GLOBAL CLIMATIC CHANGE

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Abstract: An abrupt climate change occurs throughout the world. The levels of greenhouse gas CO_2 are increasing in different parts of the world. The other greenhouse gases are water vapours, methane, ozone, nitrous oxide, fluorinated gases. The greenhouse effect is a process that keeps the earth warm enough for people, plants and animals to live on. Over the past decade the surface air temperatures have not risen very much whereas the temperatures of deep oceans have risen very much. Oceans store 97% of world's water. This water absorbed the 90% of energy of the atmosphere. The increase in the energy and temperatures of the earth is due to increase in the greenhouse gases. The human activity is changing the amount of greenhouse gases by three ways. The rain forests are cut down. The fossil fuels are being burned. The world's population has been increased. Global warming is affecting the world. The oceans and atmosphere interact both physically and chemically. They exchange energy, water, gases and particles. This exchange influences the earth's climate. It also changes the state of oceans. The salinity of the oceans has been changed, which accelerated the global rainfall and evaporation, which is responsible for climate change. The sea levels are expected to rise as the water expands due to rise in temperature. The sea levels also rise as a result of melting of polar caps. Rising sea levels impact many coastlines, and a large mass of humanity lives near the coasts or by major rivers. More CO_2 in the atmosphere more CO_2 in the oceans. This CO_2 is dissolved in water and reacts with it forming carbonic acid. The water becomes more acidic. This acidification of water significantly impacts upon the health of some fish and coral species. There are many millions of species in the oceans and each will have different sensitivities to acidification and respond in different ways. It is likely that acidified sea water will alter the makeup of marine ecosystem.

Index Term: CO_2, Ocean, Global, Ecosystem, Temperature.

I. INTRODUCTION

Climate change occurs when changes in Earth's climate system result in new weather patterns that last for at least a few decades, and maybe for millions of years. The climate system is comprised of five interacting parts, the atmosphere (air), hydrosphere (water), cryosphere (ice and permafrost), biosphere (living things), and lithosphere (earth's crust and upper mantle). The climate system receives nearly all of its energy from the sun, with a relatively tiny amount from earth's interior. The climate system also gives off energy to outer space.

As this energy moves through Earth's climate system, it creates Earth's weather and long-term averages of weather are called "climate". Changes in the long term average are called "climate change". Such changes can be the result of "internal variability", when natural processes inherent to the various parts of the climate system alter Earth's energy budget. Examples include cyclical ocean patterns such as the well-known El Nino Southern Oscillation and less familiar Pacific decadal oscillation and Atlantic multi decadal oscillation. Climate change can also result from "external forcing", when events outside of the climate systems five parts nonetheless produce changes within the system. Examples include changes in solar output and volcanism.

Human activities can also change earth's climate, and are presently driving climate change through global warming.[1] There is no general agreement in scientific, media or policy documents as to the precise term to be used to refer to anthropogenic forced change; either "global warming" or "climate change" may be used.

The field of climatology incorporates many disparate fields of research. For ancient periods of climate change, researchers rely on evidence preserved in climate proxies, such as ice cores,[3] ancient tree rings, geologic records of changes in sea level, and glacial geology. Physical evidence of current climate change covers many independent lines of evidence, a few of which are temperature records, the disappearance of ice, and extreme weather events.

II. TERMINOLOGY:

The term "climate change" is often used to refer specifically to anthropogenic climate change (also known as global warming). Anthropogenic climate change is caused by human activity, as opposed to changes in climate that may have resulted as part of Earth's natural processes.[6] In this sense, especially in the context of environmental policy, the term climate change has become synonymous with anthropogenic global warming. Within scientific journals, global warming refers to surface temperature increases while climate change includes global warming and everything else that increasing greenhouse gas levels affect.

A related term, "climatic change", was proposed by the World Meteorological Organization (WMO) in 1966 to encompass all forms of climatic variability on time-scales longer than 10 years, but regardless of cause. During the 1970s, the term climate change replaced climatic change to focus on anthropogenic causes, as it became clear that human activities had a potential to drastically alter the climate.[2] Climate change was incorporated in the title of the Intergovernmental Panel on Climate Change (IPCC) and the UN Framework Convention on Climate Change (UNFCCC). Climate change is now used as both a technical description of the process, as well as a noun used to describe the problem.

III. EVIDENCE FOR CLIMATIC CHANGES:

Figure 1: This graph, based on the comparison of atmospheric samples contained in ice cores and more recent direct measurements, provides evidence that atmospheric CO_2 has increased since the Industrial Revolution.

The Earth's climate has changed throughout history. Just in the last 650,000 years there have been seven cycles of glacial advance and retreat, with the abrupt end of the last ice age about 7,000 years ago marking the beginning of the modern climate era and of human civilization. Most of these climate changes are attributed to very small variations in Earth's orbit that change the amount of solar energy our planet receives.

The current warming trend is of particular significance because most of it is extremely likely (greater than 95 percent probability) to be the result of human activity since the mid-20th century and proceeding at a rate that is unprecedented over decades to millennia

Earth-orbiting satellites and other technological advances have enabled scientists to see the big picture, collecting many different types of information about our planet and its climate on a global scale. This body of data, collected over many years, reveals the signals of a changing climate.

The heat-trapping nature of carbon dioxide and other gases was demonstrated in the mid-19th century. Their ability to affect the transfer of infrared energy through the atmosphere is the scientific basis of many instruments flown by NASA. There is no question that increased levels of greenhouse gases must cause the Earth to warm in response.

Ice cores drawn from Greenland, Antarctica, and Tropical Mountain glaciers show that the Earth's climate responds to changes in greenhouse gas levels. Ancient evidence can also be found in tree rings, ocean sediments, coral reefs, and layers of sedimentary rocks. This ancient, or paleoclimate, evidence reveals that current warming is occurring roughly ten times faster than the average rate of ice-age-recovery warming.

3.1 EVIDENCE THAT RAPID CLIMATIC CHANGE IS COMPELLING:

3.1.1 GLOBAL TEMPERATURE RISE:

The planet's average surface temperature has risen about 1.62 degrees Fahrenheit (0.9 degrees Celsius) since the late 19th century, a change driven largely by increased carbon dioxide and other human-made emissions into the atmosphere.[4] Most of the warming occurred in the past 35 years, with the five warmest years on record taking place since 2010. Not only was 2016 the warmest year on record, but eight of the 12 months that make up the year — from January through September, with the exception of June — were the warmest on record for those respective months.

3.1.2 WARMING OCEANS:

The oceans have absorbed much of this increased heat, with the top 700 meters (about 2,300 feet) of ocean showing warming of more than 0.4 degrees Fahrenheit since 1969.

Figure 2: This image was taken during the 2012 Antarctic campaign of NASA's Operation Ice Bridge, a mission that provided data for the new ice shelf study.

3.1.2.1 WARMING OCEANS CAUSING MORE ANTARTIC ICE SELF MASS LOSS:

Calving front of the calving front of an ice shelf in West Antarctica. The traditional view on ice shelves, the floating extensions of seaward glaciers, has been that they mostly lose ice by shedding icebergs. A new study by NASA and university researchers has found that warm ocean waters melting the ice sheets from underneath account for 55 percent of all ice shelf mass loss in Antarctica. This image was taken during the 2012 Antarctic campaign of NASA's Operation Ice Bridge, a mission that provided data for the new ice shelf study. The traditional view on Antarctic mass loss is it is almost entirely controlled by iceberg calving," said Eric Rignot of NASA's Jet Propulsion Laboratory in Pasadena, Calif., and the University of California, Irvine. Rignot is lead author of the study to be published in the June 14 issue of the journal Science. "Our study shows melting from below by the ocean waters is larger, and this should change our perspective on the evolution of the ice sheet in a warming climate. Ice shelves grow through a combination of land ice flowing to the sea and snow accumulating on their surface. To determine how much ice and snowfall enters a specific ice shelf and how much makes it to an iceberg, where it may split off, the research team used a regional climate model for snow accumulation and combined the results with ice velocity data from satellites, ice shelf thickness measurements from NASA's Operation Ice Bridge -- a continuing aerial survey of Earth's poles -- and a new map of Antarctica's bedrock. Using this information, Rignot and colleagues were able to deduce whether the ice shelf was losing mass through basal melting or gaining it through the basal freezing of seawater. In some places, basal melt exceeds iceberg calving. In other places, the opposite is true. But in total, Antarctic ice shelves lost 2,921 trillion pounds (1,325 trillion kilograms) of ice per year in 2003 to 2008 through basal melt, while iceberg formation accounted for 2,400 trillion pounds (1,089 trillion kilograms) of mass loss each year. Basal melt can have a greater impact on ocean circulation than glacier calving. Icebergs slowly release melt water as they drift away from the continent. But strong melting near deep grounding lines, where glaciers lose their grip on the seafloor and start floating as ice shelves, discharges large quantities of fresher, lighter water near the Antarctic coastline. This lower-density water does not mix and sink as readily as colder, saltier water, and may be changing the rate of bottom water renewal.

3.2 SHRINKING ICE SHEETS:

The Greenland and Antarctic ice sheets have decreased in mass. Data from NASA's Gravity Recovery and Climate Experiment show Greenland lost an average of 286 billion tons of ice per year between 1993 and 2016, while Antarctica lost about 127 billion tons of ice per year during the same time period. The rate of Antarctica ice mass loss has tripled in the last decade.

Figure 3: Flowing meltwater from the Greenland ice sheet

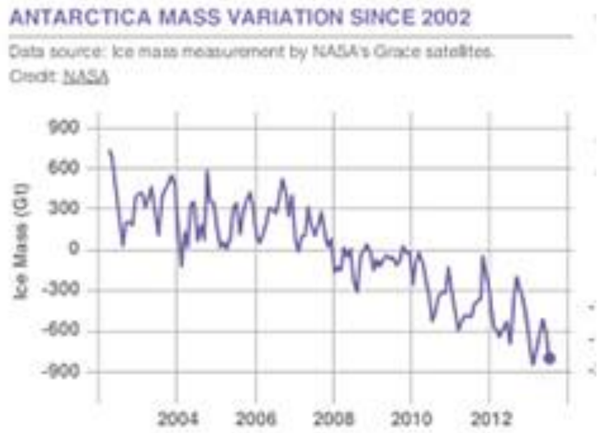

Figure 4 An indicator of the current volume and the Antarctica and Greenland ice sheets using data from NASA's Grace satellite.

Data from NASA's GRACE satellites show that the land ice sheets in both Antarctica (upper chart) and Greenland (lower) have been losing mass since 2002. Both ice sheets have seen an acceleration of ice mass loss since 2009.

3.3 GLACIAL RETREAT:

Glaciers are retreating almost everywhere around the world — including in the Alps, Himalayas, Andes, Rockies, Alaska and Africa.

Figure 5: The disappearing snow-cap of Mount Kilimanjaro, from space.

3.3.1 GLACIERS:

Glaciers are considered among the most sensitive indicators of climate change. Their size is determined by a mass balance between snow input and melt output. As temperatures warm, glaciers retreat unless snow precipitation increases to make up for the additional melt; the converse is also true.Glaciers grow and shrink due both to natural variability and external forcings. Variability in temperature, precipitation, and englacial and subglacial hydrology can strongly determine the evolution of a glacier in a particular season. Therefore, one must average over a decadal or longer time-scale and/or over many individual glaciers to smooth out the local short-term variability and obtain a glacier history that is related to climate. world glacier inventory has been compiled since the 1970s, initially based mainly on aerial photographs and maps but now relying more on satellites. This compilation tracks more than 100,000 glaciers covering a total area of approximately 240,000 km², and preliminary estimates indicate that the remaining ice cover is around 445,000 km². The World Glacier Monitoring Service collects data annually on glacier retreat and glacier mass balance. From this data, glaciers worldwide have been found to be shrinking significantly, with strong glacier retreats in the 1940s, stable or growing conditions during the 1920s and 1970s, and again retreating from the mid-1980s to the presentThe most significant climate processes since the middle to late Pliocene (approximately 3 million years ago) are the glacial and interglacial cycles. The present interglacial period (the Holocene) has lasted about 11,700 years.] Shaped by orbital variations, responses such as the rise and fall of continental ice sheets and significant sea-level changes helped create the climate. Other changes, including Heinrich events, Dalsgaard–Oeschger events and the Younger Dryas, however, illustrate how glacial variations may also influence climate without the orbital forcing. Glaciers leave behind moraines that contain a wealth of material—including organic matter, quartz, and potassium that may be dated—recording the periods in which a glacier advanced and retreated. Similarly, by tephrochronological techniques, the lack of glacier cover can be identified by the presence of soil or volcanic tephra horizons whose date of deposit may also be ascertained.

3.4 DECREASED SNOW COVER:

Snow is precipitation that forms when water vapour freezes. Because snow is so reflective, it plays an important role in regulating climate: it reflects incoming sunlight back into space, cooling the planet. Snow also supports life. Melting of seasonal snow (as well as glaciers) provides water for drinking and irrigating crops in many parts of the world. Snowmelt moisturizes soil and reduces the risk of wildfire. Too much snow, however, can lead to springtime floods when the snowpack melts. These snow cover maps are made from observations collected by the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA’s Terra satellite. Snow cover values range from medium blue (greater than 0 percent) to white (100 percent). Landmasses that do not sustain snow cover and places where MODIS did not collect data are gray. Because MODIS relies on visible light to assess snow cover, the sensor cannot collect data over the highest latitudes of the Northern Hemisphere during winter when no sunlight reaches those regions. Snow and ice cover most of the Earth’s Polar Regions throughout the year, but the coverage at lower latitudes depends on season and elevation. High-altitude landscapes such as the Tibetan Plateau and the Andes and Rocky Mountains maintain some amount of snow cover almost year round. Land area is larger and snow cover is more variable in the Northern Hemisphere than in the Southern Hemisphere.

