Book Review

Introduction to Modern Climate Change. Andrew E. Dessler: Cambridge University Press, 2011, 252 pp, ISBN-10: 0521173159

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GRAPHICAL ABSTRACT
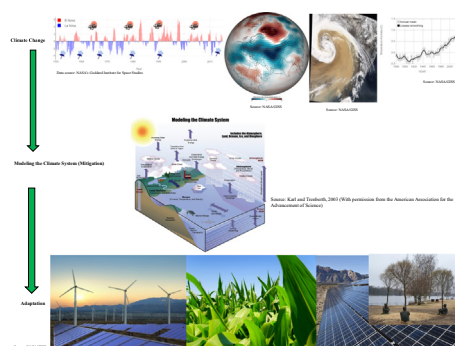
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ABSTRACT

Climate change is the variability of the climate system that includes the atmosphere, the biogeochemical cycles (Carbon cycle, Nitrogen cycle and Hydrological cycle), the land surface, ice and the biotic and abiotic components of the planet earth. Significant impact of climate change is seen in the form of rise in temperature called as global warming. Carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) are the primary greenhouse gases (GHGs) mainly responsible for the global warming and climate change. These GHGs have drawn lot of attention due to their significant role in the global warming potential. Intergovernmental Panel on Climate Change (IPCC) suggested to stop global warming at 1.5oC above preindustrial levels as warming beyond this level might lead to heat extremes, alter insect and plant phenology (Phenological shifts) and more occurrence of vector borne diseases. Climate change is the topic of interest in all fields of life starting from social science and going to the applied science. Global climate cycles and world food production systems are under threat due to the recent climate extreme events. These events include heat waves and change in the rainfall patterns. Thus, risk reduction intervention in the form of mitigation and adaptation is required to minimize the impacts of climate change. Mitigation option includes understanding the present and future components of the climate system and interaction among them through coupled modeling system i.e. Global Circulation Model (GCM). Finally, global issue of climate change could be addressed by taking worldwide cooperation and action and adopting sustainable measures like use of alternative energy sources. The visible benefit on recovery of climate has been seen recently through global lockdown against coronavirus disease 2019 (COVID-19) pandemic.

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Introduction to Modern Climate Change is an excellent attempt to define, elaborate and discuss broad spectrum of knowledge and expertise of climate change, radiation and energy balance, climate model, why and how the climate is changing with adaptation and mitigation policies for future. The book has been divided into fourteen chapters; each highlighting specific issues/challenges related to climate change.

The introductory chapter, "An introduction to the climate problem" provides a nice overview regarding climate and climate change definition, coordinate system of earth and importance of this book to understand climate change to design a risk management tool for future climate scenarios. The difference between weather and climate was presented to make short term and long term decisions. Variability in the temperature and spatio-temporal distribution in the amount, duration and intensity of precipitation was described as an important indicator of climate change. The best way to get idea about the climate of a region is by knowing its position using coordinate system. A coordinate system consists of latitude (distance in the north–south direction between the location and the equator) and longitude (angle in the east or west direction, from the prime meridian) (Fig. 1). The importance of latitude–longitude in atmospheric forecast model was documented by Staniforth and Thuburn (2012). Furthermore, the unique feature in this chapter is author emphasis on the consideration of the voice from the world's climate scientists and presented detail about the coordinated global forum i.e. the Intergovernmental Panel on Climate Change (IPCC) which was formed in 1988.

The next chapter "Is the Climate Changing?" focuses on temperature and variables affected due to temperature. Meanwhile, use of temperature anomaly and measurement of temperature by different indicators like sea surface temperature (SST), Ice, glaciers and sea level to conclude that warming is unequivocal was discussed. The author describes that warming can be studied by Paleoproxies and Paleocene–Eocene Thermal Maximum (PETM). The detail presented in this chapter can be used to study trend of climate change using indicators like monthly surface temperature anomaly, global annual average temperature anomalies (Fig. 2) and satellite measurements of the global temperature trends (Fig. 3). These climate indicators play a significant role in the understanding of pandemic disease like COVID-19 (Bashir et al., 2020) as well as in the rainfall forecasting under rainfed agriculture (van

Ogtrop et al., 2014). Similarly, according to the NOAA (National Oceanic and Atmospheric Administration), the 2019 was the second warmest year on record (1.15 °C above preindustrial average (1880–1900)) and the global annual average land and ocean surface temperature have increased at a rate of 0.07 °C per decade since 1880. However, it is twice average rate of increase since 1981 (0.18 °C). Furthermore, global warming trend pushes April temperature into record as 2020 heads for disquieting milestones (Fig. 4).

