P5 MOUNTAIN CLIMATE CHANGE AND MELTING GLACIERS: CAUSES AND CONSEQUENCES

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1. ABSTRACT

The Himalayan Mountains and the Tibetan Plateau are home to many of the world's great glaciers covering more than 70,000 square miles. The glaciers are the source of water for the main rivers of India including the sacred Ganges and the Indus. During the summer, the slowly melting glaciers provide water for drinking and irrigation, and during the winter snowfall replenishes the ice for next summer. However, warmer temperatures are causing the glaciers to melt faster during the summer, causing major flooding in the lowlands while the lack of snowfall at higher elevations during the warmer winters is causing drought.

The same is true of the glaciers along the equator in Africa. Mount Kenya has had glaciers throughout recorded history, but now only 20 percent of the glaciers there remain. The farmers in the surrounding valleys have always depended on the glaciers for their water, but the rivers are drying up and people are starving. The Snows of Mount Kilimanjaro are world famous and have been a mainstay of the people of equatorial Africa for centuries. Today the glaciers on the mountain are nearly gone and will soon vanish completely leaving the locals to fight over the limited remaining water supplies. Likewise, in the mountains of Uganda, the glaciers are disappearing at an alarming rate with 80 percent of the glacial ice melting since 1850 and all of the glaciers expected to be gone within the next 40 years.

The glaciers in the European Alps have decreased by 50 percent since the 1900s and are predicted to disappear by the middle of the 21st century. During the devastating summer heat wave of 2003 which killed at least 30,000 Europeans, the glaciers in the Alps lost 7 feet of ice. Switzerland suffered major flooding in 2005 as a result of rapidly melting glaciers and the resultant runoff. And, Glacier National Park has lost 80 percent of its glacial ice since 1850 and is expected to be glacier free within 30 years. This research examines the causes and consequences of melting mountain glaciers, ice sheets, and ice shelves across the globe.

2. THE CAUSES

The global population has grown to such an extent in absolute numbers and in per capita footprint that there are extensive surface changes created by human activity. For example, the intense development found in cities is so pronounced that a new set of climatic conditions is created called the urban heat island effect. Because global wind patterns and ocean currents effectively redistribute heat energy, the climate of the entire planet is being altered. In fact, higher latitudes are experiencing far greater warming than are lower latitudes. Such extensive change has the potential to move our planet to a new stage unknown in human history and to entirely revise socioeconomic systems.

In the developed world, the economies are largely driven by fossil fuels. The developing world increasingly is relying on fossil fuels as well. The preponderance of electricity is generated through coal-fired power plants. Crude oil is used to provide space heat in homes and office buildings and is refined to make gasoline to power automobiles and trucks. Fossil fuels were formed over millions of years when organic matter became covered with sediments and became buried in fossil rock. When those fuels are drilled, mined, and burned, the carbon that was stored for eons is released back into the atmosphere very rapidly. Presently, the burning of organic compounds is adding far greater amounts of CO_2 to the atmosphere than photosynthesis on land or in the oceans can remove. Approximately 8 billion tons of CO_2 are added to the atmosphere each year and about half is removed by the oceans and vegetation on land. Consequently, approximately 4 billion tons of CO_2 are added to the atmosphere annually. By the year 2025, the amount of CO_2 added annually is expected to increase to between 9 and 15 billion tons. For years beyond 2025, estimates are highly variable due to uncertainties about whether the countries with major emissions will take steps to reduce their output of greenhouse gases. If not, emission levels by 2100 could be five times as high as today.

The present CO_2 content of the atmosphere is higher than at any other time in at least the past 650,000 years. The concentration is now nearly 40% more than in the pre-industrial era and is increasing at an average rate of about 1.8 ppm annually. However, in 2007, world emissions of CO_2 grew by 3 percent with China passing the U.S. as the country emitting most of the greenhouse gases. In the very near future the atmospheric level will reach 400 ppm, which is the highest level attained in the past million years. This level is significant even in geologic time. The volume of coal known to exist in reserves is far more than necessary to produce such an increase in CO_2. If all the known reserves of fossil fuels were burned, the CO_2 content in the atmosphere would triple. Once the level goes up, it will remain there for centuries because there is no rapid means of removing it from the atmosphere.