Figure 6: Satellite observations reveal that the amount of spring snow cover in the Northern Hemisphere has decreased over the past five decades and that the snow is melting earlier.

3.5 SEA LEVEL RISE:

Global sea level rose about 8 inches in the last century. The rate in the last two decades, however, is nearly double that of the last century and is accelerating slightly every year.

Figure 7: Republic of Maldives: Vulnerable to sea level rise

Earth’s seas are rising, a direct result of a changing climate. Ocean temperatures are increasing, leading to ocean expansion. And as ice sheets and glaciers melt, they add more water. An armada of increasingly sophisticated instruments, deployed across the oceans, on polar ice and in orbit, reveals significant changes among globally interlocking factors that are driving sea levels higher.

Global sea level change for much of the last century has generally been estimated using tide gauge measurements collated over long periods of time to give a long-term average. More recently, altimeter measurements—in combination with accurately determined satellite orbits—have provided an improved measurement of global sea level change. To measure sea levels prior to instrumental measurements, scientists have dated coral reefs that grow near the surface of the ocean, coastal sediments, marine terraces, ooids in limestones, and nearshore archaeological remains. The predominant dating methods used are uranium series and radiocarbon, with cosmogenic radionuclides being sometimes used to date terraces that have experienced relative sea level fall. In the early Pliocene, global temperatures were 1–2˚C warmer than the present temperature, yet sea level was 15–25 meters higher than today.

According to recent studies, global-mean sea level rose by 195 mm during the period from 1870 to 2004.[Since 2004, satellite-based records indicate that there has been a further 43 mm of global-mean sea levels rise, as of July 2017.

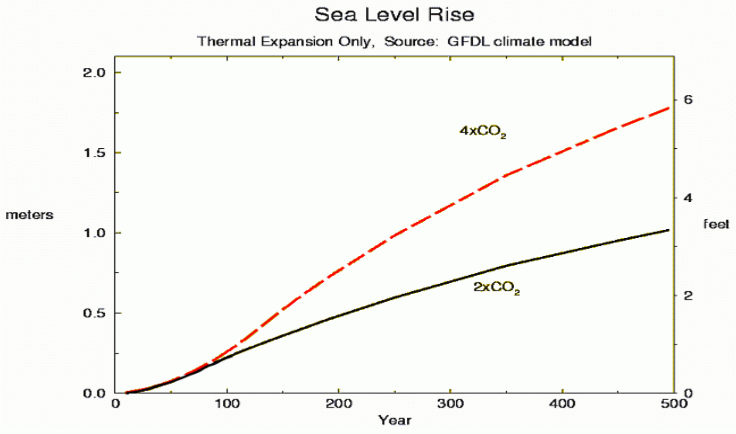

Figure 8: The estimated change in sea level caused by carbon dioxide emissions.

3.5.1 CONTRIBUTING FACTORS:

The globally averaged trend toward rising sea levels masks deeper complexities. Regional effects cause sea levels to increase on some parts of the planet, decrease on others, and even to remain relatively flat in a few places, including, in recent decades, on the California coast. Thermal expansion of seawater can be the product of regional phenomena, such as El Niño, the periodic warming of the eastern tropical Pacific. But some of these regional cycles so far show no direct link to long-term global climate change—despite, at times, independently exerting a powerful short-term influence on global climate.

3.5.2 ICE LOSS VERSUS PRECIPITATION:

While Greenland, Antarctica and most of the world’s glaciers are melting, a distinction must be made between glacial discharge into the oceans, a more permanent type of ice loss, and changes in the precipitation and evaporation that is feeding those glaciers and ice sheets, which fluctuate on the scale of decades.

3.6 TEMPERATURE (SURFACE AND OCEANS):

The instrumental temperature record from surface stations was supplemented by radiosonde balloons, extensive atmospheric monitoring by the mid-20th century, and, from the 1970s on, with global satellite data as well. Taking the record as a whole, most of the 20th century had been unprecedentedly warm, while the 19th and 17th centuries were quite cool. The ^{18}O/^{16}O ratio in calcite and ice core samples used to deduce ocean temperature in the distant past is an example of a temperature proxy method, as are other climate metrics noted in subsequent categories.

3.7 ARCTIC SEA ICE DECLINE:

The decline in Arctic sea ice, both in extent and thickness, over the last several decades is further evidence for rapid climate change.[89] Sea ice is frozen seawater that floats on the ocean surface. It covers millions of square kilometers in the polar regions, varying with the seasons. In the Arctic, some sea ice remains year after year, whereas almost all Southern Ocean or Antarctic sea ice melts away and reforms annually. Satellite observations show that Arctic sea ice is now declining at a rate of 13.2 percent per decade, relative to the 1981 to 2010 average.[9] The 2007 Arctic summer sea ice retreat was unprecedented. Decades of shrinking and thinning in a warm climate has put the Arctic sea ice in a precarious position, it is now vulnerable to atmospheric anomalies.[9] "Both extent and volume anomaly fluctuate little from January to July and then decrease steeply in August and September".[9] This decrease is because of lessened ice production as a result of the unusually high SAT. During the Arctic summer, a slower rate of sea ice production is the same as a faster rate of sea ice melting.

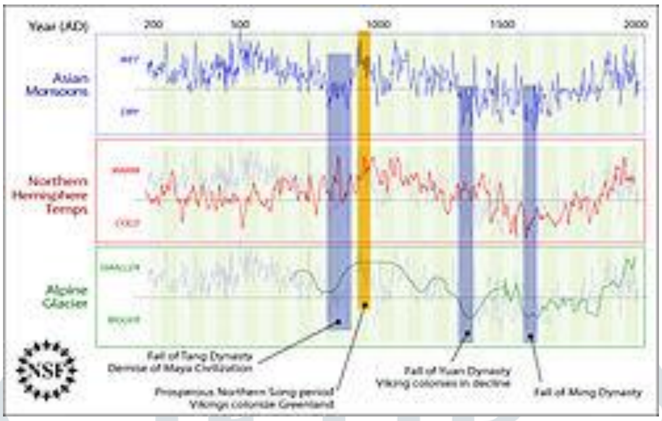

Figure 9: Comparisons between Asian Monsoons from 200 AD to 2000 AD (staying in the background on other plots), Northern Hemisphere temperature, Alpine glacier extent (vertically inverted as marked), and human history as noted by the U.S. NSF.

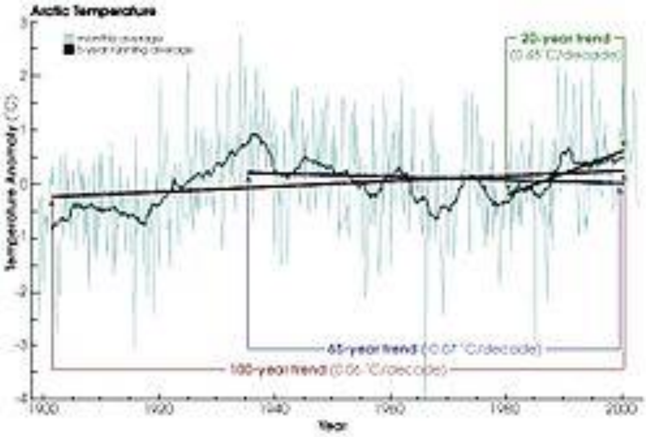

Figure 10: Arctic temperature anomalies over a 100-year period as estimated by NASA. Typical high monthly variance can be seen, while longer-term averages highlight trends.

3.8 ICE CORES:

Analysis of ice in a core drilled from an ice sheet such as the Antarctic ice sheet, can be used to show a link between temperature and global sea level variations. The air trapped in bubbles in the ice can also reveal the CO_2 variations of the atmosphere from the distant past, well before modern environmental influences. The study of these ice cores has been a significant indicator of the changes in CO_2 over many millennia, and continues to provide valuable information about the differences between ancient and modern atmospheric conditions.

3.9 CLOUD COVER AND PRECIPITATION:

Past precipitation can be estimated in the modern era with the global network of precipitation gauges. Surface coverage over oceans and remote areas is relatively sparse, but, reducing reliance on interpolation, satellite clouds and precipitation data has been available since the 1970s.Quantification of climatological variation of precipitation in prior centuries and epochs is less complete but approximated using proxies such as marine sediments, ice cores, cave stalagmites, and tree rings. In July 2016 scientists published evidence of increased cloud cover over polar regions,] as predicted by climate models.

Climatological temperatures substantially affect cloud cover and precipitation. For instance, during the Last Glacial Maximum of 18,000 years ago, thermal-driven evaporation from the oceans onto continental landmasses was low, causing large areas of extreme desert, including polar deserts (cold but with low rates of cloud cover and precipitation). In contrast, the world's climate was cloudier and wetter than today near the start of the warm Atlantic Period of 8000 years ago.

Estimated global land precipitation increased by approximately 2% over the course of the 20th century, though the calculated trend varies if different time endpoints are chosen, complicated by ENSO and other oscillations, including greater global land cloud cover precipitation in the 1950s and 1970s than the later 1980s and 1990s despite the positive trend over the century overall. Similar slight overall increase in global river runoff and in average soil moisture has been perceived.

3.10 VEGETATION:

A change in the type, distribution and coverage of vegetation may occur given a change in the climate. Some changes in climate may result in increased precipitation and warmth, resulting in improved plant growth and the subsequent sequestration of airborne CO_2. A gradual increase in warmth in a region will lead to earlier flowering and fruiting times, driving a change in the timing of life cycles of dependent organisms. Conversely, cold will cause plant bio-cycles to lag Larger, faster or more radical changes, however, may result in vegetation stress, rapid plant loss and desertification in certain circumstances An example of this occurred during the Carboniferous Rainforest Collapse (CRC), an extinction event 300 million years ago. At this time vast rainforests covered the equatorial region of Europe and America. Climate change devastated these tropical rainforests, abruptly fragmenting the habitat into isolated 'islands' and causing the extinction of many plant and animal species.] Such stress can alter the growth rate of trees, which allows scientists to infer climate trends by analysing the growth rate of tree rings. This branch of climate science is called dendroclimatology, and is one of the many ways they research climate trends prior to written records.

3.11 FOREST GENETIC RESOURCES:

Even though this is a field with many uncertainties, it is expected that over the next 50 years climate changes will have an effect on the diversity of forest genetic resources and thereby on the distribution of forest tree species and the composition of forests. Diversity of forest genetic resources enables the potential for a species (or a population) to adapt to climatic changes and related future challenges such as temperature changes, drought, pests, diseases and forest fire. However, species are not naturally capable to adapt in the pace of which the climate is changing and the increasing temperatures will most likely facilitate the spread of pests and diseases, creating an additional threat to forest trees and their populations. To inhibit these problems human interventions, such as transfer of forest reproductive material, may be needed.

3.12 POLLEN ANALYSIS:

Palynology is the study of contemporary and fossil palynomorphs, including pollen. Palynology is used to infer the geographical distribution of plant species, which vary under different climate conditions. Different groups of plants have pollen with distinctive shapes and surface textures, and since the outer surface of pollen is composed of a very resilient material, they resist decay. Changes in the type of pollen found in different layers of sediment in lakes, bogs, or river deltas indicate changes in plant communities. These changes are often a sign of a changing climate. As an example, palynological studies have been used to track changing vegetation patterns throughout the Quaternary glaciations and especially since the last glacial maximum.

3.13 ANIMALS:

Remains of beetles are common in freshwater and land sediments. Different species of beetles tend to be found under different climatic conditions. Given the extensive lineage of beetles whose genetic makeup has not altered significantly over the millennia, knowledge of the present climatic range of the different species, and the age of the sediments in which remains are found, past climatic conditions may be inferred. The studies of the impact in vertebrates are few mainly from developing countries, where there are the fewest studies; between 1970 and 2012, vertebrates declined by 58 percent, with freshwater, marine, and terrestrial populations declining by 81, 36, and 35 percent, respectively. Similarly, the historical abundance of various fish species has been found to have a substantial relationship with observed climatic conditions Changes in the primary productivity of autotrophs in the oceans can affect marine food webs.

3.14 OCEAN ACIDIFICATION:

When carbon dioxide (CO_2) is absorbed by seawater, chemical reactions occur that reduce seawater pH, carbonate ion concentration, and saturation states of biologically important calcium carbonate minerals. These chemical reactions are termed "ocean acidification" or "OA" for short. Calcium carbonate minerals are the building blocks for the skeletons and shells of many marine organisms. In areas where most life now congregates in the ocean, the seawater is supersaturated with respect to calcium carbonate minerals. This means there are abundant building blocks for calcifying organisms to build their skeletons and shells. However, continued ocean acidification is causing many parts of the ocean to become under saturated with these minerals, which is likely to affect the ability of some organisms to produce and maintain their shells. Since the beginning of the Industrial Revolution, the acidity of surface ocean waters has increased by about 30 percent.This increase is the result of humans emitting more carbon dioxide into the atmosphere and hence more being absorbed into the oceans. The amount of carbon dioxide absorbed by the upper layer of the oceans is increasing by about 2 billion tons per year.

Figure 11: Seawater

3.14.1 THE BIOLOGICAL IMPACTS:

Ocean acidification is expected to impact ocean species to varying degrees. Photosynthetic algae and seagrasses may benefit from higher CO_2 conditions in the ocean, as they require CO_2 to live just like plants on land. On the other hand, studies have shown that lower environmental calcium carbonate saturation states can have a dramatic effect on some calcifying species, including oysters, clams, sea urchins, shallow water corals, deep sea corals, and calcareous plankton. Today, more than a billion people worldwide rely on food from the ocean as their primary source of protein. Thus, both jobs and food security in the U.S. and around the world depend on the fish and shellfish in our oceans.

