Ice phenomena on the rivers of Russia: the role of academic expeditions

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Abstract. The systematic study of the ice regime of the Russian rivers began with the organization of gauges at the end of the XIX century. It was preceded by a long preparatory period of expeditionary works performed from the second half of the XVIII century. The article discusses the contribution of members of academic expeditions of the second half of the XVIII century to the study of ice phenomena on the rivers of Russia. Special attention is paid to the dangerous phenomena that often accompany opening and freezing of rivers, ice jams, floods, etc. The author summarized and systematized data and observation materials obtained during the journeys. They can be used for studying ice phenomena on the rivers.

1. Introduction
In the second half of the XVIII century, large-scale expeditions were conducted. They were based on the projects developed by M.V. Lomonosov. These are famous “physical expeditions” of Petersburg Academy of Sciences of 1768–1774. Expeditionary academic studies provided materials on geography, geology, flora and fauna of Russia; customs, languages and business traditions of the population; data on ice phenomena on the rivers of Russia (the opening and freezing times, the nature of floods, etc.).

2. Sources and methods
The study identifies, systematizes and analyzes a huge number of sources.

3. Academic expeditions of the second half of the XVIII century
The most important result of academic expeditions was publication of such fundamental works as “Journey to different provinces of the Russian Empire” by P.S. Pallas; “Daily notes of travel to different provinces of the Russian state” by I.I. Lepekhin; “Journey to Russia to explore three kingdoms of nature” by S.G. Gmelin; “Travel notes” by I.P. Falk; “Notes about the Travel from St. Petersburg to Kherson in 1781 and 1782” by V.F. Zuev and “Journey through Ladoga and Onega Lakes” by N.Ya. Ozeretkovsky. They contained descriptions of nature and observations of “the nature of the earth and waters”, features of the ice regime of rivers associated with seasonal phenomena, a set of regularly processes of the development and destruction of ice formations on water bodies. The travelers paid attention to hazardous river phenomena creating obstacles for economic activities: spring flooding, very early or late ice drift and freezing, ignition and congestion.

The expedition of 1768–1774 headed by P.S. Pallas examined European Russia, the Lower and Middle Volga region, Orenburg Territory, the Urals, Western and Eastern Siberia, and Transbaikalia. During the expedition, Pallas noted the time of freezing and opening of rivers, explained the reasons...
determining these terms, gave the first empirical “forecasts” of flooding (floods) as a result of rising water levels due to rapid snow melting and traced spatial and temporal patterns of changes in ice phenomena in various natural areas. Moreover, Pallas tried to describe and distinguish phases of the ice regime of the majority of rivers. He described autumn ice phenomena (freezing) and spring ice phenomena (opening).

On October 20, 1768, the scientist recorded autummal ice drift and freeze-up on the Volga River near Simbirsk. He paid attention to the direct dependence of the fixed ice cover (freezing) on the wind and lowering air temperature. On December 14, 1768, in Simbirsk and Tetyushi, Pallas paid attention to the dependence of the ice thickness on morphometric characteristics of the river. He wrote that near Simbirsk, it was still impossible to cross the Volga River, while in Tetyushi located where the river was much narrower, people crossed the frozen river [1].

During the freeze-up period, there are ice-free areas that have a double origin: dynamic and thermal ones. Thermal areas arise under the influence of warm groundwater described by Pallas described. He noted that the keys flowing from the coastal slopes into the river are the causes of the lack of strong ice [1].

Spring ice phenomena were observed on the Samara, Belaya, Miass, Angara, Selenga, Kame Rivers. In 1769, in Samara, due to warm weather, the snow melted for a very short time, and on April 9, the spring drift began, the level of water increased. On April 11, the ice was broken on the Volga River. By April 15, due to the strong north wind, the river ice melted. When describing the opening of the rivers and the rise of the water level, the scientist paid attention to the height of the snow cover affecting the level of the spring flood [2]. On the Oka River near Murom, Pallas identified horizontal channel deformations that cause soil erosion. To fix the soil and prevent landslide processes, he proposed to plant willow on the river banks. In 1774, on the Volga River near Tsaritsyn, Pallas observed ice clogging phenomena — blockage of the river by floating ice floes.

