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Climate Change - Increased Storms & Extreme Weather

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Abstract:
This paper explores the recent increase in storms and extreme weather events through the lens of climate change and its potential influence on these events. The purpose of this paper is to examine the changes in weather, and specifically in extreme weather events, and its incidence with increased anthropogenic factors. This paper considers available studies and data, and acknowledges the need for peer-reviewed studies concerning the causes and degree of extreme weather events around the globe. It is hoped that greater awareness and research may pursue these limitations and better contribute to global policy concerning climate change.

Keywords: *Increased hurricanes, extreme weather, climate change, heatwaves, flooding, droughts*

1. Climate Change- Increased Storms & Extreme Weather

It takes little more than a quick glance at the natural disasters throughout man's history to see that storms are becoming more and more powerful. The severity of natural disasters is based generally on the combination of loss of humanity and economic damage, with relative importance varying from study to study.

Recordkeeping, world population differences, and the corresponding civilized area of the planet undoubtedly play a part in the increase in major disasters in recent years. However, consider for a moment your own experience: perhaps you are from one of the 200 cities and towns across America which saw record highs in the summer of 2005. Or one of the unfortunate members of the world who witnessed the utter destruction caused by the tsunamis of southeast Asia,2004. Or perhaps you were privy to the horrors of the 2003 heatwave experienced throughout Europe and India. And no American will ever forget the demolition throughout New Orleans, Louisiana, and Mississippi caused by Hurricane Katrina in 2005. It would seem that weather is getting progressively more extreme and destructive.

The Earth has warmed by 0.6 C over the last century. This has caused evaporation differences on Earth- the more heat, the greater the amount of liquid water is able to acquire enough energy to assume the gaseous state and enter our atmosphere. As a result, a warming planet will bring more intense rainstorms. Heavy one-day rainfalls (>50 mm) have increased by about 20% over the past 90 years in the U.S., and increased rainfall leads to disease outbreaks. More than half of the waterborne disease outbreaks in the U.S. over the past 50 years have been preceded by heavy rainfalls (Curriero et al., 2001).

In the upcoming sections, we will explore the changes in various types of extreme weather resulting from climate change. (See table 1- Changes in Extreme Weather)

Hurricanes	Duration, max. wind speed, and energy released all increased between 1985-2000 (Emanuel, 2005). Incidents of category 4 and category 5 increased 80% in the last 35 years (Webster et al., 2005).
Winter Storms	The number of severe winter storms has nearly doubled since the mid-1970s in the Northern Hemisphere.
Heatwaves	Climate change has increased the risk of heatwaves on continental Europe by up to one hundred times (University of Oxford, 2019), while both Europe and North America will have more heatwaves (Meehl, 2004).
Flooding & Drought	Increased rainfall and evaporation lead to wetter and drier regions.
Rainfall	Heavy one-day rainfall up 20% in last 90 years in U.S. (Karl et al., 1995)

Table 1: Changes in Extreme Weather

1.1. Hurricanes

Hurricanes are tropical cyclones that occur in the Atlantic Ocean (In the Western Pacific Ocean, hurricanes are known as typhoons; In Bangladesh, Pakistan, India, and Australia, they are known as cyclones; In the Philippines, they are known as baguios.). Tropical cyclones occur when the maximum sustained surface winds reach at least 119 kph. 'Tropical'

is used due to the fact that they are formed in tropical areas of the ocean. The word 'cyclones' is used due to the fact that their winds swirl around a center- or the 'eye' of the hurricane/ storm. Hurricanes form where there is warm water, moist air, and converging equatorial winds. These winds are formed as a result of warm moist air from the ocean's surface rise and eventually form rain clouds. The water vapor condensing to rain gives off energy, warming the high-altitude air. Because it is now warmer air, it rises, being replaced by other warm ocean air. This warm air continues the process, which adds energy and moisture to the system. This enables the cyclone to gain strength- increasing the amount of water contained in its storm and the speed at which its winds are moving heat from the ocean's surface to the atmosphere around the eye.

