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Geophysics

Current Climate Change Impact on the Mtkvari (Kura) River Basin Glaciers Degradation

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(Presented by Academy Member Tamaz Chelidze)

From the beginning of the 21st century, glaciers studies are more important in Georgia. This is mainly provided with the degradation of the glaciers under current climate change that preconditions several catastrophic events: sea-level rise, worsening of glacial origin natural disasters risks and catastrophic phenomena, water balance changes etc. Impact of current climate change on the glaciers and their rapid degradation is studied determining the changes of the characteristics of the glaciated basins (number of glaciers and area), the melting statistics of small glaciers (area in the range of 0.1 to 0.5 km^2) and the retreat of large glaciers (area > 2 km^2) that are effective indicators of the regional climate change. In order to provide a scientifically based answer to the problem of glaciers melting under the impact of current climate change, it is necessary to use high-resolution satellite remote sensing (SRS), because it makes possible to study simultaneously glaciers for large regions with the necessary resolution and accuracy within limited resources and time. This is achieved based on the complex use of historical data, glacier schemes from the catalogue, existing fieldwork materials and the application of expert knowledge. In presented work, r. Mtkvari basin glaciers degradation due to the impact of the current climate change is studied. Changes in the glacier basins and melting statistics are researched. This is preconditioned by the fact that r. Mtkvari basin is the most important river basin of eastern Georgia and such detailed study has not actually been carried out for any river basin in Georgia. © *2020 Bull. Georg. Natl. Acad. Sci.*

River basin, glaciers, climate change, satellite remote sensing

Scientific interest in the study of glaciers was pronounced three centuries ago. It was caused by different factors: a study of the safety of transportation, research of scientific facts about the past glaciation age and investigation of dynamics of glaciers.

At present, to the listed factors, glaciers research necessity is stipulated by the water provision, an indication of climate change impact on glaciers at regional and global scales, surface water level rise in oceans/seas, increasing glacial origin natural disasters.

It would be mentioned that the problem of the cryosphere changes is the priority problem of IPCC studies. UN adopted the special resolution on the problem of high mountains as the priority including glacier degradation due to climate change.

The World Meteorological Organization (WMO) held High Mountain Summit in Geneva (Switzerland) at the end of 2019. At the summit work, the priority importance was assigned to cryosphere problems. Georgia was presented by the presentation of the author's of this article – *Research Results of High Mountain Glaciers Degradation in Georgia for the Last 50 Years.*

The glaciers of Georgia are located in high mountains – the Great Caucasus Range (maximum elevation 5 170 m). Glaciers are important climatic and economic resources of Georgia. They contain a large amount of freshwater and play a decisive role in the formation of water regime and regional climate.

The scientific research of the glaciers of Georgia began in 1860. This was important for assessing natural hazard risks of a glacial origin, public safety and transportation.

In 19th–20th centuries, the observations on glaciers were carried out primarily through field-works. The researchers from various institutions: Transcaucasian Hydrometeorological Research Institute, Institute of Geography of the Georgian Academy of Sciences, National Meteorological and Hydrological Service of Georgia conducted a significant amount of work. The relevant results are received and published [1-3].

The results of a 100-year glaciers study in Georgia were summarized and presented in various publications and editions of the glacier's catalogue of the former Soviet Union (hereinafter referred to as catalogue) [4]. In view of the importance of this catalogue, it was later placed in the World Glacier Inventory (WGI).

Since the second half of the 20th century, more attention has been paid to the study of glaciers due to current climate change resulted in significant degradation of glaciers and worsening of natural disasters of a glacial origin. Suffice it to recall the glaciological collapse in May and August 2014 in the Amalie-Devdoraki gorge, on July 2018 in Nenskra valley and in July 2019 in Mestia-Chala gorge, which was accompanied by human casualties and significant material losses. It is necessary to evaluate the risks of these events to prevent/reduce them.

At present, to the listed factors, glaciers research is stipulated by the necessity of water provision sustainability, an indication of climate change at regional and global scales, surface water level rise in oceans/seas, increasing frequency and intensity of the glacial origin natural disasters.

In order to provide a scientifically based answer to the problem of glaciers melting under the impact of current climate change, it is necessary to use high-resolution SRS, because it makes possible to study simultaneously glaciers for large regions with the necessary resolution and accuracy within limited resources and time.

Technological and methodological approaches based on SRS proved to be effective for glaciation studies. Therefore, to solve the planned tasks and goals, the methods tested both by other researchers [5] and developed by the authors of the present work [6, 7] are used. It can be noted that the present research implements the best practices for the SRS data use.