3.14.2 CLIMATE CHANGE AFFECTING CORAL REEFS:

Climate change has disturbed many living creatures throughout the world and coral reefs just happen to be included in that range. Warmer air has caused the ocean water temperature to rise, creating an unstable environment for the corals to live in. Corals are very sensitive to the water change and if the temperature stays above normal for a period of time, the corals begin to lose food that was stored in their tissues, this is called zooxanthellae. Zooxanthellae supply glucose, glycerol, and amino acids for the coral and are critical for maintaining a healthy state of living. Corals use glucose, glycerol, and amino acids for producing calcium carbonate, fats, carbohydrates and proteins, which are essential. The zooxanthellae contribute to the beautiful colors of the corals.

Losing quantities of zooxanthellae will cause the coral to bleach, resulting in weakness and prone to diseases. When the coral has lost all zooxanthellae, it can no longer survive, resulting in death.

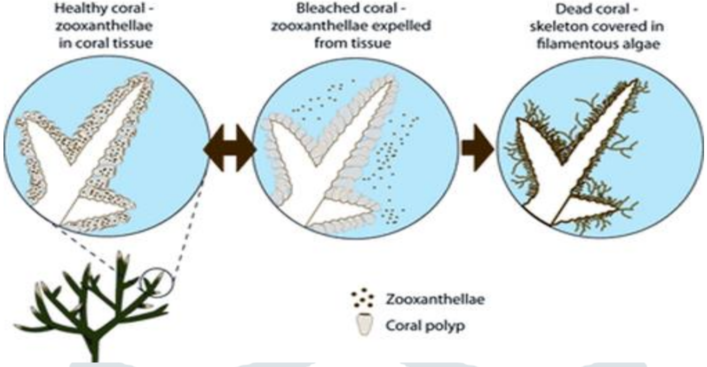

Figure 12: Losing quantities of zooxanthellae

Due to more carbon dioxide being released the ocean pH is becoming more acidic throughout the world. Since 1800, it is known that oceans have absorbed about 1/3 of the carbon dioxide from human activity and another 1/2 from the burning of fossil fuels. Corals cannot absorb calcium carbonate when the pH is lower than normal, causing their skeleton weaken and eventually dissolve right into the ocean salt water. Rising pH levels are not only going to affect coral reefs, but all organisms that live in the ocean. Organisms such as snails, clams, and urchins also make calcium carbonate so they will be affected. The ocean population will be more prone to disease because of the high acidity breaking down immunity. This can be a huge threat to both the organisms that live in and out of the oceans.

Figure 13: Changes of sea water

Based on the image above, coral is being greatly affected quickly by the carbon dioxide levels in the atmosphere. Corals provide food and shelter for many organisms that live within them, and without the corals, many fish and sea creatures will be left without it. Although coral seems to not have a huge impact on our society, it really does when you learn what it provides and how it is used in an ecosystem. Many marine organisms that produce calcium carbonate shells or skeletons are negatively impacted by increasing CO_2 levels and decreasing pH in seawater. For example, increasing ocean acidification has been shown to significantly reduce the ability of reef-building corals to produce their skeletons. In a recent paper, coral biologists reported that ocean acidification could compromise the successful fertilization, larval settlement and survivorship of Elkhorn coral, an endangered species. These research results suggest that ocean acidification could severely impact the ability of coral reefs to recover from disturbance. Other research indicates that, by the end of this century, coral reefs may erode faster than they can be rebuilt. This could compromise the long-term viability of these ecosystems and perhaps impact the estimated one million species that depend on coral reef habitat.

3.14.3 PTEROPODS:

The pteropod, or “sea butterfly”, is a tiny sea creature about the size of a small pea. Pteropods are eaten by organisms ranging in size from tiny krill to whales and are a food source for North Pacific juvenile salmon. The photos below show that a pteropod’s shell dissolves over 45 day when placed in sea water with pH and carbonate levels projected for the year 2100.

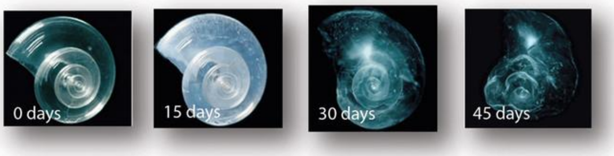

Figure 14: Pteropods

3.14.4 OCEAN ACIDIFICATION: AN EMERGING GLOBAL PROBLEM:

Ocean acidification is an emerging global problem. Over the last decade, there has been much focus in the ocean science community on studying the potential impacts of ocean acidification. Since sustained efforts to monitor ocean acidification worldwide are only beginning, it is currently impossible to predict exactly how ocean acidification impacts will cascade throughout the marine food chain and affect the overall structure of marine ecosystems. With the pace of ocean acidification accelerating, scientists, resource managers, and policymakers recognize the urgent need to strengthen the science as a basis for sound decision making and action.

3.14.5 OCEAN ACIDIFICATION:

The Other Carbon Dioxide Problem: Fundamental changes in seawater chemistry are occurring throughout the world's oceans. Since the beginning of the industrial revolution, the release of carbon dioxide (CO_2) from humankind's industrial and agricultural activities has increased the amount of CO_2 in the atmosphere. The ocean absorbs about a quarter of the CO_2 we release into the atmosphere every year, so as atmospheric CO_2 levels increase, so do the levels in the ocean. Initially, many scientists focused on the benefits of the ocean removing this greenhouse gas from the atmosphere. However, decades of ocean observations now show that there is also a downside — the CO_2 absorbed by the ocean is changing the chemistry of the seawater.

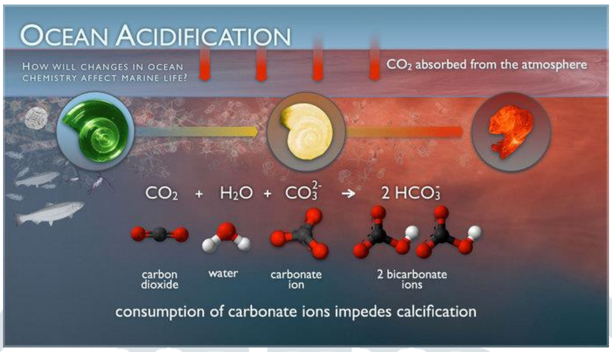

Figure 15: Ocean Acidification

To understand the changing chemistry of the oceans and the impacts of ocean acidification on marine ecosystems. Our observations of key physical, chemical, and biological parameters support NOAA's overall efforts to predict how marine ecosystems will respond and to develop management strategies for adapting to the consequences of ocean acidification

IV. EARTH’S CLIMATE:

The Earth’s climate is a solar powered system. Globally, over the course of the year, the Earth system—land surfaces, oceans, and atmosphere—absorbs an average of about 240 watts of solar power per square meter (one watt is one joule of energy every second). The absorbed sunlight drives photosynthesis, fuels evaporation, melts snow and ice, and warms the Earth system.

The Sun doesn’t heat the Earth evenly. Because the Earth is a sphere, the Sun heats equatorial regions more than polar regions. The atmosphere and ocean work non-stop to even out solar heating imbalances through evaporation of surface water, convection, rainfall, winds, and ocean circulation. This coupled atmosphere and ocean circulation is known as Earth’s heat engine. The climate’s heat engine must not only redistribute solar heat from the equator toward the poles, but also from the Earth’s surface and lower atmosphere back to space. Otherwise, Earth would endlessly heat up. Earth’s temperature doesn’t infinitely rise because the surface and the atmosphere are simultaneously radiating heat to space. This net flow of energy into and out of the Earth system is Earth’s energy budget.

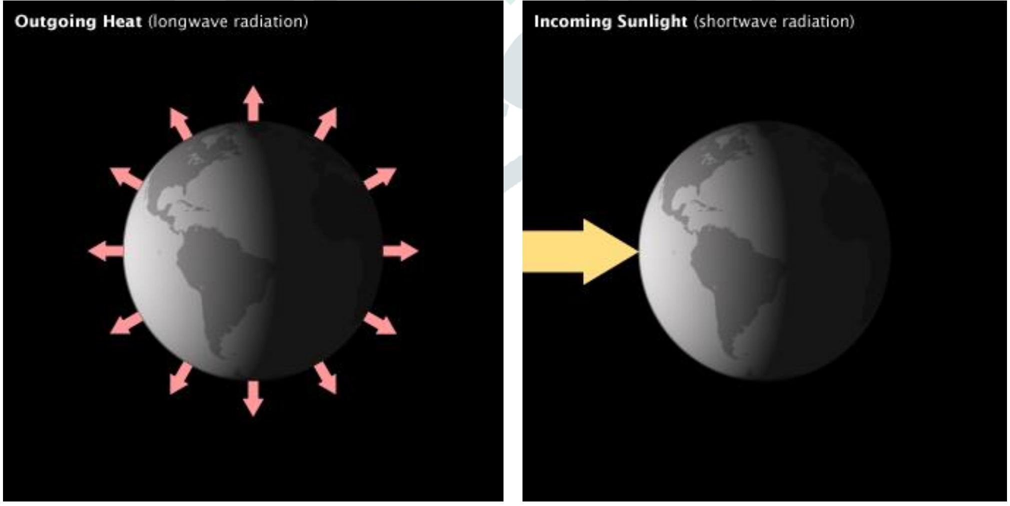

Figure 16: The energy that Earth receives from sunlight is balanced by an equal amount of energy radiating into space. The energy escapes in the form of thermal infrared radiation: like the energy you feel radiating from a heat lamp.

When the flow of incoming solar energy is balanced by an equal flow of heat to space, Earth is in radiative equilibrium, and global temperature is relatively stable. Anything that increases or decreases the amount of incoming or outgoing energy disturbs Earth’s radiative equilibrium; global temperatures rise or fall in response.

4.1 INCOMING SUNLIGHT:

All matter in the universe that has a temperature above absolute zero (the temperature at which all atomic or molecular motion stops) radiates energy across a range of wavelengths in the electromagnetic spectrum. The hotter something is, the shorter its peak wavelength of radiated energy is. The hottest objects in the universe radiate mostly gamma rays and x-rays. Cooler objects emit mostly longer-wavelength radiation, including visible light, thermal infrared, radio, and microwaves.

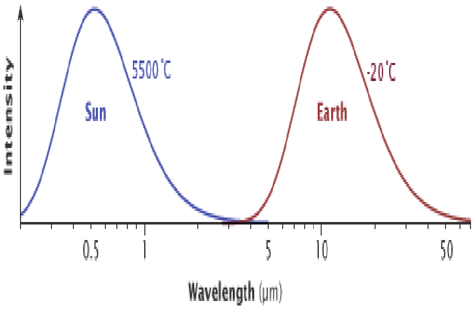

Figure 17:The Sun's surface temperature is 5,500° C, and its peak radiation is in visible wavelengths of light. Earth's effective temperature—the temperature it appears when viewed from space—is -20° C, and it radiates energy that peaks in thermal infrared wavelengths.

The surface of the Sun has a temperature of about 5,800 Kelvin (about 5,500 degrees Celsius, or about 10,000 degrees Fahrenheit). At that temperature, most of the energy the Sun radiates is visible and near-infrared light. At Earth's average distance from the Sun (about 150 million kilometers), the average intensity of solar energy reaching the top of the atmosphere directly facing the Sun is about 1,360 watts per square meter, according to measurements made by the most recent NASA satellite missions. This amount of power is known as the total solar irradiance. (Before scientists discovered that it varies by a small amount during the sunspot cycle, total solar irradiance was sometimes called "the solar constant.A watt is measurement of power, or the amount of energy that something generates or uses over time. How much power is 1,360 watts? An incandescent light bulb uses anywhere from 40 to 100 watts. A microwave uses about 1000 watts. If for just one hour, you could capture and re-use all the solar energy arriving over a single square meter at the top of the atmosphere directly facing the Sun—an area no wider than an adult's outstretched arm span—you would have enough to run a refrigerator all day. A watt is measurement of power, or the amount of energy that something generates or uses over time. How much power is 1,360 watts? An incandescent light bulb uses anywhere from 40 to 100 watts. A microwave uses about 1000 watts. If for just one hour, you could capture and re-use all the solar energy arriving over a single square meter at the top of the atmosphere directly facing the Sun—an area no wider than an adult's outstretched arm span—you would have enough to run a refrigerator all day.

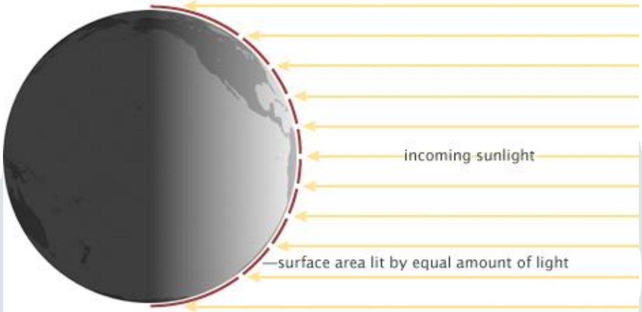

Figure 18

Energy from sunlight is not spread evenly over Earth. One hemisphere is always dark, receiving no solar radiation at all. On the daylight side, only the point directly under the Sun receives full-intensity solar radiation. From the equator to the poles, the Sun' rays meet Earth at smaller and smaller angles, and the light gets spread over larger and larger surface areas (red lines).

In addition, the total solar irradiance is the maximum power the Sun can deliver to a surface that is perpendicular to the path of incoming light. Because the Earth is a sphere, only areas near the equator at midday come close to being perpendicular to the path of incoming light. Everywhere else, the light comes in at an angle. The progressive decrease in the angle of solar illumination with increasing latitude reduces the average solar irradiance by an additional one-half. In addition, the total solar irradiance is the maximum power the Sun can deliver to a surface that is perpendicular to the path of incoming light. Because the Earth is a sphere, only areas near the equator at midday come close to being perpendicular to the path of incoming light. Everywhere else, the light comes in at an angle. The progressive decrease in the angle of solar illumination with increasing latitude reduces the average solar irradiance by an additional one-half.

