Climate Change and the Need for Future Research

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Abstract. Climate Changes have impacted our planet since the beginning of time. These were manifested by cyclic Ice Ages and Warm Periods ever since. The changes were caused by natural forcing such as, continental drift, plate tectonics, major volcanic eruptions, and internal dynamics of earth and oceans interactions with the atmosphere. The present warm period, the "Holocene Epoch", is not different from other such periods except for the sharp global warming which began at the onset of the industrial revolution. This was proven by scientific research to be due to anthropogenic drives, i.e., increased fossil fuel burning and increased Co2 and other Green House Gases (GHG) emissions into the atmosphere. These gases trap the sun radiation reflected from earth surface and result in higher earth temperature. The steep rate of rise in temperature trend since 1960s is directly linked to the use of much more fossil fuels in power production and transportation. This has led to more research to quantify the changes and their impacts on the environment and humans. This paper gives a brief history of the scientific research carried out hitherto and policy suggestions made so far to combat the negative impacts of the increasing global warming of the world. Needed future scientific research in this field is outlined, while at the same time suggesting the needs of Iraq of such research. This includes among other things, forming a regional scientific panel for the Middle East countries (ME. IPCC) for carrying out research on regional level, fostering research on national level, encouraging academics for climate change-oriented research and providing the necessary funds and facilities for such research.

1. 1. Is Climate Change a new phenomenon

Going back deeply into the past history of the planet earth, one can observe alternating cycles of ice ages and relatively warm climate periods over the 4540 million of years forming the age of earth, [1], (Fig.1). These cycles have contributed to the beginning of vegetative and animal lives and drastically impacted their evolution process by the flourishing of some species and perishing of others, leading to the present environment we live in today. These cycles were due to forcing reasons that are inherent in the dynamics of earth evolution as identified by scientists. Most prominent are being, Plate Tectonics, Earth Orbiting Force due to the tilting of earth axis, and Major Volcanic Eruptions. In addition to the internal dynamics interacting between the earth and its atmosphere, which are causing disruption of global wind circulation patterns and oceanic currents modes. In (Fig 2) a graphical representation is given of the common scales for the time of many external forces and processes, which are related to internal dynamics that effect on the climate [2]. In all these forcing factors we may say that while Plate Tectonics, Earth orbiting Force have very low frequency and long amplitudes, they still can result in

climate changes taking place over the span of the very distant future. Major Volcanic Eruptions can also result in cooling spells concentrated in short periods measured in decades or centuries. As for internal earth dynamics, manifested by the North Atlantic Oscillation (NAO) controlling wind circulation pattern in the north western hemisphere, the (EL Niño) or the Southern Oscillation (ENSO), and the Southern Annular Mode (SAM) in Antarctica; they have, caused much of the climate changes that are observed today, and they primarily result from anthropogenic activities by increasing Co2 and other Green House Gases (GHG) emissions, and changes made to the vegetative cover such as the wide scale deforestation of large areas of the earth surface, especially the rain forests of the Amazon, and the increased rice paddies plantations in Asia. Iraq has hot, dry climate characterized by long, hot, dry summers and short, cool winters. The climate is influenced by Iraq's location between the subtropical aridity of the Arabian desert areas and the subtropical humidity of the Arabian Gulf. January is the coldest month, with temperatures ranging from 5°C to 10°C, and August is the hottest month with mean maximum temperatures rising to 30°C and more (Word Climate Guide, 2022). About 70 percent of the average rainfall in the country occurs between November and March, while June, July and August are often rainless. Rainfall varies from season to season and from year to year. Precipitation is sometimes concentrated in local, but violent storms, causing erosion and flush flooding, especially in the winter months (Weather online, 2022). The average annual precipitation in Iraq varies from 120 mm in the west (Rutba town), 150 mm in the central part (Baghdad; the capital), 365 mm in the northwest (Mosul City), and reaches 745 mm in the northeast (Sulaymaniyah city) (Word Climate Guide, 2022). In Erbil city, however, the average annual precipitation is 365 mm with total of 82. 2 days/ year (Weather Atlas, 2022).

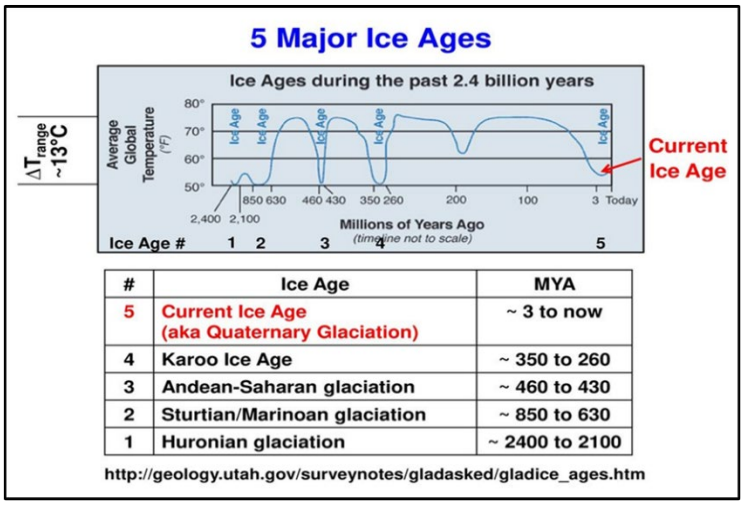

Figure 1: The five Major Ice Ages in the History of Earth. Modified from [1].

