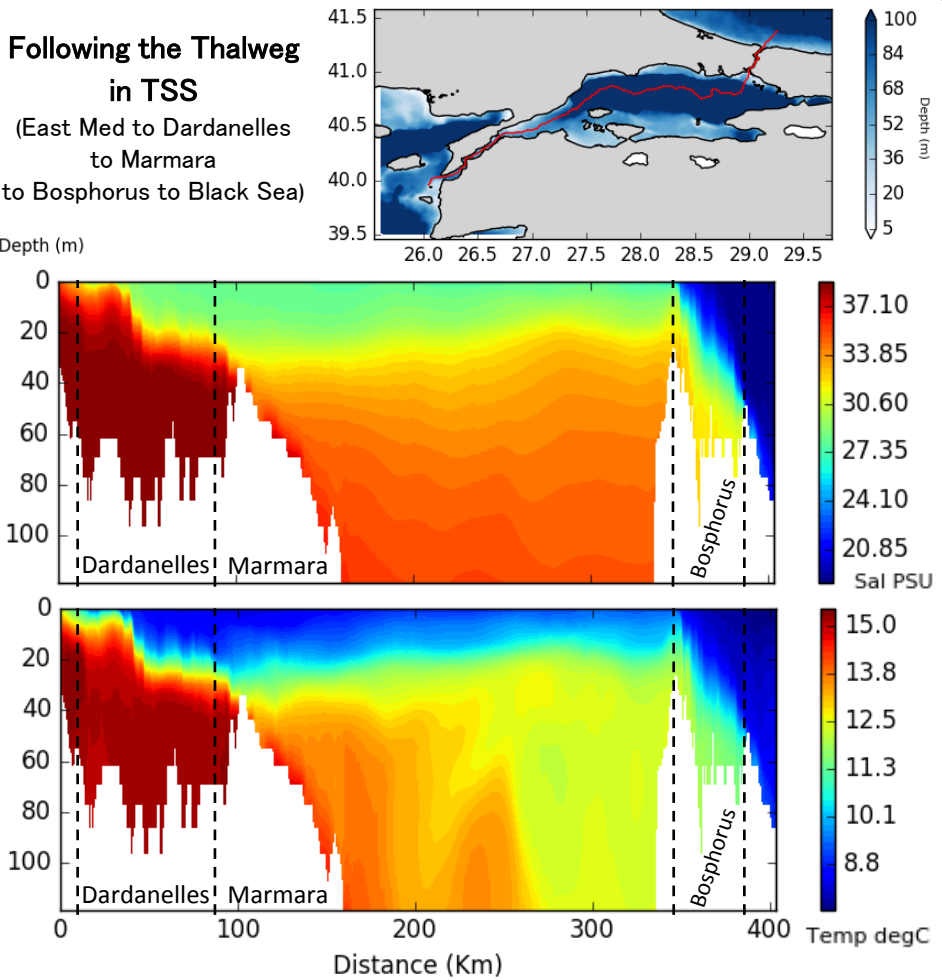Circulation at 30m

Current m/s

3. Liguro-Provencal-Catalan current (LPC)
4. Modified Atlantic Water (MAW)
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6. Tyrrhenian current and Eastern Corsica current
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Cyclonian Gyre and West Adriatic Current
e current

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Marmara Sea and Straits

Surface Circulation

Circulation at 30m

Following the Thalweg in TSS
(East Med to Dardanelles to Marmara to Bosphorus to Black Sea)

3. Liguro-Provencal-Catalan current (LPC)
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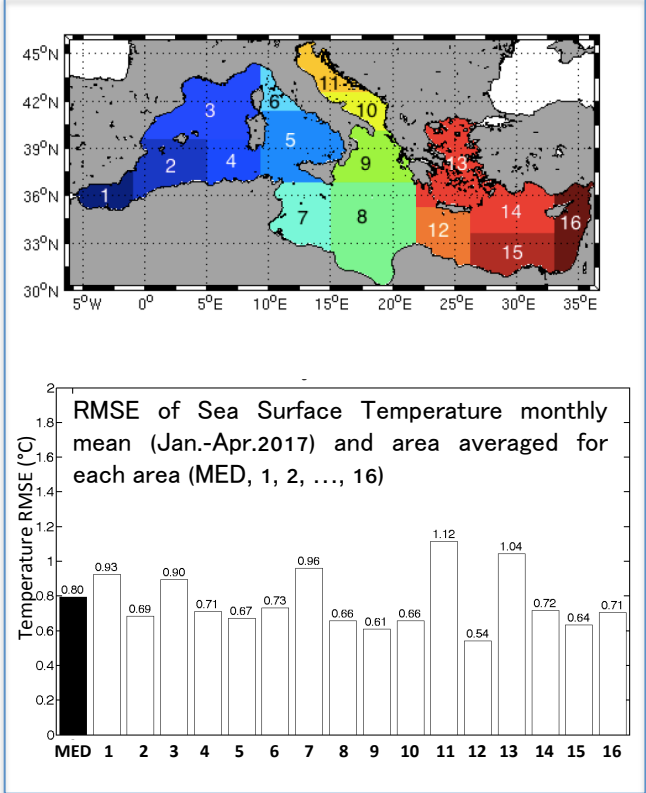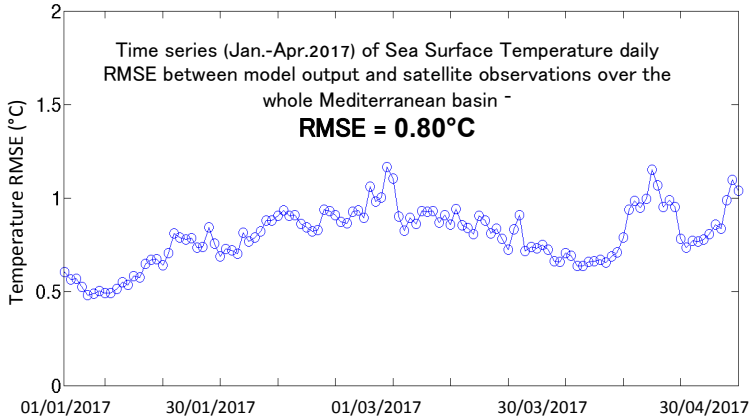# Shelf-coastal seamless Mediterranean-Black sea model nested in Atlantic Ocean
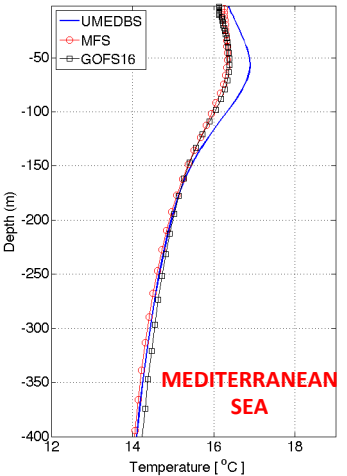
## Marmara Sea and Straits