The 1768–1773 expedition headed by I.I. Lepyohin studied the Middle and Lower Volga, the Lower and Middle Urals and part of Arkhangelsk province. In the "Daily Notes", Lepyohin specified the dates for the opening and freezing of the rivers of Kanin and Timan lands. The Usa River opened in mid-May and froze at the end of September. For Pechora, observation data were in several sections which made it possible to trace spatio-temporal changes in ice phenomena. On the basis of his own observations and data obtained from the local people, Lepyohin wrote that Pechora opened near Usttselma (Ust-Tsilma) at the end of May, and in Pustozersk, it opened a week later; near Usttselma, it froze at the beginning or in the middle of October, and in Pustozersk - a week earlier; near Izhma Slobodka (Izhma), it opened in the middle or at the end of May, and froze at the beginning or in the middle of October [3].

Lepyohin paid great attention to dangerous ice phenomena accompanying the opening of rivers. On May 7, 1773, he observed a congestion on the Northern Dvina during the spring ice drift which increased the water level, and caused flooding in Arkhangelsk [4]. The traveler paid attention to the fact that the annually recurring phenomenon prompted local residents to predict the height of the flood, linking it with the behavior of seabirds: “the higher the seagulls are flying, the higher the water level will be” [3].

Changes in the morphological structure of the river bed due to the action of flowing water (channel processes) related to instability and deformation were observed on the Kama, Vyatka, Yarenga and Sysola rivers. He wrote about the latter that its banks are sloping, sandy, swampy, subject to the detrimental effect of spring waters. He paid attention to the transport of sediment and displacement of channel forms on theVyechegda river near Yarensk which made local residents to move to less dangerous places. The Kynyrma and Lipka are like creeks in other seasons.

The 1768–1774 expedition headed by S.G. Gmelin (junior) in explored parts of European Russia and the Lower Volga region, the North Caucasus and Transcaucasia. Gmelin paid attention to the nature of spring floods affecting the life and working conditions of the coastal population. After snow melting, the Voronezh river became extremely deep, spreaded several miles and flooded the floodplain, the first and second terraces. He wrote about flooding on the Don River near Esaulovskaya that spring and autumn floods caused a lot of harm to coastal villages. On the Kuban River, spring floods were very large, the water stood until the beginning, and sometimes the end of July. Houses along gentle banks
were built on stilts, and the local population kept boats for spring communication. The same phenomena were observed on the Cuba and Kure Rivers [5].

The 1768–1773 expedition headed by J.P. Falk surveyed Orenburg Territory, the Middle and Lower Volga regions, the foothills of the North Caucasus, the Southern Urals, and Western Siberia to Tomsk and Kuznetsk. The Falk's Notes provide data on observations of ice phenomena on the rivers. Based on his own observations, Falk recorded the dates of opening and freezing and identified phases of the water regime of the rivers. The Belaya River freezes in early November and opens in mid-April; The Tom River freezes at the end of October, and opens at the end of March. For the Irtysh and Volga Rivers, the opening date depends on the location: in 1772, near Tara, the Irtysh opened on April 17, near Barabinskaya steppe, - on April 10-20. For the Volga River, the scientist tried to trace spatio-temporal changes in the onset of opening in various natural zones: in 1770, in Tsaritsyn, the Volga river opened on March 3, and int Kazan - in mid-April. For the Moscow River, the data on the duration of the freeze-up were provided [6].

Falk provided information about the width of the rivers during the ice cover: above Kuznetsk, the Tom River was 30 sazhens, below Kuznetsk - from 50 to 60 sazhens, above Tomsk - 30 sazhens, and below - 60 sazhens. Observing the spring ice phenomena, in the Terek River, Falk recorded the rising of the water level by 30-40 feet; in the Saratovka River, the left tributary of the Volga, - by 40-50 feet; in the Volga river near Tsaritsyn – by 20-30 feet. He compared flood levels in different places on the Volga river: in the spring, the water in Astrakhan rises by 8-10 feet, in Kazan - by 25-35 feet, in Saratov - by 40-50 feet.