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In addition to CO_2, other gases play a part in global warming. Methane is a greenhouse gas previously found in small amounts in the atmosphere. However, each methane molecule is about 21 times as efficient as CO_2 in warming the atmosphere. Methane began to accumulate during the past two centuries. The level of methane has risen from about 700 parts per billion (ppb) in the mid-18th century to around 1770 ppb today. The additional methane comes from raising livestock, rice cultivation, industry, mining, drilling, and landfills.

At higher latitudes in the northern hemisphere, much of the land surface is covered by permafrost. The permafrost provides a barrier for gases beneath. A large amount of methane is trapped beneath this frozen soil. Because global warming is most rapid in subarctic regions, rapid melting of the permafrost is taking place in some areas and releasing methane into the atmosphere. This release of methane is self-perpetuating. When more methane escapes into the atmosphere, it leads to still more warming and more methane release. On a global basis, methane accounts for about 23 percent of greenhouse gases. Carbon dioxide and methane combined account for 93 percent of greenhouse gas emissions.

Besides carbon dioxide and methane, much of the remainder of greenhouse gases is in the form of water vapor and nitrous oxide (N_2O). Water vapor is added to the atmosphere through evaporation and plant transpiration. The main source of N_2O is from agriculture processes, nylon production, biomass burning and soil processes. One-third or more of N_2O is now from agriculture. The rest is from non-agricultural land. Concentration of the gas has increased by about 20 percent since pre-industrial times. Other gases also have the potential to add to global warming. However, carbon dioxide, methane, water vapor, and nitrous oxide are now believed to be the main contributors.

3. THE ARCTIC

Mountain glaciers and ice caps have been subjected to a rapid decrease in snow and ice since the 1950s. As predicted, global warming is accelerating across both polar regions because these areas experience the greatest contrasts between radiation receipt in summer and winter. Also, additional heat has more of an impact on cold regions, such as the poles, that it does on regions that are already warm, such as the tropics. In the Arctic, 85 percent of Greenland's surface is covered with glaciers that are as thick as 2 miles in places. The village of Ilulissat on the west coast of Greenland is home to the Ilulissat Glacier, which is a World Heritage site recognized by the United Nations. The glacier is on the move year-round sliding toward the sea. This is a result of rising temperatures in the winter that have increased by 5° Celsius over the past 15 years. As a result, from 1979 to 2007, the Greenland Ice Sheet decreased in size by 30 percent and currently loses about 200 cubic kilometers annually. There is increasing calving of ice around the edges of the Greenland Ice Sheet as it becomes more porous due to the development of moulins. The water pouring into the moulin can melt through the ice until it makes contact with the rock base below causing the glacier to advance more rapidly and perhaps even slide off its base into the sea. While it is unlikely that the Greenland Ice Sheet will disappear altogether, continued melting could reduce it to one-third its normal size.

During the winter, sea ice covers much of the Arctic surface which can be as thick as 4 meters in some places. In recent years, the sea ice has thinned significantly and in some places it is half as thick as it was just a few decades ago. Since the 1900s, melting has rapidly increased during the summer such that since 1958, approximately 40 percent of the sea ice extent has decreased. The present rate of sea ice loss is nearly 10 percent per decade and over the course of the past 30 years, summer sea ice has decreased by 2.5 million square kilometers. In 2007, satellite images revealed that summer sea ice was 76,000 square kilometers less than the average extent for the period from 1979 to 2000. Later that summer, the Northwest Passage was open with an ice free zone encircling the Arctic from the Atlantic Ocean to the Pacific. It had been predicted that the Arctic would be free of ice in the summer between 2050 and 2100. More recently, that forecast has been amended to suggest that there might not be summer sea ice by 2030. However, with the opening of the Northwest Passage, it is now estimated that the Arctic could be ice-free each summer as early as 2020, and if the rate of melting continues, the Arctic could be entirely free of ice even in winter by 2100.

