Modeling of extreme hydrological events in the Baksan River basin, the Central Caucasus, Russia

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ABSTRACT

High mountain areas are prone to extreme hydrological events, and their study is especially important in the context of ongoing intensive deglaciation. The aim of the study is to explore actual and potential extreme hydrological events in the high-altitude part of the Baksan River basin, connected with the lake outbursts near the Bashkara Glacier and estimate impact of Bashkara Lake outburst on the discharge increasing in the different parts of the study basin.

BACKGROUND

The Baksan River basin is located within the Russian Central Caucasus, the highest part of the Greater Caucasus. This region is one of the major centers of glaciation in the Caucasus. Glaciers cover 232 km2, about 60% are located at the southeast slopes of Mt.Elbrus.

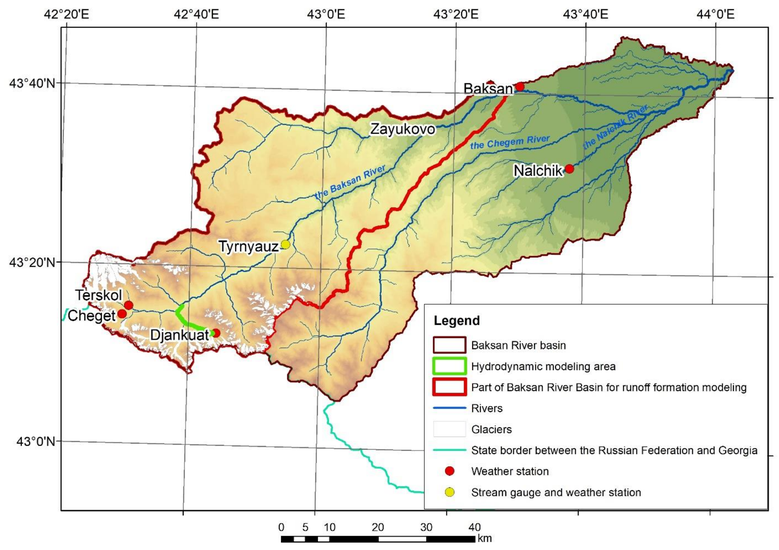

Figure 1. Study area

Bashkara Lake is located in the upper reaches of the Baksan River, in the headwaters of the Adylsu River between the right lateral moraine and the valley Bashkara Glacier. During the night from August 31 to September 1, 2017, there was an overflow and the consequent outburst of Bashkara Lake. The immediate trigger of the lake outburst was an extremely heavy rainstorm accompanied by strong over wetting of moraine dam.

DATA AND METHODS

We used a composition of the models ("model chain") to simulate the Bashkara Lake outburst flood and its impact on the Baksan River hydrograph. Two-dimensional hydrodynamic model STREAM_2D was applied to simulate the outburst process and flood wave movement downstream the Adylsu River (river length 11.5 km, basin area 101 km2). To take into account runoff process formation in the all high mountain part of the Baksan River basin from the upper reaches to the Zaykovo gauge (Baksan River length - 87 km, basin area - 2100 km2) we used ECOMAG runoff formation model. Outburst flood discharges from the system of the lakes near the Bashkara Glacier, simulated on the base of hydrodynamic model, were set as additional contribution into runoff formation model. Separate datasets were prepared for each type of model (fig.2).

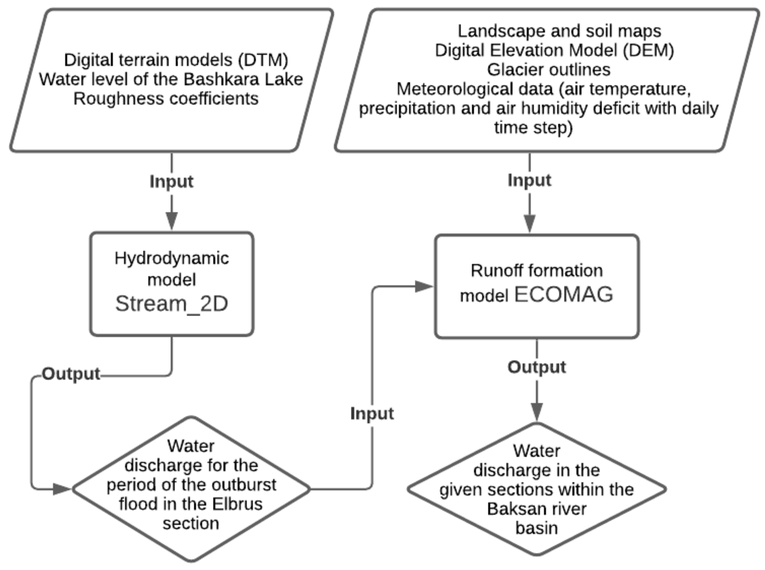

Figure 2. Model chain

In this research a model "chain" of a hydrodynamic model and runoff formation model is adopted to simulate a glacier lake outburst flood (GLOF) from Bashkara Lake (the Central Caucasus, Russia) and its effect on the downstream. In addition to an actual GLOF event, that occurred on September 1, 2017 and led to casualties and significant destruction in the Adylsu and Baksan River valleys, possible scenarios for the re-outburst of lakes and climatic scenarios are considered.

