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Global Warming And Climatic Changes: Challenge Ahead And Sustainability

Anand Mohan And Baidyanath Kumar
Department Of Biotechnology, College Of Commerce, Arts And Science, Patliputra University, Patna-800020

Abstract:
Naturally variation in solar irradiance, variations in orbital parameters of earth and volcanic activities cause climate change. Portion of incoming solar energy reflects back to space. However, a portion of such outgoing energy is absorbed by atmospheric gases and dusts. This causes an increase in temperature of earth and its atmosphere. The gases which trap the heat energy are known as greenhouse gases. This exponential increase in surface temperature of the earth and the global sea level in the last few decades is a major aspect of climate change.
After the industrial revolution the amount of greenhouse gases in the atmosphere has greatly increased due to human emission of greenhouse gases and removal of natural sinks such as deforestation and oceanic pollution. This process of increase in greenhouse effect causes warming of the earth surface and alters the energy transfer between atmosphere, space, land and the oceans. This phenomenon is referred as global warming.
Greenhouse gases give positive radiative forcing i.e.net increase in the energy absorption by earth due to increase in radiatively active natural greenhouse gases such as CO_2, CH_4, water vapour, N_2O, O_3. In addition HFCs, PFCs and SF6 are anthropogenic in origin and are accounted in national greenhouse gas inventories.
This review article emphasizes the rise of global temperature and CO2 level, rise of global mean annual temperature, factors that increase global warming, rise of annual sea level, sources of greenhouse gases, effects of global warming and mitigation practices of greenhouse effect.
Keywords: *Global Warming, Greenhouse gases, climatic changes*

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I. Introduction

Green House Gases and Global Warming: Naturally variation in solar irradiance, variations in orbital parameters of earth and volcanic activities cause climate change. Portion of incoming solar energy reflects back to space. However, a portion of such outgoing energy is absorbed by atmospheric gases and dusts. This causes an increase in temperature of earth and its atmosphere. Earth is therefore warmer than moon. In case if this natural heat trapping properties are not available the average surface temperature of the earth would be about 33^0C lower[1]. The gases which trap the heat energy are known as greenhouse gases. This exponential increase in surface temperature of the earth and the global sea level in the last few decades is a major aspect of climate change. The earth's atmosphere creates natural greenhouse effect which keeps the earth's surface warmer than it would have been otherwise. Life is an integral part of the earth system and all living things influence the composition of greenhouse gases in the atmosphere by "inhaling" and "exhaling" carbon dioxide and oxygen, thereby maintaining a chemical balance in the atmosphere. A range of human activities, which burning of fossil fuels, industrial activities and the cutting down of forest for agricultural purposes and urbanization, are substantially increasing the concentrations of greenhouse gases in the atmosphere, thereby upsetting this atmospheric chemical balance.

In recent decades, after the industrial revolution the amount of greenhouse gases (GHG) in the atmosphere has greatly increased due to human emission of GHG and removal of natural sinks such as deforestation and oceanic pollution. This process of increase in greenhouse effect causes warming of the earth surface and alters the energy transfer between atmosphere, space, land and the oceans. This phenomenon is referred as global warming. In addition, solar energy or temperature is the driving force of earth's weather pattern as it drives the wind, ocean currents, humidity pattern, movement of clouds etc. thus, the global climate get changed. This also intensify the effect of natural disasters such as storms, flooding rain, landslides, and drought, land degradation and agricultural loss, species loss and epidemics.

Greenhouse gases give positive radiative forcing i.e.net increase in the energy absorption by earth due to increase in radiatively active natural greenhouse gases such as CO2, CH4, water vapour, N2O, O3. In addition HFCs, PFCs and SF6 are anthropogenic in origin and are accounted in national greenhouse gas inventories. There are several gases which influence the global radiation budget such as CO, NO2, SO2 and

secondary pollutants such as tropospheric ozone which is formed due to reaction with volatile organic compounds with oxides of nitrogen under UV radiation. Burning of fossil fuel alone causes 30% increase in the concentration of greenhouse gases (GHG). Earth's surface temperature has risen by 0.18^0C during last century and the projected rise of current (21st) century is ranging between 1.1 and 6.4^0C^2. In the period from 1750 to 2001 increase in CO2 level was observed by 31%, 150% by methane and 16%by nitrous oxide in the atmosphere.

An international environmental treaty, called Kyoto Protocol, linked to the United Nation Framework Convention on Climate Change (UNFCCC) mandated the governments of industrialized nations to take appropriate measures that would control and stabilize global warming by reducing greenhouse gas emissions to a level that would prevent dangerous anthropogenic interference with the climate systems. The increasing energy demand by the growing population, the need for economic growth and improved standard of living in the developing countries, lack of political will and institutional weakness to make and implement appropriate environmental policies, as well as lack of related information and misinformation are the major factors that have militated against measures to reduce greenhouse gases emissions and mitigate the effects of climate change.

