DOI: https://doi.org/10.15407/ugz2026.01.116

Yatsenko, V. S. 0000-0002-7948-2983

Institute of Pedagogy of the National Academy of Sciences of Ukraine, Kyiv

Towards a Methodology for Studying Glaciological Challenges of the 21st Century in Educational Practice

UDC 551.32:551.583:556.1:37.016:91:502/504(045)

This publication aims to raise awareness among geography teachers and students about the important role of cryosphere components in the climate system and the hydrological cycle, as well as the environmental, social, and economic consequences of global climate change. The following research methods were used: theoretical (from the abstract to the concrete); comprehensive (abstraction, analysis and synthesis, induction and deduction, partial modeling); and empirical (observation, comparison, measurement, and experimentation). In the educational process, glaciological studies may begin with the first occurrences of winter atmospheric phenomena—snow, hail, ice glaze, blizzards, or heavy snowfalls—in the context of understanding the impact of global warming and climate change on specific natural processes in Ukraine. Mountain glaciers in Iceland, Scandinavia, the Alps, and the Himalayas serve as indicators of climate change; their melting is altering the landscape, potentially leading to changes in the national borders of some countries. The article's materials are intended to help students study the basics of glaciology in more detail, where the development of social skills, interaction, and independence is important. The United Nations General Assembly has proclaimed 2025–2034 as the Decade of Action for the Cryosphere Sciences. The initiative aims to enhance monitoring and scientific research on glacier melting, permafrost, and snow cover. It also envisages support for the development of educational programs that will expand geography teachers' capacity to help students better understand their natural and anthropogenic environments and act responsibly within them. To stimulate children's interest in glaciological science, scientists need to develop creative, integrated content. The novelty of the study lies in developing methodological foundations for integrating contemporary glaciological issues into the educational process, thereby ensuring the active participation of teachers and students in implementing the Decade of Action for the Cryosphere Sciences (2025–2034).

Keywords: *cryosphere, glaciological research, mountain glaciers, snow, popularization of science, methods of teaching geography.*

Relevance of the research topic

Global climate change is prompting a reorientation of glaciological research not only in remote regions of the world but also in Ukraine, where, in recent years, observations of snow cover, avalanches, glaciological debris flows, and sea and freshwater ice have remained limited. The Resolution on the *International Year of Glacier Preservation*, adopted by the United Nations General Assembly and launched on January 21, 2025 ***[1]***, conceptually defines the comprehensive implementation of sustainable development principles across its economic, social, and environmental dimensions. For the scientific and educational community, it is essential to develop international and national mechanisms that ensure access to accurate, timely information on the cryosphere, climate change, and the ecosystems of polar, mountain, and coastal delta regions. In the context of the *International Year of Glacier Preservation*, the United Nations General Assembly

For citation:
Yatsenko, V. S. (2026). Towards a Methodology for Studying Glaciological Challenges of the 21st Century in Educational Practice. *Ukrainian Geographical Journal.* 1. 116–127. [In Ukrainian] DOI: https://doi.org/10.15407/ugz2026.01.116

has proclaimed March 21 as World Glacier Day, to be observed annually starting in 2025 as a symbol of global solidarity in preserving the cryosphere. The launch of the *Decade of Action for the Cryosphere Sciences (2025–2034)* opens significant opportunities to intensify scientific and educational research aimed at a deeper understanding of global challenges such as climate change, glacier melting, sea-level rise, coastal flooding, the increasing frequency of natural disasters, and the growing number of "climate migrants."

Relevance of the Research Topic

The main sources used in the study cover a wide range of aspects of the problem and are comprehensive. These include, first and foremost, the United Nations' regulatory documents that establish the International Year of Glacier Preservation in 2025 ***[1–2-3]***. Specialized geographical sources substantiate the significance of the presented facts and working assumptions across various fields—geophysics ***[4]***, geology ***[3; 5]***, paleoecology ***[6]***, glaciology ***[7; 8; 4]***, hydrology ***[9]***, and climatology ***[12-10-11]***. In addition, educational manuals for geography teachers and students of general secondary schools were used. Online resources reflect the diversity of materials available from scientific centers and specialized platforms.

Aim of the Study

The aim of this publication is to enhance the awareness of geography teachers and students about the crucial role of cryosphere components in the climate system and the hydrological cycle, as well as about the ecological, social, and economic consequences of changes in the Earth's cryosphere. Research objectives:

1. To familiarize teachers of natural sciences with traditional and interactive information resources designed for students of general secondary education.

2. To substantiate key aspects of the methodology for developing students' research competencies in the process of learning the fundamentals of glaciology within geography education.

3. To promote the enhancement of geography teachers' professional competence in glaciological research within educational practice.

Research methods

The study employed both theoretical methods (progression from the abstract to the concrete, abstraction, analysis and synthesis, induction and deduction, and partial modeling) and empirical methods (observation, comparison, measurement, and experimentation). Among the specialized methods, where possible, geographic information systems (GIS), remote sensing techniques, measurements of atmospheric carbon dioxide, measurements of water resources in the snow cover, and Earth system modeling in the form of ice-flow simulations were employed.

Presentation of the Main Material and Substantiation of Scientific Results

Glaciers as Indicators of Climate Change

During glacial periods, extensive ice sheets repeatedly spread across North America and Europe, highlighting their crucial role as indicators of global climate change. According to the data of Anglo-Canadian landscape researchers D. Brunsden and J. Dornkamp, in the United Kingdom, ice sheets extended as far as the London area and covered most of the territory to its north ***[7, p. 111]***. Moisture concentration over the continents caused a sea-level drop of approximately 100 meters relative to present levels. More than 90% of ice sheets are located in Antarctica, about 8% in Greenland, and the remainder in mountainous regions worldwide ***(Table 1)***.