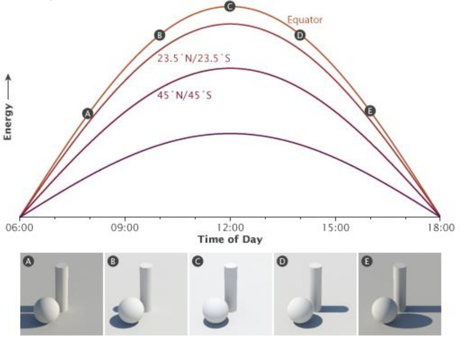

Figure 19

The solar radiation received at Earth's surface varies by time and latitude. This graph illustrates the relationship between latitude, time, and solar energy during the equinoxes. The illustrations show how the time of day (A-E) affects the angle of incoming sunlight (revealed by the length of the shadow) and the light's intensity. On the equinoxes, the Sun rises at 6:00 a.m. everywhere. The strength of sunlight increases from sunrise until noon, when the Sun is directly overhead along the equator (casting no shadow). After noon, the strength of sunlight decreases until the Sun sets at 6:00 p.m. The tropics (from 0 to 23.5° latitude) receive about 90% of the energy compared to the equator, the mid-latitudes (45°) roughly 70%, and the Arctic and

Antarctic Circles about 40%. Averaged over the entire planet, the amount of sunlight arriving at the top of Earth's atmosphere is only one-fourth of the total solar irradiance, or approximately 340 watts per square meter. When the flow of incoming solar energy is balanced by an equal flow of heat to space, Earth is in radiative equilibrium, and global temperature is relatively stable. Anything that increases or decreases the amount of incoming or outgoing energy disturbs Earth's radiative equilibrium; global temperatures must rise or fall in response.

4.2 HEATING IMBALANCES:

Three hundred forty watts per square meter of incoming solar power is a global average; solar illumination varies in space and time. The annual amount of incoming solar energy varies considerably from tropical latitudes to polar latitudes. At middle and high latitudes, it also varies considerably from season to season

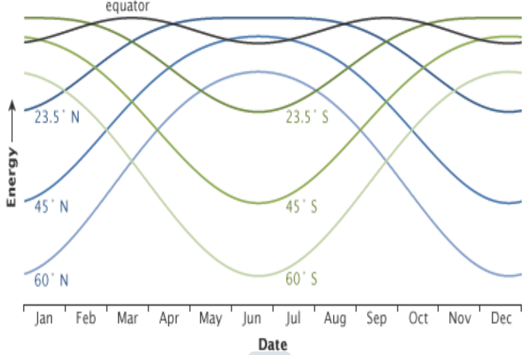

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Figure 20

The peak energy received at different latitudes changes throughout the year. This graph shows how the solar energy received at local noon each day of the year changes with latitude. At the equator (gray line), the peak energy changes very little throughout the year. At high northern (blue lines) and southern (green) latitudes, the seasonal change is extreme.If the Earth's axis of rotation were vertical with respect to the path of its orbit around the Sun, the size of the heating imbalance between equator and the poles would be the same year round, and the seasons we experience would not occur. Instead Earth's axis is tilted off vertical by about 23 degrees. As the Earth orbits the Sun, the tilt causes one hemisphere and then the other to receive more direct sunlight and to have longer days

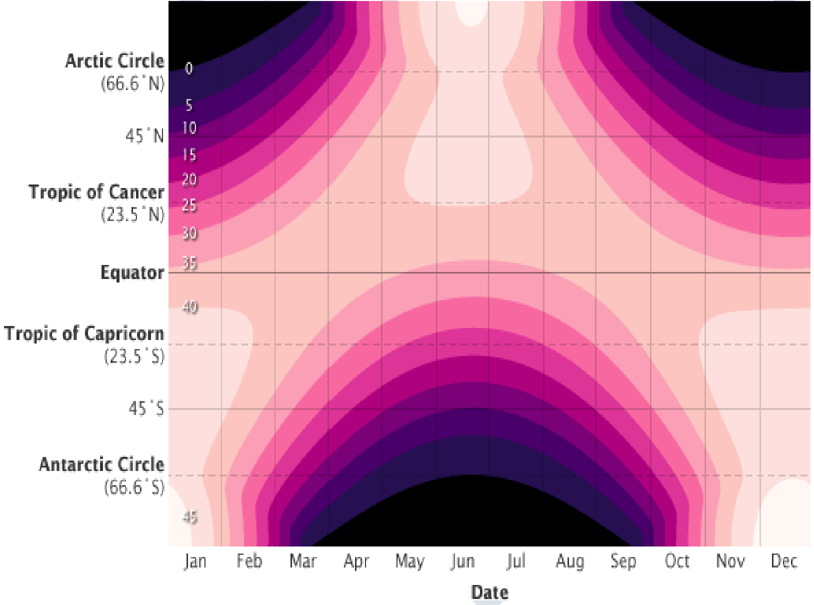

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Figure 21

The total energy received each day at the top of the atmosphere depends on latitude. The highest daily amounts of incoming energy (pale pink) occur at high latitudes in summer, when days are long, rather than at the equator. In winter, some polar latitudes receive no light at all (black). The Southern Hemisphere receives more energy during December (southern summer) than the Northern Hemisphere does in June (northern summer) because Earth's orbit is not a perfect circle and Earth is slightly closer to the Sun during that part of its orbit. Total energy received ranges from 0 (during polar winter) to about 50 (during polar summer) megajoules per square meter per day.

In the "summer hemisphere," the combination of more direct sunlight and longer days means the pole can receive more incoming sunlight than the tropics, but in the winter hemisphere, it gets none. Even though illumination increases at the poles in the summer, bright white snow and sea ice reflect a significant portion of the incoming light, reducing the potential solar heating.

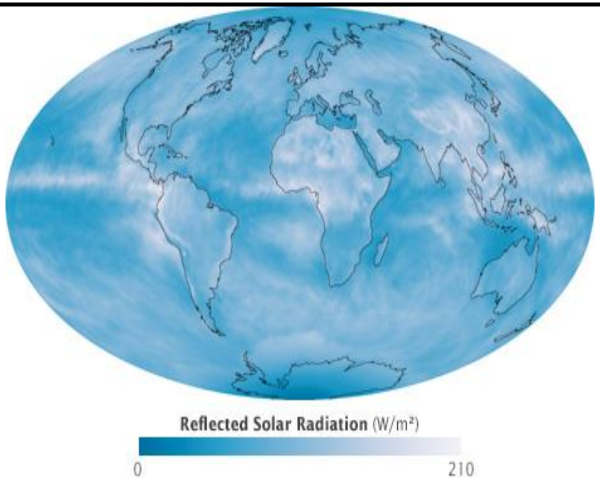

Figure 22

The amount of sunlight the Earth absorbs depends on the reflectivness of the atmosphere and the ground surface. This satellite map shows the amount of solar radiation (watts per square meter) reflected during September 2008. Along the equator, clouds reflected a large proportion of sunlight, while the pale sands of the Sahara caused the high reflectivness in North Africa. Neither pole is receiving much incoming sunlight at this time of year, so they reflect little energy even though both are ice-covered.

The differences in reflectivness (albedo) and solar illumination at different latitudes lead to net heating imbalances throughout the Earth system. At any place on Earth, the net heating is the difference between the amount of incoming sunlight and the amount heat radiated by the Earth back to space In the tropics there is a net energy surplus because the amount of sunlight absorbed is larger than the amount of heat radiated. In the Polar Regions, however, there is an annual energy deficit because the amount of heat radiated to space is larger than the amount of absorbed sunlight.

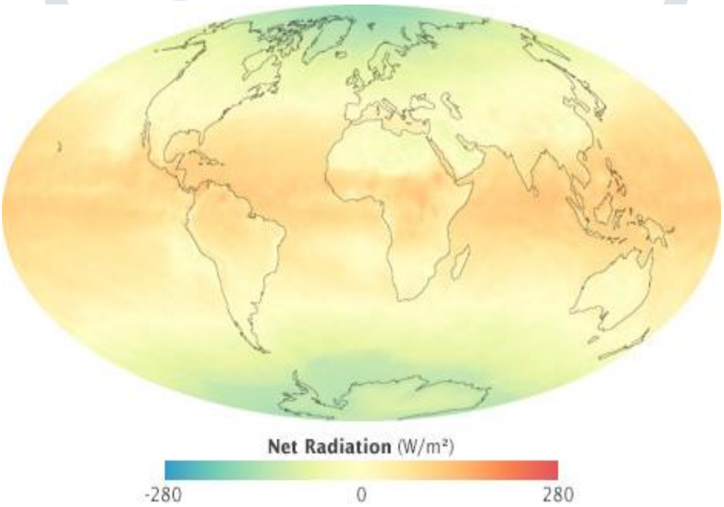

Figure 23

This map of net radiation (incoming sunlight minus reflected light and outgoing heat) shows global energy imbalances in September 2008, the month of an equinox. Areas around the equator absorbed about 200 watts per square meter more on average (orange and red) than they reflected or radiated. Areas near the poles reflected and/or radiated about 200 more watts per square meter (green and blue) than they absorbed. Mid-latitudes were roughly in balance.

The net heating imbalance between the equator and poles drives an atmospheric and oceanic circulation that climate scientists describe as a “heat engine.” (In our everyday experience, we associate the word engine with automobiles, but to a scientist, an engine is any device or system that converts energy into motion.) The climate is an engine that uses heat energy to keep the atmosphere and ocean moving. Evaporation, convection, rainfall, winds, and ocean currents are all part of the Earth’s heat engine.

V. EARTH’S ENERGY BUDGET:

Earth’s heat engine does more than simply move heat from one part of the surface to another; it also moves heat from the Earth’s surface and lower atmosphere back to space. This flow of incoming and outgoing energy is Earth’s energy budget. For Earth’s temperature to be stable over long periods of time, incoming energy and outgoing energy have to be equal. In other words, the energy budget at the top of the atmosphere must balance. This state of balance is called radiative equilibrium. About 29 percent of the solar energy that arrives at the top of the atmosphere is reflected back to space by clouds, atmospheric particles, or bright ground surfaces like sea ice and snow. This energy plays no role in Earth’s climate system. About 23 percent of incoming solar energy is absorbed in the atmosphere by water vapour, dust, and ozone, and 48 percent passes through the atmosphere and is absorbed by the surface. Thus, about 71 percent of the total incoming solar energy is absorbed by the Earth system.

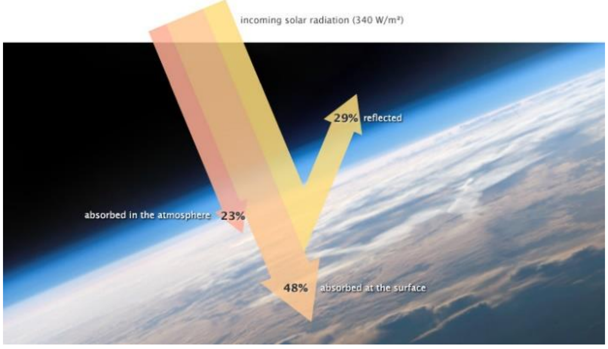

Figure 24

Of the 340 watts per square meter of solar energy that falls on the Earth, 29% is reflected back into space, primarily by clouds, but also by other bright surfaces and the atmosphere itself. About 23% of incoming energy is absorbed in the atmosphere by atmospheric gases, dust, and other particles. The remaining 48% is absorbed at the surface

When matter absorbs energy, the atoms and molecules that make up the material become excited; they move around more quickly. The increased movement raises the material's temperature. If matter could only absorb energy, then the temperature of the Earth would be like the water level in a sink with no drain where the faucet runs continuously. Temperature doesn't infinitely rise, however, because atoms and molecules on Earth are not just absorbing sunlight, they are also radiating thermal infrared energy (heat). The amount of heat a surface radiates is proportional to the fourth power of its temperature. If temperature doubles, radiated energy increases by a factor of 16 (2 to the 4th power). If the temperature of the Earth rises, the planet rapidly emits an increasing amount of heat to space. This large increase in heat loss in response to a relatively smaller increase in temperature—referred to as radiative cooling—is the primary mechanism that prevents runaway heating on Earth.

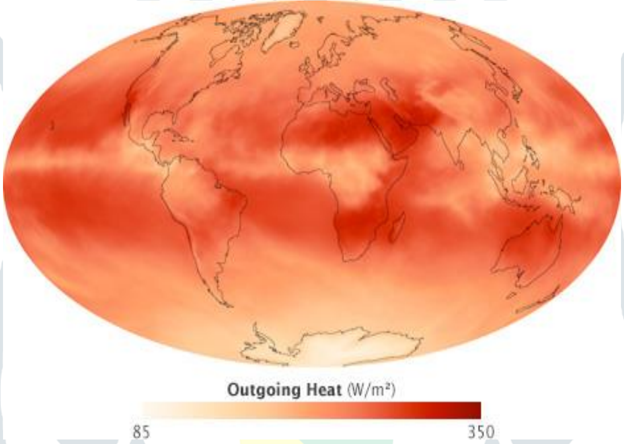

Figure 25

Absorbed sunlight is balanced by heat radiated from Earth's surface and atmosphere. This satellite map shows the distribution of thermal infrared radiation emitted by Earth in September 2008. Most heat escaped from areas just north and south of the equator, where the surface was warm, but there were few clouds. Along the equator, persistent clouds prevented heat from escaping. Likewise, the cold poles radiated little heat. The atmosphere and the surface of the Earth together absorb 71 percent of incoming solar radiation, so together, they must radiate that much energy back to space for the planet's average temperature to remain stable. However, the relative contribution of the atmosphere and the surface to each process (absorbing sunlight versus radiating heat) is asymmetric. The atmosphere absorbs 23 percent of incoming sunlight while the surface absorbs 48. The atmosphere radiates heat equivalent to 59 percent of incoming sunlight; the surface radiates only 12 percent. In other words, most solar heating happens at the surface, while most radiative cooling happens in the atmosphere.

