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Geophysics

Determination of the Likely Dates of the Complete Melting of Georgia's Glacial Basins

George Kordzakhia[*], Larisa Shengelia[*], Genadi Tvauri[**], George Guliashvili[§], Sopio Beridze[§]

[*] *Hydrometeorological Institute, Georgian Technical University, Tbilisi, Georgia*
[**] *Andronikashvili Institute of Physics, Ivane Javakhishvili Tbilisi State University, Tbilisi, Georgia*
[§] *National Environmental Agency, Tbilisi, Georgia*

(Presented by Academy Member Tamaz Chelidze)

Degradation of glaciers under climate change conditions poses a significant threat to the sustainable development of humanity, and the study of their melting is considered one of the priority research problems. High-resolution satellite remote sensing (SRS) is used to obtain a scientifically based answer regarding glacier degradation due to climate change (CC). SRS allows the study of glaciers in large regions with the appropriate spatial and temporal resolution and the necessary details and accuracy. All of the above factors enable us to conduct a quantitative assessment of the retreat of large glaciers and determine the dynamics of the degradation of glacial basins in Georgia. It has been established that the degradation of glaciers in Georgia occurs much faster in the east than in the west, since the climate of eastern Georgia is mainly dry and continental, and in western Georgia is mostly subtropical and humid. This determined that glacier studies are conducted separately for the eastern and western parts of the country. It was found that glaciers' melting is nonlinear and accelerated over time. This study aims to define the probable dates of the complete melting of glacial basins under the influence of the modern CC. The glacial basins' complete melting dates, for the glacial basins where large glaciers are observed, are already determined in previous studies by authors. The glacial basins' complete melting dates, for the glacial basins where large glaciers are not monitored are determined based on changes in glacial basins using the developed regression equations. The studies of the complete melting of glacial basins are carried out under the conditions of the selected CC worst scenario. *© 2025 Bull. Georg. Natl. Acad. Sci.*

Georgia's glaciers, satellite remote sensing, glacial basins, climate change

The study of glaciers has been relevant for several centuries. The problem of cryosphere change is a priority for IPCC studies [1,2] associated with CC. Current CC has a very negative impact on the cryosphere. Over the last decades, global warming has led to a widespread shrinking of the cryosphere, with mass loss from ice sheets and glaciers (very high confidence) [1]. Projected physical changes include global glacier mass loss, which is expected to continue at least from 2031 to 2050 due

to rising surface air temperatures (high confidence), with imminent consequences for river flows and local hazards (high confidence) [2].

Modern glaciation is unevenly distributed between different regions of the Earth and various river basins. Glaciers are particularly vulnerable in the Andes, Alps, Pyrenees and Caucasus. The UN has adopted a special resolution regarding high mountain regions, in which one of the main roles is assigned to the problem of the impact of CC on glaciers and the risks associated with their degradation.

Degradation of large glaciers is accompanied by glacial disasters, which are especially intensified due to modern CC. Recent examples of glacial disasters include the tragedy of August 3, 2023, when the Buba glacier collapsed in the Bubistskali river valley, in the area of the Shovi resort. This unprecedented disaster resulted in human casualties, when 33 people died, including children. The infrastructure was fully damaged. The Shovi resort was covered with a large amount of rock avalanche and mud, which fully destroyed it [3].

Methodology & Results

In Georgia, the glacial basins are spread in twelve river basins. The glacial basins amount, where large glaciers are met, are four; three are in West and one – in East Georgia. The likely dates of the complete melting of these glacial basins are discussed in detail in earlier research [4]. The problem is solved on the condition that CC will continue as it has been. This scenario, in climatology, as in other activities, is called Business as Usual (BaU). Based on the mentioned research [4], the complete melting likely date of each glacial basin containing large glaciers is 1. 2077 for the Abkhazia glacial basin; 2. 2149 – r. Enguri glacial basin; 3. 2161 – r. Rioni glacial basin; and 4. 2153 – r. Terek glacial basin (East Georgia).