Impact of current climate change on the glaciers and their rapid degradation is clearly visible in the changes of the characteristics of the glaciated basin (number of glaciers and area), the melting of small glaciers (area in the range of 0.1 to 0.5 km^2) and the retreat of large glaciers (area> 2 km^2) that are effective indicators of the regional climate change.

In presented work, r. Mtkvari basin glaciers degradation due to the impact of the current climate change is studied in detail. Changes of the glacier melting statistics in r. Mtkvari is researched. This is preconditioned by the fact that r. Mtkvari basin is the most important river basin of eastern Georgia and such detailed study has not actually been carried out for any river basin in Georgia. In the future, similar studies will be conducted for all glacial basins of Georgia.

Research Objective and Methodology

The objective of the research is to study of r. Mtkvari basin glaciers degradation due to the impact of the current climate change. The r. Mtkvari tributary rivers Liakhvi and Aragvi glaciation basins are considered as the glaciers are met only there. Changes of the glacier basins and melting statistics are studied.

The use of the SRS makes it possible to determine the glacier's characteristics: maximum length of the glaciers, areas, minimum and maximum elevations, heights of the firn line, ablation and accumulation areas. This is achieved based on the complex use of historical data [4], glacier schemes from the catalogue, existing fieldwork materials and the application of expert knowledge. It is important that the methodology includes the implementation of the SRS data quality assessment and quality control (QA/QC) effective procedures [6,7].

For effective research, SRS images are used, namely, the data obtained from Landsat satellites (resolution 15-30 m) and several archives of satellite data, such as the National Aeronautics Space Administration (NASA) and information available at the project „Global Land Ice Measurements from Space" (GLIMS).

Various GIS programs are used to process satellite data. The Google Earth program is effective, which offers satellite images with a high spatial resolution (0.5-0.8 m) that allows determining the glacier contours accurately.

Discussion

For determination of the impact of climate change on glaciation basins the glaciers data and images created by the above-mentioned methodology using SRS are compared with the same glaciers data from the catalogue. About 50-year difference between the catalogue and SRS data creates a prerequisite for defining the changes in glaciation basins.

The glaciers scheme from the catalogue (Fig. 1) represents locations of glaciers of the left tributaries of the Mtkvari river basin (№1-27). The №1-22 glaciers are from the r. Liakhvi basin and №23-27 belongs to r. Aragvi basin. This scheme is used for the indication of these glaciers in SRS image.

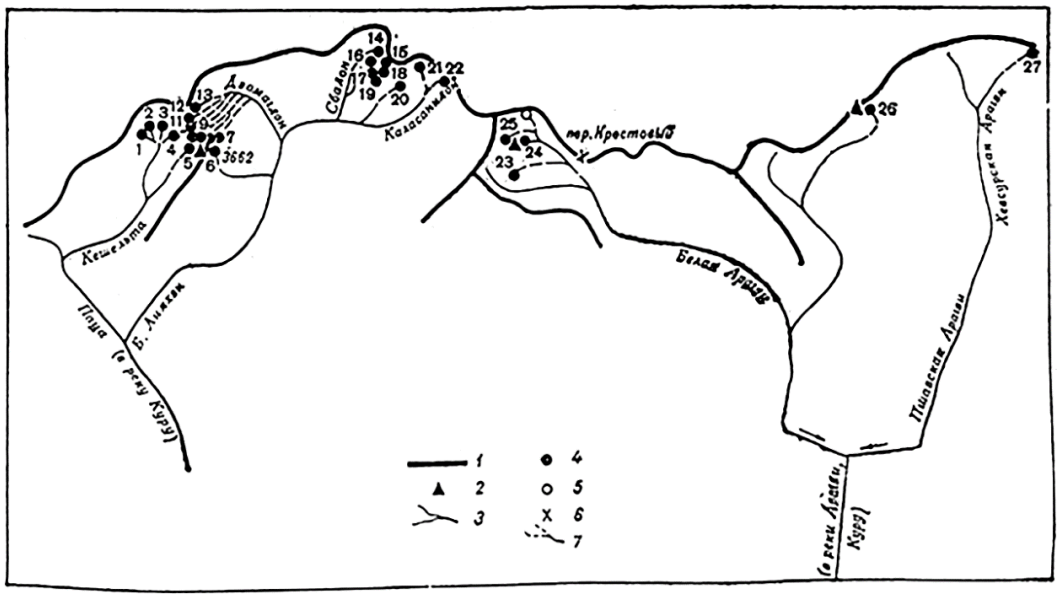

Fig. 1. Glaciers №1-27 of the left tributaries of the Mtkvari river basin: 1 – watersheds, 2 – peaks, 3 – rivers, 4 – glacier with its number, 5 – the glaciers (snowfields) with less than 0.1 km^2, 6 – passes, 7 – water flows with no permanent stream.

