25th IAHR International Symposium on Ice

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Front picture: Frazil ice in river Gaula,Norway (Photo: Knut Alfredsen)

Introduction

The IAHR symposium on ice is a biannual conference covering engineering and research on ice in fresh and salt water. The conference was first arranged in Reykjavik, Iceland in 1970. The 25th conference was planned for Trondheim, Norway in June of 2020, but due to the Covid19 pandemic it was arranged as a virtual conference in November of 2020. The conference gathered 105 participants and 87 papers were submitted and peer reviewed for the technical sessions of the conference. In addition, two plenary key note lectures were given covering the challenges of hydropower operation in the arctic and the history of ice research in Norway.

The technical sessions covered a range of topics within research on ice processes, utilisation of remote sensed data and engineering aspects related to ice jams, loads on structures and hydropower operation in fresh water and ships, floaters and fixed structures in coastal areas and on the ocean. All presentations and discussions were carried out live on a digital platform, and this fostered many interesting exchanges of information across countries and time zones.

The IAHR Ice Symposium were arranged by financial support from the Norwegian Research Council and the Norwegian University of Science and Technology. We gratefully acknowledge the support received to arrange the conference. The organising committee also wishes to thank the NTNU Centre for Continuing Education and Professional Development for support with the administration and technical arrangement. The transition from a traditional conference to a virtual meeting could not have been done without this support.

The organizing committee also want to thank the scientific committee for handling the peer review of the papers, the reviewers of the papers and not the least all authors and conference participants who made this event possible.

Knut Alfredsen
Chairman of the organizing committee.

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Ice actions on river and lake morphology

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Ice gouging conditions of the Northern Caspian depending on the severity of winters

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Ice gouging is mechanical plowing of bottom ground by ice features. Hydrometeorological conditions, changing from year to year, determine the intensity of ice features (ice hummocks, ice ridges and stamukhi) formation. In this paper, we consider the conditions of the ice gouging of the Northern Caspian seabed by ice features in winters of various severity. We used the cumulative freezing-degree days (CFDD) over a winter period as a criterion for dividing winters by severity. We used data from several nearshore meteorological stations to divide them into mild, moderate and severe. The analysis, based on aerial reconnaissance and modern satellite data, showed the variability of the number of stamukhi, their distribution and depths of grounding over recent years. We created charts of different ice gouging intensities for the different types of winters. The charts are consider not only analysis of stamukhi distribution, but also ice cover dynamics, typical position of fast ice rim and features of the bottom topography. The charts showed changes in the conditions of ice gouging at the Northern Caspian from year to year. The results allowed estimating the influence of the winters severity on the intensity of the ice features formation and ice gouging in different years. The results of this study must be considered when conducting economic activities in the Northern Caspian.

1. Introduction

The Caspian Sea is partially freezing every year. The ice conditions of the Caspian Sea are complex and variable. They vary from year to year depending on hydrometeorological conditions. The ice conditions determine the number and spatial distribution of ice features (ice ridges, hummocks, etc.). Ice features are a factor of the bottom microtopography dynamics. Grounded hummocks, named stamukhi, can move and plow the bottom. Ice gouging (ice scouring) is the process of mechanical plowing of the bottom ground by ice, associated with the ice cover dynamics, acting under the influence of hydrometeorological factors and the topography of the coastal zone (Ogorodov, 2011). Information on the stamukhi distribution and ice gouging processes is most important for pipeline design from offshore structures to shore, marine operations, including tracing and navigation of ships and air-cushion vehicles during the period of ice formation and melting. Along with changes in ice conditions in the Northern Caspian, the conditions for the ice gouging of the bottom by ice features change from year by year.

Earlier P.I. Bukharitsin (1984) suggested that the largest number of ice features form in moderate (normal) winters. The first chart of intensity of ice gouging by ice features in the Northern Caspian was created by Ogorodov (2017). Climate change should be considered when studying the conditions of bottom gouging by ice features. Under the conditions of climate warming, the character and intensity of ice impact on the coasts and seabed change significantly (Ogorodov et al., 2018). Due to the decrease of the ice thickness, ice ridging increases. The width and stability of fast ice also become lower. We analyzed the hydrometeorological conditions in the Northern Caspian and created charts showing how the ice gouging conditions vary depending on the severity of winters.

2. Materials and methods

Ice scours at the Northern Caspian were first discovered by B.I. Koshechkin (1958). The scientific research of the ice scours and gouging started along with exploration of oil deposits on the shelf (Ogorodov, Arkhipov, 2010). Now many researchers, prospectors and stakeholders pay attention to ice gouging processes (Ogorodov et al., 2019; Sigitov et al., 2019).