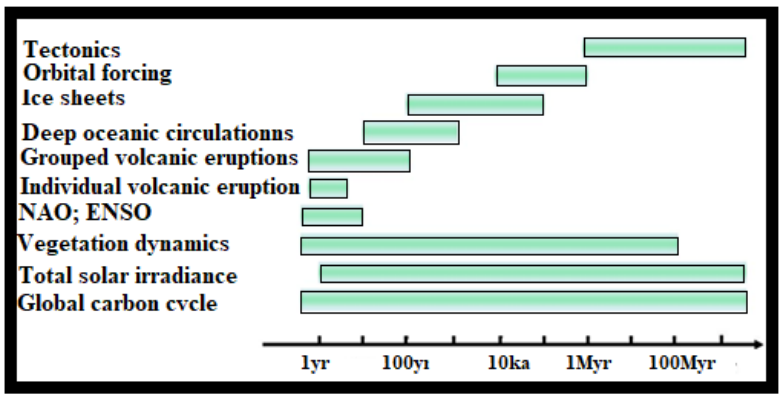

Figure 2: A diagram showing the common scale for time of many external forces and processes related to internal dynamics that effect on the climate [2].

2. 2. Global Warming and GHG Emissions

The present global warming has begun with the beginning of the Holocene Era in which we live today. This is proved from detecting changes of oxygen isotope (δ18 O) in deep cores taken from Greenland ice (Fig. 3) [3], but the actual measurement of the rise in temperature only began in the 1880s (Fig.4) and continued up to now indicating the rise of 1° Fahrenheit (Fig. 5) [4]. It is worth to state that the beginning of the Holocene Era marks also the first practice of agriculture by humans, which also modifies climate by changing CO2 concentration in the atmosphere.

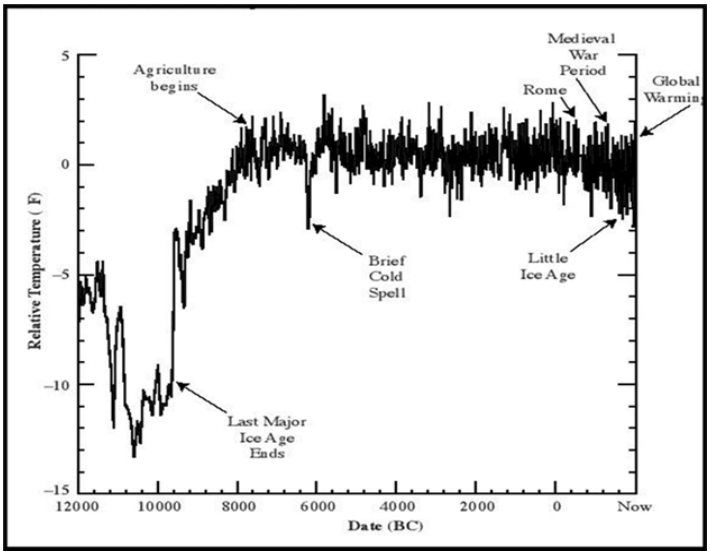

Figure 3: Curve showing temperature oscillation from 12 ka (BC) to nowadays as adopted from Greenland ice measurements of Oxygen isotopes [3].

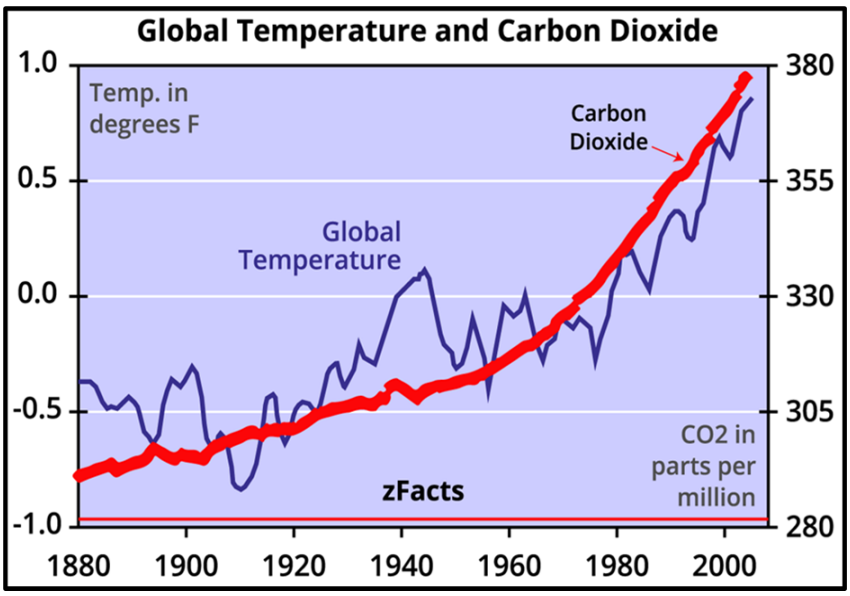

Fig. 4: Global temperature rise vs. CO2 emission from1880 up to nowadays [4].

