Assessment and intercomparison of numerical simulations in the Western Mediterranean Sea

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Introduction and objectives

The Balearic Islands Coastal Observing and Forecasting System (SOCIB) is developing high resolution numerical simulations (hindcasts and forecasts) in the Western Mediterranean Sea (WMOP). WMOP uses a regional configuration of the Regional Ocean Modelling System[1] with a high spatial resolution of 1/50º (1.5-2km). Thus, theses simulations are able to reproduce (sub-)mesoscale features that are key in the Mediterranean Sea since they interact and modify the basin and sub-basin circulation. These simulations are initialized from and nested in either the **Mediterranean Forecasting System[2] (MFS, 1/16º)** or **Mercator-Océan simulations[3] (Mercator, 1/12º)**.

In this study, MFS and Mercator are compared and evaluated using available **multi-platform observations** over 2008-2011. A **quantitative comparison** is necessary to evaluate the capacity of the simulations to reproduce observed ocean features, and to quantify the possible simulations biases. This will in turn allow to improve the simulations, so as to produce better ocean forecasts, to study and better understand ocean processes and to address climate studies. To this end, various statistical diagnostics have been developed to assess and inter-compare the simulations at various spatial and temporal scales.

Numerical simulations

	MFS[2]	Mercator[3]
Version	Sys4b2	PSY2V4R4
Model	NEMO3.2-OPA	NEMO3.1-OPA
Geographical coverage	Mediterranean Sea (6ºW-36.25ºE; 30.187ºN-45.937ºN)	Atlantic – Med Sea (103ºW-57ºE; 20ºS-81ºN)
Spatial Resolution	1/16ºx1/16º	1/12ºx1/12º
Vertical resolution	72 vertical levels	50 vertical levels
Temporal resolution	Daily mean	Daily mean
Atmospheric forcing	ECMWF (6h, 0.25º) Bulk formulae	ECMWF (3h) Bulk formulae
Runoff	Monthly mean (*Fekete et al*., 1999; *Raicich*, 1996)	Monthly climatology (*Dai and Trenberth*, 2002)
Initial conditions	T/S SeaDataNet	T/S *Levitus* (2009)
Boundary conditions	Monthly climatology 1/4ºx1/4º (*Drevillon et al*., 2008)	PSY3V3R3
Assimilation scheme	OceanVAR	SAM2v1
Assimilated data	SLA, SST, *in situ* T/S profiles	SLA, SST, *in situ* T/S profiles, MSSH

Methods for assessment

➢ Use of **all available observations**: satellite products (Sea Surface Temperature, Sea Level Anomaly), *in situ* data (temperature and salinity profiles from Argo floats, CTD, XBT, gliders, fixed moorings; velocity fields from HF radar, current meters).

➢ **Spatial and temporal interpolation** of simulations at the observations points.

➢ Development **of adequate statistics** to assess and intercompare simulations at various spatial and temporal scales, in sub-regions with typical sub-basin dynamics (*Manca et al*., 2004, see Fig. 1), along key sections and during specific events.

