The assess of the possibility of rain floods forecasting on the rivers of Western Tyva

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Abstract. This article discusses the problem of forecasting rain floods on the Elegest, Chadan and Khemchik rivers in the Western part of the Republic of Tyva. The purpose of this work is to assess the possibility of forecasting rain floods on small rivers. In this work, the following tasks are solved: collecting data on the water regime and analyzing the observed floods on the rivers of Western Tyva; collecting and analyzing data on flood-forming precipitation; statistical processing and identification of a close relationship between the flood and precipitation. In the work was used a device for correlation analysis of flood flow with measured precipitation at weather stations. A general analysis of flood-forming characteristics was carried out on the Elegest (the period from 1969 to 2018), Khemchik (the period from 1975 to 2018), and Chadan (the period from 2000 to 2018). Then was chosen daily and semi-daily precipitation on these three rivers, according to the most representative observation points: Shagonar, Hovu-Aksy and Chadan for the Elegest river; Shagonar, Teeli and Barlyk for the Khemchik river; Chadan, Hovu-Aksy and Teeli for the Chadan river. The analysis showed the relationship between the fixed precipitation at the stations and the rain flood, but it showed a weak relationship between them on the Chadan river. This circumstance is explained by the peculiarities of the formation of rain floods in the mountains and the almost complete lack of precipitation meters within the considered river basins in the valleys. However, for the Elegest and Chadan rivers, graphs of correlation between the flood height and the amount of precipitation are built, which are recommended for operational use in the Department of hydrological forecasts of the Krasnoyarsk Department of Hydrometeorological Service.

1. Introduction
Floods are characterized by non-periodic and short-term rise of the water level in the river, which can lead to catastrophic consequences and major material damage [1]. In some cases, flooding is associated with the accumulation of large water amounts in the snow cover during the winter. In other cases, heavy precipitation during snowmelt, or unusually high pre-winter moisture content of the basin, which, combined with deep freezing of the soil, makes it waterproof, has a determining influence [2]. Finally, if factors favorable to high water content and ice congestion are combined, we can observe floods becoming catastrophic [3-4].

The necessary data was collected in order to identify the possibility of developing forecasting schemes [5-8]. The work is based on the materials of standard long-term observations of flood flow and
precipitation of the hydrological network of the Krasnoyarsk Department of Hydrometeorological Service and field hydrometric work on small rivers [6].

The analysis of flood-forming characteristics was carried out for the Elegest river basin (for the period of 1969 – 2018); Khemchik (for the period of 1975 – 2018); Chadan (for the period of 2000 – 2018). Daily and semi-daily precipitation was chosen for these three rivers, according to the most representative observation points: Shagonar, Hovu-Aksy and Chadan for the Elegest river; Shagonar, Teeli and Barlyk for the Khemchik river; Chadan, Hovu-Aksy and Teeli for the Chadan river.

2. Problem statement
The problem of forecasting flood flow is currently relevant. Rain floods with a significant water level increase in the basins are observed almost annually. Particular attention should be paid to rain floods on small rivers. Since it causes irreparable damage not only to agriculture, but also to other areas of life.

3. Research questions
The subject of this study is to assess the possibility of forecasting rain floods on small rivers. The object of the research is the Elegest, Chadan and Khemchik rivers – the basin of the Yenisei river.

All the considered watercourses are located in the Asian part of Russia, the Republic of Tyva. The climate of the research area is sharply continental. Snow cover in the basins reaches only 15-20 cm, in the mountains up to 1-2 meters. Precipitation in the basins is 150-400 mm per year (in the Tyva basin - 200-220 mm, in the Todzhinskaya - 350-400 mm), in mountainous areas - from 400-600 mm to 800-1000 mm per year (Resources of surface water, 1973). The observed rivers belong to the Far Eastern type of water regime, with mild, spring high water and summer floods. River nutrition is mixed: snow and rain, with a large share of underground nutrition. During summer floods, water consumption and levels can rise to annual maximum. The summer-autumn mean water is intermittent.

3.1 The Elegest river is a left tributary of the Yenisei river. It originates on the Northern slope of the Tannu-Ola ridge at an altitude of 2400 m and flows into the Yenisei at 3454 km from the mouth. The length of the river is 177 km, the catchment area is 4810 km². The most abundant months are May, June and July. In the warm season, the water level in Elegest depends directly on the amount of precipitation - the less often it rains, the more parts of the riverbed are drying out. At the same time, the water does not fall to a critical level, and the next seasonal floods are enough to overflow its banks again in spring (Mikhailov, 1968).

