Seamless and cross-scale modelling of the ocean: from regional to shelf-coastal and harbour scale

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Modelling approach

Motivation and aim

1) Reproduce a seamless transition of different oceanographic scales (detailed focus on shelf-coastal, narrow straits and harbour scale) with a unique-continuum grid and appropriate variable resolution
2) Exploit this continuity to investigate the exchanges of inter-connected basins
3) Downscaling from consolidated models

Operational Forecasting and Unstructured-grid modelling

Development and implementation of operational modelling systems based on SHYFEM model

- **SHYFEM** (Umgiesser et al., 2004; Bellafiore and Umgiesser, 2008; Ferrarin et al., 2018) model: finite-element three-dimensional thermo-hydro-dynamic model (baroclinic), solving the Navier-Stokes equations by applying hydrostatic and Boussinesq approximations.
- **Unstructured-grid** approach based on Arakawa B with triangular meshes (Bellafiore and Umgiesser, 2010; Ferrarin et al., 2013), which provides an accurate description of irregular coastal boundaries.
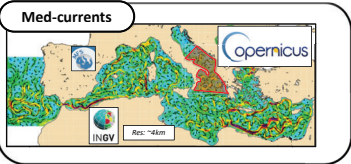
SANIFS (Southern Adriatic Northern Ionian coastal Forecasting System)

Downscaling from Regional (MFS-CMEMS 1/24) scale ...to shelf-coastal scale ...to harbour scale

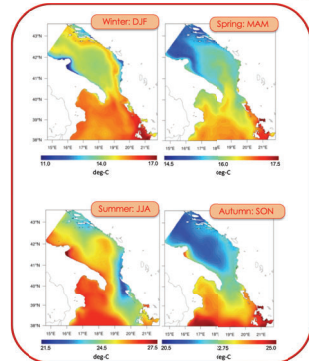Subregional, shelf-coastal and port scales

Model configuration

Hor. res.: 3km open-sea, 100m in coastal area, 20m in the main harbours of Apulia;
Vert. res.: 99 levels, 2m until 40m, then progressively (stepwise) increased;
Bathymetry: GEBCO (30arc-sec) + high res digitalized from Italian Navy
Atmospheric forcing: ECMWF (12km)
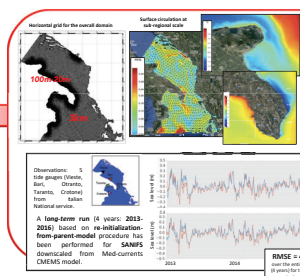
Sea Surface Temperature (i) in Gargano and Gulf of Manfredonia (Northern Apulia) in winter; (ii) in Salento (Southern Apulia) in Summer during a upwelling (Adriatic Sea) - downwelling (Ionian Sea) event.

Surface circulation at the harbour scale of Bari, Brindisi and Taranto (3D modeling with baroclinic terms)
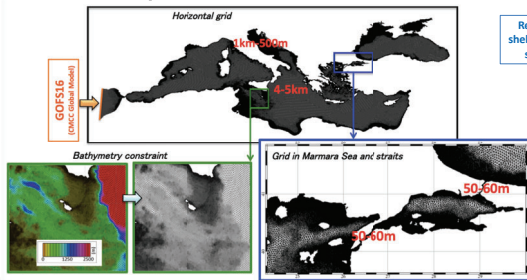
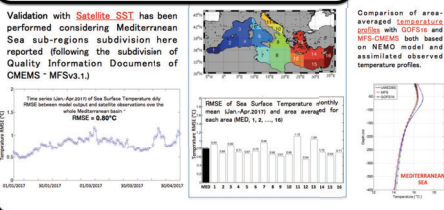Impact of large and shelf-coastal circulation in harbours and vicinity of harbours

Observations: 5 tide gauges (Vieste, Bari, Otranto, Taranto, Crotone) from Italian National service.
A long-term run (4 years: 2013-2016) based on re-initialization-from-parent-model procedure has been performed for SANIFS downscaled from Med-currents CMEMS model.

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

Tidal Harmonic Analysis for free run (1 month - Jun2012), without re-initialization: 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.