Glaciers form in regions with significant accumulation of atmospheric precipitation, where falling snow or ice accumulates, and where mean annual temperatures remain sufficiently low to preserve these deposits from year to year. A more detailed description of glaciological processes is provided in the textbook for 6th–7th grade students by V. S. Yatsenko and V. A. Kravchenko, "All About Water for Future Generations. The Nature of Water" ***[17, pp. 52–54]***. In a simple, accessible form, the textbook for students in this age group describes sea ice formation ***[17, p. 52]***, pressure ridges, icebergs, and Antarctic glaciers ***[17, p. 53]***, and the impact of the greenhouse effect on the Arctic climate ***[17, p. 54]***. American researchers François Lapointe and Raymond S. Bradley, in their study "The Little Ice Age abruptly triggered by intrusion of Atlantic waters into the Nordic Seas" ***[9]***, analyze the development of the Little Ice Age (15th–19th centuries), which followed a period of significant warming and had severe consequences for humanity, including crop failures, mass famine, pandemics, and millions of deaths in Europe. The researchers reconstructed sea

Table 1. **Area of Present-Day Glaciation of the Earth According to Different Sources and Their Losses**

Glaciation area	Key losses
Antarctica Antarctica: 13.9 million km^2 ***[2]***	Between 1997 and 2021, shelf glaciers lost about 30% of their mass.
Arctic *Greenland:* 1.71 million km^2 ***[13]***, *Canadian Arctic Archipelago:* 1.4 million km^2	The ice area is projected to decrease by more than 50% by 2100 ***[13, p. 30]***.
Europe *Iceland:* 11,060 km^2 ***[14];*** total ice volume: 3,000 km^3; average thickness: 300 m ***[15]***, *Scandinavia:* 2,949 km^2 ***[14]***, *Norway:* 6,736 glaciers with a total area of 2,300 km^2 (2022) ***[15]***, *Alps:* 4,400 glaciers with a total area of 2,000 km^2 (1% of the Alps) 100 km^3 of ice (2020) ***[15]***, *Switzerland:* 1,400 glaciers with a total area of 961 km^2 (2016) ***[7]***.	Since the 20th century, Icelandic glaciers have lost about 25% of their area. Between the 1960s and 2010s, Norwegian glaciers decreased by 10%. Since 1850, Swiss alpine glaciers have lost approximately 60% of their volume.
Asia *Hindu Kush Himalayan range:* snow cover 951–1,390 thousand km^2 in winter and 388–481 thousand km^2 in summer; glacier area — 87,340 km^2 (2025) ***[16]***. *Northern Asia:* 2,410 km^2 ***[14]*** *High Mountain Asia:* 97,605 km^2 ***[14]*** *Middle East: 1,307 km^2* ***[14]***	In the 2010s, glacier retreat occurred 65% faster than in the previous decade
North America *Alaska:* glaciers 86,725 km^2 ***[14]***, *Western Canada and the United States:* 14,524 km^2 ***[14]***.	Glaciers lose more than 80 gigatons of ice per year (about 5% of the total) ***[8]***.
South America *Southern Andes:* 29,429 km^2 ***[14]***, *Humboldt Glacier:* 0.01 km^2 ***[4]***.	In 1910, the area of the Humboldt Glacier was 3 km^2 ***[4]***.
Africa *Mount Kilimanjaro massif:* 388,500 km^2 ***[14]***.	Since 1912, the total glacier area has decreased by 91% ***[10]***.
Australia and Oceania *Low latitudes:* 2.34 km^2 ***[14]***. *New Zealand:* 1,162 km^2 ***[14]***.	The losses are estimated at over 29% ***[11]***.

surface temperatures in the North Atlantic over the past 3000 years and identified an anomalous shift: the ocean first warmed abruptly and then cooled between 1380 and 1400. This triggered rapid melting of Arctic ice, likely associated with anomalous solar activity preceding the period, which led to increased atmospheric pressure over the Greenland ice sheet. Ocean currents in the Arctic accelerate and become more chaotic due to rapid ice melt. Information on the history of the solar cycle from 1750 to 2025 is currently available on the NOAA/SWPC website, published in October 2023 ***[12]***. The formation of concepts about the regularities of change in natural and climatic conditions can be achieved through the study of Earth's geological history. In this context, it is appropriate to consider the following issues: how the Earth developed during the early stages of its geological history; the structure of platforms and the mechanisms of their formation; the interrelation between geological history, structure, and relief in different regions; and examples that illustrate rhythmic patterns within the geographical envelope. The formation of students' understanding of the regularities of changes in natural and climatic conditions can be achieved through the study of

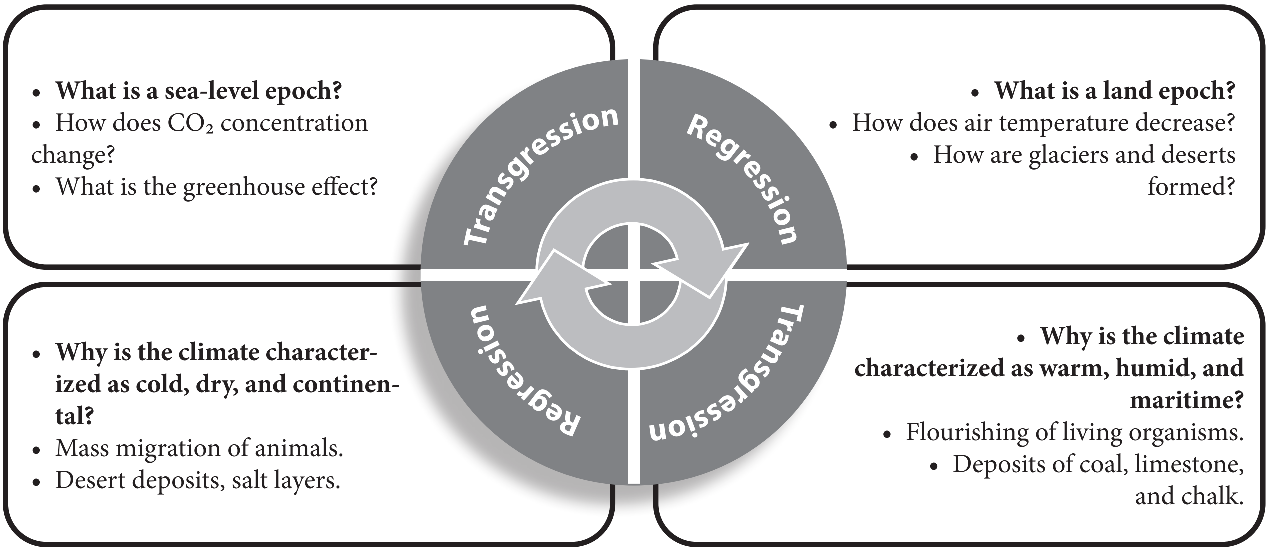

Fig. 1. An activity-based approach in geography education as a means of fostering understanding of rhythmic processes in the geographical envelope

Earth's geological history. In this context, it is appropriate to consider the following issues: how the Earth developed during the early stages of its geological history; the structure of platforms and the mechanisms of their formation; the interrelation between geological history, structure, and relief in different regions; and examples that illustrate rhythmic patterns within the geographical envelope. American researchers P. K. Shoonmaker and D. R. Foster argue that during the Quaternary period, covering the last 1.6 million years, there were approximately 24 glacial episodes alternating with interglacials. These cycles were accompanied by changes in sea level, climate, and the region's floristic composition ***[6, p. 206]***. These changes can be explained to students in an accessible form by highlighting epochs in the geological past characterized by contrasting natural conditions—the processes of marine transgression and regression ***(Fig. 1)***.

