11-1-2025

Policy Aspects of Mitigation and Adaptation to Glacier Melt

José Romero

Author(s) ORCID Identifier:
0000-0003-4538-1321

Policy Aspects of Mitigation and Adaptation to Glacier Melt

José Romero
J Romero Consultant

Abstract

Global warming is causing irreversible glacier retreat. This phenomenon will have major consequences for the environment and human systems, particularly in terms of water availability, increased natural hazards, slope and valley stability, hydroelectric power generation, tourism, culture, and local lifestyles. Only a drastic and rapid reduction in greenhouse gas emissions could slow this phenomenon, but this reduction is slow in coming. Countries are experimenting with different approaches to mitigate ice melt, including integrated management of glacial and periglacial ecosystems and the local application of technologies. These technologies raise scientific questions about their effectiveness in a warming climate, and policy questions, particularly about their governance and cost. Proactive and sustainable adaptation to glacier retreat therefore remains the only realistic and effective approach to minimize the risks associated with glacier melt. Reports provided by countries under the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement (PA) provide interesting insights into the mitigation and adaptation policies and measures they are implementing or planning, highlighting the limitations imposed by the availability of capacity and finance, as well as by the limits of adaptation. The disaster that occurred on May 28, 2025 in the Swiss Alpine village of Blatten, which was buried under a landslide of ice and rock, and its handling offer useful lessons for adaptation to a glacier disaster. The laudable idea of the United Nations General Assembly to declare 2025 the International Year of Glaciers' Preservation must primarily serve the goal of adaptation, rather than the apparent illusion that glacier melt can be prevented in the face of global warming. This article focuses on the policy aspects of mitigating and adapting to glacier melt.

José Romero is a physicist by training and worked for the Swiss Federal Office for the Environment for twenty-five years where he served as Chief Scientist Environment International and National Focal Point for the United Nations Framework Convention on Climate Change (UNFCCC), the Intergovernmental Panel on Climate Change (IPCC), and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES).

Glaciers are an important part of the Earth's climate and hydrological system, as well as the culture and economy of human societies.[1] They are found on every continent and cover an area of approximately 700,000 km² (excluding Greenland and Antarctica).[2] Glaciers influence the ecosystem around them;[3] they carve out valleys, fjords, and cirques, leaving their mark on landscapes such as Yosemite Valley and the European Alps.[4] In the Himalaya, the Andes, the Alps, and many other places, they constitute a valuable cultural heritage and provide services to downstream populations such as meltwater for drinking water supply, agricultural irrigation, and hydroelectric generation. This water contributes to the conservation of mountain river ecosystems and riverine habitats that feed aquatic food chains and fisheries downstream to the oceans.[5] Glaciers lend themselves to cultural traditions and tourism in magnificent sites and landscapes.[6]

The Intergovernmental Panel on Climate Change (IPCC) defines a glacier as "A perennial mass of ice, and possibly firn and snow, originating on the land surface by accumulation and compaction of snow and showing evidence of past or present flow. A glacier typically gains mass by accumulation of snow and loses mass by ablation. Land ice masses of continental size (>50,000 km^2) are referred to as ice sheets."[7] This definition seems to require further nuance[8] at a time when "human influence is very likely the main driver of the global retreat of glaciers since the 1990s and the decrease in Arctic sea ice area between 1979–1988 and 2010–2019."[9]

As for the data on this retreat, the GlaMBIE team estimated, on a selected set of nineteen glacier regions around the world, that "since 2000, glaciers [in all regions] have lost between 2% and 39% of their ice regionally and about 5% globally. [...] with an increase of 36 ± 10% from the first (2000–2011) to the second (2012–2023) half of the period."[10] GlaMBIE also estimates that this melting contributed to a sea level rise of eighteen mm between 2000 and 2023. These conclusions are, overall, comparable to those of AR6,[11] although with some regional differences due to the different observation methods used.

The potential consequences of mass loss from glaciers are manifold, ranging from increased risks of natural hazards such as slope instability, landslides, and glacial lake outburst floods (GLOFs), to impaired water supplies for downstream ecosystems and populations and a contribution to sea level rise with implications for coastal flooding worldwide.[12] The World Meteorological Organization's (WMO) State of the Climate 2024 report estimates that glacial melt poses risks to at least nine of the seventeen Sustainable Development Goals.[13]

The United Nations General Assembly was concerned about these risks and adopted resolution A/RES/77/158 in December 2022, declaring 2025 the International Year for Glacier Conservation, and March 21 of each year World Glacier Day, starting in 2025. These decisions aim to raise global awareness of the crucial role of glaciers in the Earth's climate system and hydrological cycle, and their importance for the environment and society.[14] The disaster that occurred on May 28, 2025, in the Swiss Alpine village of Blatten highlighted the natural risks associated with melting glaciers,[15] as well as the policy issues, particularly for adaptation, that arise in such a situation.

Climate models project that glacier retreat will continue for decades, even under the lowest emissions scenarios.[16] To slow or halt this retreat, a drastic and rapid reduction in greenhouse gas emissions from human activities is necessary.[17] In addition to reducing greenhouse gas emissions, countries are taking measures to mitigate and to adapt to glacier melt. In this article, we will define glacier melt mitigation as any human intervention, including at the local level, aimed at reducing or halting melting; and adaptation as "[in human systems,] the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities."[18] Local measures to protect glaciers will be considered here as mitigation. It should be noted that

mitigation and adaptation measures can be synergistic, and that it is sometimes difficult to clearly separate mitigation and adaptation. Countries report on their policies and measures related to glaciers in the various reports they submit to the UNFCCC, inter alia National Communications, Nationally Determined Contributions, and Adaptation Communications, which we will use as a source of information in this article.[19]

In general, countries' legislation addresses glaciers according to the services they provide and the functions they perform. Thus, because they provide water-related services, glaciers are included in water laws; because they must be protected as ecosystems or landscape elements, they are included in laws protecting the natural environment; because they generate hazards, they are included in laws preventing natural risks; and so on for their cultural, landscape, and tourism functions.[20] With the exception of Argentina[21] and Tajikistan,[22] which have adopted laws on glaciers, the countries do not have laws on glaciers specifically. This is the reason for the proposal to consider glaciers as sui generis legal entities in order to adopt legislation regulating all their aspects and functions, and not just one of them, for example solely as a "water resource."[23] This is the approach taken by Argentina with its national law on glaciers—defined as public goods—which aims to protect glaciers and the periglacial environment. The objectives of the law are the preservation of glaciers as strategic water reserves, the preservation of biodiversity, the protection of glaciers as a source of scientific information, and their promotion as a tourist attraction. The law restricts all activities that may affect the natural state of glaciers, including the emission of pollutants, the construction of architectural works or infrastructure, the exploration and exploitation of mines and fossil fuels, and the installation of industries.[24] The same applies to Tajikistan, which has a similar law.[25]

The political status of glaciers is reinforced by their inclusion among the fifty Essential Climate Variables[26] defined by the Global Climate Observing System (GCOS). The IPCC periodically assesses the policy relevance of the information gathered through monitoring and scientific research conducted in countries with glaciers and at the international level.[27]

All countries face the political challenge of financing mitigation and adaptation measures, particularly with regard to glacier melt. The resources needed to meet this demand are unevenly distributed globally.[28] For developing countries, this question arises in light of Article 4 of the UNFCCC and Articles 3 and 7 of the PA,[29] and raises a debate about the role that the public and private sectors should play.[30]

The remainder of this article considers examples of national policies for mitigation and adaptation to glacier melt, with reference to international cooperation under the UNFCCC and the PA's Global Goal on Adaptation (GGA), draws policy lessons from the Blatten disaster, and discusses the policy relevance of the efforts of glacier science networks and funding. The article concludes with recommendations for action in the face of glacier retreat.