Ice conditions in the Northern Caspian strongly depend on the thermal type of winter (Kouraev et al., 2004). We classified winter seasons of the Northern Caspian by their severity to show, how ice-gouging conditions change depending on meteorological conditions. This classification reflects the interannual dynamics of winter temperatures, which define the formation of ice in the water area. Determining the types of winter seasons is a key parameter, both when analyzing the ice regime of the seas and assessing climate change.

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 Northern Caspian was used by Tamura-Wicks et al. (2015). CFDD is usually calculated as a sum of average daily degrees below freezing for a winter season. Then we determine the type of winter season according to the preferred gradations. Dumanskaya (2013) 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.

P.I. Bukharitsin (2008) and A.V. Fedorenko (2011) perform similar technique for winters typing of the Caspian Sea.

In this research, we summarized negative air temperatures of winter seasons (from December till March) from four hydrometeorological stations of the Northern Caspian – Astrakhan, Atyrau, Makhachkala and Fort-Shevchenko. The annual sums were used to classify 1950-2019 winter seasons according to their severity.

Two main sources were used to identify stamukhi distribution in years with different severity of winters:
1) aerial reconnaissance data from 1959 to 1974 (Bukharitsin, 1984);
2) stamukhi observation data from satellite imagery deciphering (mainly Sentinel-1, usable Sentinel-2 and Landsat) from 2014 to 2019 acquired by LLP ICEMAN.KZ (Sigitov et al., 2019).

The distribution of stamukhi and ridging zones are largely dependent on the bottom topography. Therefore, a high-resolution digital elevation model (DEM) of the bottom of the Northern Caspian is required. The DEM, developed in the laboratory of geoecology of the North, Faculty of Geography, MSU, is based on the bathymetric navigation map of 1998, reduced to an average level of the Caspian Sea minus 28 m below sea level. In 2017, Ogorodov was the first to publish a chart of the intensity of ice gouging in the Northern Caspian, based on this DEM. This chart considered only aerial reconnaissance data from 1959 to 1974 for moderate (normal) winters.

Using the analysis of ice ridges and stamukhi locations, the distribution of various types of ice conditions for different types of winters (Terziev et al., 1992) and the bottom topography (DEM), we created charts of the ice gouging intensity distribution for mild, moderate and severe winters.

3. Results

The winters of the Northern Caspian were divided into three categories according to their severity: mild, moderate and severe (Table 1). For the period from 1950 to 2019, moderate types of winters prevail with 59.4%. The number of severe and mild winters is the same and amounts to 14 of each type (20.3%). Fig. 1 shows their temporal pattern. From 1950 to 1985 severe winters in the Northern Caspian occurred every 2-5 years, but from 1985 to 2019 only 3 severe winters took place (2002/03, 2007/08, 2011/12).

Considering the aerial reconnaissance (Bukharitsin, 1984) and satellite data (Sigitov, 2019), we created charts of different ice gouging intensities for the different types of winters (Fig. 2). The charts are consider not only analysis of stamukhi distribution, but also ice cover dynamics, typical position of fast ice rim and features of the bottom topography.

According to Ogorodov, 2011 we divide all the ice gouging area of the Northern Caspian into four zones: 1) fast ice zone; 2) zone of fast and drifting ice interaction; 3) drifting ice zone within deep areas; 4) drifting ice area within banks and shoals.

Table 1. The Northern Caspian winter seasons classification

Winter type	Number	%	CFDD, °C	Seasons
Severe	14	20,3	≤ 1862,05	1950/51, 1953/54,1955/56, 1959/60, 1963/64, 1966/67, 1968/69, 1971/72, 1976/77, 1979/80, 1984/85, 2002/03, 2007/08, 2011/12
Moderate	41	59,4	from -1862,05 to -858,25	1951/52, 1952/53, 1954/55, 1956/57, 1958/59, 1960/61, 1962/63, 1964/65, 1967/68, 1969/70, 1970/71, 1972/73, 1973/74, 1974/75, 1975/76, 1977/78, 1978/79, 1981/82, 1983/84, 1985/86, 1986/87, 1987/88, 1989/90,1990/91, 1991/92, 1992/93, 1993/94, 1994/95, 1995/96, 1996/97, 1997/98, 2004/05, 2005/06, 2008/09, 2009/10, 2010/11, 2012/13, 2013/14, 2014/15, 2016/17, 2017/18
Mild	14	20,3	≥ 858,25	1957/58, 1961/62, 1965/66, 1980/81, 1982/83, 1988/89, 1998/99, 1999/00, 2000/01, 2001/02, 2003/04, 2006/07, 2015/16, 2018/19

