Features of water balance in the Selenga and Onon river basins during the formation of rain floods

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Abstract. Floods are characterized by non-periodic and short-term rise in the water level in the river, which can lead to catastrophic consequences and large material damage. The aim of this work is to study in detail the components of the water balance of the river basin, which affect the amount of flood runoff. The objects of study are the rivers of Eastern Siberia Selenga and Onon rivers. For the work, materials of long-term observations of the hydrometeorological network of the Trans-Baikal UGMS were used, as well as the database of the GPCC atmospheric precipitation climatology center. The methodological basis was a comprehensive hydrological and geographical analysis of the processes of flood runoff, namely the water balance method. In the course of the study, a geographical analysis of the factors of floods in the conditions of the steppe, forest-steppe and taiga zones of Eastern Siberia was carried out. For a thirty-year period of hydrometeorological observations in the basins of the Selenga and Onon rivers, graphs of changes in water discharge over time (hydrographs) were constructed and genetically related values of flood runoff and flood-forming precipitation were calculated. The unity of landscape characteristics and climatic features determine the hydrological indicators of the river in its different sections, which gives an overall picture of the hydrological indicators of the river network as a whole. According to the ratio of the maximum discharge of water of various origins, spring floods and summer floods, in the basin of the river Selenga and Onon groups of rivers were identified according to the prevailing origin of maximum flow. For the rivers of the Selenga and Onon basins, fluctuations in river runoff and atmospheric precipitation were investigated, and their relationships with the characteristics of atmospheric circulation were established. Difficulties in the analysis of hydrometeorological processes for the considered river basins are their transboundary location.

1. Introduction

Within the considered territory of Transbaikalia, floods of rain origin are most pronounced. Systematically, in this territory, the runoff of rainfall floods in the warm season is higher than the runoff of spring floods. According to the water regime, the Onon and Selenga rivers belong to the rivers of the Far Eastern type with low spring floods, long winter low-water periods and rain floods in the summer-autumn period.

When analyzing the data of long-term observations of the water content of the considered river basins, an incorrect frequency is observed. The years with flood floods stand out: 1906-1921, 1930-1953, 1959-1975, 1983-1995, two decades 1996-2012 years characterized by the predominance of dry years, and the years 1996-2012 characterized by the predominance of dry years. According to the provision of maximum water levels, the following were distinguished: historical floods with a
provision of less than 0.1%, catastrophic from 0.1% to 1%, outstanding - from 1% to 10%, and high - from 10% to 25%. The methodological basis of this study was a complex hydrological and geographical analysis of the processes of flood runoff, namely, the water balance method. For the work, materials of long-term observations of the hydrometeorological network of the Transbaikalia UGMS were used, as well as the database of the GPCC atmospheric precipitation climatology center.

2. Materials and methods

The Selenga River basin is located in the Selenginskaya Dauria, almost the center of the Asian continent, and occupies 447 thousand km². The river originates in Mongolia from the confluence of two rivers Ider-Gol and Delger-Muren. The total length of the Selenga is 1024 km - 615 km in Mongolia and 409 km within Russia. The Selenga basin includes the northern slopes of the ridge Khangai, southern spurs of the Eastern Sayan Mountains, Selenginskoe middle mountains, Khamar-Daban and Ulan-Burgasy ridges. In the east, the basin is bounded by the Yablonovy ridge, the Khentei-Chikoiisky highlands and the western part of the Khenei ridge [1-2].

The Onon River basin occupies 96200 km² and includes the Daurusky and Borschchovochny ridges, stretching across the entire western part of the territory under consideration to the confluence of the Shilka and Argun rivers. The Nerchinsk and Gazimursky ridges protrude from the eastern part of the basin, and the Erman and Eren-Daban ridges - in the southeastern part and form a watershed between the Onon basin and the closed watersheds of the Mongolian rivers [2-3]. The source of Onon, according to V.P. Polivanov, are the upper reaches of the unnamed tributary Onon-Gol at the point with coordinates: 48° 48' 769' north latitude: 109° 01' 744' east longitude. The height of the source is 1930 m. The nameless source begins in the northern spurs of the Khenteyskiy ridge, near the height of 2407.0, designated on the map as KhenteyUla. Within Mongolia, it flows along the Khentei-Chikoiisky upland, in the lower reaches (Russia) it flows between the Mogoytuysky and Borschchovochny ridges [4].