The teacher selects and/or recommends accessible sources of geographical information and compiles a list of available video materials for students. The students independently work with the materials on the chosen research topic and summarize the results in the form of media presentations, oral reports, illustrative schemes, or drawings. Figure 1 presents suggested topics and key issues for discussion both during the process of student research and at the stage of presenting their results. In higher education institutions, these issues are appropriately addressed during preparatory sessions (pre-seminars) and academic seminars. A research-oriented special seminar is recommended within the framework of student or school scientific conferences. For both school pupils and university students, the search for answers to the concluding questions remains equally relevant: "In which epoch do we live?" and "Will the world change after 2100?".

Ancient glaciations

Epochs of continental development in specific regions represent regular stages in their geological evolution. Their detailed characterization is possible through the analysis of complex data integrating geological, paleomorphological, and paleogeographical conditions characteristic of these epochs. An important direction of research may be the work of students within the system of the Minor Academy of Sciences of Ukraine (MAN Ukraine).

At this stage, students examine in greater detail the causal relationships underlying the occurrence of glacial periods on Earth—the Late Ordovician (455–440 million years ago), the Permo-Carboniferous (335–280 million years ago), and the Cenozoic (around 35 million years ago)—using examples of ancient glaciation traces widely found in Ukraine. Of particular interest are the results of recent scientific studies on this issue, such as the work of American scholars Nan Sun, Alan D. Brandon, Steven L. Forman, and Michael R. Waters, "Geochemical evidence for volcanic signatures in Younger Dryas event deposits" ***[18]***.

Researchers substantiate the causes of climate change at the end of the Pleistocene (around 12,800

Table 2. **Kovel Complex of Regional Glacial Formations of Volyn Region** *

Eskers with fragments of chalk rocks	Alluvial cones (front of glacial tongue)	Turied exaration valleys (filled with Dnieper moraine)
Villages of Kovel district: Moshchena, Lyublynets, Bilashiv, Lyubytiv, Radoshin, Ukhovetsk	*Villages of Kovel district:* Staryi Mozyr, Velykyi Porsk, Pidrizhzhia, Zhuravline	*Villages of Volodymyrskyi district:* Selets
	Villages of Lutsk district: Ozeryany	Valley of the Turya River

* Prepared by the author from source *[19]*.

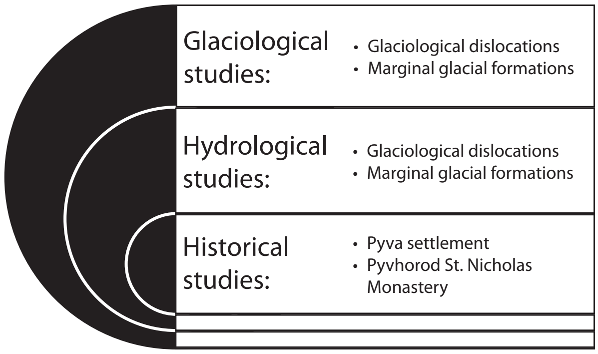

Fig. 2. Objects of glaciological, hydrological and historical studies of Mount Pyvykha, Poltava region

years ago), when the Earth abruptly returned to a glacial phase — the stage of the last glaciation. In their view, the main factors were the collapse of ice sheets into the Atlantic Ocean, the expansion of snow cover, and a series of volcanic eruptions in the Aleutian Islands, the Cascade Range, and Europe lasting from one to five years, which triggered global cooling. Studying these causal relationships enables students to better understand why the cooling occurred and ultimately led to the extinction of mammoths in the Northern Hemisphere.

Marginal glacial formations as landform features are widely represented in Ukraine. They are concentrated in separate areas that combine into complexes—discontinuous belts stretching for tens to hundreds of kilometers and up to 20–25 km in width. Ukrainian researcher A. V. Matoshko, studying the fluvial and glacial geomorphogenesis of the *Kovel complex of marginal glacial formations*, provides detailed information on landform types and their geographical distribution ***[19, p. 89]***. Students can observe in the field various glaciofluvial accumulative forms (eskers, alluvial cones), exaration valleys, and moraine covers ***(Table 2)***.

Another potential object of study is the *Hradyzk–Taburyshche complex of marginal glacial formations*—a landform in the Dnipro valley between the town of Hradyzk in Poltava region and the village of Taburyshche (now submerged by the waters of the Kremenchuk Reservoir) in Kirovohrad region.

Objects of study may include not only landforms but also geological outcrops, rocks (sands, marls), and minerals (gypsum). An interesting subject of investigation is Mount Pyvykha, located within the Globyno and partly the Kremenchuk districts of Poltava region; it has the status of a local landscape reserve. The mountain lies on the left bank of the Dnipro River, near the southern outskirts of the town of Hradyzk ***(Fig. 2)***.

Landscape studies are conducted in the local landscape reserve "Mount Pyvykha," covering an area of 285 ha, where pine, maple, aspen, elm species, and other vegetation dominate. Within the reserve, active abrasion processes are examined along with paleontological finds—sea urchins, corals, mollusks, mammoths, woolly rhinoceroses, and reindeer. Tourism studies contribute to the promotion of thematic and rural (green) tourism in the region. In 2008, Mount Pyvykha represented Poltava region in the national contest "Seven Natural Wonders of Ukraine." The aesthetic appeal of Pyvykha is comparable to that of the country's most renowned natural sites.

