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Exchanges between the open Black Sea and its North West shelf

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Exchanges between the vast NW shelf and the deep basin of the Black Sea play a significant role in maintaining the balance of nutrients, heat content and salinity of the shelf waters. Nearly 87 % of the Black Sea is entirely anoxic below 70 to 200m and contains high levels of hydrogen sulphide (Zaitsev et al, 2001), and this makes the shelf waters particularly valuable for maintaining the Black Sea ecosystem in good health. The increase in salinity of shelf waters occurs partially due to exchanges with more saline open sea waters and represents a threat to relics and endemic species.

The shelf-break is commonly considered the bottle-neck of the shelf-deep sea exchanges (e.g. (Huthnance, 1995, Ivanov et al, 1997). Due to conservation of potential vorticity, the geostrophic currents flow along the contours of constant depth. However the ageostrophic flows (Ekman drift, mesoscale eddies, filaments, internal waves) are not subject to the same constraints. It has been shown that during the winter well mixed cold waters formed on the North West shelf propagate into the deep sea, providing an important mechanism for the replenishment of the Cold Intermediate Layer (Staneva and Stanev, 1997). However, much less is known about exchanges in the warm season. In this study, the transports of water, heat and salt between the northwestern shelf and the adjacent deep basin of the Black Sea are investigated using a high-resolution three-dimensional primitive equation model, NEMO-SHELF-BLS (Shapiro et al, 2013).

It is shown that during the period from April to August, 2005, both onshore and offshore cross-shelf break transports in the top 20 m were as high as 0.24 Sv on average, which was equivalent to the replacement of 60% of the volume of surface shelf waters (0 – 20 m) per month. Two main exchange mechanisms are studied: (i) Ekman transport, and (ii) transport by mesoscale eddies and associated meanders of the Rim Current. The Ekman drift causes nearly uniform onshore or offshore flow over a large section of the shelf break. Due to the short duration of strong wind effects (4-7 days) the horizontal extent of cross-shelf-break exchanges is limited to the outer shelf. The effect of Ekman drift is confined to the upper layers. In contrast, eddies and meanders penetrate deep down to the bottom, but they are restricted laterally. During the strong wind events of April 15 – 22 and July 1 – 4, some 0.66×10^{12} and 0.44×10^{12} $m^3$of water were removed from the northwestern shelf respectively. In comparison, the single long-lived Sevastopol Eddy generated a much larger offshore transfer of 2.84×10^{12} m^3 over the period April 23 to June 30, which is equivalent to 102% of the volume of northwestern shelf waters. This result is consistent with the data obtained from satellite derived information (Shapiro et al, 2010). The open Black Sea is generally warmer and more saline than the northwest shelf. Hence the exchanges contribute to the increase in both salinity and temperature of shelf waters. Over the study period, salt exchanges increased the average density of the shelf waters by 0.67 kg m^{-3} and reduced the density contrast between the shelf and deep sea, while lateral heat exchanges reduced the density of the shelf waters by 0.16 kg m^{-3} and thus enhanced density contrast across the shelf break.

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