Glacier Melting, Mitigation, and Adaptation

The relevant policy framework and national measures relating to mitigation and adaptation to glacier melt are presented in the reports that countries provide to the UNFCCC and the PA, and focus mainly on water availability in glacier catchment areas, natural hazards associated with glacier melt, and consequences for populations and their environment. However, these reports do not necessarily provide a complete and detailed picture of national and subnational efforts by countries in all sectors affected by glacier melt. Nor are they exhaustive in terms of relevant legislation and approaches to mobilizing the necessary technological and financial resources,

including through international cooperation. A synthesis of the measures implemented or planned by all countries is not yet available and the Adaptation Committee of the UNFCCC will publish a first report on this subject soon,[31] where, it is hoped, the specific measures on glaciers will be presented. It should be noted that measures are all the more relevant and effective when they are based on scientific evidence and supported by the participation, priorities, and preferences of stakeholders, particularly local communities, who contribute useful traditional and local knowledge and for whom the aesthetic, cultural, and even spiritual dimensions of glaciers are important.[32]

In the case of glaciers, some approaches combine mitigation and adaptation. This is the case in the Peruvian Framework Climate Law,[33] which provides for ecosystem management for glacier mitigation and adaptation. In this article we will classify integrated ecosystem management as mitigation, while Argentina indicates "integrated management of glaciers and mountain basins" for adaptation, and specifies that "ecological restoration actions in glacial areas have been launched since 2020, integrating adaptive management techniques."[34]

Mitigation

The IPCC special report on the ocean and cryosphere in a changing climate (SROCC) concludes that "Reducing GHG [greenhouse gas] emissions is the main action to limit global warming to acceptable levels and reduce the occurrence of extreme events and abrupt changes."[35] Therefore, reducing emissions is the most effective mitigation measure against glacier melt. This being established, other policies and measures can contribute to reducing glacier degradation and retreat, and they will be considered in this article as mitigation measures for glacier melt.

Argentina and Tajikistan are the only countries with a law on glaciers. The Argentine law[36] aims to protect glaciers and their periglacial zone and prohibits, "in glaciers," the emission of pollutants, constructions, infrastructure or industries, exploration, and mining, which could affect the natural state of glaciers, destroy them, move them or interfere with their advance or with their functions as strategic water reserves for human consumption, agriculture, and recharge of river basins; protectors of biodiversity; sources of scientific information; and tourist attraction.[37] The Tajik law[38] is similar to the Argentine law and specifies what is "glacier protection - a set of requirements and measures to prevent and eliminate the negative impact of economic activity on glaciers." It establishes a fund for the protection of glaciers, funded in particular by international financing.

In the absence of such legislation, other countries consider glaciers to be areas that must be protected[39] and thus hope to mitigate their melting through integrated ecosystem and watershed management,[40] reducing the impact of water resource exploitation and mining in glacial and periglacial areas, and regulating tourism and related infrastructure such as ski lifts.[41] A few other examples are useful to illustrate this approach with legal instruments at the national and subnational levels. This is the case in Switzerland, which does not have a specific national law on glaciers, but protects them through two levels of jurisdiction, national and subnational (the cantons). The Swiss Civil Code defines glaciers as "ownerless and public objects" and therefore subject to cantonal legislation.[42] However, national laws protect glaciers: First of all, the Federal Law on the Protection of Nature and Landscape (LPN), with its Article 6, which stipulates that sixty-two percent of the 1,000 km² occupied by Swiss glaciers are classified as sites of national importance and must be preserved intact; and by its Article 3, which also applies to glaciers as sites "characteristic of the landscape."[43] Then, the National Law on Ski Lifts, which expressly aims

to preserve high mountains and glaciers.[44] In addition, there are the laws of the cantons, which are governed by the LPN, and require permits for activities in glacial and periglacial zones. Another example of glacier protection is provided by the Chilean mining policy,[45] one of whose objectives is the protection of glaciers. In 2024, France adopted a "Strategy for risks of glacial and periglacial origin."[46] Pakistan also announced glacier protection objectives in its Updated National Climate Change Policy (2021):[47] "Protect the HKH [Hindu Kush Himalaya] glaciers, considered the world's water tower, by declaring them as 'protected areas' through agreements among countries sharing the Himalayan region," and "Promote and encourage the use of glacier grafting techniques in high altitude areas," an ancient technique which consists of transporting ice to high altitude to create a new small glacier that serves as a water reservoir.[48] In Austria, in the state of Carinthia, the Kärntner Naturschutzgesetz 2002 - K-NSG 2002[49] provides in its Article 7 for the protection of glaciers: "In the area of glaciers and their watersheds, any lasting damage to the landscape is prohibited." However, its Article 10 allows "Exceptions to the prohibition referred to in Article 7 […] if the public interest of the measure must be considered superior, from the point of view of the common good, to the public interest of preserving glaciers and their watersheds from disruptive interventions." As can be seen, the law reflects the confrontation of divergent interests and establishes priorities.

Technologies constitute other mitigation measures, some of which have been tested in situ, while others are still at the conceptual stage.[50] They consist, for example, of adding artificial snow to the surface of glaciers using "snow cannons," modifying the albedo of the glacier surface by covering it with textiles or scattering glass microspheres that increase the reflection of incident solar radiation, stimulating precipitation on glaciers, modifying the solar radiation incident on the glacier, and pumping and adding meltwater from the base of the glacier to its surface in order to thicken the area where the glacier melts.[51] An assessment of these approaches shows that they are difficult to implement on a large scale due to their cost and technical challenges, and that they do not solve the problem of glacier melt on a global scale.[52] They raise scientific questions about the effects of their use, both locally and on a larger scale; as well as political questions about the authorization process; the involvement of local populations; and their cost and who should bear it, local actors, the national budget, or the private sector. Science is not yet able to provide answers to many of these questions, and it is unclear how countries could address the issue of liability in the event of negative effects related to the use of these technologies, as they do not have specific laws on this subject. However, with regard to snow cannons, several countries have put in place relevant regulations at the national or subnational level, particularly in the area of water resource management.[53] For the covering of glacier surfaces to protect them from melting, several countries require that promoters of such initiatives, such as operators of glacier-related tourist sites, obtain authorization from the competent authorities.[54]

