



# The Inherent Grave Consequences of Glacial Retreat

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## ABSTRACT

Glaciers are the protector of climate change. As glacier melting is a long-term process, it does not gain the same attention in comparison to other crises. The visible evidence of global warming is the glaciers. The main cause of glaciers melting is the rising temperature of the earth by CO<sub>2</sub> emission and ocean warming. Deforestation, burning fossil fuels, transportation, and other human activities raise the atmospheric concentration of CO<sub>2</sub> and other greenhouse gases (GHGs) which warm the planet and ultimately cause the glacier to melt. 90% of the earth's warmth is absorbed by the ocean and is responsible for the melting of marine glaciers. The main deglaciation consequences are sea-level rise which has contributed to rising sea level by 2.7cm since 1961. Glaciers are always been of substantial research as their long-term behavior is like a barometer to check the weather variability, change in flora and fauna, and economic activity. Deglaciation promises grave consequences for wildlife, plant, and the region's people and a frightening future. This paper showcase how glaciers are melting and hearts are frozen.

## INTRODUCTION

Currently, we are on the edge of a climate crisis, so a lot of work is to be done to control the present situation. Reducing the human carbon footprint and climate change solutions would be the main focus of society if they want to avail the nature's gift for long. Melting glaciers could create actual loss to the livelihoods of untold millions. The risks become too real in terms of unpredictable water supplies, increased extreme flooding, varying weather patterns, and changes in energy and food production. 10% of the earth's surface is covered by glaciers and 70% of the world's freshwater comes from it. The building of glaciers takes millennia and its size depends on the retaining capacity of ice glaciers throughout their lifespan. The main culprit of glaciers melting is human activity which in turn emits carbon dioxide and other greenhouse gases. It has been stated that glacial melting has accelerated over the past three decades. Per the study of 2019 satellite by the University of Zurich (Switzerland) and the World Wildlife Fund warns to evaporate over a third of all glaciers by 2100 and the loss of ice has already reached 335 billion tones/year. As soon as the glacier starts to break down, the glacier structure starts interacting with meltwater and seawater which increases the process of fast melting and retreat. The white surface of glaciers reflects the sun's rays which makes our current climate forbearing. As soon as the glacier melts, the dark surface of the glacier absorbs and releases heat and increases the earth's temperature. Glaciers

have snow with gases, dissolved chemicals, and particulates which were carried by atmospheric wind current, and this snow traps all the transported substances. Long-lived gases e.g. CO<sub>2</sub> and air bubbles accumulate over the months and years and preserve the current atmospheric conditions at the time of precipitation. The mountain glacier has a special place in the heart of people. Disappearance and fast retreat of glaciers directly impact the survival and livelihood of residents and also threaten the cultural importance of glaciers (Jurt et al. 2015). Glaciers are delicate like human beings and we humans are building instability into them. This review is focusing on the relationship between the environment and glacial retreating and how deglaciation affects the flora and fauna and tourism industry.

## GLACIERS RETREATING VS ENVIRONMENT

Direct and indirect human activity affects the climate and climate, in turn, affects the glacier retreating. Rapid increasing temperature potentially affects the natural and social system (IPCC 2014). Because of global warming, most of the world's mountain glaciers are decaying since 1950 and due to climate conditions, the glaciers are going to shrink even in the absence of future temperature rises (IPCC 2013). As glaciers are so sensitive to temperature swings and going with climate change. In the early 20th century glacial retreat (the position of a mountain glacier's terminus is farther up the valley than before) was found around the world at un-

paralleled rates. The reason for this massive glacier retreat was industrial revolution started around 1760. In this century various ice caps (a dome-shaped mass of glacier ice that spreads out in all directions) and ice shelves (a portion of an ice sheet that spreads out over the water) vanish together. Glaciers divulge clues about global warming. Within the past 200 years, 40% of CO<sub>2</sub> is enhanced in the atmosphere by human activity. Other gases e.g. methane are increased by a factor of 2 to 3 or more. Heat radiated from the surface of the earth is absorbed by these greenhouse gases and warms up the atmosphere slowly. These greenhouse gases are called heat-trapping gases and are responsible for the warm climate and glacier retreat in the past 50 years. Other causes such as the burning of fossil fuel and forests, increased dust,