Several million years ago earth's CO2 level was greater than 1000 ppm and the average global atmospheric temperature during the evaluation of mammals and dinosaurs was about220C whereas today's global average temperature is 150C3 (Fig-1). Several parts of Arctic and Antarctica were ice free and flourished with ancient trees and animals. Sea level about 55 million years ago was 100m higher than now. Norwegian Island Svalbard has fossil evidences of massive pantodont creatures, Sequoia type trees and beasts like crocodile were living in now frozen Svalbard. If current increase of CO2 and mainly anthropogenic CO2 continues in the same level it will reach 1000 ppm by the year 2100. However, global warming is not a new issue, it happens since prehistoric times. Ancient warming was natural and it was due to volcanic activities and thawing of frozen methane alone4.

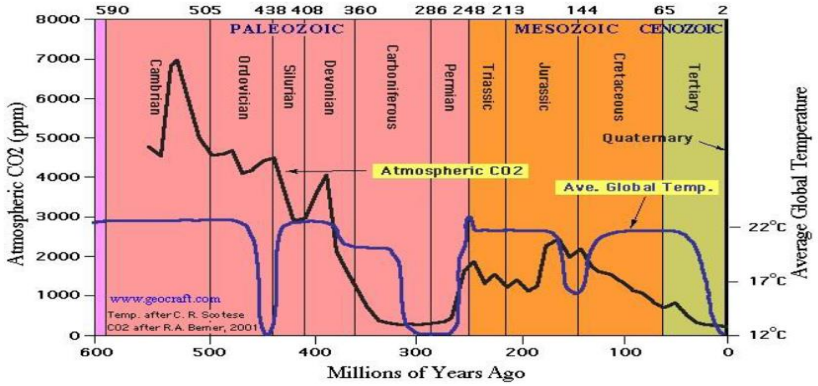

Figure-1: Global Temperature and CO2 levels over 600 million years (Source: MacRae, 2008)

The Climate Research Unit[5] has estimated the global mean annual temperature obtained by combining air temperature measured at weather stations on continents and sea temperature measured along ship tracks on the oceans. This time series is the direct, instrumental record of global warming from 1850 to 2008; the year 2007 was the eight warmest year on record, exceeded by 2005, 2003, 2002, 2004, 2006, 2001 and 1998 (Figure-2).

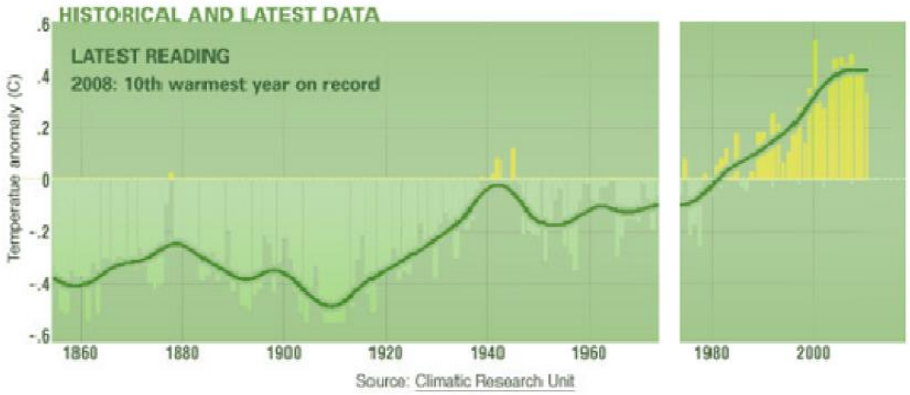

Figure-2: The global mean annual temperature from 1860 to 2000

Global Warming and Climate Change: Global warming and climate change refer to the increase in average global temperatures due to the increase in greenhouse effect by the increase in the greenhouse gases. Natural events such as forest fires, volcanic eruptions, methane release from thawing of permafrost on the ocean floor and release of methane gas from cattle, wet lands and anthropogenic sources of exhausts from all kinds of combustion, industrial production of greenhouse gases, agricultural water lodging activities such as paddy cultivation artificial wet lands and deforestation. Warming of the earth causes rapid changes in pre-existing weather pattern. According to National Oceanic and Atmospheric Administration (NOAA) there are several indicators those changes with the warming world.

Factors increases with global warming: The important factors that increase with global warming are Temperature of land, Sea surface temperature, Troposphere temperature, Temperature over oceans, Ocean heat content, Sea level and Humidity.

Factors decreases with global warming: The factors that decreases with global warming are Glaciers, Snow cover and Sea ice.