Another measure to mitigate glacier melt is to reduce anthropogenic emissions of particles such as black carbon, which settle on the surface of glaciers, absorb light, and contribute to their melting.[55] Most countries have adopted laws aimed at reducing these emissions.[56]

Also worth mentioning is the proposal to monetize the services provided by glaciers, which should lead to a rationalization of the usufruct derived from glaciers, and thus to their protection.[57] In practice, as is the case in other environmental areas,[58] a glacier protection tax would be levied on tourism, hydroelectric, mining, and irrigation services provided by glaciers and reinvested in glacier protection.[59] This tax would require political consensus and legislation defining the conditions for its collection and the use of the revenue.[60]

Adaptation

Adaptation to climate change is provided for in Articles 3 and 4 of the UNFCCC. The PA introduced a Global Goal on Adaptation in its Article 7. Adaptation is imperative given that the inertia of the climate system will induce glacier melting even with a drastic and rapid reduction in global greenhouse gas emissions.[61] This melting will have predominantly negative effects because even positive effects, such as increased availability of glacier meltwater to power hydroelectricity production, will be limited in time until the glacier melts.[62] Adaptation must therefore minimize the risks and damage resulting from glacier melting, without neglecting to take advantage of potential benefits on various time scales. In their communications to the UNFCCC and the PA,[63] countries indicate that the negative consequences to which they are exposed concern, in particular, the availability and quality of water released by melting glaciers, which could be affected by contaminants, such as mercury; the instability of high mountain slopes; the decline in agricultural yields; the degradation of the aesthetic and cultural aspects of high mountains; and tourism and recreation. In the absence of a specific law for glaciers, countries indicate adaptation measures mainly in relevant laws, notably in sectors such as water, natural hazards, and the resilience of populations and ecosystems. It should be noted that developing countries have started by taking adaptation measures before implementing climate change mitigation measures, in accordance with the provisions of Article 4 of the UNFCCC. For example, Bolivia started with adaptation in 2010 while mitigation was planned for the period 2021–2030.[64]

Regarding policies and measures—already implemented or planned—related to water management, their importance is evident, as it is estimated that almost two billion people worldwide depend on water from glaciers.[65] In the Andes, the Andean Community, which establishes a framework for regional cooperation, adopted in 2021 the Andean Strategy for Integrated Water Resources Management,[66] integrated management allowing a systemic process for the development, assignment, and monitoring of water uses, according to social, economic, and environmental objectives that seek sustainable development.[67] In Asia, the Asian Development Bank (ADB) is carrying out projects specifically targeting glacier melting and its impact on water supplies in countries[68] such as the one in Tajikistan, Managing Glacier Loss and Water Security (M-GLOW), one of whose objectives is to strengthen the capacities of decision-makers for evidence-based decision-making for climate adaptation and water resource management. Another example is that of Switzerland, in the Alps region, with the 2020–2025 Action Plan for Adaptation to Climate Change,[69] which devotes numerous measures to water management and hydrology. Before developing this Plan, preliminary work was conducted to scientifically assess the challenges, risks, and opportunities associated with climate change in Switzerland across all environmental and societal domains, particularly in the areas of water and hydrology. Based on this, a degree of urgency was defined for each challenge, risk, and opportunity, and measures were recommended.

Another major theme reported by countries trying to adapt to melting glaciers is the management of natural hazards, which affect populations and infrastructure. Nepal and Pakistan, among other countries, are announcing measures such as early warning and evacuation systems in case of danger, as well as drainage structures to reduce the risks associated with glacial lake outburst floods (GLOFs), measures that are repeated in all countries with glaciers.[70] Slope weakening in high mountains and increased landslides are additional risks associated with melting glaciers, as illustrated by the disaster that struck the Swiss village of Blatten. In this case, disaster management and minimization of human losses were ensured through national and subnational

legislation that provides measures to anticipate natural hazards.[71] At the international level, the Sendai Framework under the aegis of the United Nations Disaster Risk Reduction (UNDRR), which aims to reduce disaster risks, is relevant.[72]

Finally, countries are seeking to strengthen the resilience of populations to glacier melt through various means, such as information provision, e.g., Argentina,[73] Peru,[74] and Switzerland,[75] and infrastructure development that takes into account natural hazards, including support for climate risk insurance schemes, e.g., Switzerland[76] and Nepal.[77] Other measures promote the resilience of periglacial ecosystems and glacial basins, e.g., Peru,[78] Argentina,[79] and Tajikistan.[80]

Finally, there are some positive consequences of glacier melt, which also require adaptation measures. The first, in the short term, is greater availability of meltwater, which can create lakes. These lakes, once developed, can be used for tourism and recreation, as well as reservoirs for retaining and storing water for various purposes such as the production of hydroelectricity and irrigation. Melting glaciers could also benefit plant species living on the margins of glaciers, which will have more surface area available as the ice recedes.[81]

Lessons from Blatten

The village of Blatten, located in the Lötschental Alpine Valley in the canton of Valais, Switzerland, was 90 percent buried on May 28, 2025, under debris from the collapse of the Birch Glacier and Kleines Nesthorn.[82] Blatten is located in the Jungfrau-Aletsch-Bietschhorn region, which was declared a UNESCO World Heritage Site in 2001. This region attracts many tourists for its ski slopes and cultural heritage such as the Tschägättä carnival. Only one human casualty was reported, as the population was evacuated as early as May 19. Immediately after the collapse, the Lonza River, which flows through the valley, was dammed by the debris and formed a lake, submerging the village's unburied structures. Blatten's three hotels were destroyed, and agriculture lost its meadows, pastures, and forage areas. A few weeks after the disaster, the Blatten example provides an opportunity to examine relevant policy areas for adaptation to glacier melt, such as preparedness, disaster management, and proposed aftermath solutions.

Blatten benefited from natural hazard monitoring and the evacuation of its population on May 19, before the disaster, based on the 2023 law of the canton of Valais on natural hazards and watercourse management.[83] A critical point is that in the canton of Valais, unlike the majority of cantons in Switzerland, property insurance is not mandatory and is left to the private insurance sector, which, in the event of a disaster, can be costly for owners who have not insured their buildings.[84] At the national level, there are legislative gaps in Switzerland regarding natural disasters, as noted by the country's top magistrate, the president of the National Council, one of the two chambers of the national parliament, who declared herself in favor of adopting a national law for natural disasters, including financial aspects.[85]

The management of the situation after the disaster was carried out as provided for in the 2013 cantonal law on the protection of the population and the management of special and extraordinary situations,[86] which established a crisis management headquarters in the municipalities to collaborate closely with the cantonal authorities. In the case of Blatten, it included military specialists in natural disasters, as well as private sector experts and geologists.[87] The disaster area and the surrounding slopes, which are still unstable, remain on alert, closed to the public, and secured. The risks posed by the lake, formed by the river being blocked by debris, have been controlled so that they do not pose a danger downstream. Authorities have built emergency access

roads to the Blatten hamlets spared by the disaster, which will have temporary electricity, sanitation, and water networks by 2026.