Traces of ancient glaciations are widespread across many regions of Ukraine, and some have acquired the status of geological nature monuments ***[3]***. Such objects include: the quarry near the village of Rostan (Volyn) and geological outcrops in the basin of the Vyshnia River near Dobrynychi (Precarpathia), whose lower part consists of glacial deposits ***[3, p. 13]***; the Marmarosh Massif (Rakhiv District, Zakarpattia), which began to form 700 million years ago and bears evidence of Cenozoic glaciation — glacial troughs and cirques ***[3, p. 18]***, and can serve as an educational geo-route for students to Mount Pip Ivan Marmarosh; Middle Pleistocene glacial deposits near the villages of Rostan and Koshary (Polissia) ***[3, p. 96]***; and the Oleksandriya dendrological park (Kyiv region), represented by an aquifer complex of Middle Quaternary (Dnieper) glacial, glaciofluvial, and lacustrine-glacial deposits ***[3, p. 99]***. In our view,

Table 3. **Frequency of very heavy snowfalls in Ukraine during 1984–2004 (October–April)** ***[6, p. 303]***

Ukrainian Carpathians	Crimean Mountains	Kyiv oblast
Latest heavy snowfall: May 7–8, 1989 in the areas of Pozhezhevska, Yaremche, and Rakhiv. Duration ranged from 20.1 to 9.6 hours; precipitation amounted to 58–21 mm.	**Longest heavy snowfall:** January 31 – February 1, 1988 in the Mnohorychchia area. Duration — 22 hours.	**Snowfall with the greatest duration:** April 26–27, 1987 in Tomashivka. Duration — 19.2 hours; precipitation — 35 mm.
Earliest heavy snowfall: September 5–7, 1991 at Pozhezhevska (Carpathians). Precipitation — 69 mm (water equivalent).	**Maximum precipitation during a heavy snowfall:** February 14–15, 1997 at Ai-Petri (Crimean Mountains). Precipitation — 131 mm.	**Maximum precipitation during a heavy snowfall:** April 26–27, 1987 in Tomashivka (Kyiv Region). Precipitation — 74 mm.

geological monuments of Ukraine may serve as starting points that encourage students to explore their native land, since they are present in every region and are practically within an hour's reach of the study sites.

For example, Ukrainian scholars O. M. Adamenko and M. I. Mosiuk provide examples of glacial-type flora and fauna at the *geological nature monument "Starunia"* (Precarpathia), which can be studied by students using geographical, ecological, geological, and paleontological methods. They conclude that "their evolution and distribution across Europe begins with the Late Glacial period of humid tundra, passes into the phase of lacustrine landscapes, and continues today in open and dry biotopes" ***[5, p. 35]***.

Other effective forms of geography education include project-based activities. For instance, on October 26, 2019, students participated in Starunia in an eco-cultural festival marking the opening of the Pleistocene Park—part of the contest "Small Towns—Great Impressions," aimed at developing the cultural and economic potential of territories through support of heritage-related start-ups ***[20]***. Teachers of natural sciences who organize student field studies are advised to apply methods of economic-geographical research: statistical, cartographic, comparative, historical, economic-mathematical, systematization, regionalization, and geographical forecasting.

Snow Cover

Snow and the processes of its formation are of great importance both for nature and for humans. Snow is the main source of moisture for soils, and its deficit significantly reduces agricultural yields. In winter, snow protects vegetation from freezing, while the absence of cover makes animals more vulnerable to predators. From an economic perspective, the lack of snow reduces revenues from winter sports and tourism. These are only some examples of the importance of snow.

According to media reports, two interrelated processes are observed in different regions of the world: global warming caused by rising air temperatures, and the occurrence of natural hazards in atypical areas—hail, ice storms, blizzards, heavy snowfalls, etc. For instance, on June 9, 2020, summer snow fell in Andorra; on September 11, 2021, an unexpected snowfall occurred in the Upper Nkam area of Cameroon; on September 21, 2024, up to 2 m of snow fell in South Africa; on November 28, 2024, a powerful snowfall brought up to 18 cm of snow in the Republic of Korea; and on November 3, 2024, the first snowfall in history was recorded in the Al-Jawf region of Saudi Arabia.

An important characteristic of the winter season is snowfall, which determines the formation, intensity, duration, stratification, density, and water content of the snow cover. In Ukraine, heavy snowfalls are usually associated with the arrival of southern and southwestern cyclones from the Mediterranean (about 50%), as well as western (10%) and northwestern cyclones from Western Europe. The frequency of heavy snowfalls varies: between 1984 and 2004, the largest number of cases (46) was recorded in Crimea; somewhat fewer in Zakarpattia (31) and Ivano-Frankivsk (25) regions. In most other regions, the number of cases ranges from 1 to 4 ***(Table 3)***.

Very heavy snowfalls (precipitation of 20 mm or more within a period of up to 12 hours) are classified as extreme meteorological phenomena. Kyiv scholars I. Shcherban, V. Babichenko, N. Nikolaieva, and S. Rudishyna, summarizing data for the twenty-year period (1984–2004), concluded that the intensity and frequency of such snowfalls in Ukraine increased significantly ***[6, p. 301]***.

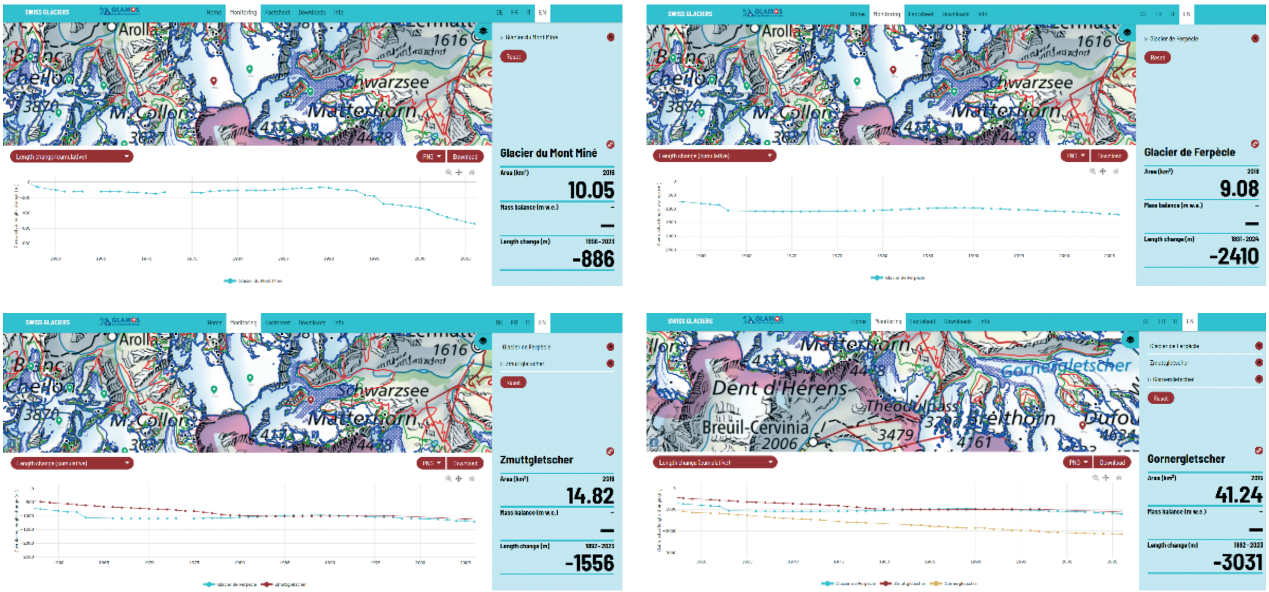

Fig. 3. Monitoring of the glaciers Glacier du Mont Miné, Glacier de Ferpècle, Zmuttgletscher, and Gornergletscher in the Swiss Alps *[24]*