Greenhouse Effect: Weather and climate of the earth is driven by solar energy. Solar radiation heats the earth surface, which in turn radiates back into the space. The atmospheric gases trap some of the outgoing energy and retain heat. This causes an increase in the global temperature and also causes the pattern of global weather. Gases which trap the heat energy are known as greenhouse gases. All the green house gases are capable of disturbing energy balance in the atmosphere. Global warming potential (GWP) can be measured in terms of cumulative radiative forcing caused by unit volume of gas over a given period of time. Generally it is measured with reference to the GWP of the CO2. If GWP of CO2 over a period of 100 years is 1, then GWP of methane is 34. The GWP value as measured by Myhre *et al*.,[6] is presented in Table-1

Table-1: The GWP values and Life times

Greenhouse gases	Life times in years	GWP time horizon in 100 years
Methane	12.4	34
HFC (Hydro fluorocarbon) 134a	13.4	1550
CFC-11 (Chlorofluorocarbon)	45.0	5350
N2O (Nitrous oxide)	121.0	298
Carbon tetra fluoride (CF4)	50000	7350

There are ten indicators by which global warming can be observed[7 & 8]. These include shrinking thermosphere, rising tropopause, less oxygen in atmosphere, release of 30 billion tons of CO2 annually, night warming faster than days, more fossil fuel carbon in coral, more heat return to earth, more fossil fuel carbon in the air, cooling of stratosphere and less heat escape to the space (Figure-3).

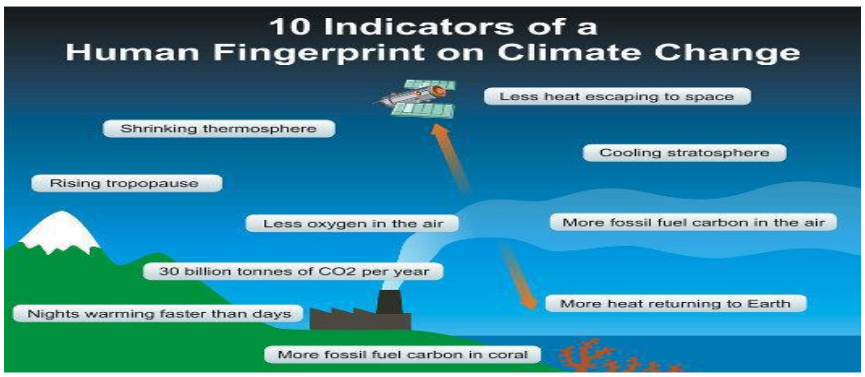

Figure-3: Ten indicators on climate change

Evidences in favour of Global warming from measurement: Results obtained from the analysis of three independent sets of observations viz., surface air temperature measurements, sea level changes and temperature profiles in boreholes show that the surface temperature of the earth is on the increase there by warming up the globe. Results obtained from each of these sets of observations confirm and complement each other. In addition, images from satellite observations of the earth surface and lower atmosphere reveals details of the effects of the increasing concentration of greenhouse gases on global warming and climate system.

Surface temperature: Analysis of the routine measurements of the earth's surface temperature reported daily from thousands of weather stations across the globe, both on land and at sea, suggests that the surface of the earth has warmed by an average of 1.0°C (1.8°F) in the last 100 years[9]. The daily temperature measurements are combined to produce mean weekly, monthly and annually temperatures. Thus, the averaged annual temperature change from year to year can easily be tracked. The mean annual temperature measurement

for a period of over 150 years (from 1850 to 2008) is shown in Figure-1. Measurements of air temperature made at weather stations were integrated with measurements of sea temperature to produce mean annual temperature for the entire globe. The graph shows a gradual increase in temperature with a minimum anomaly of about -0.5°C to a maximum of about +0.5°C. The graph indicates a steady increase in surface temperature between 1860 and 1910 and a rapid increase between 1910 and 1945, stabilizing for about 3 decades and increasing rapidly again after 1975. In the last two decades, the global mean temperature has increased by 0.1°C per decade, with 2005 being the warmest year on record[10 & 11]. Statistical methods are used to close the gaps in the measurements. The effects of large population centers on the global mean temperature, called "urban heat island effect" are computed and corrected for; however, this account for less than 15% of the observed global warming. Global warming is not uniform across the globe, both in time and in space; high latitude regions generally experience more warming than low latitude regions[12]. All regions of the earth have experienced years of cooler temperature imbedded within the warming trend. The observed spatial and temporal irregularity in global warming is an indication of a chaotic nature of global warming and climate change.

Sea Level Rise: Another pointer to global warming and climate change comes from a completely independent set of observations (the measurements of sea level changes). The volume of water in the oceans is increasing due to thermal expansion of water in the oceans, and the melting of glacier and polar ice, resulting from increasing warming of the earth. As in temperature measurements, daily sea level observations are made at many locations; daily sea level fluctuations, mainly due to tides and storms, are averaged out to obtain mean sea level over a given period of time. The mean annual sea level change per annum between 1880 and 1990 (left chart in Figure-4) and is currently rising at the rate of about 3.4 mm per annum (right chart in Figure-4). Like global temperature changes, sea level changes are not steady and the detailed changes are not exactly synchronous with surface temperature measurements. The thermal expansion of the water column tends to come later than the corresponding change in surface temperature; the differences are affected by ocean currents. The observed irregularity in sea level changes is another indication of the complexity and chaotic character of the interactions being witnessed by our planet resulting in climate change.

