Global Trend of Glacier Melting or Growing and its Impact on Heavy Storms

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ABSTRACT

Scientists calculate how much the ice sheet is growing or shrinking from the changes in surface height that are measured by the satellite altimeters. In locations where the amount of new snowfall accumulating on an ice sheet is not equal to the ice flow downward and outward to the ocean, the surface height changes and the ice-sheet mass grows or shrinks. But it might only take a few decades for Antarctica's growth to reverse, according to Zwally. If the losses of the Antarctic Peninsula and parts of West Antarctica continue to increase at the same rate they've been increasing for the last two decades, the losses will catch up with the long-term gain in East Antarctica in 20 or 30 years and it is questionable whether there will be enough snowfall increase to offset these losses. The study analyzed changes in the surface height of the Antarctic ice sheet measured by radar altimeters on two European Space Agency European Remote Sensing (ERS) satellites, spanning from 1992 to 2001, and by the laser altimeter on NASA's Ice, Cloud, and land Elevation Satellite (ICESat) from 2003 to 2008. The good news is that Antarctica is not currently contributing to sea level rise, but is taking 0.23 millimeters per year away. But this is also bad news. If the 0.27 millimeters per year of sea level rise attributed to Antarctica in the IPCC report is not really coming from Antarctica, there must be some other contribution to sea level rise that is not accounted for. On other hand, globally every country is facing heavy storm, disastrous rain fall and variance in Climate Change, causing greater loss in production of food grain, disruption of smooth living and development and enhancement of hazardous deceases on account of Global Warming and Climatic Changes. This paper focuses on the current issues and its remedial efforts to be made essentially to curb these issues and save human life and beautiful creatures on the globe.

Keywords: *Ice sheet, Glacier growing, Glacier shrinking, Global warming, Climate change.*

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1. INTRODUCTION

Most of the world's glaciers are found near the North and South Poles as Arctic and Antarctic glaciers respectively including Greenland. A large number of glaciers, however, are found in mid-latitude and tropical regions wherever the right conditions exist. Disintegrating glacier ice constitutes a substantial and accelerating cause of global sea-level rise. Researchers synthesized results from a variety of recent ice mass change studies in an effort to present a more accurate picture of changes and trends in ice volume and associated sea-level rise. This synthesis includes current results that update the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report-1, stresses the importance of dynamic processes in transporting terrestrial ice to the sea, compares the contributions of glaciers and ice caps with those from the ice sheets, and presents new projections of ice mass change to the end of the 21st century.

In this study all glaciers and ice caps (GIC) are included, whereas the Greenland and Antarctic ice sheets are excluded. But it does not include the GIC that surround and are peripheral to the great ice sheets. The study also focuses on present-day behavior (from about 1996 to 2006) because of its critical importance to society now and its relevance for runoff and sea-level projections to the year 2100.

A primary driver of recent ice loss is the rapid retreat and thinning of marine-terminating glaciers, which are susceptible to a nonlinear dynamic instability when their beds are below sea level. The increased role of this phenomenon in delivering ice to the ocean during recent warming has been demonstrated for ice sheet outlets (2–4) but is also important for many GIC. This instability can markedly raise the sensitivity of glaciers to climate change. It is conventionally assumed that under near–steady state conditions, the climatically controlled surface balance (inputs by snow and loss through melt) controls the geometry of an ice mass, and geometric transitions (changes in thickness) are forced by changes in surface mass balance. In contrast, under dynamically forced conditions, changes in ice velocity are forced instead by changes in sub-glacial mechanics, and geometric transitions are governed by changes in flux divergence rather than surface balance.

Glaciers exert a significant influence on a landscape. As glaciers move across the terrain, they pick up rock and debris, carve valleys and create landforms. Flowing glaciers erode and scour the ground beneath and to the sides of them. These rivers of ice also pick up boulders, soil, trees, and other debris and carry it along in their flow. Once the glacier begins its retreat, however, this material is deposited wherever the glacier's ice melts. Kettle lakes are formed when large chunks of ice fall off of retreating glaciers and melt, filling depressions in the ground. For more information on glacial formations, see the links below, which will connect you to some sites with photos and descriptions.

There are two main types of glaciers - valley and continental. Valley or alpine glaciers form in mountainous regions where movement is inhibited by valley walls. Continental glaciers, also known as ice sheets, are "dome-shaped mass [es] of glacier ice… greater than 50,000 square kilometers (12 million acres) (e.g., the Greenland and Antarctic ice sheets)" (NSICD).

Glaciers can form in areas characterized by cool summer temperatures and heavy winter snowfall. These conditions allow enough snow to create and maintain the glacier while limiting loss of mass. Growth is largely dependent upon precipitation. In areas with the temperatures necessary for glaciers to form, low precipitation rates will lead to slower growth (such as in Antarctica). A healthy glacier has a mass balance of zero or can be positive. This means that the glacier is accumulating as much or more than it is losing through ablation - melting, evaporation, calving, etc.

