

Hydrological Research in the Northern Part of the Black Sea in 2016 (87th, 89th and 91st Cruises of R/V *Professor Vodyanitsky*)

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The present paper represents the complex monitoring results of the hydrological field condition and water dynamics in the Black Sea northern part within the economic region of Russia carried out in the scientific expeditions in 2016 (87th, 89th and 91st cruises of R/V *Professor Vodyanitsky*). It is shown that distributions of all the thermohaline characteristics obtained from the data of three surveys demonstrate a pronounced seasonal character of a signal. It is manifested in consistent decrease of the upper mixed layer mean temperature, growth of temperature in the cold intermediate layer core and in deepening of the lower boundary of the upper mixed layer, the cold intermediate layer core and the hydrogen sulphide zone upper boundary. In course of three surveys, the Rim Current deep stream was located above the continental slope. The maximum velocities are observed nearby the Crimea southwestern coast. In the western part of the region considered, a well pronounced Sevastopol anticyclone (most distinct in October, 2016) is observed. The Sevastopol anticyclone manifests itself also in distributions of the hydrological characteristics. Temperature increase, salinity decrease and deepening of the lower boundary of the upper mixed layer and the cold intermediate layer core are observed on the sea surface in the anticyclone area.

Keywords: the Black Sea, thermohaline fields, the Rim Current, upper mixed layer, cold intermediate layer, Sevastopol anticyclonic gyre, spatial-temporal variability.

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In 2016, in the expeditions of 87th, 89th and 91st cruises of R/V *Professor Vodyanitsky*, a complex monitoring of the hydrological, hydrochemical, meteorological, hydro-optical and biological fields in the northern part of the Black Sea was carried out within the economic region of Russia. The objectives of the expeditions corresponded to the State Orders "Complex Interdisciplinary Studies of Oceanographic Processes Determining the Functioning and Evolution of the Black and Azov Sea Ecosystem on the Basis of Modern Methods of Control of the Marine Environment and Gridtechnology" and "Fundamental Research of the Processes in the Ocean – Atmosphere – Lithosphere System Determining Spatial-Temporal Variability of the Global and Regional Scale Environment and Climate", carried out by Federal State Budget Scientific Institution "Marine Hydrophysical Institute of RAS" (FSBSI MHI). Hydrological studies included the climatic monitoring of the thermohaline

structure of the Black Sea active layer waters and the study of the seasonal transformation of cold intermediate layer (CIL) waters. Based on geostrophic calculations and instrumental flow measurements, the spatial structure of water circulation was also studied.

Scheme of location of the performed hydrological stations, terms of the expeditions and quantity of hydrological sensing are shown in Fig. 1. Hydrological measurements at each station were carried out using the SBE 911*plus* complex. At all drift stations in the upper 300-m layer, velocities of currents were measured applying *Acoustic Doppler Current Profiler (ADCP)*.

Results of the analysis of expedition materials showed that in the distributions of all thermohaline characteristics from the data of three surveys, a seasonal signal was well traced. It manifested itself in a gradual decrease in the mean temperature of the upper quasi-homogeneous layer (UQL) (T_{UQL}), increase in the temperature in the CIL core (T_{CIL}), depth increase of the lower boundary of the UQL (H_{UQL}), the CIL core (H_{CIL}) and the upper boundary of the hydrogen sulphide zone according to the isopycn of 16.2 cu ($H_{16.2}$). Spatial distribution of thermohaline fields within each survey was affected by synoptic processes in the active layer of the sea, which caused the appearance of "spots" of high or low temperature and salinity, as well as areas of ascent or deepening of various isosurfaces.