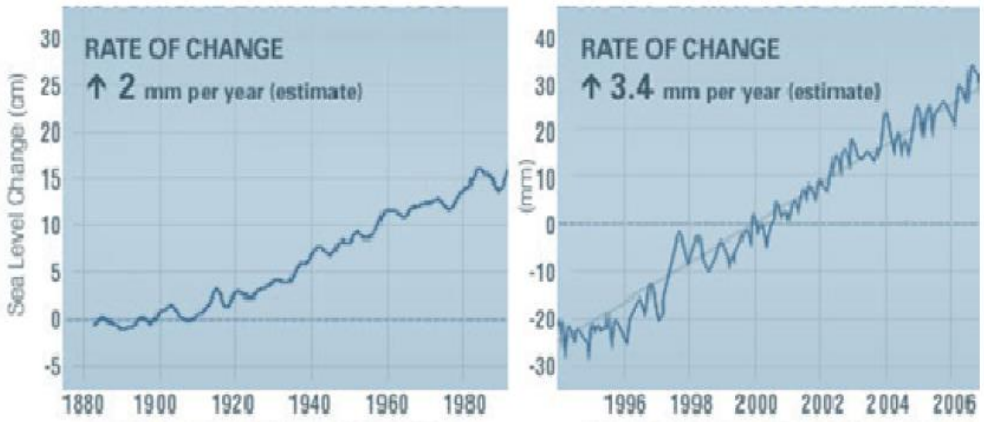

Figure 4: Mean annual sea level rise associated with the thermal expansion of sea water due to warming and widespread melting of ice sheets. Left chart: Historical sea level data derived from 23 tide-gauge measurements. Right chart: Average sea level since 1993 derived from global satellite measurements (NASA, 2009).

Borehole temperature profile: A third confirmation of global warming and climate change comes from an unlikely source – the thermal history of the earth's subsurface. The subsurface retains records of temperature changes over a period of time that can be linked to the prevailing climatic conditions about the time. This geothermal history can be accessed by measuring temperature profiles with depth in boreholes, tunnels and deep mines using sensitive thermometers. Expected temperature increase due to the upward flow of heat from the earth's interior, heat generated by crustal rocks, temperature anomalies due to geological features and fluctuations in groundwater movement are usually corrected for. The downward propagation of surface temperature oscillation attenuates with depth, with short period fluctuations attenuating more rapidly than longer ones. Thus, only long period variations of heat penetrate great depths, with seasonal variations penetrating about 15 m before the signals eventually die out. In contrast to seasonal variations, century long variations can penetrate inexpensive drilling. The subsurface acts like a selective filter which discriminates against short period temperature variations, thereby retaining excellent records of global warming and hence climate change. Figure- 4 shows evidence of surface temperature changes from the analysis of several geothermal data sets from North America. The temperature profiles of boreholes spread across a length of about 500 km of northern Alaska shows anomalous warming of 2 to 5°C in the upper 100 to 150 m of the permafrost

and rocks[13]. Similarly, borehole temperature profiles in eastern Canada as recorded by Nielsen and Beck[14], 1989 and Wang and Lewis[15] shows a less rapid warming of about 1.0°C. A warming of about 0.5 and 1.0°C are observed in Nebraska sites[16] and Utah sites[17]respectively. These results clearly show that geothermal data mimicked the geographic variations of warming as observed in weather stations data. Past centuries baseline temperature can be inferred from geothermal data, thus making it possible to connect the beginning of the industrial revolution to the present century and thereby access the impact of industrialization on global warming and climate change.

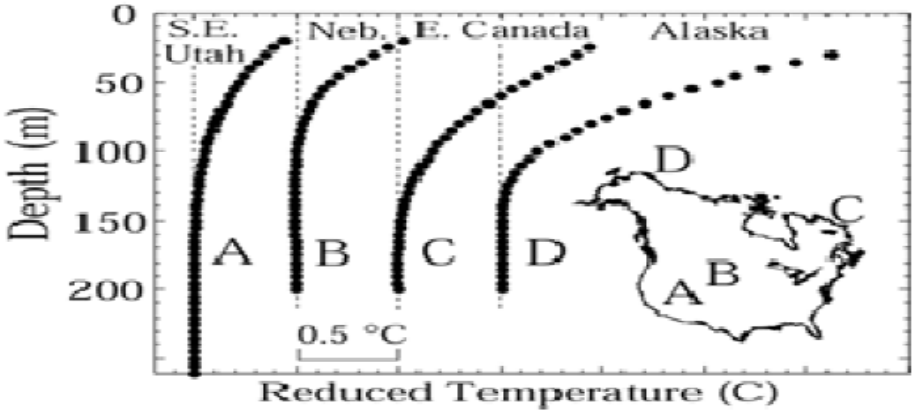

Figure -5: Borehole temperature profiles from sites in North America showing warmer temperatures within near-surface depths of 100- 150 metres. The temperature profiles suggest substantial warming in the last century from 0.6 °C in southeast Utah to more than 2.0 °C in Alaska. Curves are arbitrarily offset for display purposes (after Chapman and Davis, 2007)[18].