In places where winter snowfall survives the melt season, each year's snowfall accumulates over the last. As the years go by and the layers add up, the pressure created by the upper layers begins to turn the lower layers to ice. The glacier becomes denser still as the ice crystals grow, taking up the air space in the layers. Light at all colors of the spectrum are absorbed by this ice except one - blue. This is what makes glacial ice appear blue.

Once a glacier accumulates enough weight, gravity and the pressure of its own mass force it to move downhill, in the case of alpine glaciers, or outward, in the case of continental glaciers. This is called internal deformation. Glaciers can also move due to sliding, or basal slip. A layer of water or soft sediment with some water in it allows the overlying glacier to move over it much faster because it acts like a lubricant. Water can either be in the landscape before the glacier gets there or can come from melt water accumulating on the top of the glacier and leaking through cracks in its layers (see moulins). According to the NSIDC, "Basal slip may account for most of the movement of thin, cold glaciers on steep slopes, or only 10 to 20% of the movement of warm, thick glaciers lying on gentle slopes."

Glacial flow depends in part on the climate - warmer, drier weather leads to glacial retreat, while colder, wetter weather creates the conditions necessary for building glaciers. When temperatures increase or there is significant evaporation due to wind and warmer weather, the glacier begins to retreat. During the past 60 to 100 years, the NSIDC states that glaciers throughout the world have tended toward retreat. The Center explains "Alpine glaciers, which are typically smaller and less stable [than continental glaciers] to begin with, seem particularly susceptible to glacial retreat" (NSIDC).

Fig.1: Glacial retreat world -Muir Glacier taken on August 13, 1941, by glaciologist William O. Field; on the right, a photograph taken from the same vantage on August 31, 2004, by geologist Bruce F. Molnia of the United States Geological Survey (USGS)." Image credit: National Snow and Ice Data Center, W. O. Field, B. F. Molnia.

Over the last century, mountain glaciers worldwide have, on average, been decreasing in length and volume (**Figure 1**). Some have been disappearing at such a rate that they may completely disappear soon. In North America's Glacier/Waterton National Park, for example, there were about 150 glaciers when the park was established in 1910. Today the number of moving glaciers is below thirty. Dan Fagre, a U.S. Geological Survey ecologist working in the Park, says, "The last one will probably disappear by the year 2030, tops" (Chadwick, 2007). There have been significant changes in the ice sheets and their tidewater glaciers as well, which are discussed in our articles on Antarctica and Greenland.

The glaciers in the famed North American park are not alone. A 2005 study of 173 glaciers across the world found that since 1970, 83% of surveyed glaciers were thinning at an average loss of 0.31 m/yr (**Figure 2**) (Dyurgerov and Meier, 2005). According to the 2007 IPCC report, glaciers and icecaps have lost increasing amounts of mass since the middle of the last century. In the period between 1961 to 2004, glaciers and icecaps were losing 0.50 ± 0.18 mm yr^{-1} in sea level equivalent (SLE) in mass. Between 1991 and 2004, however, the rate was actually above the average, at 0.77 ± 0.22 mm yr^{-1} SLE (IPCC, 2007). The numbers differ regionally, with the strongest mass losses per unit area in Patagonia, Alaska, and northwest USA and southwest Canada. For example:

- According to a 2007 study of glaciers in southeast Alaska and western Canada using aerial and spatial data, glacier surface elevations have dropped in over 95% of the area analyzed from 1948 to 2000. Some of the measured glaciers had thinned by as much as 640 meters (Larsen et al., 2007).

- A 2006 study of the European Alps found that Alpine glaciers lost 35% of their total area from 850 until the 1970s, and almost 50% by 2000. Total glacier volume around 1850 is estimated at some 200 km3 and is now close to one-third of this value. (Zemp et al., 2006).

2. WHY ARE GLACIERS RETREATING?

"Glaciers and ice caps provide among the most visible indications of the effects of climate change..." the 2007 IPCC report explains. Glaciers respond quickly to changes in climate because they generally lose more mass on an annual basis compared to their total mass. This is because the mass balance of a glacier is determined by the hydrological cycle, which is in turn determined by the climate. Variability in climate in glacier-producing regions creates variation in the size of a glacier. For example, at high and mid-latitudes such as Alaska and Scandinavia, accumulation tends to occur in the winter while ablation occurs in the summer months. In these areas, the hydrological cycle is controlled in large part by the annual cycles of air temperature (IPCC, 2007). Across the Himalayas, however, both accumulation and ablation primarily take place during the summer (Fujita and Ageta, 2000). On tropical glaciers, ablation takes place throughout the year, but accumulation is dependent upon seasonal precipitation (Kaser and Osmaston, 2002). Therefore, according to Kaser et al. (2004), the response of tropical glaciers to changes in climate lag by only a few years, compared to a response time described by Paterson (2004) of up to several centuries for the largest, coldest glaciers on the smallest inclines.