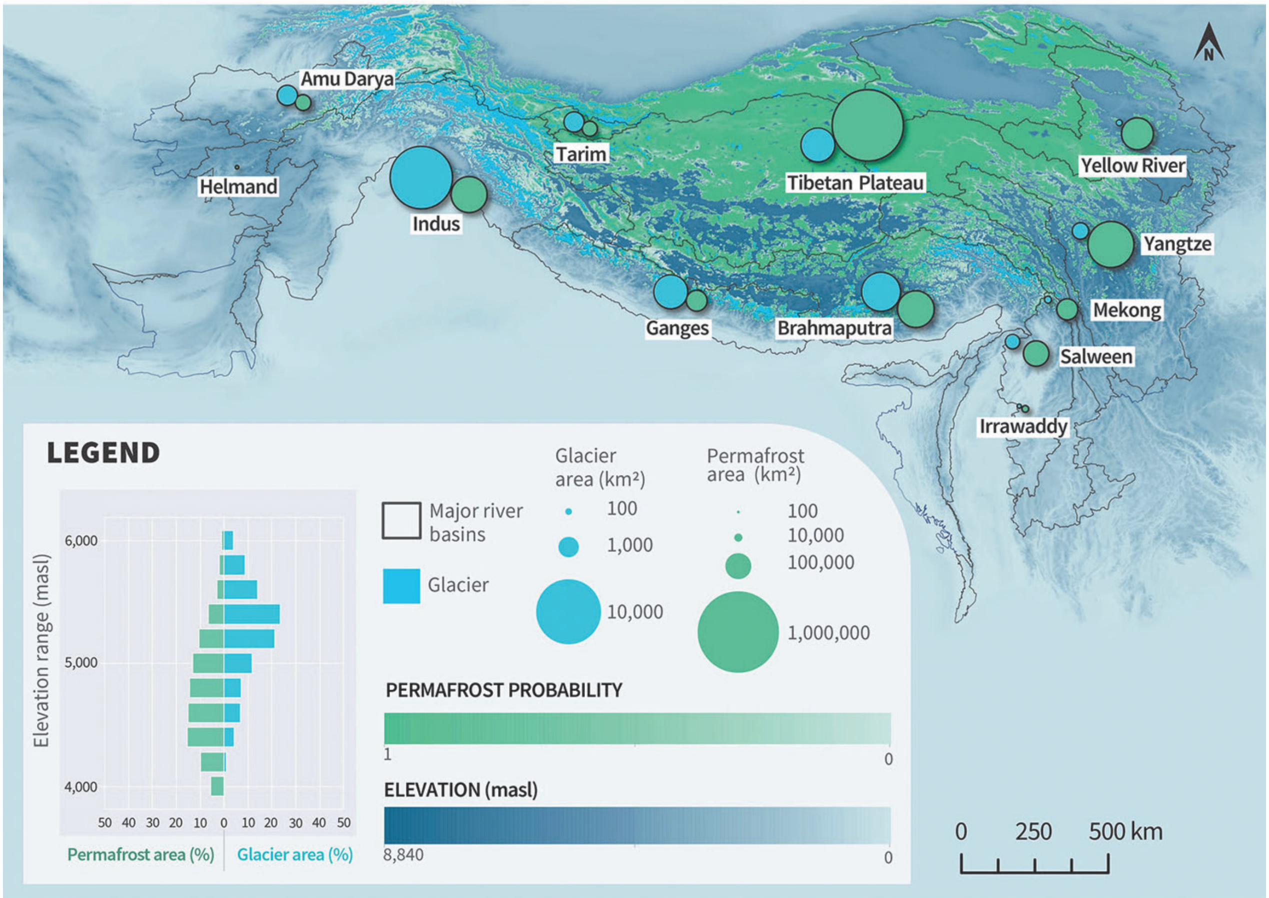

Fig. 4. Distribution of permafrost (in green) and glaciers (in blue), together with summarized statistical data on glaciers and permafrost in the major river basins of the Hindu Kush Himalaya (HKH) *[8]*.

Mountain Glaciers

The Glacier Change portal ***[12]*** provides materials for studying glaciers in ***Iceland***, ***Scandinavia***, and ***the Alps***. Students can explore collections of photographs and information on European glaciers. For educational purposes, scientific research results, works of art, photographs, and satellite images may be used. In particular, the site presents data on 39 glaciers in *Iceland*, 38 glaciers in *Norway*, and 21 Alpine glaciers. Their study expands the scope of research—from analyzing the impact of rising air temperatures and decreasing snowfall on the melting rate of European mountain glaciers to examining crustal uplift, increased volcanic activity, sea-level rise, and effects on local tourism. Alpine glaciers are the place of origin, development, and popularization of glaciology, and they are recommended as a starting point for desk work. For example, Glacier Monitoring in *Switzerland* (GLAMOS) systematically documents and monitors long-term changes in glaciers in the Swiss Alps ***[7]***. By studying glaciers in the area of the Matterhorn (4478 m) on the Swiss-Italian border, we can clearly see from statistical data how climate change has affected them ***(Fig. 3)***.

During the observation period (1880–2024), the length of the glaciers under study changed from 886 to 3031 m. The platform recommends conducting a more detailed investigation of each observed glacier. In the course of such desk-based work, it is important to foster students' social skills, including the ability to interact, communicate, and work independently.