Most of the Atlantic hurricanes originate off the coast of West Africa, starting as thunderstorms that move over the warm, tropical water. The Cape Verde hurricanes originating in Africa have produced some of the worst hurricanes in history for the Western hemisphere.

Increasing studies into the increased impact of storms- specifically hurricanes and heat waves- have been published since 2003. The duration of hurricanes, max wind speed, and energy released have all increased between 1985-2000 compared with the 15 years preceding. Furthermore, the incidence of category 4 and category 5 hurricanes- the most powerful hurricanes on the 5-step grading system- have increased by 80% worldwide during the past 35 years.

Warmer waters lead to more powerful hurricanes. Increased greenhouse gases translate into higher surface ocean temperatures. Of the increased warmth and energy in the oceans, Barnett (2005) states that 'the immediate conclusion is that human influences are largely responsible for the warming signal.' Santer & Wigley (2006) claim that humans are causing stronger storms and that 2/3 of the recent rise in sea temperature can be attributed to human influence. This is an increase over the 50% that Trenberth and Shea (2005) attributed as the direct human influence on the North Atlantic Hurricane season.

1.2. Heatwaves

Heatwaves are simply a prolonged period of excessively warm weather relative to the usual weather in the area. There is no universal definition, though in the U.S., it is used to define a period of 3 or more consecutive days above 90F (32.2C). Heatwaves are the most lethal type of weather phenomenon, leading to deaths from hyperthermia, or heat stroke. The 2003 heatwave in Europe took an estimated 35,000 lives, while the 1995 heatwave in Chicago claimed an estimated 525 lives.

Heatwaves are heavily influenced by human behavior and are likely to increase in frequency in the future. Karl & Trenberth (2003) describe the human influence on climate as becoming 'overwhelming large' compared with natural change. In a study of the 2003 heatwave in Europe, climate change was found to have at least doubled the risk of having a major heatwave on continental Europe. And both Europe and North America will see more heatwaves in the future as a result of increases in greenhouse gases. According to a recent study by Swiss scientists, by the end of the century, every two or three summers in Europe could be as warm or warmer than the heatwave in 2003.

1.3. Winter Storms

Winter storms are simply storms that bring precipitation, cold temperatures, and sometimes high winds. The conditions for winter storms require cold air, moisture, and lift. Temperatures must be below 0 C in order to make snow and/or ice. The air itself must contain moisture to form clouds and precipitation. As with hurricanes, lift is required in order to bring moisture from the ocean surface to the higher air pockets. Strong winds, extreme cold, precipitation, and heavy snow or blizzard conditions are some of the effects of winter storms. The winds and precipitation can knock down trees and power lines, causing severe damage. Extreme cold may cause bursting pipes, river ice jams, and subsequent flooding and hypothermia (frostbite). Heavy snow or blizzard conditions produce zero visibility and life-threatening wind chill. The number of severe winter storms in the Northern Hemisphere has nearly doubled since the mid-1970s.

1.4. Flooding and Drought

More evaporation takes place on both land and water as temperatures rise. This affects the water cycle in two ways- some places will experience more rainfall and flooding, while others will experience more drought. The atmosphere is able to hold some of the increased water as a result of it being at a higher temperature (for the same reason that as coffee cools, the sugar collects at the bottom of the glass). The higher amounts of moisture in the atmosphere allow for heavier rainfalls. This increased rainfall causes flooding.

However, the evaporated water does not fall uniformly throughout the globe, meaning that though the net effect is a wetter world, some areas will experience a net loss of water. In places, evaporation increases will be greater than the increase in rainfall, which causes a net loss of water. The changes to the hydrological cycle are that there are both increased droughts and floods throughout the world.

Increased flooding would have disastrous effects on various parts of the world. Increased rainfall threatens 17 million people in Bangladesh who live at an elevation of less than 3 m. above sea level and millions more living on the banks of the Ganges and Brahmaputra Rivers. Increased flooding would also affect millions of people in Bangladesh, China, and Vietnam.

Drought is a normal feature of climate that happens nearly every year in many areas of the world. A widely accepted definition of drought does not exist. It is a relative term that differs from area to area, but drought refers to a general decrease in moisture- decrease in rainfall (known as meteorological drought), decrease in water levels in reservoirs (hydrological drought), or decrease in available water for crops (agricultural drought).