The satellite images of the glaciers of the left tributaries of the r. Mtkvari are processed i.e. the identification of glaciers are done and then corresponding blue contours are created based on our methodology using SRS from 28 August 2014; the red colour contours are from the GLIMS database. These data are presented in five parts (a, b, c, d, e) of Fig. 2.

On the satellite images green pins represent glaciers with area 0.1 km^2 and more, yellow pins show glaciers (snowfields) with an area less than 0.1 km^2, and red-coloured pins mark completely melted glaciers. In r. Mtkvari basin, there are no large glaciers with the area more than 2.0 km^2.

Parts c and e of Fig. 2. represent the contours of the Abudelauri glacier and its visualization. This glacier is the most prominent among the glaciers of the left tributaries of the r. Mtkvari. It is located in Khevsureti, on the north-eastern slopes of Chiukhi. The r. Abudelauri has its source from Abudelauri glacier and is the right tributary of r. Khevsureti's Aragvi. The glacier №22 occupies the largest area of 1.0 km^2 in the Mtkvari river basin (Fig. 2. b.).

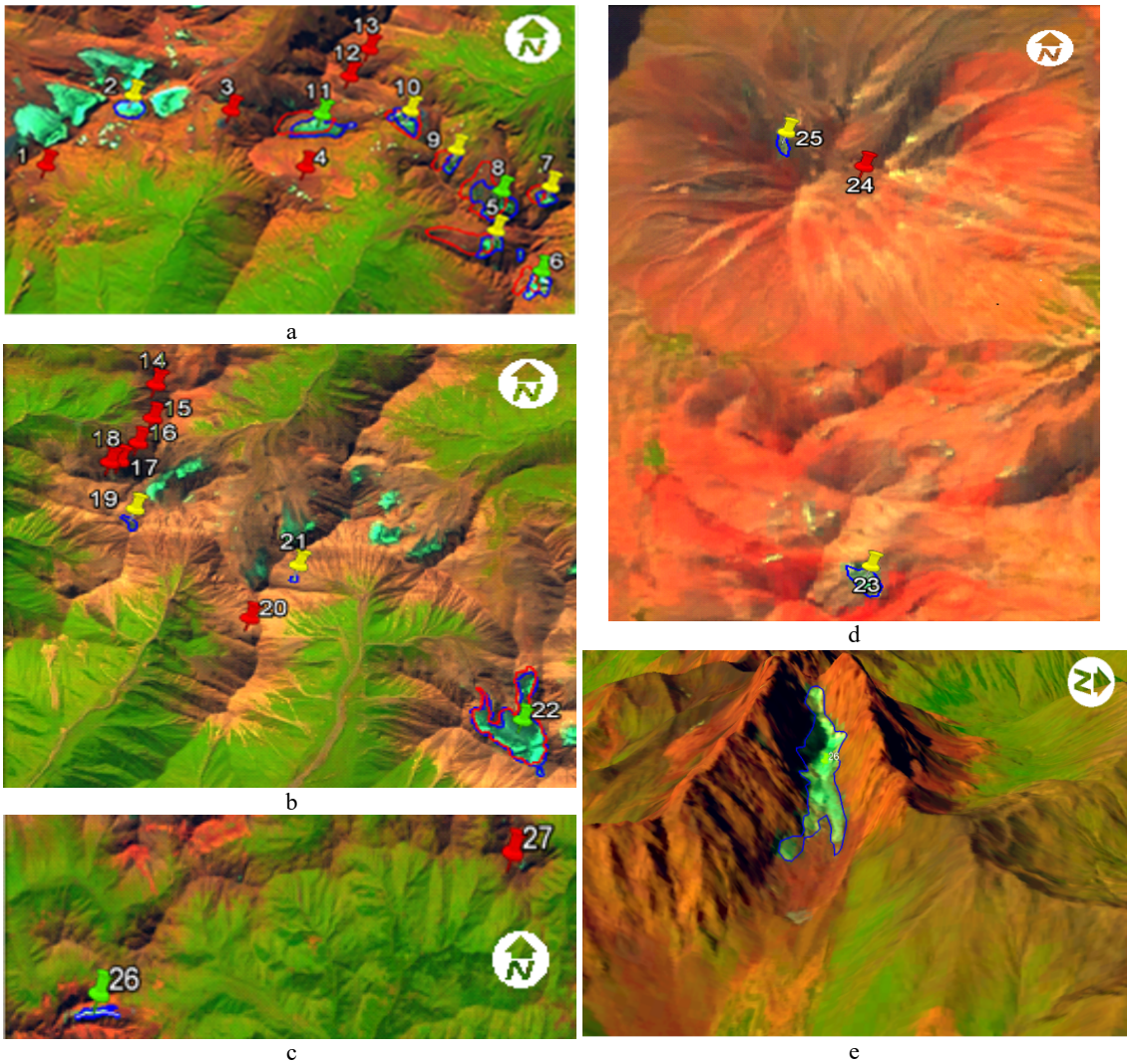

Fig. 2. Glaciers №1-27 of left tributaries of the Mtkvari river basin as of our data of 28 August 2014 (blue colour) and GLIMS database (red colour).

Table. R. Mtkvari basin glaciers main characteristics according to SRS (1) and catalogue (2)

№ according to catalogue	Name and № according to WGI catalogue	Identification №, ID according WGI	Max. Length (km)		Area (km^2)		Min. Elevation (m)		Max. Elevation (m)	
			(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
1	386a	SU5V09107001		0.4	0	0.1		2820		2880
2	386	SU5V09107002		0.4	0.09	0.2		2920		2940
3	387	SU5V09107003		0.9	0	0.3		2940		3110
4	4	SU5V09107004		0.8	0	0.1		2840		2950
5	5	SU5V09107005		1.7	0.08	0.4		2780		3200
6	6	SU5V09107006	0.3	0.8	0.1	0.2	3316	3180	3465	3400
