# CRUMBLING CRYOSPHERE – HUMAN CIVILIZATION IN EXISTENTIAL CRISIS

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1. Earth Cried (Vibrated) for Nine Days

On September 16, 2023 an unusual and long-lasting seismic signal having distinct rhythm was detected around the world. The pattern of vibrations was altogether different from those born out of earthquake. The waves were uniform, frequency monochromatic, very long, repeating every 90 seconds. Such seismic waves continued to shook planet Earth for 9 days. The incident was a glacial ice sheet thinning-induced mountain rock ice avalanche ultimately resulted in a mega tsunami, never seen before. It happened in Greenland.



#### Figure-1: Conceptual image of the occurrence of the incident

A mountain peak of approximately 1200m high collapsed into the Dickson Fjord below resulting in 200m high backsplash of water, creating a wave of 110m high. Researchers estimated that the wave progressed through 10km of fjord, reduced to 7m height within a few minutes and within a few centimeters high within few days. It was also estimated that 25 million cubic meters of rock and ice crashed into the fjord.

An incident occurred at a remote solitary place showed cascade of impacts brought in by global warming. For all purposes glaciers need to be preserved. United Nation's General Assembly realized the catastrophic effect of glaciers' melting way back in 2022.

#### 2. World Glacier Day

On 14-December-2022, in its 77<sup>th</sup> session, UN General Assembly noted that glaciers were a critical component of the hydrological cycle and that the current accelerated melting and retreat of glaciers have severe impacts on the climate, the environment, the maintenance of human well-being and health and sustainable development. General Assembly also noted with concern the findings contained in the special reports of the Intergovernmental Panel on Climate Change entitled 'Global Warming of 1.5°C and The Ocean and Cryosphere in a Changing Climate'.<sup>[1]</sup>

UN General Assembly decided to declare 2025 the International Year of Glaciers' Preservation and to proclaim 21 March of each year the World Day for Glaciers, to be observed starting in 2025. Observance of 2025 as International Year of Glaciers' Preservation and 21<sup>st</sup> March as the World Day for Glaciers are aimed at raising awareness of the importance of glaciers, snow and ice in the climate system and the hydrological cycle, and the economic, social and environmental impacts of the impending changes in the Earth's cryosphere, and to share best practices and knowledge in this regard. It is also essential to address issues related to accelerated melting of glaciers and its consequences.

#### 3. Significance of World Glacier Day

Antarctic ice sheet containing approximately 25,400,000 km<sup>3</sup> of ice, covers approximately 14,000,000 km<sup>2</sup> of area of Antarctica continent. Nature maintains coolness of Antarctic ice by keeping the warm water away from this ice sheet. The Antarctic Circumpolar Current (ACC), which swirls clockwise around Antarctica, transports around 173.3 sverdrup (Sv) of water per second.<sup>[2]</sup> No landmass is involved in this current. Thus, nature keeps warm ocean waters away from Antarctic Ice Sheet. ACC connects the Atlantic, Pacific, and Indian Oceans, and serves an important role in heat exchange among these oceans. Influx of cold water caused by melting of Antarctic Ice Sheet shall play havoc on the Earth's climate. Researchers have reported that "by 2050, the strength of the ACC declines by ~20% for a high-emissions scenario. This decline is driven by meltwater from ice shelves around Antarctica, which is exported to lower latitudes via the Antarctic Intermediate Water. This process weakens the zonal density stratification historically supported by surface temperature gradients, resulting in a slowdown of sub-surface zonal currents. Such a decline in transport, if realised, would have major implications on the global ocean circulation."<sup>[3]</sup>

Since 2000, thousands of glaciers have disappeared due to global warming. Some major glaciers have also disappeared, some are endangered and some are simply counting their days like a dying human patient as given in Table-1 below.