Surface Circulation

13
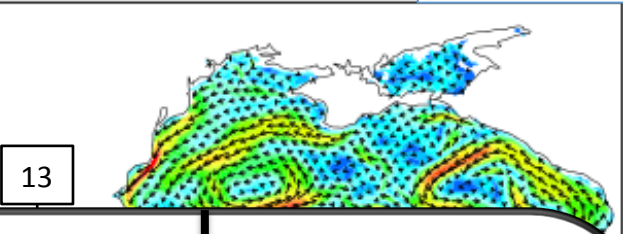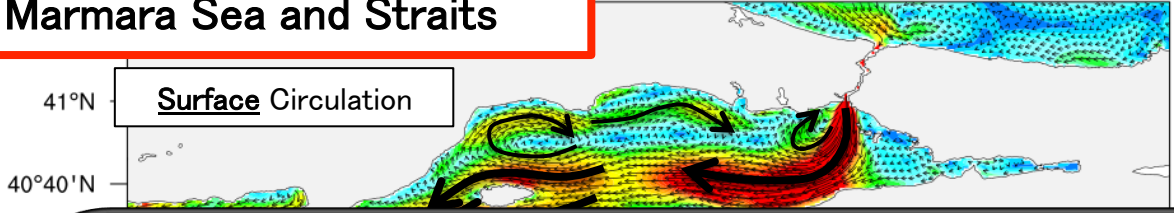
Validation with **Satellite SST** has been performed considering Mediterranean Sea sub-regions subdivision here reported (following the subdivision of Quality Information Documents of CMEMS - MFSv3.1.)


Comparison of area-averaged *temperature profiles* with GOFS16 and MFS-CMEMS both based on NEMO model and assimilated observed temperature profiles.

Time series (Jan.-Apr.2017) of Sea Surface Temperature daily RMSE between model output and satellite observations over the whole Mediterranean basin -
RMSE = 0.80°C

RMSE of Sea Surface Temperature monthly mean (Jan.-Apr.2017) and area averaged for each area (MED, 1, 2, ..., 16)