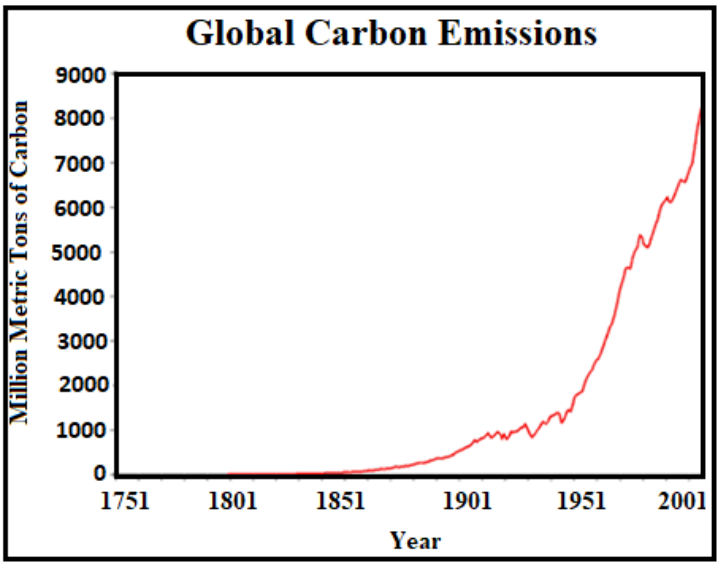

Figure 5: A curve showing the CO_2 emission during the 18th century and the increase of CO_2 until 2010 [5]

The fact that the rise in temperature is associated with CO2 increase in the air is also indicated in (Fig.4), [4]. In this graph, it may be noticed that the curve of CO2 increases in the air starts from around 1880 to 1950 gradually in linear progression. From 1950 to 2000 and beyond, CO2 is increasing in the air is steeper, more exponential curve. The Swedish scientist Svante Arrhenius had already discovered the relation between CO2 emission and rising temperature of the atmosphere in1896 and theorized that it was due to increasing of burning the fossil fuel; from the starting of the industrial revolution. This was confirmed by research work carried out later and summarized in Fig. (5). The increase of concentration of Green House Gases (GHG) as whole was also proved to be responsible for global warming. Research work did prove that for the past two thousand years the increase of concentrations of CO2, CH4, and N2O; the three significant greenhouse gases resulting from burning fossil fuel, have increased substantially starting from 1750. The increase in the rates of the levels of these gases are dramatic. CO2, for example, never increased more than 30 ppm during any previous 1,000-year period in this record, but research work published in 2020 has shown rise of 30 ppm only in the previous two decades; (Fig. 6) [6]. These results were published in the Intergovernmental Panel for Climate Change (IPCC) Fourth Assessment Report Chapter 2 (2007). During the 1950s and 1960s, the enhanced equipment, which measure long-wave radiation helped scientists to confirm that Arrhenius's Theory was correct. During that time, research also proved that CO2 levels were certainly rising yearly. During 1958, Charles D. Keeling a scientist with the Scripps Institute of Oceanography in California, performed the first dependable measurements of CO2 in the atmosphere at Hawaii's Mauna Loa Observatory and has found that the concentration of CO2 is 315 ppm and is still growing yearly [7].

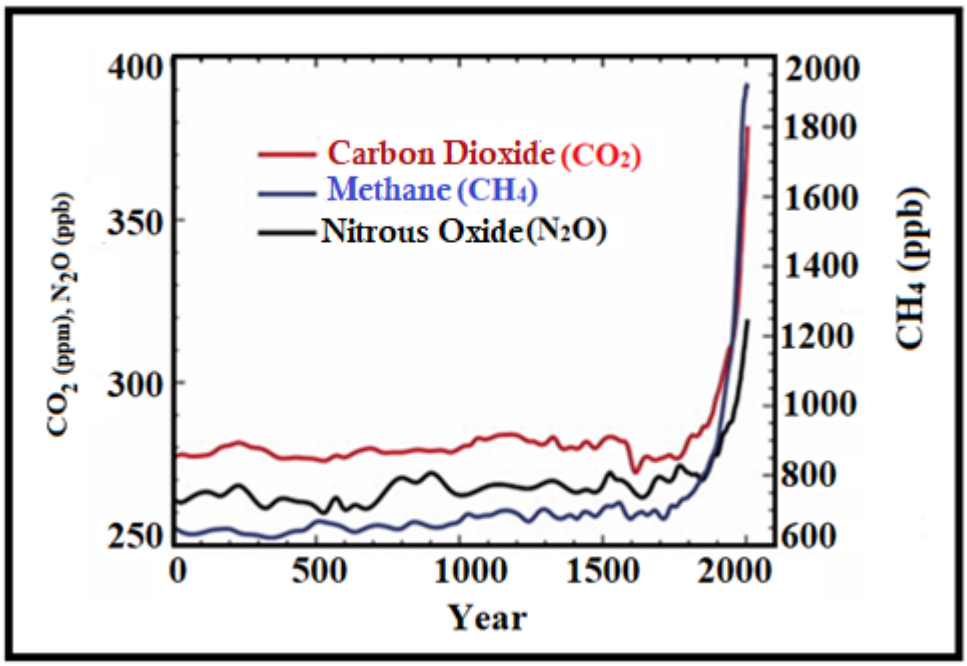

Figure 6: Curves showing the increase of the most significant greenhouse gases for the last two thousand year [6]. These results were based on the (IPCC), 4th Assessment Report (2007), Chapter 2.