Satellites Observations Of Earthlights: The solar radiation from the sun is balanced by the thermal radiations emanating from the earth; this energy balance determines the surface temperature of the earth. The incoming solar radiation depends on the solar output and the distance between the sun and the earth, and is independent of the surface temperature of the earth. On the other hand, the outgoing thermal radiation from the earth strongly depends on the earth's surface temperature. If the atmosphere was composed only of nitrogen and oxygen molecules, which do not absorb thermal radiation, the surface temperature of the earth would be controlled to about -6°C by the energy balance. This surface temperature would render much of the planet frozen. The presence of greenhouse gases, majorly water vapour, carbon dioxide and methane, in their natural abundance in the atmosphere would cause some of the outgoing thermal radiation to be trapped, thereby establishing a new energy balance with a surface temperature of about +15°C. This phenomenon, which amounts to 21°C of warming of the earth's surface, is usually called natural or beneficial greenhouse effect.

Details of the effect of greenhouse gases in the atmosphere are confirmed by satellite observations of the earthlight (Figure-6), the outgoing thermal radiation from the earth. Without an atmosphere to absorb thermal radiation, the atmospheric radiance is mapped by a smooth curved called the spectrum which peaks at a wavelength of about 20 μm, almost 40 times the wavelength of the incoming visible light. But not all the thermal radiation gets out, as much of the thermal radiation is absorbed by greenhouse gases: water vapour (45%), carbon dioxide (30%), methane (20%), and other minor greenhouse gases that account for the remaining 5%. This shows that most of the outgoing thermal radiation is absorbed by water vapour and carbon dioxide. But the change that occurs in the amount of water vapour in the atmosphere due to human activities is negligible. The greenhouse gases (Figure-7) that are changing rapidly as result of human activities are carbon dioxide, methane, nitrous oxide, ozone and chlorofluorocarbons (CFCs), and carbon dioxide is the most worrisome. The irradiative forcing increases with increasing atmospheric concentration of the human-derived greenhouse gases. The five gases shown in Figure-7 account for about 97% of the direct climate change forcing by long-lived greenhouse gas increases since 1750 and the remaining 3% is contributed by an assortment of 10 minor halogen gases[19]. The major sources contributing to the increasing concentration of carbon dioxide in the atmosphere include the burning of fossil fuels, cutting down of forest for agricultural purposes and industrial activities. About 5.4 billion metric tons of carbon is released into the atmosphere annually from the burning of fossil fuel. About 1.6 billion metric tons of carbon is in addition emitted into the atmosphere by deforestation for agricultural and other land use purposes. Figure 6 shows the global annual fossil fuel carbon dioxide emissions in million metric tons of carbon[20]. The data for the plots in Figure-7 were originally presented in terms of solid (coal), liquid (petroleum) and gas (natural gas) fossil fuel sources, and separates terms for cement production and gas flaring (natural gas lost during exploitation of oil and gas). The plot for gas flaring is the

smallest of all the categories and was added to the total emission of carbon dioxide from burning of natural gas. The carbon dioxide from cement production results from the thermal decomposition of limestone into lime, thus are technically not a fossil fuel sources.

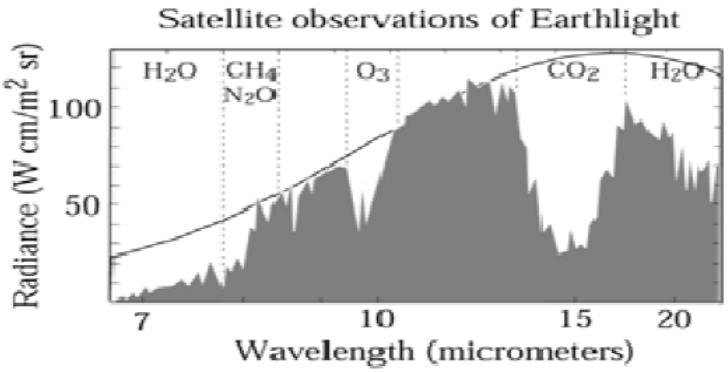

Figure-6: Earthlight confirms greenhouse effect; thermal radiation emitted from the earth's surface as observed by satellite instrument looking down the earth (irregular line). In the absence of greenhouse effect, the radiance would follow the solid smooth curve (Houghton, 1997)21 & 22.

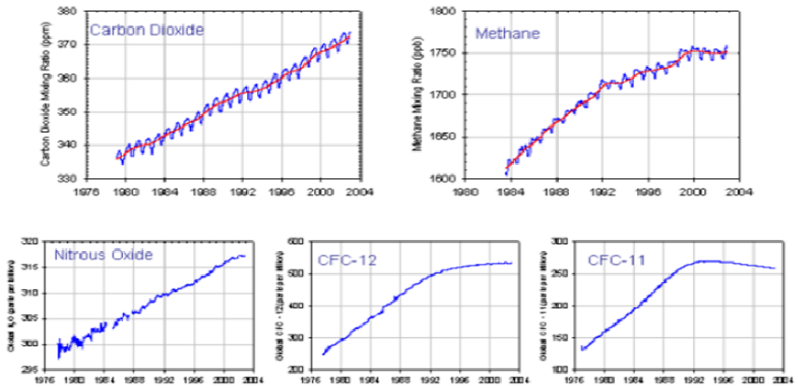

Figure-7: Global trends in major long-lived greenhouse gases between 1997 and 2003. The five gases shown account for about 97% of the direct climate change forcing by long-lived greenhouse gas increases since 1750 and the remaining 3% is contributed by an assortment of 10 minor halogen gases (Source: NOAA, 2005)[19].