The importance of energy "the capacity to do work", power, internal energy, use of kelvin scale and distribution of solar radiation into visible, infrared and ultraviolet was discussed in chapter 3 with the emphasis that climate is all about energy flow. Energy travels in the form of packets known as photons, earlier described by Planck's quantum theory of radiation, and smallest form of energy absorbed or emitted by body is known as quantum. Wien's displacement law which shows relationship between wavelength and temperature was elaborated. The equation used to present this relationship is:

$$\lambda_{max} = \frac{3000}{T} \tag{1}$$

Here λ_{max}=wavelength of the peak of the emission spectrum and T = Temperature of the object.

The author depicts that everything emits radiation (blackbody) but overall energy remains conserved. The concepts presented in this chapter are used widely now a days in the field of remote sensing, where temperature is determined by measuring the power emitted at a particular wavelength and converting this to temperature (Bacenetti et al., 2020; Dusadeerungsikul et al., 2020; Huang et al., 2020; Pôças et al., 2020; Yu and Yu, 2020). The most important way to describe the distribution of solar radiation on planet earth is to develop a climate base model using concepts of albedo and latitude as discussed in Chapter 4. The author described that the first step to understand climate is to use energy budget calculation. Since the Sun radiates 3.8×10^{26} W (380 trillion W) of power to planet earth. The exact amount of solar energy hitting the planet earth can be calculated by considering earth as a sphere surrounding the Sun with the radius equal to 150 million km (Sun-earth distance). As the sphere completely encloses the Sun thus,
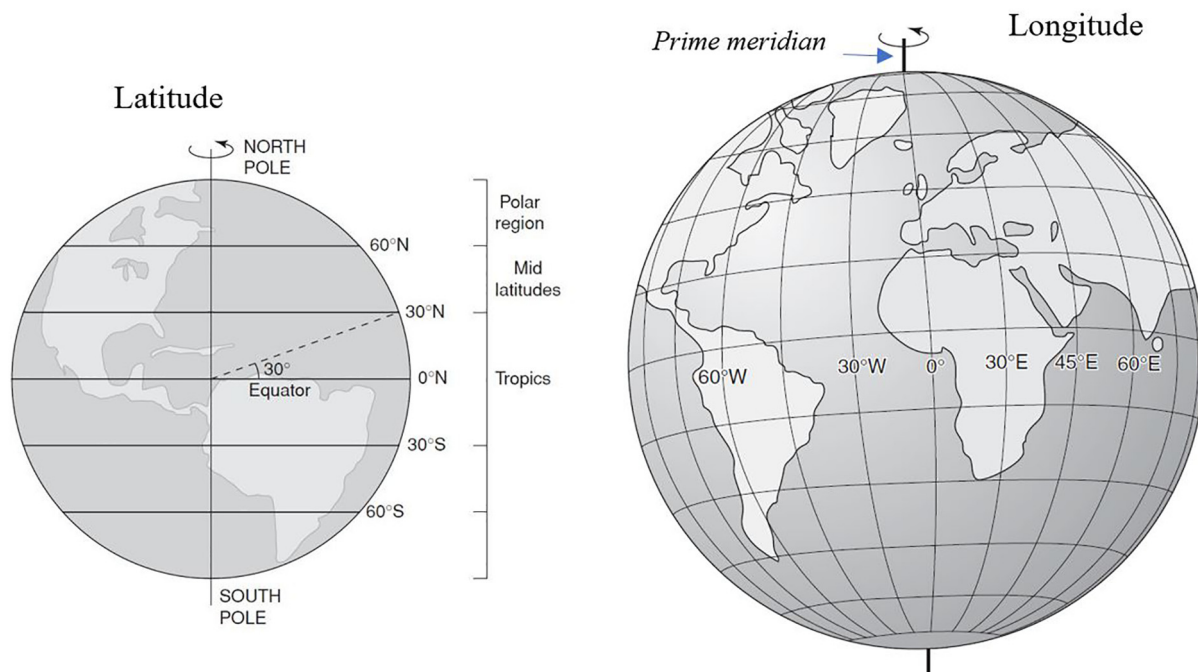