farming, and soot from grazing also affect the glacier retreat. The Worlds Glacier Monitoring Services (WGMS) monitors changes worldwide in more than 100 alpine glaciers and out of 42 of those glaciers defines as climate references glaciers with records span of more than 30 years. NASA has shared an image of the melting Upsala Glacier which is the third-largest in the Southern Patagonian Icefield of Argentina and Chile. The image depicted that a large chunk of the Upsala Glacier (Fig. 1) breaks away due to the climate crisis. The glacier retreated more than 3 km Between 2001 and 2016. The image is shot by a fresh astronaut, Thomas Pesquet from International Space Station (ISS) (NASA Image 2021).

Ice is very white and the white color reflects the sunlight more, that's why large ice fields can govern the weather

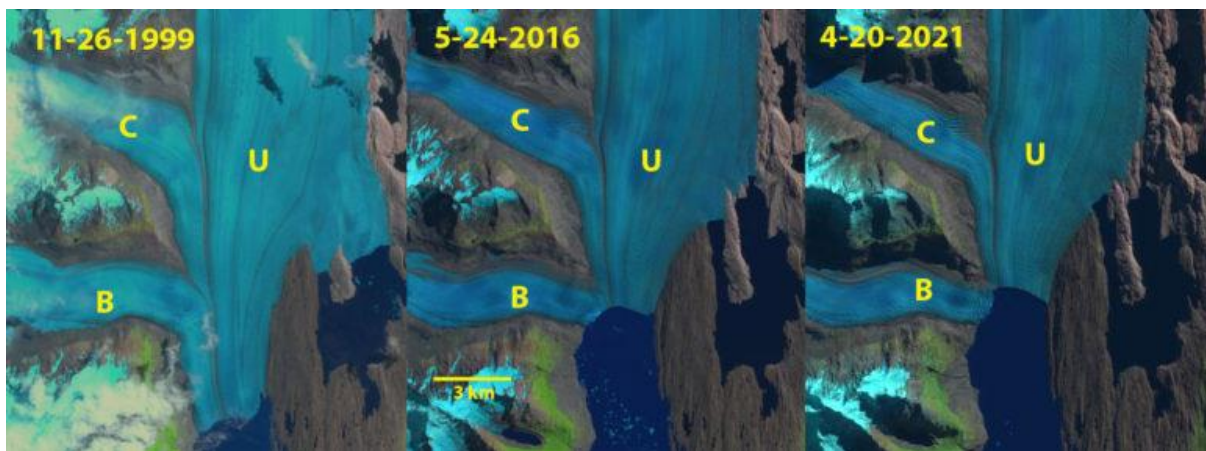


Fig. 1a. Upsala Glacier (U) in Landsat images from 1999, 2016, and 2021 illustrate both retreat and the separation from Bertacchi Glacier (B). Cono Glacier (C) is the next tributary to the north.