MEDITERRANEAN SEA

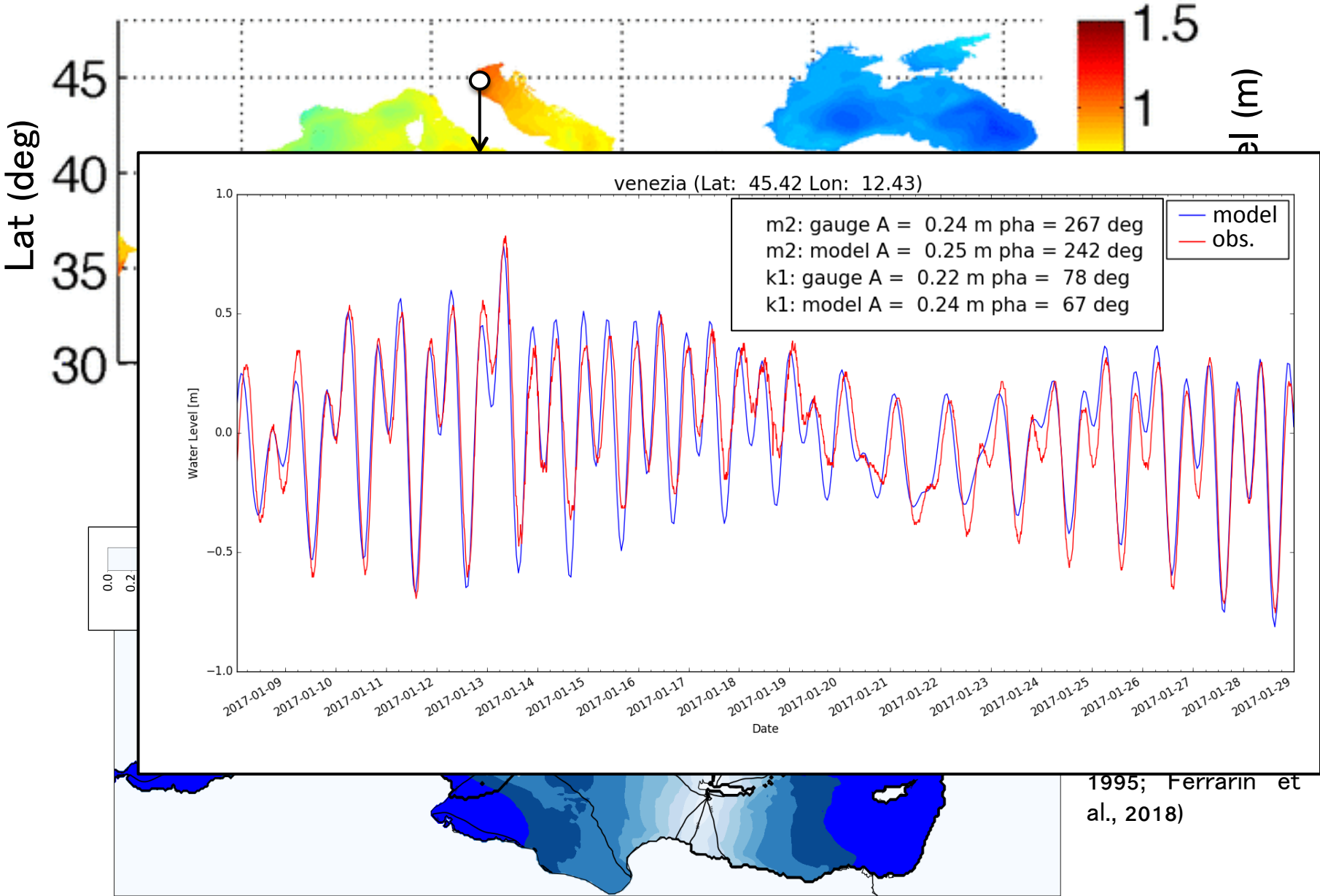# Shelf-coastal seamless Mediterranean-Black sea model nested in Atlantic Ocean
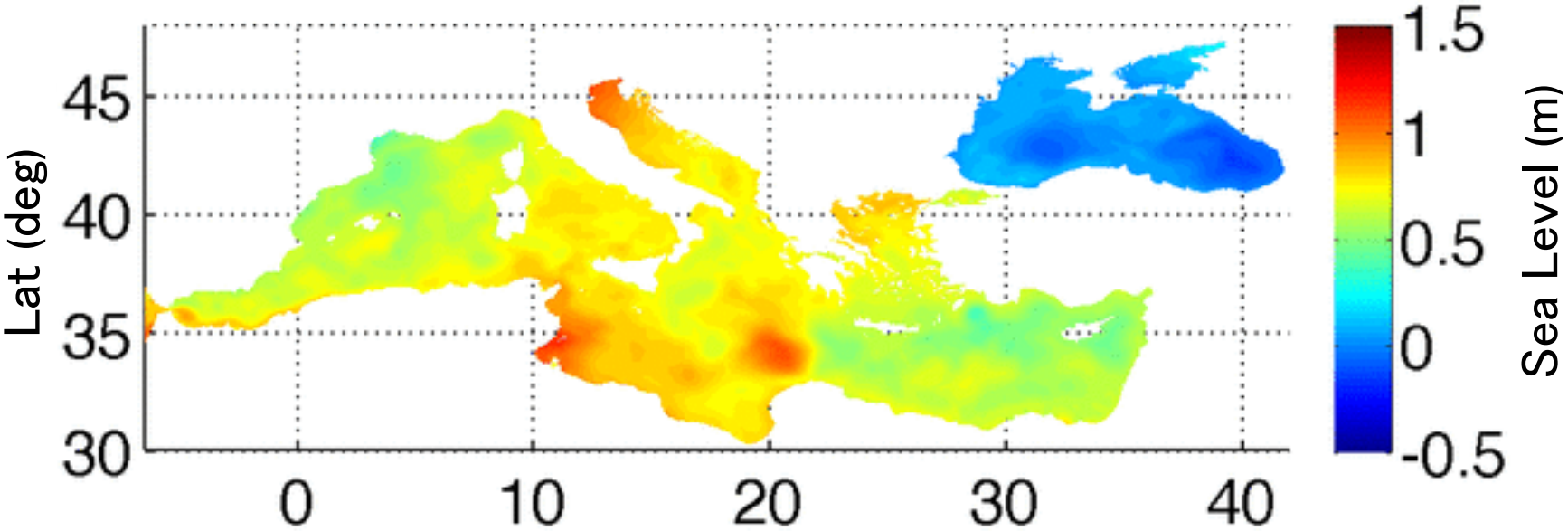
Co-tidal chart - M₂ amplitude (cm) and phase
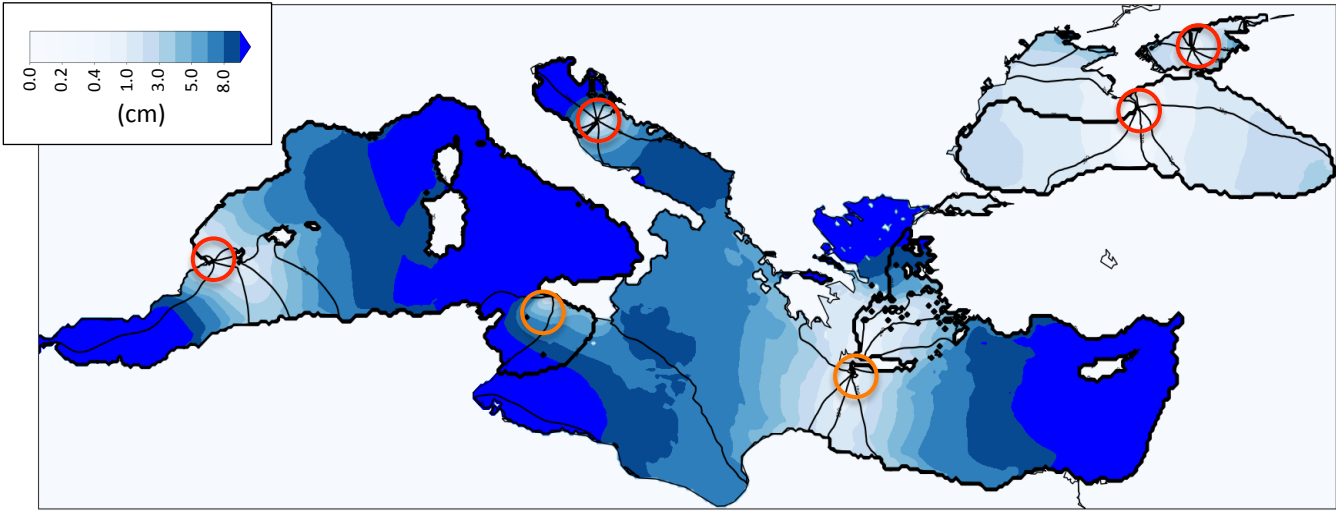
M₂ tidal map agrees qualitatively with literature studies (Ferrarin et al., 2018; Agresti, 2018)

venezia (Lat: 45.42 Lon: 12.43)

m2: gauge A = 0.24 m pha = 267 deg
m2: model A = 0.25 m pha = 242 deg
k1: gauge A = 0.22 m pha = 78 deg
k1: model A = 0.24 m pha = 67 deg

model
obs.