The residents of Blatten benefited from the solidarity of neighboring villages, which relocated them, provided them with basic necessities, and offered schools to their children. The national community also mobilized to provide emergency financial resources: millions of Swiss francs were pledged by the canton of Valais, the Swiss Confederation, and the Swiss population, in the first days and more were collected in the following weeks.[88] Solidarity with those affected by natural disasters is a well-established tradition in Switzerland.[89] The loss of livelihoods of Blatten residents in the tourism, agriculture, and service sectors exposes them to indebtedness, particularly to banks regarding mortgages on buildings. In this regard, the banks took measures to delay the payment of these mortgages. Charitable organizations such as the Red Cross and Caritas also mobilized to support the residents.[90]

Other consequences of the disaster concern the village's unique culture and heritage—the carnival characters, festivals, and landscape. These are threatened if the residents disperse to other villages and lose Blatten's identity. As for the ecosystems of the disaster area and the debris, with a lake formed by the Lonza River, a modified flow and sedimentation regime, and new coastal habitats, they will likely require several decades to revegetate.[91]

A few weeks after the disaster, the prospect of repairing the damage and rebuilding the site of the buried village is proving challenging. Pending a decision from the authorities regarding a hypothetical reconstruction of the buildings on a site to be determined, insurers have estimated the insured damage at CHF 260 million (USD 320 million) for the buildings and CHF 60 million (USD 75 million) for loss of economic activity.[92] Roads and other shared infrastructure such as drinking water services are the responsibility of the community, i.e., will be paid for through taxes.

The disappearance of the village and its hypothetical reconstruction raises the question of the limits of adaptation, which is not only a technical debate but also a question of societal values.[93] The Blatten disaster has sparked a debate in Switzerland between those who believe it is too risky, and therefore too costly, to maintain human settlements and economic activities in vulnerable high mountain areas exposed to melting glaciers, and those who believe that after the disaster, it is necessary to rebuild.[94] Nothing illustrates the attitude of the latter better—in accordance with priority four of the Sendai Framework "building back better" after the disaster—than the song "Le Vieux Chalet" by Abbé Bovet: the chalet is destroyed because "The snow and the rocks / United to tear it down." but "High up there on the mountain, there is a new chalet. / Because John, with a valiant heart, / rebuilt it more beautiful than before."[95] However, contrary to this heroic attitude, a survey conducted after the disaster revealed that when asked, "Do you think it is fair for the authorities to force people to leave their homes, even if there is only a risk of an event occurring in the medium term?", more than half of the Swiss population answered "yes."[96]

In conclusion, the Blatten disaster demonstrated the relevance of UNDRR recommendations on crisis preparedness and management.[97] It also raised the question of the limits of adaptation.

Scientific Support

International cooperation strengthens national efforts in glacier observation—for example, Glacier Monitoring in Switzerland (GLAMOS)—and research. This is the case with the World Glacier Monitoring Service, the Global Terrestrial Network for Glaciers, and the Global Climate Observing System. Glacier research is part of the World Climate Research Programme. The relevant knowledge available on glaciers is then periodically assessed by the IPCC, which

complements it with the assessment of information provided by countries.[98] The work of these organizations provides a valuable basis for making informed scientific decisions regarding glaciers.

Furthermore, the Global Framework for Climate Services (GFCS), under the auspices of the WMO, promotes relevant climate services in areas related to glaciers such as agriculture, disaster risk reduction, energy, environmental protection, tourism, and water resources (although the GFCS does not devote a specific section to them). This information serves as a basis for informed decision-making. The GFCS also encourages the establishment of national centers for climate services, which have emerged in many countries.

The Blatten disaster highlighted policy-relevant scientific issues, such as the monitoring of natural hazards at the local level, including cascading hazards; the need to clarify who should carry out this monitoring—local or national authorities, or the private sector—and whether it should be done continuously or sporadically and with what resources; the role of information, communication, and experts in political decision-making and the participation of affected populations; the adequacy of legislation to support the population against natural hazards, including financial aspects; and finally, the limits of adaptation.

Financial and technological constraints in countries limit their ability to monitor glaciers for disaster prevention purposes. This situation can lead to ad hoc monitoring solutions. In the case of Blatten, private companies under contract with the canton of Valais contributed to glacier monitoring.[99]

Funding Issues

The SROCC states that "People with the highest exposure and vulnerability are often those with the lowest capacity to respond."[100] In their communications to the UNFCCC and the PA, countries with glaciers indicate the approaches adopted to finance policies and measures in various sectors related to glaciers. However, the implementation of these policies and measures is hampered by a lack of human, financial, and technological resources. These resources, including the role of public and private insurance, also vary from country to country.[101] In addition to their own financial capacities, both public and private, developing countries rely on international cooperation and the New Quantified Collective Goal (NQCG) adopted in 2024,[102] based on Article 4 of the UNFCCC and Article 7 of the PA,[103] which is generating debates about the role of the private sector in financing adaptation.[104] International development finance institutions such as the Green Climate Fund and the Global Environment Facility are useful in supporting both mitigation (e.g., integrated management of glacial and periglacial ecosystems) and adaptation (e.g., water, agriculture, infrastructure, and hydropower projects). Developed countries, on the other hand, combine national and subnational financial resources with private resources, for example those from sectors that benefit from glacier services such as tourism and hydroelectric production.[105]

Next Steps

The most effective recommendation for protecting glaciers is to reduce greenhouse gas emissions. At the same time, and aware that global warming will inevitably lead to the melting and disappearance of many glaciers in the short and medium term, countries with glaciers should reach a political consensus around a national framework law on glaciers including elements that have been discussed in this article. If they do not adopt such a framework law, they should at least

declare glaciers as protected areas and promote the integrated management of glacial, periglacial, and watershed ecosystems. The issue of limits to adaptation should be considered.

International policy cooperation on glaciers should intensify, building on the momentum generated by the United Nations Year of Glaciers' Preservation in 2025 and, among others, the High-Level International Conference on Glaciers' Preservation held in Dushanbe in May 2025, which encouraged the "launch of a Global Glacier Agenda" to "raise the status of glaciers and the cryosphere."[106] Under the UNFCCC, the PA, the Convention on Biological Diversity, and other relevant bodies, the role of glaciers should be recognized, given their importance to the climate system, river basins, and biodiversity. The international policy processes should emphasize adaptation and promote mitigation primarily through reducing greenhouse gas emissions, declaring glaciers and their basins protected areas, and regulating technologies such as solar radiation modification. Transboundary cooperation should be encouraged where glaciers feed river basins spread across several countries. Furthermore, with regard to climate services, the GFCS should expand its information on glaciers.

