UNIT 2 CLIMATE CHANGE

Structure

2.1 INTRODUCTION

Climate change is not new for the planet earth. It has been happening across history. We have reasons to believe that during the past 650,000 years there have been seven cycles of glacial advances and retreat. The last ice age ended abruptly about 11,700 years ago and marked the beginning of the modern climate era and human civilization (NASA, 2020). Most of such climatic changes can be attributed to small variations in the earth's orbit that change the incoming solar energy to our planet.

As per the report from the scientific working group in the IPCC TAR **(IPCC, 2001)** the Earth's climate system has demonstrably changed on both global and regional scales since the pre-industrial era. This phase of climate change carries a special significance because it is extremely likely (with 95-100 % probability) due to human activities (IPCC, 2014, p4). There is compelling evidence based on observations, theories and modelling that much of the climate change which we are seeing at the moment is due to human activities. Such anthropogenic activities have been progressing at an unprecedented rate since the onset of industrial societies. This period which is quite often referred to as a period of great acceleration coincides with the accelerated rate of emission of Green House Gases (Steffen et al., 2015). There is enough scientific evidence to prove a positive correlation between GHGs and temperature (Petit et al, 1999, p429). According to the analysis of 11,944 scientific papers, written by 29,083 authors and published in 1980 journals, there is over a 97% consensus on anthropogenic global warming (Cook et al. 2013; Lehtonen, Salonen and

Cantell, 2019). However, there is still major uncertainty about the magnitude of the rise in Global Mean Surface Temperature (GMST) in response to a given amount of greenhouse forcing.

In the past century alone, the temperature has increased by 0.7 degrees Celsius, which is roughly ten times faster than the average rate of ice age recovery warming (NASA, 2020). The technological advances, particularly in the field of palaeoclimatology have now significantly enhanced human capacities to monitor changing climatic conditions on earth, analyze the data and reveal the signals of changing climate.

Current global temperatures are 0.8°C higher than pre-industrial levels and research shows that 1.5°C of warming is already locked into the Earth (World Bank Group, 2014a). The business-as-usual approach will lead the world to warming of 2°C by the middle of the century and 4°C or more by the time today's teenagers reach their 80s (World Bank Group, 2014a). Climate change is not merely confined to GHGs and a rise in temperatures but has widespread implications for human existence. This unit aims to give detailed information about definition, causes, mechanism, impacts, extent, intensity and policy.

2.2 OBJECTIVES

After studying this unit, you should be able to:

- define climate change;
- explain the mechanism and causes of climate change;
- explain the extent and intensity of climate change through some case studies;
- explain the impacts of climate change and
- explain the implications of climate change on the policies.

2.3 DEFINITION OF CLIMATE CHANGE

As per the UNFCCC, climate change is referred to as "any change in climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods" (UNFCCC 1992). However, according to the Intergovernmental Panel on Climate Change (IPCC), an international entity of United Nations (UN), climate change refers to "a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer" (IPCC 2015, p. 120). So, climate change is "*any change in climate over time, whether due to natural variability or as a result of human activity*" (IPCC 2014). There is a difference between the usage of the term climate change in the UNFCCC and IPCC. Though the definition given by UNFCCC talks about only human-induced climate change, we find that the IPCC has adopted a broader definition that includes both natural and human-induced climate change.

2.4 CAUSES OF CLIMATE CHANGE

Now, there is categorical research evidence to prove that climate change is real and that human interventions are the major contributing factors to such changes (IPCC, 2014, p4). Though there have been natural climate variability due to natural internal processes within the climate system, there is an overriding impact of alterations in the atmosphere due to human or anthropocentric activities. In a report published in 2015, IPCC had emphasized the impact of human influence saying that "*Human influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gases are the highest in history. Recent climate changes have had widespread impacts on human and natural systems*" (IPCC 2015, p. 2). Another recently published IPCC report highlights that *"human influence has become a principal agent of change on the planet, shifting the world out of the relatively stable Holocene period into a new geological era, often termed the Anthropocene"* (Allen et al. 2018, p. 53)

Response to climate change has changed both in definition and scope. Though initially, the focus was on reducing and stabilizing human-induced GHG emissions in the atmosphere, it has subsequently become broad-based (UNFCCC 1992). In addition, the scope of climate actors has also started involving non-state actors like the private sector, cities, civil society, and multilateral development institutions among others (UNFCCC 2018).