1995; Ferrarin et al., 2018)

Other SHYFEM-based modelling systems @ CMCC

Shelf-coastal seamless Mediterranean-Black sea model nested in Atlantic Ocean

Other SHYFEM-based modelling systems @ CMCC

SANIFS (Southern Adriatic Northern Ionian coastal Forecasting System)

Downscaled from Copernicus Marine (CMEMS), MED-MFC (1/24) → Operational Forecasting
Horizontal resolution: 3km open-sea, 100m in coastal area, 20m in the main harbours of Apulia
(Bari, Brindisi, Taranto)

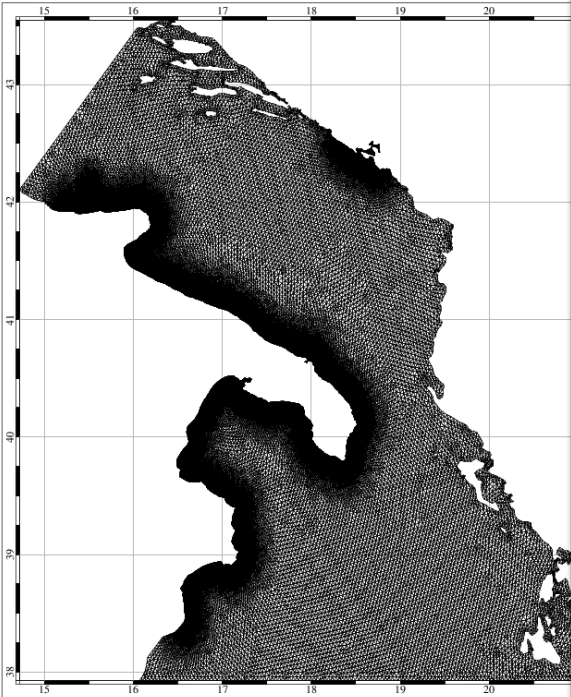**Sub-regional shelf-coastal and harbour scales**

A forecasting system for the Apulia Region in South Italy
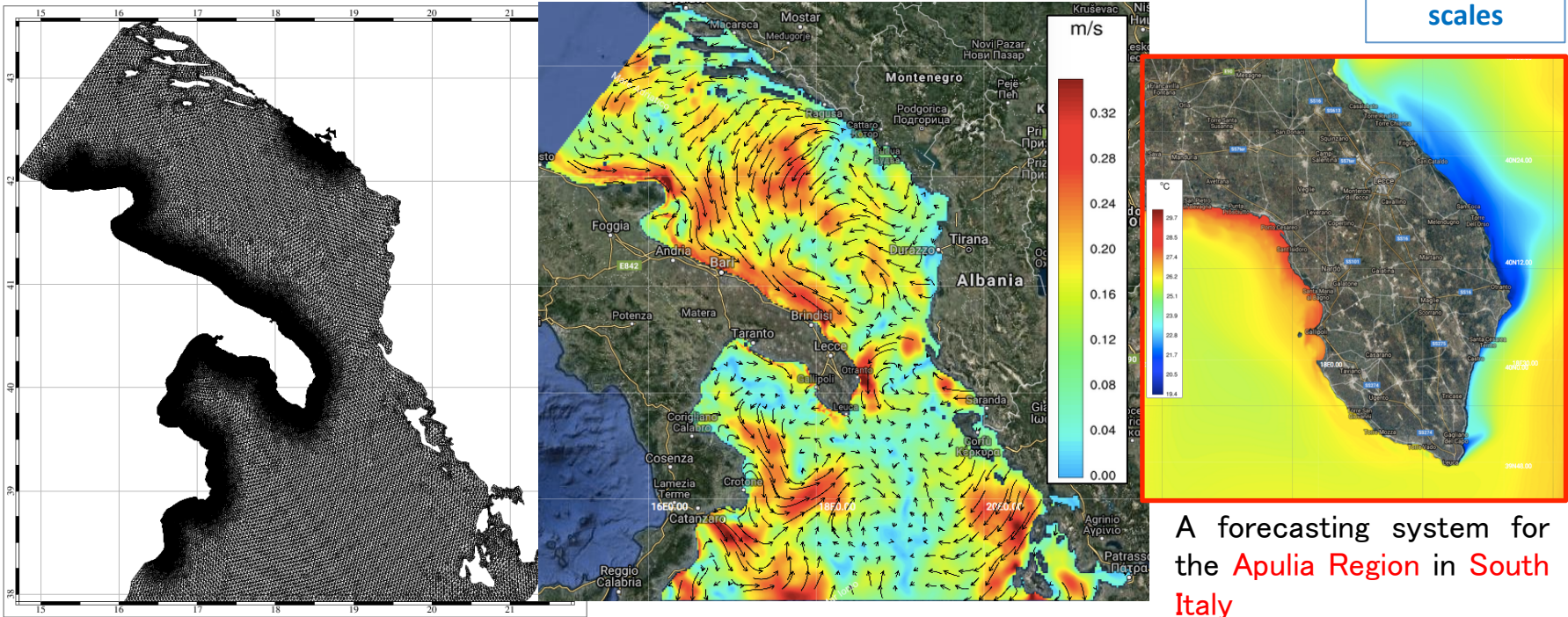
High resolution forecasts for environmental safeguard of Protected Marine Areas
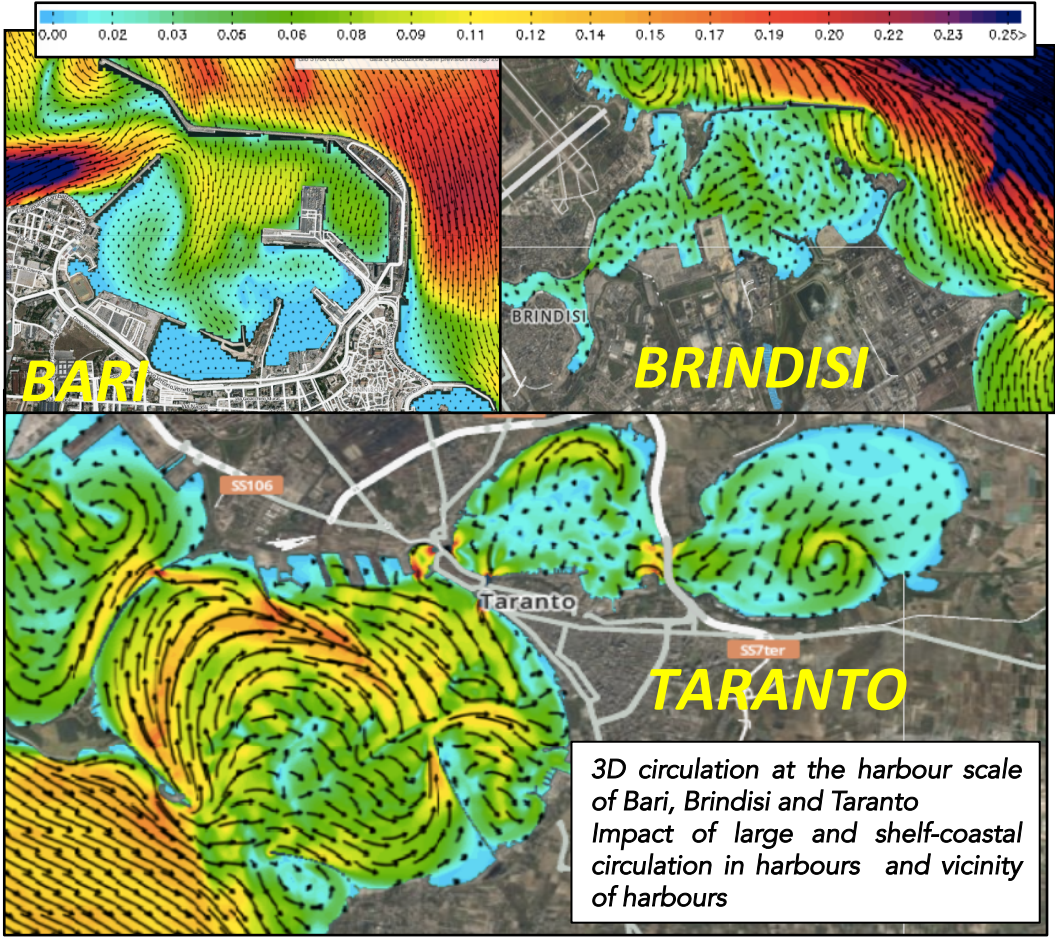(Torre Guaceto, Kotor Bay, Tremiti Islands)

