

## Volume changes of Elbrus glaciers from 1997 to 2017

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This study is dedicated to the analysis of changes in area and volume of the Mt. Elbrus glacier system, Central Caucasus during 1997-2017. It is based on helicopter-borne ice thickness measurements and comparison of high resolution imagery and two DEMs of 10 m resolution. More than 250 km of ice thickness GPR profiles with reliable reflections were obtained. Volume of Mt. Elbrus glaciers was  $5.03 \pm 0.85 \text{ km}^3$  of ice in 2017. Our results show that 68% of the total ice volume is concentrated below 4000 m a.s.l. where the average ice thickness was  $44.6 \pm 7.3 \text{ m}$ , 18 % of the volume is within 4000-4500 m ( $41.2 \pm 7.3 \text{ m}$ ) and just 14% is above 4500 m ( $29.7 \pm 6.65 \text{ m}$ ). Glacier covered area at Mt. Elbrus decreased by 10.8% over the 20 years from  $125.76 \pm 0.65 \text{ km}^2$  in 1997 to  $112.20 \pm 0.58 \text{ km}^2$  in 2017. Over the same time the volume of Elbrus glaciers decreased by 22.8%.

Glacier-wide mass balance of Elbrus glaciers was  $-0.52 \pm 0.04 \text{ a-1 m w.e.}$  in 1997-2017. Increasing rates of area and mass losses comparatively to 1957-1997 period may be explained by rise of air temperature accompanied by increase of short-wave solar radiation. Mass balance of individual glaciers is controlled by hypsometry, aspect and debris cover. West-oriented glaciers demonstrate less negative balance whereas east-and south-oriented – most negative. Among individual glaciers most negative average mass balance of  $-0.92 \pm 0.06 \text{ a-1 m w.e.}$  was registered for the east-oriented Djikiugankez. This glacier contains 28% of the total Elbrus glacier system ice volume and most of its volume is concentrated below 4000 m a.s.l. Just one small glacier at the western slope demonstrated mass gain. Our results are in good agreement with the long term direct mass balance measurements on two benchmark glaciers in Caucasus, Djankuat and Garabashi. The rate of Elbrus glaciers mass losses has doubled in 1997-2017 comparatively to 1957-1997 period.

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