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Hydrology

Catastrophic Phenomena in the Caucasian Nival Belt

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ABSTRACT. The dynamics of glacial catastrophes in the Caucasian nival zone for 1776-2002, their stimulating factors and results are studied. The hazard assessment of glacial catastrophes and elaboration of protective measures are highlighted. *© 2007 Bull. Georg. Natl. Acad. Sci.*

Key words: *glacier, ablation, mudflow, glacial pulsation.*

The existence of glacial and nival (eternal snow) zone is one of the distinguishing features of the Caucasus natural landscape. It mainly covers the adjacent territory of the Caucasus range watershed, which is located at the elevation of 3000-5000 m a.s.l. This zone is characterized by severe natural conditions with cold long winter time and short cool spring. Therefore one of the major peculiarities of its landscape is the existence of seasonal or everlasting snow cover and glaciers. Nival zone is the main nutrition source of freshwater resources and rivers, which is a great natural wealth. At the same time this zone is characterized by frequency of natural disasters, for instance glacier catastrophes. According to hazard rating glacier catastrophes belong to the strongest category: their characteristic feature is big velocities - 50-120 m/sec, 20-100 mln m^3 volume of glacial drift, big destructive force of about 200-300 t/m^2. Glacier avalanche destroys and buries everything it meets during movement, blocking gorges with 100-120 m thickness snow and glacial drift. In spite of its fierceness, it is possible to avoid glacier catastrophe. To this end it is necessary to study its nature and make an assessment of its possible manifestation. Glacier catastrophes occur during glaciers pulsation, i.e. during growth (movement forward) and decline (retreat) periods. Therefore catastrophe-causing factors differ from each other. In the growth period catastrophe-causing factor is a huge mass of glacier which is mainly estimated in the form of ice. It differs from other glaciers. For example, the catastrophe starts on the Kolka glacier when its thickness reaches 150 m, and on the Devdoraki glacier exceeds 75 m, inclination of glacier surface (a) in the cited case totals 10 and 16°, respectively. Thus the larger the glacier surface inclination, the less its thickness is and it represents glacier's critical parameter (h_{cr}) which is calculated using the old [1] and renewed formula:

$$h_{cr}=172\,\alpha^{-2}[(0.9+\rho)^6+(0.99+\rho^2)^6],$$
$$h_{cr}=172\,\alpha^{-2}\cdot 10^{0.1+1.93\rho}, \qquad (1)$$
$$h_{cr}=172\,\alpha^{-2}\cdot e^{0.23+4.44\rho}.$$

During the period of glacier retreat a decrease of the values of its indices takes place. Nevertheless, catastrophe might happen. It is caused by the action of other stimulating factors [2]. To them belong earthquakes (Devdoraki glacier, 1832), rock-avalanche fall on the glacier surface (Abano glacier, 1909), accumulation of a great amount of water from melted snow, rainfall and glacier in glacier fractures, ice pockets, ice shafts, interglacial hollows, subglacial cavities (Kolka glacier, 1969 and 2002). As a result of filling the mentioned forms with water the stability of glacier mass breaks, resulting in catastrophic events, origination of floods and glacial debris flows. During such hazards maximal water discharge (Q_m) is calculated by the formulas:

At the breakthrough area $Q_m = 1.9\,Bh^{3/2}$. (2)

On transition site $Q_{mi} = \dfrac{L}{L+L_i}\cdot Q_m$, (3)

where B denotes the width (m) of the newly cut glacier bed at the breakthrough area; h is the depth of breakthrough (m); L is the length of the expected dam (km); L_i is the distance from the breakthrough area to any section of transition site.

The boundary of the destructive force spreading (l km) of glacial air wave and the distance passed by glacial avalanche (L_{tr}) is calculated by formula [1],

$$L_{tr} = \frac{W}{b \cdot h_{cr}}, \qquad (4)$$

$$l = 1.6(0.16\sqrt{W} + \sqrt[3]{W}), \qquad (5)$$

where W *is* the volume of ice avalanche (m^3); b is the average width of the bottom (m).

The formulas (1)-(5) were checked and satisfactory results have been obtained [1]. This is also proved by completely new data about the catastrophe on Kolka glacier which took place on 20 September, 2002 [2]. It was caused by colossal accumulation of rain water and water formed as a result of melted snow and glacier. Accumulated water surged up the glacier and turned it into catastrophic mudflow at a distance of 12 km. To check this we consider the results of estimated characteristics of glacial catastrophe that occurred on the Kolka glacier based on the initial data and those obtained from literature sources.

The length and width of glacier in the glacier circus is L=3.5 km, B=750 m and b=200 m, respectively, glacier area is f=2.6 km^2, inclination of glacier surface is $\alpha = 8°$ (7-9° [2]), volume of the Kolka glacier $W_{gl}=1.1 \cdot 10^8$ m^3, water maximal discharge at the breakthrough site, formula (2) Q_m = 500000 m^3/sec, density of glacial water $\rho = 0.6$ g/cm^3, glacier's critical thickness, formula (1) h_{cr}= 50 m, the traveled distance of glacial water mixture, formula (4) L_{tr}=11 km (12 km [1]) and the boundary of destructive force of glacial wave spreading (l) formula (5) l=3.2 km (3.0-3.5 km [2]).

According to the calculated results the distance traversed by avalanche water-diluted mass flow and that of spreading air wave destructive force coincide with actual (given in brackets) values.

Thus the obtained results represent a scientific basis for technical and economic grounding of prevention of avalanche hazards. The following recommendations are given to deal with avalanches: an increase of glacial ablation or melting, conduit of channels in the obstruction mass to let impounded water pass, to dig a tunnel at the foot of the opposite slope, etc.

ჰიდროლოგია

კატასტროფული მოვლენები კავკასიონის ნივალურ ზონაში

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ნაშრომში დახასიათებულია 1776-2002 წლებში კავკასიონის ნივალურ ზონაში მყინვარული კატასტროფის დინამიკა, მათი მასტიმულირებელი ფაქტორები და შედეგები; შემოთავაზებულია ემპირიული ფორმულები, რომელთა დახმარებით განისაზღვრება მყინვარის კრიტიკული სისქე, მყინვარის ჩამონაქცევით წარმოქმნილი ჰაერის ტალღის დარტყმის ძალა და გავრცელების მანძილი, ხეობის ჩახერგვით წარმოშობილი დაგუბებული ტბის გარღვევასთან დაკავშირებული კატასტროფული წყალმოვარდნების წყლის მაქსიმალური ხარჯის გამოთვლა გარღვევის ადგილას და მდინარის დინების ტრანზიტულ უბნებზე. მოყვანილია შემოწმების შედეგები და რეკომენდაციები საშიშროების თავიდან ასაცილებლად.

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