Assisted cascading of shelf waters in the Black Sea

Georgy Shapiro, Fred Wobus

School of Biological and Marine Sciences, University of Plymouth, UK

1. Introduction

The semi-enclosed nature of the Black Sea together with its unique combination of an extensive shelf area in the North West and the deep central part make it sensitive to natural variations of fluxes, including the fluxes between the biologically productive shelf and predominantly anoxic deep sea. Exchanges between the shelf and deep sea play an important role in forming the balance of waters, nutrients and pollution within the coastal areas.

One of the mechanisms of shelf –deep sea exchange is cascading of cold waters, which are formed during winter on shelf, into the deep basin.

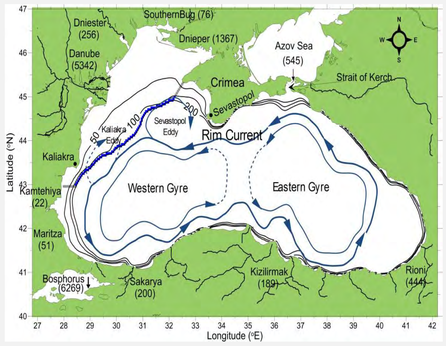

Fig 1. General circulation in the Black Sea and the boundary enclosing the northwestern Shelf

2. The model

In this study we analyse a new physical mechanisms of cascading of dense waters from the NW Black Sea shelf into the deep sea using NEMO ocean circulation model. The model is configured and optimized taking into account specific features of the Black Sea, and validated against in-situ and satellite observations. The study uses NEMO-BLS24 numerical model which is based on the NEMO codebase v3.2.1 with amendments introduced by the UK Met Office. The model has a horizontal resolution of 1/24×1/24° and a multi-enveloped s-on-top-of-z vertical coordinate system with a total of 33 layers. The lowest envelope is horizontal which generates geopotential (z-coordinate) levels below 150 m. The horizontal viscosity/diffusivity operator is rotated to reduce the contamination of vertical diffusion/viscosity by large values of their horizontal counterparts (Shapiro et al, 2013; Zhou et al, 2014).

The passive tracer implementation is based on the MYTRC module in NEMO's TOP component. Each tracer is treated as an artificial dye that "stains" a water parcel as soon as it cooled below a threshold temperature and its grid cell is located within the defined shelf area. In the following we mainly concentrate on the TRC3 tracer, which tracks any shelf water that was cooled below 7°C at some stage.

3. Results

The model has been validated against satellite derived SST and in-situ observations made during Black Sea cruises in 2004 and 2008 (BSERP-3 2004; Piotukh et al. 2011). Using the model run for 2003 as an example, we examine the fate of the tracer after 5.5 months of model integration. The mesoscale activity is intense at depths of 25 and 50 m. At 100m depth there are a number of smaller anti-cyclonic eddies which assist the cascading of cold waters originally formed on the shallow NW shelf in winter to a depth greater than at which they were originally formed.

A significant proportion of dense shelf water does not cascade locally off the NW shelf, but is transported by the Rim Current over hundreds of kilometres before cascading into the deep basin in the southern and southeastern Black Sea.

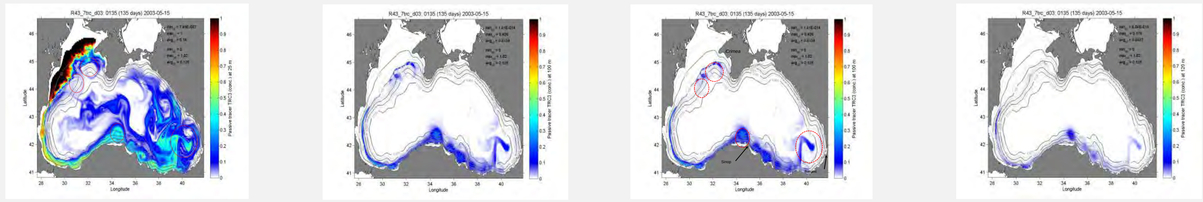

Fig 2. Maps of tracer concentration (tracking cold shelf water formed at T<7°C) at the 25, 50 100 and 120 m (left panel) and 100m (right panel) depth levels in mid-May 2003, as an example of the fate of the cold shelf water.

4. Conclusions

The numerical simulation identified and quantified a new mechanism of shelf-deep sea exchanges in the Black Sea.

This mechanism includes formation of cold dense water on the NW shelf during winter, their initial movement down the continental slope over a short distance (about 10 km) , capture by eddies and meanders of the basin scale current and transport over hundreds of miles by the basin scale current in early spring.

Then the waters of shelf origin are recaptured by local mesoscale eddies, which transport waters originated from the North West shelf into the interior of deep sea in late spring – early summer.

References:

Zhou, F., G. I. Shapiro, and F. Wobus, 2014: Cross-shelf exchange in the northwestern Black Sea. Journal of Geophysical Research: Oceans, 119, 2143-2164.

Shapiro, G., Luneva, M., Pickering, J., and Storkey, D.: The effect of various vertical discretisation schemes and horizontal diffusion parameterisation on the performance of a 3-D ocean model: the Black Sea case study, Ocean Sci., 9, 377-390, doi:10.5194/os-9-377-2013, 2013.

Acknowledgements:

This work was partly supported by EU FP7 PERSEUS, EU H2020 BlackSea Checkpoints and a number and Russian national projects.

Contact:

Georgy Shapiro (gshapiro@plymouth.ac.uk)