UMEDBS — Unstructured-grid MEDiterranean and Black Sea system

Domain and grid

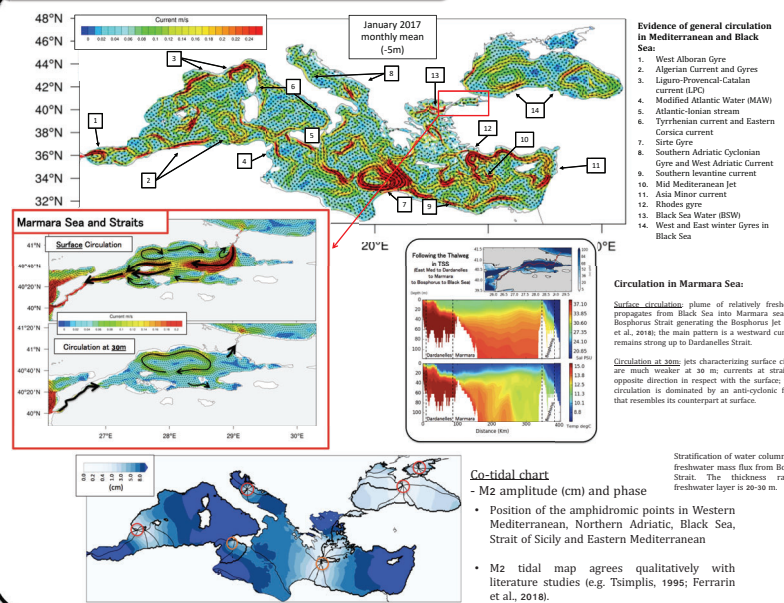- Seamless horizontal grid covering the whole Mediterranean and Black Sea and nested in Atlantic Ocean
- Resolution from 4-5km (open sea) to 1km-500m (shelf-coastal sea) to 50-60m (straits) (n: ~1.100k; e: ~2.100k)

Horizontal grid
1km-500m
4-5km
Regional shelf-coastal scales

GOFS16 (CMCC Global Model)

Bathymetry constraint

Grid in Marmara Sea and straits
50-60m
50-60m

Comparisons with obs. and models

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.)

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)

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

MEDITERRANEAN SEA

Circulation in Mediterranean and Black Sea

January 2017 monthly mean (-5m)

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)

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 Mediterranean Jet
11. Asia Minor current
12. Rhodes gyre
13. Black Sea Water (BSW)
14. West and East winter Gyres in Black Sea

Circulation in Marmara Sea:

Surface circulation: plume of relatively fresher water propagates from Black Sea into Marmara sea through Bosphorus Strait generating the Bosphorus Jet (Aydogdu et al., 2016); the main pattern is a westward current that remains strong up to Dardanelles Strait.

Circulation at 30m: jets characterizing surface circulation are much weaker at 30 m; currents at strait are in opposite direction in respect with the surface; the main circulation is dominated by an anti-cyclonic formation that resembles its counterpart at surface.

Stratification of water columns due to freshwater mass flux from Bosphorus Strait. The thickness range of freshwater layer is 20-30 m.

Co-tidal chart
- M2 amplitude (cm) and phase
- Position of the amphidromic points in Western Mediterranean, Northern Adriatic, Black Sea, Strait of Sicily and Eastern Mediterranean
- M2 tidal map agrees qualitatively with literature studies (e.g. Tsimplis, 1995; Ferrarin et al., 2018).

S-WITCH — Savannah - Water Integrated Tool for ocean, Coastal and river Hydraulics forecasting
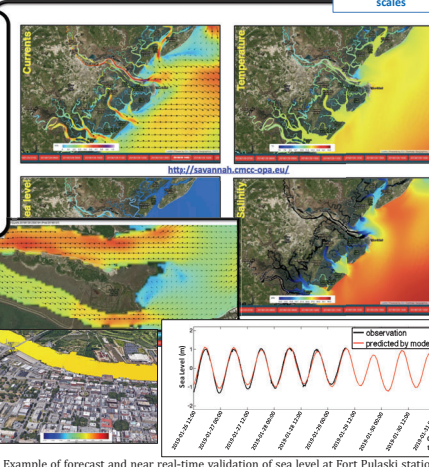
Open-ocean coastal, riverine and urban scales

SOUTH CAROLINE
GEORGIA
Savannah

Downscaling from Copernicus Marine (CMEMS) GLO-MFC (1/12) → Operational Forecasting

Horizontal resolution: 1km open-sea to 10m at the coast and in rivers

The Savannah city is set on the coastal plain and is surrounded by flat and low marshland and higher land. Saltwater marshes due to river overflow on banks and low-lying flooding are generated when high tides occur.
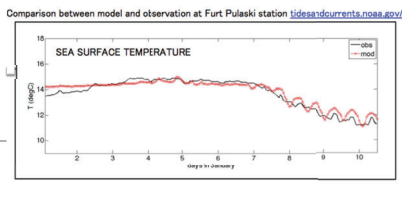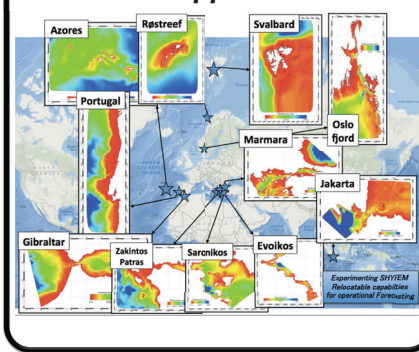
Forecast visualization

Currents
Temperature
Sea level
Salinity

http://savannah.cmcc-opa.eu/

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

SEA SURFACE TEMPERATURE

observation
predicted by model

Example of forecast and near real-time validation of sea level at Fort Pulaski station

Relocatable approach

Azores, Røstreef, Svalbard, Portugal, Marmara, Oslo fjord, Jakarta, Gibraltar, Zakintos Patras, Sarnikos, Evoikos

Experimenting SHYFEM Relocatable capabilities for operational forecasting