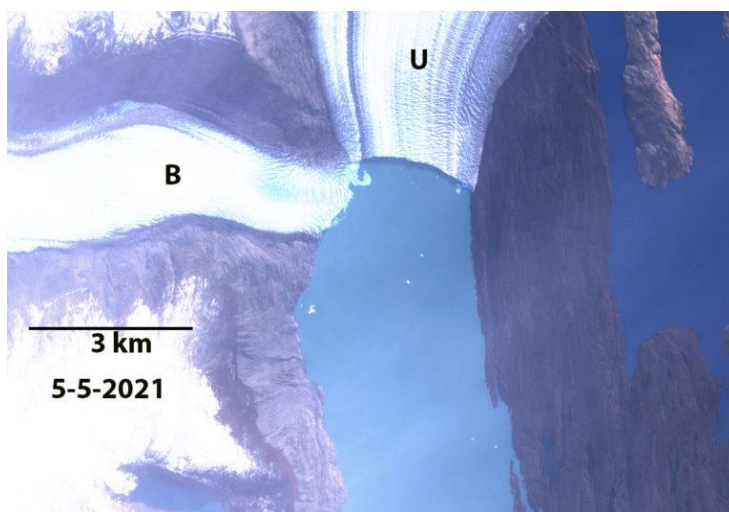


Fig. 1b. Sentinel image of terminus zone of Upsala and Bertacchi Glacier (Image, shared by NASA, was taken from the International Space Station on May 5, 2021).

patterns. Another factor is air temperature which is very high above the ice caps rather than its surface. The weather system is affected by wind patterns and can be dramatic around ice-covered land masses. International Panel on Climate change (IPCC) reported that more water flows to the seas from glaciers due to temperature rises which cause increased volume and warm ocean water. In the past hundred years, the global sea level has increased between 4 & 8 inches (10 & 20 cm). 25% (1% per year) of glaciers declined from 1975-2000 and during 2001-2005, this value dropped up to 10-15% (2 to 3 % per year) (Haeberli et al. 2007). It was estimated that by 2100, the reduction in alpine glaciers will be 4%-18% of its 2012 size (Matthias et al. 2012). During 1930-2012, a 30% reduction in the total area of the Blanca glaciers was studied in the Peruvian Andes of South America (Schauwecker et al. 2014). In the past 100 years, 85% of ice bodies have been reduced in the glacier area of Kilimanjaro National Park which was 11.40km<sup>2</sup> to 1.76km<sup>2</sup> from 1912 to 2011 (Cullen et al. 2013). Various meteorological conditions e.g. gale wind, heavy rain, fog, and strong sunlight is responsible for moraine (material left behind by the moving glacier) stability and influence glacial runoff. The climate change effect was reported by NASA Scientists because of the fast decay of ice sheets and increase global sea levels in a gigantic cavity of nearly 300 meters tall found at the bot-

tom of Thwaites Glacier in West Antarctica (Fig. 2). As per the NASA statement, Scientists found some gaps between bedrock and ice at Thwaites's bottom resulting in the flow in of ocean water and melting of the glacier from the bottom reported by Eric Rignot of the University of California, Irvine in the US. The cavity is very large and contained 14 billion tonnes of ice and mostly ice melted over the past three years (World's News 2019).

The Franz Joseph Glacier retreated 2.44 km during 1946-2008 with an annual retreat of nearly 39 km (Purdie 2013, Purdie et al. 2015). By 2100, the Franz Josef Glacier will be lost from 11 km to 6.4 km of its current length with a 62% reduction in the ice (Anderson et al. 2008). 70% of the world's tropical glaciers are found in Peru and by the 1970s, 40% of their surface area has been lost. The best example is the Patoruri glaciers in Peruvian Andes (Scott et al. 2007) reported that during 1991-2006, the Chacataya Glacier decreased by 80% in Bolivia and the glacier had completely disappeared by 2009.

Edson Ramirez, the local expert predicted the demise of an 18,000-year-old ice field namely Bolivia's 5,300 m high Chacaltaya glacier will disappear by 2015 but the last of the permanent snow disappeared in 2009 (Fig. 3). Alfredo Marinez of the neighborhood ski club Andino



Fig. 2: NASA scientists have discovered a gigantic cavity, almost 300 meters tall, growing at the bottom of the Thwaites Glacier in West Antarctica, indicating rapid decay of the ice sheet and acceleration in global sea levels due to climate change (AFP) (World's News 2019).