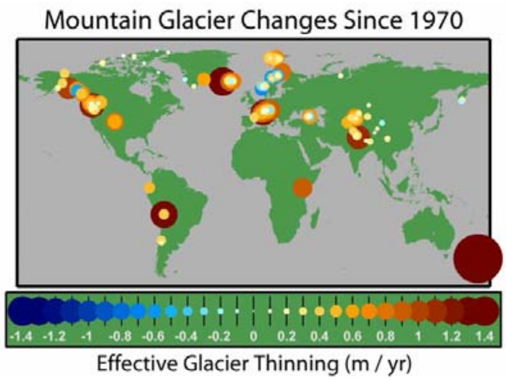

Fig.2: "The graph on the right of average annual rate of thinning since 1970 for the 173 glaciers measured in Dyurgerov and Meier (2005). Image credit: (Map) Global Warming Art compiled from the findings of Dyurgerov and Meier (2005). (Graph) Dyurgerov and Meier (2005).

In general, glacial retreat has been tied to two main climatic changes. These are increased temperatures and changes in precipitation and atmospheric moisture. Other factors, such as solar radiation, also play a role in glacial retreat.

Air temperature is considered to be one of the most important factors governing glacial fluctuations (Houghton et al., 2001).

While there is regional variation, the global average temperature has increased by about 0.74°C between 1906 and 2005 (IPCC, 2007). In many areas, warmer seasons are hotter and longer lasting than they were previously, while colder season temperatures have also increased. In Alaska, annual air temperatures have increased over the past 50 years — with winter increases double those experienced during the summer (Stafford et al., 2000). These increasing temperatures have been identified as the main driver of glacial retreat and melting. In fact, Rasmussen and Conway (2003) point out that the summer temperature increases alone could explain the losses experienced in Alaska and northwestern Canada. One reason for this is that these glaciers cover large areas at low elevations. "The greatest changes occurred at lower elevations but large changes are also apparent at higher elevations," state Larsen et al. in a 2007 study.

Increasing levels of precipitation are not enough to offset the effects of warmer temperatures in some areas, such as the Tarim River Basin in Northwestern China. Despite an increase of 23% in average annual precipitation from the period of 1956–1986 to 1986–2000, warmer temperatures have caused significant decreases in glacial mass and area (Liu et al., 2006). The Alps face a similar predicament. Model experiments in the European Alps show that a 3°C warming of summer air temperature "would reduce the currently existing Alpine glacier cover by some 80%" whereas a 5°C temperature increase would render the Alps almost completely ice-free (Zemp et al., 2006). According to the study's authors, "Annual precipitation changes of ±20% would modify such estimated percentages of remaining ice by a factor of less than two," reinforcing the significance of the role of increasing temperatures (Zemp et al., 2006).

Kilimanjaro and its rapidly dwindling glaciers are often pointed to as evidence of climate change. Retreat in tropical glaciers is due to what a recent study of Kilimanjaro's glaciers describes as a "complex combination of changes in air temperature, air humidity, precipitation, cloudiness, and incoming shortwave radiation" (Kaser et al., 2004). Melting due to an increase in temperatures, however, is not the primary underlying cause of loss of glacial mass on Kilimanjaro. The climate in the region has been getting drier since the end of the 19th century, which is likely the factor forcing glacier retreat on Kilimanjaro. A drop in precipitation and air moisture inhibits the glaciers' ability to add new snow. Additionally, glacial mass on Kilimanjaro is lost primarily through sublimation (conversion of snow and ice directly to water vapor). A 2007 study found that "glacier mass balance is 2–4 times more sensitive to a 20% precipitation change than to a 1°K air temperature change… The main cause of this sensitivity characteristic is the strong albedo feedback, which is significantly stronger than on mid-latitude glaciers. Results suggest that precipitation availability is crucial to glacier retention on Africa's highest mountain" (Mölg et al., 2007). The authors of the 2004 study report that, under present conditions, Kilimanjaro's glaciers will continue to retreat, and the mountain may lose its famous glaciers by mid-century, making it the first time Kilimanjaro glacier-free for the first time in over 11,000 years (Kaser et al., 2004).

Many locations are losing glacial mass due to a combination of increasing temperatures and changing levels of precipitation and atmospheric moisture. Connections between solar activity and glacier melting processes are also being explored. In a 2006 study, Hormes et al. measured long-term glacier length variations and found there was a significant correlation with the total solar irradiance. The IPCC (2007) also points to dynamic thinning as a culprit behind the disappearance of glaciers. Dynamic thinning has increased the velocity of a number of glaciers, leading to enhanced melting and calving rates as well as reductions in overall mass balance. Additionally, ice reflects sunlight, but the increase of dark, heat-retaining rock and soil left uncovered by retreating and melting glaciers in turn heats up the ground and causes more reduction in glacial mass.

2.1 Some glaciers are still getting bigger

Despite the worldwide trend toward retreat, a number of glaciers are growing. Dyurgerov and Meier's 2005 study found that Scandinavian glaciers were gaining mass balance. Likewise, certain glaciers in areas general retreat, including Alaska, are exhibiting evidence of expansion. A 2007 study showed that in 5% of the study area in Alaska and Canada, glaciers, such as the Taku Glacier, were experiencing thickening (Larsen et al., 2007). Fealy and Sweeny (2005) find "an increased moisture flux over the North Atlantic" as being behind glacier advances in Scandinavia. Other glaciers, such as the Taku, are getting larger mainly due to the fact they are tidewater glaciers in the late stage of their cycles. As such, they are losing mass primarily due to calving . which means they are losing mass in their ablation zones. With smaller ablation zones, the glacier tries to restore its mass balance, resulting in growth in the accumulation region and glacial advance (Larsen et al., 2007).