Increased evaporation from soil and reservoirs requires additional rainfall to compensate for the moisture loss. This increased drying of land increases the risk of wildfires.

The effects of droughts are already apparent worldwide. In the U.S. alone, extensive droughts, severe wildfires, and record dry periods have all been occurring since 1998. (See Table 2- Signs of Increased drought in the U.S.)

Warming Sign	Year, Location	Highlight
Extreme drought	1999-2002, national	One of the 3 most extensive droughts in the last 40 years.
Wildfires	2002, Western United States	2nd worst wildfire season in the last 50 years- more than 7 million acres burned. Colorado, Arizona, Oregon had their worst seasons.
Wildfires	1998 Florida	Dry conditions produced the worst wildfires in 50 years.
Dry Conditions	April- June 1998 Florida, Texas, Louisiana	Driest 3-month period in 104 years.
Dry Conditions	April-July 1999 New Jersey, Delaware, Maryland, Rhode Island	Driest four-month stretch in 105 years of record keeping.
Dry Conditions	September 2001- February 2002 Northeast United States	2nd driest six-month period on record.
Dust Storms	2002 Montana, Colorado, Kansas	Experienced severe dust storms resulting from dry conditions

Table 2: Signs of Increased drought in the U.S
Source: Natural Resources Defense Council website http://www.nrdc.org/globalwarming/fcons.asp

1.5. Biodiversity

We hear every day about species in decline or becoming extinct, and we question what impact that may have on our lives. Many claims and many others inwardly believe that man has the right to take what he needs, that nature's purpose is to simply serve man's needs. A hungry man will eat- and it is a simple choice between starving and taking life for nourishment. Survival of the fittest. However, one must stop and consider the true impact the loss of biodiversity will cause- beyond the obvious aesthetic value other creatures have.

Biodiversity is, in fact, troubled with various indicators suggesting that we are approaching the cusp of a mass extinction. Human impacts and global warming are the two most critical threats.

Biodiversity, or biological diversity, refers to the variability among living organisms. It includes diversity within species (genetic diversity), between species (species diversity), and of ecosystems (ecosystem diversity). Tropical forests are the most species-rich environment, containing as much as 90% of the world's species in 10% of the world's surface.

In terms of supporting great biodiversity, the tropical forests of the sea would be coral reefs. Though coral reefs are located in nutrient-poor tropical waters, they support an incredible amount of biodiversity. Over 4,000 species of fishes inhabit coral reefs, or 14 % of the total fish species on Earth. In addition to fish, coral reefs support such varied marine life as sponges, crustaceans (shrimp, lobster, crab), mollusks (clams, scallops, octopus, squid), starfish, sea urchins, sea cucumber, sea turtles, and also dolphins. In fact, coral reefs support more than 25% of all marine life. These animals feed on the coral reefs- either directly on the coral or as part of complex food webs. Approximately 1.75 million species, of the total estimated 14 million species on Earth, or 12.5 % of all species, rely on coral reefs for their survival.

2. Importance of Biodiversity

Environmental services originate in natural assets (soil, water, plants, other living organisms, and the atmosphere), providing mankind with economic, financial, ecological, and cultural benefits. More often than not, these benefits are taken for granted. For example, the hydrological services provided by forests, such as clean and regulated water flow and reduced sedimentation, are only noted when natural disasters, flooding, siltation of reservoirs, and scarcity of water occur as a result of the removal of forest cover. Biodiversity is important for the priceless ecosystem services that it provides, such as clean water, clean air, maintenance of critical nutrient cycles, flood control, pest control, pollination of crops, compounds for new medicines, and seeds for new crops.

The impact of decline or loss of species on the provision of environmental services is difficult to evaluate because the relationship between species diversity and ecosystem function is still unclear. Some species are known to play more significant roles than others. These have been termed 'keystone' species — the loss of one of these species has a particularly disruptive effect on the ecosystem as a whole. Reductions in the number of species affect the provision of all ecosystem services because resource capture (of energy, water, and nutrients) is greater in more diverse systems.