Falk paid attention to the changes in the direction of the flow of the river due to the spring flood. At the confluence of two rivers during the peak flood, huge masses of water can change the direction of flow of one of the rivers, directing the water upstream, i.e. to the source. The scientist observed this phenomenon on the Kazanka and Terek rivers. He wrote about the first one: “during the initial spreading, the Volga rover leaves its banks so quickly that the water enters Kazanka which flows backward for several days” [6].

Falk paid attention to the conditions of navigation which was often possible during the spring floods. According to his data, there are loaded barks from Penza to the Volga river during the spring flood; in the summer, the shipping stops; The Lesnaya Voronezh river is navigable only in spring; In spring, the Iset River is navigable for large vessels, and in summer - only for small ones: The Tura River is navigable to Turinsk, and in summer, it is navigable only to Tyumen. The Moscow River is navigable only when the level rises by one sazhen during the spring flood.

In 1781–1782, Zuev was travelling in the European part of Russia, left-bank Ukraine (to Kherson) and across the Crimea. In his travel notes, Zuev carefully described rivers, lakes and springs. When describing water bodies, he paid attention to the use of rivers for the water supply and the time of their opening and freezing. The Seim and Tuskar rivers freeze in late November or early December, and open in March; the Oka river and its tributary Orlik freeze in November or December, and open in March, sometimes in April. The traveler describes the floods in the Oka basin which result from spring ice phenomena. Travelling through the Nara river, he noted that in June 1781 it was quite wide, and during the spring flood, it is three times wider, as evidenced by sands forming the border of the “hollow water”. At the end of June, the Protva river was no more than 12 sazhens wide, and during the spring flooding, its width was more than half a verst [7]. When describing Oryol province, Zuev noted that on the Oka, Desna and Sozna rivers, navigation was possible only during the spring flood.

The 1785 expedition headed by N.Ya. Ozaretovsky travelled through the territories of the basins of Ladoga and Onega Lakes. The scientist paid attention to the difference in time of the opening of the Shaly and Vodla rivers at the point of their confluence. He noted the destructive power of the spring flood on the Lyakskile River and formation of a “waterfall” (threshold) at a distance of five kilometers from the mouth upstream. The height of the threshold reached 17 m, and the fall of water, especially strong in the springtime, threw huge boulders. He encountered a similar phenomenon in the spring on the Suna River near the Kivach threshold.
The information on the influence of snow cover on the height of the spring flood on the Vuoksa river obtained by Ozeretskovsky is valuable. He paid attention to the fact that local residents were observing the water regime of rivers flowing into Ladoga Lake. They noted that the amount of snowfall in winter affects the height of the spring flood. The water level in the lake increased and decreased. In 1785, the water level was above normal. In order to explain this phenomenon and establish the probable cause of changes in the water regime, Ozeretskovsky pointed out the need to monitor the water level at several points, and the circumstances that may affect the changes in the water level (rainfall, snow, fogs, the number of sunny days). This would help establish causes of the change in the water regime [8].

4. Conclusion

The data obtained during academic expeditions of the second half of the XVIII century are still relevant. These observations are a basis for the retrospective analysis of the rivers in the XVIII century. They can be sued for assessing climate changes. P.S. Pallas, I.I. Lepeyokhin and I.P. Falk paid attention to the spatial and temporal patterns of changes in the periods of opening and freezing of rivers in different natural zones, described phases of the ice regime in certain sections of rivers in different regions.

We see their desire to explain the causes of spring floods depending on changes in climatic and ice conditions of the water system. They tried to establish the dependence of the ice cover on morphometric characteristics of the river and hydrometeorological elements.

The works are valuable because they can be a basis for further studies on the ice regime of Russian rivers.

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