The Hindu Kush mountain system in South Asia plays a crucial role in the region's natural and social systems. Extending for 3500 km across eight countries, it is the source of ten major rivers that provide water resources for about 240 million people, and nearly 2 billion when including river basins. Mountain socio-ecological systems are exposed to significant risks due to climate change. Accelerated glacier melting alters river runoff; precipitation increasingly falls as rain under warmer conditions; this affects drinking water quality through the accelerated release of accumulated substances (mercury, phosphorus, nitrogen) and reduces agricultural yields in high-altitude areas ***[14, 11]***.

An important challenge remains raising students' awareness of the cryosphere, which includes glaciers, snow, permafrost, as well as lake and river ice. Particular emphasis is placed on informing about the significance and impact of cryosphere changes on ecosystems and society ***(Fig. 4)***.

Fig. 4 may serve as a starting point for research aimed at developing fundamental understanding of the cryosphere and glaciology. In particular, students may explore the following questions:

- What is a mountain glacier and what is a moraine?
- How does a glacier transport ice?
- Why do glaciers grow or shrink?
- What do glacier advance and retreat mean, and which factors determine glacier length?
- What influences the rate of glacier retreat or advance?
- Are glaciers reliable indicators of climate change?
- What retreat trends are observed for Hindu Kush-Himalaya glaciers, and could their disappearance occur within the next decades?
- What do Himalayan glaciers reveal about climate change?

Ben Marzeion (Germany), Regine Hock (USA), Brian Anderson (New Zealand), and others, analyzing a large dataset, concluded that the melting of mountain glaciers (excluding the ice sheets of Greenland and Antarctica) may contribute about 24 % of sea-level rise ***[25, 2]***. According to them, the greatest source of uncertainty in projecting glacier mass at the end of the 21st century is the lack of precise knowledge regarding future emission scales, similar to uncertainties in global mean temperature changes. The projected global glacier mass loss by 2100, compared with 2015, is estimated to correspond to 79–159 mm of sea-level rise ***[ibid.]***.

The next stage of research conducted by teachers with students may involve analyzing the risks of floods and inundations along coastal zones and river deltas, water resource deficits, biodiversity and ecosystem loss, as well as impacts on tourism and recreation. Such studies can also be carried out in Ukraine, where glacial deposits in the Ukrainian Carpathians resemble moraines of mountain glaciers that once occupied weakly dissected massifs: Chornohora (including Mt. Hoverla), Svidovets, the Rakhiv massif, and the Chyvchyn Mountains ***[26]***. Many modern mountain lakes have glacial origins—for example, Vorozheske (0.7 ha, 1460 m), Herashaska (1.2 ha, 1577 m), Nesamovyte (0.3 ha, 1750 m), and others ***[26, p. 36].*** Research may also

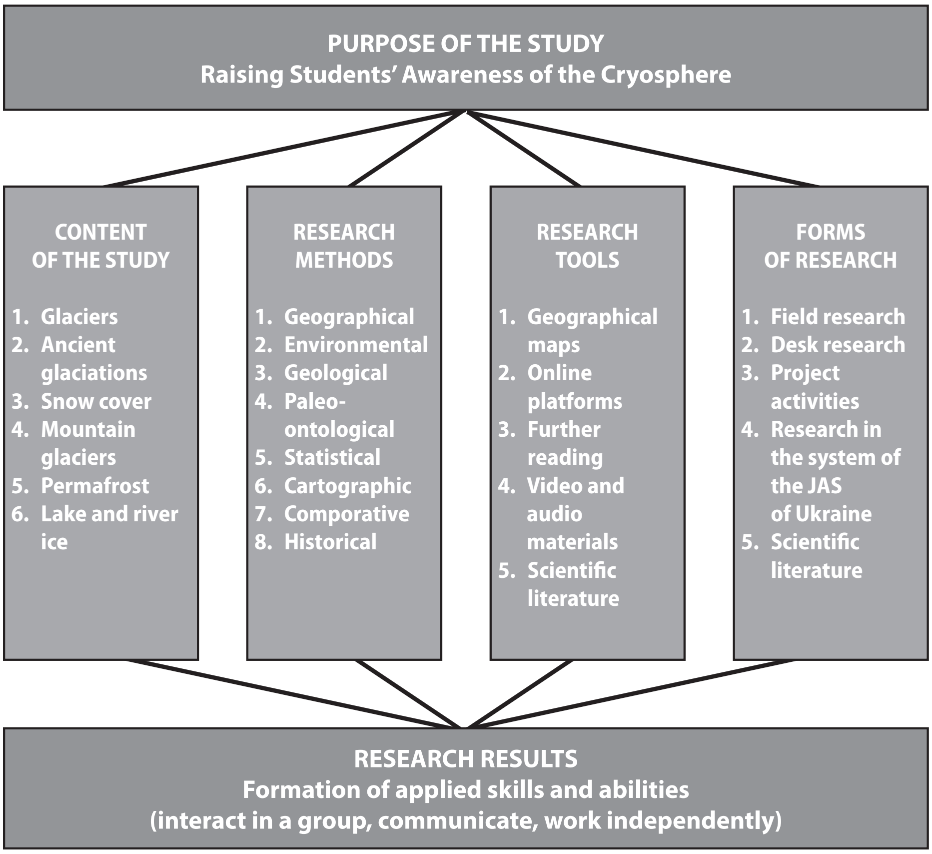

Fig. 5. Methods for studying glaciological problems in geography courses in general secondary education institutions

include contemporary glaciological processes, such as observing ice formation on lakes during the winter season.

International Year of Glacier Preservation (2025) is co-chaired by UNESCO and WMO, offering a variety of educational resources for students and teachers. Among them:

- *Global Glacier Casualty List*—a database for studying glacier-related incidents (https://glaciercasualtylist.rice.edu/?page=Page);
- *Ice School*—an educational platform for students and teachers (https://isskolen.dk/wp/?page_id=7477);
- *Glacier Change Portal*—an information portal on glacier changes (*https://glacierchange.com/en/*);
- *Exploring Our Earth through Human and Science*—video-based learning materials (https://www.undergroundchannel.dk/);
- *Climate Guide*—a single access point for climate change information (https://climateguide.fi/frontpage);
- *Polar Portal*—data on ice and climate in the Arctic (https://polarportal.dk/forsiden/).

Based on the study's results, we can develop a methodology for studying glacial problems in geography courses at general secondary education institutions ***(Fig. 5)***.

We have previously outlined the purpose, content, and methods of student research. Now, we will focus on the research subjects and incentives for these studies.