To determine the likely dates of the complete melting of the glacial basins without large glaciers, regression equations are used under the BaU climate change scenario. For glacial basins of East Georgia, let's consider small and medium glaciers for which the data of Landsat 4, 5, 7, and 8 satellites are used for the time interval from 1984 to 2022. Only six satellite images were found to be useful for such research. This circumstance is due to both cloudiness and wide geography, which characterizes the location of these glacial basins in East Georgia (from Liakhvi valley to Piriqita Alazani valley).

Satellite data processing includes several steps. First, the research area was defined, then the existing glaciers were separated according to the glacial basins of the rivers Liakhvi, Aragvi, Asa (Arkhoti), Arghuni and Piriqita Alazani. To determine the area of glaciers, the processing of satellite data was carried out, in particular, the determination of the reflectivity of the earth surface, the topographic correction of the obtained results and the so-called unsupervised data classification. After the classification, it was possible to determine the total area of glaciers of individual basins and their chronological change.

Table 1. The dynamics of glacial basins total areas decrease

Date	Satellite	Time (years)	Area (km^2) according to the glacial basins				
			Liakhvi	Aragvi	Asa	Arguni	Piriqita Alazani
9/26/1984	Landsat 5	0	2.50	0.40	1.04		6.90
8/31/1989	Landsat 4	4.9315	3.15	–	0.85	1.06	–
9/6/1994	Landsat 5	9.9507	2.50	–	0.74	0.92	3.63
8/28/2014	Landsat 8	29.9397	1.80	0.24	0.77	0.58	2.25
9/5/2017	Landsat 8	32.9644	1.56	0.25	0.65	0.33	1.28
9/13/2022	Landsat 8	37.9890	0.67	0.10	0.30	0.08	0.35

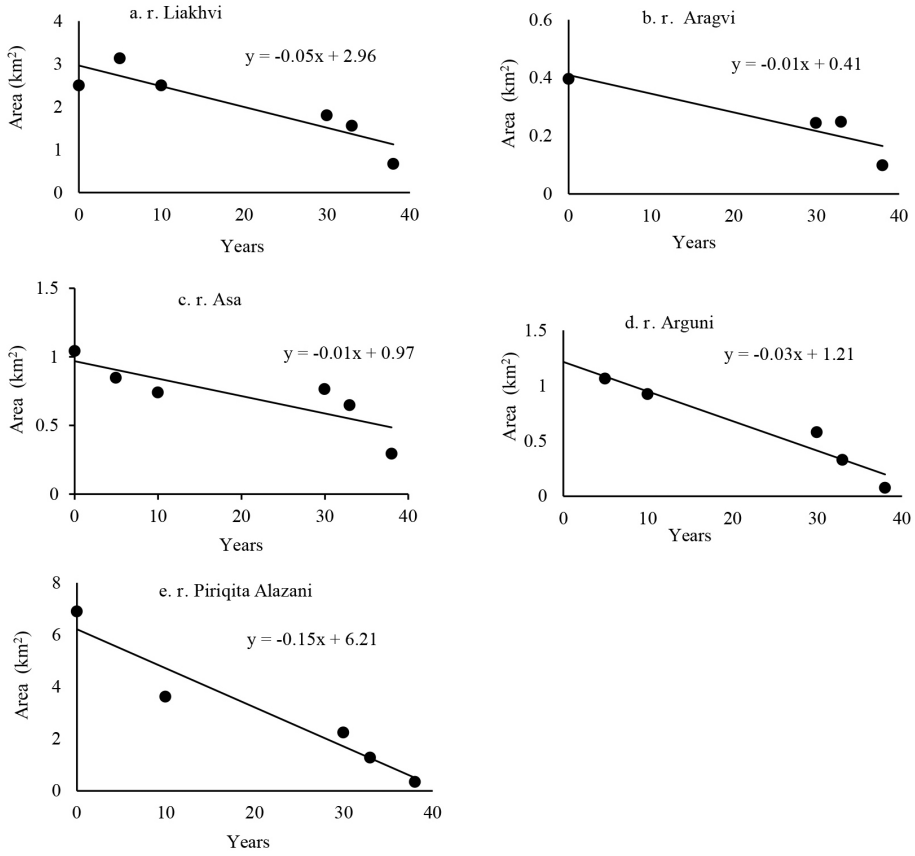

Fig. 1. The dependence of the total areas of glaciers on time.

