IOP Conference Series: Earth and Environmental Science

PAPER • **OPEN ACCESS**

Features of the formation of ice cover of rivers in the Ob basin

Features of the formation of ice cover of rivers in the Ob basin

Zh A Tusupbekov [1,3], N L Ryapolova[1], V S Nadtochiy[1] and S I Mashtaeva[2]

[1] Omsk State Agrarian University named after P A Stolypin, 1, Institutskaya Square, Omsk, 644008, Russia
[2] L.N. Gumilyov Eurasian National University, Satpayev Str., 2, Nur-Sultan, 010008, Republic of Kazakhstan

[3] E-mail: gggkiovr@mail.ru

Abstract. The article discusses the issues of assessing the change in the thickness of the ice cover by studying the intensity of growth in different periods of formation. The results of assessing the formation of ice thickness are presented on the basis of 40 gauging sections of rivers located in the Ob river basin. By means of graphical analysis, the features of the intensity of the growth of the ice cover, depending on the heat and power and orographic characteristics of the terrain, are highlighted. An assessment of the influence of ice cover on the change in winter runoff was carried out, as well as an analysis of the influence of the temperature regime of the ambient air in the autumn-winter period, the morphological and morphometric characteristics of the channel and river valley on the process of water crystallization and the intensity of ice formation. The results obtained can be used in the economic development of the rivers of the studied basin during the winter dry season.

1. Introduction
River runoff is one of the main components of natural-territorial complexes, influencing the development and dynamics of aquatic and near-water ecosystems.

Sustainable development and change of the natural environment by human activity does not have an unambiguous assessment, for this it is necessary to comprehensively assess the physical-geographical and hydrological-climatic factors. River runoff, which integrates the nature of water resources over the basin and features of changes in basin geosystems over time, is one of the leading components of natural-territorial complexes and can be used to assess their state and predict their development under conditions of increased water use.

It is known that one of the most important parameters characterizing the level of sustainable economic development of the region, as well as the degree of use of water resources, is the indicator of water consumption. The higher the water consumption, the more intensely developed the productive forces and the higher the indicator of the use of water resources [1].

In turn, the main characteristic that determines the attractiveness of the territory for the creation of water management systems and their development is the availability of water resources suitable for use and their intra-annual distribution with guaranteed conditions for water supply.

The conditions for the formation of river runoff and, in general, the nature of changes in water resources across the territory and in time are influenced by a huge number of factors that require a comprehensive study. Of paramount importance in the formation of water resources is the climatic factor, on which the heat and power resources of the territory and the resources of general moisture will depend [2]. The joint influence of heat and moisture resources on river runoff becomes especially important in the low-water period of the winter season, when part of the river runoff accumulates in the form of an ice cover, as well as in spring, when the process of destruction of the ice cover begins and their further movement downstream. As you know, the value of winter runoff determines the value of the minimum water consumption, and, consequently, the impact on the sustainability of economic development of the watercourse basin [3].

The need to study the influence of the ice regime on the transformation of river runoff is dictated by the fact that the change in river runoff itself is reflected in the conditions of water use, the operation of water management complexes, water transport and other sectors of the economy of the territory under consideration. Such sectors of the national economy as water transport, ice crossings, and the operation of hydraulic structures directly depend on the timing and duration of ice phenomena. In many cases, ice phenomena cause dangerous hydrological processes that can cause enormous damage to the national economy and endanger the safety of the population.

2. The object of research is the rivers of the Ob river basin

The considered basin of the Ob River is located from south to north almost throughout the territory of western Siberia and is a complex territory with various climatic and orographic conditions.

The climatic conditions of the territory under consideration are formed due to its geographical location. The location inside the continent dictates the conditions for the movement of air masses and the distribution of radiation characteristics, which in turn, together, are the main climatic factors influencing the formation of water resources of a given territory and their quantitative redistribution within a year [4]. According to the peculiarities of the circulation of air masses, according to the orographic characteristics, the territory under consideration is distinguished by severe, long winters with strong winds, snowstorms, persistent snow cover and rather hot summers. Transitional seasons are short, with sharp temperature fluctuations. Spring and early summer are dry.

A significant variety of natural and climatic conditions influenced the regular distribution of the main geomorphological zonal areas within the basin, represented from south to north by forest-steppe and forest zones, taiga, forest-tundra and tundra. In orographic relations, the beginning of the basin is located in the mountainous conditions of Altai, and the middle and lower parts are of a flat nature. The diversity of the terrain and climatic conditions significantly influenced the change in heat and power resources and the peculiarities of the formation of water resources in the latitudinal direction.

