The genesis of ideas about ice phenomena: from the first fixations to the beginning of the XVIII century

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Abstract. The study of ice events on rivers is of great importance, especially in our country where some rivers are covered by ice for months. The needs of shipping, the construction and operation of hydraulic structures, the study of channel deformations caused by ice phenomena and other purposes require knowledge of the ice regime of the rivers. The article explores the beginning of visual observations of ice phenomena and their consequences on the rivers of Russia in the XI-XVII centuries. The study is based on numerous annalistic sources describing the passage of high water, floods, and also indicate the dates of opening and freezing of rivers. It also analyzes notes of foreigners travelling throughout Russia in the 15th - early 18th centuries. The authors separately examined the observation of the passage of spring floods on the Moscow River in the second half of the 17th century.

1. Introduction

The systematic study of the ice regime of rivers in Russia began with the organization of a permanent network of water gauging posts at the end of the 19th century. In the earlier period, the study used mainly expeditionary methods to provide navigation [1]. Already the “Tale of Bygone Years” included in various parts of the Russian annals contains some data of a physical-geographical nature. There are also numerous references to the rivers of the main watershed of the Black, Baltic and Caspian seas, which had important transport and military-strategic importance. The first references to ice phenomena and their negative consequences are found in annals from the 11th century. The Novgorod and Pskov annals contain especially many such records. Although these records often do not indicate to which river or to which destination they refer, and when the phenomenon has occurred. However, they are of exceptional scientific value.

2. Materials and methods

The study used the identification, systematization and analysis of a huge number of annalistic and other sources that describe the study period.

3. Visual observations of ice phenomena and their consequences

Since the beginning of the 11th century, there has been an interest in meteorological and hydrological phenomena: high water in spring, floods, and ice phases of rivers. Novgorod annals contain descriptions of this kind of phenomenon, namely floods: in 1127 snow lay until April 30 (here and below we use modern chronology and dates by the old style), and in spring, the water in the Volkov River rose very high [2]; in 1128 there was a snowy winter resulted in the spring flood of the Volkov...
River that caused destruction [3]. Annals from 1291, 1539, 1543, 1555 noted high levels of spring floods but did not indicate their consequences. But at the end of April 1338, they recorded a flood on the Volkhov River caused by the rapid melting of snow, which had never happened before: “The water stood for three weeks and caused a lot of trouble to the city dwellers, including the demolition of two bridges” [2].

In 1437 in Novgorod in the spring there was another severe flood with the erosion of soil: “That spring, water washed the city near the Kremlin, and the land crawled from the wall, the stone wall and the bell tower fell from Volkhov” [2], two years later this part of the wall and the bell tower has been restored. In the autumn of the same year, the ice going along the Volkhov River broke several bridges and “did a lot of evil to the Novgorodians” [4]. Professor of Moscow State University, geographer and climatologist M.A. Bogolepov notes: “The abundance of the meteorological element in the weather records of the Novgorod annals is very understandable since the city traded exclusively in water, and any decrease and rise of water in the rivers, depending on the weather, greatly affected the well-being of Novgorodians” [5].

Not only Novgorod but also other annals contain data on the passage of spring floods. The Nikon Chronicle from 1002 noted that in the spring there was high water on the Volkhov River. The Ipatiev Chronicle states that in the spring of 1108 there were high floods on the Dnieper, Desna and Pripyat rivers. The Tver Chronicle for 1143 reports a cold snowy winter and an excessively wet, high-water spring: “The same spring there was a great flood in the rivers” [6]. In 1496, according to the Sofia Chronicle, the winter was fierce and very snowy, and in the spring there was a high flood on the Moscow River and other rivers, which the locals did not recall earlier [7].