The precision, accuracy and continuity of Keeling's research over the span of decades provided one of the most important scientific linkages between fossil fuel combustion and global climate change due to the greenhouse effect. Keeling's methods of measuring atmospheric carbon dioxide revealed clear natural and man-made trends. The graph of Keeling's data from Mauna Loa is known as the Keeling Curve published by the National Oceanic and Atmospheric Administration (NOAA) shows jagged red line which indicates natural oscillations caused by plant growth cycles, while the increase over time is caused by human activities, especially the burning of fossil-fuels (Fig.7) [8].

3. 3. Climate Models and Simulations

Following the alarming rate of rise of world's temperature in the 1960s (Fig. 4) a great scientific interest in climate models began to gather momentum. The increased computational capacities achieved from that time onwards made it possible to accumulate extensive real time data bases of climate variables including temperature measurements, wind velocity rates, atmospheric pressure values, precipitation, and relative humidity measurements. All these enabled scientists to develop climate models and simulation techniques for following the variations occurring anywhere on earth. Climate models proved themselves ever since, as significant tools to improve how we understand and predict the climate behavior seasonally, annually, in decades, as well as in time scales; centennially. These models investigate to which degree the recognized climate changes can be because of natural variability, human's activities, or both. Their results and projections supply basic data to have ultimate decisions nationally, regionally, and local significance, like management of water resources, agricultural and transportation activities, and urban planning.

Climate models' development over the last few decades was in such a way that different components were first developed separately and later were coupled into comprehensive climate models. During 2003, the state of development of these models along the previous 30 years is shown in (Fig. 8) [9].

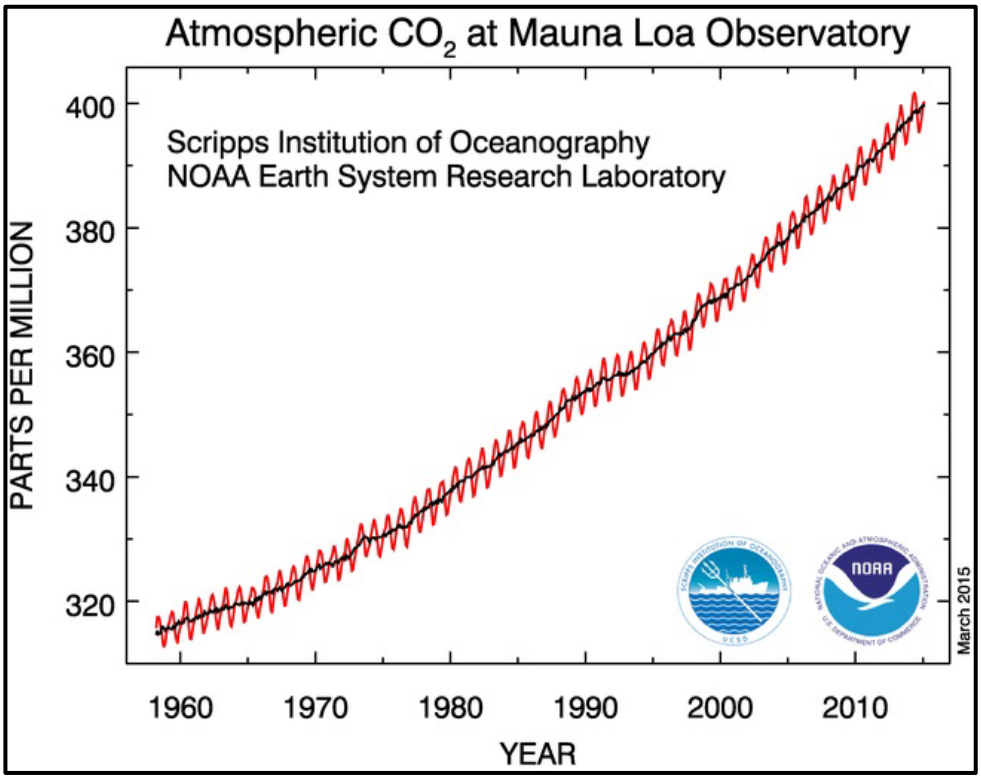

Fig. 7: Keeling curve shoeing the increase of CO2 concentration (ppm) from 1958 up to 2015 [8].

These scientific findings were vital as basis for the next stage of research for predicting climate change in the following years and in more distant future.

