2025 Glacier Dynamics Causes, Consequences, and Preservation: In the Era of Climate Change

World Water Day

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As glaciers retreat, they don't just disappear—they reveal the scars of a warming planet.

Water and its significance



Essential for Life: Water is vital for survival, supporting all forms of life—humans, animals, and plants.



Health & Hygiene: Critical for drinking, sanitation, and disease prevention.



Agriculture & Food Security: Irrigates crops, ensuring food production.



Economic Growth: Supports industries, energy production, and transportation.



Ecosystem Balance: Sustains biodiversity and regulates climate.

Water is Life – Conserve It!



- Saltwater Dominance: About 97.5% of Earth's water is saltwater, primarily in oceans and seas, making it non-potable.
- Freshwater Scarcity: Only 2.5% of Earth's water is freshwater, essential for human consumption, agriculture, and ecosystems.
- Glaciers and Ice Caps: Nearly 68.7% of freshwater is stored in glaciers, ice caps, and permanent snow, mostly in Antarctica and Greenland.
- Groundwater Reserves: Around 30.1% of freshwater is groundwater, crucial for drinking water and irrigation.
- Surface Water & Other Sources: Only 1.2% of freshwater is surface water and other accessible sources, including lakes, rivers, and soil moisture.
 - **Lakes and Rivers**: Lakes contain **87%** of surface freshwater, while rivers, though only 0.49%, are vital for ecosystems and human settlements.
 - Human Accessibility: Less than 1% of Earth's freshwater is readily available for direct human use.

India's Water Crisis: Challenges of Quality and Scarcity

Glaciers and its significance

- Glaciers, those frozen giants, are not just beautiful landscapes; they are vital reservoirs of freshwater, holding approximately 70% of the world's freshwater supply. Their meltwater sustains ecosystems, provides drinking water, supports agriculture, and powers our industries.
- However these ice formations are rapidly retreating due to climate disruption. Preserving these crucial resources is essential for environmental sustainability, economic stability and safeguarding cultures and livelihoods.

Water towers of the world!

Distribution of Glaciers



Global distribution of inventoried glaciers. Data sources: WGI data provided by the WGMS, Zurich, Switzerland; glacier layers of GLIMS data and of the Digital Chart of the World provided by NSIDC/GLIMS, Boulder, U.S.A. GLIMS Inventory date: January 2014.

Glaciers exist on every continent except Australia. Approximate distribution is:

- 91% in Antarctica
- 8% in Greenland
- Less than 0.5% in North America (about 0.1% in Alaska)
- 0.2% in Asia
- Less than 0.1% are in South America, Europe, Africa, New Zealand, and Indonesia.

Shrinking Glaciers and Growing Lakes As Temperatures Rise on the Tibetan Plateau



October 12, 1987

October 9, 2021

Alarming Shrinkage of Norway's Ålfotbreen Glacier – "Cannot Survive the Current Climate"



Satellite image of Ålfotbreen glacier in Norway, captured on August 23, 2003.

Satellite image of Ålfotbreen glacier in Norway, captured on September 4, 2022.

The Alps Are Melting: Four Decades of Glacier Loss Captured From Space



Satellite view of the Great Aletsch Glacier in southwestern Switzerland captured on August 6, 2024. Satellite view of the Great Aletsch Glacier in southwestern Switzerland captured on September 2, 1984.

The Shrinking Giant: A 40-Year Look at Alaska's Mendenhall Glacier



Satellite image of Mendenhall Glacier captured on August 17, 1984, by the Thematic Mapper on Landsat 5.



Satellite image of Mendenhall Glacier captured on July 28, 2023, by the Operational Land Imager on Landsat 8.



Glaciers Under Threat

The period from 2022 to 2024 saw the largest three-year loss of glacier mass ever documented. The year 2024 marked the third consecutive year of net glacier mass loss in all 19 monitored regions. Some areas, like the Canadian Arctic, experienced moderate reductions, but others, such as Scandinavia and North Asia, suffered record-breaking depletion. Some regions, such as Central Europe, have lost nearly 40 per cent of their glacial ice, showing how unevenly the effects of climate change are distributed.

