Higher resolution physical numerical model of the Mediterranean Sea in the Copernicus Marine Service

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Introduction

INGV is responsible for the operational production of the physical component of the Mediterranean Sea Monitoring and Forecasting Center (Med-MFC) of the Copernicus Marine Service Monitoring System (CMEMS).
The system was implemented in 2000 by the INGV National Group of Operational oceanography (GNOO) and has been developed in years thanks to a number of European projects.
The Med-MFC is a coupled hydrodynamic-wave model with data assimilation component with a resolution of 1/16°.
The Nucleus for European Modelling of the Ocean (NEMO, Madec, 2008) is used for the hydrodynamics and WaveWatch-III (Tolman, 2009) for the waves.
The model solutions are corrected by the variational assimilation (based on a 3DVAR scheme) of Temperature and Salinity vertical profiles (from ARGO, CTD, XBT and Gliders observations) and along track satellite Sea Level Anomaly (SLA) observations.
In order to meet the requirements for Copernicus Marine Service Phase I the increase of the horizontal (to 1/24°) and vertical resolution of the hydrodynamic component of Med-MFC has been planned.
The major improvements expected from this development are the following: 1) to better resolve the mesoscale processes in the Mediterranean region where the Rossby radius of deformation is about 12-15 km (1/24° is about 4-5 km); 2) to resolve the tidal forcing at Gibraltar, entering from the Atlantic into the Mediterranean, known to provide about 30% amplitude of the tidal signal in the Mediterranean; 3) to better resolve vertical mixing processes.

The Prototype version workflow

A prototype version of the NEMO model for Mediterranean Sea configuration at higher horizontal (1/24°) and vertical (91 unevenly spaced levels) resolution has been developed following the workflow described in Figure 1. The setup for the new configuration built (N24expA), as well as the setup for the control configuration (N16expG) is described in Table 1. A twin simulation experiment has been performed from 2004 to 2012 in order to evaluate the performances of the new configuration with respect to the control configuration.

The Workflow

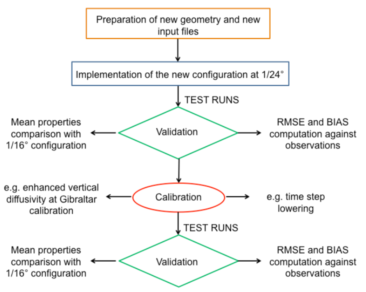

Fig. 1: workflow for the development of NEMO Mediterranean Sea configuration at higher horizontal and vertical resolution.

Experiment	N16expG	N24expA
Model settings		
Horizontal resolution	1/16 deg	1/24 deg
Vertical levels (z-partial steps)	72	91
Lateral Open Boundary Conditions	Climatological	Climatological
Tracer advection	MUSCL	MUSCL
Momentum advection	Vector form	Vector form
Diffusivity/Viscosity [m^4/s]	$-3.e^9$ / $-5.e^9$ (Prandtl=1.67)	$-6.e^8$/ $-1.e^9$ (Prandtl=1.67)
Time step	600 sec	400 sec
Initial Conditions	Medatlas Climatological Initial Conditions	Medatlas Climatological Initial Conditions

Tab. 1: setup of the new configuration developed (N24expA) compared to the setup of the control configuration (N16expG).

The Prototype version results

Model results have been evaluated using ARGO floats. Root Mean Square Error (RMSE) and BIAS have been computed both for the entire basin and for the three sub-basins shown in Figure 2. Results are shown in Table 2 and Table 3.

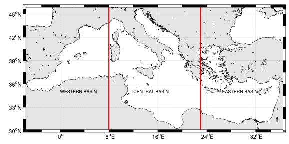

Fig. 2: basin subdivision used to compute RMSE and BIAS.

