Glacial Melt and Transboundary Water Insecurity: A Legal Dilemma

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Abstract: Global climate change is causing glaciers in the polar regions and high mountain ranges to melt at an unprecedented rate. This process directly threatens water resource security and ecological stability in transboundary river basins. The current international legal system, however, exhibits significant structural shortcomings in providing judicial remedies for such harm. Drawing upon potential customary international law, this study examines the applicability and limitations of existing legal frameworks in addressing the emerging challenge of glacial melt as a novel form of cross-border damage. The findings indicate that holding major contributing states accountable faces three intertwined dilemmas: difficulty in attributing responsibility, confusion in establishing causation, and a lack of applicable legal norms. Together, these obstacles substantially hinder states from seeking judicial redress. The paper concludes that while transboundary harm resulting from glacial melt demands a response from international law, traditional litigation alone is insufficient to resolve this crisis. Only through innovative mechanisms-such as implementing the precautionary principle and establishing a global glacier adaptation fund-can we move beyond the litigation dilemma and achieve effective remedies and climate justice.

Keywords: Glacial Melt; Transboundary Harm; International Law Dilemma; Global Glacier Adaptation Fund; Climate Justice

1. Introduction

Glacial melt is not merely an environmental crisis; it also represents a profound crisis in international law. As "solid-water reservoirs on Earth," glaciers sustain the survival and development of billions of people worldwide. The transboundary water fluctuations caused by glacial melt directly impact the ecological security, economic stability, and social well-being of downstream countries. However, the existing international legal system is primarily built upon experiences addressing point-source and immediate transboundary harm. When confronted with emerging forms of harm that are systemic, cumulative, and characterized by long causal chains-such as glacial melt-this system proves to be lagging and ineffective. Traditional litigation pathways face fundamental obstacles in terms of attribution, causation, and the application of relevant legal norms, resulting in a "governance deficit" within international law regarding the provision of effective remedies.

Accordingly, this study pursues three objectives. First, it seeks to legally characterize the nature of transboundary harm arising from glacial melt. Second, it aims to critically examine the structural dilemmas embedded within existing international law remedies. Third, it proposes an institutional framework that moves beyond the litigation paradigm-specifically, a cooperative governance mechanism centered on a Global Glacier Adaptation Fund-to shift the international response from debates over liability toward substantive remediation.

2. Literature Review

Scholarship on the legal implications of glacial melt has emerged from multiple disciplinary perspectives both domestically and internationally. However, existing studies still exhibit notable gaps in systematically addressing the distinctive transboundary harm characteristics associated with this phenomenon.

2.1 Domestic Research Status

Domestic scholarship has primarily approached the issue from the perspectives of foundational environmental law theories, climate change regulatory pathways, and the development of specific institutional frameworks. However, legal research specifically addressing glacial melt as a distinct phenomenon remains in its

early stages and lacks systematic inquiry.

First, regarding the legal characterization of climate change and its regulatory pathways, scholars have proposed rethinking the environmental law system to address climate-related challenges. He Xiangbai points out that China's current environmental legal framework is built upon the conceptual foundation of environmental pollution and ecological degradation, and has yet to encompass emerging risks such as climate change[1]. This observation precisely identifies the institutional limitations of domestic environmental law in responding to climate change, and provides important context for considering the legal characterization of harm caused by glacial melt.

Second, regarding the challenges of remedies and liability realization for climate change-related harm, scholars have begun exploring models that move beyond traditional compensation. Du Jianxun proposes that a legal liability system centered on "ecological restoration" should be established[2]. Remedies for harm caused by glacial melt should not be confined to conventional compensation, but rather should emphasize supporting adaptation and restoration in affected areas through financial mechanisms. This provides a potential theoretical foundation for the "Global Glacier Adaptation Fund" contemplated in this study.

2.2 International Research Status

Overseas scholarship has addressed the specific impacts of glacial changes and adaptation practices at a relatively earlier stage, with in-depth explorations conducted at the levels of international legal theory and climate litigation.

On one hand, empirical research has revealed adaptation practices and governance bottlenecks in glacier regions. Aggarwal et al. found that successful implementation of adaptation is generally constrained by insufficient stakeholder capacity, limited collaboration, and-most critically-a lack of financial resources[3]. This study clearly demonstrates that providing financial support is an urgent necessity in responding to the impacts of glacial melt, which aligns with this study's proposal to establish a Global Glacier Adaptation Fund.

On the other hand, scholars are actively exploring how to advance climate responsibility through litigation. The wave of climate litigation, exemplified by the Urgenda Foundation v. The Netherlands case, has generated extensive academic discussion regarding state obligations, the boundaries of judicial review, and the establishment of causation[4]. Although these studies do not specifically address glaciers, their analysis of causation and interpretation of state obligations provide important research perspectives and theoretical tools for examining the attribution and causation dilemmas facing litigation over transboundary harm caused by glacial melt.