3.2 The Khemchik river is a left tributary of the Yenisei. It originates on the Shapsalsky ridge at an altitude of 3122 m. It flows into the Sayano-Shushensky reservoir. The length of the river is 320 km, the catchment area is 27 thousand km². There are 654 lakes in the basin with a total area of 76.7 km². There is a dense network of irrigation channels in the upper reaches of the river. The river's catchment is located between two mountain systems – Western Sayan and Western Tannu-Ola, this is an area of insufficient moisture. In the lower reaches the river flows through the Khemchik basin, where precipitation is extremely low. The most abundant month is July.

3.3 The Chadan river is a right tributary of the Khemchik river and flows into it at 101 km from the mouth. The river is 98 km long and has a catchment area of 2200 km². The river originates on the North-Western slopes of the Western Tannu-Ola range. The upper point of the basin is the city of Jarkul (2929 m), near the city of Chadan the mark of the water boundary is 805 m. In the middle and lower reaches, the river passes through the dry Khemchik basin, which along the Chadan river valley reaches a maximum width of 60 km.

4. Purpose of the study
The purpose of this work is to assess the possibility of forecasting the characteristics of rain floods on the rivers in the Western part of the Republic of Tyva. In this work, the following tasks are solved: collecting data on the water regime and analyzing the observed floods on the rivers of the Western Tyva; collecting and analyzing data on flood-forming precipitation; statistical processing and identification of a close relationship between the flood and precipitation.
5. Research methods
In the work were applied such research methods as:

- the method of observation (collecting data on flood flow and flood-forming precipitation);
- the method of analysis (statistical processing of hydrological characteristics, identification of outstanding floods, determining the duration);
- the statistical method with the use of correlation analysis (the device of correlation analysis to identify the relationship between the characteristics of flood flow with measured precipitation at the weather stations was applied) [9].

6. Findings
In some years, there are no floods at all, and in some years, their number reaches 3 per one mean water. Floods are usually short. They may occur in July and remain until the end of September. Due to the close location of the considered basins of the Elegest, Khemchik and Chadan rivers, the floods on them are quite synchronous, taking into account the shift for the time of reaching. Only in some years, flooding is observed only on one of the rivers (Hydrology of the South of Eastern Siberia, 1966).

On all three rivers, the duration of water rising is on average 2 days. There are also rapidly developing floods of 1 day duration. The longest floods were observed on the Khemchik river in June 1986. Then the water level rose 5 days. During the observation period on the Elegest river, 9 high floods with the water level rising above 300 cm can be distinguished (1985, 1986, 1994, 1996, 1997, 2003, 2009, 2018). High flood was observed in July 2003, its water level reached 414 centimeters. During the observation period on the Khemchik river, high floods with a water level of 509 centimeters were observed in July 1985 and in June 1986, when the water level reached 530 centimeters. There were 3 maximum floods on the Chadan river, with a water level of more than 400 centimeters (2017, 2018) and 362 centimeters in 2003. Table 1 shows actual data on the maximum rain flood on the Elegest and Chadan rivers in July 2003, and Khemchik in 1985.

Table 1. Maximum rain flood on the Elegest, Chadan (July 2003) and Khemchik (July 1985) rivers.

| date (Elegest July 2003) | time | level (cm) | date (Chadan July 2003) | time | level (cm) | date (Khemchik July 1985) | time | level (cm) |
|------------------------|------|------------|------------------------|------|------------|--------------------------|------|------------|
| 26                     | 8    | 238        | 24                     | 8    | 263        | 19                       | 8    | 358        |
| 26                     | 20   | 238        | 24                     | 20   | 263        | 19                       | 20   | 361        |
| 27                     | 8    | 236        | 25                     | 8    | 264        | 20                       | 8    | 369        |
| 27                     | 20   | 260        | 25                     | 20   | 278        | 20                       | 20   | 425        |
| 28                     | 8    | 264        | 26                     | 8    | 362        | 21                       | 8    | 440        |
| 28                     | 20   | 264        | 26                     | 20   | 340        | 21                       | 20   | 465        |
| 29                     | 8    | 264        | 27                     | 8    | 323        | 22                       | 8    | 470        |
| 29                     | 20   | 331        | 27                     | 20   | 314        | 22                       | 20   | 509        |
| 30                     | 8    | 414        | 28                     | 8    | 307        | 23                       | 8    | 500        |
| 30                     | 11   | 379        | 28                     | 20   | 303        | 23                       | 20   | 474        |
| 30                     | 14   | 379        |                        | 24   | 307        |                        | 8    | 462        |
| 30                     | 17   | 359        |                        | 24   | 307        |                        | 20   | 453        |
| 30                     | 20   | 356        |                        | 25   | 307        |                        | 8    | 426        |
| 31                     | 8    | 311        |                        | 25   | 307        |                        | 20   | 425        |
| 31                     | 20   | 342        |                        |      |            |                          |      |            |