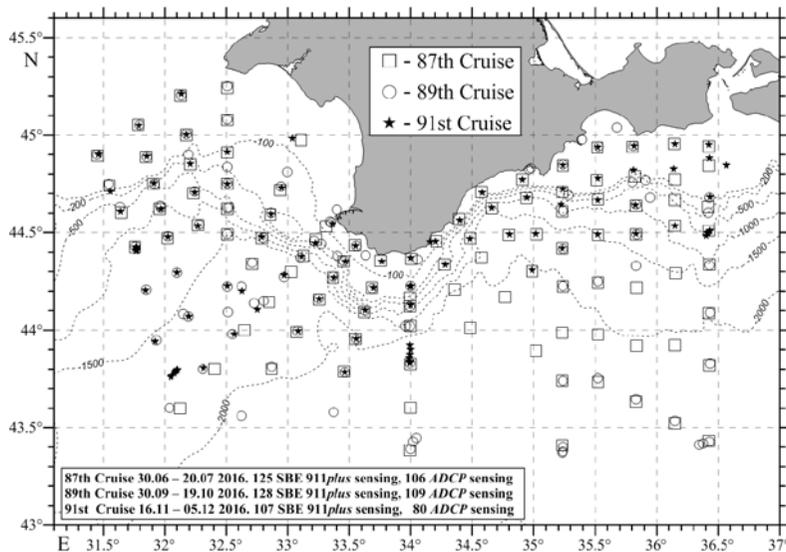
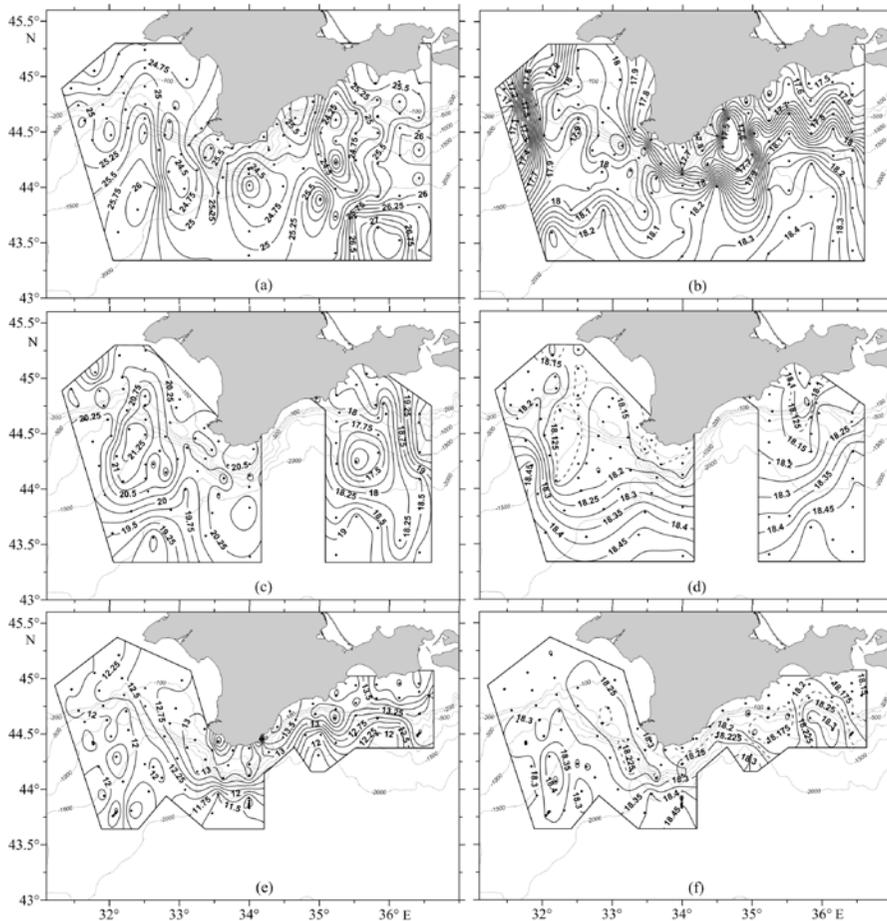


Fig. 1. Scheme of location of the performed hydrological stations, terms of the expeditions and quantity of hydrological sensing in the 87th, the 89th and the 91st cruises of R/V *Professor Vodyanitsky*. Thin dashed lines on Fig. 1, 2 and 3 are the main isobaths