It is clear from Figure (9) that interest was concentrated on Ocean and Sea Ice Models in the early 1990s, and models of Sulphur Cycle, Carbon Cycle and Atmospheric Chemistry have been in continuous progress in the late 1990s up to the present. Leading role and pioneering activities were achieved by researchers from Princeton University supported by the US National Oceanic and Atmospheric Administration (NOAA) funding [10]. But Climate Models development was not restricted to the US, and it extended to other countries. The EU, for example, has funded project PRIMEVERA as world-leading global climate models that, together with advanced analysis, tell us more about the processes that have driven changes in weather and climate in recent decades and how they might play out in the future, [11]. Climate Models have, therefore, advanced the knowledge of climate variability and changes to a very far extent. Because there is partial disagreement through various models of climate, but the mentioned models depend on ultimate physical principles, either for simulated processes or for parameterized processes, directly and indirectly, respectively. The extensive check for the results of an experiment by models of a large community and research around the world (IPCC, for example) has reduced the uncertainty. Mainly, simulations produced models of nowadays and past climates of large scale, which conform the acquired observations. Accurate hindcast of climate changes during the 20th century has produced climate models, which include increase in air temperature party because of emissions of CO2. The acquired result confirms the usage of the mentioned models to predict changes in climate in future. Meanwhile, the climate models may object on different acquired results and projections because of natural variabilities, differences in forcing and in feedbacks. Variability in the natural climate can be reduced by applying ensemble of simulations with faint changes in each that has produced an average and reveals to forcing. The forcing; however, varies largely through climate models.

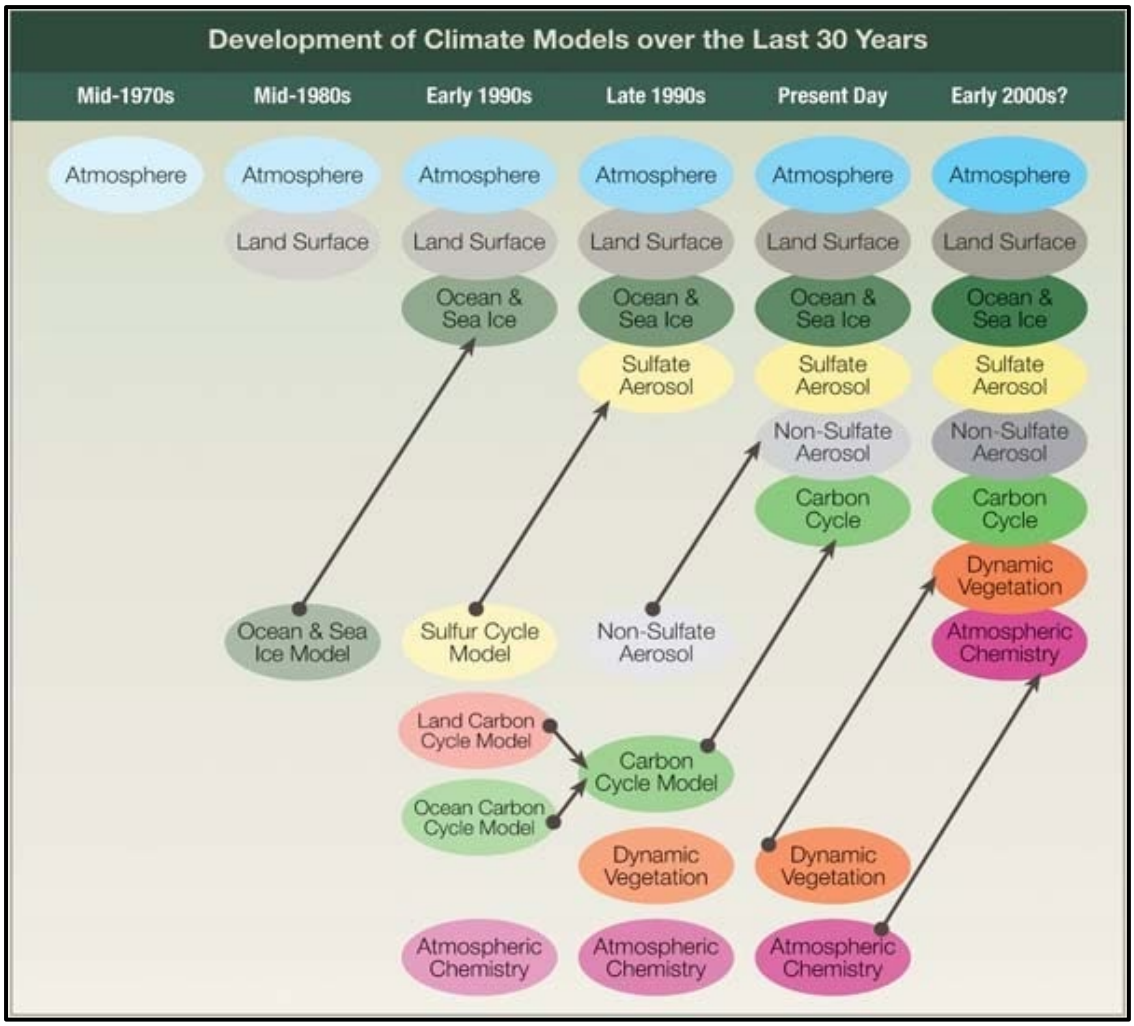

Fig. 9: Development of Climate Models over the Last 30 Years, (taking 2003 as time reference). Published by US Global Change Research Program [9].