VISUAL CAPITALIST DATASTREAM

Visualizing the GREAT ICE MELTDOWN

A new scientific survey, based on satellite observations and numerical models, reveals that **28 TRILLION TONNES** of the Earth's ice has melted away in just 24 years.





Source: Slater, T. et al. "Review article: Earth's ice imbalance", The Cryosphere (2021)

Glaciers Under Threat

- "WMO recently confirmed that 2024 was the warmest year on record and has sounded repeated Red Alerts about the state of our climate, including the retreat of glaciers. In 2023, glaciers suffered the largest mass loss in the five decades of record-keeping. It was the second consecutive year in which all regions in the world with glaciers reported ice loss. Melting ice and glaciers threaten longterm water security for many millions of people. This international year must be a wake-up call to the world," said Celeste Saulo, Secretary-General of WMO.
- The preservation of glaciers stands as one of humanity's most urgent challenges. These ancient ice formations are not just frozen water – they are the guardians of our planet's climate history, the source of life for billions, and sacred places for many cultures. Their rapid disappearance is a stark reminder that we must act now," said Audrey Azoulay, Director-General of UNESCO.

Glaciers Under Threat



Glaciers are critical to life - their meltwater is essential for drinking water, agriculture, industry, clean energy production and healthy ecosystems. Rapidly melting glaciers are causing uncertainty to water flows, with profound impacts on people and the planet. Global reductions in carbon emissions and local strategies to adapt to shrinking glaciers are essential. This World Water Day, we must work together to put glacier preservation at the core of our plans to tackle climate change and the global water crisis. Glaciers are melting faster than ever. As the planet gets hotter due to climate change, our frozen world is shrinking, making the water cycle more unpredictable and extreme.



Glacial retreat threatens devastation. For billions of people, meltwater flows are changing, causing floods, droughts, landslides and sea level rise, and damaging ecosystems.

Water Tower of Asia



Water Tower of Asia is under Severe threat

- 600 GT lost 2023 alone
- Over 25000 glacier lakes exists
- 47 considered potentially hazardous due to the risks Glacial Lake Outburst Floods
- Thyanbo glacial lake outburst on aug. 16 2024
- 7 feb 2021 tapovan Thermal project was swept away by flash flood
- The Silkyara Bend–Barkot tunnel, involved the successful rescue of 41 trapped workers after a 17-day ordeal following a collapse on November 12, 2023.
- 2 march 2025: A massive avalanche struck a Border Roads Organisation (BRO) camp near Mana village in Uttarakhand's Chamoli district, burying 54 workers under snow. Rescue teams saved 46 workers, but eight workers tragically lost their lives. As the search continued on Sunday, the body of the last trapped worker was found in the afternoon while agencies were trying to locate him using advanced technology and aerial support.





Uttarakhand Glaciers



Uttarakhand's Topography and Glacial Landscape

State of Snow Cover in Uttarakhand: Trends and Transformations

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	1992		2002		2012		2022	
LULC class	Area in Sq. km	Area in %						
Snow	14951.98	27.93	12348.07	23.07	8864.64	16.57	13311.16	24.87

Snow cover in Uttarakhand has decreased from 27.93% in 1992 to 24.87% in 2022, indicating a 3.06% decline over three decades.

Causes of Glacier Retreat



Rising Global Temperatures: Increasing temperatures due to climate change are accelerating glacier melt at an unprecedented rate.



Reduced Snowfall & Altered Precipitation: Changes in precipitation patterns lead to less snowfall, which affects glacier

accumulation and sustainability.



Black Carbon Deposition: Pollution from industrial emissions and forest fires deposits black carbon on glaciers, reducing their albedo and increasing heat absorption.



Deforestation & Land Use

Changes: Human activities such as deforestation and urban expansion contribute to regional warming, impacting glacier health.