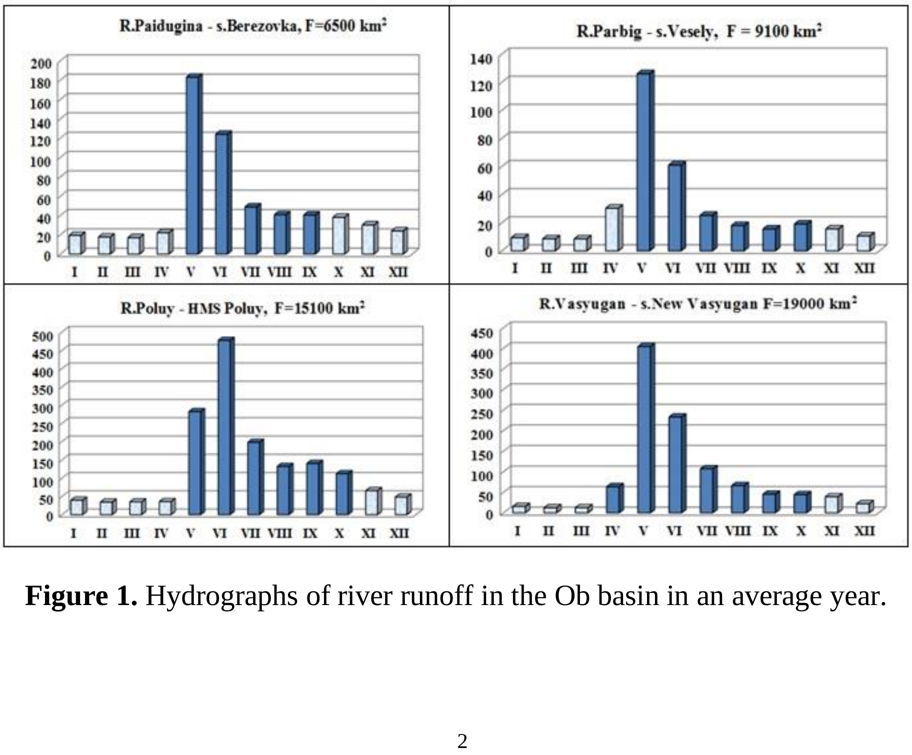

Figure 1. Hydrographs of river runoff in the Ob basin in an average year.

Within the study area, 40 river basins were considered, located along the entire length of the Ob river, including two rivers located in the Ob-Irtysh interfluve (the Burla-village of Khabar and the Kargat-village of Zdvinsk). For all basins, the values of the intra-annual runoff distribution were analyzed in the context of the long-term period during the open channel periods and in more detail during the winter period.

The minimum flow rates within the year are observed during the summer-autumn and winter low-water periods, and the highest values are observed mainly in May on the rivers in the southern part and in June on the rivers in the northern part of the basin. On all rivers with a natural flow regime, winter minimums are 1.5-3 times less than summer-autumn ones (figure 1).

With the onset of negative air temperatures and the cooling of the water surface, conditions are created for the formation of an ice cover. The time of the onset of ice phenomena on the rivers, the duration of the freeze-up and the time when the rivers are completely free of ice are determined by climatic conditions [5], the structure and size of river systems. In terms of duration, the freeze-up period lasts from five months - on rivers in the middle and upper reaches, as well as on rivers with significant runoff, up to six - on rivers of the lower reaches and watercourses with insignificant flows.

3. Materials and methods

For the analysis of ice phenomena, the main hydrological characteristics of 40 rivers located in the Ob river basin were considered. To describe the water regime and the peculiarities of changes in ice phenomena, the hydrological characteristics of the studied hydrological stations for the period from 1945 to 1987 were analyzed. To analyze changes in climatic conditions, we used long-term average data on meteorological points located on river catchments.

The purpose of this work was to assess the impact of ice cover on the change in winter runoff. Of the 72 hydrological stations considered in the Ob basin, it was possible to use the data of only 40 stations, which is due to the insufficient and lack of information about the ice regime in many small water bodies. The values of hydrological characteristics were used for the observation period from 1945 to 1987.

The variety of natural and climatic conditions from south to north of the study area naturally influenced a significant change in the thickness of the ice cover not only in space, but also in time [6]. The maximum ice thickness within the study area is on average about 85...90 cm, depending on the location area, increasing to the north and river discharge, being inversely related to the discharge. The largest values of the ice cover thickness corresponded to the rivers Nyda-Nyda and Taz-Tazovskoe, respectively 136 and 151 cm, which were observed in April.

The ice regime affects the flow regime. With the establishment of low negative air temperatures, the river runoff decreases, including due to the fact that part of the runoff is involved in the formation of the ice cover. Runoff losses due to ice formation can reach from 10 to 90% of the total river runoff.

