



2025
International
Year of Glaciers'
Preservation

Managing risks from Glacial Lake Outburst Floods

Key recommendations and solutions





Upper Varshedz, Tajikistan

© Laura Niggli

Glacial lakes can drain suddenly, causing dangerous Glacial Lake Outburst Floods (GLOFs).

Effective strategies – such as lowering water levels and early warning systems – can protect communities and infrastructure from GLOFs.

Glacial lakes form when moraines (deposits of debris left by glaciers), ice, or rock create dams that hold back meltwater. When these natural dams fail, the resulting GLOF can lead to significant risks or even disasters as occurred in the Indian Himalayas in 2013 ([Uttarakhand](#)) and 2023 ([Sikkim](#)). GLOFs can be triggered by ice or rock avalanches, the collapse of moraines due to excessive lake water, melting, or earthquakes.

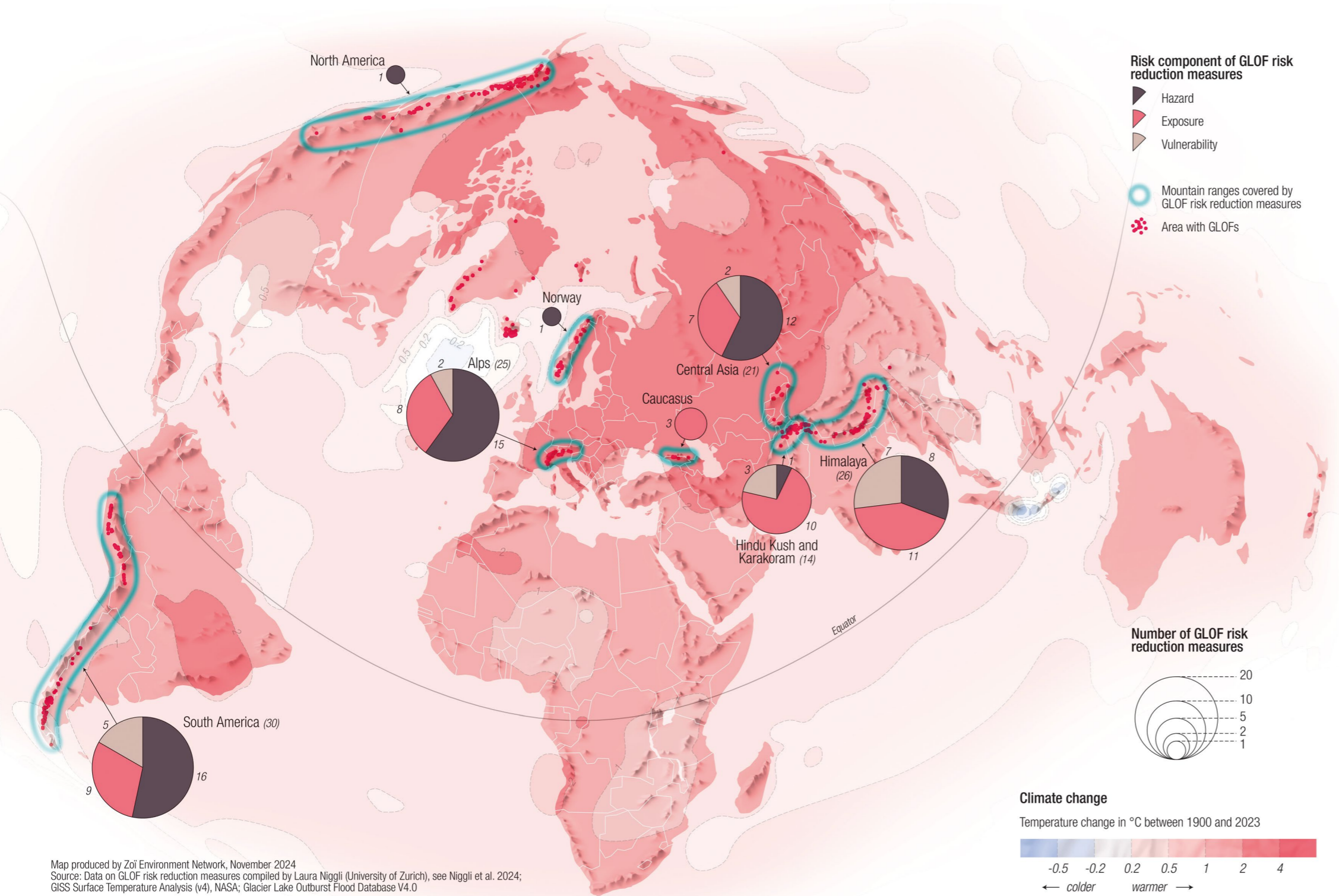
Glaciers around the world are retreating rapidly, and the risks from GLOFs are expected to increase where new lakes develop, and where downstream exposure of communities and infrastructure is expanding.