Fig. 1. Diagrammatic representation of latitude and longitude.
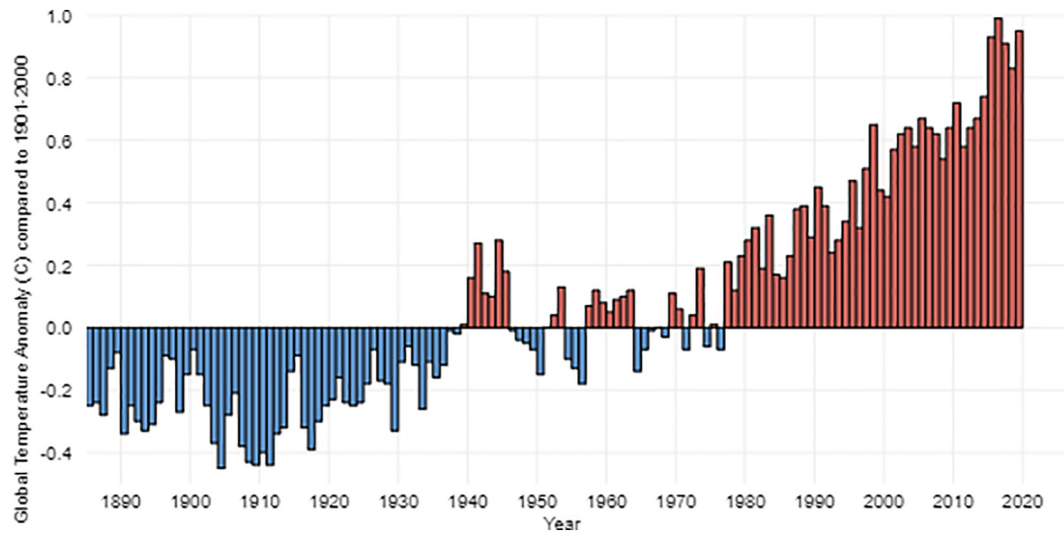
Fig. 2. Global temperature anomaly.
(Source: NOAA)

sunlight emitted by the Sun will fall on the interior of the sphere. The surface area of sphere is $4\pi r^2 = 4\pi(150 \text{ million km})^2 = 2.8 \times 10^{17}$ $\text{Km}^2 = 2.8 \times 10^{23}$ m^2. The energy emitted by the Sun falling on one-meter square surface of the sphere is 3.8×10^{26} W/2.8×10^{23} m$^2 =$ 1360 W m^{-2} called as solar constant for the earth. Furthermore, concept of reflectivity (Albedo, α) was presented which could be used to
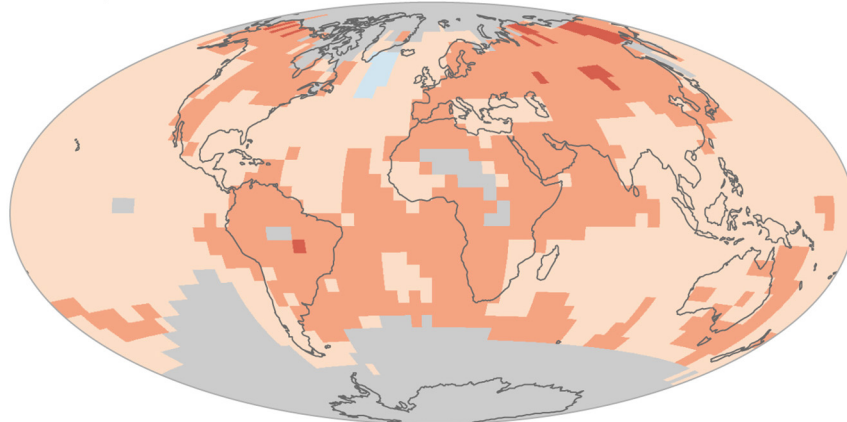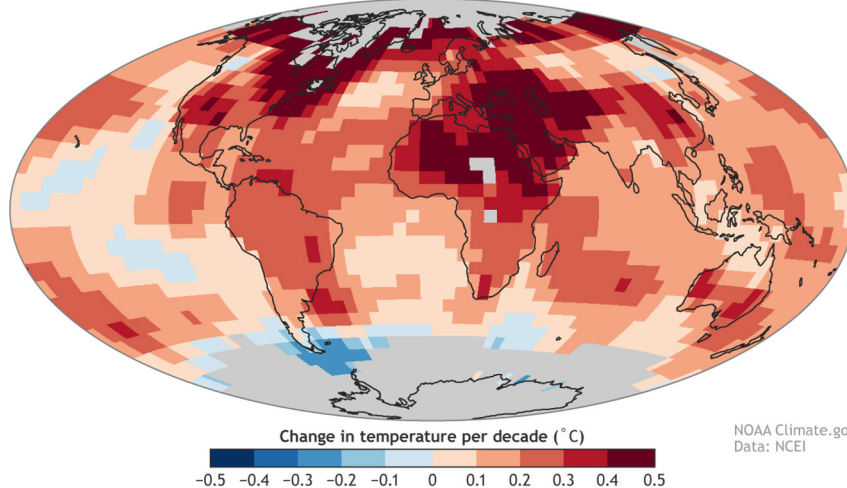
Fig. 3. Global temperature trends.
(Source: NOAA)