3. Legal Characterization

Glacial melt, as a clearly identifiable physical process, constitutes a legal issue that must first be resolved before any meaningful discussion of remedies and institutional design can take place. Whether it can be legally characterized as transboundary harm under international law is an unavoidable prerequisite question.

3.1 Legal Elements of Transboundary Harm in International Law

Under international law, "transboundary harm" refers to significant damage caused to the environment or interests of another state by the physical consequences of activities conducted within the jurisdiction or control of a state that cross national boundaries. Harm resulting from glacial melt largely falls within this definition[5].

Regarding the actor element, greenhouse gas emissions that contribute to glacial melt originate from activities conducted within the territory or under the jurisdiction of numerous states. Their cumulative effect constitutes activities attributable to states for legal purposes.Regarding the harm element, the physical loss of glaciers within upstream states translates into water scarcity or flooding within downstream states, satisfying the transboundary requirement.Regarding the nature of the harm, the long-term, systemic impairment of water resources-which are strategic and essential for survival-clearly exceeds the level of interference that states are ordinarily expected to tolerate in international relations, thereby constituting significant harm.

Thus, although the sources of harm are diffuse and the causal chain is complex, the core characteristic-crossing national boundaries and adversely affecting the vital interests of other states-nevertheless brings glacial melt within the legal purview of "transboundary harm" for

examination and regulation.

3.2 Preliminary Legal Consequences of Transboundary Harm from Glacial Melt

Once legally characterized as transboundary harm, a series of preliminary legal consequences follow.

First, it triggers the obligations of prevention and cooperation. Under the "no-harm principle" in customary international law, states have a duty of due diligence to take appropriate measures to prevent activities within their territory from causing significant transboundary harm. Major emitting states are therefore required to undertake reasonable mitigation actions and to engage in information exchange and consultations with potentially affected states regarding transboundary risks.

Second, it opens potential avenues for legal accountability. Affected states thereby acquire the legal interest to bring claims before international tribunals. At the domestic level, innovative attempts have also emerged, such as the case of Peruvian farmers suing the German energy company RWE, which sought to hold major emitters liable under domestic tort law-an effort to localize a global problem through judicial means[6].

Finally, it exposes the fundamental inadequacies of the existing legal framework. Traditional international watercourse law primarily regulates direct pollution or excessive extraction of water bodies, but lacks clear rules addressing fundamental reductions in water volume caused by climate change-reductions that originate outside the watercourse itself. This normative gap and legal lag create significant obstacles to the remedial steps that should logically follow legal characterization, thereby giving rise to the core dilemmas that this study will next examine in depth.

4. Why Traditional International Law Remedies Fail: Three Dilemmas

In seeking remedies, affected parties may invoke various legal bases-including climate treaties, customary international law, international watercourse law, or human rights law-but each has inherent limitations. Treaty obligations are primarily conduct-based rather than result-oriented. The no-harm principle imposes a high threshold of proof. Watercourse law struggles to regulate emissions originating outside the basin. Human rights law is often applied with restraint on grounds of policy discretion. These limitations manifest in three specific dilemmas.

4.1 Attribution Dilemma

This is the most fundamental of the three dilemmas. Climate change results from the combined effect of cumulative global emissions. The uniform mixing of greenhouse gases in the atmosphere means that no specific instance of harm can be traced back to individual or even a few emitting activities in the same way that a pollution source can be identified. In legal proceedings, requiring proof that a defendant state's specific emissions were the material cause of a particular harm to the plaintiff presents nearly insurmountable scientific and legal obstacles. Although source attribution science has advanced to the point where it can quantify a country's contribution to global temperature rise, there is still no reliable method to establish an exclusive, legally cognizable causal link between such global contributions and a specific instance of harm. Can a party that contributed one percent to a global problem be held fully or proportionally liable for a specific harm caused by that problem? Existing international liability law provides no clear answer to this question.

4.2 Causation Dilemma

International adjudication typically requires a "sufficiently direct and certain causal link" between the wrongful act and the harm suffered. The causal chain in climate-related harm, however, is extraordinarily lengthy: from specific emissions, to increased global concentrations and enhanced radiative forcing, to global warming and altered regional climate patterns, to changes in the mass balance of specific glaciers and subsequent hydrological shifts in particular rivers, and ultimately to economic losses or threats to survival. Each link in this chain is fraught with scientific uncertainty-natural variability, model errors, and the influence of other environmental stressors, among others. Defendant states can readily raise plausible challenges at any stage, placing upon plaintiffs an almost impossible burden of proof. To establish legal certainty, plaintiffs would need to exclude all other possible causes-a task that is nearly unattainable.

4.3 Applicable Law Dilemma

Even if the first two dilemmas are partially

overcome, prevailing in a lawsuit still faces final hurdles. The relevant rules of international law are largely principled and framework in nature, lacking clear and quantifiable standards of conduct, which grants defendant states significant room for interpretation and defense. Moreover, the quantification of damages is a bottomless pit. Finally, and most critically, the enforcement of international judgments lacks compulsory guarantees. In a system of sovereign equality among states, there is no supranational enforcement body. The risk always exists that a losing state, based on political or economic considerations, will refuse to comply with the judgment, potentially reducing a lengthy litigation to nothing more than a piece of paper. This severely undermines the effectiveness and deterrent power of legal remedies. Together, these dilemmas demonstrate that merely patching up existing litigation pathways is insufficient to effectively address systemic challenges such as glacial melt.