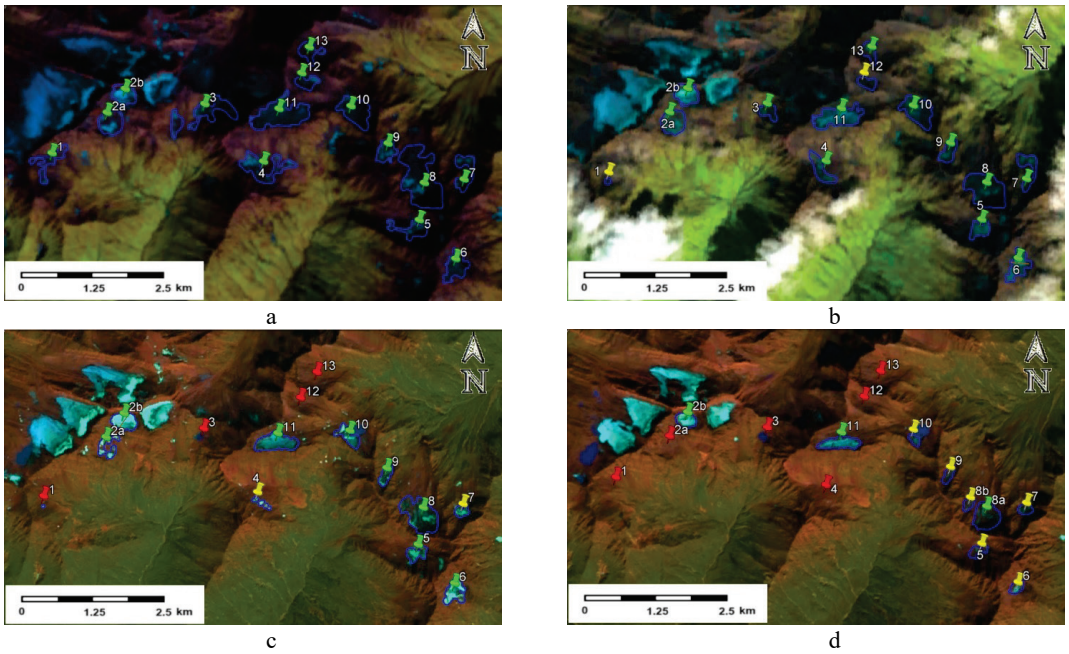

Fig. 2. Visualization of r. Liakhvi glacial basin degradation by years using the following satellite data: a − Landsat 5 TM, September 26, 1984, b − Landsat 5 TM, September 17, 1998, c − Landsat 8 OLI TIRS, August 28, 2014, d − Landsat 8 OLI TIRS, September 13, 2020.

After classification, the number of raster image pixels occupied by glaciers in the satellite image is determined. This allows determination of the glaciers' area based on the spatial resolution of Landsat satellite images (30 m). Table 1 summarizes the results of these glacial basin change studies.

Figure 1 shows the dependence of the total areas of glaciers on time.

Figure 2 presents the visualization of the r. Liakhvi glacier basin degradation. Glaciers are marked with green, snowfields are shown with yellow ones, and glaciers that have disappeared with red ones.

If we set in the melting equations of the glacial basins coordinate y equal to zero we will get the likely time of complete melting of each glacial basin, namely: a. river Liakhvi – about 61 years, b. river Aragvi – 64 years, c. river Arghuni – 45.3 years, d. river Asa – 76.3 years, e. river Piriqita Alazani – 41.3 years. Adding to these values the date (1984) of initial observation, we receive the likely dates of the complete melting of each glacial basin of eastern Georgia (Table 2).