Other SHYFEM-based modelling systems @ CMCC

SANIFS (Southern Adriatic Northern Ionian coastal Forecasting System)

Downscaled from Copernicus Marine (
Horizontal resolution: 3km open-sea,
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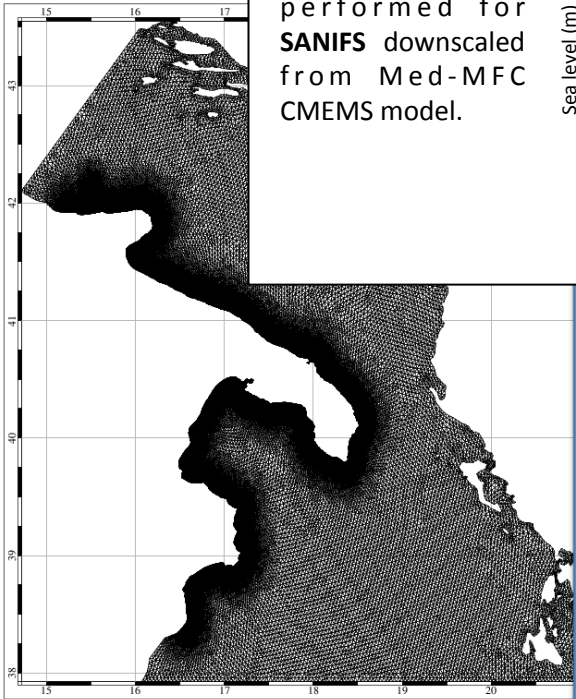High resolution forecasts for enviro
(Torre Guaceto, Kotor Bay, Tremiti I

BARI

BRINDISI

TARANTO

3D circulation at the harbour scale of Bari, Brindisi and Taranto
Impact of large and shelf-coastal circulation in harbours and vicinity of harbours

Other SHYFEM-based modelling systems @ CMCC

SANIFS (

Downscaled from
Horizontal resol
(Bari, Brindisi, Ta

A **long-term** run (4 years: **2013-2016**) based on **re-initialization-from-parent-model** procedure has been performed for **SANIFS** downscaled from Med-MFC CMEMS model.

