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Hydrometeorological hazards during the winter periods in the Sea of Azov and dynamics under the influence of climatic changes

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ABSTRACT

Hydrometeorological hazards of the Sea of Azov during the winter periods 1950 – 2020 – surges, storms, extreme ice events (for example, early freeze-up, ice storm, etc.) due to climatic changes were investigated. Oceanographic database for the Azov and Black Seas was used to identify hydrometeorological hazards. Ice data of the Sea of Azov was analyzed based on geodatabase of the GIS "Ice regime of the southern seas of Russia". Storm activity in the Sea of Azov were reconstructed using SWAN spectral wave model. Based on the cumulative freezing-degree days winters were divided by severity - mild, moderate and severe. In recent years, there has been an increase in mild winters. As a result, extreme ice events are not observed since 2000. For the sea, the hydrometeorological multi-hazards is typical - storms, as a rule, are accompanied by surges, i.e. the highest wave height is caused by southwestern winds. All of them are characteristic of the ice-free period.

KEY WORDS: the Sea of Azov, hydrometeorological hazards, wind waves, surges, early freeze-up

INTRODUCTION

Natural hazards represent a threat to the stable and safe interaction between the nature and society, the rational use of natural resources and influence negatively territorial development, transport, energy, navigation, water supply and resource extraction (Yaitskaya, Tretyakova, 2016).

Between 1970 and 2019, 79% of disasters worldwide involved hydrometeorological and climate-related hazards. These disasters accounted for 56% of deaths and 75% of economic losses from disasters associated with natural hazards events reported during that period.

Over the last 10 years (2010-2019), the percentage of disasters associated with hydrometeorological and climate related events increased by 9% compared to the previous decade – and by almost 14% with respect to the decade 1991-2000 (WMO, 2020).

Several natural hazards during winter periods have occurred in the southern region of Russia since the beginning the 21st century. Abnormally low air temperature (for example, in 2006 and 2012) led to the formation of the hummocks up to 2 m in the Sea of Azov, the Black Sea froze from Musura Bay to Karkinit Bay; the Caspian Sea froze to Makhachkala. The number of extreme surges and storm surges has increased. In the entire region, the annual amplitude of air temperature has increased significantly.

The Sea of Azov is the shallowest sea in the world. The sea has been determining the economic conditions and activity of the regions of the South of Russia. About 1.2 million people live in the coastal zone. In recent years, against the background of climatic changes, the anthropogenic activity on the Sea of Azov has increased: the growth of marine traffic, the construction and development of new and old ports, recreational development of the coastal zone.

The growth of natural hazards are negatively affect to the sustainable development and development of the coastal zone of the seas, including the Sea of Azov.

In Russia, monitoring of natural hazards is carried out by The Federal Service for Hydrometeorology and Environmental Monitoring (Roshydromet). Hydrometeorological hazards are identified for the Sea of Azov: abnormally low winter air temperature (the severe winters), storms (wave height over 3 m) and storm surges, early freeze-up and multi-hazards such as ice storms, etc.

The article is devoted to analyze of hydrometeorological hazards of the Sea of Azov during winter periods 1950 – 2020 due to climatic changes.

Materials and methods

In this article we are considering the period from 1950 to the present. Oceanographic database for the Azov and Black Seas was used to identify hydrometeorological hazards.

The following data was used to identify hydrometeorological hazards:

- oceanographic database for the Azov and Black Seas (Matishov et al, 2014);
- ESIMO database (portal.esimo.ru/portal);
- internet portal of the company "Raspisaniye Pogodi"(https://rp5.ru);
- geographic information system (GIS) "Southern Seas of Russia"(Yitskaya, Loshchinskaya, 2012).

Winter seasons of the Sea of Azov were classified by their severity. This classification reflects the interannual dynamics of winter temperature, which define the formation of ice in the water area. The most common method of classification of winters by severity is calculating the cumulative freezing-degree days (CFDD). A similar approach for winters typing in the Sea of Azov was used by Bukharitsin (2008), Fedorenko (2011), Dumanskaya (2013). In this research, we summarized negative air temperature of winter seasons (from December till March) 1950-2020 from three hydrometeorological stations of the Sea of Azov – Taganrog, Genichesk, Kerch (Figure 1). We use open-source data from RIHMI-WDC (Bulygina et al., 2017). The CFDD for three stations were summarized. Then we determine the type of winter season according to the preferred gradations. We classify moderate (normal) winters as winters with CFDD corresponding to the interval from “average minus 20% amplitude” to “average plus 20% amplitude”. Winters with CFDD in the interval above are classified as mild and in the interval below are indicated as severe. Moreover, two extreme abnormal winters (the coldest and the warmest) are excluded from statistics.