First, we will address the widespread use of digital platforms, exemplified by research on mountain glaciers. It is important to consider the various methods of implementing this research. We recommend incorporating these activities more widely into educational programs, utilizing them as both a method and a form of project-based learning. This could include ecological and cultural festivals, as well as thematic competitions at different scales—local (within communities), regional (across united territorial communities), and national (Ukraine-wide).

Additionally, participation in international projects is encouraged. For example, the International Year of Glacier Conservation in 2025 can serve as a model for assessing students' competencies in geography education at the secondary school level. These competencies, such as teamwork, communication, and independent problem-solving, are valuable lifelong skills.

Conclusions

The launch of the Decade of Action for Cryosphere Sciences (2025–2034) will encourage scientists and educators to devote greater attention to issues of climate change, the melting of mountain and ice-sheet glaciers, sea-level rise, and the increasing number of "climate migrants" in the near future.

The substantiation of the presented research results relates to the following key questions:

- **Glaciers as indicators of climate change**, which can be studied using traditional methods of working with sources of geographic information, including teaching aids for teachers and students, online platforms, and specialized websites. In educational practice, an activity-based approach is recommended to enhance students' understanding and awareness of rhythmic processes in the geographic environment.
- **Applying methods of geology, paleomorphology, and paleogeography** in the educational process enables students to understand glaciological processes in an accessible way—from the formation of ancient glaciations in Europe and North America to the present-day melting of mountain glaciers. The consequences of cooling or warming have catastrophic impacts on biodiversity loss in specific locations, the formation of modern landforms and landscapes, and the use of cultural heritage by local communities.
- **The importance of snow cover** lies not only in its impact on nature and the economy but also in its potential as a subject of study for students in general secondary education. This includes theoretical exploration of the processes of snow, hail, glaze, ice crust, blizzards, and heavy snowfalls, correlated with an understanding of the consequences of global warming in different regions of the world, particularly in Ukraine.
- **Interactive methods of studying mountain glaciers** in Iceland, Scandinavia, the Alps, and the Himalayas enable students to observe their retreat and the resulting impact on shifting national borders. During desk-based research, it is essential to foster students' social skills, ability to collaborate and communicate, as well as their capacity for independent work.

The novelty of the study lies in the development of methodological foundations for studying glaciological issues of the 21st century within educational practice, encouraging active involvement of geography teachers and students in the Decade of Action for Cryosphere Sciences (2025–2034). The popularization of glaciological knowledge can be achieved through interactive shows, exhibitions, storytelling, excursions, visits to natural history museums and scientific centers, and presentations of popular science books. These forms of engagement stimulate children's imagination, foster interest in science through play and discovery, and enhance scientific literacy, creative potential, and critical thinking. They also promote collaboration and peer learning, thereby shaping a new type of scientific citizenship.

References [Література]

1. Resolution adopted by the General Assembly International Year of Glaciers' Preservation, 2025. [on the report of the Second Committee (A/77/443, para. 32) on 14 December 2022]. URL: https://documents.un.org/doc/undoc/gen/n22/755/97/pdf/n2275597.pdf
2. Davison, B. J., Hogg, A. E., Gourmelen, N. and others (2023). Annual mass budget of Antarctic ice shelves from 1997 to 2021. *Science Advances.* 9(41). DOI: https://doi.org/10.1126/sciadv.adi0186
3. Geological heritage—bright evidence of earth evolution (2011). *Materials of Second International theoretical and practical conference.* Kyiv: Logos. 142 p. ISBN 978-966-171-396-2 [In Ukrainian]. [Геологічні пам'ятки — яскраві свідчення еволюції Землі : зб. матеріалів ІІ Міжнародної науково-практичної конференції. К. : Логос, 2011. 142 с. : іл. ISBN 978-966-171-396-2]
4. Hansen, K. Venezuela's Last Glacier, Humboldt, Has Melted Away. NASA Earth Observatory. 07 June 2024. URL: https://scitechdaily.com/venezuelas-last-glacier-humboldt-has-melted-away/
5. Adamenko, O. M., Mosiuk, M. I. (2020). Paleogeographical changes of the playstocene-holocene landscapes of the prykarpattia (according to the sections of the geological sight "Starunia"). *Ukr. geogr. ž.*, 3, 30–35. [In Ukrainian]. [Адаменко О. М., Мосюк М. І. (2020). Палеогеографічні зміни плейстоцен голоценових ландшафтів Прикарпаття (за даними розрізів геологічної пам'ятки «Старуня»). *Укр. геогр. журн.*, 3, 30–35.]. DOI: https://doi.org/10.15407/ugz2020.03.030
6. Schoonmaker, P. K., Foster, D. R. (1991). Some Implications of Paleoecology for Contemporary Ecology. *Botanical Review*, 57(3), 204–245.

7. Glacier Monitoring in Switzerland (GLAMOS). URL: https://swiss-glaciers.glaciology.ethz.ch/en/#/A54m-03 GLAMOS 1881–2023, The Swiss Glaciers 1880–2022/23, Glaciological Reports No. 1–142, Yearbooks of the Cryospheric Commission of the Swiss Academy of Sciences (SCNAT), published since 1964 by VAW / ETH Zurich. DOI: https://doi.org/10.18752/glrep_series

8. Amos, J. Climate change: Satellite maps warming impact on global glaciers. *BBC Science.* URL: https://www.bbc.com/news/science-environment-65399580

9. Lapointe Francois and Bradley Raymond S. Little Ice Age abruptly triggered by intrusion of Atlantic waters into the Nordic Seas. *Science Advances.* 15 Dec 2021. 7(51). DOI: https://doi.org/10.1126/sciadv.abi8230

10. Glaciers, the fragile mirrors of climate change. The UNESCO Courier. 2025. January-March. 56 p. URL: https://courier.unesco.org/en/latest

11. The GlaMBIE Team (2025). Community estimate of global glacier mass changes from 2000 to 2023. *Nature*, Vol. 639, p. 382–388. DOI: https://doi.org/10.1038/s41586-024-08545-z

12. Space Weather Prediction Center. National Oceanic and Atmospheric Administration USA. URL: https://www.spaceweather.gov/products/solar-cycle-progression

13. ACIA, Impacts of Warming Arctic: Arctic Climate Impact Assessment (2004). Cambridge University Press. 144 p.

14. AR6 Synthesis Report: Climate Change 2023. Chapter 2: High Mountain Areas. URL: https://www.ipcc.ch/srocc/chapter/chapter-2/

15. Portal Glacier Change. URL: https://glacierchange.com/en/

16. International Centre for Integrated Mountain Development (ICIMOD). Water, Ice, Society, and Ecosystems in the Hindu Kush Himalaya. URL: https://hkh.icimod.org/hi-wise/

17. Yatsenko, V. S., & Kravchenko, V. A. (2011). All about water for future generations. Nature of water: Textbook for 6–7 grades of general education schools. K.: Editorial board of the magazine *Water supply and drainage*. 152 p. (Series *Rational use and protection of water resources*). [In Ukrainian]. [Яценко В. С., Кравченко В. А. (2011). Все про воду для майбутніх поколінь. Природа води : Навч. посібник для 6–7 кл. загальноосвіт. шк. К.: Редакція журналу «Водопостачання та водовідведення», 2011. 152 с. (Серія «Раціональне використання і охорона водних ресурсів»)].