Fig. 4. Global surface air temperature anomalies during April 2020 relative to 1981–2010 average (Source: Copernicus Climate Change Service).

calculate total rate of energy in (E_{in}) for the earth and represented by the following equation:

$$E_{in} = S\,(1-\alpha)\pi R^2 \tag{2}$$

where α = fractions of photons reflected, 1-α = fraction of photons absorbed, S = Solar constant. However, total rate of energy per m^2 of the earth surface area could be calculated by using following equation:
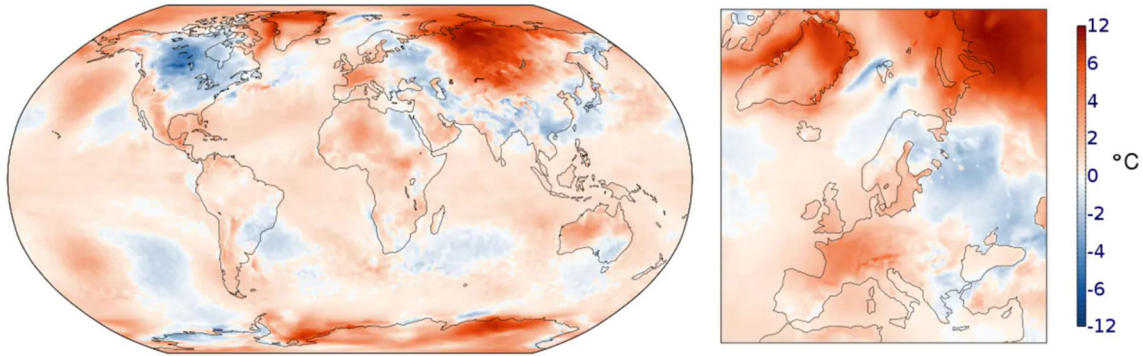
$$\frac{E_{in}}{area} = \frac{S(1-\alpha)\pi R^2}{4\pi R^2} = \frac{S(1-\alpha)}{4} = 238\ Wm^2 \tag{3}$$

The author elaborates that variations in the amount of solar energy received by the planet earth is linked with latitude. Due to this reason tropics get more solar energy than mid-latitudes while polar regions receive less solar energy. However, tropics have low albedo and more heating compared to high latitudes where albedo is high due to ice (Loeb et al., 2012; Stephens et al., 2015). Earth is receiving energy from the sun continuously but why it is not reaching to the same temperature as the sun was answered with the concept that rate at which earth is receiving energy from the Sun is equal to the rate the earth is losing energy. If earth loses energy back to space by means of blackbody radiation than $P/_a = \sigma T_4$ where $P/_a$ = Power emitted per m^2, T = Planet temperature and σ = Stefan–Boltzmann constant (5.67×10^{-8} Wm^{-2}/K^4). Considering that the rate of energy in is equal to the rate of energy out the new equation will be:

Rate of energy in = Rate of energy out

$$\frac{S(1-\alpha)}{4} = \sigma T_4 \tag{4}$$

Solving Eq. (4) to get T:

$$T = \sqrt[4]{\frac{S(1-\alpha)}{4\sigma}} \tag{5}$$

Putting values in Eq. (5):

$$T = \sqrt[4]{\frac{1360(1-0.3)}{4\left(5.67 \times 10^{-8}\right)}}$$

After solving this equation the T we get is 255 K ($-18\ °C$), but the actual earth temperature is close to 288 K so the question remains is "Why the estimation gives such cold temperature". The author suggested that the reason for this was that in this equation the heating of the earth also known as the greenhouse effect was neglected. The author emphasize that n-layer model incorporating the number of layers in the atmosphere(n), the solar constant (S) and albedo (α) could be used to calculate the surface temperature of the planet earth. The model equation to

calculate surface temperature was:

$$T = \sqrt[4]{(n+1)}S(1-\alpha) \div 4\sigma \tag{6}$$

The author connected this equation with real world by considering number of layers equivalent to the amount of greenhouse gases (GHGs) in the atmosphere. More the GHGs more will be the number of layers and ultimately higher the warming as elaborated in next chapter.

The flows of carbon in the ecosystem known as carbon cycle is elaborated in Chapter 5 with description of GHGs like water vapor, CO_2, N_2O, halocarbons and O_3. Since elevated CO_2 is main challenge of modern climate change, author discussed its exchange in the atmosphere, biosphere and ocean via photosynthesis, respiration, absorption and deposition as sugar, carbonic acid and calcium carbonate. During 2010 the concentration of CO_2 was 0.0390% (390 ppm meaning that there are 390 molecules of CO_2 in every million molecules of air) but now in April 2020 the concentration of CO_2 is 416.21 ppm and it was 413.33 ppm in April 2019 (Fig. 5). Thus, CO_2 concentration is increasing day by day. This elevated CO_2 have shown differential effects on different systems such as global human nutrition (Smith and Myers, 2018), nutritional quality of vegetables (Dong et al., 2018), water efficiency (Varga et al., 2015), legume symbioses (Sulieman et al., 2015), nitrogen cycle (Rütting and Andresen, 2015), soil organic matter composition and substrate diversity (Tfaily et al., 2018) and crop physiology and crop management (Tausz et al., 2013). The author further stated that main CO_2 comes from human activities like burning of fossil fuels and deforestation which can be finger printed by the use of isotopes of carbon. Similarly, CH_4 which has 20 times more powerful GHG than CO_2 was discussed in detail. The main source of CH_4 is raising of livestock (Tongwane and Moeletsi, 2020), rice paddies (Qian et al., 2020) and bacterial action on landfills and wastes (Li et al., 2020a, 2020b). Meanwhile, petrochemicals industry and coal mines are also big contributor of CH_4 (Gao et al., 2020). Therefore, author concluded in this chapter that 35% of the CH_4 emissions are natural, and 65% are due to human activities.

The author started "Chapter 6" with assumptions that heat capacity of the atmosphere is zero because energy in equals energy out. However, if one layer or multilayer atmosphere is added to the planet it will increase temperature because of presence of GHGs but committed warming or described more informally as warming "in the pipeline" is also going on. Similarly, Radiative forcing (RF) is the transition in energy due to changes imposed on the planet earth before the adjustment of temperature. Andrews and Forster (2020) stated that RF is a fundamental quantity for understanding anthropogenic and natural drivers of past and future climate change. Therefore, RF could be used to measure climate perturbation. The author further elaborated that GHGs has RF of $+3.0\ W/m^2$ and 55% role was from CO_2 but net RF till now is $+1.6\ W/m^2$. However, aerosols and land use changes have negative RF and author emphasized that we must take certain measures and build such
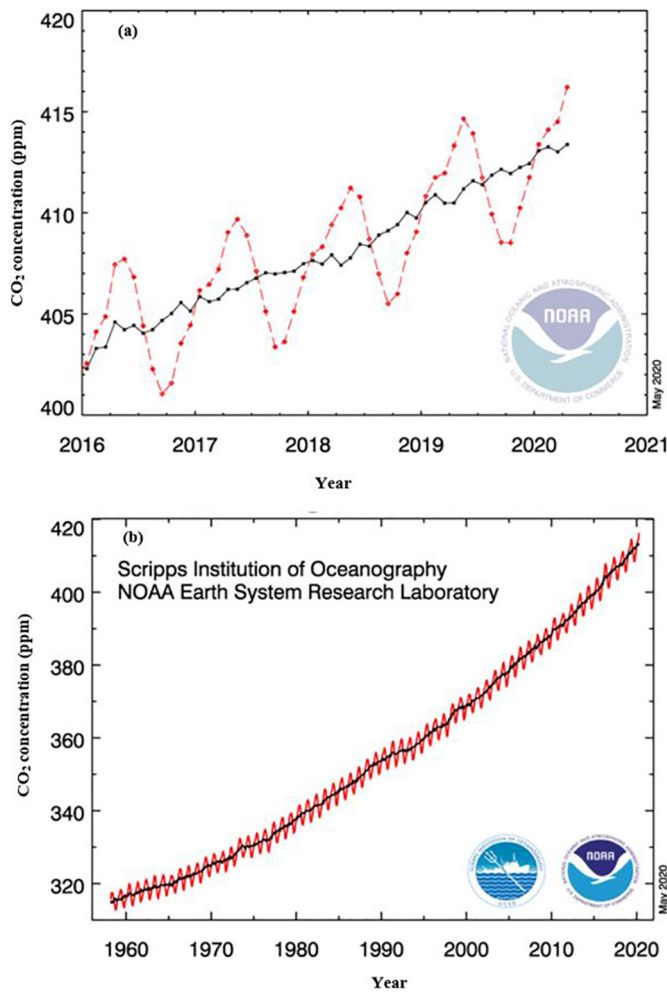
Fig. 5. Monthly mean CO_2 (a) and atmospheric CO_2 (b) at Mauna Loa observatory (Source: NOAA).

