Features of the dynamics of ice formation in Western Yakutia

D D Nogovitsyn, K V Nikulin, Z M Sheina and L P Sergeeva

1 Department of Energy Problems, Institute of Physical and Technical Problems of the North named after V.P. Larionov of the Siberian Branch of the Russian Academy of Sciences, 1, Oktyabrskaya Str., Yakutsk, 677980, Russia

E-mail: zin.scheina2016@yandex.ru

Abstract. Ice formation may cause quite serious and even catastrophic complications during the construction and operation of various types of engineering facilities. Forming on the surface of the earth, ice affects the surrounding landscape, changes the morphology of river valleys, amount of solar radiation, temperature, evaporation, condensation. Accumulating underground runoff in winter, ice redistributes it and regulates the surface runoff giving water reserves in spring and summer that were abandoned during long winter. The paper considers the dynamics of ice formation located in the basin of an unnamed watercourse, the left tributary of the Taryng-Yuryakh River. The main purpose of the study is to identify ice, observe annual changes in its shape, volume, area and power. The research area is located in the south-west of Yakutia. The length of the stream is 5 km, the watershed area is 7.62 km². The water regime is characterized by spring floods, summer floods, long and low-water summer and winter low water, stable ice supply. According to the results of the study, the correlation between the maximum ice area, the value of atmospheric precipitation of the previous year and the sum of negative average monthly air temperatures was not established.

1. Introduction

Special attention was paid to the study of ice processes in the late 19th–early 20th centuries caused by the construction of main pipelines. The study revealed that climate plays an important role in the formation of these processes [1]. The formation of ice is natural and the main cause of it is prolonged persistent frosts, which entail thickening of the ice cover on watercourses up to complete freezing [2]. For this reason, there is some decrease in the living section of the river bed. Water, in this case, cannot pass through the remaining living section and opens the ice under pressure, and comes to the surface of the ice through the cracks [3]. Such exits may be observed in different parts of the river, although, as a rule, the main water outlet occurs at places where the cross section of the channel decreases. Hydrogeological, climatic and permafrost conditions are required to form ice, which determine regional and zonal features of their distribution [4]. The natural formation of ice occurs due to a sharp decrease in air temperature. Ice formation processes are mainly associated with their source of nutrition, its character and productivity, as well as the terrain morphology [5].

The territory of Yakutia is mainly located in the zone of continuous distribution of permafrost rocks. The widespread occurrence of ice phenomena is one of the natural features of the northern region [6]. A characteristic feature of ice is its layered structure [7].

The amount of ice is increasing from south to north, as well as in the foothills and mountainous regions. Besides, in the northernmost regions at the maximum height, a decrease in its amount is associated with a decrease in ice-forming waters [1].

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.

Published under licence by IOP Publishing Ltd
2. The subject of the study

The paper considers the dynamics of ice formation located in the basin of an unnamed watercourse, the left tributary of the Taryng-Yuryakh River.

The research area is located in the south-west of Yakutia, within the Prilensky structural and denudative plateau of the Middle Siberian highlands [8]. This territory is located in the zone of massive island distribution of permafrost rocks (PR) [11]. The bottoms of the valleys and lower parts of the slopes are characterized by the lowest average annual PR temperatures up to –1.7 °C, and the highest temperatures (0 – –0.6 °C) are confined to watershed spaces. Underground waters are found in the floodplain part at a depth of 0.3 m. There is a close occurrence of groundwater, flooding of the territory and frosty expansion of clay soils, which increased humidity at the time of freezing.

The slopes of the Bezymyanny stream are very gentle (2–4 deg.). The bottom of the valley and the channel are sandy. In the valley, the open wood of pine and larch prevails, the floodplain is overgrown with shrubs, hygrophilous grass and nomadic. The length of the stream is 5 km, the watershed area is 7.62 km². According to the classification of P.S. Kuzina [9], it is part of the Vilyisky hydrological region. The water regime is characterized by spring floods, summer floods, long and low-water summer and winter low water, stable ice supply.

Spring flood begins in the first decade of May, the maximum takes place in the middle of this month. The shape of the flood is single-peak and streamlined flood. The total flood volume on average in the identified hydrological region is 55 mm.

The climatic conditions of Western Yakutia are characterized by significant severity, large amplitudes of fluctuation in air temperature in winter and summer. The temperature drops to –55 °C, and sometimes to –60 °C. The average air temperature in Lensk in January is –30 °C [10]. Winter lasts from 6 to 7 months. Low winter air temperatures cause negative annual average temperatures (–6.1 °C). The presence of a stable negative value of the average annual air temperatures contributes to the preservation of permafrost, which is one of the main factors that affects the formation and regime of surface and groundwater. The amount of annual precipitation for the city of Lensk, according to the weather station, is 340 mm, the bulk of which falls in summer providing soil humidification during the vegetation period [10].

3. Materials and methods

Archival data, literary sources, space images, as well as field research data were used.

4. Research results

The in situ study of the territory included a visual examination of ice (Figures 1 and 2) with a measurement of the ice power (Table 1) and a description of the area. Background material on various climate elements is shown in Table 1 [11].

![Image](image_url)

**Figure 1.** Ice formation on the left tributary of the Taryng-Yuryakh River. Shooting date: 17.03.2019. Photo by Nikulin K.V.
Figure 2. Ice formation on the left tributary of the Taryng-Yuryakh River.
Shooting date: 23.03.2020. Photo by Nikulin K.V.