2.1. Biodiversity Loss

Plants and animals alike are finding it hard to compete with man on Earth. Between 1970 and 2000, populations of terrestrial and marine species dropped by 30 percent, and freshwater species by 50 percent. The IUCN Red List is an assessment 'highlighting taxa threatened with extinction, and therefore promote their conservation.' In the latest 2004

report, 41% of species tested were found to be threatened- either critically endangered, endangered or vulnerable. (See table 3- Species threatened by extinction)

The number of species threatened with extinction is 15,589. This includes one in 3 amphibians, one in 5 mammals, and one in 8 birds. Gymnosperms are by far the most threatened of the plants- having 31% facing possible extinction, or almost one out of every 3 species.

Extinction is a naturally occurring part of life. A species is extinct if 'a single individual member cannot be found despite exhaustive surveys over a long period of time.' In mammals and birds, one species becomes extinct every 500-1000 years. This is known as the background rate of extinction. Currently, the rate of extinction is estimated to be between 1000 and 10000 times higher than it would naturally be without man's negative influence.

	Number Threatened As % of Species Described	**Number Threatened As % of Species Evaluated**
Vertebrates		
Mammals	20%	23%
Birds	12%	12%
Amphibians	32%	32%
Reptiles	4%	61%
Fishes	3%	46%
Subtotal	9%	23%
Invertebrates		
Insects	0.06%	73%
Molluscs	1%	45%
Crustaceans	1%	86%
Others	0.02%	55%
Subtotal	0.17%	57%
Plants		
Mosses	0.5%	86%
Ferns and allies	1%	67%
Gymnosperms	31%	34%
Dicotyledons	4%	74%
Monocotyledons	1%	68%
Subtotal	2.89%	70%
Others		
Lichens	0.02%	100%
Subtotal	0.02%	100%
Total	1%	41%

Table 3: Species Threatened by Extinction

Source: IUCN (International Union for the Conservation of Nature and Natural Resources), 2004. Accessed 5.9.06 at http://www.iucn.org/themes/ssc/red_list_2004/summarytables_EN.htm

2.2. Causes of Biodiversity Loss

The ultimate causes of biodiversity loss are human population growth together with unsustainable patterns of consumption, increasing production of waste and pollutants, urban development, international conflict, and continuing inequities in the distribution of wealth and resources.

Climate change has emerged as a major threat to biodiversity. In the latest study conducted on how climate change affects biodiversity, the lead author, Dr. Jay Malcolm, stated that 'climate change is becoming the most serious threat to the planet's biodiversity.' Climate change could lead to serious negative impacts on ecosystems and on the goods and services they provide. Some ecosystems risk total dissolution, and others could see extreme variations in species composition. (See Table 4- Examples of the Effects of Global Warming on Biodiversity)

Effect of Global Warming	**Resulting Change in Biodiversity**
Loss of Habitat	Polar Bear population and size have declined as a result of melting ice. Plankton are losing breeding ground from melting Arctic ice.
Invasive Species	Global warming is likely to enhance the spread of invasive species.
Genetic changes in animals	Global warming causes genetic changes in the span of a few generations.
Destroying Coral Reefs	Global warming is endangering the existence of coral reefs through bleaching and acidification of oceans.

Table 4: Examples of the Effects of Global Warming on Biodiversity

2.3. Current Changes Resulting from Climate Change

Warming temperatures have brought about the recent extinction of dozens of amphibian species in tropical America. Climate change created favorable conditions for a pathogenic fungus in Central and South America, which in turn led to the widespread extinction of harlequin frogs. This is but one of many examples of how the changing world is causing the alteration of life.

Global warming changes the natural patterns of behavior of organism's dependent on temperature. These changes are evident in the change of timing of seasons. Life that reproduces rapidly- having a short reproduction cycle- is better equipped to change in response to climate change than are those species which reproduce less frequently.