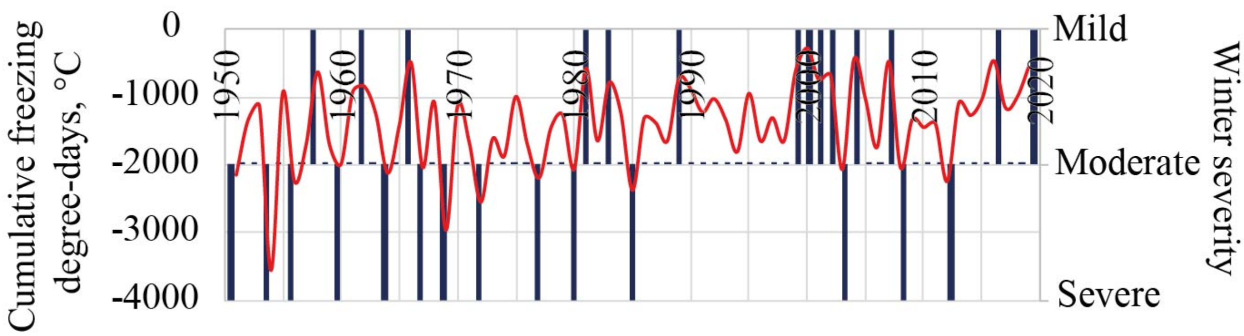

Figure 1. Winter severity timeline of the Northern Caspian

Fast ice zone is characterized by limited scour impact of ice features, mainly ice ridges and grounded hummocks. The intensity of ice gouging is determined by immobility of fast ice. Bottom scouring by ice floes with frozen ice ridges occurs only during the fast ice breack-up. The zone of fast and drifting ice interaction is characterized by intensive scour impact on seabed by keels of ice ridges on fast ice rim and ice hummocks frozen into drifting ice floes, rarely by stamukhi. Drifting ice zone within deep areas is characterized by intensive scour impact on seabed by keels of ice ridges frozen into drifting ice floes. Drifting ice zone within banks and shoals is characterized by the most intense scour impact on seabed by keels of ice ridges frozen into drifting ice floes and large stamukhi.