Forcing's are the main movers of climate change, and the significant differences through climate models involve aerosols (i.e., a colloidal suspension of particles dispersed in air, typically consisting of soil lifted by the wind, or pollen). The aerosols have uncertain impact on the earth's energy balance. Accordingly, the climate's feedback to aerosols like existence and concentrations of vapor and clouds is different. This is attributed to the existing uncertainty in the parameterized processes. Moreover, various accuracies of climatic models are produced with different resolutions. The equations controlling the climate are known precisely, however, even the nowadays computers can solve them exactly, when are used. Tracking each molecule of the climate system cannot began; therefore, we must average them over large blocks of time and space. The climate models of nowadays, for example, are typically over blocks of the atmosphere, which are 100 km2 and may be 1 km thick, and over time intervals of many tens of minutes. Accordingly, the used averages cause mistakes and skips over significant climate processes [12]. The Danish Physicist Niels Bohr once remarked, "Prediction is very difficult especially about the Future". Certainty of the accuracy of any prediction is indeed the main difficulty. Number of different strategies have been developed by scientists to measure the uncertainty and were used these results to estimate the range of probable temperatures that will foresee in future. It is good to mention, however, that there are about 40 models of climate, which are run by many organizations in the world, and they all give partly different predictions as the response of climate to increasing of greenhouse

gasses' concentrations is concerned. Moreover, a significant task for the researchers is to estimate how the contents of the gasses of greenhouses of the atmosphere will evolve during next centuries. This requires not only understanding of physics, chemistry, and biology, which control the emission of these gasses, but to assess human's behavior, how much greenhouse gasses will be emitted? These questions were tackled by the Intergovernmental Panel on Climate Change (IPCC). This panel was established in 1988 by concerned government of the world together with the United Nations World Meteorological Organization (WMO), the United Nation Environmental Program (UNEP) to provide policymakers with regular scientific assessments on the current state of knowledge about GHG emissions and their impacts on climate change. The IPCC took up on itself the responsibility of collecting climate change research work from thousands of scientists all over the world, analyze them and come up with conclusions for what the future would look like and proposals for policy makers to produce actions to limit climate change impacts.The accumulated knowledge during the years of (IPCC) work has enabled it to issue six assessment reports, the 1st was in 1990 and the last in 2021. These reports embodied the results of research carried out on climate change and their impacts during this period, but one of its basic achievements was in defining the most likely scenarios of Green House Gases (GHG) emissions up to 2100, on which policy decisions to combat the adverse expected impacts on man and its environment can be made. The six emission scenarios covered expected climate change in terms of global warming and their impacts based on the current emissions sources and all the forcing related to projected demographic and economic developments, technological changes and expected deforestation and agricultural changes. Moreover, these expected impacts and corrective actions should fall within the framework of governments policies, and decisions to be adopted by them. (Fig. 10) gives a glimpse of the said scenarios but full coverage may be obtained from [13] [14] [15]. In summary, the mentioned scenarios showed different futures which possibly will appear. The special Working Group of IPCC have conducted these scenarios through identifying and estimating processes of natural and anthropogenic sources of emissions. Moreover, through recognizing the key factors, which are more likely to effect on the future emissions from the mentioned sources. Accordingly, many assumptions were made about how these factors may be changed in the future, and hence estimating the impact of these changes, together on emissions. The resulting scenarios meet the needs of the IPCC by providing emissions estimates that behave according to specifications, consistent with a world that is evolving in a specified and reasonable manner.

4. Needs for Further Research

Governments and research institutes have made great efforts in their research as climate change is concerned and how the impact in future will be on the environment and on mankind. It is believed, however, that still there should be more research to better understand of all considered phenomena, to define better mitigation measures and tools to the policy makers, for enhanced and powerful actions to keep the global rise in the temperature though limits which are manageable. The accuracy of the increasing climate model includes continuous improvement to its completeness, correctness, and resolution. This can be achieved through adding of new processes, which represent many components like cycles of land and ocean, interactions between cloud droplets and aerosols, and ice sheets. Before the component are coupled into the climate model, they are initially developed and tested offline, and then are allowed to interact with other components.

