Modeling of sea currents and the spread of an oil slick in the Labrador Sea area

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Abstract. The article discusses the modeling of an oil spill in the Labrador Sea region using the Cardinal software package. The capabilities of the software package are shown. The use of a rectangular and curvilinear grid is presented, and the calculation of currents and spread of an oil slick is carried out under the condition of topographic irregularities of the sea bottom, the field of currents and wind conditions. As a result of the work, maps of the current field and sea level were obtained. The parameters of the oil spill were calculated, including the volume of dispersed and evaporated oil. And in conclusion, the transformation of an oil spill in the center of the sea for 5 days is shown.

1. Introduction
In recent decades it has seen an increase in oil production, but the number of accidents associated with oil spills is also increasing. Such accidents occur both during the direct production of oil and during its transportation [1-2]. It is impossible to predict in advance the exact location of the spill, therefore, it is necessary to develop plans for the timely elimination of such accidents [3].

To plan a response to spills, it is necessary to predict these spills: information on the behavior and nature of the slick, possible runoff paths and places of oil accumulation, impact on natural and other objects [4]. The Cardinal software package is a system for predicting the consequences of oil spills, based on methods of mathematical modeling, taking into account the hydrodynamic and climatic features of the spill zone, which will help to cope with the above tasks. Based on the results obtained, decision-making on the problems of liquidation of accidents and other situations during oil production or transportation can be based [5-7].

2. Materials and methods
The depth field for the Labrador Sea was imported from the NOAA website, and the most common wind speed and direction were used to define the wind characteristics [5]. To calculate the spread of currents and oil spills, the Cardinal software package was used, which is a system for predicting the consequences of oil spills, based on mathematical modeling methods, taking into account the hydrodynamic and climatic features of the spill area [8].

Using the sea depth field, a rectangular grid was constructed, and zero depth values were used to mark land depths (figure 1) [9-10]. Then the number of nodes of the longest size of the area is set equal to 101 (figure 2). Therefore, the grid spacing is 19 km.
After constructing a rectangular grid, the depths of the computational grid are interpolated (figure 3).

For clarity of the performed interpolation, the distribution of depths was built (figure 4), where the darker areas correspond to the greatest depths. Off the coast of Greenland and Canada, the depths are shallow, on average 150-200 m. The deepest is the central part of the sea, where the depth is about 3500 m.
After the performed operations, the calculation of the current field is carried out at a given wind speed and a time step. Based on the resulting curvilinear grid, the level and current velocity fields were plotted for a day using data on tidal level fluctuations from the WXTide website.

The oil spill parameters were calculated using the ADIOS2 program. The closest locations of the oil source (Newfoundland area), wind speed and direction, water temperature and salinity, current speed and direction, and the amount of oil discharged were determined. The program determines the amount of dispersed and evaporated oil [11].

3. Results

The field of currents was calculated by setting the north wind with a speed of 14 m / s, with a time step of 96 sec. The resulting field of currents per day, indicating the speed and direction of the current (figure 5).

When constructing a curvilinear mesh, it is additionally required to close the contour passing along the zero isobath, and, as well as for a rectangular mesh, the imported depths were interpolated to each point of the computational mesh (figure 6).
On the basis of the obtained curvilinear grid, the fields of the level and current velocity for a day were constructed using data on tidal level fluctuations from the WXTide site. Two open borders were selected in the north and south of the sea area. Maps constructed current field (figure 7), sea level (figure 8) and level stroke (figure 9).

**Figure 6.** Curved mesh depth interpolation.

**Figure 7.** Flow field.

**Figure 8.** Level contour field (cm).
To calculate the parameters of the oil spill, the nearest locations of the oil source (Newfoundland area), the speed and direction of the wind, the temperature and salinity of the water, the speed and direction of the current, as well as the amount of oil released were determined. The program determines the amount of dispersed and evaporated oil (figure 10).

