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Evaluation of snow avalanches contribution into glacier accumulation

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The evaluation of snow avalanches' contribution into mountain glacier ice accumulation with a lack of direct observational data on snow avalanches and the amount of avalanche-drifted snow deposited on glaciers implies a highly relevant task delivering the important knowledge of one of the least studied components of the glaciers mass balance and it is affected by changing climate. However, in many cases it is not possible to apply commonly accepted methods for the evaluation of avalanche accumulation on the glaciers due to poor data availability and lack of possibilities to obtain the required field data.
We present a new approach for the numerical estimation of snow avalanches contribution into accumulation on glaciers without carrying out detailed terrestrial snow surveys based on DEM and meteorological data analysis using GIS and numerical modeling of snow avalanches. Our approach consists of the following steps: DEM analysis; avalanche release, track and run out zones assessment; meteorological data re-calculation for the avalanche release zones; indication of active avalanche release zones and snow fracture height in them during the analyzed winter period; avalanches volumes assessment; numerical simulations of avalanches in three-dimensional terrain using avalanche dynamics program RAMMS; verification – comparison of modeling results with field observations and remote sensing data; evaluation of the contribution of snow avalanches, coming from outside the glacier limits, into the seasonal accumulation on the glacier.
Our approach was tested on the Batysh Sook Glacier, Tian Shan. A case study was realized for 2015/2016 balance year based on the data of regular meteorological observations from distance nearest to the glacier meteorological station (Kumtor Tien Shan) and high-resolution DEM obtained from a drone in July 2016. To evaluate the contribution of snow avalanches, coming from outside the glacier limits, into the seasonal accumulation, we estimated release zones that were most probably active during the winter season 2015/2016 based on the regional dependences of avalanche activity on relief and climate characteristics. We performed the numerical simulation of avalanches that were most probably released during the winter period 2015/2016 using RAMMS and estimated avalanches run out distances, flow velocities and deposition heights. RAMMS simulation results (run out distances and deposition heights) were compared with field measurements (July 2016). The simulation results were sufficiently accurate. The outlines of avalanches deposits as well as deposition heights were relatively well reproduced by RAMMS using predicted input model parameters taking into account the time difference with field measurements. The estimated total volume of avalanche drifted snow deposited on the Batysh Sook Glacier during the winter season 2015/2016 was 75 000 m3. Snow avalanche accumulation on the Batysh Sook Glacier during the winter season 2015/2016 turned out to be 13+/-4 % of total accumulation.
Snow avalanches can be a significant accumulation resource, which is not usually counted in mass-balance observations. The results of numerical assessment of snow avalanches contribution into glacier accumulation possess a high scientific significance due to high sensitivity of all components of glacial mass balance to climate change.