Boliviano wrote in a very tearful nostalgic message for the glacier “*Chacaltaya was my bride in white-now she’s dressed for a funeral*”. Another very good example of glacier retreat due to climate effect is the largest glacier in the Italian Alps, the Forni glacier which retreated 535m and annually retreats more than 30m. The Forni Glacier area had lost 0.51 km<sup>2</sup> by 2012 as compared to 2007 (Azzoni et al. 2017). During 1950-2000, the air temperature increased by 2.5°C and in the 1930s the regional rapid warming increased (Turner et al. 2017, Vaughan et al. 2003). Glacier recession and ice-shelf collapse have been observed due to the southward movement of annual mean air temperature by -9°C isotherm. Warming in the region of James Ross Island started around 600 years ago and rapidly increased over the last century. This situation of warming is uncommon (Mulvaney et al. 2012). So global warming is responsible for the disappearing, shrinking, and retreating of glaciers (Marzeion et al. 2014, Zemp et al. 2015, Roe et al. 2017).

### GLACIER RETREATING VS FLORA

Scientists revealed that facilitation and competition work together in the same ecosystem. So, competition alone is not the factor for studying criteria of species succession and coexistence (Callaway & Lawrence 1997, Losapio et al. 2015), especially in the mountain ecosystem. The role of species interaction and environment present geophysical focus is helpful to understanding the biotic pattern.

Ecological succession also depends upon the interactions with surroundings organisms, such as seed predators, herbivores, soil microbes, and pollinators. The retreat of glaciers disturbs the natural hazards, water availability, landscape configuration, and the world’s ecosystem, and ultimately great impact on society (Fell et al. 2017, Cauvy-Fraunie & Dangles 2019). Plants communities are very sensitive to the proglacial environments and ongoing glacier recession and sensitive to planning and projecting sustainable ecosystem management and biodiversity dynamics (Walker & Del Moral 2003, Erschbamer 2007). Losapio et al. (2021) studied the environmental condition, leaf traits, fine spatial scale, Spatio-temporal context, and species-to-species studies in various plant communities spanning 0 to 5000 years on average and collected the data after glacier retreat. Scientists found that 22% of plant species showed a response to glacier retreat non-linearly and with glacier extinction, the local species disappear. 66% of the species contribute to distribution patterns positively in soil carbon enrichment. In addition to 34% of the variance in plant communities is found in driving the Spatio-temporal dynamics. This study concluded that with the glacial retreat, the plant diversity first increases and more than a fifth of plant species considerably decreases and will lose with glacier disappearance. Coldwater temperature is the requirement for the survival of many aquatic flora and fauna species in the mountain environment. The loss of 4glaciers threatened various rare and endemic species that exist at their tolerance limits. Deglaciation affected