Strategies such as lowering water levels and implementing early warning systems can effectively protect communities and infrastructure from GLOF events.

Cover photo

Lake Palcacocha, Peru

© Lalo de Almeida / Panos Pictures



Effective GLOF risk reduction calls for solutions that address the hazard while reducing both exposure and vulnerability.

To date in most regions, GLOF risk management has concentrated on hazard reduction, and has taken a largely structural approach – drainage, lowering or regulating lake water levels, and the artificial fortification and stabilisation of the dam or downstream channels. Such measures are typically limited in their spatial coverage, and offer only short- to medium-term benefits.

Typically, no single solution is successful on its own, and ideally, combinations of short- and long-term solutions should be utilised. The [Reducing Risks and Vulnerabilities from Glacial Lake Outburst Floods in Northern Pakistan](#) project, for example, implemented a range of activities starting with the construction of check dams, flood protection walls, and bridges, and continuing through to longer-term efforts to establish early warning systems, strengthen institutional capacities and enhance awareness in local communities.

Map produced by Zoï Environment Network, November 2024
 Source: Data on GLOF risk reduction measures compiled by Laura Niggli (University of Zurich), see Niggli et al. 2024; GISS Surface Temperature Analysis (v4), NASA; Glacier Lake Outburst Flood Database V4.0



Upper Tien Shan valley in Central Asia
© Bergimus communicati / Adobe Stock

GLOF risk reduction should be part of integrated multi-hazard management that considers cascading hazards and impacts.

Measures in downstream areas to reduce exposure and vulnerability go beyond solutions that target specific glacial lakes, and bring wide-ranging co-benefits that reduce overarching risks. This approach aligns with the current push from the [UNDRR](#) towards multi-hazard and people-centered approaches. In Bhutan, for instance, a major project – [Addressing the Risks of Climate-induced Disasters through Enhanced National and Local Capacity for Effective Actions](#) – takes an integrated disaster risk management approach that considers GLOFs together with other threats such as droughts, floods, landslides, windstorms and forest fires. Global experience shows that early warning systems that are designed to warn of several hazards, and are based on coordinated and compatible mechanisms, efforts and capacities, are more efficient and likely more sustainable.





Pumping system in the Ulken Almaty river, Kazakhstan

© M. Kassenov

Strong coordination and stable governance are key to sustainable GLOF risk management.

Effective coordination in GLOF risk management calls for the establishment of close ties and strong collaboration among sectors and entities – governmental departments, scientific institutions, development practitioners, and local stakeholders and communities. In India, the National Disaster Management Authority applied a remarkable [science-policy process](#) to establish [Guidelines for the Management of GLOF Risks](#). These guidelines tailor international best practices to local use, and clearly outline the regulatory framework for GLOF disaster risk management in India. Beyond signifying a political priority, these guidelines provide the necessary basis upon which to build capacities and to generate a robust roll-out of GLOF disaster risk management.





Solukhumbu, Nepal
© ZUMA Press / Alamy

Incorporating local culture and socio-economic context, knowledge and perception is essential to successful GLOF risk reduction.