2.2 Antarctic Ice Sheet is GROWING, Not shrinking as per NASA

Fig.3: Antarctica's ice sheet
(Source: Michel Bastasch said on Nov 02, 2015)

For years, scientists assumed Antarctica's ice sheet was shrinking, but new research challenges the consensus on how global warming is impacting the world's largest ice sheet. National Aeronautic and Space Administration (NASA) study showing that Antarctica's ice sheet has been thickening for at least a thousand years from extra snowfall, and the South Pole actually increased in mass from 1992 to 2008. More importantly, NASA researchers found the mass gains in Antarctica mean the South Pole is not contributing to global sea level rise. In fact, scientists don't expect Antarctica to contribute to sea level rise for another 20 or 30 years.

"We're essentially in agreement with other studies that show an increase in ice discharge in the Antarctic Peninsula and the Thwaites and Pine Island region of West Antarctica," Jay Zwally, a NASA glaciologist and lead author of the study, said of past research on the south pole.

"Our main disagreement is for East Antarctica and the interior of West Antarctica-there, we see an ice gain that exceeds the losses in the other areas," Zwally said.

For the past few years, scientists have been worried over Antarctica's western ice sheet. The United Nations Intergovernmental Panel on Climate Change (IPCC) reported Antarctica was losing ice overall in a major 2013 report. This set the stage for increased worries about sea level rise from the world's largest ice sheet. Media reports of Antarctica's imminent demise highlighted how collapsing South Pole glaciers would contribute to sea level rise, making coastal cities much more vulnerable to flooding. Subsequent studies found the Thwaites and Pine Island glaciers were collapsing and discharging large amounts of ice. In 2013, NASA found that Antarctica's western ice sheet was facing imminent collapse.

Researchers at University of Washington estimated the western ice sheet collapse would occur over the next 200 to 900 years. Other research claimed Antarctica's eastern ice sheet was losing ice as warm water calved it from below. Scientists have also postulated that rapid ice loss from Antarctica caused record-high sea ice extents during the Southern Hemisphere's winter. South Pole sea ice was so thick earlier this year that scientists had trouble reaching the region by boat. But Zwally's research, published in the Journal of Glaciology, found Antarctica gained 112 billion tons of ice per year from 1992 to 2001 and 82 billion tons of ice per year from 2003 and 2008.

Eastern Antarctica gained 200 billion tons of ice per year from 1992 to 2008, according to Zwally's study, outweighing ice losses from western Antarctica totalling 65 billion tons per year. This means the South

Pole is actually contributing to sea level declines, not sea level rises.

"The good news is that Antarctica is not currently contributing to sea level rise, but is taking 0.23 millimeters per year away," Zwally said. "But this is also bad news. If the 0.27 millimeters per year of sea level rise attributed to Antarctica in the IPCC report is not really coming from Antarctica, there must be some other contribution to sea level rise that is not accounted for."

Zwally's team also found that snowfall over East Antarctica dramatically decreased since 1979, meaning the region's thick ice came from ancient snowfall that hardened and thickened over the last thousand years. East Antarctica and the interior of West Antarctica have thickened by 0.7 inches per year over the last millennia - a huge gain of ice.

3. ANTHROPOGENIC OR NATURAL CLIMATE CHANGES?

According to Hormes, et al., "…glaciers show a response to changing climate, but cannot give any answer to the question about whether the forcing is natural or not" (Hormes et al., 2006). Glacial retreat, after all, is not something new. In the Swiss Alps, for example, glaciers were much larger during the Mini Ice Age than they are now. However, they have been both smaller in volume and shorter in length than they are currently at a number of times throughout the past 320 to 2500 years (Hormes et al., 2006). Additionally, there is now evidence that during the last interglacial period 125,000 years ago, some Alpine glaciers were smaller than they are now or even non-existent (Joerin et al., 2006).

Glaciers are particularly sensitive to changes in climate, and that is why they are pointed to as an indicator of climate change in general and of anthropogenic climate change in specific. The IPCC directly links current rates of glacial retreat to anthropogenic climate change in its 2007 report by saying, "The late 20th-century glacier wastage likely has been a response to post-1970 warming" (IPCC, 2007). (In the summary of the IPCC report it is also mentioned that "Most of the observed increase in globally averaged temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations.") Around 1970, mean glacier mass balances were close to zero regionally and globally, leading scientists to believe they were close to equilibrium. Since that time, however, the global mean has tended toward a negative mass balance, indicating .glacier wastage in the late 20th century is essentially a response to post-1970 global warming. (IPCC, 2007).