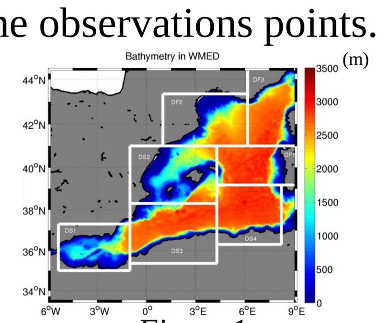


Figure 1

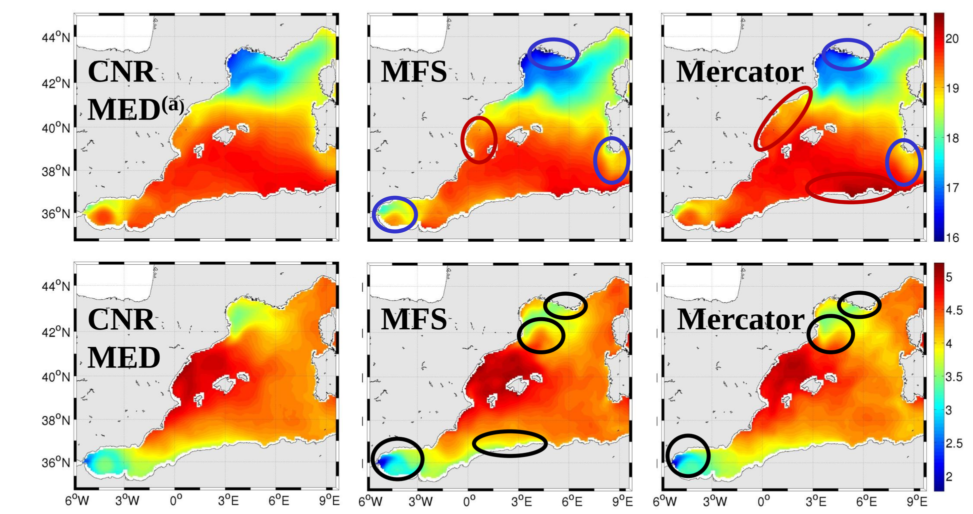
Surface conditions and general circulation

(a) CNR MED: satellite products L4, 1/16º, daily mean
(b) AVISO: mapped satellite products, 1/8º, weekly

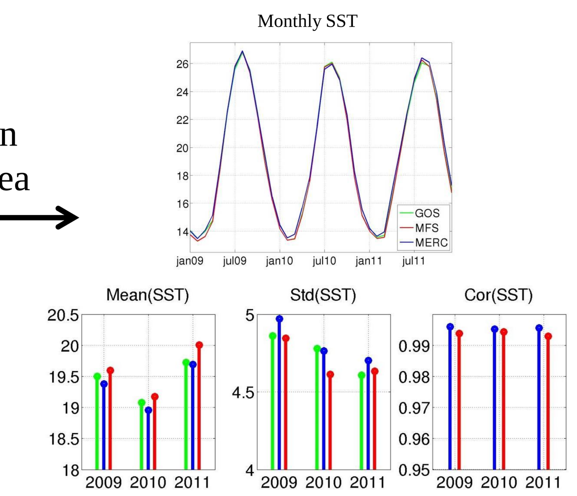
Sea Surface Temperature (ºC) over 2009-2011

Temporal mean

Standard deviation

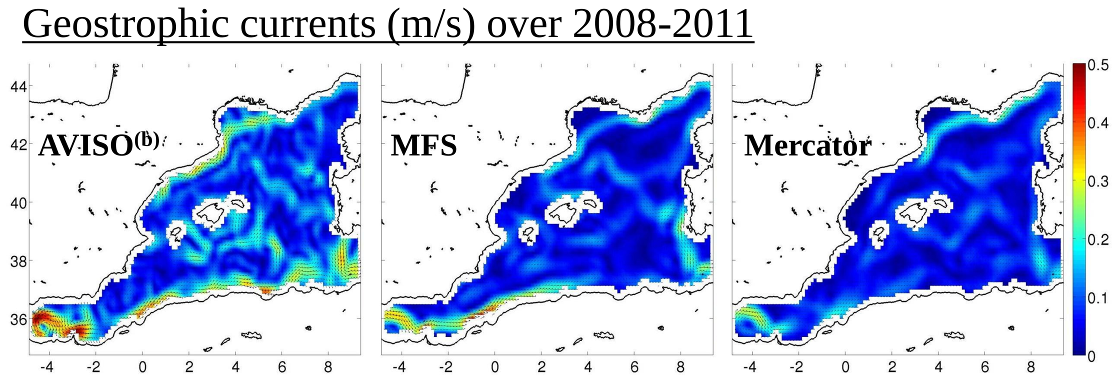


Average in Balearic Sea



➢ The spatial structure of SST mean and variability over 2009-2011 is reasonably well reproduced in MFS and Mercator, as well as the seasonal and interannual variability in term of amplitude and phase. Although SST data are assimilated in both simulations, persistent differences with satellite products are found, especially in high mesoscale activity areas (Alboran, Algerian Current), in coastal area with strong river inputs (North Gulf of Lion), in areas with strong seasonal variability of SST (Balearic Sea).