5. Breaking the Impasse: A Global Glacier Adaptation Fund

The dilemmas discussed above reveal a fundamental tension between traditional adversarial litigation and the nature of climate change-induced harm. Therefore, the international community urgently needs to promote a paradigm shift in legal thinking: moving from a "jurisprudence of adjudication" focused on ex post facto determinations of fault and allocation of compensation, toward a "jurisprudence of governance" emphasizing ex ante risk prevention, cooperative management, and collective restoration.

5.1 Legal Foundation

As the core institutional embodiment of this new paradigm, this study proposes the establishment of a dedicated Global Glacier Adaptation Fund. Its legal foundation rests on three principles[7]. First is the principle of common but differentiated responsibilities and respective capabilities. This principle recognizes that developed countries bear primary responsibility for historical emissions and possess greater capacity to respond, and thus have an obligation to support developing countries financially and technologically. Second is the precautionary principle, which calls for preventive financing measures to reduce the exposure and sensitivity of vulnerable communities when science has issued clear warnings, even before harm has fully materialized. Third is the principle of international cooperation. In addressing transboundary global challenges, cooperation is a legal obligation, not merely a policy choice.

5.2 Institutional Design

First, the funding sources must be diversified, adequate, and sustainable. These could include: mandatory financial contributions from developed countries calculated based on indicators such as their historical cumulative emissions and economic capacity; a proportion of revenues from international aviation and maritime carbon taxes; designated shares of proceeds from global carbon market transactions; and voluntary donations from the private sector and philanthropic sources.

Second, the governance structure is essential to the fund's legitimacy and credibility. A governing board, composed of representatives from both contributing and recipient states, should be established as the highest decision-making body. To balance rights and interests, a "double majority" voting mechanism could be adopted, whereby decisions require approval from both a majority of contributing states and a majority of recipient states.

Last, Funding models and priorities are key to the fund's effectiveness. The "direct access" modality pioneered by the UN Adaptation Fund should be fully adopted and optimized, authorizing recipient states to directly apply for, manage, and implement projects through their accredited national implementing entities. Funding should be strictly targeted toward the most vulnerable communities directly affected by glacial melt, with priority given to supporting: engineering adaptation, social adaptation, ecological adaptation, and capacity building.

5.3 Feasibility and Prospects

The political feasibility of a Global Glacier Adaptation Fund lies in its offering developed countries a manageable, predictable, and results-visible channel for fulfilling responsibilities, thereby avoiding the risk of uncertain and substantial compensation claims in court. For developing countries and the most vulnerable communities, it provides a tangible pathway to access urgently needed and specialized resources. In the context of the International Court of Justice's advisory opinion of 23 July 2025, which reinforces state

obligations regarding the prevention of transboundary environmental harm and the duty to cooperate in addressing climate change, the conception of such a fund gains increased practical urgency and negotiating momentum[8].

6. Conclusion

Glacial melt records the profound transformations occurring within the Earth's system; the response of international law tests the wisdom and solidarity of the human community. Facing this challenge-one that concerns water security and intergenerational justice-legal innovation must have the courage to break free from established conventions. This study is not merely an academic paper, but also an attempt: an attempt to shift international law from addressing past, localized pollution toward governing future, systemic risks; an attempt to translate abstract climate justice into actionable cooperative mechanisms. We hope that through continued research and international cooperation, more just, effective, and resilient institutions can emerge to safeguard all lives and civilizations that depend on the gifts of glaciers.

References

[1] He, X.B. (2020) The Environmental Law Approach to Climate Change Regulation: Legal Demands and Institutional Choices. China Legal Science, (5): 25-41.

[2] Du, J.X. (2025) On the Environmental Legal Liability System Centered on “Ecological Restoration”. Jianghuai Tribune, (1): 112-119.

[3] Aggarwal, A., Frey, H., McDowell, G., et al. (2022) Adaptation to climate change induced water stress in major glacierized mountain regions. Climatic Change, 170(3-4): 22.

[4] Urgenda Foundation v. The State of the Netherlands. (2019) Supreme Court of the Netherlands, Case No. 19/00135.

[5] Birnie, P., Boyle, A., Redgwell, C. (2009) International Law and the Environment. 3rd ed. Oxford University Press, Oxford.

[6] Saúl Luciano Lliuya v. RWE AG. (2022) Higher Regional Court of Hamm (Germany), Case No. 5 U 15/17.

[7] Mace, M.J., Verheyen, R. (2016) Loss, damage and responsibility after COP21: All options on the table. Review of European, Comparative & International Environmental Law, 25(2): 197-212.

[8] International Court of Justice. (2025) Advisory Opinion on the Obligations of States in respect of Climate Change, 23 July 2025.