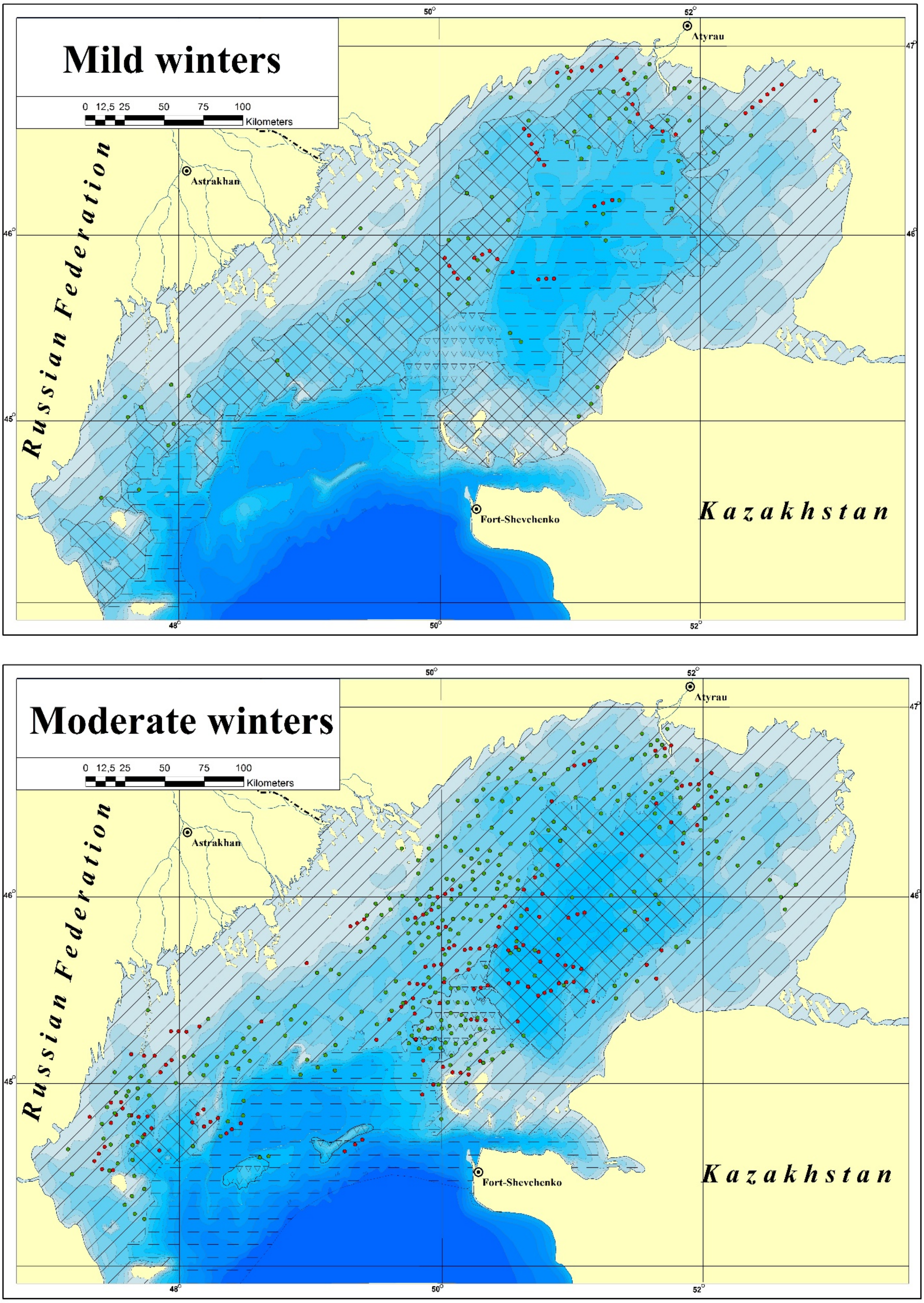

Figure 2. (Continued below)

