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Revisiting the catastrophic 1941 outburst flood of Lake Palcacocha (Cordillera Blanca, Peru)

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In 1941, the glacial Lake Palcacocha in the upper Cojup Valley of the Cordillera Blanca (Peru) drained suddenly for unknown reasons, thereby eroding a massive, 56 m deep breach in its moraine dam. Consuming Lake Jircacocha on the way, the resulting mass flow reached the town of Huaraz 23 km downstream, resulting in at least 1800 fatalities and major destruction. Even though Lake Palcacocha has lost most of its volume during this event, it has subsequently grown due to glacier retreat over the past decades up to a current volume of > 17.5 million m^3 and is now again considered a threat for the downstream communities, including the city of Huaraz.

The present work focuses on a GIS-based reconstruction of (1) the topography and lake volume before and after the 1941 event; (2) the volumes involved and the changes in topography induced by the event, including the breach formation at the dams of Lake Palcacocha and Lake Jircacocha, as well as the basal and lateral erosion of the flow channel; and (3) the simulation of the process chain with the GIS-based open source computational tool r.avaflow, designed for the simulation of two-phase mass flows and process chains.

The topographic reconstruction, based on a recent 5 m DTM, contemporary field and aerial images and reports, results in pre-event lake volumes of 9.4 million m^3 (Lake Palcacocha) and 3.3 million m^3 (Lake Jircacocha), corresponding well to some of the earlier estimates. 2.0 million m^3 of sediment from the moraine dam of Lake Palcacocha, and 2.8 million m^3 of the landslide dam of Lake Jircacocha were eroded and incorporated into the flow, but mainly deposited again shortly below the dams. A maximum of 11.4 million m^3 of material were eroded form the base and the slopes of the flow channel, most of it (up to 7.3 million m^3) in the lower, steeper portion of the flow path directly upstream from the city of Huaraz, where the channel bed was lowered by up to 50 m, according to eyewitnesses. However, these are only maximum estimates, assuming that all erosional features visible in the recent DTM are related to the 1941 event.

The r.avaflow simulation reproduces the observed and reconstructed patterns (impact area, topographic changes, and involved volumes) at a reasonable degree of empirical adequacy, however with parameter sets optimized to meet the observation. Simulated travel times correspond to those of previous simulations for a comparable event.

Besides the better understanding of the processes and volumes involved in one of the most destructive glacier lake outburst events in historical times, the insights gained from this reconstruction shall serve as a basis for a deeper understanding of this type of extreme event, in order to better anticipate possible future events. Still, predictive simulations of future events are highly challenging as they have to rely on multiple scenarios, based on guiding parameter ranges derived from the back-calculation of multiple well-documented events of comparable characteristics and magnitude.