5.1 SURFACE ENERGY BUDGET:

To understand how the Earth's climate system balances the energy budget, we have to consider processes occurring at the three levels: the surface of the Earth, where most solar heating takes place; the edge of Earth's atmosphere, where sunlight enters the system; and the atmosphere in between. At each level, the amount of incoming and outgoing energy, or net flux, must be equal. About 29 percent of incoming sunlight is reflected back to space by bright particles in the atmosphere or bright ground surfaces, which leaves about 71 percent to be absorbed by the atmosphere (23 percent) and the land (48 percent). For the energy budget at Earth's surface to balance, processes on the ground must get rid of the 48 percent of incoming solar energy that the ocean and land surfaces absorb. Energy leaves the surface through three processes: evaporation, convection, and emission of thermal infrared energy.

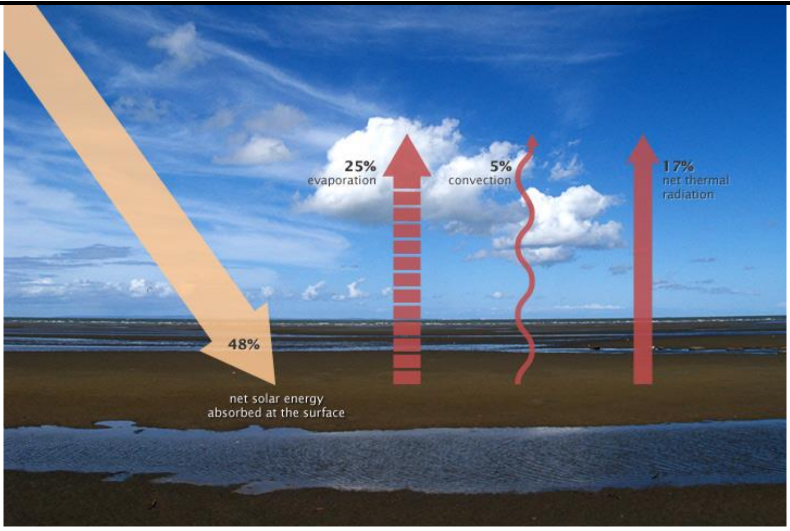

Figure 26: The surface absorbs about 48% of incoming sunlight. Three processes remove an equivalent amount of energy from the Earth's surface: evaporation (25%), convection (5%), and thermal infrared radiation, or heat (net 17%).

About 25 percent of incoming solar energy leaves the surface through evaporation. Liquid water molecules absorb incoming solar energy, and they change phase from liquid to gas. The heat energy that it took to evaporate the water is latent in the random motions of the water vapour molecules as they spread through the atmosphere. When the water vapour molecules condense back into rain, the latent heat is released to the surrounding atmosphere. Evaporation from tropical oceans and the subsequent release of latent heat are the primary drivers of the atmospheric heat engine. An additional 5 percent of incoming solar energy leaves the surface through convection. Air in direct contact with the sun-warmed ground becomes warm and buoyant. In general, the atmosphere is warmer near the surface and colder at higher altitudes, and under these conditions, warm air rises, shuttling heat away from the surface. Finally, a net of about 17 percent of incoming solar energy leaves the surface as thermal infrared energy (heat) radiated by atoms and molecules on the surface. This net upward flux results from two large but opposing fluxes: heat flowing upward from the surface to the atmosphere (117%) and heat flowing downward from the atmosphere to the ground (100%). The Sun's peak radiation is at visible and near-infrared wavelengths. The Earth's surface is much cooler, only about 15 degrees Celsius on average. The peak radiation from the surface is at thermal infrared wavelengths around 12.5 micro meters.

5.2 THE ATMOSPHERE'S ENERGY BUDGET:

Just as the incoming and outgoing energy at the Earth's surface must balance, the flow of energy into the atmosphere must be balanced by an equal flow of energy out of the atmosphere and back to space. Satellite measurements indicate that the atmosphere radiates thermal infrared energy equivalent to 59 percent of the incoming solar energy. If the atmosphere is radiating this much, it must be absorbing that much. Clouds, aerosols, water vapour, and ozone directly absorb 23 percent of incoming solar energy. Evaporation and convection transfer 25 and 5 percent of incoming solar energy from the surface to the atmosphere. These three processes transfer the equivalent of 53 percent of the incoming solar energy to the atmosphere. If total inflow of energy must match the outgoing thermal infrared observed at the top of the atmosphere, where does the remaining fraction (about 5-6 percent) come from? The remaining energy comes from the Earth's surface.

VI. CAUSES OF CLIMATE CHANGE:

On the broadest scale, the rate at which energy is received from the Sun and the rate at which it is lost to space determine the equilibrium temperature and climate of Earth. This energy is distributed around the globe by winds, ocean currents,and other mechanisms to affect the climates of different regions. Factors that can shape climate are called climate forcing's or "forcing mechanisms".[12] These include processes such as variations in solar radiation, variations in the Earth's orbit, variations in the albedo or reflectivity of the continents, atmosphere, and oceans, mountain-building and continental drift and changes in greenhouse gas concentrations. There are a variety of climate change feedbacks that can either amplify or diminish the initial forcing. Some parts of the climate system, such as the oceans and ice caps, respond more slowly in reaction to climate forcings, while others respond more quickly. There are also key threshold factors which when exceeded can produce rapid change. Forcing mechanisms can be either "internal" or "external". Internal forcing mechanisms are natural processes within the climate system itself (e.g., the thermohaline circulation). External forcing mechanisms can be either anthropogenic (e.g. increased emissions of greenhouse gases and dust) or natural (e.g., changes in solar output, the earth's orbit, volcano eruptions). Whether the initial forcing mechanism is internal or external, the response of the climate system might be fast (e.g., a sudden cooling due to airborne volcanic ash reflecting sunlight), slow (e.g. thermal expansion of warming ocean water), or a combination (e.g., sudden loss of albedo in the Arctic Ocean as sea ice melts, followed by more gradual thermal expansion of the water). Therefore, the climate system can respond abruptly, but the full response to forcing mechanisms might not be fully developed for centuries or even longer.

6.1 INTERNAL FORCING MECHANISMS:

Scientists generally define the five components of earth's climate system to include atmosphere, hydrosphere, cryosphere, lithosphere (restricted to the surface soils, rocks, and sediments), and biosphere.[13] Natural changes in the climate system ("internal forcings") result in internal "climate variability".[14] Examples include the type and distribution of species, and changes in ocean-atmosphere circulations.

6.1.1 OCEAN-ATMOSPHERE VARIABILITY:

The ocean and atmosphere can work together to spontaneously generate internal climate variability that can persist for years to decades at a time. Examples of this type of variability include the El Niño–Southern Oscillation, the Pacific decadal oscillation, and the Atlantic Multi decadal Oscillation. These variations can affect global average surface temperature by redistributing heat between the deep ocean and the atmosphere and/or by altering the cloud/water vapour/sea ice distribution which can affect the total energy budget of the earth. The oceanic aspects of these circulations can generate variability on centennial timescales due to the ocean having hundreds of times more mass than in the atmosphere, and thus very high thermal inertia. For example, alterations to ocean processes such as thermohaline circulation play a key role in redistributing heat in the world's oceans. Due to the long timescales of this circulation, ocean temperature at depth is still adjusting to effects of the Little Ice Age which occurred between the 1600 and 1800s.

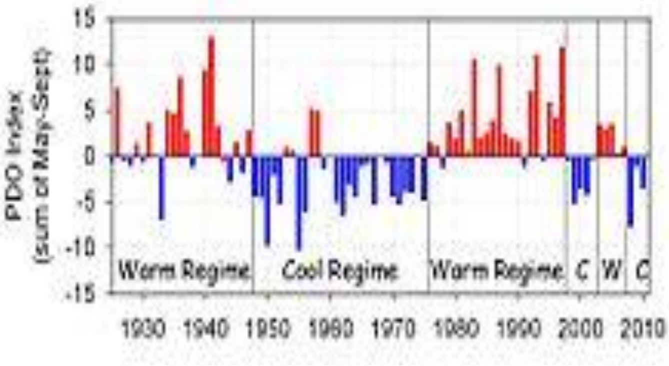

Figure 27

6.1.2 LIFE:

Life affects climate through its role in the carbon and water cycles and through such mechanisms as albedo, evapotranspiration, cloud formation, and weathering. Examples of how life may have affected past climate include:

Glaciation 2.3 billion years ago triggered by the evolution of oxygenic photosynthesis, which depleted the atmosphere of the greenhouse gas carbon dioxide and introduced free oxygen. another glaciation 300 million years ago ushered in by long-term burial of decomposition-resistant detritus of vascular land-plants (creating a carbon sink and forming coal termination of the Paleocene–Eocene Thermal Maximum 55 million years ago by flourishing marine phytoplankton reversal of global warming 49 million years ago by 800,000 years of arctic azolla blooms Global cooling over the past 40 million years driven by the expansion of grass-grazer ecosystems.

6.2 EXTERNAL FORCING MECHANISMS:

6.2.1 HUMAN INFLUENCES:

GLOBAL WARMING:

Global warming is a long-term rise in the average temperature of the Earth's climate system, an aspect of climate change shown by temperature measurements and by multiple effects of the warming. Though earlier geological periods also experienced episodes of warming, the term commonly refers to the observed and continuing increase in average air and ocean temperatures since 1900 caused mainly by emissions of greenhouse gasses in the modern industrial economy. In the modern context the terms global warming and climate change are commonly used interchangeably but climate change includes both global warming and its effects, such as changes to precipitation and impacts that differ by region. Many of the observed warming changes since the 1950s are unprecedented in the instrumental temperature record, and in historical and paleoclimate proxy records of climate change over thousands to millions of years.

In 2013, the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report concluded, "It is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century."The largest human influence has been the emission of greenhouse gases such as carbon dioxide, methane, and nitrous oxide. Climate model projections summarized in the report indicated that during the 21st century, the global surface temperature is likely to rise a further 0.3 to 1.7 °C (0.5 to 3.1 °F) to 2.6 to 4.8 °C (4.7 to 8.6 °F) depending on the rate of greenhouse gas emissions and on climate feedback effects. These findings have been recognized by the national science academies of the major industrialized nations and are not disputed by any scientific body of national or international standing.

Future climate change effects are expected to include rising sea levels, ocean acidification, regional changes in precipitation, and expansion of deserts in the subtropics. Surface temperature increases are greatest in the Arctic, with the continuing retreat of glaciers, permafrost, and sea ice. Predicted regional precipitation effects include more frequent extreme weather events such as heat waves, droughts, wildfires, heavy rainfall with floods, and heavy snowfall.[Effects directly significant to humans are predicted to include the threat to food security from decreasing crop yields, and the abandonment of populated areas due to rising sea levels. Environmental impacts appear likely to include the extinction or relocation of ecosystems as they adapt to climate change, with coral reefs mountain ecosystems, and Arctic ecosystems most immediately threatened. Because the climate system has a large "inertia" and greenhouse gases will remain in the atmosphere for a long time, climatic changes and their effects will continue to become more pronounced for many centuries even if further increases to greenhouse gases stop.

Possible societal responses to global warming include mitigation by emissions reduction, adaptation to its effects, and possible future climate engineering. Most countries are parties to the United Nations Framework Convention on Climate Change (UNFCCC), whose ultimate objective is to prevent dangerous anthropogenic climate change.[25] Parties to the UNFCCC have agreed that deep cuts in emissions are required and that global warming should be limited to well below 2.0 °C (3.6 °F) compared to pre-industrial levels, with efforts made to limit warming to 1.5 °C (2.7 °F). Some scientists call into question climate adaptation feasibility, with higher emissions scenarios,[or the two degree temperature target.

Public reactions to global warming and concern about its effects are also increasing. A 2015 global survey showed that a median of 54% of respondents consider it "a very serious problem", with significant regional differences: Americans and Chinese (whose economies are responsible for the greatest annual CO_2 emissions) are among the least concerned.

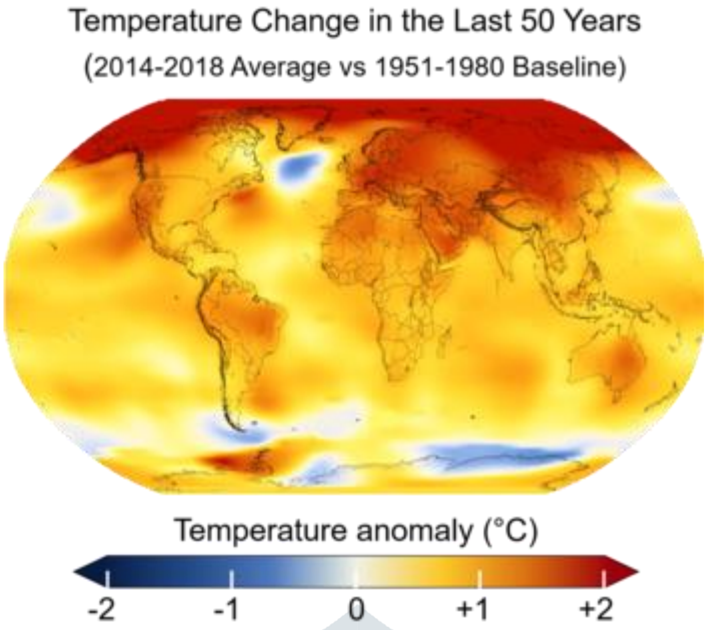

Figure 28: Average global temperatures from 2014 to 2018 compared to a baseline average from 1951 to 1980.