Geostrophic currents (m/s) over 2008-2011



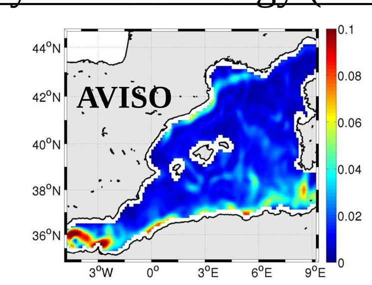
➢ The geostrophic currents are weaker in the simulations than in satellite products, especially in areas with strong mesoscale (Alboran Sea, Algerian and Northern Currents).

➢ The observed and simulated mean circulations differ in the Balearic Sea and along the Western coast of Corsica.

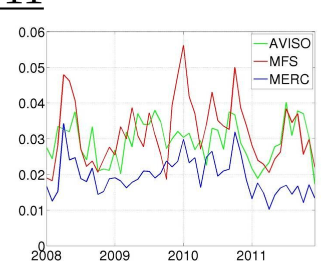
Mesoscale variability (Alboran Sea)

WAG: Western Anticyclonic Gyre
EAG: Eastern Anticyclonic Gyre

Eddy Kinetic Energy (m^2/s^2) over 2008-2011



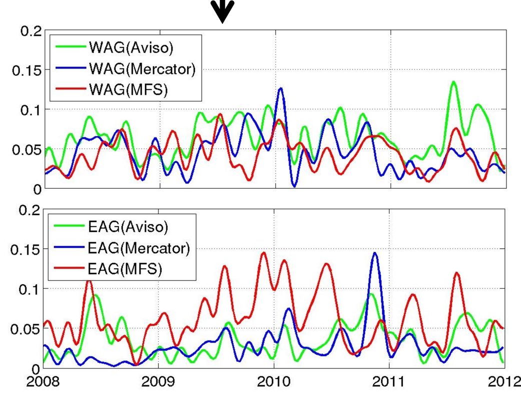
Average in Alboran Sea



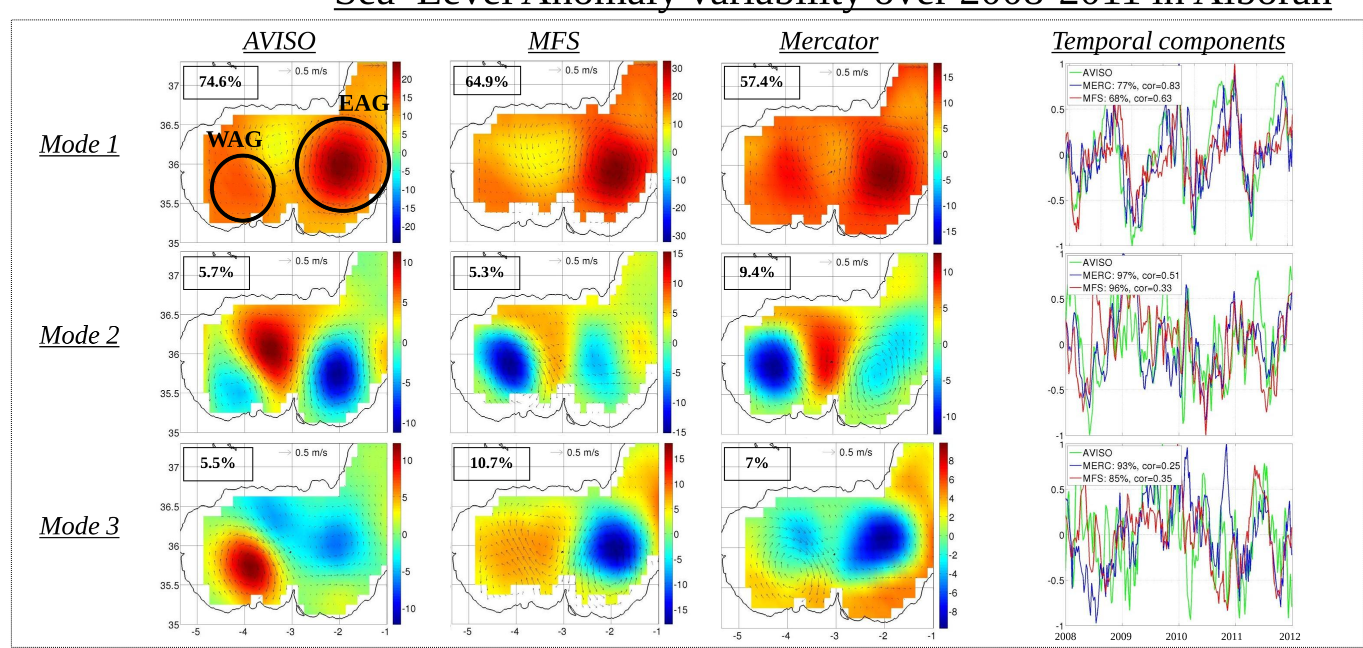
➢ Maximum of mesoscale activity observed in the Alboran Sea.

➢ Weaker energy in Mercator than in satellite and MFS.

Average in WAG & EAG boxes



Sea Level Anomaly variability over 2008-2011 in Alboran



➢ Observed SLA & EKE variability in agreement with literature[4]:
Mode1: steric contribution of seasonal cycle, WAG & EAG intensification (weakening) during spring-summer (winter-fall).
Mode2: WAG intensification (weakening) - EAG weakening (intensification) in opposite phase - anticyclonic (cyclonic) eddy at the east.
Mode3: marked dipole separated by Almoran-Oran Front = intensification (weakening) of EAG - cyclonic (anticyclonic) eddy.
WAG, EAG: energy[WAG]>energy[EAG], stronger energy[WAG, EAG] the second half of the year, quasi-persistence of WAG whereas EAG disappears in winter (replaced by cyclonic eddy in the east).

➢ The main observed modes of SLA variability are found in the simulations. The simulated WAG energy is properly represented (amplitude, phase), but the simulated EAG has too strong energy & quasi-persistence in MFS, no existence in 2008 in Mercator.

Vertical structure of temperature/salinity misfits

Positions of available profiles over 2008-2011
(from ENACT-ENSEMBLES[5])

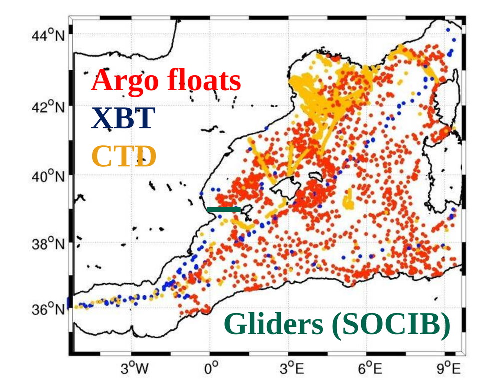
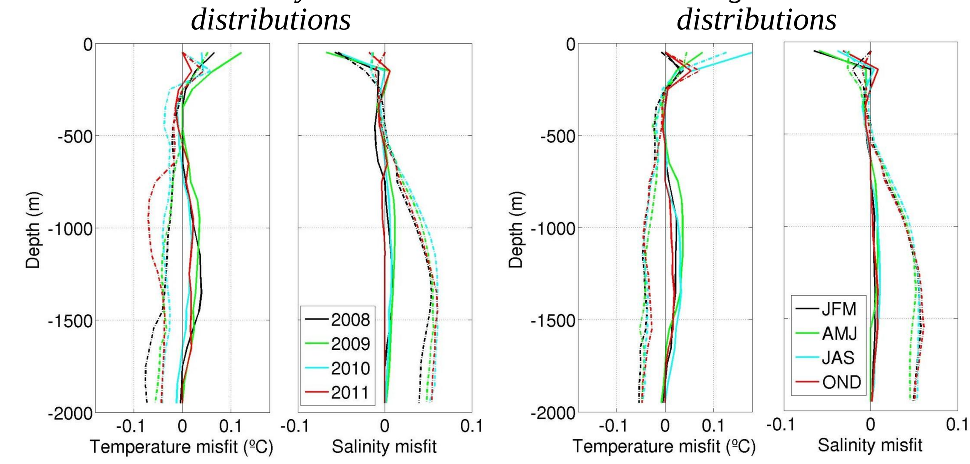