Table 2. Likely dates of complete melting of glacial basins without large glaciers

№	Glacial basin	Likely dates of complete melting (year)
1	r. Liakhvi	2045
2	r. Aragvi	2048
3	r. Assa	2060
4	r. Arguni	2029
5	r. Piriqita Alazani	2025

In West Georgia, only two of the six glacial basins, namely the r. Bzibi and r. Kelasuri basins, do not have large glaciers. Data from Landsat 5, 7 and 8 satellites for the time interval from 1986 to 2023 have been used to discuss the dynamics of glacier area changes in these basins. Fourteen different dates of satellite data were available for the mentioned period. Table 3 shows the total areas of glaciers determined by SRS according to dates.

Table 3. Total areas of glaciers in the glacial basins of Bzibi and Kelasuri rivers according to dates

Date	Satellite	Time (year)	Glacial basin area (km^2)	
			Bzibi	Kelasuri
8/29/2086	Landsat 5	0	6.43	1.05
9/25/1990	Landsat 5	4.0767	5.96	0.92
9/20/1994	Landsat 5	8.0657	5.33	0.90
9/19/1997	Landsat 5	11.065	5.36	0.92
9/19/1997	Landsat 7	14.0493	4.86	0.91
9/20/2000	Landsat 5	14.0712	4.74	0.87
9/6/2001	Landsat 7	15.0328	5.06	0.90
10/7/2006	Landsat 5	20.1205	4.99	0.87
10/1/2007	Landsat 5	21.1041	4.27	0.78
1/19/2011	Landsat 5	24.4082	3.45	0.74
9/2/2014	Landsat 8	28.0301	3.41	0.70
9/3/2017	Landsat 8	31.0356	3.3291	0.6714
10/13/2020	Landsat 8	34.1480	2.3796	0.5472
9/7/2023	Landsat 8	37.0493	2.1942	0.5454

Figure 3 shows the graphs of changes in the total areas of glaciers determined by SRS in the glacial basins of the Bzibi and Kelasuri rivers.

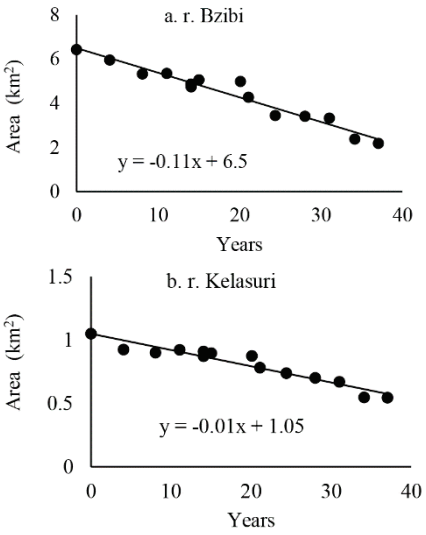

Fig. 3. Graphs of total area changes of the glacial basins of rivers Bzibi (a) and Kelasuri (b).

The equations of glacier area change are used to determine the likely dates of their complete melting. This issue is resolved under the BaU scenario of climate change. Let's set the ordinate y to zero in the trend equations and determine the solution. We will get the likely time of complete melting for each glacial basin, namely: for the r.

Bzibi glacial basin, this time is 58 years, and for the r. Kelasuri glacial basin – 82 years. If we add these values to the date of the initial observation (1986), the approximate dates of complete melting of each glacial basin are, respectively, 2044 for the Bzibi glacial basin and 2068 years for the Kelasuri basin.

Conclusion

Glacial basin degradation under climate change poses a significant threat to the country's sustainable development, and the study of their retreat is considered one of the priority activities. To obtain a scientifically based answer regarding the glacial basin degradation, considering the impact of current climate change, it is necessary to use high-resolution satellite remote sensing (SRS). This is provided by the fact that, on the one hand, at present, it is impossible to carry out expensive GBO on the necessary scale in the conditions of limited resources and time and on the other hand SRS allows studying glaciers for large regions with appropriate space and time resolution with the necessary details and accuracy.