GLACIERS DISAPPEARED, ALMOST DISAPPEARED & ENDANGERED				
				Year of
SI. No.	Glacier Name	Country	Category	Disappearance
1	Breifonn Glacier	Norway	Almost Disappeared	
2	Burroughs Glacier	USA	Almost Disappeared	
3	Mount Kenya Glaciers	Kenya	Almost Disappeared	
4	Punak Jaya Glaciers	Indonesia	Almost Disappeared	
5	Sanata Isable Glacier	Colombia	Almost Disappeared	
		Canada/Inuit		
6	Ansuiktuk Glacier	Nuangat	Critically Endangered	
7	Careser Glacier	Italy	Critically Endangered	
8	Dagu Glacier	China	Critically Endangered	
	Fontana Bianca			
9	Glacier	Italy	Critically Endangered	
10	Gergati Glacier	Georgia	Critically Endangered	
	Hofsjokull eystri			
11	Glacier	Iceland	Critically Endangered	
12	Kilimanjaro Glacier	Tanzania	Critically Endangered	
	Monte Perdido			
13	Glacier	Spain	Critically Endangered	
14	Yala Glacier	Nepal	Critically Endangered	
15	Calderon Glacier	Italy	Disappeared	2000
16	Anderson Glacier	USA	Disappeared	2015
17	Clark Glacier	USA	Disappeared	2018
18	Martial Sur Glacier	Argentina	Disappeared	2018
19	Pizol Glacier	Switzerlasnd	Disappeared	2019
20	Baumann Glacier	Newzealand	Disappeared	2020
21	Schneeferner Glacier	Germany	Disappeared	2022
22	Glisan Glacier	USA	Disappeared	2023
23	Sarenne Glacier	France	Disappeared	2023
24	Pico Humbolt Glacier	Venezuela	Disappeared	2024
Source: Global Glacier Casualty List (GGCL), a platform founded in 2024 through a collaboration				
between Rice University, the University of Iceland, the Iceland Glaciological Society, the World Glacier				

# Disappearance of glaciers result in drying up of rivers, lakes, SLR etc. It also results in loss of aquatic wealth, making lives of the indigenous people miserable. Glaciers are part of cryosphere. It is essential to discuss about Earth's cryosphere also.

Monitoring Service and UNESCO. https://glaciercasualtylist.rice.edu/?page=Page

# 4. Cryosphere

'cryo' in Cryosphere has come from Greek word 'kryos' meaning frost or ice cold.

World Meteorological Organization has mentioned – "Cryosphere includes the components of the Earth System at and below the land and ocean surface that are frozen, including snow cover, glaciers, ice sheets, ice shelves, icebergs, sea ice, lake ice, river ice, permafrost, and seasonally frozen ground, and solid precipitation."<sup>[4]</sup>

Earth System: The universe is a system. Milky Way Galaxy is a sub-system within Universe. Solar System is a sub-system within Milky Way Galaxy. Earth System is a sub-system within Solar System. Earth System refers to interactions of physical, chemical, biological, geological and other processes and it comprises of five major sub-systems, viz., Atmosphere, Hydrosphere, Cryosphere, Geosphere and Biosphere. Prefixes like 'atmo' has come from Greek word 'atmos' meaning 'vapour or steam or smoke'; similarly, 'geo' means 'ground' and so on. Suffix 'sphere' in these words means 'realm or world' of something.

In a nutshell, Cryosphere is the realm of ice and ice like things. Each of the five sub-systems mentioned above are interconnected which may not be perceptible in human eyes. Any damage in one sub-system shall alter the ecosystem of the planet Earth.

#### 5. <u>Role of Cryosphere</u>

The incident – 'Earth vibrated for nine days' in 2023 showed, interlink between cryosphere, hydrosphere and geosphere. As such, importance of Cryosphere is obvious. Each and every constituent of cryosphere has got their own role in preserving environment of the planet earth. For example, permafrost when frozen is harder than concrete, does not allow decomposition of organic carbon (plant carbon), keep the microbes and viruses away by freezing them. Some other roles of cryosphere are given below:

- 1. Cryosphere is the major source of fresh water.
- 2. Fresh snow reflects back 85% of Sunrays, thus glaciers act as thermostat.
- 3. Rivers originate from mountain-tops. Cryosphere provides water to the rivers. Human habitats living in low lying areas or in the delta areas are completely dependent on river water.
- 4. Specific heat of water is highest. It requires a large amount of heat for raising of temperature compared to other matters. Cooling of earth's climate stays for a longer time.
- 5. Density of ice is less than liquid water, meaning, for the same mass of water, ice covers more area than that of water. Whatever may be the form of ice in cryosphere, it covers a wider area thus imparting cooling for a wider area compared to what would have been by same mass of water.
- 6. 4 & 5 above, makes the cryosphere to function as temperature moderator for Earth's climate.