3.1 Consequences of the disappearance of mid-latitude glaciers

There are likely to be significant and widespread consequences of glacial retreat and of the disappearance of glaciers. Many people across the world are dependent upon glaciers for water, energy, and safety. Additionally, many organisms, ecosystems, and ecosystem processes are reliant upon glaciers. Dr. Phil Porter of the University of Hertfordshire sums it up well when he says "There is a short-term danger of too much water coming out… and a greater long-term danger of there not being enough" (McKie, 2005).

3.2 Reduction in Availability of Freshwater for Consumption

Glaciers store about 75% of the world's freshwater. Some mountain cities and the surrounding regions are dependent upon glacier runoff for their freshwater supply (USGS, 2005), such as in South America. The Andes Mountains in South America are home to 70% of the world's tropical glaciers, which provide water for drinking, agriculture, and hydropower for 30 million people (ESN, 2008). Quito, Ecuador, for example, draws 50% of its water supply from the Antizana and Cotopaxi glacier basins. La Paz, Bolivia draws 30% of its water supply from the same basins (Vergara et al., 2007). However, these glaciers are rapidly dwindling.

In some areas of Asia and the Andes increased glacial runoff has translated into more water in the areas' rivers. However, once the glaciers diminish, their hydrologic inputs will disappear as well. Many of the towns in the Andes region have already felt the impacts of water shortages for drinking water and agriculture. In El Alto, Bolivia, Vergara et al. (2007) mention "…water supply is now just about enough to meet demand during dry season." Despite projects to help with water supply, demand for water will outstrip supply in the La Paz-El Alto area by 2009. Quito, Ecuador is scheduled to run into serious water shortages by 2015 (Tehran Times, 2007). Additionally, crops have had to be relocated to higher areas that receive more water from the glacier, but that have poorer soil, limiting their yield. Domesticated animals such as alpaca are also suffering from lack of food, resulting in decreasing wool production. Where once the townspeople could rely on their own production, now they must buy fertilizer and other supplies (World Bank, 2008).

A report from the National Meteorology and Hydrology Service of Peru has found that Andean glaciers have lost 20% of their volume since 1970 (World Bank, 2008). Some, like the Chacaltaya glacier in Bolivia, have already lost up to 99% of their volume (World Bank, 2008). Scientists have predicted that the Andes will be glacier-free by mid-century (Tehran Times, 2007). In a 2007 interview, Walter Vergara, who was the lead author of the 2007 World Bank report and who also is the Bank's lead climatologist, stated "All these ecosystems are changing very quickly. In fact, every year they change at a faster pace, which has all of us very alarmed" (Tehran Times, 2007).

A number of countries are highly dependent upon its glaciers and glacial runoff for energy production. In the Andes region, hydropower supplies 81% of Peru's electricity, 73% of Colombia's, 72% of Ecuador's, and 50% of Bolivia's (World Bank, 2008). In India, 50% of hydroelectric power is generated by runoff from Himalayan glaciers (Kargel, et al., 2002). Glacial runoff supplies hydropower for 50% of Switzerland's electricity as well (Paul et al., 2007). All of these countries face billions of dollars worth of investment in infrastructure to accommodate new types and sources of energy production, some of which release more greenhouse gases than hydroelectricity.

4. CONSEQUENCES OF ECOLOGICAL IMBALANCES

Humans will not be the only losers when it comes to depleted glacial runoff. "These changes are likely to have significant, widespread consequences for the fauna of alpine stream ecosystems,"Brown et al. state in a 2007 report, "…it may be impossible to prevent the loss of species adapted to meltwater stream conditions as climate warms and snowpacks and glaciers shrink." Plants, animals, and other organisms that are strongly influenced by the hydrologic impacts of glacial ecosystems will suffer as river channel stability, water temperature, and suspended sediment load are drastically altered due to changes wrought by glacial wastage in meltwater contributions and valley geomorphology (Brown et al., 2007). Additionally, glacial runoff feeds a number of rivers and lakes, thereby serving significant purposes in the area ecosystems, as well as in general ecosystem processes. As glaciers disappear, the benefits of glacial systems and inputs of glacial runoff will likewise evaporate.

4.1 Flooding

Because of rapid glacial melting and wasting, an increasing number of avalanches and floods have been occurring. Ice avalanches from steep or hanging glaciers, such as the 1996 avalanche from Gutz Glacier near Grindelwald, Switzerland, cause infrastructure damage and injury. Much more hazardous are **glacial lake outburst floods** (also called GLOFs or Jökulhlaups) which occur when glacial melt is dammed by unstable moraines at the terminus. The failure of this dam due to volcanic eruption, erosion, water pressure, avalanches or calving, or earthquakes, results in the release of the water in the glacial lake.