Ice shelves are large chunks of floating ice that are attached to the larger land mass. There are six such ice shelves in the Canadian Arctic and it is thought that they are been around for some 3000 years. In August 2005, the Ayles Ice Shelf which was attached to Ellesmere Island broke away. The 100 square kilometer floating iceberg drifted out to sea. Again in 2008, the 50 square kilometer Markham Ice Shelf broke free from Ellesmere Island. Also during the summer of 2008, the Ward Ice Shelf, which is huge at 440 square kilometers, started to breakup losing 10 percent of its area. In all, the ice shelves of the Arctic have lost 90 percent of their size in just the past 100 years.

4. ANTARCTICA

On the other side of the world, the ice sheets in Antarctica, which are the largest on the planet, are also experiencing rapid melting. From 1950 to 2000, the mean annual temperature across West Antarctica rose by 2.5° Celsius while the temperature during the middle of winter increased by 4.5° Celsius. The West Antarctic Ice Sheet consists of approximately 29,500 cubic kilometers of ice and it has been suggested that if it were to melt, global sea level could rise six meters. Antarctica is surrounded by ice shelves like the Arctic. A large piece of the Ross Ice Shelf about 300 kilometers by 40 kilometers broke free in 2000. Similarly, the Larson B Ice Shelf lost a 3100 square kilometer chunk of ice in 2002. These shelves act like dams helping prevent the glaciers on the ice sheets from advancing toward the sea. As the ice shelves disintegrate, they allow the glaciers to slip into the Southern Ocean thus contributing to sea level rise.

5. MOUNTAIN GLACIERS

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4. PERMAFROST

Ice sheets and glaciers are not all that are melting. It is estimated that 20 to 25 percent of the global landmass is permafrost and much of that is softening as the climate continues to warm. Across Siberia, the temperature of the permafrost has risen by more than 1°C since 1960 causing trees in the forests to lean in all directions like staggering drunks and buildings to crack and crumble as the underlying frozen soil begins to thaw. In some places around Fairbanks, Alaska, the permafrost has warmed by nearly 3°C causing the same destruction seen in Siberia as well as a rash of fires as summers become drier and bark beetle infestations migrate northward wiping out entire forests of evergreens. Melting permafrost could also potentially free the billions of tons of methane that are currently locked in the frozen soil. If vast amounts of methane, which is 21 times more effective as a greenhouse gas than carbon dioxide, were to be suddenly released, all the worst-case projected global warming scenarios would be realized.

5. CONCLUSION

The mean global temperature of Earth has not deviated more than 1°C from the average since the beginning of civilization. By 2100, Earth's temperature is forecast to increase from 1.5°C to 4°C if present rates of warming continue. This rate of temperature increase is unequivocal in that it has no equal in the past half million years. Variations in the energy output of the sun, changes in the relative positions of the sun and Earth, shifting locations of the continents, volcanic eruptions and other alterations of atmospheric composition all combine to cause climate change. The long term changes in Earth's temperatures are encompassed within a range of natural variability. Global warming refers to the relatively rapid, recent changes that are outside this range of natural variability. The evidence for global warming is overwhelming and includes melting glaciers and sea ice, rising sea level, increased heights of storm surges, a greater frequency of severe weather events, including category 4 and 5 hurricanes, an increased number and severity of floods, droughts, and wild fires, and an increase in the acidity of the world's oceans.

The burning of fossil fuels and deforestation during the last 100 years has increased the level of carbon dioxide (CO2) from 280 parts per million (ppm) to 390 ppm, and CO2 is a potent greenhouse gas. Countries around the globe have convened to find a resolution to this pressing problem as they met at Kyoto, Japan, in 1997, Copenhagen, Denmark, in 2009, and at Cancun, Mexico, in 2010. The Intergovernmental Panel on Climate Change (IPCC) is a body of more than 2000 of the world's foremost atmospheric scientists and is held to be a reliable source of information on all aspects of global warming. In their fourth assessment report published in 2007, these experts outlined the importance of the choices made by societies in determining the degree to which the planet will continue to warm in their Special Report on Emission Scenarios (SRES). The atmosphere will continue to warm throughout the next century. However, the boldness and efficiency with which individuals and governments act will make a substantial difference in the depth of the disasters that will ensue.