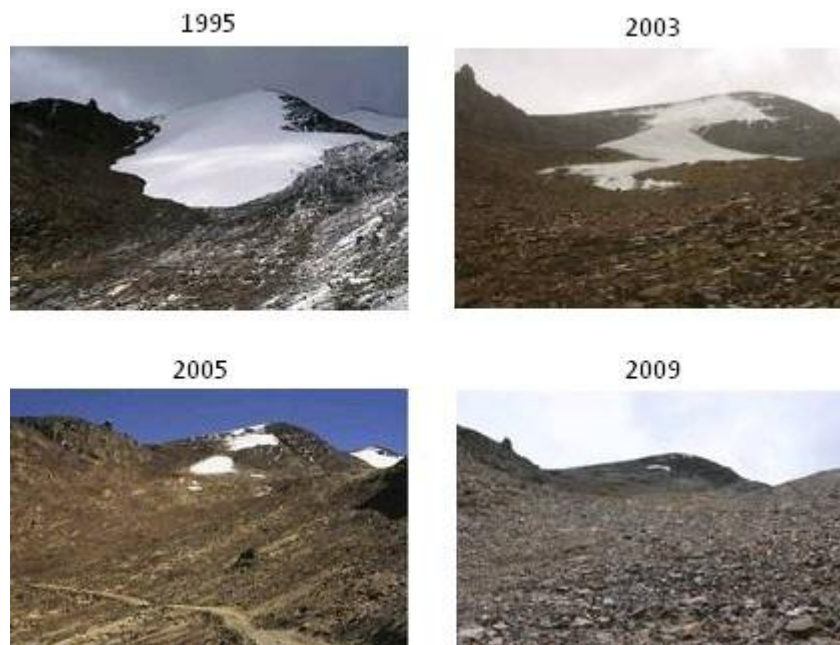


Fig. 3. A nostalgic look back at the demise of the world’s highest Chacaltaya glacier (Wilkin 2013).

plant succession and was investigated in Alaska-USA and Glacier Bay (Cooper 1923a, Cooper 1923b, Cooper 1923, Cooper 1939, Gurung et al. 2012). Three main vegetation types were reported at Glacier Bay: Spruce forest, willows alder thicket, and pioneer community. Soil development due to deglaciation is the major cause of this vegetation. Various factors such as temperature, availability of nutrients, length of growing seasons, and topography are affected the plant succession in de-glaciated soil. In East, Brogger Glacier scattered patches of vascular plants and Bryophytes are found in comparison to the older de-glaciated area where well-developed patterns of some bryophytes and vascular plants exist (Kleiden & Mooney 2000, Minami et al. 1996, Cannone et al. 2004). The four steps seen for the plant succession in the Alexander Fiord region are mass, graminoid forest, deciduous shrub moss, and evergreen dwarf-shrub moss (Jones & Henry 2003). As per the reporter of BBC, Victoria Gill, climate change destroy Antarctica's ancient moss bed. Every Antarctica summer, the lush green mosses come out from the ice in East Antarctica. Prof. Robinson has done a pilot study in 2003, with continuous monitoring in 2003 and 2008, and found that green moss beds had first turned dark red and then grey (means dying). He reported that the mosses

are severely stressed and the antioxidant and UV-Screening compounds and pigments were produced by the mosses to protect themselves (Victoria 2018) (Fig. 4).

### GLACIER RETREATING VS FAUNA

Glacier retreat impact is also seen in the extinction of animals that live on or near glaciers. Glaciers are the home of many unique organisms e.g. the entire life of the tiny ice worms spends on ice. Feeding on glacier algae and once in a while snatched up by hungry snow bunting. These worms disintegrate over 50C and their physiological adaptation to survive at 0°C remains unknown. The 3000 years old "epishelf lake" in the Northern hemisphere supported a rare ecosystem in which marine organisms lived in harmony with their freshwater brethren. It was quoted that 96% of this low-salinity habitat has been disappearing by 2002 (WWF Report 2016). Animals that are directly dependent on glaciers are also threatened. Small living sea birds (Kittitz murrelet) who depend on food, especially in areas where glacial meltwater enters the oceans are going to be extinct. The population of these birds is located in Alaska. Kittitz's murrelet is very unique and found its inmost association with



Fig. 4. Stressed Antarctic mosses turn from green to red as they produce compounds to protect themselves (Victoria 2018).

glaciers in danger. Deglaciation creates the disturbance of the bird's glacial habitat and decreases the availability of the fish which it eats. In 2001, Lynn Canal Conservation and Sitka Conservation society listed Kittitz's murrelet on the list of endangered species. By 2013, a landmark agreement called the federal listing proposal comes for the protection of 757 species including the Kittiltz's murrelet (Siegel 2009) (Fig. 5).