Figure 2

Median of distribution of T/S misfits (model-observation) as a function of depth over 2008-2011 in Western Med.



Solid line: Mercator. Dashed line: MFS
Observations=Argo, XBT (intense CTD sections excluded)

➢ Strongest T/S biases at surface in Mercator & MFS: warm in summer, fresh in winter.

➢ Persistent strong cold and salt biases in deep layer (>800m) in MFS.

➢ The main results/biases are consistent over all sub-regions defined in Fig. 1 (not shown).

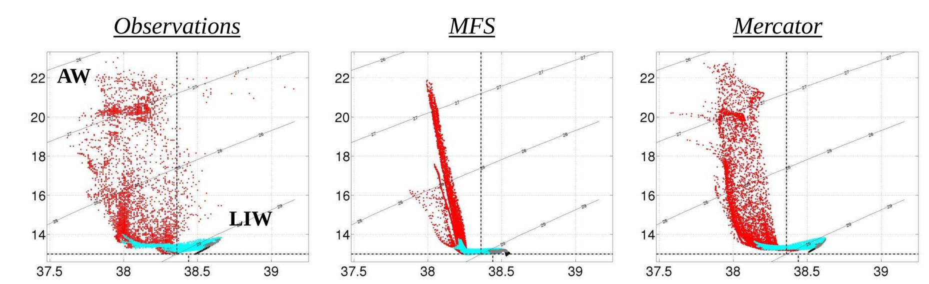
Water masses

AW: Atlantic Water
LIW: Levantine Intermediate Water
WIW: Winter Intermediate Water
WMDW: Western Mediterranean Deep Water

North-eastern boundary (May-June 2011)

CTD section Corsica - French coast (see Fig. 2)

TS diagram



0-100m
100-400m
400-800m
800-1500m

➢ Although T/S biases, Mercator reproduces the observed water masses (AW, LIW, DW).

➢ In MFS, the maxima of salinity associated to observed LIW is not well represented.