Following the territorial distribution of precipitation, the highest values of the annual runoff rate are observed at river sources, in the watershed area. Within the Russian part of the Selenga river basin, the highest runoff is confined to the area of the Khamar-Daban ridge (southern Baikal region) and in the east - the source of the Chikoy River, the Malkhansky and Yablonovy ridges. In the Mongolian part of the basin, the region of the spurs of the Eastern Sayan Mountains (Prikhubsugul region) is characterized by increased water content. In the steppes of Mongolia and Russia, the annual runoff is reduced to 50 - 10 mm.

Throughout the basin of the Onon River, the runoff is 20–80 mm, sharply increasing (up to 250–300 mm) in the source (slope of the Malkhansky ridge, Mongolia) and in the lower reaches (Borschchovochny ridge, Russia).

The intra-annual flow distribution in the Selenga and Onon river basins is characterized by low spring floods, high summer-autumn flows, and exceptionally low winter flows. The latter is characteristic of the conditions for the spread of permafrost. The uneven distribution of runoff in a year is mainly determined by the peculiarity of the atmospheric circulation in different periods of the year. The maximum runoff of rainfall floods falls most often in the month of August. In the intra-annual distribution of runoff in the territory under consideration, the largest in terms of water content is the spring-summer period (the volume of runoff is 70-94% of the annual), described in detail in [5-6]. The share of runoff in the autumn-winter period is much lower, in it the winter season is especially distinguished with 0.1% - 6% of the annual volume [5-6] (table 1).

Group 3 includes the northernmost rivers of the Selenga River basin, namely the Uda river and the Khilok river.

The most outstanding floods with the maximum daily water discharge for the period under consideration (1980-2010) are shown in (table 2).
Table 1. Groups of rivers in the study area, identified by the ratio of the maximum flow rates of spring floods and rain floods.

| Group characteristics                                                                 | Group number |
|------------------------------------------------------------------------------------------------------------------------------------------|--------------|
| Rivers with maximum annual water discharge (Q) of rain origin are observed in 84% or more of the number of years of observation         | 1            |
| Rivers with maximum annual water discharge (Q) of rain origin are observed from 68 to 84% of the number of years of observation         | 2            |
| Rivers with maximum annual water discharge (Q) of rain origin are observed from 57 to 68% of the number of years of observations      | 3            |

Table 2. Maximum water discharge on the Selenga River and Onon River.

| Paragraph          | F, km. sq. | Date            | Average daily water consumption Q, m³/s | Module max. flow, l/s*km² | Runoff layer for flood, mm |
|--------------------|------------|-----------------|----------------------------------------|---------------------------|---------------------------|
| Selenga river -    | 360 000    | 10.08.1993      | 6080                                   | 16.89                     | 12                        |
| Novoselenginsk      |            | 26.08.1994      | 3890                                   | 10.80                     | 3                         |
|                    |            | 15.08.1990      | 3730                                   | 10.36                     | 0.4                       |
|                    |            | 19.08.1998      | 5680                                   | 12.76                     | 20                        |
| Selenga river -    | 445 000    | 13.08.1993      | 5660                                   | 12.72                     | 10                        |
| Kabansk             |            | 06.09.1990      | 5350                                   | 12.02                     | 12                        |
|                    |            | 30.06.1985      | 2740                                   | 60.89                     | 25                        |
| Onon River -        | 45 000     | 12.08.1998      | 2330                                   | 51.78                     | 23                        |
| Upper Ulkhun        |            | 19.07.1990      | 2140                                   | 47.56                     | 19                        |
|                    |            | 11.08.1985      | 1570                                   | 20.90                     | 19                        |
| Onon River -        | 75 100     | 15.07.1990      | 1520                                   | 20.24                     | 16                        |
| Tin                 |            | 16.09.1988      | 1520                                   | 20.24                     | 16                        |
|                    |            | 20.08.1998      | 2770                                   | 28.97                     | 8                         |
|                    |            | 15.08.1985      | 2560                                   | 26.78                     | 14                        |
|                    |            | 23.07.1988      | 2030                                   | 21.23                     | 11                        |

According to the ratio of the maximum discharge of water of various origins, spring floods and summer floods, in the basin of the Selenga and Onon rivers, groups of rivers were identified according to the prevailing origin of the maximum runoff. In general, as expected, there is a general predominance of rainfall, but its share varies and ranges from 68% of cases of the number of years and reaches 84% or more table 1. Most rivers belong to group 1 and are located in the western and southwestern parts of the considered territory occupying most of it (68%). This group includes the Selenga and Dzhida rivers, as well as part of the Onon River (from the source to the village of Verkhniy Ulkhun). Rivers of the second group are located east of the rivers of the first group and occupy 21% of the territory. The second group includes the rivers Ilya, Chikoy, Kurba and part of the Onon river from the village of Verkhniy Ulkhun to its mouth.