Cryosphere is a part of Earth System, which itself speaks for its role to play.

# 6. Cryosphere is in severe crisis

World Meteorological Organization has confirmed 2024 as warmest year on record at about  $1.55^{\circ}$ C above pre-industrial level (average of 1850-1900). Considering the gloomy picture even at  $1.5^{\circ}$ C Consistent Pathways with peak CO<sub>2</sub> about 430ppm given in the report – "State of the Cryosphere 2024 – Lost Ice, Global Damage. We cannot negotiate with the melting point of ice" prepared by International Cryosphere Climate Initiative, it can be inferred that global eco system is already in great danger.

Under the heading 'Cryosphere Thresholds and Tipping Points' the report mentioned:

- Any overshoot of the 1.5°C lower Paris temperature limit is extremely risky due to the Cryosphere's response: the longer this 1.5°C threshold is breached, and the higher the peak temperature, the greater the risk of crossing tipping points for both polar ice sheets; many land glaciers; and the Atlantic Meridional Overturning Circulation (AMOC).
- Permafrost thaw on the other hand increases with every fraction of warming, with no sudden tipping point": there is no "safety margin" for acceptable permafrost thaw, and warmer temperatures worsen local damage and global feedbacks.
- Polar ocean acidification similarly has no discrete tipping point, but lasts for thousands of years: worsening with each rise in atmospheric CO<sub>2</sub>, and causing observed damage to shelled organisms already today.<sup>[5]</sup>

Consequences of global warming beyond 1.5°C is simply frightening.

# 7. CRYOSPHERE related to INDIA

# 7.1 Teesta-III Hydroelectric dam collapse in October, 2023

On 04-October-2023, the dam of 1200 Megawatt Teesta-III Hydroelectric Project was washed away. Teesta river has come out of South Lhonak Lake in Sikkim, India. This is a glacial lake and is located at 5200m above sea level. Chungthang Dam was constructed for Teesta-III Hydroelectric Project, this dam is the first dam downstream of the Teesta River from the South Lhonak Lake. This dam collapsed due to Cloudburst induced Glacial Lake Outburst Flood (GLOF) originated from South Lhonak Lake resulting in a multi-hazard cascade. In the affidavit placed before the National Green Tribunal, the State of Sikkim mentioned – "----- the natural disaster was unprecedented and the avoidance thereof was beyond human capacity----."<sup>[6]</sup> Casualties caused by this GLOF incident is given in Table-2, below.

Та	bl	e-	2

Item of casualty	Extent of damage	
Number of Districts Affected	4 (Mangan, Gangtok, Pakyong,	
	Namchi)	
Number of Villages Affected	100	
Number of Population Affected	88400	
Number of Human Lives Lost	40 (including 11 Army personnel)	
Number of people missing	76	
Number of damaged houses	2002	
Number of people rescued	2563	
Number of people evacuated	4418	
Number of animals lost	1831	
Number of Poultry lost	29,389	
Number of others lost	507	
Source: Before the National Green Tribunal, Eastern Zone Bench at		
Kolkata, original application no. 171/ 2023, IN, Re.: News item		
appeared in East Mojo on 05.10.2023 titled "Sikkim: here's why the		
Chungthang Hydro-dam breach is a big deal" Applicant versus The		
State of Sikkim & Ors Respondents. Page-15 and 63.		

Catastrophic effect of global warming is evidenced by the extent of damage caused by this GLOF incident.

Glacial lakes are formed by glaciers' movement. Such movement erodes bottom topography of the valley and depressions are created on the surface of the glacier. Because of global warming, glacier retreats and melts. Such meltwater gets accumulated in the depressions created and a lake is formed. When the glacier moves, then it also push forward some debris. Such debris, moraine, ice, rocks, eroded mountain materials etc. create a dam around such a lake. In winter, such glacial lake is frozen, starting from spring to autumn, the frozen ice gets melted, which when induced by some external force, like heavy rain, cloudburst, landslide etc shall result in GLOF.

There are approximately 405 glaciers and 640 glacial lakes in the state of Sikkim while IHR is having 28,000 glacial lakes.