OBSERVED TEMPERATURE CHANGES:

Multiple independently produced datasets confirm that between 1880 and 2012, the global average (land and ocean) surface temperature increased by 0.85 [0.65 to 1.06] °C. Since 1979 the rate of warming has approximately doubled (0.13±0.03 °C per decade, against 0.07±0.02 °C per decade). Climate proxies show the temperature to have been relatively stable over the one or two thousand years before 1850, with regionally varying fluctuations such as the Medieval Warm Period and the Little Ice Age. Although the increase of the average near-surface atmospheric temperature is commonly used to track global warming, over 90% of the additional energy stored in the climate system over the last 50 years has accumulated in the oceans. The rest has melted ice and warmed the continents and the atmosphere. The warming evident in the instrumental temperature record is consistent with a wide range of observations, as documented by many independent scientific groups.[1] Examples include sea level rise, widespread melting of snow and land ice, increased heat content of the oceans, increased humidity, and the earlier timing of spring events, e.g., the flowering of plants.

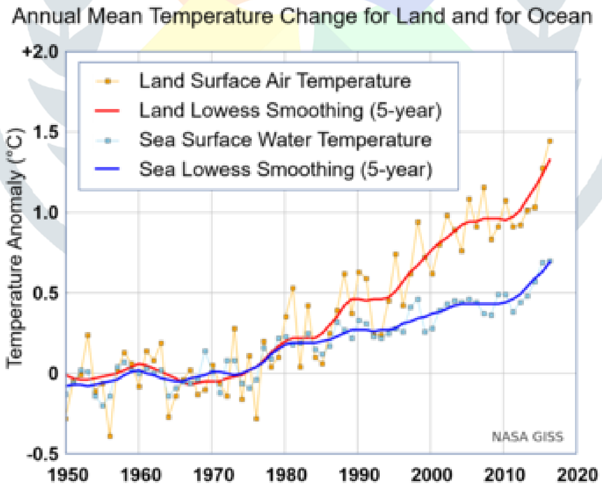

Figure 29: Annual (thin lines) and five-year lowess smooth (thick lines) for the temperature anomalies averaged over the Earth's land area (red line) and sea surface temperature anomalies (blue line) averaged over the part of the ocean that is free of ice at all times (open ocean)

REGIONAL TRENDS:

Global warming refers to global averages, with the amount of warming varying by region. Since 1979, global average land temperatures have increased about twice as fast as global average ocean temperatures.[1] This is due to the larger heat capacity of the oceans and because oceans lose more heat by evaporation. Where greenhouse gas emissions occur does not impact the location of warming because the major greenhouse gases persist long enough to diffuse across the planet, although localized black carbon deposits on snow and ice do contribute to Arctic warming.

The Northern Hemisphere and North Pole have heated much faster than the South Pole and Southern Hemisphere. The Northern Hemisphere not only has much more land, its arrangement around the Arctic Ocean has resulted in the maximum surface area flipping from reflective snow and ice cover to ocean and land surfaces that absorb more sunlight Arctic temperatures have increased and are predicted to continue to increase during this century at over twice the rate of the rest of the world. As the temperature difference between the Arctic and the equator decreases, ocean currents like the gulf stream that are driven by that temperature difference are weakening. Studies have also linked the rapidly warming Arctic to extreme weather in mid-latitudes as the jet stream becomes more erratic.

The rate of ice loss from glaciers and ice sheets in the Antarctic is a key area of uncertainty since Antarctica contains 90% of potential sea level rise. Polar amplification and increased ocean warmth are undermining and threatening to unplug Antarctic glacier outlets, potentially resulting in more rapid sea level rise. To date, increased snowfall in Antarctica has offset some of the ice loss from West Antarctica, with East Antarctica ice sheets recently beginning to shed mass as well.

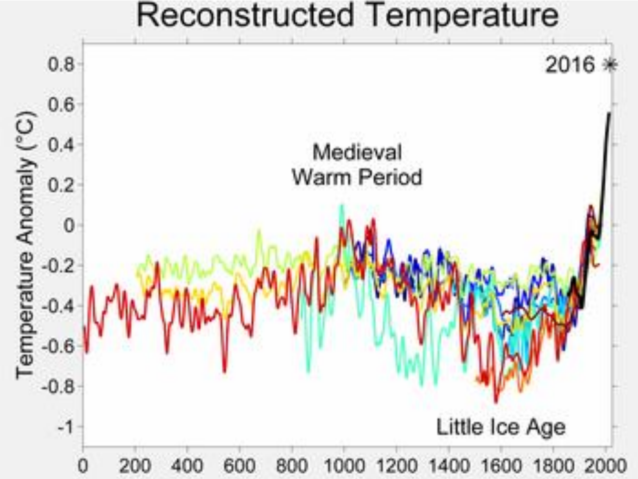

Figure 30: Two millennia of mean surface temperatures according to different reconstructions from climate proxies, each smoothed on a decadal scale, with the instrumental temperature record overlaid in black.

SHORT-TERM FLUCTUATIONS VS. OVERALL TREND:

Because the climate system has large thermal inertia, it can take centuries for the climate to fully adjust. While record-breaking years attract considerable public interest, individual years are less significant than the overall trend. Global surface temperature is subject to short-term fluctuations that overlay long-term trends, and can temporarily mask or magnify them.

An example of such an episode is the slower rate of surface temperature increase from 1998 to 2012, which was dubbed the global warming hiatus by the media and some scientists. Throughout this period ocean heat storage continued to progress steadily upwards, and in subsequent years surface temperatures have spiked upwards. Climate models account for the global warming hiatus by incorporating heating and cooling from sunspot cycles, and volcanic eruptions that reach the stratosphere.

INITIAL CAUSES OF TEMPERATURE CHANGES (EXTERNAL FORCINGS):

By itself, the climate system may generate random changes in global temperatures for years to decades at a time, but long-term changes emanate only from so-called external forcings.These forcings are "external" to the climate system, but not necessarily external to Earth.[Examples of external forcings include changes in the composition of the atmosphere (e.g., increased concentrations of greenhouse gases), solar luminosity, volcanic eruptions, and variations in Earth's orbit around the Sun.

REENHOUSE GASES:

The greenhouse effect is the process by which absorption and emission of infrared radiation by gases in a planet's atmosphere warm its lower atmosphere and surface. On Earth, an atmosphere containing naturally occurring amounts of greenhouse gases causes air temperature near the surface to be warmer by about 33 °C (59 °F) than it would be in their absent Without the Earth's atmosphere, the Earth's average temperature would be well below the freezing temperature of water. The major greenhouse gases are water vapour, which causes about 36–70% of the greenhouse effect; carbon dioxide (CO_2), which causes 9–26%; methane (CH_4), which causes 4–9%; and ozone (O_3), which causes 3–7%.Human activity since the Industrial Revolution has increased the amount of greenhouse gases in the atmosphere, leading to increased radiative forcing from CO_2, methane, tropospheric ozone, CFCs, and nitrous oxide. According to work published in 2007, the concentrations of CO_2 and methane had increased by 36% and 148% respectively since 1750.[71] These levels are much higher than at any time during the last 800,000 years, the period for which reliable data has been extracted from ice cores. Less direct geological evidence indicates that CO_2 values higher than this were last seen about 20 million years ago.

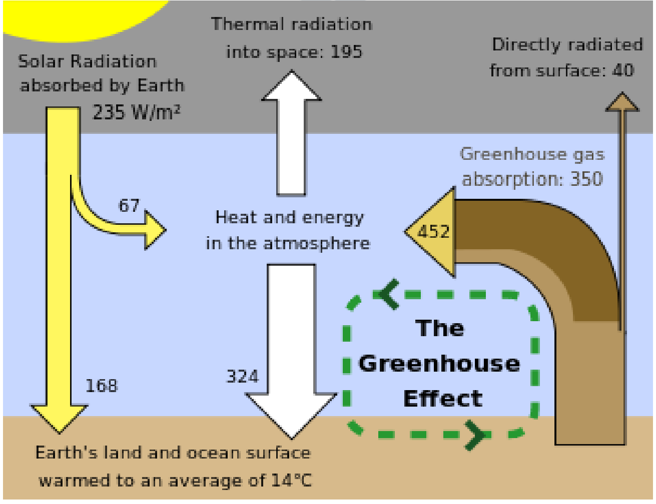

Figure 31: Greenhouse effect schematic showing energy flows between space, the atmosphere, and Earth's surface. Energy exchanges are expressed in watts per square meter (W/m^2)

Fossil fuel burning has produced about three-quarters of the increase in CO_2 from human activity over the past 20 years. The rest of this increase is caused mostly by changes in land-use, particularly deforestation. Another significant non-fuel source of anthropogenic CO_2 emissions is the calcination of limestone for clinker production, a chemical process which releases CO_2

Estimates of global CO_2 emissions in 2011 from fossil fuel combustion, including cement production and gas flaring, was 34.8 billion tonnes (9.5 ± 0.5 PgC), an increase of 54% above emissions in 1990. Coal burning was responsible for 43% of the total emissions, oil 34%, gas 18%, cement 4.9% and gas flaring 0.7%.

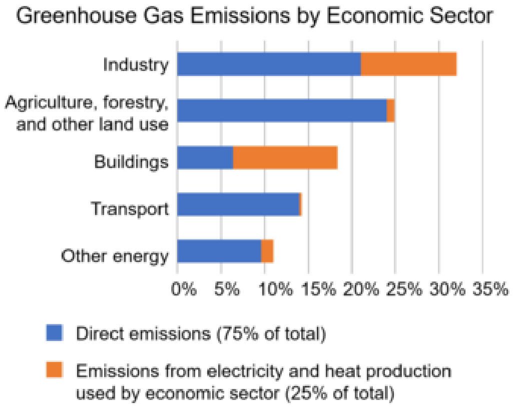

Figure 32: Annual greenhouse gas emissions attributed to different sectors as of the year 2010.

Emissions are given as a percentage share of total emissions, measured in carbon dioxide-equivalents, using global warming potentials from the IPCC Fifth assessment report

Readings for CO_2 taken at the world's primary benchmark site in Mauna Loa surpassed 400 ppm in 2013. This is likely the first time CO_2 levels have been this high for about 4.5 million years Carbon emission rates plateaued from 2014 to 2016, rose by 1.6% in 2017, then rose again by 2.7% in 2018.

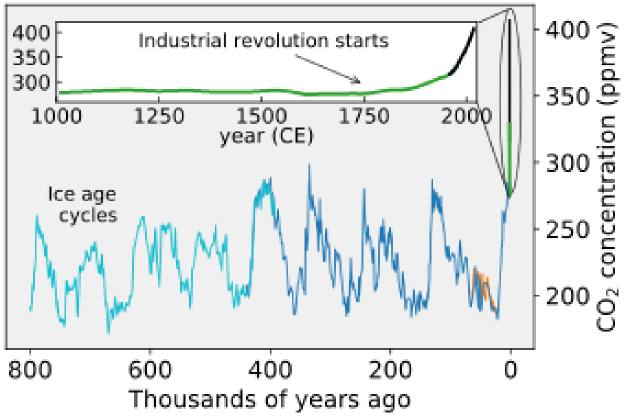

Figure 33: Co_2 Concentartion over past 400 years

Over the last three decades of the twentieth century, gross domestic product per capita and population growth were the main drivers of increases in greenhouse gas emissions. CO_2 emissions are continuing to rise due to the burning of fossil fuels and land-use change. Emissions can be attributed to different regions. Attributions of emissions due to land-use change are subject to considerable uncertainty.

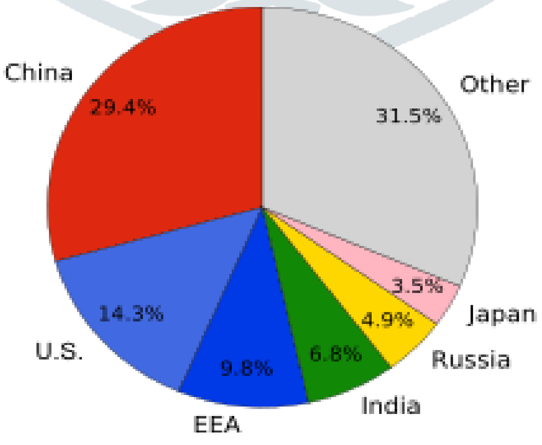

Figure 34: Carbon dioxide emission in various countries by the year 2018

Emissions scenarios, estimates of changes in future emission levels of greenhouse gases, have been projected that depend upon uncertain economic, sociological, technological, and natural developments.] In most scenarios, emissions continue to rise over the century, while in a few, emissions are reduced. Fossil fuel reserves are abundant, and will not limit carbon emissions in the 21st century.] Emission scenarios, combined with modelling of the carbon cycle, have been used to produce estimates of how atmospheric concentrations of greenhouse gases might change in the future. Using the six IPCC SRES "marker" scenarios, models suggest that by the year 2100, the atmospheric concentration of CO_2 could range between 541 and 970 ppm.

Aerosols and soot: Global dimming, a gradual reduction in the amount of sunlight reaching the Earth's surface, was observed from 1961 until 1990. Solid and liquid particles known as aerosols, produced by volcanoes and human-made pollutants, are thought to be the main cause of this dimming. They exert a cooling effect by reflecting incoming sunlight, with NASA estimating that between 1850 and 2010 aerosols limited global warming by 1 degree Celsius.]Aerosol removal by precipitation gives tropospheric aerosols an atmospheric lifetime of only about a week, while stratospheric aerosols can remain for a few years. Global aerosols have been declining since 1990, removing some of the masking of global warming that aerosols had been providing.

