ENEA
Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile
Climate modelling and impacts laboratory – ENEA (Italy)

Use of satellite data for the validation of a high-resolution model of the Mediterranean Sea-Black Sea system

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1. A new model of the Mediterranean Sea-Black Sea system

A high-resolution forecasting model of the circulation of the Mediterranean Sea-Black Sea system has been developed, which, for the first time, includes the effects of the four main astronomical tides (M2, S2, K1, O1). The model is based on the hydrostatic version of the Massachusetts Institute of Technology general circulation model (MITgcm). It has a uniform horizontal resolution of 1/48° (about 2 km) over most of the domain, except in the Straits of Gibraltar, Dardanelles and Bosphorus, where resolution is further increased, down to few hundred meters, to correctly resolve the local dynamics. At the single open boundary, to the west of the Gibraltar Strait, boundary conditions from the NEMO operational model are prescribed, whereas surface forcing (hourly wind stress, heat and fresh water fluxes) is derived from a high-resolution (5 km) regional atmospheric model (SKIRON). The new model, named **MITO** (MIT Operational), is running operationally since the beginning of 2018, producing daily 5-days forecasts.

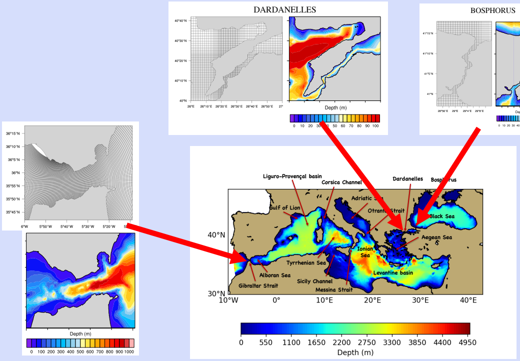


Figure 1. Model domain and bathymetry.

2. Validation of the tidal dynamics

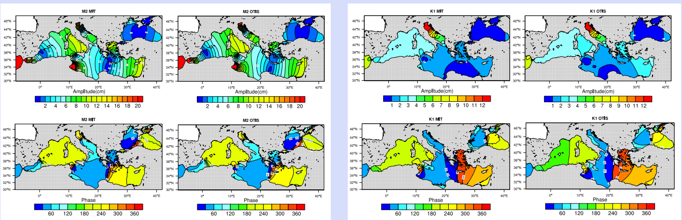


Figure 2. To evaluate the global quality of the representation of the tidal dynamics we have performed a one-year integration with a barotropic version of the model. Here, the maps of the tide constituents (for M2 and K1) obtained from the harmonic analysis of the surface elevation of this run are compared with reference maps obtained using the Oregon State University tidal inversion software (OTIS)

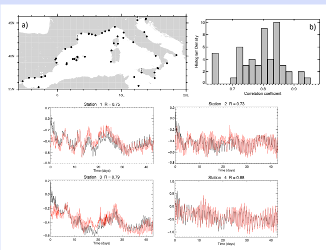


Figure 3. Local time series of the model surface elevation, from a 40-days validation run, compared with corresponding surface height time series extracted from the tide gauges available through the COPERNICUS portal, whose positions (54 stations) are shown in panel a). Panel b) provides a histogram plot of the correlation coefficient (R) between the two time series, computed at each site (the elevation values are extracted from the simulation at the grid point nearest to the tide gauge, with a time interval of 1 hour). Values of the coefficient are high in almost all stations (R > 0.8 for 31 of the 54 tide gauges).

3. Effects of the tides on the circulation (Sicily Channel)

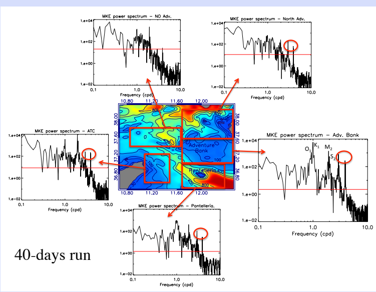


Figure 4. Power spectra of the mean kinetic energy, averaged over the five regions enclosed in the red boxes drawn in the central panel, illustrating the respective importance of the tidal components.
The peaks in the red ovals correspond to periods of about 8 and 6 hours, respectively. They indicate the presence of **nonlinear interactions:** M4 overtides (6h period), and MK3 compound tides (K1 + M2; 8h period).