2.5 DRIVERS OF CLIMATE CHANGE

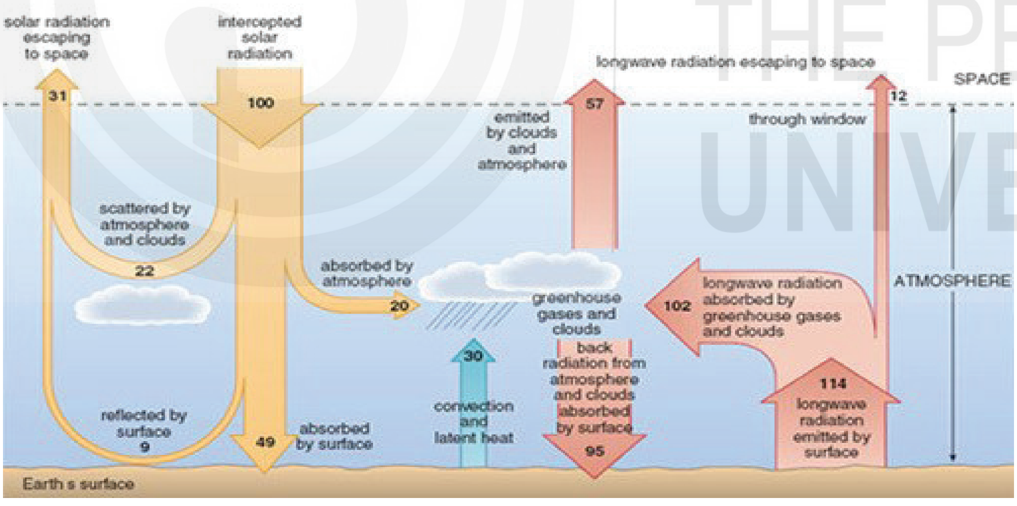

Fig. 2.1 Energy Budget of Earth and its atmosphere: A Schematic representation Source: UKOU website

The schematic diagram as shown in Fig. 2.1 displays the energy budget of the earth and atmosphere. The figures are global annual averages expressed as a percentage of the rate per unit area at which solar radiation is intercepted by the Earth; i.e., 100 units are equivalent to 342 W m^{-2}. Fig. 2.1 demonstrates that the entire Earth-atmosphere system is in a dynamic equilibrium. However, as we can see from this figure that energy circulates within the system at a higher rate compared to the rate of input or output at the top of the atmosphere. Therefore, we find the earth's surface to be warmer than it otherwise would be. We also observe from this figure that there is no net accumulation of thermal energy in any specific part of the earth-atmosphere system. Therefore, Global Mean Surface Temperature (GMST) cannot change in this scenario. It is however interesting to find out what might cause Earth's GMCT to change? If we look at the energy budget as depicted in Fig. 2.1, we can easily understand that any disturbance in the radiation balance at the top of the atmosphere has the potential to force the global climate to change. Such a disturbance can either warm-up or cool down till a balance is reached. This kind of energy perturbation in the energy balance of the entire earth-atmosphere system (expressed in W m^{-2}) is called radiative forcing. Starting from its first major report published in 1990, IPCC has used the concept of "radiative forcing" as the potential mechanism for climate change. There could be several ways in which the energy balance can get disturbed.

1. **Change in Solar Constant**

   For instance, we can work out the effect of change in the solar constant. Let us assume that planetary albedo remains unchanged (at 31%). Under these circumstances, an increase in the solar constant will lead to a positive radiative forcing. It means that the earth-atmosphere system will absorb solar radiation at a higher rate than the rate at which it emits. It will have a warming effect. Similarly, a reduction in solar constant will create a negative radiative forcing thereby leading to a cooling effect.

2. **Volcanic Eruptions**

   The energy balance can also be disturbed by volcano eruptions which generally discharge a huge quantity of gases and volcano ash into the atmosphere. Sometimes these eruptions are so powerful that they inject materials up to the stratosphere. At such high altitudes, these materials gradually spread around the world and bring about a widespread cooling effect for a long time. The sulphur dioxide emitted during the eruption has a far-reaching impact as chemical reactions convert this gas into droplets of sulphuric acid. These sulphate aerosols persist in the stratosphere for several years and enhance the backscattering of solar radiation. However gradually these aerosols comedown to the troposphere and get washed away by rain.

BOX-2.1: Case Study: Impact of Volcano Eruption on Climate Change

The eruption of Mount Tambora, a large volcano event in Indonesia in April 1815 and its impact on climate change is well documented. It resulted in a period of abnormally cold weather during the spring and summer of 1816 and its impact was severely felt in many parts of the Northern Hemisphere, especially in the northeastern United States. Average temperatures in New England were observed up to 3.5 °C below normal in June besides unseasonal frosts and snowfalls. Similarly, Europe also suffered from crop failures and famine in England, France and Germany. The below-average temperatures lasted for about two years. Even in the summer of 1816, there were also widespread reports of a dim Sun or persistent haze that was not dispersed by surface wind or rain (since it was actually up in the stratosphere).