3. Results and discussion

The melt water runoff of the studied rivers, due to low snow reserves, does not provide a significant contribution to the annual runoff. The main source of food for rivers is rain, which in the summer months makes up 70% of the annual precipitation. The variability of precipitation significantly affects the river flow. According to V.I. Kornienko's estimates [7], only 10-15% of precipitation is formed by local evaporation. Sediment advection is formed under the influence of circulation processes. The frontal system with atmospheric circulation in temperate latitudes and tropics forms, depending on its position, precipitation of different intensity. There is a direct connection between cyclonic and anticyclones activity and the amount of atmospheric precipitation: an increase in cyclonic activity is
accompanied by an increase in precipitation, and its weakening is associated with a decrease in precipitation. In addition, the mountainous relief exerts its influence on the processes of sedimentation, in the conditions of which ascending and descending air currents are formed. Ascending air currents promote condensation of water vapor and the formation of atmospheric precipitation. Extreme precipitation in the study area is formed during periods with a predominance of SE and NW directions of air mass transfers, the distribution of which may have a local character. In the period under consideration (1980-2010), in the time course of average annual water discharge and air temperature, time intervals with high and low values are distinguished figure 1.

Figure 1. Changes in the average flow rate of the river Selenga (Q) and the amount of precipitation (x) in the river basin Selenga for March-October 1980-2010 (1 - water discharge of the Selenga river Q; 2 - average, for 1980-2010, water discharge Q; 3 - precipitation for March-October (Ulan-Ude city).

In changes in temperature over the past 100 years, the following periods can be identified according to the scheme given in the study by Shimaraev M. N. [8]: from 1896 to 1950 - an increase in the average annual air temperature was observed; from 1950 to 1970 the temperature starts to drop; from 1970, the temperature began to rise and this trend continues to the present. The variability of the atmospheric circulation regime, expressed by changes in the position of the frontal system separating the air masses of temperate latitudes and the air masses of the summer East Asian monsoon [7-8], causes fluctuations in average precipitation values. Deviations of average precipitation values from the norm for the calculated period characterize (figure 1) temperature changes over the last 100 years according to the scheme given in the study [8]. The rates are calculated for 1951-1990 (figure 2) and for 1951-2010 (figure 3). The vertical axis shows latitude coordinates, and the horizontal axis shows longitude coordinates. The position of the Selenga River is characterized by the following coordinates: source - 49° 15' 43" north latitude, 100° 40' 47" east longitude; mouth - 52° 16' 33" north latitude, 106° 16' 20" east longitude; Onon River - source - 48° 50' 32" north latitude, 108° 47' 18" east longitude; mouth - 51° 42' 16" north latitude, 115° 50' 32" east longitude (rivers are shown on the diagrams for 1975 and 1996). A noticeable increase in average precipitation values in areas of the territory colored with shades of blue was noted in 1975, 1982 - 1986 and 1988 - 1990 (Selenga and Onon rivers), 1996 (Onon river), 1998 (Selenga and Onon), which is caused by an increase in the frequency of movement of the eastern monsoon and / or invasions of air masses of temperate latitudes.

In 1999 - 2007 and 2009 - 2010 low water content can be traced, caused by the weakening of the indicated circulation processes (figure 3). As emphasized by Marchenko O.Yu. [9], despite the fact that the basins of the rivers under consideration are located on the northern edge of the arid belt of the Asian continent (northern part of Mongolia, south of Eastern Siberia), at a great distance from moisture sources, the amount of daily precipitation here can reach rather high values, up to 90-100 mm. In the European part of Russia, only in a few places does the amount of precipitation reach the
same values according to Zhakov S.I. [10]. For example, on June 26, 1985, in the Selenga basin, precipitation up to 93.7 mm (Kabanskoe) was recorded, caused by northern and northwestern invasions. July 21, 1988 (Onon river basin) precipitation was 80.6 mm (point). In this case, southeastern and northern transfers were predominant. A combination of factors is required for high and low precipitation. So, the formation of high precipitation is observed with strong ascending movements in a moist air mass, or ascending movements and low air temperatures. Following Marchenko O.Yu. [9], Table 3 presents information on precipitation formed at various trajectories of particle transfer. Despite some conventionality of the connection of each trajectory of the transfer of air masses with a certain source of moisture due to the transformation of air masses, Marchenko identified the following connections: the western direction is the source of moisture Atlantic Ocean, NW and N is the Arctic Ocean, NE and E are the Pacific Ocean, SE - Pacific and Indian Ocean.