The sea level rises continuously by 0.2-0.4 mm per year due to glaciers retreating. A recent study of Alaska and the Patagonia Icefield confirmed the increase in the sea level by 0.375mm/year. A 1 m global sea level rise displaces 24 million people in Bangladesh, India, and Indonesia and overwhelms 80% of the Maldives. The Sunderban, the home of the world's largest tiger population, disappeared by the end of the 21st century due to rising sea levels. The primary factor is the tiger's ability to adapt as a result of Sunderban's anticipated sea level rise (WWF report 2010). By 2070, a 28 cm sea level rise will result in a 96% loss in the Sunderban's remaining tiger habitat. Keya Chatterjee, director of WWF-US reported that due to climate change the sea-ice of the polar bear and mangrove forest of the Bengal tiger, and various species of reptiles, fishes, birds, and mammals will effect. The rapid melting of the glacier causes the transport and mobilization of various organic and inorganic molecules with some pollutants (Fountain et al. 2012). In the mountain area of the Alps, the level of nickel and other heavy metals

increases due to the melting of rock glaciers which was a great threat to the ecosystem (Thies et al. 2007).

### GLACIAL RETREATING VS TOURISM

Various organizations and programs such as World Meteorological Organization and the United Nations Environment program give special focus on the impact of climate change on tourism (Hall et al. 2013, Wang 2015). The sustainable development, beauty, and quality of glacier tourism are greatly affected by global warming (Wang & Jiao 2012, Wang & Cao 2015, Wang & Zhou 2019). The shrinking and retreating of glaciers around the world have been proved by a time series analysis of glacier areas, lengths, volumes, and physical balance monitoring changes (IPCC 2013). Rocky Mountain, the Andes, and the Alps are the world's glacier tourist destinations that have lost 7000 km of ice from 1971-2010 (WGMS, 2012). Glacier tourism is a multimillion-dollar industry. Glacial retreat causes a change in surface morphology, thinning rates, and assessing hazards that create difficulty in the access of the glaciers. The impact of deglaciation on the economic earner was significant but only a few studies have been reported (Burki et al. 2005, Ritter et al. 2012). Another aspect of glacier retreating is to increase the interest in glacier tourism. In Norway, at Jostedalbreen, tourists take the effect of climate change as a catalyst, and the number of visitors increases (Aal & Høyer 2005). They take this as a last-time opportunity and their response is like a final



Fig. 5. The Kittiltz's murrelet is found only in Alaska and portions of the Russian Far East (Siegel 2009).



Fig. 6: Antarctica tourism is heating (Halpern 2020).

chance to tourism. So it can be said that “Tourists specifically look for disappearing landscape” (Lemelin et al. 2010). Tourists want to explore the location where distinct species, landscapes, or social heritages are going to vanish. In China, at Biashui Glacier No. 1, various tourism opportunities like glacier museums and telescope tours are developed to retain the disappearing resources as pristine as possible (Lemelin et al. 2012). The Canadian Rocky Mountains did a survey and found that the warmer temperature conditions increase the summer tourist season (Scott et al. 2016). Internationally, different measures are adopted to give momentum to glacier tourism, and in this direction, the ski industry is very proactive. In New Zealand, the ski-industry value is exceeding 1.4 million per year (Price 2010). In 2018-2019, 5000 people traveled to the Southern part of the Antarctica glacier (Fig. 6). It was a 53% jump from 2014-2015 as per the data of the International Association of Antarctic Tour Operators (IAATO) (Halpern 2020).

Now snowmaking technology is the main focus of the ski industry for increasing the economic value of the industry in

terms of monetary and environmental aspects (Hendrikx et al. 2012). Eijgelaar said, “*Glaciers are unlike endangered species and when they’re gone, they’re gone forever.*” The glacier was God’s great plow so enjoy every bit of the existence of the beauty of it.

## CONCLUSION

For controlling the glacier retreat there must be a collaboration between the scientific community and government policy. The gap between science and industry should be addressed. Important studies like surface morphology change, bed topography, remote sensing, hazard analysis, surface melting and increased debris studies, etc. are helpful to know the cause, process, and impact of glacier retreats and how safely they can be accessed (Brook & Winkler 2013). As our globe is under the new environmental pressure of glacial retreating which in turn affect very-very wrong with our ecosystem and disastrous consequence elsewhere. At last, we have to think about “*What happens when the roof of the world melts.*”

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