Ice data of the Sea of Azov was analyzed based on geodatabase of the GIS "Ice regime of the southern seas of Russia". It contains tables, maps and other spatial information (Yaitskaya, Magaeva, 2018). Freeze-up and break-up dates and ice duration of the Sea of Azov were analyzed by standard statistical analysis.

Storm activity in the Sea of Azov were restored using the SWAN spectral wave model (SWAN, 2006). A detailed description of the calculations and results is presented in the papers (Lopatoukhin, Yaitskaya, 2019; Yaitskaya, 2017a; Yaitskaya, 2017b).

All hydrometeorological data are unified and brought to a single time scale of standard synoptic terms with an interval of 3 hours. Reference hydrometeorological stations (HMS) are:

- for the Sea of Azov - Taganrog and Primorsko-Akhtarsk;
- for the Black Sea - Anapa, Tuapse.

Storm events were selected in accordance with the hazard criteria given in the Emergency Situations Ministry's Storm Warning Instruction for the Southern Federal District.

Figure 1. Hydrometeorological stations of the Azov and Black Seas

Results

The winters of the Sea of Azov were divided into three categories according to their severity: mild, moderate and severe. Between 1950 and 2020, 20% of winters are severe. The sum of negative average daily air temperature (three observation points) is more than 1300 °C.

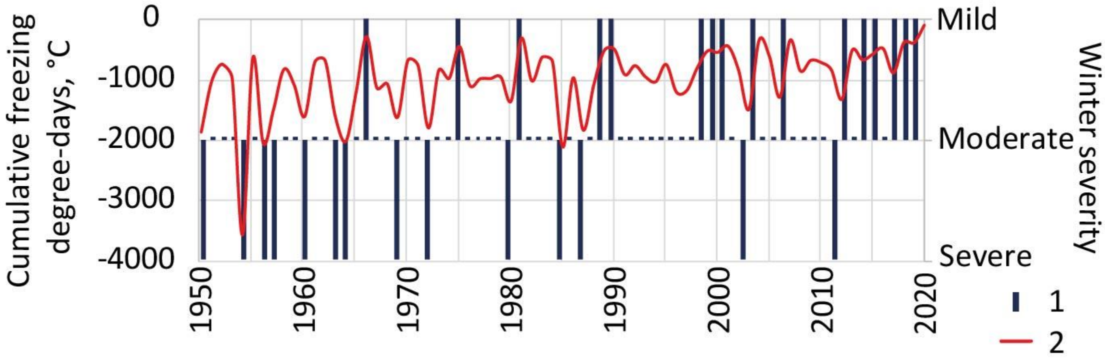

Figure 2. Winter severity timeline of the Sea of Azov
1 – Type of winter (severe, moderate, mild), 2 – cumulative freezing degree-days, °C

During the severe winters, the area of ice cover and the duration of the ice season can be abnormal compared with the average long-term values. For example, the winters 1971/1972, 2002/2003 (Figure 3), 2011/2012. Since mid-January, the whole of the Sea of Azov is covered an ice (including the Kerch Strait), ice concentration is 9-10 points and ice thickness is 50-70 cm, the duration of the ice season is 120-140 days. The most severe winter was in 1953/1954 (including the Northern Caspian and the Black Sea), CFDD amounted minus 1653°C in Taganrog. The water area was covered with fast ice, the maximum ice thickness reached 75 cm. Hummocks were noted on the northern approaches to the Kerch Strait.