Figure 2. Average values of deviations of precipitation from the norm in the territory of the Onon and Selenga river basins in the period 1975-1990.

Figure 3. Average values of deviations of precipitation from the norm (1951-2000) in the basin of the Onon and Selenga rivers in the low-water period 1996-2010.

The influence of precipitation in (table 3) on the runoff of the Selenga and Onon for the example of two years is shown on the runoff graphs. The stripes in figures 4 and 5 mark the precipitation from
table 3 (the captions indicate the direction of air mass transfer and the amount of precipitation). Hydrographs show how the indicated precipitation increases the river flow. If precipitation is not so significant, or it falls on the peak of the previous flood, no new increase in discharge is observed, but the decline becomes more extended and gentle.

| Year | Transfer Invasion Start Date | Air mass transfer directions | Selenga river basin (average for 4 points) | Precipitation, mm Basin of the Onon River (average over 8 points) | Continue, days |
|------|-----------------------------|-----------------------------|------------------------------------------|-----------------------------------------------------------------|----------------|
| 1998 | June 13 NW                   | 18.3                        | -                                        | -                                                               | -              |
|      | June 16 NW                   | 38.7                        | 2                                        | 45.6                                                            | 3              |
| 1993 | July 7 N                     | -                           | 5                                        | 59.2                                                            | 5              |
|      | August 1 NW                  | 25.4                        | 3                                        | 27.4                                                            | 1              |
|      | August 7 N                   | 36.6                        | 1                                        | 40.4                                                            | 1              |
| 1990 | August 17 NW/NW/NOW          | 19.7                        | 4                                        | 27.9                                                            | 2              |
|      | August 26 NW                 | 44.3                        | 1                                        | 21.8                                                            | 1              |
| 1988 | June 22 NW                   | 23.1                        | 1                                        | 13.4                                                            | 1              |
|      | July 16 NW                   | 10.4                        | 2                                        | 25.3                                                            | 2              |
| 1985 | July 24 SO/SOU               | 22.5                        | 1                                        | 21.0                                                            | 1              |
|      | June 20 N/NW                 | 45.2                        | 1                                        | 12.2                                                            | 1              |

**Figure 4.** Hydrograph r. Selenga - s. Kabansk 1993.

4. Conclusion

1. The physical and geographical conditions of the territory of the Selenga and Onon river basins affect the runoff and water regime. The unity of landscape characteristics and climatic features determine the hydrological indicators of the river in its different sections, forming an overall picture of the hydrological indicators of the river network as a whole. The role of landscape areas in the formation of runoff is not the same. The largest contribution to the formation of the runoff in the study area is made by high-mountain areas with larch and pine forests, which are characteristic of the upper part of the Selenga and Onon river basins. Steppe landscapes form the lowest flow. According to the ratio of the maximum discharge of water of various origins, spring floods and summer floods, in the
basin of the Selenga and Onon rivers, groups of rivers were distinguished according to the prevailing origin of the maximum runoff.

![Hydrograph r. Onon - s. Chiron 1985.](image)

**Figure 5.** Hydrograph r. Onon - s. Chiron 1985.

2. The amount of precipitation falling on the territory of the considered basins is subject to significant interannual fluctuations. Precipitation anomalies can cover a significant part of the area under consideration. They change with certain cyclicity in time, causing periods of increased or decreased water content. The conditions for the formation of long periods of high water and low water in the studied basins, as noted above, are due to changes in the position of the frontal system separating the air masses of temperate latitudes and air masses of the summer East Asian monsoon. The dry period for 1999–2012 is due to a decrease in the role of the summer East Asian monsoon north of 30° north latitude and an increase in the influence of western transports on the formation of summer precipitation in Mongolia and the southern part of Eastern Siberia. This process is cyclical.

3. Difficulties in the analysis of hydrometeorological processes for the considered river basins are their transboundary location. The insufficient number of observation points for precipitation, their location in river valleys, cannot take into account individual, local rainfall and do not fully take into account the amount of precipitation in the mountains, allow only an approximate estimate of the course of precipitation of frontal origin.

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