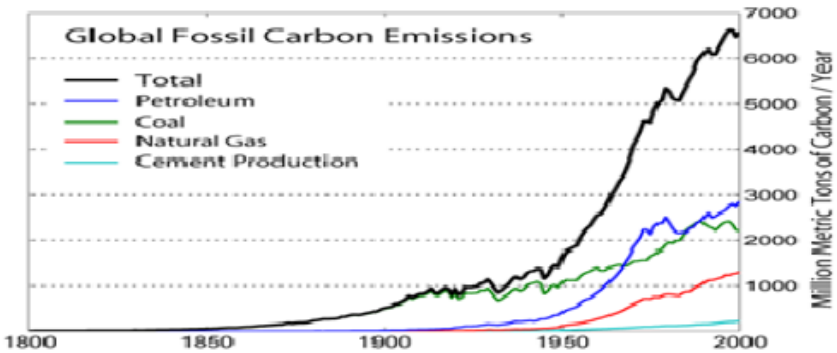

Figure-8: Global annual fossil fuel carbon dioxide emissions in million metric tons of carbon (Marland *et al.*, 2003)[20].

Variations in the concentration of carbon dioxide in the last 400 thousand years are given in Figure-9a. The largest changes that occurred can be related to glacial/interglacial cycles within the current ice age. Glacial cycles are mainly caused by changes in the earth's orbit; these changes also influence the carbon cycle which in turn feeds back into the glacial system. Since the industrial revolution in 1900, the burning of fossil fuels has caused a dramatic increase in carbon dioxide concentration in the atmosphere, reaching levels unprecedented in the last 400 thousand years. This increase has been largely implicated as the primary cause of global warming and climate change. The combined emissions of carbon dioxide from fossil fuel sources and deforestation

amount to about 30% increase in the concentration of carbon dioxide in the atmosphere from 280 to 385 parts per million by volume (ppmv) since 1860 as revealed by results of the experimental observation made at Mauna Loa Observatory in Hawaii (Figure-9b). The results show a rise and fall of carbon dioxide in the atmosphere to about 6 ppmv per annum, indicating the growing and dormant seasons for plants; but the annual maximum and minimum carbon dioxide increases by about 1.5 ppmv. This annual growth in the concentration of carbon dioxide in the atmosphere poses a major threat to global warming and climate change because the average lifetime of carbon dioxide in the atmosphere is 100 to 150 years. Carbon dioxide can only be depleted by dissolution in the oceans over time, but much of it is spewed back to the atmosphere as a result of warming.

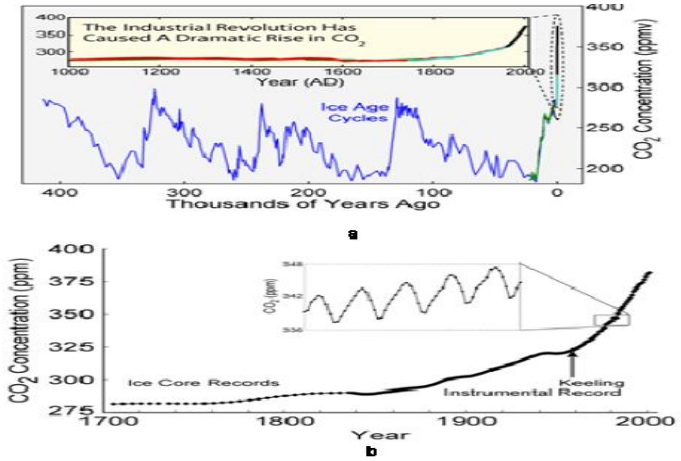

Figure-9: Variations in the concentration of atmospheric carbon dioxide: (a) in the last 400 thousand years, the largest changes that occurred can be related to glacial/interglacial cycles within the current ice age; and (b) between 1700 and 2000, the concentration of carbon dioxide in earth's atmosphere increased steadily from 270 to 385 ppmv since 1700 (Source: Mauna Loa Observatory, NOAA).

The major sources of Greenhouse gases

The major sources of green house gases as suggested by Kemp[23] are as follows (Table-2).