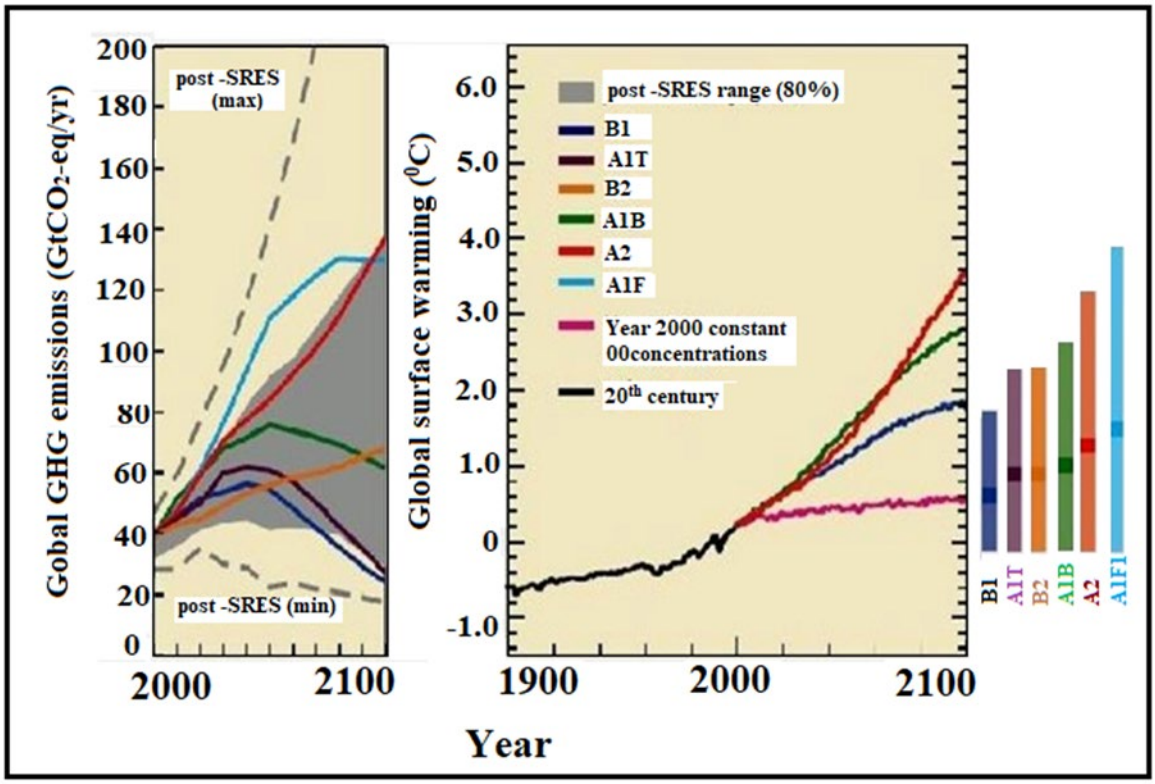

Figure 10. Scenarios for GHG emission from 2000 to 2100 in the absence of additional climate policies, and projections of surface Temperature [13]

The last National Climate Assessment report that was released in 2009 by the U.S. Global Change Research Program (USGCRP), has recommended many fields that should be carried out in future research needs:

1) To improve understanding, modeling, and projections of climate changes by means of continuous efforts, especially in a regional scale. This should include diving forces of emission and changes in land use, changes in temperature, rainfall, soil moisture, runoff, groundwater, evapotranspiration, permafrost, ice and snow cover, sea level change, and ocean processes and chemistry,

2) The characterization of significant sources of uncertainty should be improved, this includes feedbacks and possible thresholds in the climate system, which are associated with changes in clouds, land and sea ice, aerosols, greenhouse gases, land use and land cover, emissions scenarios, and ocean dynamics,

3) Development of indictors, which can allow reporting and enhances public understanding of climate change, and which allows anticipation and attribution of changes that include sudden changes and extreme events in the context of a climate change, and,

4) Enhanced understanding of climate change's interaction with natural variability at many time scales. This includes seasonal to decadal changes (and consideration of climate oscillations including the El Niño Southern Oscillation, Pacific Decadal Oscillation, and the North Atlantic Oscillation), and main events like hurricanes, droughts, and floods [16]. This report was issued before 13 years; however, still more research is needed on the same lines, pursue the results of this research,

and to enforce the required steps to mitigate the impact of the climate change, towards preserving our Planet, Peoples and Environment. Apart from climate changes themselves, more research is needed in their impacts and their mitigation measures. Renumerating such needed research fields includes among other things; extreme precipitation events and resulting flush flooding, recurrent droughts and the consequent loss of crops, severe dust storms and their increased frequency, increased energy consumption needed for heating, cooling and ventilation, and worst of all impacts on human health [17]. It is common knowledge that climate change negatively affects human health. Climate change can increase the risk of high temperature–related diseases, diseases associated with air pollution, vector-borne diseases, allergies, and other conditions. The World Health Organization estimates that approximately 250 000 elderly people will die each year between 2030 and 2050 from exposure to heat waves, diarrhea, malaria, dengue fever, and coastal flooding. To effectively implement policy measures promoting adaptation to climate change nationwide, studies should be conducted not only on heat waves but also on the variety of health effects of climate change. In their systematic review on climate change and its health effects scientists all over the world have reported negative health effects due to climate change, but only few studies are immediately applicable to the process of policy implementation. Furthermore, although many studies on infectious diseases have been conducted, most of these were studies on malaria. In other areas, studies lack enough evidence to establish an agenda item regarding the health impacts of climate change, [18].