The scientific support needed for glacier policy is not limited to monitoring and geophysical research on the inexorable loss of glacier mass. For research on adaptation—which has become inevitable—to be policy relevant, it must take into account the diverse perceptions and interests of populations and economic actors[107] on "1) socioeconomic impacts; 2) hydropower; 3) agriculture, irrigation, and food security; and 4) cultural impacts."[108] This does not mean abandoning glacier monitoring and research efforts at the national and international levels. On the contrary, these efforts as well as international collaboration must be continued and intensified. A first step toward making scientific research policy relevant is to engage with policymakers and communities affected by glacier melt to define the objectives of glacier observation and scientific research. These partners formulate policy-relevant questions that the scientific community can address, including socioeconomic and cultural issues. A second step is the assessment of this knowledge in the Seventh Assessment Report of the IPCC and in the Second Global Report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, both currently in preparation. The final step is to share with decision-makers and affected populations the options for successful and transformative adaptation, taking into account the diversity of interests and visions regarding glaciers and their melting. It should be noted that the sharing of knowledge and observational data is not self-evident, and specific policies should promote it. To this end, hopes are placed in the United Nations Decade of Action on Cryospheric Sciences (2025–2034).

International consensus on financial support for developing countries regarding glaciers should be reached under the UNFCCC and the PA, and echoed by international funds and institutions responsible for climate finance. In developing countries, this funding is required both for observation and research, as well as for implementing measures. The role of private finance needs to be clarified. Further consideration should also be given to the idea of taxing the services provided by glaciers and reinvesting the revenue in glacier protection.

A new avenue not explored in this article is one that could be opened up by the recent advisory opinion of the International Court of Justice on the "Obligations of States in respect of Climate Change,"[109] which could be relevant to the protection of glaciers.

Conclusion

From a physical perspective, preserving a piece of ice can be achieved by protecting it from mechanical destruction or maintaining it at a low temperature. Conversely, glaciers are exposed to mechanical damage caused by tourism, infrastructure, and mining activities, as well as rising atmospheric temperatures. This suggests that glaciers are inevitably doomed to retreat and melt. Snow cannons or covering certain glacier areas with textiles can only slow this trend locally. All that remains is to adapt to the melting of glaciers. At the national level and from a political perspective, only a law on glaciers can ensure the necessary coherence and the means for effective action, harmonizing the diverse visions of the relationship between humans and nature, the safety of populations and ecosystems, and economic interests. Argentina and Tajikistan are currently the only two countries, out of twenty-four countries with glaciers, to have adopted a law on glaciers. Other glacier-covered nations should do the same. In the meantime, efforts to mitigate and adapt to glacier melt must continue. For mitigation, integrated ecosystem-based management approaches to glaciers, periglacial areas, and their watersheds are useful. As for the proposed technologies, they have limited potential, are costly, and raise numerous questions, particularly in terms of the environment and governance. The very principle of the use of these technologies is questionable in the context of global warming, which inexorably leads to glacier melt. For adaptation, countries are continuing their efforts, individually and collectively, particularly within the framework of the PA's global adaptation goal, including financing measures in developing countries. The urgency of climate action must be understood by all and foster the necessary political agreements, both at the national level and within the PA, by setting priorities, promoting international collaboration, and making sufficient resources available. The Blatten disaster highlighted the need to prepare to minimize the effects of the disaster, manage the crisis, and support the affected populations. Each glacier is unique, as are the dangers it poses. Responses to these risks must involve local populations in the decision-making process.

Acknowledgments

I would like to express my deep gratitude to Ambassador Dr. Fareed Yasseen for asking me to write this article, to Dr. Carolina Adler, Executive Director of the Mountain Research Initiative, for providing me with the Dushanbe Glaciers Declaration, and to the New England Journal of Public Policy for publishing this article.

Notes

[1] Hans-Otto Pörtner, Debra C. Roberts, Valérie Masson-Delmotte, Panmao Zhai, Melinda Tignor, Elvira Poloczanska, and Nora M. Weyer, eds., "The Ocean and Cryosphere in a Changing Climate," in *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate* (2019), 133–135, https://www.ipcc.ch/srocc/.
[2] RGI 7.0 Consortium, *Randolph Glacier Inventory—A Dataset of Global Glacier Outlines*, version 7.0 (National Snow and Ice Data Center, 2023), https://doi.org/10.5067/f6jmovy5navz.
[3] "Glaciers and Landscape Change," U.S. Geological Survey, April 24, 2025, https://www.usgs.gov/programs/ecosystems-land-change-science-program/science/glaciers-and-landscape-change.
[4] "Glacial Geology," US National Park Service, last updated September 19, 2024, https://www.nps.gov/glac/learn/nature/glacial-geology.htm.