Vieste

Otranto
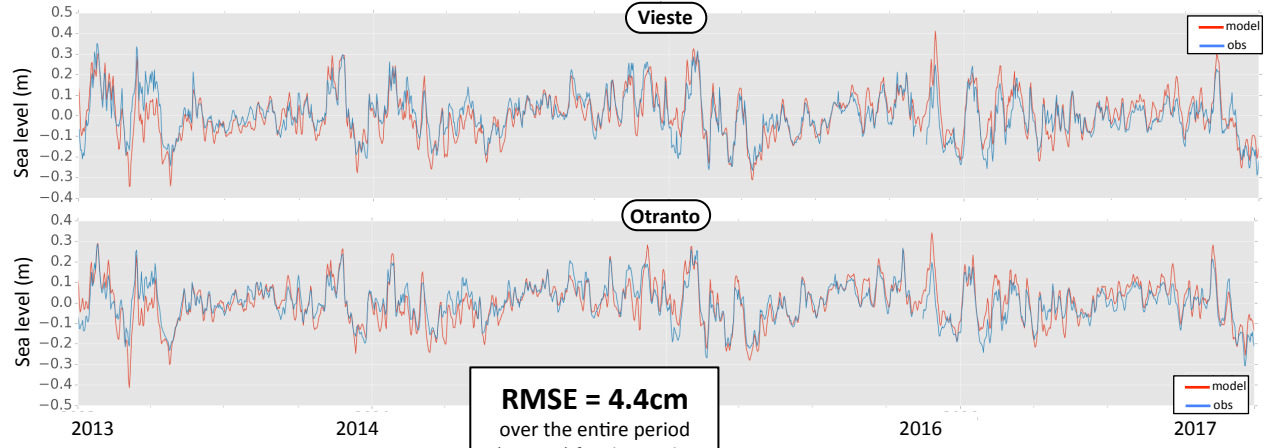
RMSE = 4.4cm
over the entire period (4 years) for the 5 tide-gauges in the SANI area
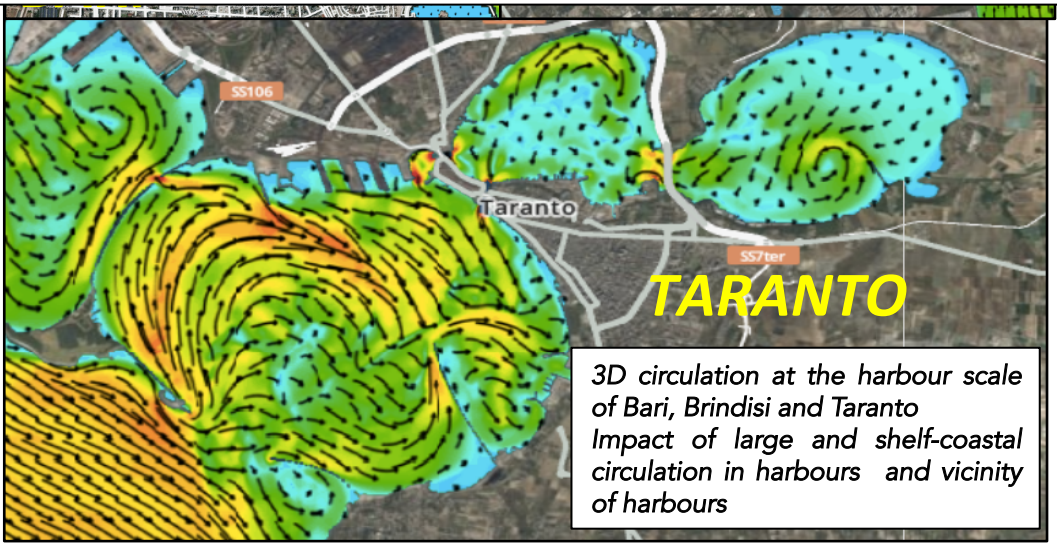
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TARANTO

3D circulation at the harbour scale of Bari, Brindisi and Taranto Impact of large and shelf-coastal circulation in harbours and vicinity of harbours
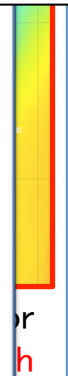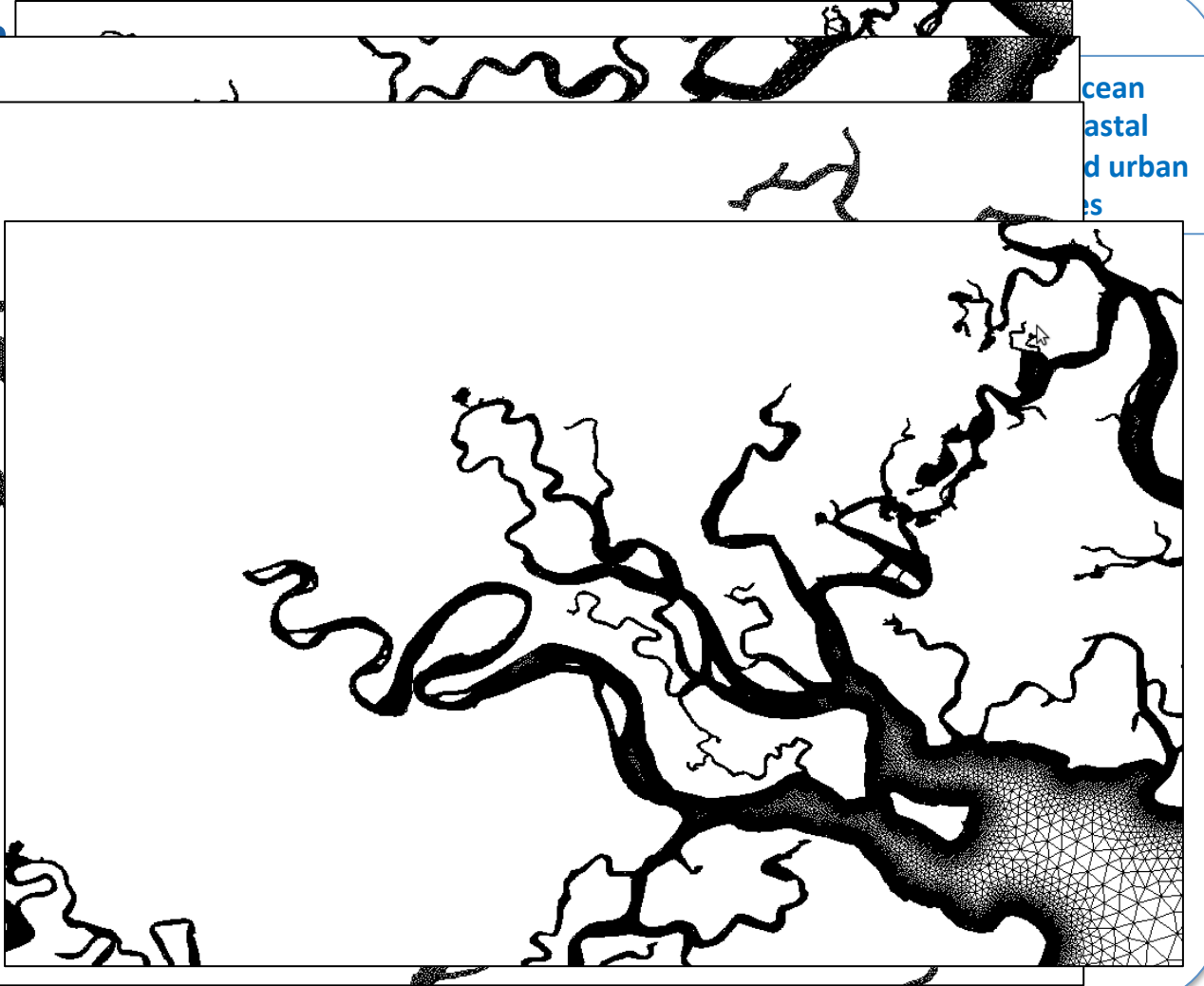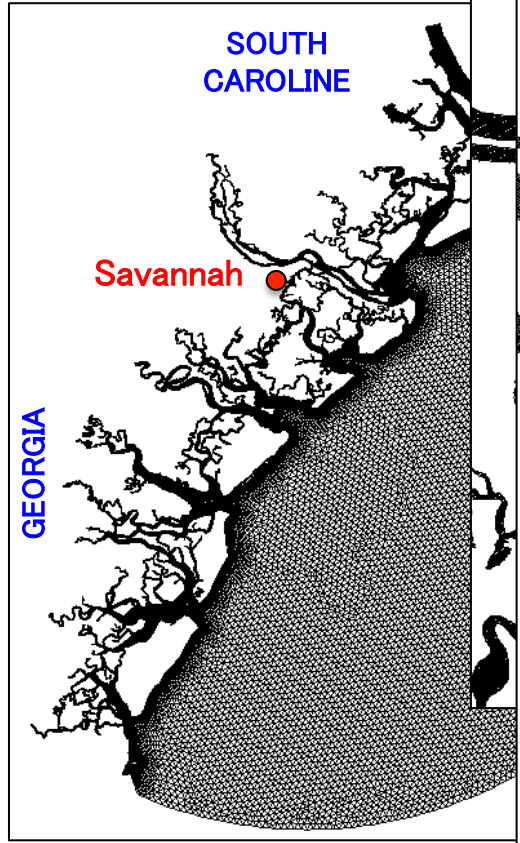
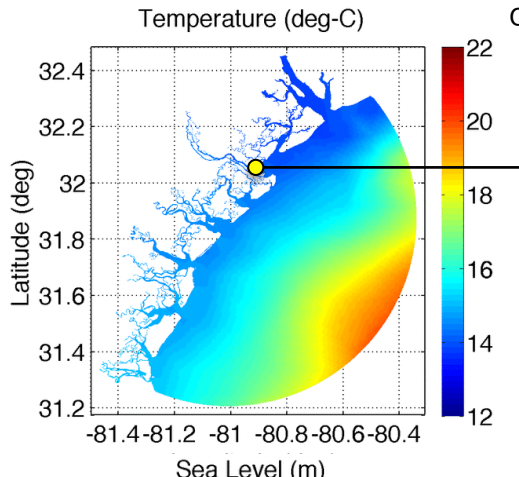## *Other SHYFEM-based modelling systems @ CMCC -* Georgia Tech