3. Accumulation of Greenhouse Gases in the atmosphere

The increasing burden of greenhouse gases can also create imbalances in the radiation budget of the earth-atmosphere system and thus give rise to radiative forcing. This fact can be well understood through an illustrative example. Let us assume that the atmospheric concentration of carbon dioxide is doubled instantaneously but other parameters, for instance, the solar input, planetary albedo, concentrations of other greenhouse gases, etc. remains the same. The obvious impact will be higher absorption of outgoing long waves and consequent reduction in net emission to space (from 236 W m^{-2} to 232 W m^{-2}) for a CO_2-doubling. It gives a very reliable reason to believe that increasing anthropogenic concentrations of greenhouse gases have created warming of the earth's atmosphere (which may also be referred to as greenhouse forcing).

Observed warming in the earth's atmosphere cannot be explained keeping in view the natural factors alone and thus can largely be attributed to anthropogenic influence. IPCC (2007) states that during the last 50 years "the sum of solar and volcanic forcings would likely have produced cooling, not warming".

CHECK YOUR PROGRESS 1

Note: i) Use the space given below for your answers.

ii) Check your answers with those given at the end of the unit.

1. List out three possible factors which could disturb the radiation balance at the top of the atmosphere?

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2.6 EXTENT OF CLIMATE CHANGE

We have sound reasons to believe that the concentration of carbon dioxide and other greenhouse gases is increasing in the atmosphere. Furthermore, monitoring programs established during the 1980s reveal an upward trend in the levels of two other natural greenhouse gases namely methane (CH_4) and nitrous oxide (N_2O). There are very convincing reasons to believe that buildup of all three greenhouse gases is non-linear and can be attributed to human intervention including a very unlikely source - the vast ice sheets of Greenland and Antarctica.

It is now well-realized and understood that fossil-fuel-based material consumption and changing lifestyles are the major culprits for climatic change. These factors have increased the emission of Greenhouse Gas (GHG) for example carbon dioxide, methane, and nitrous oxides (Allen et al. 2018, p. 53). The impact of such emissions results in rising temperature across the globe which has manifestations like increased floods and droughts, sea-level rise, biodiversity loss, loss of agricultural productivity, and risks to human health. Such impacts thwart initiatives for sustainable development, particularly in those countries which are most vulnerable to its impacts. The extent of climate change as manifested in different indicators is summarized in Table 2.1.

Table 2.1: The Extent of Climate Change as manifested in different indicators

Indicator	**The extent of climate change**
Levels of CO_2 observed at Mauna Loa	The data collected from Mauna Loa shows a consistent rise in CO_2 concentration. These measurements began in 1958 when the level was 315 ppm. However, levels had reached more than 378 ppm in 2004. It appears to be accelerating. For instance, it took around 200 years (1750 to 1975) for carbon dioxide levels to build up from 280 to 330 ppm but it took just 30 years for it to increase by a further 50 ppm. It has also been seen that the three natural greenhouse gases are fairly uniformly mixed up in the troposphere. Hence their concentration in the atmosphere does not vary much from place to place.
Rising global mean temperature	Global mean warming is now approximately 0.8 degrees Celsius above preindustrial levels (World Bank,2012, ch2, p6)
Increasing ocean heat storage	Approximately 93 per cent of the additional heat absorbed by the earth, resulting from increasing greenhouse gas concentration since 1955 is stored in the ocean. Between 1955 and 2010 the world's oceans to the depth of 2000 m have warmed on average by 0.09 degrees Celsius (World Bank,2012, ch2,p7).
Rising Sea Levels	Sea level rise has been indicated to be 20 cm from the pre-industrial times to 2009. The rate of sea-level rise was close to 1.7mm/year during the 20th century. This accelerated to 3.2 mm/year on average since the beginning of the 1990s (World Bank,2012 ch2, p8).
Increasing loss of ice from Greenland and Antarctica	Both the Greenland and Antarctic ice sheets have been losing mass since at least the early 1990s and losses of ice are shared roughly equally between them (World Bank,2012 ch2, p8).
Loss of Arctic Sea Ice	The linear trend of September ice extent since the beginning of the satellite record indicates a loss of 13 per cent per decade (World Bank,2012 ch2, p12).
Ocean Acidification	From 1750 to 1994, a decrease in surface pH of 0.1 has been calculated, corresponding to a 30 per cent increase in H^+ ions. An increase in ocean acidity is more pronounced in higher latitudes than in tropics or subtropics (World Bank,2012 ch2, p11).
Heatwaves and extreme temperature	Heatwaves with temperatures typically more than 3 Standard Deviation warmer, which were highly unusual earlier, started getting more frequent. The five hottest summers in Europe since 1500, all occurred after 2002(World Bank,2012 ch2, p13).
Source: Compiled from World Bank (2012, ch 2)	

