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Hydraulic Modeling of a Glacial Lake Outburst Flood (GLOF) Scenario at the River Biya

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Abstract

Climate change is increasing the severity of numerous natural hazard processes: rising global air temperatures have, over the past decades, led to an acceleration of glacial retreat in many places around the world, causing increases in volume at many existing glacial lakes and the development of new ones. The increased risk of glacial lake outburst floods (GLOFs) endangers human infrastructure downstream. Hydraulic modeling is a vital tool in the process of GLOF risk assessment. The affected areas are usually difficult to access, hence the model inputs are often derived from remote sensing. The present study simulates a major scale GLOF event at the River Biya in the Siberian Altai Mountains. The propagation of possible hydrographs was modeled alongside mobilized grain sizes. Results like these can be used to anticipate the extent of a flood event of a certain magnitude and to evaluate whether any infrastructure is endangered.

Keywords: GLOF, cataclysmic flood, remote sensing.

1. INTRODUCTION

Like other parts of the Altai Mountains, part of the Biya's 300 km channel was shaped by a cataclysmic flood event triggered by the outburst of Lake Teletskoye about 37.5 thousand years ago (Baryshnikov et al. 2016). The aim of this study was to simulate flood wave propagation of this major scale scenario mobilized grainsizes as indicators for the damage potential of such an event. The river geometry was generated from modern day ASTER GDEM (v3) and is used as a basis for hydraulic modeling (HECRAS 5.0.7) of the reconstructed GLOF scenario.

2. RESULTS AND DISCUSSION

The simulated GLOF hydrograph was designed as a symmetric linear rise/fall hydrograph (Watson et al. 2015) with a peak of 2 Mio m^3s^{-1} and a duration of the rising stage of 7 h to approximate the estimated total release volume of around 49 km^3 of the event (main scenario, Section 2.1). Flood wave propagation was modeled for nine additional scenarios (see Section 2.2).

2.1 Modeling results of the 'main scenario' (inflow peak: 2 Mio m^3s^{-1})

Figure 1A shows the spatiotemporal development of the modeled GLOF-wave. The white dashed lines illustrate the difference between the inflow (peak: 2 Mio m^3s^{-1}) and outflow (peak: 1.03 m^3s^{-1}) hydrograph. There are clear retention effects, mainly between rkm 120 and 230.

The critical diameter (D_{50}) for sediment movement of coarse materials (Fig. 1B: upper Biya) was estimated using depth and velocity information from the HEC-RAS simulations based on the approach described by Van Rijn (2019). Figure 1B gives an impression of the force of the simulated GLOF events that is particularly strong within the narrowest, steepest section in the beginning of the upper Biya, where the simulated flood wave has the potential to mobilize rocks of diameters higher than 15 m.

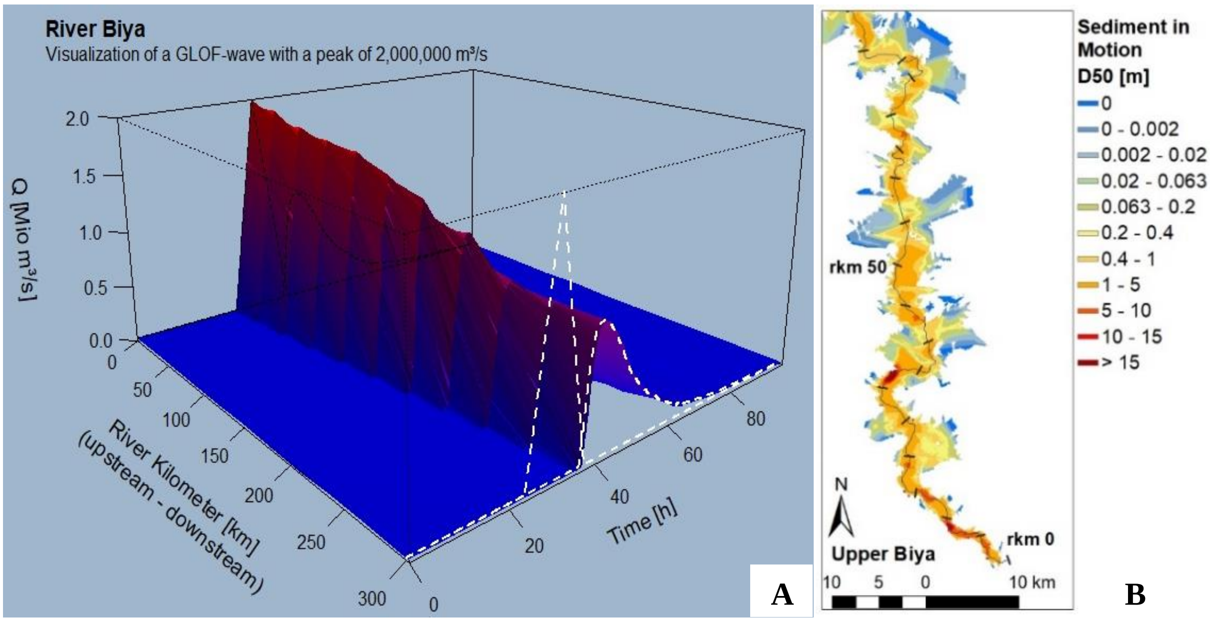

Fig. 1. Modeling results of the performed GLOF simulations.

2.2 Other results

In total, simulations for ten hydrographs were performed. These hydrographs differ from each other regarding peak discharge and duration. They were designed, to represent comparable scenarios regarding total release volume approximating the described GLOF scenario. While the peak of the moderate simulation scenario (0.3 Mio m^3s^{-1}) was only reduced by 12%, the simulated peak reduction of the most extreme scenario (3 Mio m^3s^{-1}) amounted to 61% (Table 1).

Table 1

Modeled hydrograph scenarios (peak of the inflow hydrograph vs. reduction at the outflow)

Peak Q (in)	[Mio m^3s^{-1}]	3	2.7	2.25	2	1.75	1.5	1	0.75	0.5	0.3
Peak reduction	[%]	61	58	53	48	44	41	28	26	17	12

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