[5] Jean-Baptiste Bosson, Matthias Huss, Sophie Cauvy-Fraunié, Jean-Christophe Clément, Guillaume Costes, Mauro Fischer, Jérôme Poulenard, and Florent Arthaud, "Future Emergence of New Ecosystems Caused by Glacial Retreat," *Nature* 620, no. 7974 (2023): 562–69, https://doi.org/10.1038/s41586-023-06302-2.
[6] Peter G. Knight, *Glacier: Nature and Culture* (Reaktion Books, 2019).
[7] Intergovernmental Panel on Climate Change (IPCC), "Annex VII: Glossary," in *Climate Change 2021—The Physical Science Basis: Working Group I Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge University Press, 2023), 2215–56; J. G. Cogley, R. Hock, L. A. Rasmussen, A. A. Arendt, A. Bauder, R. J. Braithwaite, et al., *Glossary of Glacier Mass Balance and Related Terms*, IHP-VII Technical Documents in Hydrology No. 86, IACS Contribution No. 2 (UNESCO-IHP, 2011).
[8] Allen Pope, "Glacier or Not? The Importance of Nuance in Definitions of Vanishing Glaciers," preprint, EarthArXiv, September 8, 2025, https://doi.org/10.31223/X5GQ81.
[9] Hoesung Lee, Katherine Calvin, Dipak Dasgupta, Gerhard Krinner, Aditi Mukherji, Peter Thorne, Christopher Trisos, et al., *Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (IPCC, 2023).
[10] GlaMBIE Team, "Community Estimate of Global Glacier Mass Changes from 2000 to 2023," *Nature* 639 (2025): 382–88, https://doi.org/10.1038/s41586-024-08545-z.
[11] Lee et al., *Climate Change 2023*.
[12] Pörtner et al., "The Ocean and Cryosphere."
[13] World Meteorological Organization, *State of the Global Climate 2024*, WMO-No. 1368 (WMO, 2025).
[14] "77/158. International Year of Glaciers' Preservation, 2025," United Nations General Assembly, December 14, 2022, https://digitallibrary.un.org/record/3998543?v=pdf.
[15] Christian Huggel, "Christian Huggel's Post," LinkedIn, accessed May 28, 2025, https://www.linkedin.com/posts/christian-huggel-433671258_swiss-glacier-collapse-buries-most-of-village-activity-7333562946586894336-9U-k/.
[16] David R. Rounce, Regine Hock, Fabien Maussion, Romain Hugonnet, William Kochtitzky, Matthias Huss, Etienne Berthier, et al., "Global Glacier Change in the 21st Century: Every Increase in Temperature Matters," *Science* 379, no. 6627 (2023): 78–83, https://doi.org/10.1126/science.abo1324.
[17] Lee et al., *Climate Change 2023*.
[18] Lee et al., *Climate Change 2023*.
[19] "Party-Authored Reports," United Nations Framework Convention on Climate Change, accessed August 26, 2025, https://unfccc.int/reports.
[20] Jennifer Cox, "Finding a Place for Glaciers Within Environmental Law: An Analysis of Ambiguous Legislation and Impractical Common Law," *Appeal: Review of Current Law and Law Reform* 21 (2016): 21.
[21] "Ley Nacional de Glaciares 26639/2010," República Argentina, October 28, 2010, https://www.argentina.gob.ar/normativa/nacional/ley-26639-174117/texto.
[22] "ЗАКОН РЕСПУБЛИКИ ТАДЖИКИСТАН О ЗАЩИТЕ ЛЕДНИКОВ 2026" [Law of the Republic of Tajikistan on the Protection of Glaciers 2026], Republic of Tajikistan, January 3, 2024, https://faolex.fao.org/docs/pdf/taj224299.pdf.
[23] Cox, "Finding a Place for Glaciers"; Maximilian Hautzenberg, "Schutz und Nutzung der Gletscher im alpinen Rechtsraum: Beiträge zu einem nachhaltigen Gletscherschutz in Österreich," *Fachbeiträge des Österreichischen Alpenvereins*, Serie *Alpine Raumordnung*, no. 38 (2013).
[24] "Ley Nacional de Glaciares 26639/2010."
[25] "ЗАКОН РЕСПУБЛИКИ ТАДЖИКИСТАН."
[26] "Essential Climate Variables," Global Climate Observing System (GCOS), accessed August 26, 2025, https://gcos.wmo.int/site/global-climate-observing-system-gcos/essential-climate-variables.
[27] "Glaciers and Ice Caps," World Meteorological Organization, accessed August 26, 2025, https://wmo.int/topics/glaciers-and-ice-caps.
[28] United Nations Environment Programme, *Adaptation Gap Report 2024: Come Hell and High Water—As Fires and Floods Hit the Poor Hardest, It Is Time for the World to Step Up Adaptation Actions* (UNEP, 2024), https://doi.org/10.59117/20.500.11822/46497.
[29] "United Nations Framework Convention on Climate Change and Paris Agreement," accessed August 26, 2025, https://unfccc.int/sites/default/files/convention_text_with_annexes_english_for_posting.pdf; PA https://unfccc.int/sites/default/files/english_paris_agreement.pdf.
[30] "G77 and China Submission on Baku to Belém Roadmap to 1.3 Trillion," G77 and China, May 18, 2025, https://unfccc.int/documents/646948.

[31] "Regular Synthesis Reports on the State of Adaptation Action by Parties," United Nations Framework Convention on Climate Change and Paris Agreement, April 30, 2025, https://unfccc.int/documents/646623.
[32] "G77 and China Submission"; "Key Findings from the Technical Dialogue of the First Global Stocktake," United Nations Framework Convention on Climate Change and Paris Agreement, September 21, 2023, https://unfccc.int/documents/631600.
[33] "Ley Marco sobre Cambio Climático 30754," Republic of Peru, April 18, 2018, https://www.gob.pe/institucion/presidencia/normas-legales/355750-30754.
[34] "2da Comunicación Nacional de la República Argentina a la Convención Marco de las Naciones Unidas sobre Cambio Climático," Republic of Argentina, August 26, 2008, https://unfccc.int/resource/docs/natc/argnc2s.pdf.
[35] Pörtner et al., "The Ocean and Cryosphere."
[36] "Ley Nacional de Glaciares 26639/2010."
[37] Ibid.
[38] "ЗАКОН РЕСПУБЛИКИ ТАДЖИКИСТАН."
[39] Michael Bütler, "Glaciers—Objects of Law and International Treaties," in *alpine space—man and environment*, vol. 3, *The Water Balance of the Alps*, ed. Roland Psenner and Reinhard Lackner (Innsbruck University Press, 2007), 19–31; "Stratégie relative aux risques d'origines glaciaire et périglaciaire: Plan d'actions interministériel 2024–2026," République Française, 2024, https://www.ecologie.gouv.fr/sites/default/files/documents/24233_Strategie_risques_glaciaire_periglaciaire.pdf.
[40] "National Adaptation Plan (NAP) 2021–2050," Nepal, October 30, 2021, https://unfccc.int/documents/307952.
[41] Bütler, "Glaciers."
[42] "Code civil suisse," Confédération suisse, archived January 1, 2025, https://www.fedlex.admin.ch/eli/cc/24/233_245_233/fr.
[43] "Federal Act on the Protection of Nature and Cultural Heritage [LPN], RS 451," Confédération suisse, archived August 1, 2025, https://www.fedlex.admin.ch/eli/cc/1966/1637_1694_1679/en.
[44] "Ordonnance sur les installations à câbles transportant des personnes, RS 743.011," Confédération suisse, archived June 1, 2025, https://www.fedlex.admin.ch/eli/cc/2007/14/fr.
[45] "Minería 2050: Política Nacional Minera," República de Chile, 2022, https://www.minmineria.cl/?casas=mineria-2050-politica-nacional-minera.
[46] "Stratégie relative aux risques."
[47] "Updated National Climate Change Policy (2021)," Islamic Republic of Pakistan, June 2, 2022, https://unfccc.int/documents/497822.
[48] Ramsha Munir, Tehzeeb Bano, Iftikhar Hussain Adil, and Umer Khayyam, "Perceptions of Glacier Grafting: An Indigenous Technique of Water Conservation for Food Security in Gilgit-Baltistan, Pakistan," *Sustainability* 13, no. 9 (2021): 5208, https://doi.org/10.3390/su13095208.
[49] "Kärntner Naturschutzgesetz 2002 - K-NSG 2002," Republic of Austria, accessed August 26, 2025, https://www.ris.bka.gv.at/eli/lgbl/KA/2002/79/P1/LKT40003596?Abfrage=Gesamtabfrage.
[50] Feiteng Wang, Yida Xie, Lin Wang, Shuangshuang Liu, and Xiang Jin, "Mitigating Ice Sheets and Mountain Glaciers Melt with Geoengineering," *Science of the Total Environment* 963 (2025): Article 178450, https://doi.org/10.1016/j.scitotenv.2025.178450; Matthias Huss, Ursina Schwyn, Andreas Bauder, and Daniel Farinotti, "Quantifying the Overall Effect of Artificial Glacier Melt Reduction in Switzerland, 2005–2019," *Cold Regions Science and Technology* 184 (2021): Article 103237, https://doi.org/10.1016/j.coldregions.2021.103237; Mark Carey, Jordan Barton, and Sam Flanzer, "Glacier Protection Campaigns: What Do They Really Save?," in *Ice Humanities*, ed. Klaus Dodds and Sverker Sörlin (Manchester University Press, 2022), 89–109.
[51] Tom J. Battin, Albert van Wijngaarden, Birgit Sattler, Alexandre M. Anesio, Joseph Cook, Matthias Huss, and Arwyn Edwards, "Glaciers Are Not Just Blocks of Ice—Plans to Save Them Mustn't Overlook Their Hidden Life," *Nature* 639, no. 8056 (2025): 861–63, https://www.nature.com/articles/d41586-025-00897-4; Albert van Wijngaarden, John C. Moore, Bjorn Alfthan, Tiina Kurvits, and Lars Kullerud, "A Survey of Interventions to Actively Conserve the Frozen North," *Climatic Change* 177, no. 4 (2024): 58, https://doi.org/10.1007/s10584-024-03705-6.
[52] Wang et al., "Mitigating Ice Sheets"; Huss et al., "Quantifying the Overall Effect"; Battin et al., "Glaciers Are Not Just Blocks of Ice"; "Analyse des risques climatiques en Suisse: Base pour l'adaptation aux changements climatiques," Confédération suisse, 2025, https://www.bafu.admin.ch/uw-2502-f.
[53] "Bayerisches Wassergesetz (BayWG) vom 25. February 2010 (GVBl. S. 66, 130) BayRS 753-1-U," Federal Republic of Germany, archived August 1, 2025, https://www.gesetze-bayern.de/Content/Document/BayWG-35?hl=true; Federal Act on the Protection of Waters, 814.20," Confédération suisse, archived August 1, 2025,