BOX 2.2: The CO_2 Measurement Observatory at Mauna Loa

The hypothesis proposed by John Tyndall (Tyndall 1861) that the concentration of atmospheric CO_2 influences the climate of the earth, were systematically investigated by Charles D. Keeling. He started systematically measuring atmospheric CO_2 in 1958 at the Mauna Loa Observatory, Hawaii (Keeling et al. 1976; Pales & Keeling 1965). Mauna Loa was especially identified as a suitable place for this purpose primarily because it was remote from external sources and sinks of carbon dioxide. Mauna Loa Observatory is located on the north flank of Mauna Loa Volcano, on the Big Island of Hawaii, at an elevation of 3397 meters above sea level. The Observatory has been collecting and monitoring data related to atmospheric change since the 1950s. Mauna Loa is strategically identified for measuring CO_2. Firstly, it's isolated and far from sources of pollution and secondly, its lava coated flanks are free from plants and trees thereby making it free from their processes of photosynthesis. Despite its location on the active volcanic island, volcanic emissions, from the summit do not reach the observatory where atmospheric carbon dioxide is measured. However, any rare instance of elevated level can be easily removed from the final data set using simple mathematical filters (Earth Observatory, 2006). The measurements of Keeling show an increase from 316 ppm (parts per million) in March 1958 to 391 ppm in September 2012. However, the seasonal variations were superimposed on this generally increasing trend. Such small variations can be attributed to the growth of plants in the Northern Hemisphere leading to greater uptake of carbon from the atmosphere (Pales and Keeling 1965).

Source: NASA

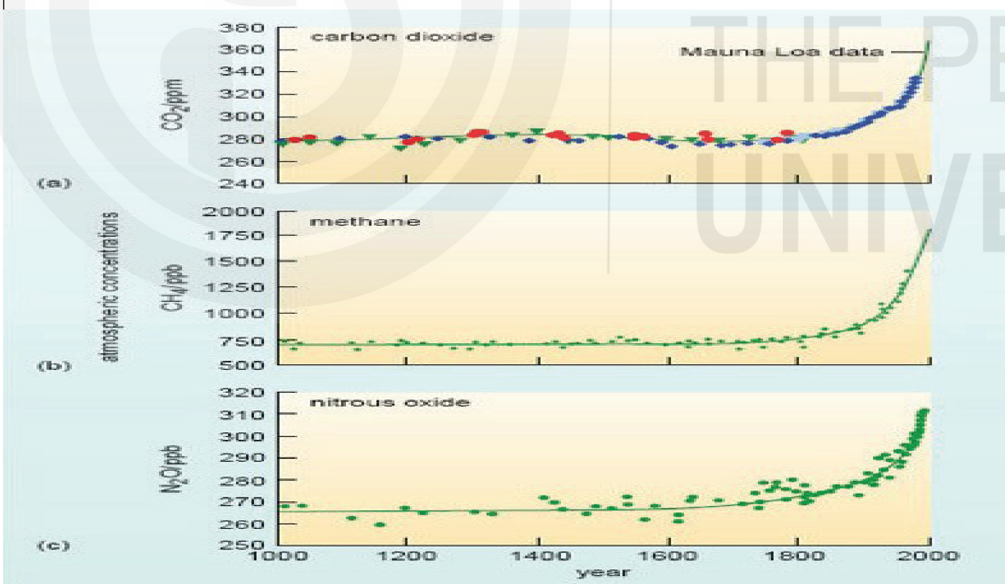

Fig. 2.2 Changing concentration of Greenhouse Gases

BOX 2.3: HOW DO WE MEASURE TEMPERATURES PREVAILING IN PAST CLIMATES

It is a challenge to find out the temperatures prevailing in past climates. There are several proxy ways to reconstruct past climates. These methods give us indicative figures of the temperatures.

a. Archaeological Inscriptions and Historical Documents

For a long time in human history, people have recorded the vicissitudes of climate and their impact on human affairs. Such archaeological inscriptions and historical documents (diaries, ship logs, etc.) are a valuable source of information about prevailing climatic conditions.

b. Palynology

Plants produce pollen in large quantities which are extremely resistant to decay. Such pollens can be found in sediment layers, the density of which gives indications about prevailing climatic conditions(palynology). The abundance of the pollens of a given vegetation period or year depends partly on the weather conditions of the previous months.

c. Study of ancient ice cores (Paleoclimatology)

Several proxy climate indicators like oxygen isotopes, methane concentrations, dust content as well as many other parameters are used in palaeoclimatology to examine ice core data. For instance, the ratio between the ^{16}O and ^{18}O water molecule isotopologues in an ice core gives indicative figures of past temperatures. The heavier isotope condenses more readily as temperature decreases whereas the lighter isotope needs colder conditions to precipitate. Hence analysis of isotope ratios in ancient ice provides information about climatic conditions in the past. Similarly, air bubbles in the ice, which contain trapped GHGs for example carbon dioxide and methane also give indications about past climatic changes. The European Greenland Core Drilling Project drilled in central Greenland from 1989 to 1992. The ices were found to be 3840 years old at a depth of 770 m, 40000 years at 2521m and 200000 years old or more at 3029 m bedrock. Similarly, the ice cores in Antarctica can reveal climate records for the past 650000 years.