## 7.2 Himalayas, Tibetan Plateau and Hindukush-Karakoram-Himalayan (HKH) Glaciers

Cryosphere in India is marked by a geographic region centred around the Himalayas and Tibetan Plateau. Constituents of cryosphere in this geographic region contain the largest reserve of fresh water outside the polar regions. For this reason, it is known as the Third Pole, the other two poles being The Arctic and The Antarctic. Importance of cryosphere in this region lies in the fact that it is the source of 10 major river systems which serve as lifeline for almost 2 billion people, that is, approximately 25% of world population. A brief is given in Table-3 below:

	Indus	Ganges	Brahmaputra	
Basin area (km²)	11,16,086	10,01,019	5,28,079	Source of Data mentioned at Source- (1) below.
Number of glaciers	18,495	7,963	11,497	
Glacier area (km <sup>2</sup> )	21,193 (1.9%)	9,012 (0.9%)	14,020 (2.7%)	
Volume (Km <sup>3</sup> )	2,696	794	1,303	
Glaciers under debris cover (%)	20.6	26.3	25.6	Source of Data
Percentage of Glaciers smaller than 1km <sup>2</sup> (%)	71.7	45.2	64.5	mentioned at Source- (2) below.
Mean size of supra glacial and pro- glacial lakes (km²)	0.05 and 0.07	0.17 and 0.33	0.15 and 0.31	
Estimated contribution from snow and ice melt to the total annual river discharge (%)	60	9	21	Source of Data mentioned at Source- (3) below.

<u>Table-3</u>

**Source (1):** Presentation on 05-Dec-2019: Himalayan Cryosphere in a changing climate by Parmanand Sharma, ESSO-National Centre for Polar and Ocean Research (ESSO-NCPOR), Ministry of Earth Sciences, Goa, India. Table: Glacier cover and volume estimates for the Indus, Ganges and Brahmaputra basins from different Studies.

**Source (2):** Research Article: Glacier Inventory in Indus, Ganga and Brahmaputra Basins of the Himalaya by A. K. Sharma, S. K. Singh, A. V. Kulkarni, Ajai. Article in National Academy Science Letters · October 2013

**Source (3):** Tayal, Shresth 2019. Climate Change Impacts on Himalayan Glaciers and Implications on Energy Security of India, TERI Discussion Paper. New Delhi: The Energy and Resources Institute. Page-11.

Indian population is highly dependent upon glacier-origin river water as may be seen from the Table-4 below:

Utilizable Surface Water resources	Utilizable water provided by Indus, Brahmaputra and Ganges	% water provided by Indus, Brahmaputra & Ganges	
(in km³)	(in km³)	(in %)	
690	320	46.38%	
Source: Tayal, Shresth 2019. Climate Change Impacts on Himalayan Glaciers and Implications on Energy Security of India, TERI Discussion Paper. New Delhi: The Energy and Resources Institute. Page-11.			

#### <u>Table-4</u>

India is under compulsion to protect glaciers and other elements of cryosphere in Indian Himalayan Region (IHR).

IHR is characterized by tropic region at bottom and cold at the top. Warm tropic region, causes delayed freezing and solidification of ice in the glaciers atop the mountain peaks. "Extremely low snowfall combined with extremely high summer temperatures likely contributed to the high 2024 loss in many of these regions, with record-low snowfall in the Hindu Kush Himalaya, causing growing concern for South Asia water supplies."<sup>[7]</sup> Experts had also mentioned that – "Equilibrium Line Altitude (ELA) already above glacier's highest point are bound to disappear, larger glaciers will continue to shrink for next few decades even if the temperature stabilizes in near future. The ELA in western Himalaya is reported to have shifted upward by 300 m in the last 40 years, while many glaciers in eastern Himalaya, like Pokalde Glacier in Nepal have been reported to be showing a tendency with the ELA reaching above their highest points (for example in 2011–2012) and are expected to disappear in the near future."<sup>[8]</sup> To minimise chances of glacier disappearance, efforts must be made to reduce vulnerability of IHR.