5. Conclusion: What Does Iraq Need?

Although Iraq is not one of the major players in Co2 and other GHG emissions in the world, it has been one of the most severely hit countries in the world by the resulting global warming [19-37]. This has shown its marks in the reduction of the Tigris and Euphrates water resources, less total annual precipitation and more of its erratic distribution, in addition to recurrent severe droughts resulting in loss of agricultural land and crops which has caused economic damages and even disruption of social peace. Moreover, severe heat waves accompanied with increasing maximum temperatures and unusual freezing spells have shown their negative results on the health of the people, not to also mention sandstorms that have increased in intensity, frequency, and durations in recent years. The forcing drives of these impacts lay not only in the global nature of weather disturbance in the whole world, but also in the prevailing conditions within the neighboring countries to Iraq forming the Middle East region as one geographical region. Nowadays similar impacts are also common in Turkey, Iran, Syria, Jordan and Saudi Arabia forming this region. To combat the negative impacts of climate change it is, therefore, important to take necessary actions not only on the national scale but on the regional level also, and the following courses of action may be worthy of consideration.

1) As climate change is hitting hard all the Middle East countries, the resulting impacts should be addressed on a regional scale; for this, it is suggested to form one Regional Intergovernmental Panel on Climate Change on the same lines of the IPCC under the name of the “Middle East Panel on Climate Change (ME-IPCC)”. Iraq being so adversely affected can take the initiative in forming this panel. The panel shall have in its memberships the governments of Iraq, Turkey, Iran, Syria, Lebanon, Jordan, Kuwait, Saudi Arabia, UAE, Bahrain and possibly Egypt. It shall take it as its duty to coordinate with the IPCC, WMO, and UNEP on research work and policy issues, while at the same time it shall pioneer, encourage, organize scientific research in all member countries, analyze the results and store them into the form of accessible data base for all. Scientific research managed by (ME-IPCC) shall be mostly of regional nature directed into issues common to the member States. And priority in this work shall be given to create regional Climate Models and Simulations to tackle the forcing drives affecting water resources and air quality problems common to all the member countries, being precipitation or aerosols causing sandstorms.

2) ME- IPCC, in further actions shall develop and adopt Co2 and GHG Emission and Policy Scenarios to be used in the developed, regional or available global climate models, using local data for finding the necessary solutions of the expected negative impacts on the member countries and work out tools for policy makers for common actions on mitigation measures. In an another far sighted step, one

common fund may be established, financed by the member governments and supported by interested world authorities such as the World Bank, EU Commission and United Nations. This fund shall be used to finance the necessary research work and the implementation of corrective measures.

3) On the national level, the government of Iraq is called upon to take up the duty of building the scientific research capacity. This is done by appropriating the necessary funds and encouraging academics within the universities, to carry out specialized research in the field of Climate Models and Simulations taking local conditions into consideration. In addition, increasing their capabilities with further studies, interaction with world scientific community and attending scientific conferences, while at the same time invest more in graduate studies in this field.

4) Climate models and simulations require very large computing capabilities to cope with the huge stream of real time data of the various weather parameters, whether in sorting them out or/and storing them for further use. Moreover, such capacities are necessary to perform all the complex solutions of the mathematical equations and algorithms. At the same time, and as the accuracy of the models and simulations outputs depends greatly on the adequacy and accuracy of the collected data, this means that the government of Iraq will have to install and run extensive and advanced measuring and communicating capabilities for the continuous collection, transmitting of data to one central institute for running the required climate models, analyze the outputs and come up with correct conclusions, and not spare any effort in this field.

5) A new national water resources management plan should be adopted that takes into consideration ongoing and future expected effects of climate change and agriculture. In this context, it is suggested the broad outlines of such a plan should consider the following:

a. Taking all necessary actions by the concerned governments to improve sharing common water resources with riparian countries (Turkey, Iran and Syria).

b. Revolutionizing irrigation methods and practices by converting irrigation projects to closed systems instead of open channel networks, maximize use of sprinkler and drip irrigation and avoid flood irrigation.

c. Adopting reasonable pricing policy for water consumption rates considering water as vital economic commodity and enforcing methods of collection.

d. Introducing more rational and reasonable legislations and update all outdated laws and regulation.

e. Extending the application of rainwater harvest for ground water recharge.

f. Using treated wastewater for agriculture.

g. Using desalination of salty water from existing reservoirs (Tharthar, Razzazah, Al Dalmaj… etc.) and drainage water (Main outfall Drain).

h. Improving Iraqi rivers water quality by reducing contaminating pollutant and salinity.

I. Using water saving crop strains and avoid crops with high water requirements.

j. Using high intensity crop rotations to make maximum use of residual soil moisture at the end of each season.

k. Combating desertification by planting large areas and green zones around cities using drought resistant plants and trees. This will help also in reducing the intensity of sand storms over large areas.

l. Preserving vegetative land cover as much as possible to reduce effects of storm burst causing erosion and degradation of the land. This may be done by controlled land grazing and plantation of shrubs and trees and other soil stabilization methods.

m. Conducting intensive studies and research on future expected impacts of (SLR) for better understanding the extent and magnitude of this problem.

n. Preparing long term action plans for mitigating (SLR) negative effects on costal installations and inland infra structures in the deltaic region.

o. Adopting public awareness program about climate change and water resources.

p. Adopting human resources development program.

No serious and meaning action of the above has been done so far in Iraq up to now [38-42], but in view of the severe degradation in its environment caused by global warming and its negative impacts, it may be too late to delay any more. A quick start must be done now.

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