2.4. Climate Changes Causes Genetic Changes

Some species of animals, such as birds, squirrels, and mosquitoes, are changing genetically in the span of a few generations in order to adapt to rapid climate change, recent studies show. A wide range of animal populations have changed genetically in response to altered seasonal events- such as Canadian red squirrels reproducing earlier in the year, German blackcap birds migrating and arriving at their nesting ground, marmots end their hibernations about 3 weeks earlier compared with 30 years ago, polar bears are thinner and less healthy than those 20 years ago, many fish species are moving northward in search of cooler waters, and North American mosquitoes entering their pupa stage 8-10 days later than they did in the 1970s in response to the later-starting winters. Studies show that over the past several decades, rapid climate change has led to heritable, genetic changes in animal populations (Bradshaw and Holzapfel, 2008).

2.5. Climate Change Increases Invasive Species

While ninety percent of immigrant species do no obvious harm to their new home environment, a small number do disproportionate damage. By definition, 'invasive species' are 'an alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health.'

Invasive species cause billions of dollars in damage per year. In the United States alone, the economic cost of invasive species- in terms of the damage they do and the expense of controlling them- is estimated at $137 billion a year (Pimentel et al., 2000).

Invasive species disrupt ecosystems primarily by preying on local species and competing with native species over limited resources. Invasive species can also bring in diseases that the native species may be poorly equipped to resist.

Global warming will change ecosystems- changing the hydrological cycle and increasing temperatures. Invasive species may be better equipped for survival and may threaten native species in new ecosystems. Recent studies have, in fact, found that global warming will increase the rate of invasive species in all ecosystems.

2.6. Climate Change Causes Loss of Habitat

The loss of winter ice in the Arctic is critical for plankton, the bottom rung of the oceanic food chain. When this ice melts in the summer, it provides a crucial breeding ground for the plankton, upon whose survival all oceanic species depend.

Climate change affects many species in a multitude of ways. One such example is the melting ice causing the loss of habitat for polar bears. With the loss of summer sea ice, polar bears relocate onto land in northern Canada and Alaska- which gives the perception that polar bear numbers are increasing. However, in the Hudson Bay area, polar bear populations have decreased from 1200 in 1989 to 950 in 2004, and they are 22 percent smaller than they used to be. Polar bears are being found drowned- a new phenomenon in the animal kingdom. Having to travel many miles in search of ice in areas where the ice used to be plentiful proves too difficult for some to manage.

3. Global Warming and Coral Reefs

Coral reefs are estimated to cover 284,300 square kilometers, mainly in the Indo-Pacific Region, which includes the Red Sea, Indian Ocean, Southeast Asia, and the Pacific Ocean. Southeast Asia accounts for 29.7 percent of the world's coral reefs, while the Pacific, including Australia, contains 37.5 percent. Atlantic and Caribbean coral possess only 7.6% of the world's coral.

Many fisheries depend on the fish that spend the first part of their lives in coral reefs before making their way out to the open ocean. The Great Barrier Reef is especially important to the Australian economy and generates 1.5 billion U.S. dollars every year from fishing and tourism. In addition to the wealth of life that depend on coral reefs for their survival, coral reefs also protect shores from the impact of waves and storms as well as provide services to man. For example, the relatively small coral reefs of the Caribbean stand to cost affected areas 350-870 million U.S.$ per year by 2015 of the total 3,100 million U.S.$ worth of current annual benefits received by the coral reefs in the form of fisheries, dive tourism, and shoreline protection services.

Given the sensitive nature of coral reef ecosystems, tropical marine environments are likely to be the first casualties of climate change. Widespread mortality among coral reefs has already taken place. 20% of the world's coral reefs have been destroyed and show no prospects of recovery. Jamaica has been particularly hard hit, having an estimated 95% of its coral reefs either dying or dead. In the Indian Ocean region, up to 90% of coral cover has been lost in the Maldives, Sri Lanka, Kenya, Tanzania, Seychelles, and Congo.

3.1. Global Warming Causes Increased Sea Surface Temperatures

The major emerging threats to coral reefs in the last decade have been coral bleaching and global warming. Elevated sea surface temperatures cause the coral to expel their unicellular algae- which provides the color to healthy

coral, and they become 'white.' This alga forms a critical component of the food web due to their being at the first rung of the coral's food chain, a photosynthesizer.