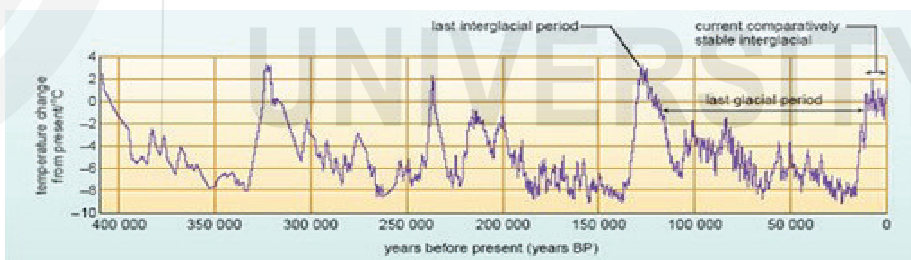

Fig. 2.3: Temperature changes over the past 400 000 years reconstructed from the Vostok ice core, the longest continuous ice-core record to date.

***e. Determining past climate from annual tree rings (**Dendroclimatology)*

Dendroclimatology is the science of determining past climate from annual tree rings. The trees in many parts of the world experience an annual growth cycle. The tree rings are wider when conditions favour growth and narrower during difficult times. The thickness and/or density of a ring depends on the local temperature and moisture conditions thereby giving a unique opportunity to find the temperatures of the respective climate period. There are other properties like maximum latewood density (MXD) which are better proxies than simple ring width. This data can then be matched with overlapping records from other trees to produce longer time series.

Using tree rings scientists have estimated many local climates for hundreds to thousands of years. In a few cases, the preservation of fossil trees has allowed continuous records from 11 000 years ago to the present to be constructed.

Fig. 2.4: The growth pattern from year to year appears as a series of rings that give valuable information about the respective climate period. This science is called *dendroclimatology*

f. Ocean Coral Skeletal Rings or bands

Palaeoclimatological information can also be derived from Ocean Coral Skeletal Rings or bands. Cyclical responses lead to annual banding in corals, which can provide information about sea-surface temperatures, sea level and other ocean conditions - typically back to some 400 years ago.

Source: UKOU

2.7 IMPACT OF CLIMATE CHANGE

Climate change has widespread impacts extending well beyond an increase in temperature. It has an implication for almost everything which we depend upon, for example, water, energy, transportation, wildlife, agriculture, ecosystems, and human health. Anthropogenic activities have already caused major climatic changes and have set in motion, still more changes. Moreover, carbon dioxide, the predominant Greenhouse Gas (GHG), continues to linger in the atmosphere for hundreds of years and it takes a while for the planet to respond (for example oceans). As a result of this, the impact persists for at least several more decades, even if we stop emitting. In the absence of major action to reduce emissions, global temperature is on track to rise by an average of 6 °C (10.8 °F), according to the latest estimates (NASA Global Climate Change). The temperature of the earth's surface does not react instantaneously to the rising carbon dioxide levels. It happens because a sizeable amount of excess energy is stored in the ocean (large heat capacity). Even if all emissions were to stop today, some further warming will be unavoidable before temperatures stopped rising. Therefore, we cannot afford to wait to control GHG emissions till it becomes intolerable.

The warning signs of climate change have started impinging upon the lives of people (Please see Box 2.4). The battle against climate change will have to be fought on two major fronts 1) “mitigation” – reducing the flow of greenhouse gases into the atmosphere; and 2) “adaptation” – learning to live with, and adapt to, the climate change that has already been set in motion. It will require both a globally-coordinated response (such as international policies and agreements between countries, a push for cleaner forms of energy) and local efforts on the city- and regional level (for example, public transport upgrades, energy efficiency improvements, sustainable city planning, etc. (NASA Global Climate Change).