7	393	SU5V09107007		0.8	0.05	0.2		2830		3130
8	391	SU5V09107008	0.6	1.4	0.3	0.7	2993	2860	3214	3220
9	392	SU5V09107009		0.7	0.05	0.1		2880		3160
10	388a	SU5V09107010		0.7	0.08	0.4		2900		3080
11	388	SU5V09107011	0.9	1.5	0.2	0.5	3237	3000	3449	3160
12	389	SU5V09107012		0.6	0	0.1		3010		3130
13	390	SU5V09107013		0.4	0	0.1		3020		3140
14	395a	SU5V09107014		0.2	0	0.1		3040		3180
15	395b	SU5V09107015		0.5	0	0.3		3060		3240
16	395c	SU5V09107016		0.2	0	0.1		3040		3160
17	395d	SU5V09107017		0.5	0	0.1		3260		3340
18	395e	SU5V09107018		0.2	0	0.1		3400		3440
19	395	SU5V09107019		0.7	0.04	0.3		3340		3400
20	20	SU5V09107020		0.5	0	0.1		3070		3190
21	21	SU5V09107021		0.7	0.01	0.3		3330		3440
22	396	SU5V09107022	2.0	2.2	1.0	1.8	3145	3120	3700	3860
23	23	SU5V09107023		0.7	0.02	0.1		3200		3400
24	397	SU5V09107024		0.8	0	0.3		3380		3690
25	25	SU5V09107025		0.8	0.01	0.2		3250		3600
26	Abudelauri 399	SU5V09107026	1.7	2.4	0.3	0.8	2960	2910	3550	3380
27	27	SU5V09107027		0.5	0	0.2		3010	-	3160

Using the catalogue schemes, the identification of r. Mtkvari basin all glaciers are done and the main characteristics of these glaciers are determined (Table).

According to the catalogue, in the r. Liakhvi glaciation basin: the total area of the glaciers was 6.6 km^2 and the number of glaciers was equal to 22. There were two medium glaciers and 20 small glaciers. Currently, according to the SRS data, due to the impact of climate change in the r. Liakhvi glaciation basin 1 medium glacier and 3 small glaciers are left; the number of snowfields is 7, and 11 glaciers completely disappeared. At present, in the r. Liakhvi glaciation basin the total area of the glaciers is 1.6 km^2 and the number of glaciers reduced to 4. Thus, the area of r. Liakhvi glaciation decreased by 5 km^2, or by 75.76% of the existing in the catalogue, and the number of glaciers reduced by 18 or with 81.8% of the existing ones in the catalogue.