In June (87th cruise) T_{UQL} was 24.0–28.0° C (Fig. 2, *a*) and H_{UQL} – 10–20 m. T_{CIL} and H_{CIL} values ranged from 8.19° C and 45 m, respectively, in the deep water southern survey area to 8.49° C and 95 m in the northwestern survey area seaward the continental slope. Maximum values of $H_{16.2}$ (160–170 m) were traced above the continental slope near the Crimea coast. The minimum ones (90–100 m) – in the southern area of the survey in the central part of the large-scale Western cyclonic gyre of the Black Sea [1–3].



and October surveys, and was 8.50–8.58° C. The highest values of T_{CIL} were observed near the Heracleian Peninsula and the eastern coast of Crimea. The maximum values of H_{CIL} (90–100 m) were traced in the northwestern part of the polygon and along the eastern coast of Crimea, the minimum ones (50–55 m) – in the seaward southern survey area. Distribution of $H_{16.2}$ qualitatively coincided with the distribution of H_{CIL} – in the northwestern part of the polygon and along the eastern coast of Crimea, its values reached 160–180 m, in the southern part of the polygon, they decreased to 110–120 m.

Spatial distribution of salinity in the surface layer from the data of three surveys showed a significant decrease in the range of its variability from July to December. In July (87th cruise) salinity at the polygon varied over a wide range from 17.00 to 18.40‰ [1]. The lowest salinity values (to 17.00‰) were noted in the extreme west of the survey area and were traces of the powerful desalination on the northwestern shelf of the Black Sea. Another area of relatively desalinated water (to 17.50‰) was observed in the northeastern part of the survey area closer to the Crimea coasts. Origin of these desalinated waters was associated with the release of the water from the Kerch Strait area on the northern periphery of the Rim Current. In the seaward area of the survey the salinity increased up to 18.30–18.40‰ (Fig. 2, *b*). In October (89th cruise) salinity increased in the south from 18.10–18.15‰ near the Crimea coasts to 18.45–18.50‰ near the southern boundary of the polygon (Fig. 2, *d*). In November–December (91st cruise) spatial changes of the salinity were insignificant – from 18.20 to 18.40‰. During this period, the release of the poor-desalinated waters (18.15–18.20‰) from the Kerch Strait area was monitored. Traces of such waters reached the Heracleian Peninsula and could be traced even on the traverse of the Kalamitsky Gulf (Fig. 2, *f*).

The water circulation analysis based on geostrophic calculations and instrumental measurements showed that the Rim Current centerline was located above the continental slope during the three surveys, and the Rim Current velocities significantly changed in its separate parts. Maximum velocities (60–70 cm/s) were usually observed near the southwestern coasts of Crimea. During the July survey, high velocities (up to 50 cm/s) were also observed in the eastern part of the polygon to the south of the Kerch Peninsula and on the traverse of the Feodosiya Gulf.

The Rim Current was a meandering stream, while the formation of gyres and meanders most intensively occurred in the western part of the survey area. A well-pronounced anticyclonic gyre was recorded here: it's the Sevastopol anticyclone [3, 4], which was most clearly manifested in October, 2016 [5]. According to the instrumental data, in this period the velocities in the southwestern periphery of the gyre reached 40 cm/s, in the northeastern one – up to 20 cm/s (Fig. 3, *a*). The Sevastopol anticyclone was also observed in the distribution of hydrological characteristics. In the anticyclone zone, the temperature increase (up to 21.25° C) and the salinity decrease (up to 18.22 ‰) were traced on the surface (Fig. 2, *c*, 2, *d*). There was an increase in the depth of occurrence of the lower boundary of UQL (up to 30–32 m) and CIL core (up to 90–91 m), while the temperature values in the CIL core slightly decreased (to 8.42° C) (Fig. 3, *b*, 3, *c* and 3, *d*).