2.7.1 Impacts of climate change on Atmosphere

All these anthropogenic changes have the potential to modify the chemical composition of the atmosphere. Changes in atmospheric temperature also affect the rates at which chemical reactions take place (World Meteorological Organization, 2009). Climate warming is expected to enhance the release of biogenic hydrocarbons into the atmosphere which in turn contributes to the worsening of regional air quality (World Meteorological Organization, 2009). Emissions of nitric acid by bacteria in soils are sensitive to temperature and soil moisture and are affected by climate change (World Meteorological Organization, 2009). An increasing number of wildfires and droughts will lead to larger emissions of combustion products like carbon monoxide, nitric oxide, soot and other compounds, affecting the regional and global air quality. Changes in ocean temperature affect the ocean-atmosphere exchanges of compounds such as dimethyl sulphide, which are a source of sulphate aerosols. Just like greenhouse gases, aerosols can have profound impacts on the earth’s radiative and energy balance. By controlling the amount of energy that reaches the earth from the sun, aerosols can create a cooling effect by reflecting the sun’s energy into space. However, there is one aerosol soot (also known as black carbon), that can create a warming effect and thus contribute to global warming. Climate models have predicted that aerosols have masked about 50 per cent of the warming that would otherwise have been caused by greenhouse gases (NASA, 2009). Intergovernmental Panel on Climate Change has concluded that industrial aerosols have acted as a significant brake on the increase in global temperatures over the last 30 years or so. Although aerosols have limited the warming, they also have detrimental effects on human health such as lung damage. Aerosols also affect rainfall patterns, some areas like India and China can experience reduced rainfall. They can also alter the pattern of wind and atmospheric circulation. Aerosol as air pollutants cause tens of thousands of premature deaths every year in the UK alone (the University of Leeds, nd).

2.7.2 Heat Waves and Extreme Temperatures

Climate change also leads to more extreme weather events for example more intense hurricanes, more droughts, and more floods, with all the devastation to life, livelihood and property that accompanies them. The past two decades have witnessed a greater occurrence of extreme heatwaves leading to heat-related deaths, forest fires, and harvest losses. Such events include the European heatwave of 2003, the Greek heatwave of 2007, the Australian heatwave of 2009, the Russian heatwave of 2010, the Texas heatwave of 2011, and the U.S. heat wave of 2012. Quite often referred to as 3-sigma events, these events involve monthly and seasonal temperatures typically more than 3 standard deviations (sigma) warmer than the local mean temperature. Normally frequency of such events is only once in several hundreds of years. If we count the five hottest summers in Europe since 1500, we surprisingly find that all of them took place after 2002. The European heatwave of 2003 and the Russian heatwave of 2010 took the exceptional death toll of 70,000 and 55000 respectively. Extreme summer temperatures are gradually affecting an increasing proportion of the land area. They can be attributed to growing climatic warming since the 1960s. In the 1960s, three-sigma events were practically absent and affected less than 1 per cent of the Earth's surface. However, the area affected by such extreme events has grown to 4–5 per cent by 2006–08, and 6–13 per cent of the land surface by 2009–11. The studies have now predicted that such events typically cover about 10 per cent of the land area now. It certainly could not have happened in the absence of global warming.

2.7.3 Socioeconomic Impacts

Climate change can have far-reaching socio-economic impacts. Societies that are most at risk are close to physical and biological thresholds. Ocean warming for example can reduce fishing catch, affecting 650 million to 800 million people relying on fishing for their livelihoods. In Ho Chi Minh City, direct infrastructure damage from a 100-year-old flood could increase from $200 million to $300 million today to $500 million to $1 billion by 2050. The average share of annual outdoor working hours lost due to extreme heat and humidity could increase from 10 per cent today to 15 to 20 per cent in 2050. Socioeconomic impacts of climate change can have non-linear impacts as system thresholds are breached and knock-on effects.

Poorer regions often have climates that are closer to physical thresholds therefore, they rely more on outdoor work and natural capital and have fewer financial means to adapt quickly. Therefore, these regions are most at risk. However, the impact of climate change has been devastating even for developed countries like the USA which lost some 1.5 per cent of GDP to such weather-related events in 2017 alone. But some regions are likely to gain from climate change for example Canada where crop yields are expected to increase. Also, the rising temperature can boost tourism in northern Europe.

2.7.4 Climate Change Impacts on Health

Climate change affects many of the social and environmental determinants of health such as clean air, safe drinking water, sufficient food and secure shelter. Extreme heat can contribute directly to deaths from cardiovascular and respiratory disease, particularly among elderly people. High temperature raises the levels of ozone and other pollutants in the air that worsen cardiovascular and respiratory disease. Increased levels of pollen and other aeroallergens in high temperatures can trigger asthma affecting around 300 million people. Rising sea levels and extreme weather conditions can destroy homes and other essential medical facilities. Also, variable rainfall patterns can affect the availability of freshwater thus compromising hygiene and increasing the risk of diarrheal disease, which kills over 500 000 children aged under 5 years, every year.

