Hydrology and water circulation in the Black Sea

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In the course of a century-long exploration of the Black Sea, oceanographers have managed to determine the major regularities of its hydrologic regime and water dynamics. However, until today we are faced with a host of questions of utmost importance, for which no coherent response has yet been provided. Amongst these is the problem of seasonally-varying water circulation, formation of the vertical structure, the active layer response to external forcing, primarily, to wind. Naturally, all these issues are related to the cardinal problem of water circulation in the basin.

It is well known that the Black Sea cyclonic circulation is composed of two basin scale gyros in the western and eastern parts of the deep central section. However, there exist a variety of contrary views of seasonal variability, position, configuration and intensity of these dynamic features. Summarizing the data from a series of studies, one may infer that the water circulation in the Black Sea becomes most intensive in winter and feeble in summer. On the other hand, analysis of the historical data on surface circulation of geostrophic lows in the upper Black Sea during late summer shows that in summer cyclonic circulation in the northwestern section of the basin frequently transforms into its opposite, when the recurrence of southerly and south-westerly winds increases.

All studies of the Black Sea current vertical structure point out that current velocities rapidly decrease with depth. Some investigators hold that an opposite-sign, that is anticyclonic circulation is likely at depths below 300 m, whereas other researchers adduce proofs to the effect that the water circulation in the deep section of the sea is one-layered. During the late autumn/winter period, the vertical current variability in the northwestern shelf area is relatively insignificant, with the exception of the thin near-bottom layer, being 1 to 2 m thick at most. in spring and summer, diverse dynamical situations are likely to occur, including an absolute disparity between the horizontal patterns of currents in the upper layer and the bottom one. Those phenomena, obviously, are the result of the water circulation's sign alternating in the area.

In the course of the 1980's, oceanographers were seeking to elaborate and validate the current views on the variable water circulation through the use of contemporary techniques of research, specifically, the monitoring of currents by moored buoys, numerical diagnostic computations of water circulation from density fields with the wind field and bottom relief taken account of, and the numerical calculations of circulation evolution under the impact of external forcing mechanisms (wind, heat and volume fluxes through the sea surface).

The investigations carried out in recent years have shown that alongside the quasi-stationary dynamic features and geostrophic water circulation in the Black Sea, there occur mesoscale nonstationary disturbances of planetary/wave character. The horizontal scales and the accessible potential energy of both modes of general circulation are comparable between them, which is consistent with the known theoretical concepts. Notwithstanding the seeming absurdity of the implication that mesoscale eddies and rim current meanders, travelling with the planetary (Rossby) wave velocity, are present in Black Sea climatic fields, physically, this conclusion appears to be more valid than the traditional views on the Black Sea pattern of currents.

In fact, a restricted size of the basin does not contribute to the formation of a baroclinic layer with thickness sufficient for the accumulation of accessible potential energy comparable with the oceanic one. This shows off in the relatively small intensity of the quasi-stationary elements of circulation, the latter's velocity being not larger than 10 to 11 cm. s-1. On the other hand, intense nonstationary external forcings, primarily, in the form of verticity induced by wind with a pronounced seasonal variability, with maxima occuring during transition seasons and minima during summer and mid-winter, cause the generation of planetary/wave mesoscale disturbances.

The relatively stable annual recurrence of specific atmospheric forcings adds to the likelihood of the repeatability of the Black Sea's typical nonstationary response, which is manifest even in the climatic (mean multi-annual) fields. The basin's being limited in size also facilitates the waters' regular dynamic response to the external forcing, since the related nonstationary motions are expected to have parameters of the confined basin's proper oscillations. Only such motions (both gravitational and planetary quasi-geostrophic) may have considerable energy for a sufficiently long time.

Analysis of the energetics of climatic nonstationary disturbances of water circulation has revealed that these occur mainly in the central deep-water part of the Black Sea. Here, the energetics of the process is largest. Its reduction in the coastal zone is equivalent, on the average, to 20 to 30 percent. Climatic disturbances are likely to generate less consistent synoptic fluctuations. Their energy is concentrated in the coastal zone. The principal mechanism behind these disturbances seems to be related to the Black Sea rim current's hydrodynamic instability. All these mesoscale motions in the open sea can give rise to the eddies and coastal trapped waves, alongside the local wind forcing.

The various types of mesoscale, nonstationary waves exist in the Black Sea and are permanently interacting. A result is the complex structure of water circulation retrieved from all quasi-synoptic surveys accomplished in various Black Sea areas. A goal of future research is to identify the different types of dynamic disturbances and to study their properties in detail. This will allow us to gain an insight into the major mechanisms responsible for the formation, transformation and variability of the thermohaline barrier. It should be anticipated that the entire Black Sea ecosystem is functioning in the same mesoscale nonstationary regime. Thus, a study of the latter may be of significant relevance in terms of various practical implications designed to improve management and control of the diverse activities in the Black Sea waters and its shores.