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A new numerical model for the Black Sea circulation

Diego Bruciaferri (1), Georgy Shapiro (1), Sergey Stanichny (3), Andrey Zatsepin (2), Tal Ezer (4), Fred Wobus (1), Xavier Francis (1), and Dan Hilton (1)

(1) University of Plymouth, School of Bilogical and Marine Sciences, Plymouth Ocean Forecasting Centre, Plymouth, Devon, United Kingdom (gshapiro@plymouth.ac.uk), (2) Shirshov Institute of Oceanology, 36 Nahimovski prospect, Moscow, 117997, Russia, (3) Marine Hydrophysical Institute, Sevastopol, Kapitanskaya St., 2, Sevastopol, 299011, Russia, (4) Old Dominion University, Center for Coastal Physical Oceanography, 4111 Monarch Way, Norfolk, VA 23508, USA

There are a number of Black Sea ocean models which use one of the standard discretization schemes. None of the current methods are free from errors, the most well-known are either the pressure gradient force (for terrain following systems) and overmixing over the continental slope (for z- coordinate systems). Both methods are also prone to the contamination of weak diapycnal exchanges with strong isopycnal processes in cases the computational surfaces cross the isopycnals. We introduce a new model which reduces the above errors by using a novel multi-envelope vertical discretisation scheme, has a variable horizontal resolution and still perseveres the advantages of the structured grid and the ability to use a well-developed and supported codebase for core calculations.

In this study, we simulate the Black Sea hydrodynamics by using a modified version of NEMO ocean model for the period 2007-2009. The model uses a curvilinear orthogonal horizontal grid with increased resolution (∼950m) over the shelf break in order to simulate correctly the important processes over the continental slope. The model uses lower resolution (∼6km) in the areas where the scale of the relevant processes defined by Rossby radius is larger, about 20km, and does not require high resolution. In the vertical, the model uses the new multi-envelope s-coordinate system of Bruciaferri et al. (2018). The computational surfaces are selected in order to optimise the representation of the important feature of the Black sea water masses called the Cold Intermediate Water (CIW), see e.g., Shapiro (2008).

All our numerical results are obtained in a free-run mode and validated against observational datasets. We also compare the accuracy of the new model with the data from EU Copernicus CMEMS Black Sea reanalysis dataset, which is a highly data-assimilating system. The comparison shows that the new model in free-run has a comparable accuracy to the CMEMS data assimilating model for at least 3 years. This means that the new model if run in an operational mode is likely to require less frequent data assimilation, and is less computationally expensive. We show that optimising the numerical mesh for the prevailing physical processes allows improving the accuracy of a free-running multi-years simulation to a level comparable with the one of the best and highly data-assimilative reanalysis system.

Finally, we analyse the inter-annual variability of the Mean Kinetic Energy (MKE) of geostrophic currents and CIW properties simulated by the new model. The MKE time series is well consistent with satellite derived altimeter data. The CIW shows an intermittent temporal variability, and very small replenishment in 2009 in accordance to recent literature.

References

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