In addition to their direct effect by scattering and absorbing solar radiation, aerosols have indirect effects on the Earth's radiation budget. Sulfate aerosols act as cloud condensation nuclei and thus lead to clouds that have more and smaller cloud droplets. These clouds reflect solar radiation more efficiently than clouds with fewer and larger droplets, a phenomenon known as the Twomey effect. This effect also causes droplets to be of more uniform size, which reduces growth of raindrops and makes the cloud more reflective to incoming sunlight, known as the Albrecht effect.[1 Indirect effects are most noticeable in marine stratiform clouds, and have very little radiative effect on convective clouds. Indirect effects of aerosols represent the largest uncertainty in radiative forcing.

While aerosols typically limit global warming by reflecting sunlight, black carbon in soot can also increase global warming when deposited on snow and ice. Not only does it increase the absorption of sunlight, it also directly exacerbates melting and sea level rise. Limiting new black carbon deposits in the Arctic could reduce global warming by 0.2 degrees Celsius by 2050.] When soot is suspended in the atmosphere it directly absorbs solar radiation, heating the atmosphere and cooling the surface. In isolated areas with high soot production, such as rural India, as much as 50% of surface warming due to greenhouse gases may be masked by atmospheric brown clouds. The influences of atmospheric particles, including black carbon, are most pronounced in the tropics and sub-tropics, particularly in Asia, while the effects of greenhouse gases are dominant in the extratropics and southern hemisphere.

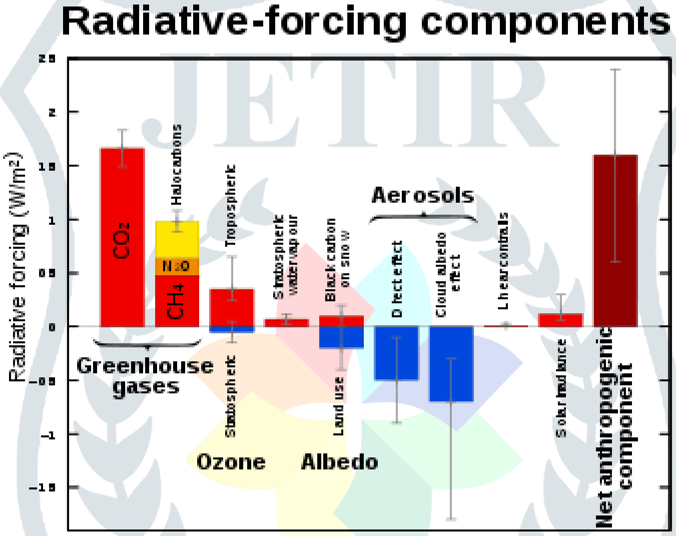

Figure 35: Contribution of natural factors and human activities to radiative forcing of climate change.

Radiative forcing values are for the year 2005, relative to the pre-industrial era (1750). The contribution of solar irradiance to radiative forcing is 5% of the value of the combined radiative forcing due to increases in the atmospheric concentrations of carbon dioxide, methane and nitrous oxide.

EFFECTS OF GLOBAL WARMING: (Physical environmental)

The environmental effects of global warming are broad and far-reaching. They include the following diverse effects:

- Global warming has led to decades of shrinking and thinning in a warm climate that has put the Arctic sea ice in a precarious position, it is now vulnerable to atmospheric anomalies. Projections of declines in Arctic sea ice vary Recent projections suggest that Arctic summers could be ice-free (defined as an ice extent of less than 1 million square km) as early as 2025–2030. Since 1993, sea level has on average risen with 3.1 ± 0.3 mm per year. Additionally, sea level rise has accelerated from 1993 to 2017.] Over the 21st century, the IPCC projects (for a high emissions scenario) that global mean sea level could rise by 52–98 cm.[
- Extreme weather, extreme events, tropical cyclones: Data analysis of extreme events from 1960 until 2010 suggests that droughts and heat waves appear simultaneously with increased frequency.] Extremely wet or dry events within the monsoon period have increased since 1980. Projections suggest probable increase in the frequency and severity of some extreme weather events, such as heat waves.
- Changes in ocean properties: the physical effect of global warming on oceans include an increase in acidity, and a reduction of oxygen levels because it is less soluble in warmer water (ocean deoxygenation). Increases in atmospheric CO_2 concentrations have led to an increase in dissolved CO_2 and thus ocean acidity, measured by lower pH values.
- Long-term effects of global warming: On the timescale of centuries to millennia, the magnitude of global warming will be determined primarily by anthropogenic CO_2 emissions. This is due to carbon dioxide's very long lifetime in the atmosphere.] Long-term effects also include a response from the Earth's crust, due to ice melting and deglaciation, in a process called post-glacial rebound, when land masses are no longer depressed by the weight of ice. This could lead to landslides and increased seismic and volcanic activities. Tsunamis could be generated by submarine landslides caused by warmer ocean water thawing ocean-floor permafrost or releasing gas hydrates.
- Abrupt climate change, tipping points in the climate system: Climate change could result in global, large-scale changes in natural and social systems. Examples include ocean acidification caused by increased atmospheric concentrations of carbon dioxide, and the long-term melting of ice sheets, which contributes to sea level rise.] Some large-scale changes

could occur abruptly, i.e. over a short time period, and might also be irreversible. Examples of abrupt climate change are the rapid release of methane and carbon dioxide from permafrost, which would lead to amplified global warming. Another example is the possibility for the Atlantic Meridional Overturning Circulation to slow or to shut down (see also shutdown of thermohaline circulation) This could trigger cooling in the North Atlantic, Europe, and North America. It would particularly affect areas such as the British Isles, France and the Nordic countries, which are warmed by the North Atlantic drift.

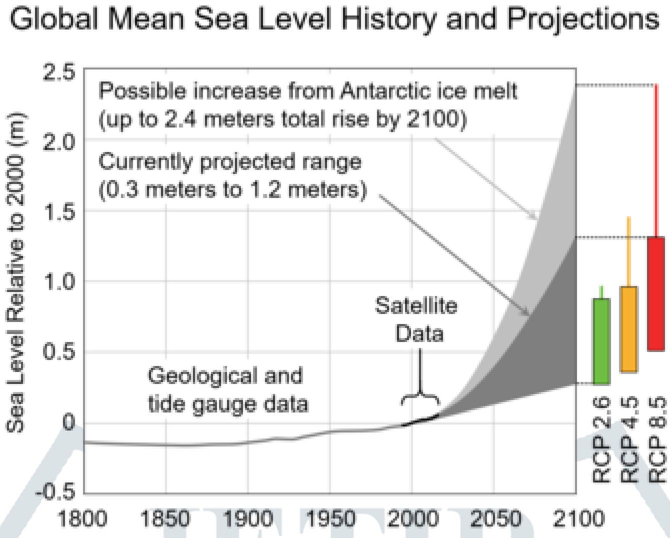

Figure 36: Historical sea level reconstruction and projections up to 2100 published in January 2017 by the U.S. Global Change Research Program for the Fourth National Climate Assessment.

6.2.2 SOCIAL SYSTEMS:

The effects of climate change on human systems, mostly due to warming or shifts in precipitation patterns, or both, have been detected worldwide. The future social impacts of climate change will be uneven across the world. Many risks are expected to increase with higher magnitudes of global warming. All regions are at risk of experiencing negative impacts,[with low-latitude, less developed areas facing the greatest risk. Economic growth (measured in GDP growth) of poorer countries is much more impaired with projected future climate warming than more developed countries. In small islands and mega deltas, inundation as a result of sea level rise is expected to threaten vital infrastructure and human settlements.[This could lead to issues of homelessness in countries with low-lying areas such as Bangladesh, as well as statelessness for populations in countries such as the Maldives and Tuvalu. Climate change can be an important driver of migration, both within and between countries. A 2014 meta-analysis concluded rise violence increases by up to 20% for each degree of warming, which includes fist fights, violent crimes, civil unrest, or wars. The violent herder–farmer conflicts in Nigeria, Sudan and other countries in the Sahel region have been exacerbated by climate change. Crop production will probably be negatively affected in low latitude countries, while effects at northern latitudes may be positive or negative. Global warming of around 4.6 °C relative to pre-industrial levels could pose a large risk to global and regional food security. The impact of climate change on crop productivity for the four major crops was negative for wheat and maize, and neutral for soy and rice, in the years 1960–2013.See also Climate change and agriculture. Generally impacts on public health will be more negative than positive. Impacts include: the effects of extreme weather, leading to injury and loss of life; and indirect effects, such as undernutrition brought on by crop failures. There has been a shift from cold- to heat-related mortality in some regions as a result of warming Temperature rise has been connected to increased numbers of suicides.

6.2.3 REGIONAL IMPACTS:

Regional impacts of climate change are now observable at more locations than before, on all continents and across ocean regions The Arctic, Africa, small islands and Asian mega deltas are regions that are likely to be especially affected by future climate change.

Africa is one of the most vulnerable continents to climate variability and change because of multiple existing stresses and low adaptive capacity. Existing stresses include poverty, political conflicts, and ecosystem degradation. By 2050, between 350 million and 600 million people are projected to experience increased water stress due to climate change (see Climate change in Africa). Climate variability and change is projected to severely compromise agricultural production, including access to food, across Africa.] Research projects that regions may even become uninhabitable, with humidity and temperature reaching levels too high for humans to survive. Livelihoods of indigenous peoples of the Arctic have been altered by climate change, and there is emerging evidence of climate change impacts on livelihoods of indigenous peoples in other regions. Polar bears enter inhabited areas more than in the past, owing to climate change. Global warming reduces sea-ice and forces bears to visit land in search of food.

6.2.4 ORBITAL VARIATIONS:

Slight variations in Earth's motion lead to changes in the seasonal distribution of sunlight reaching the Earth's surface and how it is distributed across the globe. There is very little change to the area-averaged annually averaged sunshine; but there can be strong changes in the geographical and seasonal distribution. The three types of kinematic change are variations in Earth's eccentricity, changes in the tilt angle of Earth's axis of rotation, and precession of Earth's axis. Combined together, these produce Milankovitch cycles which affect climate and are notable for their correlation to glacial and interglacial periods, their correlation with the advance and retreat of the Sahara,] and for their appearance in the stratigraphic record. The IPCC notes that Milankovitch cycles drove the ice age cycles, CO_2 followed temperature change "with a lag of some hundreds of years", and that as a feedback amplified temperature change. The depths of the ocean have a lag time in changing temperature (thermal inertia on such scale). Upon seawater temperature change, the solubility of CO_2 in the oceans changed, as well as other factors affecting air-sea CO_2 exchange.

6.2.5 SOLAR OUTPUT:

The Sun is the predominant source of energy input to the Earth. Other sources include geothermal energy from the Earth's core, tidal energy from the Moon and heat from the decay of radioactive compounds. Both long- and short-term variations in solar intensity are known to affect global climate.

Three to four billion years ago, the Sun emitted only 75% as much power as it does today. If the atmospheric composition had been the same as today, liquid water should not have existed on Earth. However, there is evidence for the presence of water on the early Earth, in the Hadean and Archean eons, leading to what is known as the faint young Sun paradox Hypothesized solutions to this paradox include a vastly different atmosphere, with much higher concentrations of greenhouse gases than currently exist.] Over the following approximately 4 billion years, the energy output of the Sun increased and atmospheric composition changed. The Great Oxygenation Event—oxygenation of the atmosphere around 2.4 billion years ago—was the most notable alteration. Over the next five billion years from the present, the Sun's ultimate death as it becomes a red giant and then a white dwarf will have large effects on climate, with the red giant phase possibly ending any life on Earth that survives until that time.

Solar output varies on shorter time scales, including the 11-year solar cycle and longer-term modulations Solar intensity variations, possibly as a result of the Wolf, Spörer, and the Maunder Minima, are considered to have been influential in triggering the Little Ice Age. This event extended from 1550 to 1850 AD and was marked by relative cooling and greater glacier extent than the centuries before and afterward. Solar variation may also have affected some of the warming observed from 1900 to 1950. The cyclical nature of the Sun's energy output is not yet fully understood; it differs from the very slow change that is happening within the Sun as it ages and evolves. Some studies point toward solar radiation increases from cyclical sunspot activity affecting global warming, and climate may be influenced by the sum of all effects (solar variation, anthropogenic radiative forcings, etc.)

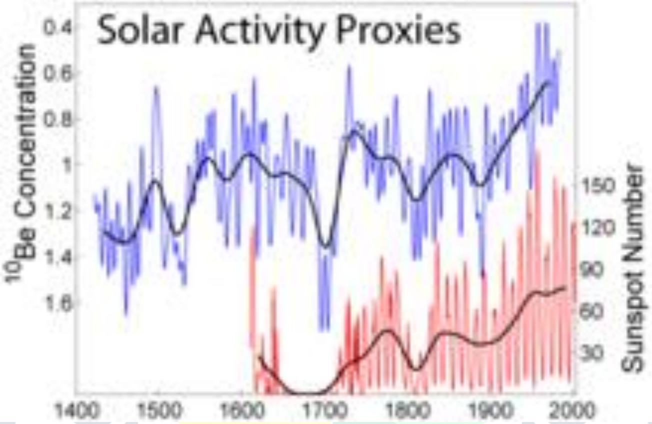

Figure 37: Variations in solar activity during the last several centuries based on observations of sunspots and beryllium isotopes. The period of extraordinarily few sunspots in the late 17th century was the Maunder minimum.