All of the above mentioned factors allowed us to conduct a quantitative assessment of the retreat of large glaciers and determine the dynamics of degradation of glacial basins in Georgia; determine the nature of the degradation of glaciers and determine the approximate dates of the complete melting of the large glacial basins and those glacial basins where large glaciers are not observed. Of these, it is worth noting that the melting of glaciers has a non-linear character and it is still accelerated in time. Degradation of glaciers is much faster in eastern Georgia than in its western part, which is due to the big difference in climate between these parts. Those glacial basins where no large glaciers are observed will likely completely melt in this century and those basins where large glaciers are observed are not expected to melt completely in this century.

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გეოფიზიკა

საქართველოს მყინვარული აუზების სრული დნობის სავარაუდო თარიღების დადგენა

გ. კორძახია*, ლ. შენგელია*, გ. თვაური**, გ. გულიაშვილი§, ს. ბერიძე§

* *საქართველოს ტექნიკური უნივერსიტეტი, ჰიდრომეტეოროლოგიის ინსტიტუტი, თბილისი, საქართველო*
** *ივანე ჯავახიშვილის სახ. თბილისის სახელმწიფო უნივერსიტეტი, ე. ანდრონიკაშვილის სახ. ფიზიკის ინსტიტუტი, თბილისი, საქართველო*
§ *გარემოს ეროვნული სააგენტო, თბილისი, საქართველო*

(წარმოდგენილია აკადემიის წევრის თ. ჭელიძის მიერ)

კლიმატის ცვლილების პირობებში მყინვარების დეგრადაცია მნიშვნელოვან საფრთხეს უქმნის კაცობრიობის მდგრად განვითარებას და მათი დნობის შესწავლა ითვლება ერთ-ერთ პრიორიტეტულ კვლევის პრობლემად. მაღალი გარჩევადობის თანამგზავრული დისტანციური ზონდირება (თდზ) გამოიყენება კლიმატის ცვლილების გამო მყინვარების დეგრადაციის შესახებ მეცნიერულად დაფუძნებული პასუხის მისაღებად. თდზ იძლევა მყინვარების შესწავლის საშუალებას დიდ რეგიონებში შესაბამისი სივრცითი და დროითი გარჩევადობით, საჭირო დეტალიზაციითა და სიზუსტით. ყველა ზემოთ ჩამოთვლილი ფაქტორი საშუალებას გვაძლევს ჩავატაროთ დიდი მყინვარების უკანდახევის რაოდენობრივი შეფასება და განვსაზღვროთ მყინვარული აუზების დეგრადაციის დინამიკა საქართველოში. დადგენილია, რომ საქართველოში მყინვარების დეგრადაცია ქვეყნის აღმოსავლეთ ნაწილში გაცილებით სწრაფად ხდება, ვიდრე დასავლეთში, ვინაიდან აღმოსავლეთ საქართველოს კლიმატი ძირითადად მშრალი და კონტინენტურია, ხოლო დასავლეთ საქართველოში უმეტესად სუბტროპიკული და ნოტიო. ამან განსაზღვრა, რომ მყინვარების კვლევები ცალ-ცალკე ტარდება ქვეყნის აღმოსავლეთ და დასავლეთ ნაწილში. აღმოჩნდა, რომ მყინვარების დნობა არაწრფივია და დროთა განმავლობაში აჩქარებულია. ამ კვლევის მიზანია წინა კვლევების შედეგებზე დაყრდნობით მყინვარული აუზების სრული დნობის სავარაუდო თარიღების დადგენა. მყინვარული აუზების სრული დნობის თარიღები, მყინვარული აუზებისთვის, სადაც დიდი მყინვარები შეინიშნება, უკვე დადგენილია ავტორების წინა კვლევებში. მყინვარული აუზების სრული დნობის თარიღები, მყინვარული აუზებისთვის, სადაც დიდი მყინვარები არ შეინიშნება, განისაზღვრება მყინვარული აუზების ცვლილებების საფუძველზე განვითარებული რეგრესიული განტოლებების გამოყენებით. მყინვარული აუზების სრული დნობის კვლევები ტარდება კლიმატის ცვლილების შერჩეული სცენარის პირობებში.

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