4. Results and discussion

The first signs of ice formation in water bodies begin with the onset of negative air temperatures. Compared to lakes, on rivers, depending on the morphological and morphometric characteristics, the process of water crystallization begins with a slight delay. The intensity of ice formation is influenced not only by the temperature regime of the ambient air in the autumn-winter period, but also by the morphological and morphometric characteristics of the channel and river valley. During the freeze-up period, the thickness of the ice cover changes under the influence of heat exchange processes on the upper and lower surfaces of the ice, as well as in the thickness of ice and snow located on the ice cover. A sharp increase in ice thickness in February - March is usually associated with the release of water onto the ice and the formation of ice. A significant increase in ice thickness on small rivers is often due to freezing to the bottom of the underlying layers by the absence of current in the station section. The role of ice cover is significant for small rivers with a shallow water flow depth, since the process of ice formation in such small channels often leads to freezing of the living section of the flow.

The onset of freeze-up has a latitudinal character [7] and corresponds to a month with negative mean monthly temperatures. An increase in ice thickness occurs gradually from the coastal part by ice crystallization with the appearance of negative temperatures, freezing of sludge starting from areas with lower flow rates, and also as a result of freezing of snow falling on the water surface after being saturated with water. With an increase in the thickness of ice on the rivers, there is a slight decrease in the river runoff, due to the participation of some part in the ice formation process.

The rivers located south of 60 N. begin to be covered with ice from November, with the exception of the areas located in the upper part (the Baksa-village Konovalovo, the Baksa-village Pikhtovka), where the beginning of ice formation is observed at the beginning of the third decade of October, and by the end of the month - the beginning of freeze-up. The early onset of ice phenomena in such rivers is also associated with an insignificant underground runoff. On rivers located to the north, the appearance of ice formations begins after October 10, and by October 20...25, freeze-up is already forming.

Small rivers with a length of less than 10 km that prevail in the territory under consideration most often have an insignificant depth of 10-50 cm. Therefore, the process of ice formation in such rivers is most often characterized by a rapid decrease in the free cross-section and throughput of the channel as a whole [8], as well as in most cases leads to complete freezing, which in turn leads to a complete cessation of the inflow of groundwater [9]. This process also affects the water content of large rivers, reducing the total inflow from the river basin by tributaries of a different order. Therefore, rivers with small drainage areas can be considered the most vulnerable during the period of ice formation.

It is obvious that the formation of crystals at the beginning of the ice formation period and its further development are primarily influenced by the air temperature during the autumn-winter dry season. In addition to air temperature, such flow characteristics as the speed and morphological characteristics of the channel, which ultimately determine the nature of water mixing and the intensity of cooling of the flow jets, have a significant effect on the ice formation mode [10].

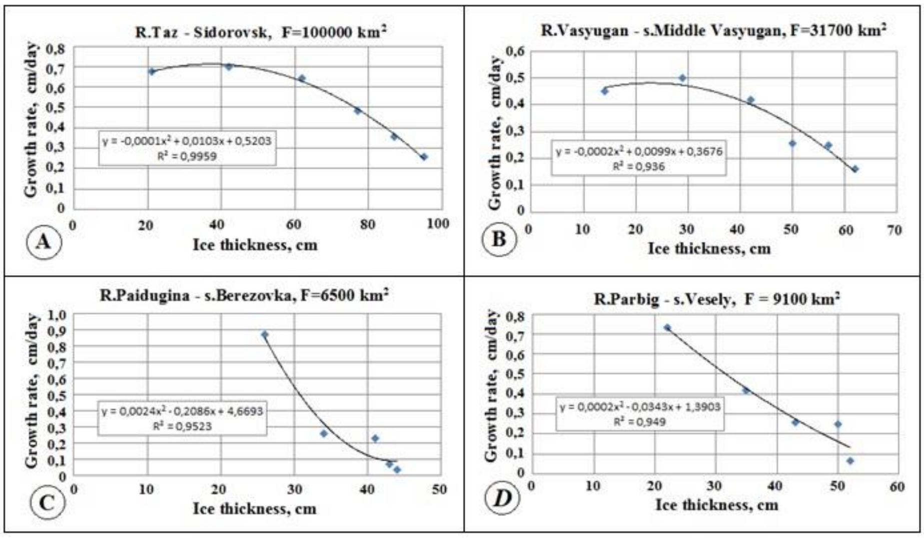

Figure 2. The intensity of the ice thickness increase in the rivers of the Ob.

