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Reconstruction of salinity data in the Sea of Azov from satellite measurements in the visible spectrum

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ABSTRACT. A method based on the use of statistical procedures and three-dimensional hydrodinamical simulation with assimilation of remote sensing data to obtain regular information on the temperature and salinity of the Sea of the Azov is proposed. We used the *in situ* measurements of temperature and salinity for the period 1913–2012 and the observations data from MODIS-Aqua/Terra instruments regularly passing over the Sea of the Azov and the simulation results of three-dimensional hydrodynamic Princeton Ocean Model. The possibility of the operative recovery of salinity values is based on regression statistics on the bio-optical characteristics remote sensing reflectance band ratio $index34 = R_{RS}(531)/R_{RS}(488)$ and particulate backscattering coefficient $b_{bp}(555)$.

Keywords: Sea of Azov, salinity, MODIS color scanner data, three-dimensional hydrodynamic model, bio-optical characteristics, assimilation, *in situ* measurement, regression relations

1. Introduction.

Salinity is one of the main hydrological components of the marine environment (Wolanksi and Elliott, 2015). Salinity changes are reflected in the biological resources of the water area, which is especially noticeable in shallow water basins such as the Sea of the Azov. The most reliable tool for determining the salinity of seawater is contact measurement data. The high cost of obtaining them and the need for an operational forecast led to the search for alternative possibilities for determining the salinity of the sea ox. One of them is based on the use of remote sensing data. However, the presence of gaps caused by general problems of remote sensing significantly limits the amount of information available. To fill the gaps in satellite data, the results of three-dimensional hydrodynamic modeling are used (Shul'ga and Suslin, 2018; Konik et al., 2019). The model must have high spatial resolution comparable to satellite imagery and constantly assimilate satellite data streams.

2. Material and methods.

A numerical study of the circulation of waters in the basin of the Sea of Azov and is based on the application of a three-dimensional sigma coordinate of the hydrodynamic Princeton Ocean Model (Blumberg and Mellor, 1987). Modeling is performed for real bottom topography, taking into account the river flow of the Don River (Kosenko et al., 2018). As the initial conditions for temperature and salinity in the model, monthly mean monthly fields of temperature and salinity obtained on the basis of mean long-term climatic data (Matishov et al., 2006; Shul'ga et al., 2020) summarizing observations for 1891–2012 are assimilated in the model. The numerical experiments take into account the real atmospheric forcing according to the SKIRON regional atmospheric reanalysis data (Kallos et al., 1997). The SKIRON reanalysis data (http://forecast.uoa.gr) are hourly assimilated into the POM model by interpolating the wind speed and atmospheric pressure values to the computational grid of the Sea the Azov basin.

The data on temperature and salinity in the Sea of Azov were obtained from the oceanographic database of the Southern Scientific Centre of the Russian Academy of Sciences for 1913–2006 (Matishov et al., 2006), supplemented with data for 2007–2012 from the Atlas of Climatic Changes in large Marine Ecosystems of the Northern Hemisphere (Matishov et al., 2014), http://atlas.ssc-ras.ru/azs/azs-invent.html. These data are summarized with information on temperature and salinity in the Sea of Azov from the oceanographic data bank of the Marine Hydrophysical Institute of the Russian Academy of Sciences for 2002–2006.

To implement the proposed methods, we used the primary hydro-optical characteristics of the Sea of the Azov obtained from NASA Ocean Color data (NASA, AQUA, 2018; NASA, TERRA, 2018). The

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satellite data sets were transformed into spatial maps of the distribution of bioptical characteristics *index*34 and b_{bp}(555) over the water area the Sea of the Azov. The *index*34 characterizes the total concentration of living and non-living components of organic matter in seawater. The second is an indicator of light backscattering by particles of a suspension at a wavelength of 555 nm (Suslin and Churilova, 2016). In case of partial or complete absence of images, MODIS-Aqua data are supplemented with MODIS-Terra data (Shul'ga and Suslin, 2018).

3. Results.

The research was carried out in several stages. Initially, the preliminary processing of the available field data for different periods from different oceanographic databases was carried out for use in the model. The assimilated data in POM was based on averaged annual values for each month of measurements and grouped into arrays related to the surface, middle and bottom layers of the sea. At the next stage, data from MODIS-Aqua/Terra color satellite scanners were processed and spatial distribution maps of *index*34 and b_{bp}(555) were constructed. The regression relationship between the salinity values in the surface layer of the sea and biotic indices was determined in the presence of a sufficient amount of satellite and *in situ* data. For this, the bio-optical indices are calculated by coordinates deviating from the point of measurements by no more than 0.01°. The final stage was designed to obtain continuous information on the temperature and salinity of sea water in the Sea of the Azov based on the simulation results. The simulation was carried out for 365 days, the beginning of the simulation from 01.01.2017.

The relationship between the values of the salinity of the Sea of the Azov and bio-optical indicators was determined for two time periods, characterized by the presence of a large amount of satellite and field data. The analysis of 2002–2006 was carried out for June as the most informative month (N = 25684). The value of the correlation coefficient ≥ 0.85 was an indicator for using the regression dependence to restore salinity according to the values of *index*34 and b_{bp}(555). Regression analysis for the spring and autumn seasons in 2007–2008 was carried out using sets of field and satellite data (N = 846). In total, three main regression relationships were obtained, characterized by a correlation coefficient greater than 0.6.

4. Conclusions.

Observations and simulation salinity field showed a good qualitative agreement between regions of desalinated seawater and the direction of change in the position of their boundaries in the Sea of Azov. The results have demonstrated the possibility of using remote sensing data to obtain continuous information about the three-dimensional structure of the seawater temperature and salinity fields on the example of the Sea of Azov.

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