18. Sun, N., Brandon, A. D., Forman, S. L. & Waters, M. R. (2021). Geochemical evidence for volcanic signatures in sediments of the Younger Dryas event. *Geochimica et Cosmochimica Acta,* 312, 57–74. DOI: https://doi.org/10.1016/j.gca.2021.07.031

19. Maslyak, P. O., & Shyshchenko, P. G. (1994). Textbook on the Geography of Ukraine. A Teacher's Guide. Kyiv: Geneza, 448 p. ISBN 5-7707 5872-4. [In Ukrainian]. [Масляк П. О., Шищенко П. Г. Хрестоматія з географії України : Посіб. для вчителя. К.: Генеза, 1994. 448 с. ISBN 5-7707 5872-4].

20. "Small Cities—Big Impressions": Schedule of October Events. We invite you to visit! Association of Ukrainian Cities. [In Ukrainian]. [«Малі міста — великі враження»: розклад жовтневих подій. Запрошуємо відвідати! Асоціація міст України.]. URL: https://www.auc.org.ua/novyna/mali-mista-velyki-vrazhennya-rozklad-zhovtnevyh-podiy-zaproshuyemo-vidvidaty

21. Dangerous natural phenomena. Educational and methodological center of civil protection and life safety of Khmelnytsky region. [In Ukrainian]. [Небезпечні стихійні явища. Навчально-методичний центр цивільного захисту та безпеки життєдіяльності Хмельницької області.]. URL: https://nmc.dsns.gov.ua/km/news/ ostanni-novini/119

22. Pilorz, W., Laskowski, I., Surowiecki, A., & Łupikasza, E. (2023). Fatalities related to sudden meteorological events across Central Europe from 2010 to 2020. *International Journal of Disaster Risk Reduction,* 88. URL: https://www.sciencedirect.com/science/article/ pii/S2212420923001024

23. Severe Weather 101 – Types of Winter Weather. NOAA National Severe Storms Laboratory. URL: https://www.nssl.noaa.gov/education/svrwx101/winter/types/

24. ICIMOD. (2023). Water, ice, society, and ecosystems in the Hindu Kush Himalaya: An outlook. (P. Wester, S. Chaudhary, N. Chettri, M. Jackson, A. Maharjan, S. Nepal, & J. F. Steiner [Eds.]). ICIMOD. DOI: https://doi.org/10.53055/ICIMOD.1028

25. Marzeion, B., Hock, R., Anderson, B., Bliss, A., Champollion, N., Fujita, K., et al. (2020). Partitioning the uncertainty of ensemble projections of global glacier mass change. *Earth's Future.* 8, e2019EF001470. DOI: https://doi.org/10.1029/2019EF001470

26. Salyuk, M., Mykyta, M. (2020). Methodological materials for studying the course Geography of the Carpathian Region (for students of the specialty 8.014 — Secondary education. Geography) / ed. M. Salyuk, M. Mykyta. Uzhgorod: Publishing House of State Higher Educational Institution "UzhNU." 76 p. [In Ukrainian]. [Салюк М., Микита М. Методичні матеріали до вивчення курсу Географія Карпатського регіону (для студентів спеціальності 8.014 — Середня освіта. Географія). Ужгород : Видав. ДВНЗ «УжНУ», 2020. 76 с.].

The article was received by the editorial office on 02/22/2025,
accepted for publication on 03/05/2026.

Яценко В. С. 0000-0002-7948-2983

Інститут педагогіки НАПН України, Київ

До методики вивчення гляціологічних проблем XXI століття в освітній практиці

УДК 551.32:551.583:556.1:37.016:91:502/504(045)

Мета цієї публікації полягає в підвищенні поінформованості вчителів географії про важливість ролі об'єктів кріосфери у кліматичній системі та гідрологічного циклу, а також екологічні, соціальні та економічні наслідки змін клімату. Використано методи, як теоретичні, від абстрактного до конкретного, комплексні (абстрагування, аналізу і синтезу, індукції та дедукції, частково моделювання), а також емпіричні методи дослідження (спостереження, порівняння, вимірювання, експерименту). Гляціологічні дослідження в освітньому процесі можуть розпочинатися від першого снігу, граду, ожеледі, ожеледиці, хуртовини, сильних снігопадів у кореляції усвідомлення наслідків глобального потепління і змін клімату з конкретними проявами в Україні. Гірські льодовики Ісландії, Скандинавії, Альп та Гімалаїв слугують індикаторами змін клімату, впливають на зміни ландшафтів і навіть положення державних кордонів окремих країн. Матеріали розраховані на посилення робіт з учнями із основ гляціології, де важливо формувати соціальні навички, вміння взаємодіяти, спілкуватися, а також самостійно працювати. Десятиліття дій для наук про кріосферу 2025–2034 рр. забезпечує освітню систему та розширює можливості вчителів географії, щоб навчити учнів краще розуміти природне середовище та діяти відповідально. На часі створення науковцями розробок креативного та інтегрованого контенту, щоб стимулювати цікавість і наближення гляціологічної науки до учнівської молоді. Новизна полягає у формуванні методичних основ вивчення гляціологічних проблем XXI ст. в освітній практиці для потреб залучення вчителів і учнівської молоді до виконання заходів Десятиліття дій для наук про кріосферу 2025–2034 рр.

Ключові слова: *кріосфера, гляціологічні дослідження, гірські льодовики, сніг, популяризація науки, методика навчання географії.*

Цитування:
Яценко В. С. (2026). До методики вивчення гляціологічних проблем XXI століття в освітній практиці. *Український географічний журнал.* 2026. 1, 116–127. DOI: https://doi.org/10.15407/ugz2026.01.116