Glacial lake outburst floods have occurred across the world and at many scales. At the end of the last ice age, massive glacial outburst floods occurred, such as the Missoula Floods, which created the Columbia River Basin. The number of glacial lake outburst floods, however, has been increasing during the second half of the 20th century according to UNEP. A 2005 report in Nature indicated there has been a 10-fold increase in the number of glacial outburst floods over the past two decades alone. These floods are incredibly devastating, and result in economic losses as well as casualties. In 1985, water released from the Dig Tsho Lake in Nepal destroyed 14 bridges and caused $1.5 million in damage to a hydropower plant downstream. More recently, in 1994 an outburst at Luggye Tsho, 90km upstream from Punakha in Bhutan caused massive flooding and erosion on the Pho Chhu River, destroyed many buildings in the town, and resulted in 21 casualties (McKie, 2005). Accelerated glacial retreat due to climate change is already raising the likelihood and imminence of these types of catastrophes, especially in areas like the Alps, Andes, and Himalayas.

4.2 Sea level rise

According to the IPCC's 2007 report, "The most important cryospheric contributions to sea level variations arise from changes in the ice on land (e.g., glaciers, ice caps, and ice sheets)." In a 2007 study, Meier et al. agree, stating "Ice loss to the sea currently accounts for virtually all of the sea-level rise that is not attributable to ocean warming." According to Meier et al. (2007), however, about 60% (**Figure 4**) of the ice loss is from glaciers and ice caps rather than from the Greenland and Antarctic ice sheets.

Since 1961, total global sea level rise has been 3.1 ± 0.7 mm/year (Meier et al., 2007). Of that total, the IPCC (2007) points to glaciers as contributing about 0.50 ± 0.18 mm per year during the period between 1961 and 2003. During that period, the contributions to sea level rise of these glaciers accelerated — the rate increased to an average of 0.77 ± 0.22 mm per year from 1993 to 2003 (IPCC, 2007).

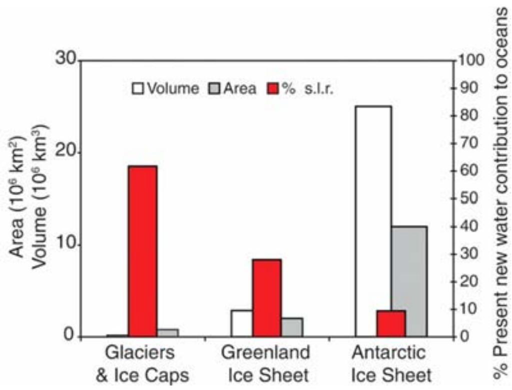

Fig.4:"Contributions of GIC, Greenland, and Antarctic Ice Sheets to present-day rate of sea-level rise (s.l.r.), along with their respective volumes and areas." Image credit: Meier et al., Science, 2007

As mentioned earlier, the largest glacial mass losses have been observed in Patagonia, Alaska, the northwest U.S., and southwest Canada. Therefore, the biggest contributions to sea level rise since the IPCC's Third Assessment Report in 2001 have come from Alaska, the Arctic, and Asia. (IPCC, 2007). According to Meier et al. (2007), this increase is "in part due to marked thinning and retreat of marine-terminating glaciers associated with a dynamic instability that is generally not considered in mass-balance and climate modeling." The study predicts that accelerating rates of glacial melt may lead to an additional 0.1 to 0.25 meter of additional sea level rise by 2100 above the IPCC projections (Meier et al., 2007). Luthcke *et al.* (2008) estimated that the glaciers draining into the Gulf of Alaska were responsible for 0.23mm/year of global sea level rise between 2003 and 2007.

Warmer water in the oceans pumps more energy into tropical storms, making them stronger and potentially more destructive. Even with storms of the same intensity, future hurricanes will cause more damage as higher sea levels exacerbate storm surges, flooding, and erosion (**Fig.5a**).

(a) **(b)** **(c)**

Fig. 5: a) Storm surges, flooding, and erosion **b).** Droughts conditions and increase of the risk of wildfires and **c).** Intense Rainstorms.

4.3 Drought and Wildfire

Warmer temperatures could increase the probability of drought. Greater evaporation, particularly during summer and fall, could exacerbate drought conditions and increase the risk of wildfires (**Fig. 5b**).

4.4 Intense Rainstorms

Warmer temperatures increase the energy of the climatic system and can lead to heavier rainfall in some areas. Scientist's project that climate change will increase the frequency of heavy rainstorms, putting many communities at risk for devastation from floods (**Fig.5c**).

5. CURRENT SCENARIOS IN US AND OTHER COUNTRIES

5.1 Flash floods sweep vehicles along Spanish street 8 September 2015 at 23:55 BST

Fig.6: Footage has emerged of the moment when torrential storms in south east Spain caused flash floods that washed cars and trucks along a street.

Fifty homes, 30 shops and 200 cars were damaged when flood waters swept through the town of Adra, in the province of Almeria on Monday.

Heavy downfalls particularly affected the regions of Andalucía, Murcia and Valencia with more than 300 rain-related incidents being reported to the emergency services.

In the province of Granada, three men drowned when they were caught in rising water. *(Footage courtesy of Francisco Fernandez)*

5.2 US- The Latest on Texas storms: Body of woman found in central Texas raises death toll to 6

A fast-moving storm packing heavy rain and destructive winds overwhelmed rivers and prompted evacuations Friday in the same area of Central Texas that saw devastating spring floods. (James Gregg/ Austin American-Statesman via AP)

Fig.7: Aaron Witt attempts to restart his disabled vehicle on South First Street near Oltorf Blvd., Friday, Oct. 30, 2015, in Austin, Texas.