A point in the center of the sea was selected as the spill source. The calculation time is 5 days (figure 11-14).
4. Discussion
The field of currents was calculated by setting the north wind with a speed of 14 m / s, with a time step of 96 sec. The resulting field of currents per day, indicating the speed and direction of the current (figure 5), suggests that the highest velocities are on average 10-40 cm / s, in rare cases reaching 75 cm / s, in open sea areas the current velocity is less than 10 cm / s. from. The direction of the current is mainly to the south and throughout the sea area.

On the basis of the obtained curvilinear grid, the fields of the level and current velocity for a day were constructed using data on tidal level fluctuations from the WXTide site. Two open borders were selected in the north and south of the sea area. The current velocity is on average 15-55 cm / s and weakening moves to the south, where the speed is already about 15 cm / s, in the north it reaches 75 cm / s (figure 7). The sea level decreases from north to southeast, thus the level is lower in the eastern part of the sea (figure 8). In the northern part of the sea the level reaches 440cm, in the southern part - about 170cm. The minimum level is 130cm in the open sea and in the eastern part. The height of the level is on average 250 cm, the period of level fluctuations is semi-daily (figure 9).
Figure 14. Oil spill after 5 days.

A point in the center of the sea was selected as the spill source. The calculation time is 5 days (figure 11-14). The concentration at the source at the beginning of the release was 6.53 g / l, at 15 hours it was 6.56 g / l, after 2 days - 4.4 g / l, after 3 days it was 4.38 g / l, on day 5 it was 4.35 g at the source.

The direction of the spread of the oil slick is predominantly in the direction of the current; for all 5 days of the study, the area of the oil slick stretched to the south, thereby the area of the contaminated surface increased more than 5 times.

5. Conclusion
In conclusion of the presented work, it should be noted that modeling the propagation and changes in the parameters of an oil spill is an urgent area of work, since it is of great importance for eliminating accidents of a similar nature. The Cardinal software complex qualitatively performs these calculations and its use to ensure the environmental safety of the Arctic region can play an important role.

For the study, using the example of the Labrador Sea, the volumes of dispersed and evaporated oil were revealed, the direction of the oil slick spreading was determined, which corresponds to the circulation of currents in this area, and the concentration was calculated for 5 days.

References
[1] Vitsin D Y and Alekseev V A 2014 Modeling the emergency outflow of oil products on a permeable surface. Bulletin of Kazan University 4 263-265
[2] Stanovoy V V, Lavrenov I V and Neelov I A 2007 A system for modeling oil spills in the ice seas. Problem of the Arctic and Antarctic 77
[3] Ovsienko S N, Zatsepa S N and IvchenkoA A 2005 Oil spill modeling and environmental impact risk assessment. Proceeding of GOIN 209 533
[4] Sharapov M E, Alekseev V A 2012 Numerical modeling of a spill during depressurization of a pipeline Bulletin of the Kazan Technological University 12 221-223
[5] Martyn I, Petrov Y, Stepanov S and Sidorenko A 2020 Features of the spatial and temporal distribution of chlorophyll a and its relation to the water surface temperature by manifestations in the earth remote sensing data. E3S Web of Conferences 222 5005
[6] Sidorenko A, Stepanov S, Petrov S, Petrov Y and Martyn I 2020 Application of a remote sensing data processing method for assessment ice cohesion in the Arctic navigation. IOP Conference Series: Earth and Environmental Science 539(1) 012128
[7] Istomin E, Martyn I, Petrov Y, Stepanov S and Sidorenko A 2020 Study of intra-dynamics of
currents in the area of the navigable strait of Baltiysk to adjust the movement of water transport. *IOP Conference Series: Materials Science and Engineering* **817**(1) 012013

[8] Gill A 1986 *Dynamics of the atmosphere and ocean* (Moscow: Mir) 396

[9] Doronin Y P 1980 *Dynamics of the ocean* (Leningrad:Hydrometeoizdat) 302

[10] Doronin Y P 2000 *Physics of the ocean* (SPb:RSHU) 274

[11] Doronin Y P 2000 *Oceanography of the shelf zone* (SPb:RSHU) 302