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Analysis of the hydrophysical structure of the Sea of Azov in the period of the bottom anoxia development

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Abstract

The hydrophysical and hydrochemical structure of the Sea of Azov, with developed bottom anoxia, was studied during the RV "Akvanavt" cruise from July 31 to August 03, 2001. The anoxic zone with a thickness from 0.5 to 4 m above the bottom was found in all deep regions of the Sea. Concentrations of hydrochemical parameters were similar to the pronounced anoxic conditions (about 90 mmol m^{-3} of hydrogen sulfide, 17 mmol m^{-3} of ammonia, 6 mmol m^{-3} of phosphate, 7 mmol m^{-3} of total manganese). The hydrophysical structure was characterized by the uniform distribution of temperature in the upper 6–7 m mixed layer (UML). Below this a thin (0.4–0.8 m) thermocline layer was observed, just above the anoxic waters. Formation of this phenomenon was connected with that summer weather conditions. Intensive rains led to increased influx of river waters in June. That resulted in large input of allochtonous organic matter (OM) and inorganic nutrients; the latter were consumed on the additional autochthonous organic matter production. In July the weather was characterized by a significant rise in the daily averaged air temperature and large oscillations of temperature during the day. In this period a wind of constant direction was absent, but wind bursts were observed. The completed analyses showed that the formation of such a structure could be connected with the following factors: (i) positive growth trends of the daily averaged temperature and the daily oscillations of temperature, (ii) presence of wind bursts. The joint action of these factors resulted in the formation of the UML. The amplitude of wind bursts determined the depth of UML, and the value of trend determined the value of the temperature change in the thermocline. An initial presence of bottom halocline (caused by the Black Sea water influx to the bottom of the Sea of Azov) prevented the heating of the bottom layer and therefore led to an increase of vertical gradient of temperature in the thermocline. The spatial distribution of the turbulent exchange coefficient confirmed the existence of a "stagnation" area located above the anoxia zone, which is also, apparently, the reason for its occurrence.

Keywords: Nutrient cycles; Anoxic conditions; Turbulent diffusion; Russia; Sea of Azov

1. Introduction

Anoxic conditions are a natural feature of numerous areas in coastal and marginal seas. These conditions arise when transport rates of organic matter and oxygen into deeper layers of the coastal seas do not balance and oxygen is used up, leaving an excess of organic material

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to be decomposed. The decomposition processes continue by bacterial activity employing electron acceptors other than oxygen and usually ending up with reduction by sulphate (a major constituent in seawater). This process leads to the production of hydrogen sulphide, noxious and toxic to higher life forms, once it is emitted from the sea. Its appearance in water is a threat for the functioning of healthy coastal ecosystems and thereby a direct danger to human health and economic welfare of coastal societies (Richardson and Jorgensen, 1996).

One of the regions that are liable to this catastrophic event is the Sea of Azov (Fig. 1). The Sea of Azov is a shallow (average depth of 5 m) 39,000 km^2 basin with very high biological productivity. The anoxic events of natural origin that occur in the Sea of Azov are a consequence of specific features of its hydrological and hydrochemical regime (Datsko, 1955; Simonova, 1991). The Sea is connected with the Black Sea through the Kerch Straight in the south and is influenced by two large rivers — the Don, which influxes from the northeast through the Taganrog Bay, and the Kuban, which enters from the southeast about 30 km east from the Kerch Straight.

The common explanation for anoxic events is an increased inflow of autochthonous organic matter under the conditions of limited water aeration, which may be due to insufficient water mixing in the conditions of absence of wind. Weak wind-induced water mixing reduces the supply of dissolved oxygen to the bottom layers, while the oxidation of the OM results in the disappearance of oxygen and to the formation of anaerobic conditions. The summer hypoxia and anoxia in the Sea of Azov happens in certain years from the beginning of the 20th century (Datsko, 1955). Large anoxia were observed in 1937, 1946, and 1987 (Datsko, 1955; Simonova, 1991).

During the RV "Akvanavt" cruise from July 30 to August 4, 2001 we collected a unique hydrophysical and hydrochemical data set during the development of a very intensive anoxic event in the Sea of Azov. The details of the observed hydrochemical structure of the Sea are discussed in (Yakushev et al., 2003). In this paper we analyze the peculiarities of the hydrophysical structure connected with this anoxia and reveal the base typical features of the mechanism that is responsible for formation of such a structure during the summer periods. We apply a simple model allowing comparison of the relative roles of horizontal and vertical factors and in formation of the vertical distribution of temperature and salinity.

2. Field measurements

In this chapter we will discuss hydrochemical and hydrophysical structure observed during the Sea of Azov anoxia event in 2001. All field data presented in this study was collected during the RV "Akvanavt" cruise in the Sea of Azov from July 30 to August 4, 2001.

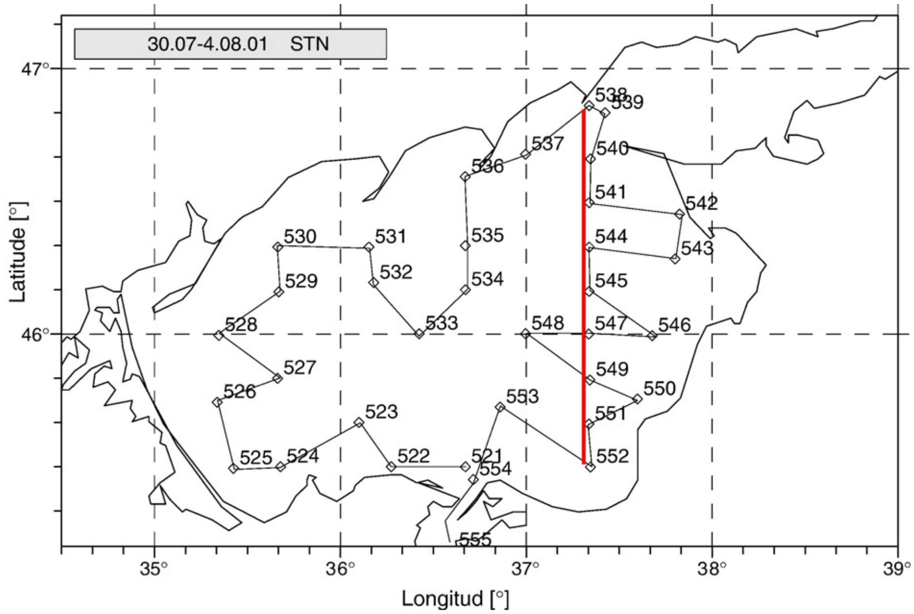

Fig. 1. Scheme of cruise and position of a transect along the 37′ 20° meridian.