policies which can stabilize RF. These could be achieved by stopping activities which produce positive RF called as mitigation and doing activities that produce negative RF referred as geoengineering. Feedback is another mechanism that responds to changes in the surface temperature described by author affecting climate either positively or negatively. These include fast (ice–albedo, water-vapor, lapse-rate and cloud) and slow (carbon-cycle and vegetation) feedbacks of warming. The author further made a beautiful comparison between RF and feedback. In the end of this chapter the author discussed about sensitivity as increased temperature (2.0–4.5 °C) due to doubling of CO_2 while in term of RF it is 0.5–1.1 °C/(W/m^2) with best estimate of 0.75 °C/(W/m^2).

The Movement of the continents (tectonic motion), Sun, Earth's orbit (eccentricity), internal variability, GHGs and their combined effect on climate change are discussed in Chapter 7. The author depicted that the location of the continent determines the ice sheet formation which can results in cooling of the planet. Similarly, locations of continents determine ocean circulation and change in the position of continents may lead to change in rainfall pattern and wind distribution. Meanwhile, solar constant is another factor which controls climate but due to increased fusion in the Sun it becomes 30% brighter over this time. Therefore, author concluded that Sun has positive RF. The position of earth from sun has a significant effect on the solar constant. Since earth orbit is not a perfect circle and it is an ellipse whose *eccentricity (*the ratio of the length of the ellipse to the width) varies with time. Hence, as the orbit become more eccentric it will lead to increased earth-sun distance resulting to less solar constant and change in climate. However,

if earth reaches closest to the sun (*perihelion*) with tilt (*obliquity*) will alter the climate due to variability in the amount of sunlight without change in solar constant. The author considers orbital variations effect on sunlight regulation which changes climate as Milankovitch cycles (Campisano, 2012). Internal variability in our climate like El Niño/Southern Oscillation (ENSO) comes from internal physics of system has cold (La Niña) and hot (El Niño) phases. Therefore, author concluded that ENSO is the dominant and best-known internal variation in the climate system. Teleconnection of climate change and El Niño–Southern Oscillation (ENSO) was well documented by Li et al. (2020a, 2020b). Meanwhile the author described how scientist can deal with outlier (a point that does not agree with scientific expectations). Similarly, GHGs which are primarily due to human activities are responsible for cold and hot events as evident by climate models and IPCC.