Abnormally high 1998 sea temperatures, the warmest on record, are thought to have bleached and killed most of the corals in the Indian Ocean and in many areas of the Western and Eastern Pacific. This bleaching claimed 16% of the world's coral. Initially, this mass bleaching was cited as a once in a 1,000-year phenomenon in many areas of the world. However, recent studies have predicted that such events as 1998 could become commonplace in the latter half-century. If climate change is not stopped, coral bleaching is set to steadily increase in frequency and intensity all over the world until it occurs annually by 2030 - 2070. In 1998, the worst coral bleaching in 700 years struck the Great Barrier Reef, followed by even worse bleaching only 4 years later. Coral reefs face additional problems currently. Ocean waters off the Australian coast, thought to be the warmest in 400 years, have seen freak weather conditions negatively affecting coral systems.

Higher ocean temperatures render coral susceptible to coral diseases. Of particular note is the staghorn and elkhorn species, which were decimated by disease and bleaching in the 1980s and 1990s. From being the dominant reef-building corals of the reefs of Florida and the Caribbean for the past half-million years, they have suffered an 80-98% decline over the last 30 years over much of their range. Efforts are being made to protect these species under the federal Endangered Species Act (ESA).

3.2. Global Warming Causes Acidification of Oceans

Higher temperatures from global warming aren't the sole contributor to coral destruction. Oceans are believed to absorb half of the man-made CO2 emissions. These increased CO2 levels contribute a unique threat to coral reefs.

Increased CO2 levels lead to overwhelming the natural draw by the coral of carbonic acid. Consequently, the levels of carbonic acid are rising, and the oceans are 'turning sour.' The shells of marine creatures are made of calcium carbonate, the same substance as chalk, which is vulnerable to acidity. Even a slight increase in acidity would mean many creatures would dissolve. Others might be able to rebuild their shells but would be unable to reproduce. Also, the loss of this marine life eliminates the current service of removing CO2 from the oceans, which these creatures currently provide. Salmon, mackerel, herring, cod, and baleen whales all feed on pteropods, one of the species most threatened by rising acidity. Furthermore, the increased CO2 concentrations in the ocean lead to net calcium carbonate production on coral reefs very likely to decline. This problem leads to an inability of coral reef-building capacity to decline, shrinking our coral communities.

4. Conclusion

And global warming leads to an increase in allergies in man, and the list goes on. This section kept its argument within the confines of global warming and the three major problems discussed. Mother Nature may very well have her natural fluctuations in processes. However, it has become apparent that Father Nature- human beings- has his own set of changes to the natural world, which effectively is overwhelming 'nature.'

Global warming has potentially life-altering or life-ending consequences for man. Melting ice has been found to be increasing at record rates. This contributes to the global warming problem by raising the amount of the sun's energy which the Earth absorbs. The melting ice causes sea levels to rise, decreasing the amount of land on Earth- and threatening coastal communities and islands. The possible disruption of the Great Ocean Conveyor Belt could plunge most of the northern hemisphere into an ice age- something not without precedent. The human impacts of the large-scale melting of ice may be most acute with respect to the melting of the Himalayan glaciers. Hundreds of millions of people rely on the glaciers for their source of water in areas already hydrologically impoverished, featuring high population growth.

Biodiversity is an issue beyond simple moral value. When the global annual gross product was about $18 trillion, U.S. researchers calculated the value of the goods and services provided by the Earth to the world economy- $33 trillion U.S. Beyond simple financial benefit, life on Earth provides environmental functions that keep life on Earth possible. The basis of life is life itself.

In realizing solutions, one must first perceive a problem. It should be recognized that global warming poses serious potential dangers to civilization both in the immediate and long-term outlook on planet Earth. Global warming threatens the quality of life which we pass on to future generations. Furthermore, man's own hand in the creation and enhancement of the problem cannot be ignored. Our current home is being threatened on a global scale by anthropogenic factors. The current reliance on fossil fuels is the single biggest cause of global warming. In addition to the harm caused by man in contributing towards climate change, man has also been straining other natural systems- and planet Earth herself- by sheer population.

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