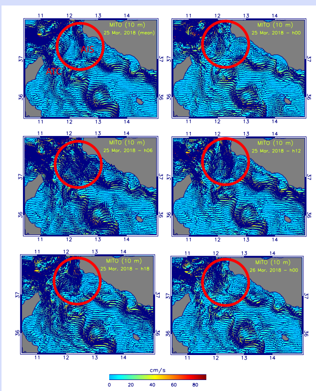


Figure 5. Tide effects on the surface circulation: note the diurnal rotation of the flow pattern over the Adventure Bank, and the diurnal and semidiurnal modulations of the ATC strength.

4. Model validation using satellite data

The performances of the new model have been tested performing a 40-days (19 March-30 April 2018), tide-including simulation, with initial and boundary data produced by coarser resolution operational models. No relaxation or assimilation was applied.

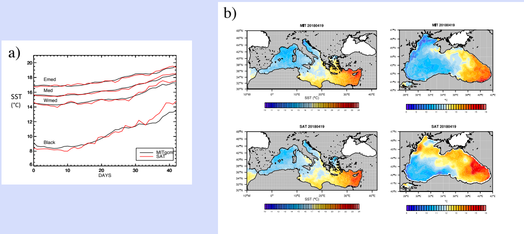


Figure 6. Comparison with satellite SST. Both the (sub)-basin averaged SST time series (a)) and the maps after one month of simulation (b)) show good agreement between the model and the observed SST.

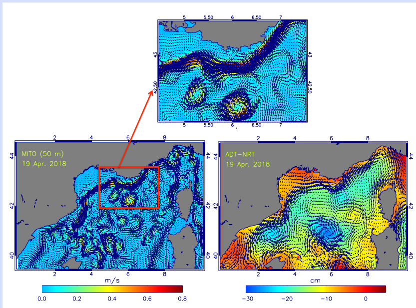
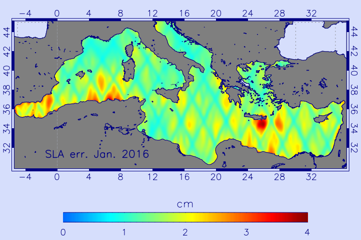


Figure 7. Surface circulation (19 April; 50 m depth) in the Liguro-Provençal basin. The model circulation (left) is compared with the geostrophic flow derived from altimeter data (right). Despite some differences in shape and locations, after one month of simulation, all the main structures present in the altimetric reconstruction are also found in the model output.

There are places, however, where the comparison is not as good. These are places where errors on the SLA are higher, and where the MDT reconstruction is delicate, because of complex dynamics, and/or of strong seasonal variability. Two such places are the Algerian basin, where a strong stream of Atlantic water (Algerian current) flows towards east, and the area to the southeast of Crete, where wide mesoscale features are located.



Another problem with the use of altimeter data concerns the Black Sea, since ADT maps for this area are apparently lacking (no MDT available?).

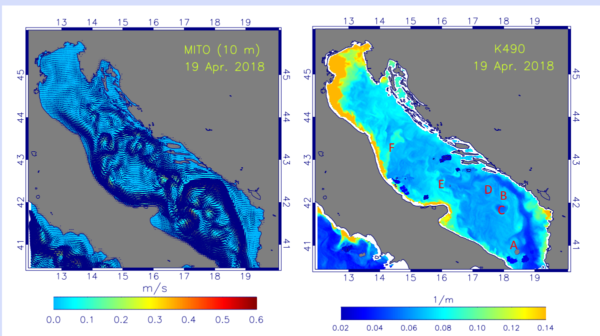


Figure 8. Turbidity (K490) images may also provide useful information on the structure of the surface circulation. On April 19, the sky was clear over the Adriatic Sea, yielding the beautiful, cloud-free image on the right. The image shows the typical circulation structure in the central and southern parts of the basin, characterized by two wide cyclonic cells. To the south, one can see a blue stream (less turbid water) entering from the Otranto Strait that bounds the southern cyclone to the east, in very good agreement with the model circulation pattern. Along this boundary there are several places in which the less turbid water is transported towards the inner part of the gyre, following curved paths that appear to correspond to the boundaries of small mesoscale structures that are present in the model output.
In this example, it would be useful to have the highest resolution (if possible) in non-coastal areas, to better highlight the different circulation structures.

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