There are two types of ice phenomena on rivers: stable (at least 30 days) and unstable. In many regions of Russia, instability of ice phenomena includes the repeated formation of ice cover and its destruction. The example of this phenomenon is the records in the Pskov Chronicle for 1479 telling about the severe flooding on the Velikaya River, which began on November 13 and was preceded by short freezing of the river. After the re-establishment of the ice cover, another thaw ensued and triggered an even greater flood, and the water rose even higher: “The ice was demolished and many disasters were caused, and the third time the ice rose to the mouth to the lake, and Christians are good healthy” [3].

The same chronicle from 1563 to 1564 noted that after the high-water fall when the floods in the rivers were three times the same as in the spring, the Velikaya River was covered with ice on December 3, and the ice on it was solid for six days. On December 9 it warmed up: “There was a lot of water along rivers and streams, for many years there was no such case, and there was rain before Christmas, and there was no snow, from December 9 to January 9 people couldn’t go along the road. Such a reason was previously only December 9, 1474)” [3].

For persistent ice events, there are some time frames for their start and end or average long-term dates of ice events. They share the main phases of the ice regime: freezing, ice formation and breaking. The Novgorod Chronicle reports that in 1401 the winter was early, and the Volkhov River was covered by the ice on October 18. The ice was strong all winter, until March: “That winter we travelled through Volkovo on ice from Lukin day to March” [3]. The Tver Chronicle describes that in 1452 the Volga River froze only "on Christmas eve" [6]. The Nikon Chronicle for 1475 states that the Volkov River froze on November 8 [4], and in 1477: "the autumn was dry and cold, the ice rose on the river on November 12" [4].

Often the annals tell about the negative impact of not only spring floods but also autumn ice phenomena on the life of the coastal population. So, in the autumn of 1335, ice that was brought from Lake Ilmen spoiled the bridge across the Volkov River. On September 6, 1345, a strong south wind with snow “blew ice into the Volkov, which broke the bridge” [8]. The Nikon Chronicle for 1388 tells that after September 17, frost came, rivers and lakes froze, but on October 26 a strong storm broke the ice in Novgorod, demolished several bridges across the Volkov and brought many other troubles to people [9]. In the fall of 1436, there were significant floods in Ilmen and Volkov “that water was great that autumn, several bridges were damaged by ice” [2], in 1437 the same strong flood
wave caused great damage to the coastal regions of Novgorod [4].

Repeatedly in the annals, it is indicated that the Volkhov River can flow back. In 1063, the Ipatiev Chronicle described this phenomenon: “In Novgorod, the Volkhov River flowed back five days” [8]. This is the result of the small slope of the channel in the upper reaches of the river. If a lot of water accumulates due to heavy rains or fast snow melting in the spring, and the level of Lake Ilmen at this time is still at a low level, then the river turns back and flows in the opposite direction, namely towards Lake Ilmen. The Nikon Chronicle for 1065 and 1415 also mentions this phenomenon: “In the holy week of this, in Novgorod, water went back in Volkhov and many other rivers” [9], the Novgorod Chronicle for 1176, 1373, 1376, 1377 years and the Sofia Chronicle for 1525: “In the second week of Easter, the water in Volkhov went up, not by the wind, nor by the storm, but by the order of God Creator; and she walked for nine days, and on the tenth day she returned in her own image” [7].

The above Chronicles of the 11th – 16th centuries evaluated hydrometeorological phenomena only comparatively. There were not any hydrometric observations. Nevertheless, the annals have evidence of an understanding of the natural connection of phenomena: “At that time (in 1421) the winter was very snowy, and then the water was great and strong in the spring, and the same water in Novgorod, and flooded the whole Pskov yard, demolished the bridge in Volkhov, flooded many holy churches and monasteries, the icons of saints and books, flooded many people and did much evil in Novgorod; and that water was great all summer” [3].