Table 1. Main hydrological and meteorological characteristics of the research area and ice parameters on the left tributary of the Taryng-Yuryakh River over the long period (2000–2020)

| Years of observation | Amount of precipitation, mm | Sum of negative temperatures, °C | Ice area, thousand m² | Average ice thickness, m |
|----------------------|-----------------------------|----------------------------------|-----------------------|-------------------------|
| 2000                 | 342.2                       | 143.2                            | -                     | -                       |
| 2001                 | 400                         | 132.7                            | 68330                 | -                       |
| 2002                 | 451.9                       | 115.6                            | -                     | -                       |
| 2003                 | 438.3                       | 105.8                            | -                     | -                       |
| 2004                 | 404.8                       | 124.8                            | -                     | -                       |
| 2005                 | 443                         | 121.7                            | -                     | -                       |
| 2006                 | 346.7                       | 138                              | 57570                 | -                       |
| 2007                 | 486.6                       | 103.5                            | -                     | -                       |
| 2008                 | 555.5                       | 111.2                            | -                     | -                       |
| 2009                 | 497.8                       | 139.1                            | -                     | -                       |
| 2010                 | 359.8                       | 133.9                            | -                     | -                       |
| 2011                 | 474.4                       | 108.4                            | 154490                | -                       |
| 2012                 | 373.7                       | 141.4                            | -                     | -                       |
| 2013                 | 540.3                       | 120.1                            | -                     | -                       |
| 2014                 | 378.8                       | 126.7                            | -                     | -                       |
| 2015                 | 394.3                       | 103.8                            | -                     | -                       |
| 2016                 | 422.4                       | 116.7                            | 34750                 | -                       |
| 2017                 | 457.4                       | 109.2                            | -                     | -                       |
| 2018                 | 393.1                       | 114.2                            | -                     | 0.73                    |
| 2019                 | 470.8                       | 104                              | -                     | 1.0                     |
| 2020                 | 452                         | 86.9                             | 52020                 | 0.58                    |

The sum of atmospheric precipitation over the previous hydrological year, the sum of negative air temperatures, as well as the rate of freezing of water-containing rocks of the hyporheic thawed reach play a key role for the growth dynamics and the final volume of emerging groundwater deposits [12].

According to observations on the dynamics of ice formation on the left tributary of the Taryng-Yuryakh River (2000–2020) at the Lensk weather station, the most high-water years were 2008 and 2013 (annual rainfall exceeded 500 mm), and the most droughty – 2000 and 2006 [12], the winters of 2000–2001 and 2009–2010 were the most severe, and the mildest – 2007–2008 and 2019–2020.
It is worth noting that the maximum area of ice on the left tributary of the Taryng-Yuryakh River was in 2011, when the previous year was average in terms of the water content. According to data in [13], for the period of 2000–2020 the ice area changed from 34,750 thousand m² to 154,490 thousand m². Aerospace method is used to determine location and area of ice, which consists in fixing ice massifs on aerospace images [13].

In view of the difficulties of fixing ice contours in winter in relation to late snowfall and high spring cloud cover within the studied territory, the most detailed and accurate option for ice interpretation in 2001–2020 was the first decade of May. Figures 3 and 4 show examples of ice interpretation on the left tributary of the Taryng-Yuryakh River.

![Figure 3. Area of ice on the left tributary of the Taryng-Yuryakh River according to data interpretation for 2006](image1)

![Figure 4. The area of ice on the left tributary of the Taryng-Yuryakh River according to data interpretation for 2011](image2)

5. Conclusion
The conducted long-term studies give reason to assert that crevasse-vein ground and freezing waters play a special role in the formation of ice in the research territory. The formation of ice accounts for most of the amount of underground runoff. Ice begins to form in early November under natural conditions. The growth and development of ice continues throughout the winter. According to the results of full-scale surveys of the studied ice, in March there is a water outlet, and at night at a negative temperature there is an intense growth of ice. The growth of ice stops in mid-April, the process of destruction begins in late April – early May.

According to the results of the correlation analysis, there is no connection between the maximum area of ice, the value of atmospheric precipitation of the previous year and the sum of negative air temperatures. The interpretation results show that the shape and area of ice is subject to long-term changes as it is associated with a change in the position of the channel and the depth of seasonal thawing.

References
[1] Pomortsev O A, Kashkarov E P and Popov V F 2010 Ice: global warming of the climate and processes of ice formation (rhythmic long-term forecast) *Bulletin of SEFU* 7(2) 40–48
[2] On the Vilyi River... Retrieved from: https://news.myseldon.com/ru/news/index/244970309 (08.02.2021)
[3] Ice and methods of fight with it Retrieved from: http://www.ekspertizasmert.ru/statyi/proekt/naledi.shtml (09.02.2021)
[4] Ice and methods of fight with it Retrieved from: https://znanio.ru/media/naledi-i-metody-borbyssi-nimi-2498706 (08.02.2021)
[5] Classification of ice... Retrieved from: https://studopedya.ru/2-8675.html (09.02.2021).
[6] Cryogenic conditions... Retrieved from: https://stud.wiki/geography/2c0a65635a2bc69b5c53a88421206c27_0.html (10.02.2021)
[7] Alekseev V R 2007 Heritage: dictionary-directory (Novosibirsk: Publishing House of the SB RAS)
[8] Regional geomorphology... Retrieved from: https://pandia.ru/text/78/018/24173-2.php (13.02.2021).
[9] Kuzin P S 1960 Classification and hydrological zoning of the USSR (Leningrad: Hydrometeoisdat)
[10] Gubkin M P 1984 Nature and resources of The Middle Prilenye (Novosibirsk: Publishing House of the Siberian Branch of the USSR Academy of Sciences)
[11] Rosgidromet site in Lensk Retrieved from: http://www.meteorf.ru (13.02.2021)
[12] Zavadsky F R 2013 Dynamics of ice formation in the territory of Southern Yakutia Science and education 2 36–40
[13] Alekseev V R 2005 Landscape indication ice phenomenon (Novosibirsk: Science)