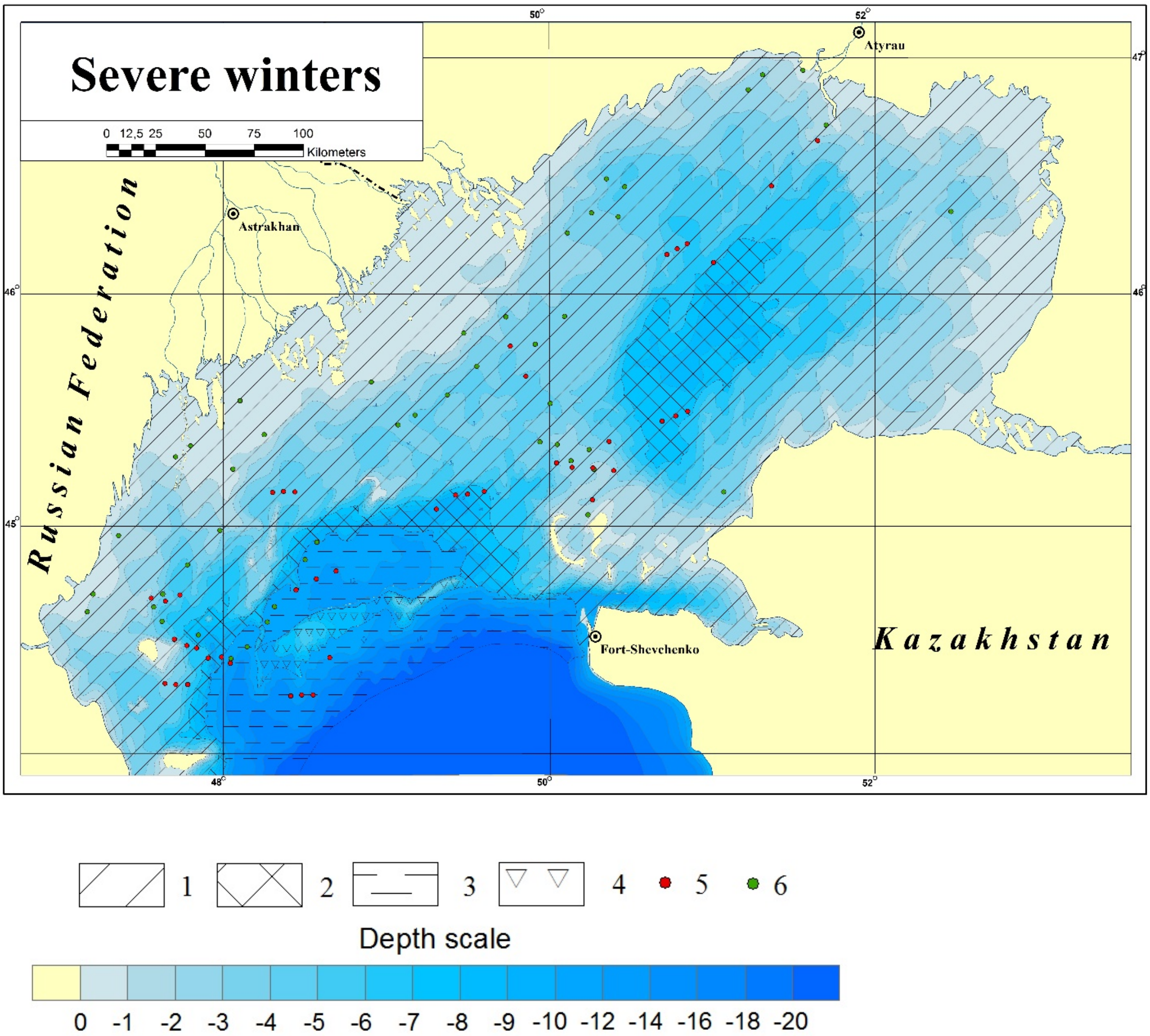

Figure 2. Charts of ice gouging intensity of the Northern Caspian: 1) fast ice zone; 2) zone of fast and drifting ice interaction; 3) drifting ice zone within deep areas; 4) drifting ice area within banks and shoals; 5) ice hummocks and ice ridges; 6) stamukhi.

4. Discussion

Severe winters in this region are caused by meridional activity, bringing cold air from the Arctic often. Surge of air far to the south leads to a cold snap and prolonged cooling. Mild winters occur when latitudinal activity takes place in Europe, the East European Plain, the Caucasus and the Caspian Sea (Solovjev, 1973). The winter season of 1953/54 was the most severe in the North Caspian region, the CFDD for Astrakhan station amounted -1166.5 °C. The mildest was the winter of 1999/00, the CFDD for Astrakhan station amounted minus 78.7 °C.

Depending on the temperatures, the beginning and the end of freeze-up can be shifted earlier or later. The ice coverage of the Caspian Sea also vary significantly - from 30% to 85% of the area of the Northern Caspian (winters 1999/2000 and 1953/1954, respectively) (Magaeva, 2017).

The classification of winter severity shows that in recent years (after 1985) severe winters occur less frequently, while moderate winters predominate. Earlier Bukharitsin (1984) supposed the largest number of ice features is formed in moderate (average in ice coverage) winters. In severe winters, landfast ice is more stable, and the width of the ridging zone is less. Ogorodov (2011) suggested that in mild winters, ridging is also low due to the limited fast ice extension.

The intensity of ice gouging depends primarily on the number of ice features scouring the seabed and the general ice coverage. Previously, the conditions of bottom scouring were considered depending on level fluctuations and ice coverage (Bukharitsin et al., 2015). The charts (Fig. 2) show that, the ice-gouging areas of various intensity change along with the number of ice features. The comparison of the ice-gouging intensity patterns showed the difference of them from year to year. The area of low intensity of ice-gouging (1) related to the extension of fast ice is reduced in mild winters both absolutely and relatively. We suppose that, during mild winters, fast ice is thinner and brasher, which favor to more active ridging in this zone. This fact is confirmed by modern data from 2014-2019, showing many ice features in fast ice. According to Sigitov (2019), the majority of stamukhi in mild years is formed in proximity to the coastline, and the most intense ridging and stamukhi formation is observed in the zone of fast ice. This provides a greater intensity of bottom scouring in this zone compared to moderate and severe winters.

At the same time, in mild winters, the area of the intensive ice-gouging (2) expands either relatively or absolutely. However, in mild winters, the intensity in this zone decreases significantly compared to the same zone for moderate or severe winters. Ice features in mild winters consist of weak ice, which reduces ice impact.

Moreover, the area of drifting ice in mild, moderate and severe winters remains almost unchanged both in relatively deep waters (3), and in banks and shoals (4). In severe winters, the fast ice area is maximum; it occupies about 75% of the Northern Caspian. Fast ice in severe winters is extremely strong, which prevents active ridging. The example cases show that, depending on the severity of winters, the ice-gouging conditions change. From year to year the ice-gouging intensity patterns vary significantly, but also the degree of intensity in different zones are diverse.

5. Conclusion

The study shows that in recent years the number of severe winters in the Northern Caspian decreased significantly, moderate winters predominate. The created charts of the ice-gouging intensity revealed changes in the conditions of bottom scouring depending on types of winters. Despite the climate warming, the intensity of bottom scouring in the Northern Caspian does not decrease. In moderate winters, the intensity of ice-gouging processes is highest, but in mild winters the intensity is also high. Studying the changes in ice-gouging intensity depending on the severity of winters allow us to predict the formation of ice scours in certain zones during ongoing climate changes. The results of this study must be considered when conducting economic activities in the Northern Caspian.

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