5.3 Floods in Gujarat, Rajasthan, West Bengal and Odisha Affected 80 Lakh people and Death toll 81.

(Source: Press Trust of India, Date: 03/ 08/2015 07:44 IST)

At least 81 people died and more than 80 lakh people were affected in fresh floods due to excessive rains in worst affected Gujarat, Rajasthan, West Bengal and Odisha.

In Gujarat, 14 districts and population of about 40 lakh were affected in recent floods due to heavy rainfall in the last few days. More than 10 lakh food packets have been airdropped or distributed to the flood victims, an official statement said here today.

Temporary relief camps have been set up in affected areas and peoples are accommodated on need basis. A total of 17 National Disaster Response Force (NDRF) teams have been deployed for rescue and relief operations in Gujarat. In Rajasthan, so far 28 people have lost their lives, out of which 12 people died during past few days owing to very heavy rainfall and flood like situation in many parts of the state.

Rajasthan has experienced excessive rainfall in most of its districts. The situation is grim particularly in districts of Jalore, Jhalawar, Baran, Sirohi, Barmer and Dungarpur. Apart from State Disaster Response Force, Police, RAC etc., at present eight teams of NDRF were deployed for rescue and relief operations.

Fig.8: Flood Situation Grim In West Bengal, Over 1 Lakh Displaced

So far, more than 630 peoples have been rescued from various districts in Rajasthan. Relief materials have been distributed to the affected population. In West Bengal, 48 deaths have been reported from various parts of the state during the floods owing to lightening, wall collapse, electrocution, snake bite and drowning.

Fig.9: Flood Situation affected In West Bengal

As reported by State government due to cyclone KOMEN, heavy to very heavy rainfall occurred at isolated places in almost all South West Bengal districts. So far, 12 districts consisting of 210 blocks and 9,691 villages have been affected due to floods.

A population of 36,90,627 are affected. State Government has deployed 121 boats for rescue and relief operations. A total of 5,672 cattle is also lost in the floods. The State Government has set up 1,537 relief camps and 2,14,306 people have been accommodated, it said. In Odisha, seven districts namely Jajpur, Mayurbhanj, Keonjhar, Bhadrak, Balasore, Jharsuguda and Deogarh were affected by the floods, the statement said (**Figs. 8** and **Fig. 9**).

A total of five people lost their lives and 644 villages and population – 4,80,399 are affected. ODRAF units are carrying out relief and rescue operations. So far 1574 peoples have been evacuated to safer places. Seven relief camps have been opened and 55 people have been accommodated. 132 boats have been deployed for rescue operations.

Union Home Minister Rajnath Singh spoke to West Bengal Chief Minister Mamata Banerjee over phone and enquired about the flood situation in the state. According to state secretariat officials, Singh during his conversation with the chief minister discussed the situation in all affected districts.

Meanwhile, Banerjee held discussions with district officials of all affected districts through video conference and took reports of the latest flood situation.

She is also monitoring the situation from time to time by meeting senior officials at the state secretariat.

5. CONCLUSION

From the above study, it is learnt that entire globe is facing following specific issues:

- The number of category 4 and 5 storms has greatly increased over the past 35 years, along with ocean temperature.
- Hurricane Katrina of August 2005 was the costliest and one of the deadliest hurricanes in U.S. history and caused economic losses in the order of $125 billion.
- The 1999-2002 national droughts were one of the three most extensive droughts in the last 40 years.
- Warming may have lead to the increased drought frequency that the West has experienced over the last 30 years.
- The 2006 wild land fire season set new records in both the number of reported fires as well as acres burned. Close to 100,000 fires were reported and nearly 10 million acres burned, 125 percent above the 10-year average.
- Firefighting expenditures have consistently totaled upwards of $1 billion per year.
- National annual precipitation has increased between 5 and 10 percent since the early 20th century, largely the result of heavy downpours.
- The Intergovernmental Panel on Climate Change reports that intense rain events have increased in frequency during the last 50 years and human-induced global warming most likely contributed to the trend.

Recent years in 2014 and 2015, all over the World situation became bad to worst in respect of floods, draughts, storms, heavy rain fall and snow fall. This will continue in coming years, till situation of Global Warming is not curbed. Thus awareness about Climate Change is to be focused and all country has to address this on top priority to Save Earth and Save Life.

REFERENCES

[1] Aniya, M., 1988: Glacier inventory for the Northern Patagonia Icefield, Chile, and variations 1944/45 to 1985/86. *Arctic and Alpine Research*, 20: 179–187.

[2] Arendt, A., Echelmeyer, K., Harrison, W. D., Lingle, G., and Valentine, V., 2002: Rapid wastage of Alaska Glaciers and their contribution to rising sea level. *Science*, 297: 382–386.