Starting from the XV, we also find information about ice phenomena in the notes of foreigners travelling around Russia, they relate mainly to the Moscow River. The Venetian merchant and diplomat Josaphat Barbaro, who visited Russia in 1436–1452, wrote: “The frost there is so strong that the river freezes” [10]. The Venetian Ambassador Ambrogio Contarini, who visited Russia in 1476-1477, noted that “at the end of November, the river flowing through the city freezes all; on it, people build shops for various goods” [10]. Another Venetian ambassador, Francesco Tiepolo, reported in 1560 that in Muscovy, most of the rivers freeze and spill due to snowmelt in spring. Archdeacon Pavel Aleppsky, who came to Moscow twice in 1655–1656 and 1666–1669, spoke about the catastrophic flood on the Moscow River, which “arrived much on a spring night so that it overturned the Kremlin’s outer stone wall, sank and destroyed many houses with a considerable number of people and uprooted many trees” [10]. In winter, people walked across the river on the ice, and now they sail in the boats from house to house. This continued for several days until the water level began to drop, and “in August, people on horseback waded it, so it became shallow” [10].

The Dutch artist and traveller Cornelius de Bruin, who was visiting Moscow at the beginning of the 18th century, mentioned that the Yauza River was covered with ice in mid-November, and also described the sudden onset of flooding on the Moscow River. It resulted from sharp warming in early April; the snow melted in a day and the ice came down from the river, the water “rose as high as the old-timers do not remember” [11]. At the end of April, he went from Moscow to Astrakhan by water, describing the flooded Oka River: “the river spilt so much that it was difficult to find out the real river channel and swim along.” Near the village of Terekhova, “the banks were flooded so that the water reached the branches of tall trees.” Such floods occur here every year, until June when the water begins to subside. 106 km from the city of Kasimov, the Oka also had the flooded banks. The image of this area is shown in Figure 1, made by the traveller himself [11].

In the second half of the 17th century, during the reign of Alexei Mikhailovich, there was the establishment of the Secret Affairs Order (Tsar’s own office) obliged to keep daily records and, among other things, enter weather information in them. Some surviving “Day notes of the order of secret affairs” contains information about the passage of floods on the Moscow River, according to which in 1660 the river cleared of ice on March 29; on March 30, water arrived about half a meter; on March 31, another meter arrived. April 1 after a table meal, the great sovereign went to look at the Moscow River from Naberezhnye Horomy. And on that day, a quarter of arshins of water disappeared in the Moskva River” (about 90 cm), on April 3, a little less than half a meter is gone, on April 4, about half a meter arrived, on April 6, it was about thirty centimetres [12]. They conducted observations of fluctuations in the level of the river with some intervals until April 24th: “nothing happened in the
Moscow river that day” [12]. We can say that Tsar Alexei Mikhailovich is one of the first who conducted water-measuring observations on the rivers of Russia.

The “Daily Notes” for 1662 describes an ice breakdown, after which the ice cover re-formed: “on that day (March 12), the ice started to flow on the Moscow River ...” [12], and on March 13, it froze at night, and the river again covered with solid ice.

The release of rivers from ice cover has two components: melting and destruction of ice. Destruction occurs by the mechanical action of a water stream on an obstacle [13]. Melting of ice accompanied by a decrease in the thickness of the ice sheet usually precedes this process. The records of the Secret Affairs Order for April 5, 1666 note precisely this sequence: “That day was windy and melted, and at night there was a little frost and the ice broke on the Moscow River” [12]. The next day, the river was completely cleared of ice.

4. Conclusion
The interest of chroniclers in meteorological and hydrological phenomena began to appear from the beginning of the 11th century. The information about ice phenomena and their negative consequences for the population, which came from the annals and descriptions of foreign travellers, is fragmentary and obtained through simple everyday observation. In the second half of the XVII century, episodic water-metering observations on the Moscow River began for the first time, primarily observations of the height of spring floods. In general, there has not yet been the observation of the hydrological characteristics of rivers: fluctuations in levels, flow rates, water flow rates, opening and freezing periods. Further study of ice phenomena is associated with the beginning of the accumulation of hydrological data obtained using instrumental measurements during numerous expeditions of the 18th century. [14, 15].

Figure 1. High water on the Oka, 1703
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