https://www.fedlex.admin.ch/eli/cc/1992/1860_1860_1860/en; "Waters Protection Ordinance, 814.201," Confédération suisse, archived August 1, 2025, https://www.fedlex.admin.ch/eli/cc/1998/2863_2863_2863/en.
[54] "Valais: Un permis pour bâcher les glaciers," Radio Télévision Suisse, April 23, 2008, https://www.rts.ch/info/suisse/1096489-valais-un-permis-pour-bacher-les-glaciers.html.
[55] Pörtner et al., "The Ocean and Cryosphere"; Michael Boy, Erik S. Thomson, Juan-C. Acosta Navarro, Olafur Arnalds, Ekaterina Batchvarova, Jaana Bäck, Frank Berninger, et al., "Interactions Between the Atmosphere, Cryosphere, and Ecosystems at Northern High Latitudes," *Atmospheric Chemistry and Physics* 19, no. 3 (2019): 2015–61, https://doi.org/10.5194/acp-19-2015-2019.
[56] *The Case for Action on Black Carbon: Avoiding Climate Tipping Points, Building Resilience, and Delivering Clean Air*, Clean Air Fund, CSTEP, Berkeley Air Monitoring Group, Orbis Air, Daniel McDougall, December 2023, https://www.cleanairfund.org/resource/black-carbon/; Muthukumara Mani, *Glaciers of the Himalayas: Climate Change, Black Carbon, and Regional Resilience* (World Bank Publications, 2021).
[57] Zhengyong Zhang, Lin Liu, Xinlin He, Zhongqin Li, and Puyu Wang, "Evaluation on Glaciers Ecological Services Value in the Tianshan Mountains, Northwest China," *Journal of Geographical Sciences* 29, no. 1 (2019): 101–14, https://doi.org/10.1007/s11442-019-1586-1; Xingran Cai, Chunhai Xu, Yanqing Liang, Zhongwu Zhang, Zhongqin Li, Feiteng Wang, and Shijin Wang, "Glacier Service Value and Influence on Human Well-Being in Qilian Mountains," *Journal of Geographical Sciences* 33, no. 11 (2023): 2211–36, https://doi.org/10.1007/s11442-023-2173-z; Catherine J. Bruns and Ida Vikøren Andersen, "The Worth of Nature: Valuations of Glaciers in Alaskan and Norwegian Media Discourse," *Environmental Communication* 18, no. 3 (2024): 250–65, https://doi.org/10.1080/17524032.2023.2263655.
[58] "Prélèvements fiscaux liés à l'environnement," Confédération suisse, archived November 28, 2023, https://www.estv.admin.ch/dam/estv/fr/dokumente/estv/steuersystem/dossier-steuerinformationen/d/d-umweltbezogene-abgaben.pdf.download.pdf/d-umweltbezogene-abgaben.pdf.
[59] OECD, *Towards Green Growth* (OECD Publishing, 2011), https://doi.org/10.1787/9789264111318-en.
[60] "Prélèvements fiscaux liés à l'environnement."
[61] Harry Zekollari, Lilian Schuster, Fabien Maussion, Regine Hock, Ben Marzeion, David R. Rounce, Loris Compagno, et al., "Glacier Preservation Doubled by Limiting Warming to 1.5°C versus 2.7°C," *Science* 388, no. 6750 (2025): 979–83, https://doi.org/10.1126/science.adu4675.
[62] Pörtner et al., "The Ocean and Cryosphere."
[63] "Party-Authored Reports."
[64] "Actualización de las CND para el periodo 2021–2030 en el marco del Acuerdo de París," Estado Plurinacional de Bolivia, 2021, https://unfccc.int/sites/default/files/NDC/2022-06/CND%20Bolivia%202021-2030.pdf.
[65] Rounce et al., "Global Glacier Change."
[66] "Estrategia Andina para la Gestión Integrada de los Recursos Hídricos, DECISIÓN 763," Comunidad Andina, August 22, 2011, https://www.comunidadandina.org/DocOficialesFiles/decisiones/DEC763.doc.
[67] Neil S. Grigg, "Framework and Function of Integrated Water Resources Management in Support of Sustainable Development," *Sustainability* 16, no. 13 (2024): 5441, https://doi.org/10.3390/su16135441.
[68] "ADB Launches Major Initiative to Build Resilience to Melting Glaciers," Asian Development Bank, November 14, 2024, https://www.adb.org/news/adb-launches-major-initiative-build-resilience-melting-glaciers.
[69] "Adaptation aux changements climatiques en Suisse: Plan d'action 2020–2025," Confédération suisse, August 19, 2020, https://www.bafu.admin.ch/bafu/fr/home/themes/climat/publications-etudes/publications/adaptation-aux-changements-climatiques-en-suisse-plan-d-action-2020-2025.html.
[70] "National Adaptation Plan (NAP) 2021–2050"; "Updated National Climate Change Policy (2021)."
[71] "Natural Hazards: Acts and Ordinances," Confédération suisse, last updated June 3, 2022, https://www.bafu.admin.ch/bafu/en/home/topics/natural-hazards/law/acts-ordinances.html.
[72] "What Is the Sendai Framework for Disaster Risk Reduction?," United Nations Office for Disaster Risk Reduction, accessed August 27, 2025, https://www.undrr.org/implementing-sendai-framework/what-sendai-framework#documents.
[73] "Ley Nacional de Glaciares 26639/2010."
[74] "Ley Marco sobre Cambio Climático 30754."
[75] "Adaptation aux changements climatiques en Suisse."
[76] Ibid.
[77] "National Adaptation Plan (NAP) 2021–2050."
[78] "Ley Marco sobre Cambio Climático 30754."
[79] "Ley Nacional de Glaciares 26639/2010."

