Physical Oceanography, Vol. 17, No. 1, 2007

MATHEMATICAL MODELING OF MARINE SYSTEMS

MODELING OF THE BLACK-SEA ECOSYSTEM

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UDC 511.46

We study the seasonal variability of the Black-Sea ecosystem by using a three-dimensional physical-biogeochemical model. Its physical part is a model of circulation in the Black Sea with high spatial resolution capable of the description of both large-scale circulation in the basin and mesoscale eddies. The ecological module of the model is based on a version of the already applied one-dimensional model generalized to the three-dimensional case and includes two components of phytoplankton, two groups of zooplankton of different sizes, bacteria, dissolved and suspended organic substances, jointly described nitrates and nitrites, and ammonium. The application of the eddy-resolving model as the basic model of circulation in the Black Sea enable us to qualitatively reproduce the processes of vertical entrainment of deep-sea waters rich in biogenic elements into the upper layer and transfrontal transport of the coastal waters into the open part of the sea. Our numerical experiments also demonstrate that this model realistically reproduces the seasonal dynamics of the distribution of phytoplankton in the Black Sea. In addition, the model reproduces the space structure of the biogeochemical variables of state correlated with the mesoscale features of circulation.

Under the conditions of restricted possibilities of organization of continuous and multifactor observations of the biogeochemical processes and continuous monitoring of the dynamics of the sea, a potentially important role is played by the models of the Black-Sea ecosystem. The numerical models of the ecosystem combined with a model of dynamics of the sea must guarantee the possibility of interpolation and extrapolation of the data of regular satellite observations of the sea color and fragmentary biogeochemical contact observations in space and time and continuous reproduction of the collections of variables whose direct measurement is impossible. However, the construction of a mathematical model capable of giving an adequate quantitative description of decadal variations of the Black-Sea ecosystem is an extremely difficult problem. For the last 30–40 yr, the Black-Sea ecosystem suffered noticeable transformations caused by the climatic changes and anthropogenic influence. Therefore, a model used for the continuous monitoring of the ecosystem must correctly reproduce diverse and complex interactions between various species or groups of species playing different roles in all stages of the evolution of the ecosystem.

The experiments aimed at modeling the Black-Sea ecosystem were originated relatively long ago. Their description can be found in the works by Vinogradov et al. [1, 2] and Belyaev et al. [3, 4]. Models of various types are also presented in [5, 6]. The models of ecosystems are, as a rule, based on the nitrogen cycle. Therefore, all variables are expressed via the equivalent concentration of nitrogen and the equations used to describe the evolution of the ecosystem reflect the balance of nitrogen in its transitions between different forms. However, in recent years, the greatest successes were attained in [7–10]. These investigations were based on a one-dimensional model of the ecosystem reproducing the vertical distributions of the fields and taking into account five different

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Translated from Morskoi Gidrofizicheskii Zhurnal, No. 1, pp. 59–72, January–February, 2007. Original article submitted September 1, 2005; revision submitted October 7, 2005.