Savannah (Georgia
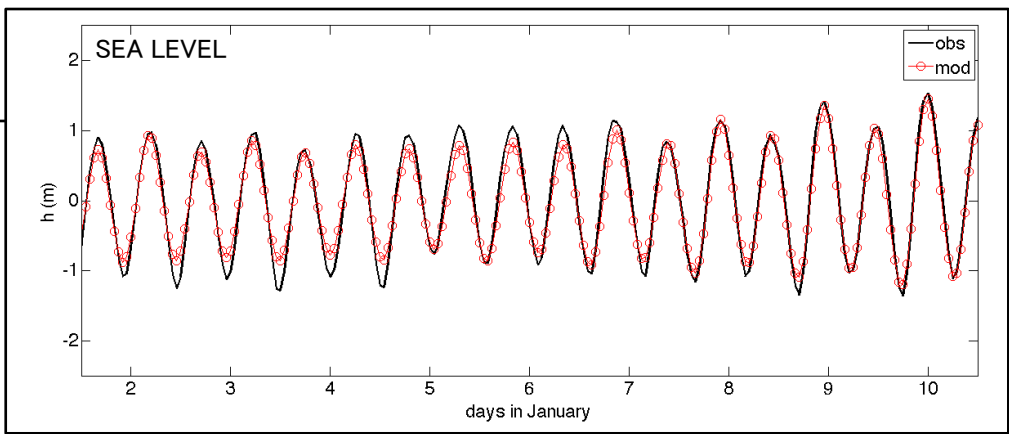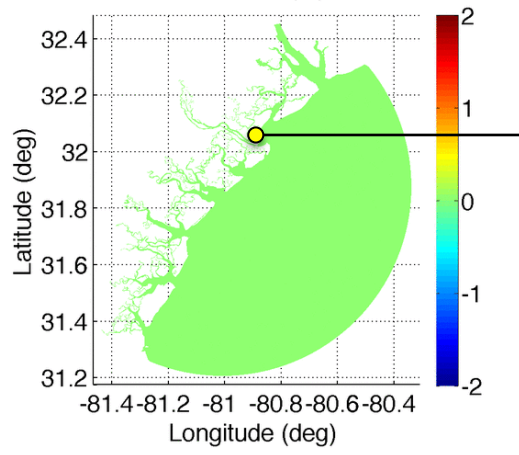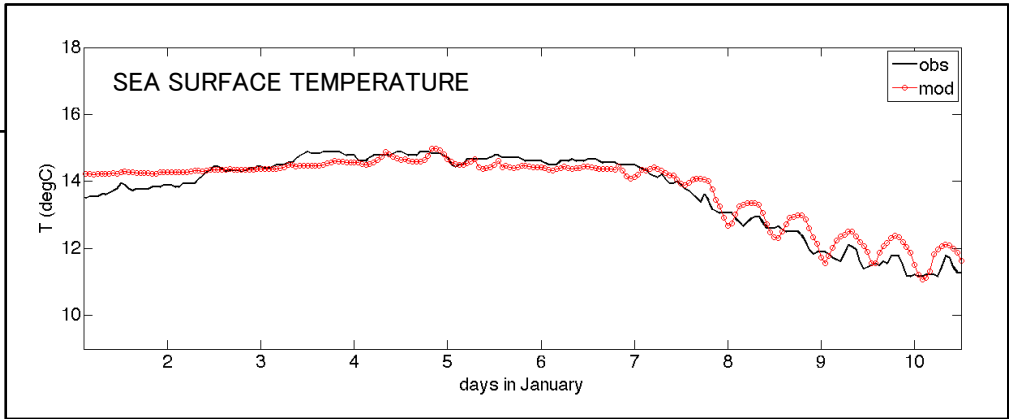
Downscaled from Copernicus
Horizontal resolution: 1km ope