BOX 2.4: Some Emerging Warning Signs of the Climate Change

1. Glaciers are contracting at an average rate of 15m per year in the central and eastern Himalayas. If this trend continues, these glaciers are expected to vanish by 2035. This can have serious impingements on the population depending on the glaciers for drinking water supplies etc. Kumbu Glacier, on the popular climbing route to the summit of Mount Everest, has retracted by 5km. The swelling of glacial lakes in Bhutan and the increasing risk of catastrophic flooding is another example of such a phenomenon (ICIMOD, 2019).
2. The thawing of Permafrost in the Arctic region poses a serious threat to the critical infrastructure of the region. This can also pose threat to the utilization of natural resources and sustainable development of the region. Around 70 per cent of the infrastructure located in permafrost is at high risk of being thawed. One-third of Pan-Arctic infrastructure and 45 per cent of hydrocarbon extraction in the Russian Arctic are located in high hazard regions (Hjort et al., 2018).
3. Sundarbans are the natural walls for some coastal areas of India and Bangladesh against climate change. But with rising waters and illicit logging, these mangrove trees are nearing their extinction. Therefore, many local people and local species are losing their habitat. Coastal areas are losing their natural defence against extreme climate change phenomena such as floods and cyclones. In 1998 a large flood occurs in Bangladesh, which covered about 70 per cent of the country (Schwartzstein, 2019).
4. Advancement in flowering time for around 385 British plants species by 4.5 days has been observed. This reflects the serious effects of temperature change on the ecosystem, as flowering is a phenomenon that is sensitive to temperature (Fitter & Fitter, 2002).
5. In Monteverde, Costa Rica, twenty out of fifty species of Anurans disappeared during a population crash in 1987. These crashes are expected to be the result of demographic changes that affected communities of birds, amphibians etc. These changes are associated with dry mist frequency, which is negatively correlated with sea surface temperature (Pounds, Fogden, & Campbell, 1999).
6. *Antarctic peninsula* Adélie penguin populations have shrunk by 33%, in the past 25 years population has declined by 33 per cent owing to their declining winter sea ice habitat. Adélies depend on sea ice as a resting and feeding platform. They are being replaced by gentoo penguins (a sub-Antarctic species that has begun to migrate towards the pole) which thrive in open water.

Source: Compiled from different Sources

2.8 WHICH COUNTRY HAS CONTRIBUTED THE MOST?

Any country's total carbon emission does not give us a full picture of the country's contribution to global warming. For example, China is the biggest emitter of CO_2 among all the countries (since it overtook the USA in 2007), however, the per capita contribution is just 6.98 tonnes per capita as against 16.24 tonnes per capita of the USA. Sharp variations in CO_2 emission per capita have triggered a debate to fix the responsibility among developed and developing countries. The reasons for such variations are primarily due to the availability of energy resources and the energy policies followed by them. For example, Australia emits around 20.6 tonnes per person which is partly due to its reliance on CO_2 intensive coal. However, consumption recorded in the UK is 9.7 tonnes/person which is partly due to relatively CO_2-light gas power stations. On the other hand, African countries like Kenya have a footprint as low as 0.3 tonnes, which is likely to drop even further with the country's surge in wind power.

BOX 2.5: Global Warming: The Key Contributors

The global average temperature has increased by more than 1°C since its pre-industrial levels. The emission of carbon dioxide has been consistently increasing (~36 billion tonnes of CO_2 per year) and its concentration has reached well over 400 ppm-the highest ever level in over 800,000 years. However, there are marked differences in the contribution of different countries to this massive emission. There are more than 100-fold differences in per capita CO_2 emissions between the countries. Interestingly the countries in the high-income group emit more whereas those in the low-income group emit less than their population share. As far as the contributions of different countries are concerned, China is the world's largest CO_2 emitter (accounting for more than one-quarter of emissions) which is followed by the USA (15%); EU-28 (10%); India (7%); and Russia (5%). So far USA has cumulatively contributed the most of global emissions (25% of cumulative emissions) followed by the EU-28 (22%); China (13%); Russia (6%) and Japan (4%). There are large inequalities in the emission patterns across the countries which makes climate change a matter of serious international diplomacy. The worlds poorest have contributed less than 1% of emissions but are worst affected by the overall impact of emissions. However, a large amount of CO_2 is embedded in traded goods. Therefore, if we look at emissions based on consumption rather than production, figures might change. However, the IPCC guidelines on national emission accounting and reporting are written based on production-based emissions. These are the standards adopted internationally for emission reporting and taken into account for climate reporting. Moreover, such figures are available to the entire world since the mid-eighteenth century. The world is not on track to limit global warming to 2°C above the pre-industrial level, as targeted in Paris Agreement. It is expected that the continuance of existing policies will enhance global warming up to the range 3.1-3.7°C

Source: Hannah Ritchie and Max Roser (2020): Our World in Data

2.9 POLICY IMPLICATIONS OF CLIMATE CHANGE

Complex and policy sensitive issues like climate change can evoke conflicting responses from interest groups and policymakers who tend to adopt a "pick n mix" approach to the available scientific evidence, promoting research that reinforces their existing arguments and beliefs, and neglecting or criticizing more uncomfortable findings. Even today, quite often we come across people who deny the climate crisis. It has seriously affected the global fight against climate change. Quite often the facts of climate change come in conflict with people's values, ideologies and political allegiances.