Table-2: Sources of Greenhouse gases

Sector	Activities	Greenhouse gases
Energy	**Combustion of Fossil fuels, Leakage of Natural gases, Industrial activities, Biomass burning**	**CH_4, N_2O, CO_2 and O_3**
Forest	**Harvesting, Clearing and Burning**	**CH_4, N_2O and CO_2**
Agriculture	**Paddy fields, Animal husbandry and Fertilizer uses**	**CH_4, CO_2 and N_2O**
Waste management	**Sanitary landfill incineration and Biomass decay**	**CO_2, CH_4, N_2O, O_3 and CFCs**
Industrial	**Metal smelting and processing, Cement production, Petrochemical production and miscellaneous activities**	**CO_2, CH_4, N_2O, CFCs, SF_6, CF_4, C_2F_6**

Some important Greenhouse gases: CO_2: The atmospheric temperature increases as the CO_2 concentration rises22 & 23. CO_2 contributes about 56% of the global warming. The major source of CO_2 is burning of fossil fuel. Volcanic eruption and forest fires account for large efflux of CO_2. Increased deforestation, degradation of oceanic algal photosynthesis due to marine pollution also reduces the uptake of CO_2 from the atmosphere. According to NASA GCC[24] the current CO_2 level is expected to increase 2.75 ppm/year.

Methane: In the atmosphere, methane is produced by decaying process of biomass in natural wetlands. It has GWP of 21 and its radiating force is 11%. Methane in the atmosphere increases at the rate of twice the rate of CO_2. Methane reacts with OH- ions to produce water and CO_2 and therefore, its life span is reduced in comparison to CO2. Anthropogenic sources account for half of its release to the atmosphere. Agricultural activities increase with increase cattle and pig farming and non-dairy ruminants. These activities increase methane in the atmosphere. Tropical grass lands of termite concentrated areas and forests release considerable amount of methane[25]. The flooded wetlands due to anaerobic decomposition of cultivated crops also generate methane. Coal mining process and oil refineries plants also generate a huge amount of methane[26]. A huge amount of methane is also trapped in higher latitude permafrost and in deep ocean sediments as methane

hydrates and Clathrates[27]. The current methane emission is estimated to be 450-500 Tg per year (NASA GISS[28]).

Nitrous oxide (N_2O): Nitrous oxide ranks third highest greenhouse gas whose increase in rate is 0.1-0.7% per year[29]. N_2O is released from fertilizers during intermittent process of nitrification and de-nitrification, breakdown of nitrogen from livestock manure and urine. These account for 5% of the global N_2O efflux. Nitrous oxide is also produced as by-product during industrial production of nitric acid and inorganic fertilizers and production of nylon[30].

CFC in Global warming: CFCs are halogenated carbon used as refrigerants, insulating foams and aerosol sprays. The GWP of CFCs is 12,000 and its radiative forcing is 24%[31]. However, the use of CFC is completely banned by Montreal Protocol.

Effects of Global warming:

1. Rise in sea level: There are two basic factors to rise in sea level. First, by addition of water from melting ice and the second, expansion of sea water due to warming. Shaftel[34] calculated that the rate of increase in sea level is 3.19 mm per year. This causes loss of low lying land, submergence of island states in Indian and Pacific Ocean might disappear completely, loss of valuable habitats and beaches (Figure-10).

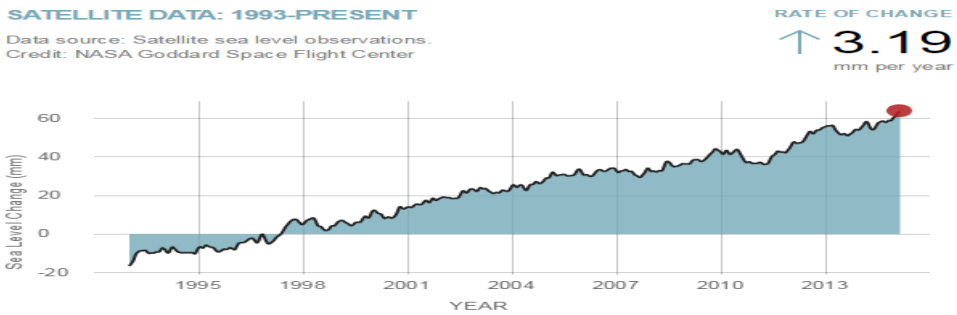

Figure-10: Sea level change according to NASA Global Climate Change Land Ice (2015).

2. Warming Oceans: Absorption of heat by the oceans by the 700 m of the sea cause warming of ocean to about 0.302^0F.

3. Shirking Ice Sheath: In Green land and Antarctica the ice sheaths are declining in their mass. It has been estimated that the Greenland lost 150-250 cubic kilometer of ice per year and Antarctica about b152 Kilometer of ice per year. According to NASA-GCC-Land ice (2015) the loss of ice mass in Antarctica is at the rate of 147 billion metric tons of ice per year, and 258 billion metric tons per year in Greenland.

4. Declining trend of Arctic sea ice: Snow causes reduction in warming by reflecting the sunlight back. The melting seasonal snow provides fresh water for life. Increased ice melting due to global warming leads to spring time floods.