[3] Abdalati, W., Krabill, W., Frederick, E., Manizade, S., Martin, C., Sonntag, J., Swift, R., Thomas, R., Wright, W., and Yungel, J., 2001: Outlet glacier and margin elevation changes: Near-coastal thinning of the Greenland ice sheet, 2001. *Journal*

of Geophysical Research, 106(D24): 33,729–33,742.

[4] Arendt, A. A., Echelmeyer, K. A., Harrison, W. D., Lingle, C. S., and Valentine ,V. B., 2002: Rapid wastage of Alaska glaciers and their contribution to rising sea level. *Science*, 297: 382–386.

[5] Armstrong, R. L., and Brodzik, M. J., 2001: Recent Northern Hemisphere snow extent: a comparison of data derived from visible and microwave satellite sensors. *Geophysical Research Letters*, 28(19): 3673–3676.

[6] Bahr, D. B., and Meier, M. F., 2000: Snow patch and glacier size distributions. *Water Resources Research*, 36(2): 495–501.

[7] Bamber, J., and Payne, A. (eds.), 2004: *Mass balance of the Cryosphere. Observations and modeling of contemporary and future changes*. Cambridge: Cambridge University Press, 644 pp.

[8] Chinn, T. J., 1996: How much ice has been lost? *New Zealand Alpine Journal*, 1996: 88–95.

[9] Dowdeswell, J., and Hambrey, M., 2002: *Islands of the Arctic*. Cambridge: Cambridge University Press, 280 pp.

[10] Dolgushin, L. D., 2000: Sovremennoe nazemnoe oledenenie [Present land glaciation]. *Materialy Glyatsiologicheskikh Issledovaniy (Data of Glaciological Studies)*, Moscow, 88: 158–208. (Russian)

[11] Dyurgerov, M. B., 2001: Mountain glaciers at the end of the twentieth century: global analysis in relation to climate and water cycle. *Polar Geography*, 25(4): 241–338.

[12] Dyurgerov, M. B., 2002: *Glacier mass balance and regime: data of measurements and analysis*. Boulder: University of Colorado Institute of Arctic and Alpine Research Occasional Paper 55. (available online at http://instaar.colorado. edu/ other/occ_ papers. html)

[13] Hall, M. P. and D. B. Fagre. 2003. Modeled climate-induced glacier change in Glacier National Park, 1850-2100. Bioscience 53(2):131-140.

[14] *Koji Fujita and Yutaka Ageta, 2006,* Effect of summer accumulation on glacier mass balance on the Tibetan Plateau revealed by mass-balance model.

[15] Keane, R.E., C.C. Hardy, K.C. Ryan, and M.A. Finney. 1997. Simulating effects of fire on gaseous emissions and atmospheric carbon fluxes from coniferous forest landscapes. World Resource Re-view 9:177-205.

[16] Key, C. H., D. B. Fagre, and R. K. Menicke. 2002. Glacier retreat in Glacier National Park, Montana.Pages J365-J381 In R. S. Jr. Williams and J. G. Ferrigno, (eds.) Satellite Image Atlas of Glaciers of the World, Glaciers of North America - Glaciers of the Western United States. U.S. Geological Survey Professional Paper 1386-J. United States Government Printing Office, Washington D. C., USA.

[17] Mote, P., A. Hamlet, M. Clark, and D. Lettenmaier. 2005: Declining mountain snowpack in western North America. Bulletin of the American Meteorological Society 86-1-39, DOI: 10.1175.

[18] Pederson, G.T., L.J. Graumlich, D.B. Fagre, T. Kipfer and C.C. Muhlfeld. 2009. A century of climate and ecosystem change

in Western Montana: what do temperature trends portend?. Climatic Change 96: DOI 10.1007/s10584-009-9642-y, 22pp.

[19] Pederson, G. T., D. B. Fagre, S. T. Gray, and L. J. Graumlich. 2004. Decadal-scale climate drivers for glacial dynamics in Glacier National Park, Montana, USA. Geophysical Research Letters. 31:L12203, doi: 10.1029/2004GL0197770.

[20] Pepin, D. M. and F. R. Hauer. 2002. Benthic responses to groundwater-surface water exchange in two alluvial rivers in Northwestern Montana. Journal of the North American Benthological Society. 21(3):370-383.

[21] Peterson, D.L. 1998. Climate, limiting factors, and environmental change in high-altitude forests of western North America. Pages 191-208 In M. Beniston and J.L. Innes (eds), The Impacts of Climate Variability on Forests, Springer, Heidelberg.

[22] Selkowitz, D. J., D. B. Fagre, and B. A. Reardon. 2002. Interannual variations in snowpack in the crown of the continent ecosystem. Hydrological Processes. 16:3651-3665.

[23] T. Mölg, N. Cullen, D. Hardy and G. Kaser, Mass balance of a tropical glacier and its sensitivity to climate fluctuations: Kilimanjaro, 5873 m a.s.l**.**

[24] Web links:http://dailycaller.com/2015/11/02/nasa-antarctic-ice-sheet-is-growing-not-shrinking/#ixzz42rzyA4YM.