Glacier Lake Expansion &

Outbursts: Rapid melting has led to the formation and expansion of glacial lakes, increasing the risk of Glacier Lake Outburst Floods (GLOFs).



Unsustainable Tourism & Infrastructure Development: Unregulated tourism, road construction, and hydropower projects disturb the fragile ecosystem.

- Geological & Seismic Activity: The region's natural tectonic movements and seismic activity can destabilize glaciers, triggering avalanches and landslides.
- Reduced Ice Formation Rates: Warmer winters and shifting monsoon patterns hinder new ice formation, further contributing to glacier retreat.



The Changing Fate of Uttarakhand's Glaciers: Challenges and Insights Accelerated Melting: All 900 glaciers in Uttarakhand are melting at an alarming rate due to global warming, raising concerns about future water scarcity.

Recent Glacier : Related Disasters: A glacier burst in Chamoli district (February 2025) triggered an avalanche, causing fatalities and highlighting glacial instability.

Gangotri Glacier Retreat: The glacier has been retreating since 1780, with an accelerated rate in recent decades retreating over 850 meters in the last 25 years.

Impact on Rivers & Ecosystems: Glacier melt is affecting river flow, increasing flood risks, and impacting biodiversity and hydropower projects.

Effects of melting Glaciers



Effects of melting Glaciers

• Impact on the climate Glacial thawing at the poles is slowing the oceanic currents, a phenomenon related to altering the global climate and a succession of increasingly extreme weather events throughout the globe.

• **Disappearance of species** Glacial melting will also cause the extinction of numerous species, as glaciers are the natural habitat of a number of animals, both terrestrial and aquatic.

Less fresh water

The disappearance of glaciers also means less water for consumption by t' population, a lower hydroelectric energy generation capacity, and less water available for irrigation.

Impact of Retreating Glacier on Environment and Human Health

Environmental Impacts - Rising Sea Levels

Key Facts:

- ► Glaciers contribute ~30% of sea-level rise.
- Threatens coastal cities (e.g., Miami, Mumbai, Shanghai).
- Glacial melting has contributed to raising sea levels by 2.7 centimeters since 1961. Furthermore, the world's glaciers contain enough ice — about 170,000 cubic kilometres — to raise sea levels by nearly half a metre.

Consequences:

- Increased flooding
- Saltwater intrusion into freshwater
- Loss of habitable land

Environmental Impacts - Water Scarcity

► Glaciers act as natural reservoirs.

Effects of Retreat:

- Reduced freshwater supply for millions (e.g., Ganges, Indus rivers).
- Droughts and agricultural losses.
- Conflicts over water resources.



Environmental Impacts -Ecosystem Disruption

Biodiversity Loss:

• Species dependent on cold habitats (e.g., polar bears, snow leopards) face extinction.

Altered River Systems:

- Changes in fish migration patterns (e.g., salmon).
- Loss of wetlands.

Human Health Impacts - Waterborne Diseases

Glacial melt releases trapped pollutants & pathogens.

Increased risks of:

- Cholera
- Dysentery
- Heavy metal poisoning (e.g., mercury, lead)



Human Health Impacts -Food Security Threats

Agriculture at Risk:

- Reduced irrigation water \rightarrow crop failures.
- Livestock affected by drought.

Malnutrition & Famine Risks in vulnerable regions. Human Health Impacts - Natural DisastersGlacial Lake Outburst Floods (GLOFs):

- Sudden floods destroy villages, infrastructure.
- Landslides & Avalanches:
 - Increased instability in mountainous regions.



Case Studies

Himalayas:

- 1 billion people rely on glacier-fed rivers.
- Increased flooding in Nepal, Bangladesh.

Andes:

 Water shortages affecting Peru, Bolivia.

Alaska & Arctic:

Permafrost thaw releasing methane.



Measures to Mitigate the Retreating Glaciers

Government Policies - National Level
►Carbon Tax & Emission Regulations:

Incentivize industries to reduce emissions.

Protected Areas & Glacier Conservation Laws:

- Example: Bhutan's Climate Change Policy (carbon-neutral commitment).
- Water Management Policies:
 - Efficient irrigation, rainwater harvesting.