## 8. Cryosphere, Mining and Minerals

Mangroves in coastal regions act as a regulator between exchange of materials at the ocean, land and atmosphere ecosystems. Various geo-chemical cycles are undergone in estuarine sediments. Through these processes critical mangroves and estuarine sediments act as sink for Rare Earth Elements. Glacier melting shall cause Sea Level Rise (SLR). SLR reduces sediment availability in coastal deltas. This in turn shall deprive the nations from coastal-sediment-born REEs.

Mining in mountain areas or in proximity of mountains shall cause deposition of mineral dust on glaciers surface. Glaciers loss their reflectance by deposition of mineral dust. Loss of reflectance of glaciers shall aggravate global warming. Mining involves hydrology. Exchange of knowledges between glaciologists and mining engineers shall give a better understanding to deal with hydrology involved in GLOF.

#### 9. Shinning Edge in otherwise Gloomy picture:

It is India which has shown ray of hope for arresting cryosphere degradation. Ladakh is a mountain desert of India, it gets very low rainfall. In 2024, Ladakh had average rainfall of 26mm. People at Ladakh traditionally depends upon water from glacier melting as primary source. Due to global warming, the glaciers are receding, resulting in substantial loss of water from ice melting and flowing into the rivers having no use for the people at the mountain region. Chewang Norphel of Ladakh, an Engineer by profession could foresee the problem way back in 1966. He observed taps were kept open in winter to prevent freezing of water inside the pipe, when water dripping from the tap fell on ground then that water was getting converted into a film of ice. From this observation, applying his Engineering knowledge and passion to get a solution, he thought of accumulating water in summer and autumn season by arresting water born out of the melted ice and flowing to rivers or canyons. He created such storage far away from the glacier and at a lower level and channelized such water into such tanks. He also arranged shed over such water storage thus ensuring coolness even in summer time. Such field storages turned into glaciers during winter time. Being at a level lower than that of original glaciers, ice in these new glaciers started melting early from spring season thus meeting the much-required water necessity of the inhabitants of Ladakh. Continuation of this cycle established newly created glaciers as providing water to the Ladakh society. In this process, he has built 15 artificial glaciers of different lengths ranging from 152m to 2km long.

Chewang Norphel is known as 'Iceman of India'. Government of India conferred him with Padma Shri award in the year 2015.

#### 10. Conclusion

Rise in climate temperature by 1.55°C and record high CO<sub>2</sub> level at 428ppm, both in 2024 is unprecedent in the history of human civilization. On one hand, world is thinking of welcoming 136 million babies within a total population of 9.7 billion in the year 2050, on the other hand, apocalyptic predictions are also being made. Sustainability is oscillating between these two extremes. Awareness and dynamicity in adoption to evolving situations are the need of the day.

ABBREVIATIONS		
GLOF	Glacial Lake Outburst Flood	
нкн	Hindukush-Karakoram-Himalayan	
IHR	Indian Himalayan Region	
REE	Rare Earth Elements	
SLR	Sea Level Rise	

GLOSSARY		
Antarctic Circumpolar Current (ACC)	Antarctic Circumpolar Current (ACC) is an ocean current around Atarctica continent. Viewed from South pole, this current flows clockwise from west to east. It is an important circulation of Southern Ocean.	
Equilibrium- Line Altitude (ELA)	The equilibrium-line altitude (ELA) marks the area or zone on a glacier separating the accumulation (snow gain) zone from the ablation (ice loss) zone and represents where annual accumulation and ablation are equal, thus a point of zero mass balance is reached.	
GLOF	The sudden release of huge quantity of water from a lake origined from a glacier is termed a GLOF.	
Pro-glacial Lake	When a lake is formed by any of the processes like (1) damming action of a moraine during the retreat of a melting glacier, (2) damming action of a glacial ice dam, (3) by meltwater trapped against an ice sheet caused by isostatic depression of the crust around the ice, then it is called a proglacial lake.	
Supraglacial	A lake situated on the surface of a glassier	
sverdrup	Sverdrup is an unit of volume transport used in describing ocean currents and is denoted by symbol, Sv. 1 Sv = 1,000,000 cubic meters per second.	

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- 7. Same as 5. Page-x.
- 8. Tayal, Shresth 2019. Climate Change Impacts on Himalayan Glaciers and Implications on Energy Security of India, TERI Discussion Paper. New Delhi: The Energy and Resources Institute. Page-10.