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VORTICITY DISTRIBUTION, VARIABILITY AND SOURCES IN THE BLACKSEA

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Abstract

The vorticity balance in the upper layer of the Black Sea is analyzed using several data sources (drifter data, Argo float CTD profiles, satellite sea level anomalies and ocean surface wind velocities) in order to estimate the respective contribution of each term in the vorticity equation. The tube stretching term induces positive vorticity in all the regions of the Black Sea and seems to play an important role in the vorticity balance of the basin.

Keywords: Black Sea, Wind, Circulation

Vorticity is an important descriptive feature of ocean dynamics, whose variations are related to the balance of external forcing, associated with wind-stress, and internal processes. Internal processes produce vorticity variations through adjustment of internal pressure gradients (i.e. baroclinic adjustment) and/or through variations in the depth of the tube flow (tube stretching).

The Black Sea is a typical marginal, semi-enclosed, dilution basin characterized by a stable stratification, a simple basin geometry and a smooth bottom topography; therefore, it is the ideal location to study the relative contribution of the different terms to the vorticity balance in the ocean and to analyze fundamental hydrodynamic interactions common to different areas of the World Ocean.

The large scale structure of the Black Sea upper-layer dynamic is predominantly cyclonic (i.e. positive vorticity) with some anticyclonic rotations (i.e. negative vorticity) located in the coastal areas of the north-west and south-east sectors. According to the previous studies cyclonic circulation of the basin is maintained by wind-stress curl ([4]), although input due to winds is not able to reproduce the observed vorticity levels ([3]).

This consideration opens the issue of analysing the relative contribution of the individual terms that concur to the vorticity balance of the basin. The Black Sea is divided in four sectors, following the spatial distribution of prevailing winds, and the mean values of the vorticity equation terms over the period 1999-2008 are estimated for each sector.

In Table 1 the main results of this analysis are presented. The vorticity of the geostrophic currents is positive in the North-East, South-West and South-East sectors and slightly negative in the North-West sector. The wind stress works against the current vorticity in all sectors except in the North-East sector, with values of order 10^{-13} s^{-2}. The tube stretching terms induce a positive vorticity in all the sectors of the Black Sea, with larger values in the North-East and South-West areas and magnitudes comparable with the wind stress terms. Also the baroclinic terms prompt the cyclonic vorticity of the upper layer circulation, but their contributions are three/two orders of magnitude smaller than the wind stress and the tube stretching terms.

These considerations suggest that the tube stretching terms plays an important role in the vorticity balance of the Black Sea. The predominant role of the tube stretching term is supported by significant yearly variations in the upper layer thickness of the basin, as estimated from the phase speed of the internal gravity waves, and by the increment of freshwater inflow in the basin during the period considered ([1]; [2]).

Table 1. Mean amplitude of geostrophic currents, relative vorticity field associated with surface circulation, wind vorticity input, tube stretching and baroclinic terms estimated in each sector of the Black Sea.

	NW	NE	SW	SE
Mean geostrophic currents (cm/s)	9.3	15.8	15.8	12.4
Relative vorticity (s^{-1})	-3e-8	1.7e-6	2.3e-6	9.1e-7
Wind vorticity term (s^{-2})	-0.7e-13	0.12e-13	-4.4e-13	-0.6e-13
Tube stretching term (s^{-2})	3e-12	5.2e-12	5.3e-12	4.1e-12
Baroclinic term (s^{-2})	0.88e-15	2.5e-15	2.5e-15	1.6e-15

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