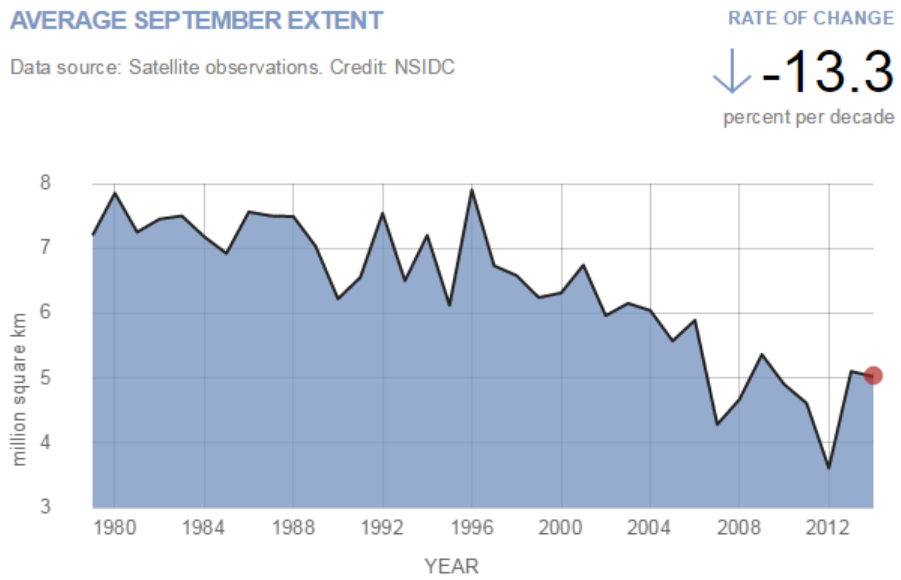

Figure-11: Decline in arctic sea ice (NASA GCC Arctic Sea Ice[32])

5. Melting of Antarctic and loss of ice shelf: According to Shaftel[34] there is a mass loss of 1,089 trillion kilogram ice per year in Antarctic ice shelves. Warm ocean water melts the ice sheet from underneath, and this account for 55% of the ice shelf melts.

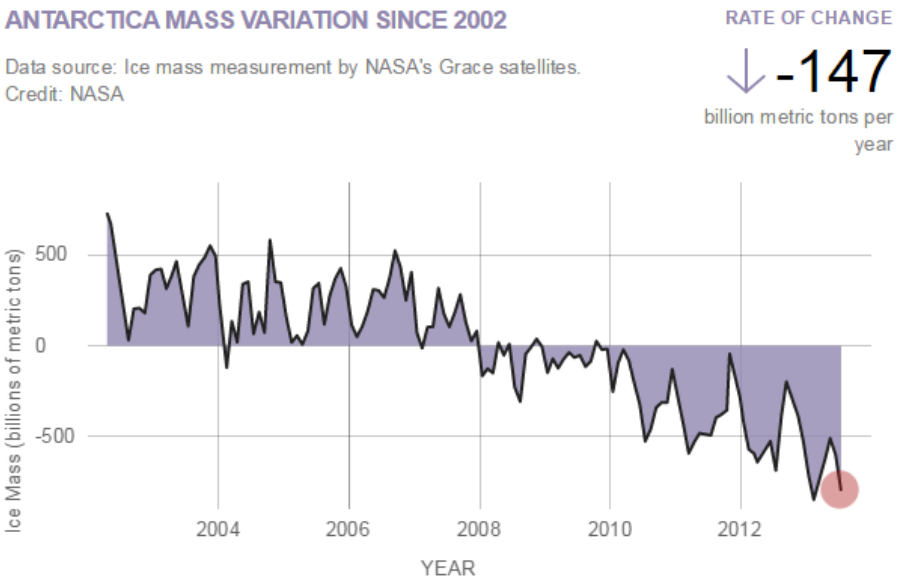

Figure-12: Year wise mass variation in Antarctica (NASA Global Climate Change Land Ice[33]).

6. Glacial retreats: Glaciers are retreating everywhere such as Alps, Himalayas, Andes, Rockies and Africa.

Some important extreme events caused by global warming include flood and landslides, Hurricanes and Tornadoes, Droughts, Forest fires, Heat waves, Ocean acidification[35, 36, 37].

Global warming adversely affects biodiversity and health. Epidemics of water and vector bore diseases increase due to global warming.

Mitigation of greenhouse effect: There are several methods to reduce the greenhouse effects. These include CO2 mitigation, carbon sequestration, nitrogen oxide (NOx) mitigation, afforestation and reforestation etc. Several approaches have to be adopted to mitigate global warming. These include increase energy efficiency in engines and boilers, reduction of greenhouse emission in industries, development of agriculture, restoration of wetlands etc.

II. Conclusions:

Global warming is increasing day by day and an important environmental issue. The average temperature of earth is warmed by 0.8^0C because about 30 billion tons of CO2 is being released to atmosphere. Carbon capturing and sequestration can be employed to minimize the CO2 level in atmosphere. Clean Development Mechanism (CDM) of Kyoto protocol promotes the reduction of greenhouse gas emission.

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