Cooling or warming is not necessarily bad for some areas. For example, Siberia might get warmer in a few decades and this could be profitable for the local population. On the other hand, the impact of climate change may force others to leave their homes because of changing environmental conditions. For instance, in the Sahel region of Africa, for example, declining agricultural productivity has driven people out of their homes for the past 30 years; this is expected to continue as a result of climate change, putting the lives of 60 million people who live in the Sahel region at risk (Goosse, 2005). Further, the opinions of individual scientists are often influenced by decision-makers or the media than the reliability of their knowledge. It has created a scenario where the disputes within the scientific community are often extensively reported by the media and become a matter of public debate.

The politicization of climate change-related issues which have seriously undermined the scientific pieces of evidence has often been observed. For instance, 2001shortly after he assumes office, President George W. Bush withdrew the US from the Kyoto Protocol specifying that it would harm the US economy. It was seen across the world as the influence of business-backed lobby groups in government. The allegations were reported in the media that officials of the white house had tried to interfere with a report from US Environmental Protection Agency (EPA) to downplay the seriousness of climate change. Similarly, in 2019 President, Donald Trump who had mocked climate science as a hoax, decided to withdraw from Paris Climate Change Declaration. Though a clearer picture of American participation in the agreement will emerge after the 2020 election, it has created a worldwide concern for the future of global efforts to prevent climate change.

2.10 IMPLICATIONS FOR POST-2015 DEVELOPMENT AGENDA

The Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC) unequivocally highlights the rise in global mean temperature and warming of the climate system. Global warming has a widespread cross-cutting impact on almost all the Sustainable Development Goals (SDG). The task of achieving SDGs will be very challenging in a 2°C world, but in a 4°C world there is serious doubt whether this can be achieved at all (World Bank,2014b). It makes climate change the biggest developmental challenge of our times. The repercussions have already started being felt across the world, particularly in the most vulnerable communities. The situation is serious, as the countries worst affected by climate change are the ones that contribute least to it. As the global temperatures are progressing, problems are likely to further exacerbate, adversely affecting people in every aspect of their lives for instance food availability, water availability, diseases, frequent occurrence of floods, droughts, rising sea levels, oceanic acidification, rising inequalities, etc. It is well realized that strong and early actions based on clean, low carbon pathways are the only answer to slow down the unsustainable growth strategies which will far outweigh the costs. Many of the worst projected climate impacts could still be avoided by holding warming to below 2°C (World Bank, 2014b).

2.11 LET US SUM UP

Climate change presents a complex, borderless and intergenerational phenomenon. It has diverse and far-reaching setbacks to the process of development. As Mike Toman, Research Manager, Research Department, World Bank says "*Climate change is an issue that presents great scientific and economic complexities, some very deep uncertainties, profound ethical issues, and even lack of agreement on what the problem is*". It is now believed to be a classic example of a super wicked problem The super wicked problem has been described in the research literature as comprising of four key features: *"time is running out; those who cause the problem also seek to provide a solution; the central authority needed to address it is weak or nonexistent; and, partly as a result, policy responses discount the future irrationally (Levin et al,2012)*.

Human civilization is witnessing an unprecedented phase of human history where the availability of natural capital and social capital are the limiting factors for future economic growth (Hawken 1997). Furthermore, the prosperity of one nation cannot be seen in isolation from the prosperity of all other nations. It is well realized that solutions for global problems have to be collective and should be explored simultaneously on social, economic and environmental fronts. Thus, first time in history, human beings can determine the habitability of the planet. The capacities of the people at various levels need to be built to sustain the environment. It is due to this reason that systems of capacity building have come to the forefront of the development agenda. A collective global effort through 'out of box' initiatives is the only answer to address this problem.

2.12 KEY WORDS

Climate System: The climate system is a highly complex system consisting of five major components: the atmosphere, the hydrosphere, the cryosphere, the lithosphere and the biosphere, and the interactions between them. The climate system evolves in time under the influence of its internal dynamics and because of external forcings such as volcanic eruptions, solar variations and anthropogenic forcings such as the changing composition of the atmosphere and land-use change.

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2.14 ANSWERS TO CHECK YOUR PROGRESS

Check Your Progress 1

1. Please refer to section 2.5