According to the catalogue, in the r. Aragvi glaciation basin the total area of the glaciers was 1.6 km^2 and the number of glaciers was equal to 5. There were one medium glacier and 4 small glaciers. Currently, according to the SRS data, due to the impact of climate change in the r. Aragvi glaciation basin remains 1 small glacier; the number of snowfields are 2 units, and two glaciers are completely disappeared. At present, in the r. Aragvi glaciation basin the total area of the

glaciers is 0.3 km^2 and the number of glaciers reduced to 1. Thus, the area of r. Aragvi glaciation decreased by 1.3 km^2 or 81.25% of the existing in the catalogue, and the number of glaciers reduced by 4 units or by 80.0% of the existing ones in the catalogue.

Thus, according to the catalogue in the r. Mtkvari glaciation basin the total area of the glaciers was 8.2 km^2 and the number of glaciers was equal to 27. There were 3 medium glaciers and 24 small glaciers. Currently, according to the SRS data, due to the impact of climate change in the r. Mtkvari glaciation basin 1 medium glacier and 4 small glaciers remain; the number of snowfields is 9 units, and the 13 glaciers are completely disappeared. At present, in the r. Mtkvari glaciation basin the total area of the glaciers is 1.9 km^2 and the number of glaciers is reduced to 5. Thus, the area of r. Mtkvari glaciation decreased by 6.3 km^2 or 76.8% of the existing in the catalogue, and the number of glaciers reduced by 22 units or by 81.5% of the existing ones in the catalogue.

Conclusion

Current climate change impact on the Mtkvari river basin glaciers degradation can be summarized as follows:

1. The glaciation area of the r. Mtkvari and the number of glaciers is significantly reduced during the last 50 years;
2. The glaciation area of the r. Mtkvari basin decreased by 6.3 km^2, or 76.8% of the existing amount in the catalogue and the number of glaciers decreased by 22 or 81.5% of existing ones in the catalogue.

გეოფიზიკა

კლიმატის მიმდინარე ცვლილების მოქმედება მდ. მტკვრის აუზის მყინვარების დეგრადაციაზე

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(წარმოდგენილია აკადემიის წევრის თ. ჭელიძის მიერ)

21-ე საუკუნის დასაწყისიდან მყინვარების კვლევები საქართველოში მეტ მნიშვნელობას იძენს. ეს ძირითადად გამოწვეულია მყინვარების დეგრადაციის შესწავლის აუცილებლობით კლიმატის მიმდინარე ცვლილების გამო, რაც განაპირობებს მრავალი კატასტროფული მოვლენის განვითარებას: ზღვის დონის აწევას, მყინვარული წარმოშობის ბუნებრივი კატასტროფების რისკებისა და კატასტროფული მოვლენების რაოდენობრივ ზრდას, წყლის ბალანსის ცვლილებას და სხვა. კლიმატის მიმდინარე ცვლილების მყინვარებზე ზემოქმედების და მათი დეგრადაციის

შესწავლა ხდება მყინვარული აუზების მახასიათებლების (მყინვარების რაოდენობისა და ფართობის) ცვლილებების განსაზღვრით, მცირე მყინვარების დნობის სტატისტიკის (ფართობი 0,1-დან 0,5 კმ² ჩათვლით) დადგენით და დიდი მყინვარების (ფართობი > 2 კმ²) უკანდახევის განსაზღვრით, რაც რეგიონალური კლიმატის ცვლილების ეფექტური ინდიკატორია. კლიმატის მიმდინარე ცვლილების მყინვარების დნობის პრობლემაზე მეცნიერულად დასაბუთებული პასუხის გასაცემად აუცილებელია მაღალი გარჩევადობის თანამგზავრული დისტანციური ზონდირების გამოყენება, რადგან ეს შესაძლებელს ხდის ჩატარდეს მყინვარების ერთდროული შესწავლა დიდი რეგიონებისთვის საჭირო გარჩევადობითა და სიზუსტით შეზღუდული რესურსების და დროის პირობებში. ეს მიიღწევა ისტორიული მონაცემების, მყინვარების კატალოგის, არსებული საველე სამუშაოების მასალებისა და ექსპერტული ცოდნის კომპლექსური გამოყენების საფუძველზე. წარმოდგენილ ნაშრომში განსაზღვრულია მდ. მტკვრის აუზის მყინვარების დეგრადაცია კლიმატის მიმდინარე ცვლილების გამო, შესწავლილია მყინვარების ცვლილებები და დნობის სტატისტიკა. ეს მნიშვნელოვანია, რადგან მდ. მტკვრის აუზი არის აღმოსავლეთ საქართველოს ყველაზე მნიშვნელოვანი აუზი. აღსანიშნავია, რომ დღესდღეობით საქართველოში სხვა მდინარის აუზისთვის მსგავსი დეტალური შესწავლა არ ჩატარებულა.

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