	N16expG RMSE Salinity [PSU]	N24expA RMSE Salinity [PSU]	N16expG BIAS Salinity [PSU]	N24expA BIAS Salinity [PSU]
ENTIRE BASIN	0.24	0.23	-0.16	-0.15
WESTERN BASIN	0.28	0.23	-0.24	-0.19
CENTRAL BASIN	0.20	0.22	-0.08	-0.09
EASTERN BASIN	0.24	0.25	-0.17	-0.19

Tab. 2: RMSE and BIAS of Salinity [PSU] from surface to 1500m depth for N16expG VS N24expA.

	N16expG RMSE Temperature [C°]	N24expA RMSE Temperature [C°]	N16expG BIAS Temperature [C°]	N24expA BIAS Temperature [C°]
ENTIRE BASIN	0.66	0.70	-0.1	-0.2
WESTERN BASIN	0.57	0.56	0.00	-0.01
CENTRAL BASIN	0.57	0.64	0.09	-0.08
EASTERN BASIN	0.90	0.98	-0.42	-0.56

Tab. 3: RMSE and BIAS of Temperature [C°] from surface to 1500m depth for N16expG VS N24expA.

N16expG and N24expA surface circulation in Alboran Sea and in the eastern part of the Mediterranean basin for a sample day (15th of January 2012) is shown in Figure 3.

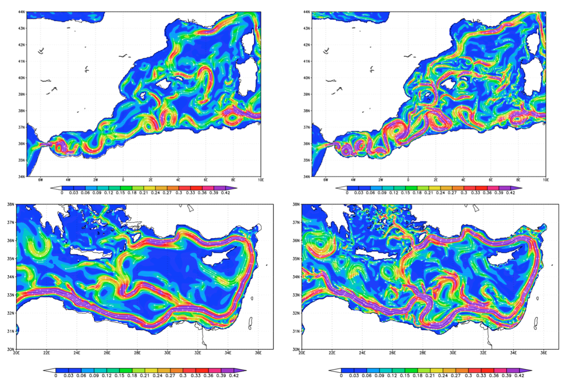

Fig. 3: N16expG surface circulation [m/s] in Alboran Sea (up-left panel) and in the eastern part of Mediterranean Sea basin (bottom-left panel); N24expA surface circulation [m/s] in Alboran Sea (up-right panel) and in the eastern part of Mediterranean Sea basin (bottom-right panel)

Work in progress

On the basis of the experience gained in building the prototype version of the higher resolution physical numerical model, many possible developments have been investigated in order to further improve the performances of the higher resolution configuration:

- The NEMO version which will be used for the further developments will be 3.6 STABLE instead of 3.4 STABLE version used for the prototype version
- A new bathymetry will be used, created starting from a higher resolution bathymetric dataset in addition to a new algorithm to build a land/sea mask for the Mediterranean Sea on the basis of a high resolution coastline dataset
- New vertical discretizations for the model grid have been implemented: 121 and 141 levels vertical grids are being tested, in addition to a new distribution of the 91 levels vertical grid
- A higher resolution ECMWF atmospheric forcing dataset at 1/8° will be used instead of the 1/2° and 1/4° used for the prototype version
- Daily lateral open boundary conditions (BDY) provided by CMEMS Global Monitoring and Forecasting Centre (Glo-MFC) will be used instead of the climatological lateral open boundary conditions used for the prototype version (Drévillon et al.,2008)
- More rivers will be implemented with respect to the prototype version
- The Dardanelles will be implemented as lateral boundary condition (BDY), while in the prototype version they are implemented as surface boundary conditions

Conclusions

The experiments performed with the prototype version of the higher resolution physical numerical model show that :

- The higher resolution configuration (N24expA) has similar performances for Salinity and Temperature with respect to control configuration (N16expG); a slight improvement in Salinity and slight worsening in Temperature can be noticed for N24expA with respect to N16expG
- The Mediterranean Sea circulation seems to be better represented in N24expA with respect to N16expG, in particular in Alboran Sea and in the eastern part of the Mediterranean basin
- Many developments are in progress in order to further improve the physical numerical model of the Med-MFC

References

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