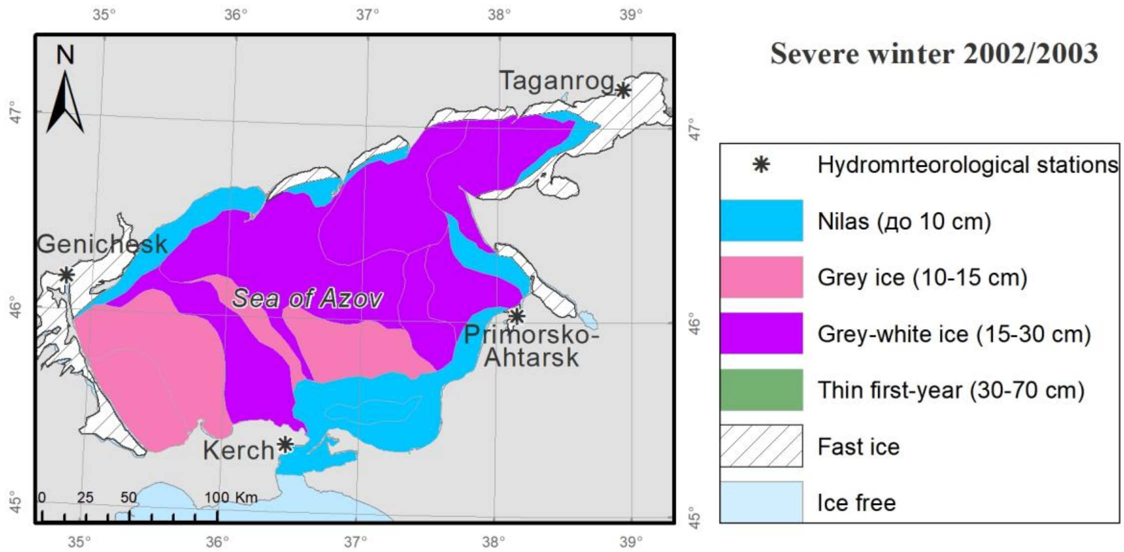

Figure 3. Ice cover of the Sea of Azov at the severe winter 2002/2003

According to the instructions of Roshydromet, early freeze-up is a natural hazard if the ice cover was formed earlier than November 11 in the northern part and November 25 in the southern part of the Sea of Azov. But we analyzed the freeze-up data over a long-term period and established that freeze-up before November 15-29 is early for the Sea of Azov depending on the observation point.

Negative air temperature anomalies in the pre-winter period (October-November) lead to early freeze-up. In this case ice duration is 125-145 days.

Since 1950, the number of cases of early ice formation is:

- 15 cases each for Taganrog and Genichesk;
- 13 for Primorsko-Ahtarsk;
- 5 for Kerch.

Sometimes early freeze-up occurs with negative surge. Such phenomena were observed in November 2019 and 2020. An extremely early strengthening of the Siberian maximum was observed this year. As a result, negative air temperature with an easterly wind of 10-15 m / s led to a decrease in sea level and the formation of ice (Roshydromet, 2019).

In recent years, an increase of moderate and mild winters amount undoubtedly affects the ice regime. From 1990 to 2020, only two severe winters were observed. Winter 2019/2020 was the warmest since the beginning of observation period 1900. As a result, ice area (also fast ice; from 36,7% to 12,1%) and ice duration (from 116 to 103 days) have decreased. Early freeze-up are not observed since 2000.

At the same time, extreme storms and surges are observed during moderate to mild winters. For the sea, the hydrometeorological multi-hazards is typical - storms, as a rule, are accompanied by surges, i.e. the highest wave height is caused by southwestern winds. Since 1950, 102 days were observed, when a significant wave height with western winds in the central part of the sea was 1.0-2.0 m; 11 days with a wave height of 2.0-3.0 m. All of them are characteristic of the ice-free period.

Our previous research has shown that the likelihood of extreme storm conditions is highest during mild winters, when the sea ice cover does not exceed 30%.

Since 1950, the maximum of storm events (seven) in combination with storm surges occurred in the winter of 1989/90. Since 2000, the number of winter storm events has been decreasing. Only 6 possible storm events can be noted, this is an average of 2 phenomena for 5 years.
In general, at the Taganrog and Primorsko-Akhtarsk hydrometeorological stations, the wind speed above 15 m / s was continued 6 or more hours only in four cases in the same date. In Taganrog, the maximum number of storm events occurs in February, in Primorsko-Akhtarsk - in March. Extreme hydrometeorological conditions occur mainly during mild to moderate winters.

In the Taganrog Bay and the northeastern part of the Sea of Azov, dangerous storm events mainly occur due to low atmospheric pressure. One of the reasons of storm surges is the passage of cyclones over the Sea of Azov. When a cyclone moves through the Black Sea and the Kerch Strait, it can lead to extremely natural hazards.

An increase in sea level by 2.0 m or more due to a storm surge occurs without ice cover (or minimal ice cover) in the Sea of Azov, slightly increased or close to normal (1013 hPa) atmospheric pressure and West and South-West wind directions. An increase in sea level within 1.0-2.0 m can occur both at low and high atmospheric pressure to the same extent. At the same time, ice cover up to 20% can be observed.

Change in wind direction is of interest in this research. At low atmospheric pressure, the prevailing wind direction can vary from southern to western. At high atmospheric pressure wind direction is southwestern or western with maximum speeds (more than 15 m/s). An increase in sea level to 1.0 m occurs in the same way as in the previous case due to low (with southeast and northwest winds) or high (with southwest winds) atmospheric pressure.

At the same time, the area of the ice cover varies widely - from 0 to 40%. With the maximum area of ice cover in winter, a minimum increase in sea level and slight waves are observed.

