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Two dimensional modeling of large glacier lake outburst floods (GLOF) in the Patagonian Andes and the Pamir/Alay range

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Very large debris flows from glacier lake outburst floods (GLOF) can be highly destructive due to large amounts of released water. Related peak discharges generally are several orders of magnitude larger than the peak flows of rainfall and snowmelt floods in the same basin. Maximum drain volumes can reach tens to hundreds of millions cubic metres and run-out distances of 200 km have been documented.
Considering the devastating potential emanating from such water-driven processes, it is of great importance to improve the understanding of involved processes and dynamics. However, due to the difficulty of directly measuring high-magnitude mass flows, it is challenging to approach the lack of information. The definition of flow parameters is needed for numerical modelling, which provides a valuable tool for quantitative prediction of large-scale floods. Thereby flow parameters need to be adjusted and calibrated based on well-characterised events, and perhaps even more importantly, models have to be fully validated with adequate field studies.
Although significant advances have been achieved with respect to the flood routing models, computation capacities and digital terrain models, simulating large-scale floods in steep terrains remains very demanding. The high peak discharges combined with high velocities, highly turbulent flow conditions and sediment entrainment are just some aspects that make modelling challenging. Few studies exist where large GLOFs or lahars were systematically modelled using two-dimensional dynamic flow models.
This study contributes to the field of modelling and understanding of large-scale lake outburst floods in the Patagonian Andes and the Pamir/Alay range. In Patagonia, we analyzed a glacier lake outburst flood at Tronador (41°12'S; 71°49'W), that occurred in May 2009, with the purpose to gain information about flow rheology, flow dimensions and dam break mechanism. Sediment size distributions of deposited material and of the remains of the dam were assessed, areas of scour and deposition identified and flow volume and peak discharge estimated. With the field data collected, sensitive model parameters could be defined and the estimated flow hydrograph was then numerically routed. For model validation, calculated inundation depths were compared with in situ measured ones.
The calibrated and validated program can be used to simulate a range of possible scenarios of potentially dangerous glacier lakes. In Tajikistan scenarios of glacier lake outburst volumes between 500,000 and 30 million cubic metres were modelled in order to delineate hazard zones. The results have shown that debris flows in the order of 107 to 108 m3 are a major challenge for currently available model and computation environments but that the observation can be replicated by adequate selection of input parameters and model setup. Maximum inundation depths and flow velocities of realistic scenarios provided by the model results have proven to be very useful for effective prevention measures.