Government Policies - International AgreementsParis Agreement (2015):

Global commitment to limit warming to 1.5°C.
 UN Sustainable Development Goals (SDG 13: Climate Action).

Sustainable Agriculture Practices

- •Climate-Resilient Crops:
 - Drought-resistant seeds (e.g., millets, quinoa).
- •Precision Farming:
 - Al-based irrigation to reduce water waste.
- •Agroforestry:
 - Planting trees alongside crops to prevent soil erosion.

Sustainable Industrial Practices

- Green Manufacturing:
 - Shift to renewable energy (solar, wind-powered factories).
- •Circular Economy:
 - Reduce waste, recycle materials (e.g., zero-waste policies).
- •Carbon Capture & Storage (CCS):
 - Trapping CO₂ emissions from industries.

Sustainable Transport Systems •Electric Vehicles (EVs) & Public Transport:

• Subsidies for EVs (e.g., Norway's policies).

•Green Urban Planning:

• Bike lanes, pedestrian-friendly cities.

•Aviation & Shipping Reforms:

• Biofuels, hydrogen-powered ships.

Sustainable Consumption Patterns •Reduce Meat Consumption:

- Livestock farming is a major methane emitter.
 Minimize Plastic Use:
 - Microplastics accelerate glacial melt.
- •Energy-Efficient Appliances:
 - LED lighting, smart thermostats.

Awareness Programs – Public Education •School & University Curricula:

• Climate change education.

•Media Campaigns:

• Documentaries (e.g., *Chasing Ice*).

•Community Workshops:

• Training farmers on water conservation.

Awareness Programs – Corporate Responsibility •ESG (Environmental, Social, Governance) Reporting:

• Companies disclose carbon footprints.

•Green Certifications:

• LEED, Fair Trade, Carbon Neutral labels.

Transboundary Dialogue – River Basin Management •Himalayan Rivers (Ganges, Brahmaputra, Indus):

• India, Nepal, China, Bangladesh must collaborate.

•Andean Glaciers:

• Peru, Bolivia, Chile joint water-sharing policies.

Transboundary Dialogue – International Treaties •UN Water Convention:

• Promotes cooperation on shared water resources.

•Arctic Council:

• Addresses permafrost & glacier melt in polar regions.

Intergovernmental Panels – Global Level •IPCC (Intergovernmental Panel on Climate Change):

• Provides scientific data for policymakers.

•World Glacier Monitoring Service (WGMS):

• Tracks glacier retreat globally.

Intergovernmental Panels – Regional LevelHindu Kush Himalaya (HKH) Initiative:

• ICIMOD's research on glacier impacts.

•Andean Glacier Project:

• UNESCO-supported monitoring.

Intergovernmental Panels – Micro-Level Actions •Local Governance:

- Village councils implementing glacier conservation.
- •Indigenous Knowledge Integration:
 - Traditional water management (e.g., *qanats* in Iran).

Nature-Based Solutions – Reforestation •Mountain Afforestation:

• Trees stabilize soil, reduce landslides.

•Wetland Restoration:

• Natural water filtration, flood control.

Nature-Based Solutions – Artificial Glaciers •Ice Stupas (Ladakh, India):

- Frozen cones store winter water for summer.
- Leh ursi village: Construction wall along wind, Fromation of artificial glacier.
- •Glacier Grafting:
 - Accelerating ice formation in Himalayas.

Technology-Based Solutions – Remote SensingSatellite Monitoring (NASA, ESA):

• Tracks glacier retreat in real-time.

•AI & Big Data:

- Predicts glacial lake outburst floods (GLOFs).
- Early warning system

Technology-Based Solutions – Renewable Energy

•Hydropower from Glacial Rivers:

• Sustainable but requires careful planning.

•Solar-Powered Desalination:

• Mitigates freshwater shortages.

The time to act is now—before the glaciers disappear.

Every drop of melted glacier is a tear from our planet

Thank You