Chapter 8, "The future of our climate" has been started with projections of GHGs emissions, known as emissions scenarios. In the start author discussed relationship of GHGs with society goods consumption. Therefore, author depicted that GDP (gross domestic product) could be used as an indicator to check the total emissions by the society. However, population, affluence and GHGs intensity have big contribution to GHGs emissions. Therefore, total emissions of GHGs (I) could be expressed as product of population (P), affluence (A) and GHGs intensity (T). The author further breakup T into energy intensity (EI) and carbon intensity (CI). Thus, increased emissions have direct relationship with P and A which will be changing in coming century with advancement of technology. The author further elaborated that it is hard to make predictions especially about the future, but emission scenarios could be used to do so same as IPCC. Furthermore, author discussed about A (A1 and A2) and B (B1 and B2) scenarios where A describe worlds with high rates of economic growth while B describes where economic growth is slow. After this, scenarios are converted into GHG concentrations by using carbon-cycle model. This model estimated low, medium, and high rates of greenhouse-gas emissions for the B1, A1B, and A2 scenarios respectively with 1.8 to 3.6 °C increased temperature at the end of twenty-first century. The author depicted that temperature would rise with 0.4 °C even if GHG emissions are stabilized referred as committed warming. However, the author suggests the use of models in appropriate way by incorporating climatic variability to predict climate system accurately. The author argues that the quality and quantity of data is crucial to make progress in the field of modeling. Different scenarios have been developed in recent decades but most important one includes (i) Six IPCC 1992 (IS92) scenario (ii) Six special report on emission Scenarios (SRES) (iii) Four RCP (Representative concentration pathways) and (iv) Nine forcing scenarios. The IS92 scenario was used for 2nd assessment report (SAR) while SRES was used in the IPCC 3rd (TAR) and 4th (AR4) assessment reports. According to SRES future GHGs emissions are the product of very complex dynamic systems, determined by driving forces such as demographic development, socio-economic development, and technological change (Nakicenovic et al., 2000). Representative Concentration Pathways (RCPs) replaced SRES in 5th assessment report (AR5) as it was needed to predict how future global warming will contribute to climate change. The RCPs are a standard set of scenarios that can be used to ensure starting conditions, historical data and projections so that they can employed consistently across the various branches of climate science. The RCPs includes four pathways: RCP2.6 (Very low forcing level, also referred to as RCP3PD, where 'PD' stands for Peak and Decline) (van Vuuren et al., 2011), RCP4.5 (Medium stabilisation scenarios) (Thomson et al., 2011), RCP6 (Medium stabilisation scenarios) (Masui et al., 2011) and RCP8.5 (High emission scenario or business as usual) (Riahi et al., 2011). Gidden et al. (2019) presented a suite of nine scenarios of future emissions trajectories of anthropogenic sources. These nine forcing scenarios have been used to develop upcoming 6th assessment report (AR6) based on the shared socioeconomic pathways (SSPs). These set of scenarios are bounded on the low end by a 1.9 Wm^{-2} scenario ideal for analysing a world with end of century well below 2 °C

and on the high end by an 8.5 Wm^{-2} scenario, resulting increase of 5 °C over preindustrial levels. These emissions data have been used by Fiedler et al. (2019) to estimate the differences in the radiative forcing of anthropogenic aerosol at the end of the 21st century.

The main components of climate include physical impact on climate system which describes how temperature, rainfall, sea level and extreme events will change and what will be their impacts on humans are discussed in Chapter 9, "Impacts". Since temperature is increasing therefore, overall activities will be altered that needs to be monitored by models. Meanwhile, the author elaborates that frequency and intensity of rainfall and drought will grow that might cause flooding, erosion, runoff and famine. Thus, predictions of future rainfall must be parameterized in climate models to avoid uncertainties. Sea level rise and acidification are other indicators of climate change discussed by the author. The author concluded that to quantify all these impacts i.e. physical impacts on the climate system (How temperature, precipitation, sea level, extreme events, and other such phenomena will change) and impact of such changes on human and environment we need to understand our sensitivity to climate change.

Since all these abrupt changes have negative impacts on humans, agriculture and freshwater availability therefore, the author emphasized that this all should be managed by adaptation and mitigation strategies (Wiebe et al., 2019; Grafakos et al., 2020; Hussain et al., 2019). Yang et al. (2020) suggested landscape approach should be used to achieve food security and sustainability goals particularly within the context of climate change. In Chapter 10, "Exponential growth" which is directly proportional to the size of sample was discussed but author emphasized that Exponential growth cannot go on forever, and when it ends, it often ends suddenly. Similarly, "rule of 72" referred to doubling effect, discounting and cost benefit effect was discussed. Meanwhile, Malthus who depicted that population grows exponentially whereas, food production grows in a linear fashion was discussed in a beautiful way.