Top-down approaches and inadequate stakeholder coordination and cooperation weaken the local sense of ownership and responsibility required for effective and long-term sustainable GLOF risk management. Local risk perceptions and tolerance levels are shaped by experience, cultural and social norms, and religious belief systems. Meaningful engagement with local communities begins with the generation of risk knowledge, and continues through the design of GLOF disaster risk management measures that address local needs and expectations. The [Community-Based Flood and Glacial Lake Outburst Risk Reduction](#) project is a well-documented example from Nepal.



**Even with available solutions,
some remaining GLOF risks require
insurance or financial support.**

GLOF-related disasters, such as those that occurred in the Indian Himalayas in 2013 ([Uttarakhand](#)) and 2023 ([Sikkim](#)), have shown the devastating economic impacts on the tourism and energy sectors. Innovative and flexible solutions that allow for confident and secure investment in our global mountain regions are needed. At present, however, the development of appropriate risk transfer mechanisms in GLOF risk management is still an emerging field.



Kedarnath, India

© Stocksvids / Adobe Stock

Further resources

- Niggli, L., Allen, S., Frey, H., Huggel, C., Petrakov, D., Raimbekova, Z., Reynolds, J., Wang, W., 2024: GLOF Risk Management Experiences and Options: A Global Overview. In Oxford research encyclopedia of natural hazard science. Oxford University Press.
- [Adaptation at Altitude Solutions Portal](#)
Includes solutions that address a wide array of climate impacts
- The Leave No Mountain Behind synthesis series
Provides insights and good practice examples on [finance](#), [transboundary adaptation](#), [Indigenous knowledge](#), and [ecosystem restoration](#)
- [IPCC AR6 Cross-Chapter Paper 5: Mountains](#)
Gives the latest scientific assessment of climate change in mountains – impacts, risks, and adaptation
- [Policy Brief on Mountain Observations](#)
Provides an overview on the state of monitoring, data, and information for science, policy and society
- [Guidance for Parliamentarians](#)
Discusses legislative, budgetary, and process-based options for Members of Parliament
- [Leave No Mountain Behind – Disaster Risk Reduction for All](#)
Provides an overview of disaster risks from natural hazards in mountains and strategies for managing them

About Adaptation at Altitude

Adaptation at Altitude, a collaborative programme launched and co-supported by the Swiss Agency for Development and Cooperation, is dedicated to increasing the resilience of mountain communities and ecosystems to climate change. It aims to improve the availability and use of data and knowledge, strengthen science-policy platforms and dialogues, and build capacity and resource mobilisation for the evidence-informed formulation and implementation of effective climate change adaptation policies and institutional measures at the national, regional, and global levels. Reducing climate-induced risks and adapting to climate change in mountainous regions is a global concern. All countries of the world are in one way or another affected by climate impacts in the mountains. Temperatures in mountainous areas are rising faster than the global average, water resources are increasingly affected by variable climate patterns, and disasters related to natural hazards – including the downstream consequences – are becoming more frequent and severe, placing some of the world's most vulnerable areas at greater risk.

Imprint

Author

Simon Allen (University of Geneva and University of Zurich)

Contributors

Johanna Zwahlen, Otto Simonett and Alex Mackey (Zoï Environment Network)

Data

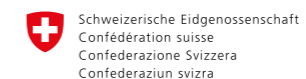
Data on GLOF risk reduction measures compiled by Laura Niggli (University of Zurich), see Niggli et al. 2024

Graphic design

Carolyne Daniel (Zoï Environment Network)

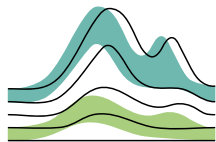
Map

Matthias Beilstein (Zoï Environment Network)



With financial support from:

Swiss Agency for Development
and Cooperation SDC



ADAPTATION
AT ALTITUDE



GLOFCA
GLACIER LAKE OUTBURST
FLOODS IN CENTRAL ASIA



2025
International
Year of Glaciers'
Preservation