[80] "ЗАКОН РЕСПУБЛИКИ ТАДЖИКИСТАН."
[81] "Adaptation aux changements climatiques en Suisse."
[82] Huggel, "Christian Huggel's Post."
[83] "Loi sur les dangers naturels et l'aménagement des cours d'eau, 721.1," Canton du Valais, Confédération suisse, archived January 1, 2023, https://lex.vs.ch/app/fr/texts_of_law/721.1.
[84] "Les assureurs privés apportent une aide pragmatique et sans formalités administratives à la population de Blatten," Association suisse d'assurances, June 27, 2025, https://www.svv.ch/fr/les-assureurs-prives-apportent-une-aide-pragmatique-et-sans-formalites-administratives-la.
[85] "La présidente du National demande une loi pour l'aide en cas de catastrophe," HZ Insurance, June 23, 2025, https://www.handelszeitung.ch/insurance/la-presidente-du-national-demande-une-loi-pour-laide-en-cas-de-catastrophe-836246.
[86] "Loi sur la protection de la population et la gestion des situations particulières et extraordinaires, 501.1," Canton du Valais, Confédération suisse, archived September 1, 2019, https://lex.vs.ch/app/fr/texts_of_law/501.1.
[87] Didier Morard, "Encore méconnus, les états-majors de conduite jouent un rôle clé lors de catastrophes," *Rhône FM*, June 17, 2025, https://www.rhonefm.ch/valais/encore-meconnus-les-etats-majors-de-conduite-jouent-un-role-cle-lors-de-catastrophes-1010444; Beat Michel and Sandro Zulian, "À Blatten, ces missions délicates qui attendent l'armée," *Blick*, June 3, 2025, https://www.blick.ch/fr/suisse/elle-attend-le-feu-vert-a-blatten-larmee-devra-remplir-ces-deux-missions-cles-id20928123.html.
[88] Ivan Radja and Patrick Oberli, "Les dons affluent pour aider Blatten à se relever," *24 heures*, June 1, 2025, https://www.24heures.ch/glacier-du-birch-les-dons-affluent-par-millions-pour-aider-blatten-306744474908.
[89] Christian Pfister, ed., *Am Tag danach: Zur Bewältigung von Naturkatastrophen in der Schweiz 1500–2000* (Haupt, 2002).
[90] Laura Manent, "La Croix-Rouge et Caritas préparent la deuxième phase d'aide à Blatten," *24 heures*, June 24, 2025, https://www.24heures.ch/blatten-la-croix-rouge-et-caritas-lancent-la-2e-phase-daide-270135269579.
[91] Sophie Cauvy-Fraunié and Olivier Dangles, "A Global Synthesis of Biodiversity Responses to Glacier Retreat," *Nature Ecology & Evolution* 3, no. 12 (2019): 1675–85, https://doi.org/10.1038/s41559-019-1042-8.
[92] "320 millions de francs de dommages assurés après l'éboulement à Blatten," Association suisse d'assurances, June 17, 2025, https://www.svv.ch/fr/320-millions-de-francs-de-dommages-assures-apres-leboulement-blatten.
[93] Daniel Puig, Neil W. Adger, Jon Barnett, Lisa Vanhala, and Emily Boyd, "Improving the Effectiveness of Climate Change Adaptation Measures," *Climatic Change* 178, no. 1 (2025): 7, https://doi.org/10.1007/s10584-024-03838-8; Ben Orlove, "Glacier Retreat: Reviewing the Limits of Human Adaptation to Climate Change," *Environment: Science and Policy for Sustainable Development* 51, no. 3 (2009): 22–34, https://doi.org/10.3200/ENVT.51.3.22-34; Holly Moulton, Mark Carey, Christian Huggel, and Alina Motschmann, "Narratives of Ice Loss: New Approaches to Shrinking Glaciers and Climate Change Adaptation," *Geoforum* 125 (2021): 47–56, https://doi.org/10.1016/j.geoforum.2021.06.011.
[94] Bernard Debarbieux, "Trois leçons à tirer de la catastrophe de Blatten," University of Geneva, June 27, 2025, https://www.unige.ch/environnement/home/actualites/trois-lecons-tirer-de-la-catastrophe-de-blatten.
[95] Abbé Bovet, "Le Vieux Chalet" (1911), performed by Les Armaillis de la Roche, à la désalpe 2011 de Charmey (Suisse), posted September 30, 2011, YouTube, https://www.youtube.com/watch?v=_9Scg3kzpD8&list=RD_9Scg3kzpD8&start_radio=1.
[96] "Bergsturz in Blatten," Sotomo, accessed August 29, 2025, https://sotomo.ch/site/projekte/4694/.
[97] "What Is the Sendai Framework for Disaster Risk Reduction?"
[98] Pörtner et al., "The Ocean and Cryosphere."
[99] Luigi Jorio, "Mit Hightech gegen Erdrutsche und Naturgefahren in den Bergen," *Swissinfo*, July 8, 2025, https://www.swissinfo.ch/ger/klimaanpassung/mit-hightech-gegen-erdrutsche-und-naturgefahren-in-den-bergen/89645703.
[100] Pörtner et al., "The Ocean and Cryosphere."
[101] United Nations Environment Programme, *Adaptation Gap Report 2024*.
[102] "New Collective Quantified Goal on Climate Finance," FCCC/PA/CMA/2024/L.22, Conference of the Parties serving as the meeting of the Parties to the Paris Agreement, Sixth session, November 24, 2024, https://unfccc.int/documents/643641.
[103] "ЗАКОН РЕСПУБЛИКИ ТАДЖИКИСТАН"; "Ley Marco sobre Cambio Climático 30754"; "National Adaptation Plan (NAP) 2021–2050."
[104] "G77 and China Submission."
[105] "Adaptation aux changements climatiques en Suisse."

[106] "Dushanbe Glaciers Declaration," High-Level International Conference on Glaciers' Preservation, May 31, 2025, https://wmo.int/sites/default/files/2025-06/Dushanbe%20Glaciers%20Declaration-%20High-Level%20International%20Conference_v31May2025_final.pdf.
[107] Moulton et al., "Narratives of Ice Loss."
[108] Carey et al., "Glacier Protection Campaigns."
[109] "Obligations of States in Respect of Climate Change," International Court of Justice, July 23, 2025, archived July 23, 2025, https://www.icj-cij.org/sites/default/files/case-related/187/187-20250723-adv-01-00-en.pdf.