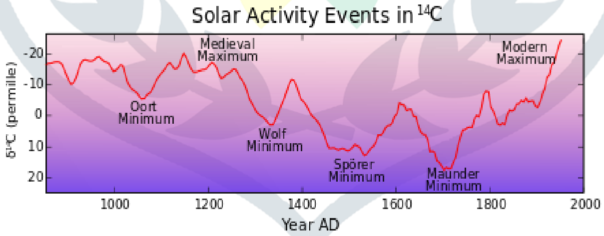

Figure 38: Solar activity events recorded in radiocarbon

6.2.6 VOLCANISM:

The eruptions considered to be large enough to affect the Earth's climate on a scale of more than 1 year are the ones that inject over 100,000 tons of SO_2 into the stratosphere. This is due to the optical properties of SO_2 and sulfate aerosols, which strongly absorb or scatter solar radiation, creating a global layer of sulfuric acid haze. On average, such eruptions occur several times per century, and cause cooling (by partially blocking the transmission of solar radiation to the Earth's surface) for a period of several years. The eruption of Mount Pinatubo in 1991, the second largest terrestrial eruption of the 20th century, affected the climate substantially, subsequently global temperatures decreased by about 0.5 °C (0.9 °F) for up to three years Thus, the cooling over large parts of the Earth reduced surface temperatures in 1991–93, the equivalent to a reduction in net radiation of 4 watts per square meter. The Mount Tambora eruption in 1815 caused the Year Without a Summer. Much larger eruptions, known as large igneous provinces, occur only a few times every fifty – one hundred million years – through flood basalt, and caused in Earth past global warming and mass extinctions. Small eruptions, with injections of less than 0.1 Mt of sulphur dioxide into the stratosphere, affect the atmosphere only subtly, as temperature changes are comparable with natural variability. However, because smaller eruptions occur at a much higher frequency, they too significantly affect Earth's atmosphere. Seismic monitoring maps current and future trends in volcanic activities, and tries to develop early warning systems. In climate modelling the aim is to study the physical mechanisms and feedbacks of volcanic forcing. Volcanoes are also part of the extended carbon cycle. Over very long (geological) time periods, they release carbon dioxide from the Earth's crust and mantle, counteracting the uptake by sedimentary rocks and other geological carbon dioxide sinks. The US Geological Survey estimates are that volcanic emissions are at a much lower level than the effects of current human activities, which generate 100–300 times the amount of carbon dioxide emitted by volcanoes. A review of published studies indicates that annual volcanic emissions of carbon dioxide, including amounts released from mid-ocean ridges, volcanic arcs, and hot spot volcanoes, are only the equivalent of 3 to 5 days of human-caused output. The annual amount put out by human activities may be greater than the amount released by supererruptions, the most recent of which was the Toba eruption in Indonesia 74,000 years ago.

6.2.7 PLATE TECTONICS:

Over the course of millions of years, the motion of tectonic plates reconfigures global land and ocean areas and generates topography. This can affect both global and local patterns of climate and atmosphere-ocean circulation. The position of the continents determines the geometry of the oceans and therefore influences patterns of ocean circulation. The locations of the seas are important in controlling the transfer of heat and moisture across the globe, and therefore, in determining global climate. A recent example of tectonic control on ocean circulation is the formation of the Isthmus of Panama about 5 million years ago, which shut off direct mixing between the Atlantic and Pacific Oceans. This strongly affected the ocean dynamics of what is now the Gulf Stream and may have led to Northern Hemisphere ice cover. During the Carboniferous period, about 300 to 360 million years ago, plate tectonics may have triggered large-scale storage of carbon and increased glaciation. Geologic evidence points to a "mega monsoonal" circulation pattern during the time of the supercontinent Pangaea, and climate modelling suggests that the existence of the supercontinent was conducive to the establishment of monsoons. The size of continents is also important. Because of the stabilizing effect of the oceans on temperature, yearly temperature variations are generally lower in coastal areas than they are inland. A larger supercontinent will therefore have more area in which climate is strongly seasonal than will several smaller continents or islands.

6.2.8 OTHER MECHANISMS:

The Earth receives an influx of ionized particles known as cosmic rays from a variety of external sources, including the Sun. A hypothesis holds that an increase in the cosmic ray flux would increase the ionization in the atmosphere, leading to greater cloud cover. This, in turn, would tend to cool the surface. The non-solar cosmic ray flux may vary as a result of a nearby supernova event, the solar system passing through a dense interstellar cloud, or the oscillatory movement of the Sun's position with respect to the galactic plane. The latter can increase the flux of high-energy cosmic rays coming from the Virgo cluster. Evidence exists that the Chicxulub impact some 66 million years ago had severely affected the Earth's climate. Large quantities of sulphate aerosols were kicked up into the atmosphere, decreasing global temperatures by up to 26 °C and producing sub-freezing temperatures for a period of 3−16 years. The recovery time for this event took more than 30 years.

6.2.9 HUMAN IMPACTS:

According to the IPCC, human-caused global warming is driving climate changes impacting both human and natural systems on all continents and across the oceans. Human-caused global warming results from the increased use of fossil fuels in transportation, manufacturing and communications. Internet induced climate change is newest contributor to human-induced climate change. Some of the impacts include the altering of ecosystems (with a few extinctions), threat to food production and water supplies due to extreme weather, and the dislocation of human communities due to sea level rise and other climate factors. Taken together these hazards also exacerbate other stressors such as poverty. Possible societal responses include efforts to prevent additional climate change, adapting to unavoidable climate change, and possible future climate engineering.

VII. RECOMMENDATIONS TO REDUCE THE GLOBAL CLIMATIC CHANGE:

7.1 FOREGO FOSSIL FUELS:

The first challenge is eliminating the burning of coal, oil and, eventually, natural gas. This is perhaps the most daunting challenge as denizens of richer nations literally eat, wear, work, play and even sleep on the products made from such fossilized sunshine. And citizens of developing nations want and arguably deserve the same comforts, which are largely thanks to the energy stored in such fuels.

Oil is the lubricant of the global economy, hidden inside such ubiquitous items as plastic and corn, and fundamental to the transportation of both consumers and goods. Coal is the substrate, supplying roughly half of the electricity used in the U.S. and nearly that much worldwide—a percentage that is likely to grow, according to the International Energy Agency. There are no perfect solutions for reducing dependence on fossil fuels (for example, carbon neutral biofuels can drive up the price of food and lead to forest destruction, and while nuclear power does not emit greenhouse gases, it does produce radioactive waste), but every bit counts. So try to employ alternatives when possible—plant-derived plastics, biodiesel, wind power—and to invest in the change, be it by divesting from oil stocks or investing in companies practicing carbon capture and storage.

7.2 INFRASTRUCTURE UPGRADE:

Buildings worldwide contribute around one third of all greenhouse gas emissions (43 percent in the U.S. alone), even though investing in thicker insulation and other cost-effective, temperature-regulating steps can save money in the long run. Electric grids are at capacity or overloaded, but power demands continue to rise. And bad roads can lower the fuel economy of even the most efficient vehicle. Investing in new infrastructure, or radically upgrading existing highways and transmission lines, would help cut greenhouse gas emissions and drive economic growth in developing countries

Of course, it takes a lot of cement, a major source of greenhouse gas emissions, to construct new buildings and roads. The U.S. alone contributed 50.7 million metric tons of carbon dioxide to the atmosphere in 2005 from cement production, which requires heating limestone and other ingredients to 1,450 degrees Celsius (2,642 degrees Fahrenheit). Mining copper and other elements needed for electrical wiring and transmission also causes globe-warming pollution.But energy-efficient buildings and improved cement-making processes (such as using alternative fuels to fire up the kiln) could reduce greenhouse gas emissions in the developed world and prevent them in the developing world.

7.3 MOVE CLOSER TO WORK:

Transportation is the second leading source of greenhouse gas emissions in the U.S. (burning a single gallon of gasoline produces 20 pounds of CO_2). But it doesn't have to be that way. One way to dramatically curtail transportation fuel needs is to move closer to work, use mass transit, or switch to walking, cycling or some other mode of transport that does not require anything other than human energy. There is also the option of working from home and telecommuting several days a week.

Cutting down on long-distance travel would also help, most notably airplane flights, which are one of the fastest growing sources of greenhouse gas emissions and a source that arguably releases such emissions in the worst possible spot (higher in the atmosphere). Flights are also one of the few sources of globe-warming pollution for which there isn't already a viable alternative: jets rely on kerosene, because it packs the most energy per pound, allowing them to travel far and fast, yet it takes roughly 10 gallons of oil to make one gallon of JetA fuel. Restricting flying to only critical, long-distance trips—in many parts of the world, trains can replace planes for short- to medium-distance trips—would help curb airplane emissions.

7.4 CONSUME LESS:

The easiest way to cut back on greenhouse gas emissions is simply to buy less stuff. Whether by forgoing an automobile or employing a reusable grocery sack, cutting back on consumption results in fewer fossil fuels Think green when making purchases. For instance, if you are in the market for a new car, buy one that will last the longest and have the least impact on the environment. Thus, a used vehicle with a hybrid engine offers superior fuel efficiency over the long haul while saving the environmental impact of new car manufacture.being burned to extract, produce and ship products around the globe. Paradoxically, when purchasing essentials, such as groceries, buying in bulk can reduce the amount of packaging—plastic wrapping, cardboard boxes and other unnecessary materials. Sometimes buying more means consuming less.

7.5 BE EFFICIENT:

A potentially simpler and even bigger impact can be made by doing more with less. Citizens of many developed countries are profligate wasters of energy, whether by speeding in a gas-guzzling sport-utility vehicle or leaving the lights on when not in a room. Good driving—and good car maintenance, such as making sure tires are properly inflated—can limit the amount of greenhouse gas emissions from a vehicle and, perhaps more importantly, lower the frequency of payment at the pump. Similarly, employing more efficient refrigerators, air conditioners and other appliances, such as those rated highly under the U.S. Environmental Protection Agency's Energy Star program, can cut electric bills while something as simple as weatherproofing the windows of a home can reduce heating and cooling bills. Such efforts can also be usefully employed at work, whether that means installing more efficient turbines at the power plant or turning the lights off when you leave the office.

7.6 STOP CUTTING DOWN TREES:

Every year, 33 million acres of forests are cut down. Timber harvesting in the tropics alone contributes 1.5 billion metric tons of carbon to the atmosphere. That represents 20 percent of human-made greenhouse gas emissions and a source that could be avoided relatively easily. Improved agricultural practices along with paper recycling and forest management—balancing the amount of wood taken out with the amount of new trees growing—could quickly eliminate this significant chunk of emissions. And when purchasing wood products, such as furniture or flooring, buy used goods or, failing that, wood certified to have been sustainably harvested. The Amazon and other forests are not just the lungs of the earth, they may also be humanity's best short-term hope for limiting climate change.

7.7 UNPLUG:

Believe it or not, U.S. citizens spend more money on electricity to power devices when off than when on. Televisions, stereo equipment, computers, battery chargers and a host of other gadgets and appliances consume more energy when seemingly switched off, so unplug them instead. Unplug—Believe it or not, U.S. citizens spend more money on electricity to power devices when off than when on. Televisions, stereo equipment, computers, battery chargers and a host of other gadgets and appliances consume more energy when seemingly switched off, so unplug them instead. Swapping old incandescent lightbulbs for more efficient replacements, such as compact fluorescents (warning: these lightbulbs contain mercury and must be properly disposed of at the end of their long life), would save billions of kilowatt-hours. In fact, according to the EPA, replacing just one incandescent lightbulb in every American home would save enough energy to provide electricity to three million American homes.

7.8 FUTURE FUELS:

Replacing fossil fuels may prove the great challenge of the 21st century. Many contenders exist, ranging from ethanol derived from crops to hydrogen electrolyzed out of water, but all of them have some drawbacks, too, and none are immediately available at the scale needed. Biofuels can have a host of negative impacts, from driving up food prices to sucking up more energy than they produce. Hydrogen must be created, requiring either reforming natural gas or electricity to crack water molecules. Biodiesel hybrid electric vehicles (that can plug into the grid overnight) may offer the best transportation solution in the short term, given the energy density of diesel and the carbon neutral ramifications of fuel from plants as well as the emissions of electric engines. A recent study found that the present amount of electricity generation in the U.S. could provide enough energy for the country's entire fleet of automobiles to switch to plug-in hybrids, reducing greenhouse gas emissions in the process. But plug-in hybrids would still rely on electricity, now predominantly generated by burning dirty coal. Massive investment in low-emission energy generation, whether solar-thermal power or nuclear fission, would be required to radically reduce greenhouse gas emissions. And even more speculative energy sources hyper efficient photovoltaic cells, solar energy stations in orbit or even fusion—may ultimately be required. The solutions above offer the outline of a plan to personally avoid contributing to global warming. But should such individual and national efforts fail, there is another, potentially desperate solution.

7.9 EXPERIMENT EARTH:

Climate change represents humanity's first planetwide experiment. But, if all else fails, it may not be the last. So-called geoengineering, radical interventions to either block sunlight or reduce greenhouse gases, is a potential last resort for addressing the challenge of climate change.Among the ideas: releasing sulphate particles in the air to mimic the cooling effects of a massive volcanic eruption; placing millions of small mirrors or lenses in space to deflect sunlight; covering portions of the planet with reflective films to bounce sunlight back into space; fertilizing the oceans with iron or other nutrients to enable plankton to absorb more carbon; and increasing cloud cover or the reflectivity of clouds that already form..All may have unintended consequences, making the solution worse than the original problem. But it is clear that at least some form of geoengineering will likely be required: capturing carbon dioxide before it is released and storing it in some fashion, either deep beneath the earth, at the bottom of the ocean or in carbonate minerals. Such carbon capture and storage is critical to any serious effort to combat climate change.

CONCLUSION:

Climate change has contributed to changing patterns of extreme weather across the globe, from longer and hotter heat waves to heavier rains. From a broad perspective, all weather events are now connected to climate change. While natural variability continues to play a key role in extreme weather, climate change has shifted the odds and changed the natural limits, making certain types of extreme weather more frequent and more intense. While our understanding of how climate change affects extreme weather is still developing, evidence suggests that extreme weather may be affected even more than anticipated. Extreme weather is on the rise, and the indications are that it will continue to increase, in both predictable and unpredictable ways.

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