The obtained information on the spatial-temporal distribution of hydrological parameters and instrumentally measured currents has significantly supplemented the archival database of the hydrological data of the Black Sea. Further comprehensive anal-

ysis of hydrological, hydrochemical, hydro-optical and biological data with the involvement of historical databases will give possibility to determine the anomaly degree of hydrological fields and to evaluate the overall ecological condition of waters in the northern part of the Black Sea within the economic region of Russia in 2016.

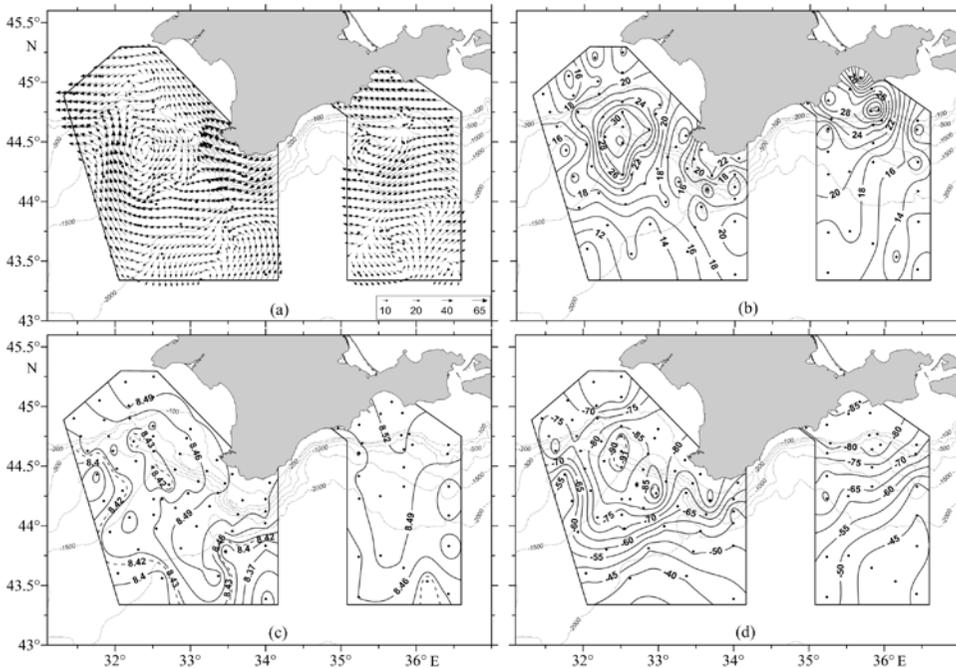


Fig. 3. Distribution of the vectors of the instrumentally measured currents at the 10 m horizon (a), depths of the UQL lower boundary (b), temperature in the CIL core (c) and depths of the CIL location (d) in October, 2016

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Contribution of the co-authors:

Yuriy V. Artamonov – general scientific supervision of the research, setting out the objectives and tasks of the research, development of methods and conducting of experimental studies, qualitative analysis of results and their interpretation, discussion of the results, making conclusions

Elena A. Skripaleva – literature review in the research problem, qualitative analysis of results and their interpretation, the processing and description of the results of the study, discussion of the results, making conclusions, the article text preparation, text finalization

Dmitriy V. Alekseev – qualitative analysis of results and their interpretation, discussion of the results, making conclusions

Alexandr V. Fedirko – software development and debugging for secondary processing of experimental data, computer implementation of algorithms, construction of graphs and diagrams, participation in the discussion of article materials

Sergey A. Shutov – the data collection and systematization, computer implementation of algorithms for primary processing of the experimental data

Roman V. Kolmak – the data collection and systematization

Rostislav O. Shapovalov – the data collection and systematization, computer implementation of algorithms for primary processing of the experimental data

Sergey V. Shcherbachenko – the data collection and systematization, computer implementation of algorithms for primary processing of the experimental data, participation in the discussion of the article materials

All the authors have read and approved the final manuscript.

The authors declare that they have no conflict of interest.