Modeling of the Caspian Sea ice on a seasonal scale

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Introduction

The ice cover of the Caspian Sea, which is formed mainly in its northern part from November to March, has a significant impact on shipping, oil and gas production. The methods used to predict the characteristics of the Caspian Sea ice are usually based on statistical relationships between meteorological and ice parameters. As an example, there is a method of short-term forecasting of ice thickness in the northeastern part of the Caspian Sea, based on the relationship between the sum of negative air temperatures in forecast for 3-5 days and the ice thickness increase (Naurozbayeva, Lobanov, 2020).

Recently, hydrodynamic models have been used to predict the characteristics of ice conditions. The paper (Fomin et al. 2020) presents the results of a 24-h forecast of ice conditions in February 2017. Our paper discusses the results of experimental application of the **C**ommunity **I**ce **C**od**E** (CICE) model for modeling the ice characteristics of the Caspian Sea in the winter seasons of 2005-2008.

Model configuration and data used

Most of the sea ice parametrization and modeling systems developed in recent years have been assembled by the scientific community and integrated into complex sea ice models. The most advanced and complete of them, apparently, is the CICE sea ice model (CICE Documentation, 2021). The general access software of the CICE model is distributed in combination with the Icepack package, the set of physical parameters of which takes into account thermodynamic and dynamic subgrid processes. To account for changes in the sea ice thickness, the ice cover is divided into several classes in the CICE model. Each class represents a range of sea ice thickness and describes the evolution of the thickness distribution in time and space. The CICE model is used at several prognostic centers.

To simulate the characteristics of the Northern Caspian Sea ice based on the CICE-v6 package 6.3 (CICE Documentation, 2021), a version of an autonomous forecast model with a bi-polar orthogonal computational grid (Bouillon et al.,2009; Ross, 1996) and anisotropic elastic-viscous-plastic rheology (Hunke et al.,2011) has been created. This approach makes it possible to perform numerical experiments using the extensive test archive of the CICE consortium, which includes the following global data:

- seabed bathymetry;
- monthly average water temperature, salinity and currents;
- 3-hour reanalysis data of JRA55 (Tsujino et al.,2018) from 2005 to 2009 for short-wave and long-wave radiation fluxes, wind direction and speed, air temperature and humidity.

Results of modeling the ice characteristics for the Caspian Sea

Ice characteristics were calculated for four winter (October-March) seasons of 2005-2009. The numerical results were analyzed for the area near Bolshoy Peshnoy Island, as it is most representative for the ice conditions of the Northern Caspian Sea (Naurozbayeva, Lobanov 2020). The ice concentration and thickness were calculated along with the dates of ice formation and disappearance. The quality of modeling was evaluated by comparing the calculated and actual dates of ice formation and disappearance, as well as the maximum ice thickness and the dates of its formation.

The dates of ice formation and disappearance were determined by calculation of ice concentration. In three cases (2005, 2006 and 2008), the calculated ice formation dates were nearly correct (the error was 1 - 4 days). In all cases, the ice actually disappeared earlier than in calculations (by 4 days in 2006 and 24 days in 2008). The greatest differences in the maximum thickness and the date of formation relate to January-March 2007, when the ice thickness was the

smallest of the four seasons (15 cm). At the same time, in February 2008, when the thickness was the largest (60 cm), the calculation can be considered satisfactory, both in thickness (47 cm) and in the date of formation (see Figure).

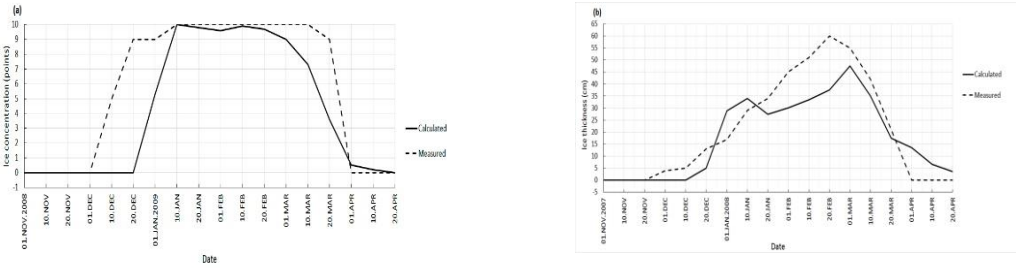

Fig. Calculated and measured ice concentration (points) in the winter season 2008-2009 (a) and ice thickness (cm) in the winter season 2007-2008 (b).

Conclusions

Based on numerical experiments with the CICE model (version V6.3) it is shown that the CICE model with a bi-polar orthogonal computational grid and anisotropic elastic-viscous-plastic rheology satisfactorily reproduces the processes of ice build-up and melting in the Caspian Sea. In some years there are significant discrepancies between the calculated and actual dates of ice formation and disappearance. It should be noted that the results of calculating the ice maximum thickness coincide well with the observational data.

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