The duration of the freeze-up period has latitudinal zoning and ranges from five, mainly in the southern half of the territory, to eight in the north. A decrease in ice thickness is observed in the last month of freeze-up, in accordance with the latitude of the area - in March (in the south) and May (in the north). It should be noted that the average monthly temperature of the last month of freeze-up remains in the zone of negative values. In most of the territory, the freeze-up period from the moment of formation to the destruction of the ice cover is from November to April (the rivers Togul, Tom, Burla, Kargat, Chuzik, Chulym, Parbig, Kenga, etc.), on some rivers located in the southern part from November to March (Inya, Iksa, Alei), and on northern rivers from October to May (Nyda, Nadym, Taz, Pur, Lyapin, Poluy, Pukya-Pur, Tym, etc.)

The performed analysis of the formation of the ice cover shows that the greatest intensity of the increase in ice thickness occurs at the beginning of ice formation and ranges from 0.5 to 1.1 cm/day (figure 2). In subsequent months, the value of the growth rate decreases and a minimum is observed with the greatest ice thickness, usually at the end of March in the south and in April in the northern part of the territory.

According to the increase in the intensity of the ice cover, two types can be distinguished, which are explained by the temperature regime of the air. The first type is rivers with a slow increase in intensity from 0.3 ... 0.5 cm / day in the south, and up to 0.5...0.8 cm/day in the north (figure 2A, 2B), with an increase in subsequent months, respectively, up to 0.7...0.9 and 0.9...1.1 cm/day. The second type can be attributed to watercourses with maximum intensity already at the beginning of the ice formation period 0.7...1.0 cm/day (figure 2C, 2D).

Regardless of the rate of increase in both cases, the decrease in intensity by the end of the freeze-up period is 0.2...0.1 cm/day.

As a result of the analysis, it was revealed that the first type of increase in intensity is observed at relatively high values of the average monthly temperature of the first month of ice formation - not less than -7...-8 °C. It should also be noted that the first type of development of the process of increasing ice thickness is characteristic of northern rivers.

5. Conclusion

The main factors influencing the formation of water resources of a given territory and their quantitative redistribution within a year are climatic conditions characterized by the movement of air masses and the distribution of radiation characteristics in the aggregate by the terrain.

The variety of natural and climatic conditions from south to north of the study area naturally influenced a significant change in the thickness of the ice cover not only in space, but also in time.

The maximum ice thickness within the study area averaged about 85 ... 90 cm in the southern part and 136 ... 151 cm in the north of the territory.

In addition to the air temperature, such flow characteristics as the speed and morphological characteristics of the channel, which ultimately determine the nature of water mixing and the intensity of cooling of the flow jets, have a significant effect on the ice formation regime.

The duration of the freeze-up period has latitudinal zoning and ranges from five, mainly in the southern half of the territory, to eight in the north.

The highest intensity of the ice thickness increase occurs at the beginning of ice formation and ranges from 0.5 to 1.1 cm / day, in the following months the intensity value decreases and the minimum is observed with the greatest ice thickness (late March in the south and April - in the northern part of the territory).

The smallest values of ice thickness are observed in the last month of freeze-up, in accordance with the latitude of the area - in March (in the south) and May (in the north), while the average monthly temperature of the last month of freeze-up remains in the zone of negative values.

References

[1] Belonenko G V and Popova N B 2007 *Water management of Russia: problems, technologies, management* (Ekaterinburg) **3** 25-32
[2] Tusupbekov Zh A, Nadtochiy V S and Ryapolova N L 2019 Geographical Foundations and Ecological Principles of the Regional Policy of Nature Management (Irkutsk)
[3] Vuglinskiy V S and Gronskaya T P 2006 *Modern Problems of Hydrometeorology* (St. Petersburg: Publishing house. Asterion) p 229-44
[4] Rawlins M A, Ye H, Yang D, Shiklomanov A and McDonald K C 2009 *Journ. of Geophys. Research* **114**
[5] Agafonova S A, Aibulatov D N, Frolova N L and Kozlov D V 2014 *Hydraulics, hydrology, water resources* (Moscow) **3** 60-2
[6] Frolova N L, Magritsky D V, Kireeva M B, Agafonova S A and Povalishnikova E S 2018

Questions of Geography (Moscow: Publishing House "Codex") **145** 233-51
[7] Agafonova S A 2017 *Arctic and Antarctic* **2** 25-33
[8] Buzin V A and Zinoviev A T 2009 *Ice processes and phenomena on rivers and reservoirs* (Barnaul: Publishing house of LLC "Five plus") p 168
[9] Markov M L and Gurevich E V 2019 Hydrosphere *Hazard processes and phenomena* **4** 477-89
[10] Belonenko G V and Tusupbekov Zh A 2014 Scientific problems of transport in Siberia and the Far East (Novosibirsk) **4** 94-7