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The Devdorak ice-rock avalanche and consequent debris flow from the slope of Mt. Kazbek (Caucasus, Georgia) in 2014

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We have studied catastrophic glacial events of 2014 in the Kazbek-Dzhimaray massif, Caucasus Mts., Georgia. The first event is a so called "Kazbek blockage" of the Georgian Military Road, on 17 May 2014, which formed as a result of an ice-rock avalanche onto the Devdorak Glacier, and is similar to blockages which occurred in the same location in the 18th-19th century. The second event is a consequent debris flow on 20 August 2014.
In May, June 2014 and September 2015 we conducted three field investigations of the disaster zone, which includes Devdorak Glacier, Amilishka and Kabakhi river valleys, the Terek River valley near the Kabakhi River mouth, and a temporary lake.We analyzed field research data, interpreted SPOT 6, Landsat-8 OLI, Terra ASTER, and Pleiades satellite imagery, as well as post-disaster helicopter imagery. To assess dynamic features of the ice-rock flow on 17 May 2014, we measured valley crossections with Bushnell laser ranger. In 2015 we have marked a 180-m baseline for ground stereosurvey and made a stereopair of the Devdorak glacier terminus from a distance of 700 m.
The 17 May 2014 ice-rock avalanche initiated at 4500 m. a.s.l. It collapsed onto the tongue of the Devdorak Glacier which reaches down to 2300 m a.s.l. Downstream of the tongue, the avalanche transformed into an ice-rock "avalanche flow" which blocked the Terek River valley. The traffic on Military Georgian Road (part of E117 highway) which connects Russia with Georgia was stopped. 7 people were killed in their vehicles. The total length of the ice-rock avalanche and the subsequent flow was over 10 km. A temporary lake formed in the Terek river valley, reaching 300 m in length, and over 10 m in depth. For several hours, the lake was threatening another debris flow downstream the Terek river valley. According to field estimates at the Devdorak glacier tongue and in Amilishka, Kabakhi and Terek river valleys, the volume of the transported ice-rock avalanche mass, which deposited in the middle and lower course of the valley below 3000 m a.s.l. was about 2 million cubic metres, while the ice content in the deposits reached 25-30%. It is planned to assess the volume of the trigger mass in the initiation zone later. The flow went along the valley with characteristic superelevations and run-ups, as it moved from one valley side to the other. We identified six superelevaions in fresh deposits, with differences of up to 45 m in flow height on the left and right valley banks. Instrumental measurements of superelevations and subsequent calculations yield the flow velocities of over 200 km/hour. These results lead to a reassessment of similar events which occurred in this valley in 18-19th centuries. Previously the trigger of these events was supposed to be the ice accumulation during surges of Devdorak glacier with subsequent temporary damming of the Amilishka River valley. The analysis of the 2014 event demonstrates that a similar trigger was possible in the past: an ice-rock avalanche onto Devdorak glacier tongue from significantly higher locations.
Following the field data analysis, we issued a warning through mass media on 12 August 2014, forecasting a high risk of a new glacial disaster in this site and a new blockage of the Terek River valley and of Military Georgian Road. This forecast came true on 20 August 2014: a glacial debris flow reached the Terek River valley, and partially buried the Dariali hydropower station (under construction), the customs and border control buildings. Three people have been killed. We studied the deposits of this debris flow and morphology of the gully. The deposits entrained by the flow were previously deposited by the ice-rock avalanche of 17 May 2014. The debris flow started after shower rains. The debris flow-gully has a box-like crossection. At the confluence of Amilishka and Chach rivers it reached 30-32 m in width, and eroded the deposits of 17 May 2014 by 7 m. The channel slope at this location was about 7 degrees. Remnant ice in the transit zone has nearly melted by September 2015; however, the ice remains in the deposits near the glacier tongue and in the ice-rock avalanche deposits on the tongue.
We have registered the advance of one of the termini of Devdorak Glacier. It moved forward by about 200 m from summer 2014 to September 2015, and became significantly higher. This part of the glacier was overloaded by the

ice-rock avalanche deposits which provoked its advance, and should be closely monitored as it can raise the debris flow activity further. The hazard of new ice-rock avalanches and debris flows in the Devdorak gorge remains high. We have developed recommendation on the installation of an early warning system, continuation of glacier hazard monitoring, and suggestions on the construction of a road tunnel to mitigate the risk and avoid casualties in the future.