SOUTH CAROLINE

Savannah

GEORGIA

cean
astal
d urban
es

Other SHYFEM-based modelling systems @ CMCC - Georgia Tech

## *Savannah (Georgia, U.S.) modelling system*

Downsca...
Horizon...

GEORGIA

Temperature (deg-C)

Sea Level (m)

Comparison between model and obseration at Furt Pulaski station tidesandcurrents.noaa.gov/)

SEA SURFACE TEMPERATURE

SEA LEVEL

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Other SHYFEM-based modelling systems @ CMCC -

Savannah (Georgia, U.S.) modelling system
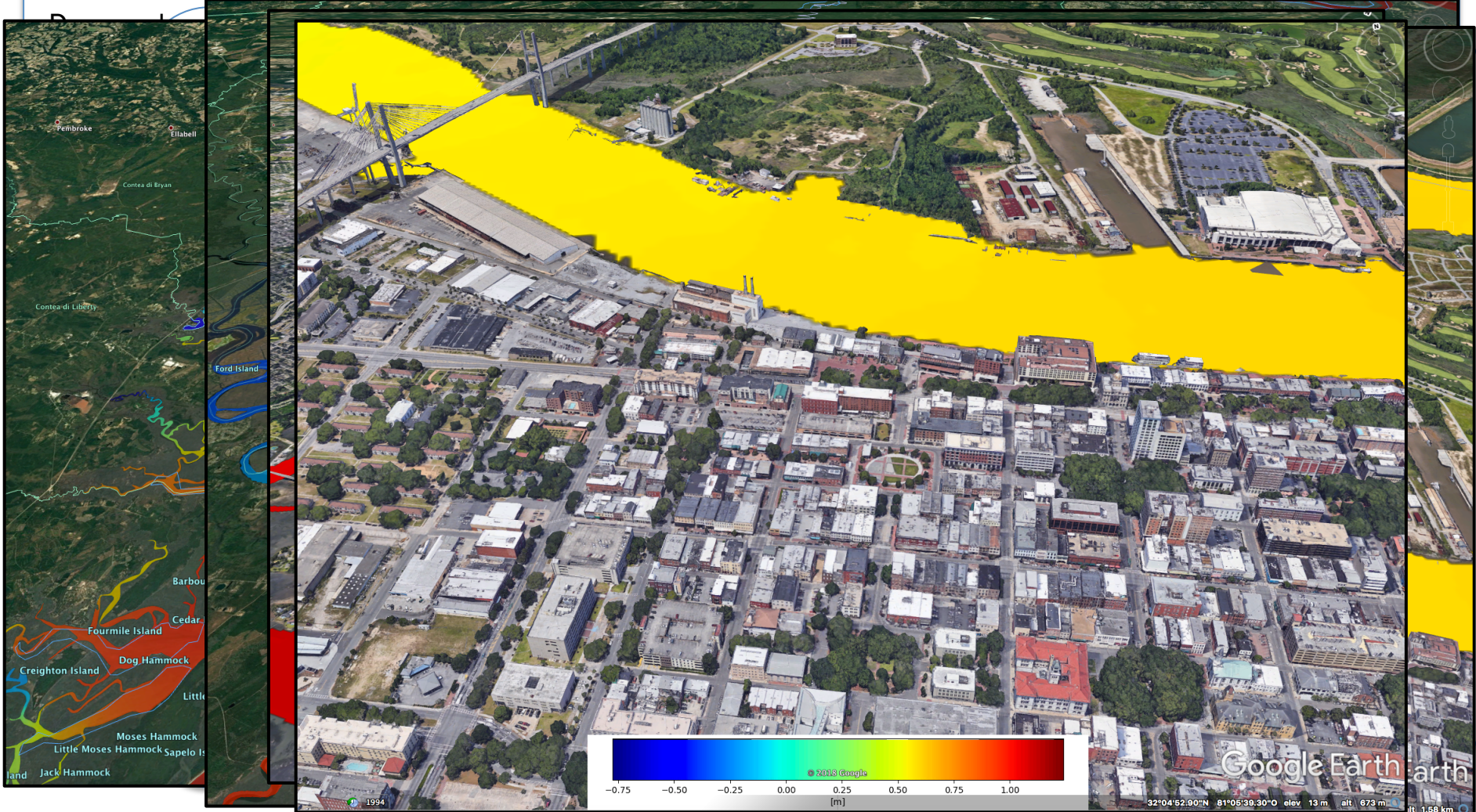
Conclusions and future steps

o uMEDBS: <u>Unstructured-grid fully-baroclinic tide-included</u> implementation set up covering both the Mediterranean and Black Sea with seamless and cross-scale modelling

o Promising preliminary validation of SST and Sea Level

➢ Improve tidal modelling on shelves→ vertical coordinates treatment: z* coordinates (Adcroft and Campin 2004)

➢ Introduce data-assimilation for operational forecasting tasks (without "slave mode" from mother model)

➢ Investigate the dynamics at the straits (from Gibraltar to Kerch) and exchange between basins.

▪ SHYFEM in seamless and cross-scale mode, including harbour (e.g. SANIFS, Italy) and riverine modelling (e.g. Savannah, GA, U.S.)

Thank you!