Figures 1-6 show graphs of the correlation of maximum rain floods on the rivers and precipitation at representative points. The rise in levels on the graphs is observed 11 to 12 hours after precipitation. The lack of precipitation observations on the territory of the basins of the Elegest and Chadan rivers complicates the identification of flood-forming precipitation. There are frequent cases of the lack of significant precipitation at adjacent stations during the formation of flood flow.
Figure 1. Pluviogram and the course of the water level on the Elegest river in the period from July 25 to August 1, 2003 according to observations at the stations of Shagonar, Hovu-Aksy and Chadan.

Figure 2. Pluviogram and the course of the water level on the Elegest river in the period of July 17-23, 2018 according to observations at the stations of Shagonar, Hovu-Aksy and Chadan.

Figure 3. Pluviogram and the course of the water level on the Khemchik river in the period of July 20-27, 1985 according to observations at the Teeli station and Barlyk post.
Figure 4. Pluviogram and the course of the water level on the Khemchik river in the period of July 18-23, 2018 according to observations at the Teeli station and Shagonar post.

![Pluviogram and water level course](image1)

Figure 5. Pluviogram and the course of the water level on the Chadan river in the period of July 24-29, 2003 according to observations at the stations of Teeli, Hovu-Aksy and Chadan.

![Pluviogram and water level course](image2)

Figure 6. Pluviogram and the course of the water level on the Chadan river in the period of July 18-24, 2018 according to observations at the stations of Teeli, Hovu-Aksy and Chadan.

For the practical use, we recommend to build the correlation of the total rise of the water level on the Elegest, at Hovu-Aksy and precipitation amounts for the previous 12 hours, see figure 7. For the practical application, it is recommended to build the correlation of the flood water level on the Chadan river near the city of Chadan and the amount of precipitation, see figure 8 [11]. A rare network of precipitation observation points, located on the arid bottom of the Khemchik basin, makes it difficult to detect flood-forming precipitation. There are frequent cases of the lack of significant precipitation at weather stations during the formation of flood flow on the Khemchik river. From the whole variety of connections between the flood flow characteristics and the amount of precipitation in the summer-autumn period, no suitable prognostic schemes have been identified [12]. To identify them, a deeper and more comprehensive analysis is required.

![Correlation of water level and precipitation](image3)

Figure 7. Correlation of the total rise of the water level on the Elegest near the village of Hovu-Aksy and precipitation amounts at the Shagonar weather station for the previous 12 hours.
Figure 8. Correlation of the flood water level on the Chadan river near the city of Chadan and the amount of precipitation at the Chadan weather station.

7. Conclusion
As a result of the study of the Elegest and Chadan rivers were built graphical correlations of the flood height and amount of precipitation, which can be recommended for the use in the Department of hydrological forecasts of the Krasnoyarsk Department of Hydrometeorological Service. For the Khemchik river, we can observe a weak correlation of precipitation recorded at the stations and the fact of rain flooding. This circumstance is explained by the peculiarities of the formation of rain floods in the mountains and the almost complete lack of precipitation meters in the valleys of the considered river basins. For the reliability of the development of floods on the rivers, it is necessary to consider the whole catchment, and not its separate parts, because the combination of landscape characteristics and climatic features determine hydrological indicators of rivers at different sections, forming the general picture of the hydrological indicators of the river network as a whole [2, 13].

A comprehensive analysis of the characteristics of forming river flow: data on precipitation in the river basin; air temperature, soil; degree of moisture, soil freezing; data on the height of snow cover for a long period when using the software will help to make a more detailed analysis and forecast of flood flow [14, 15].

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