In the Chapter 11, "Fundamentals of climate change policy" in which author outline various options available to us to address climate change which include adaptation, mitigation and geoengineering. Adaptation means responding to the negative impacts of climate change that might also be considered as form of aid. Therefore, author emphasizes on action before climate change occurs like construction of resilient infrastructure and flood insurance. Meanwhile, "Mitigation" refers to policies that avoid climate change in the first place like reduction in GHGs by population control or reduction in the use of goods. However, the author narrated that if this is not possible, we need to reduce greenhouse-gas intensity by efficiently using energy resources through advancement of technology (carbon-free or climate-safe). The reduced carbon intensity and renewable energy resources include nuclear, carbon capture and sequestration. The author further emphasized on the use of hydroelectric, solar, wind, and biomass energy as best mitigation option under changing climate. However, these have some pros and cons like in nuclear energy the big issue is stability of nuclear reactors and disposal of nuclear wastes. Finally, the intent of making of nuclear bomb and cost are one of the big problems in the implementation of nuclear energy (Toon et al., 2019). Therefore, the author has given final option of carbon capture and storage, also known by its initials CCS or carbon sequestration. Geoengineering refers to active manipulation of the climate system and is another approach the author suggested to incorporate that can be broken down into two categories, solar radiation management and carbon cycle engineering.

Adaptation is not only the reliable option therefore, the author in Chapter 12, "Mitigation policies" discussed mitigation as successful option to avoid climate change. The author suggested certain regulations like command and control and market based to avoid climate change. In command and control the author discussed about use of specific products like hybrids in cars to enforce standard of GHGs. Furthermore, author emphasized on the use of specific innovative technology, regulations of emission standards and incentives for the reduction in GHGs. Thus, making emitters to pay for their emissions is a market-based

solution suggested by the author. This includes carbon taxes and cap-and-trade systems. Similarly, author made a beautiful comparison between carbon taxes and cap-and-trade. Offsets are action taken to remove CO_2 from air by planting forest called as negative emissions (Ainsworth et al., 2020; Bustamante et al., 2019). However, letting person to release GHGs on the expense of offsets is same as to forgive wealthy one on sin. Therefore, the author suggested offset an immoral action and emphasized on information dissemination as best way to mitigate climate change.

A brief history of climate change science, policy, and politics, Chapter 13 is description of beginning of climate science initially by Joseph Fourier (1820) as greenhouse effect followed by John Tyndall and Louis Agassiz. Similarly, the author discussed the idea of Arrhenius as beginning the theory of human induced global warming. The author presented "Nature" in 19th century as an enemy to mankind and the battle against nature was a battle for survival. After that, concept of ozone depletion and acid rains was discussed, and it was suggested that CFC needs to be banned by phase-out process. Next adaptation of Montreal protocol was reviewed, and author narrated that problem of climate change become political due to the intervention of US congressman in 1988. This led to the formation of IPCC (Intergovernmental Panel on Climate Change) and treaty of Framework Convention on Climate Change (FCCC). Meanwhile the Kyoto Protocol is another implementation of policies discussed by author to mitigate climate change.

In the last chapter, "Putting it together: A long-term policy to address climate change" the author concludes that a collaborative effort needed to implement mitigation program to reduce emissions but we have to implement such policies which have long term goal. Meanwhile, cost benefit ratio needs to be calculated so that we can develop mitigation plan accordingly. In the end author suggested the role of individual to motivate the emissions reductions necessary to stabilize the climate. This requires collective and coordinated actions. Recently, COVID-19 lockdown is one of the examples where it has been reported that this lockdown helped to minimize emissions of GHGs. For example, Muhammad et al. (2020) in their work concluded that COVID-19 is a global pandemic and serious threat to human health which halt the economic activities, but it is "Blessing in Disguise", where pollution is reducing, and nature is reclaiming itself. Similarly, they reported that this impact on environment may be short term, but we should learn from this lockdown and find ways to reduce pollution on long term basis. Furthermore, Rosenbloom and Markard (2020) concluded that pandemic directly threatens individuals and health systems, whereas climate change undermines broader natural and human systems. They suggested that climate impacts will worsen the longer we wait. So, we are faced with overlapping crises that require immediate societal mobilization. In general, the book will cater to the needs of climate scientist, modellers, researchers/scientists, undergraduate, and graduate students in all fields of study. It is a valuable contribution to the current knowledge on climate change and provides historical background, successes, and potential for the future. I strongly recommend this book to readers as a valuable source of information and a worthwhile addition to one's book shelf.

Declaration of competing Interest

Author declares no conflict of interest.

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