RESULTS

Several scenarios were considered while modeling the formation of runoff in the Baksan River basin: the superposition of the actual outburst flood on the autumn and summer runoff, the overlap of a possible repeated outburst flood on the contemporary autumn and summer runoff, as well as modified runoff regime according to IPCC scenarios (increase in background air temperatures by 2° C, increase in precipitation by 10% in winter and a decrease by 10% in summer). Based on the results of scenario simulations, the impact of the outburst flood on the Baksan River discharge significantly decreases downstream. So, according to the modeling results for September 1, 2017 outburst, in the Elbrus settlement on the Baksan River at the mouth of the Adylsu River the outburst flood contribution into the total Baksan River water discharge accounts for 45% of the peak discharge, in the Tyrnyauz city (40 km downstream) - 30%, in the Zayukovo village (70 km downstream) - 20% (fig 3a).
If the outburst of the lakes in 2017 overlap summer annual peak flow, then both base and total water discharges would be higher, while the GLOF contribution to the total water discharge at the indicated sections would decrease to 38%, 26 % and 17%, respectively (fig. 3a-d).
An assessment of the contribution for a potential GLOF to the discharge in the Baksan River showed that, its influence is not so significant as for the occurred GLOF. The contribution of the outburst flood varies from 18% near Elbrus settlement to 5% near Zayukovo under the "autumn" scenario (fig 3c), from 13% to 5% under the "summer" scenario, depending on the distance from the outburst site (fig 3d).
Under scenario with changed meteorology, a rise in runoff in winter and a drop in summer is projected (fig 3e-h). The contribution of outburst flood into the total peak discharge decreases. For example, for the September 1st, 2017 GLOF, under changed meteorological conditions, the contribution of the outburst near Elbrus settlement would be 41%, and would decrease to 30% near Tyrnauz in summer, and correspondingly from 42% to 30% in autumn. The contribution of the repeated outburst flood from the total discharge will decrease in the village of Elbrus to 16%, in Tyrnyauz at 40 km - 10%, in Zayukovo at 70 km - 6%, in the "autumn" (fig.3e) and "summer" scenarios (fig 3f).
In all cases, the contribution of the GLOF to the peak discharges of the Baksan River is less in summer comparatively to autumn conditions. In case of projected change in meteorological conditions the role of the base runoff in total peak flow of the Baksan River increases under the "autumn" scenario, and decreases under the "summer" scenario.

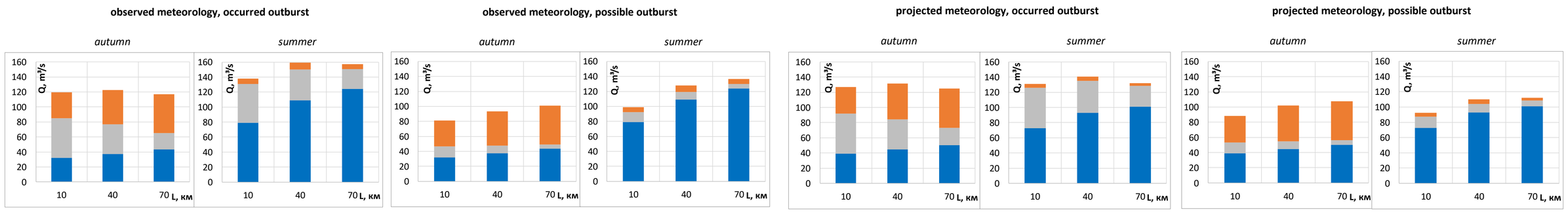

Figure 3. Base flow (blue), contribution of the precipitation (orange) and contribution of the outburst flood (grey) to an increase in daily water discharges along the Baksan River with observed/ and changed meteorology : a/e) occurred outburst of September 1st, 2017, b/f) the same GLOF peak discharge in case of summer conditions; c/g) re-outburst in autumn, d/h) re-outburst in summer.

CONCLUSIONS

The synthesis of the STREAM_2D hydrodynamic model and the ECOMAG runoff formation model in the model chain showed the possibility of combining them to assess the scale of extreme hydrological events in mountainous areas.
The range of possible impact of the outburst flood on the peak water discharges in the receiving Baksan river was assessed.
Research to assess climate change impact on river runoff in the high-mountainous part of the Baksan River over a long-term period, taking into account changes in glaciation in the basin, is necessary further step.
The results obtained in the work indicate the need for a comprehensive assessment of both the flood wave movement and the accompanying meteorological situation in the mountain river basins, which should be taken into account both in the analysis of events that have already occurred and in the development of forecast and warning systems.