CONCLUSIONS

The analysis of winter hydrometeorological hazards of the Sea of Azov was carried out. Due to climatic changes, the number of severe winters have decreased. As a result, ice area (also fast ice; from 36,7% to 12,1%) and ice duration (from 116 to 103 days) have decreased. Early freeze-up (before November 15-29) are not observed since 2000.

At the same time, extreme storms and surges are observed during moderate and mild winters. For the sea, the hydrometeorological multi-hazards is typical - storms, as a r ule, are accompanied by surges, i.e. the highest wave height is caused by southwester n winds. Since 1950, 102 days were observed, when a significant wave height with western winds in the central part of the sea was 1.0-2.0 m; 11 days with a wave hei ght of 2.0-3.0 m. All of them are characteristic of the ice-free period.

We suppose that decreasing ice area and duration and increasing of extreme storms and surges in the winter periods are one of the factors of the coastal destruction of the Sea of Azov. But this issue has not been sufficiently studied for the conditions of the Sea of Azov.

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REFERENCES

Bukharitsin, P.I., 2008. Comparative characteristics of the long-term ice cover variability the northern part of the Caspian and Azov Seas. *Bulletin of Astrakhan state technical university*, 3, pp.207-213.

Dumanskaya I.O., 2013. Typical conditions on the main shipping lanes of the seas of the European part of Russia for winters of varying severity. *Transactions of the Hydrometeorological Research Center of the Russian Federation*, 350, pp.142-166.

Fedorenko A.V.,2011. The study of seasonal and intra-annual variations of the main ice parameters on the southern seas (the Sea of Azov and the Caspian Sea). *Proceedings of the SOI*, 215, pp.15-25.

Lopatoukhin, L.I., Yaitskaya, N.A., 2019. Wave Climate of the Caspian Sea, Input Wind Data for Hydrodynamic Modeling, and Some Calculation Results. *Oceanology*, 59, pp.7–16.

Matishov, G.G., Berdnikov, S.V., Zhichkin, A.P., Dzhenyuk, S.L., Smolyar, I.V., Kulygin, V.V., Yaitskaya, N.A., Povazhniy, V.V., Sheverdyaev, I.V., Kumpan, S.V., Tret'yakova, I.A., Tsygankova, A.E., D'yakov, N.N., Fomin, V.V., Klochkov, D.N., Shatohin B. M., Plotnikov, V.V., Vakul'skaya, N.M., Luchin, V.A., Kruts, A.A., 2014. *Atlas of Climatic Changes in Nine Large Marine Ecosystems of the Northern Hemisphere (1827-2013).* NOAA Atlas NESDIS 78.

Raspisaniye Pogodi [Online] Available at: https://rp5.ru [Accessed 15 February 2021].

Roshydromet Press Center, 2019. *Wind surge at the mouth of the Don River and the beginning of ice formation in the Sea of Azov.* [Online] (Updated 27 November 2019) Available at: http://www.meteorf.ru/press/news/20104/ [Accessed 20 February 2021].

SWAN. Technical documentation. Delft University of Technology, Faculty of Civil Eng. and Geosciences, Environmental Fluid Mechanics Section, 2006.

Unified system of information about the situation in the World Ocean [Online] Available at: portal.esimo.ru/portal [Accessed 15 February 2021].

World meteorological organization (WMO), 2020. *2020 State of climate services*, [Online] Available at: https://library.wmo.int/doc_num.php?explnum_id=10385 [Accessed 15 February 2021].

Yaitskaya N. A. and Loshchinskaya V. V., 2013. Creation of GIS system of the southern Russian seas for storage of historical cartographic information. *Ekologia, Ekonomika, Informatika*, 2, pp.211–217.

Yaitskaya N.A., 2017a. The results of hindcasting experiments of wind wave in the Sea of Azov (as illustrated by winters 2015-2017). *Science in the south of Russia*, 13(4), pp.60-70.

Yaitskaya N.A., 2017b. Retrospective analysis of wind waves in the Caspian sea in the second half of the XX - beginning of the XXI century and its connection with the regional climate changes. Geographical bulletin, 41(2), pp.57-70.

Yaitskaya N.A., Magaeva A.A., 2018. Dynamics of the ice regime of the Sea of Azov in the XX–XXI centuries. *Led i Sneg. Ice and Snow*, 58(3), pp.373-386.

Yaitskaya, N. A., & Tretyakova, I. A., 2016. Mathematical modeling of dangerous storm and surge phenomena in the basin of the Sea of Azov (March 24, 2013). *16th International Multidisciplinary Scientific GeoConference SGEM 2016, Conference Proceedings*, pp.481-488.