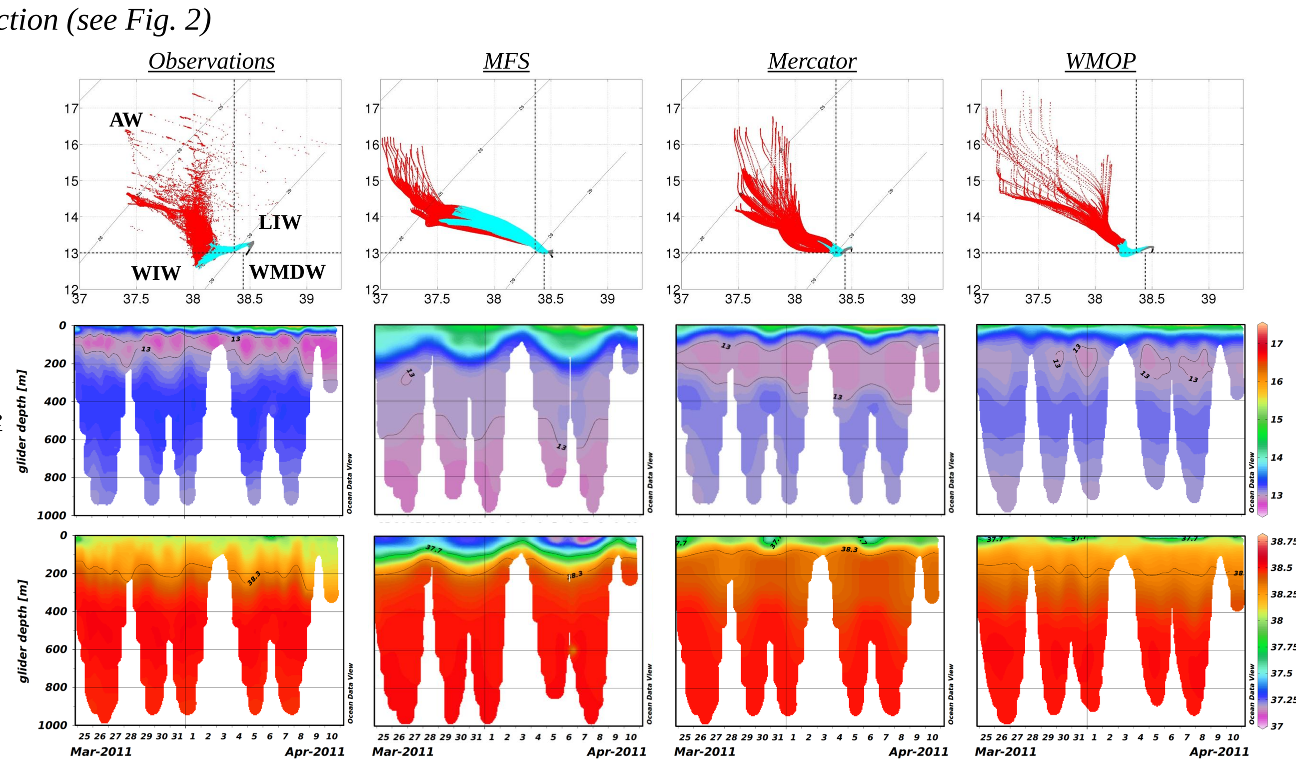
Ibiza Channel (March-April 2011)

Glider section (see Fig. 2)

TS diagram

Vertical Temperature

Vertical Salinity



➢ The observed T/S diagram & associated sections reveal the typical water masses of WMED (AW,LIW,WMDW) & the presence of WIW (formed in Northwestern Med[6]).

➢ MFS has strong surface T/S biases and does not reproduce the presence of WIW.

➢ Mercator represents the presence of WIW, although T/S biases are found.

➢ The high-resolution simulation WMOP (initialized and nested in Mercator) better represents the water masses in the Ibiza Channel.

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Conclusions and perspectives

➢ Surface: warm (spring-summer) and fresh biases in MFS & Mercator; reasonable general circulation, although with regional biases and underestimated energy; main observed modes of SLA variability reproduced in both simulations, but strong biases are found in the seasonal variability (amplitude, phase) of gyres in the Alboran.

➢ Intermediate and deep layers: strong persistent T/S biases have been found especially in MFS; Mercator is able to reproduce the presence of WIW in the Ibiza Channel.

➢ The high-resolution WMOP simulation has stronger EKE (not shown). Additionally, WMOP is able to properly reproduce the water masses structure in the Ibiza Channel, where exchanges between North and South Mediterranean Sea occur.

➢ Quantitative comparisons between WMOP (nested in MFS and Mercator) and parent models are being done over the last years; process studies using both observations and WMOP simulations are being carried out in a realistic context[6].