Environmental Science: An Indian Journal

Review | Vol 17 Iss 12

Global Climate Variability: A brief review of climate change from Palaeocene epoch to Holocene epoch.

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Received: December 03, 2021**; Accepted:** December 16, 2021; **Published:** December 23, 2021

Abstract

By 2099, it is anticipated that the temperature will increase nearly 1.8°C to 4° C than pre industrial era. The larger areas will become arid as the section of land is in drought condition and is anticipated to increase up to 10 percent by 2050. The sea level is estimated to increase between 35 cm to 82 cm by 2100 .These trends indicate that the carrying capacity will be compromised due to this climate change. Paleoclimate data can help us in assessing the climate sensitivity. Out of the many interglacial and glacial periods reviewed in this study, the mid-Pliocene climate is most suited for the future prediction of climate change. In the past, all the major climate change were due to natural causes like orbital forcing , radioactive of greenhouse gases, insolation and ocean water circulation . However, the current climate change is mainly due to the anthropogenic activities, which altered the climate at a very abrupt rate. This study helps in understanding the comparison between past climate change and present climate.

Keywords: Climate change; Paleoclimate; orbital forcing; radiative forcing etc

Introduction

Average weather conditions for nearly 30 years of any area is termed as Climate. It includes the average of temperature, rainfall, humidity, and sunshine. Main Factors affecting the global climate are atmospheric circulation, ocean currents.

However, the whole climate system of Earth is quite complex. Apart from the earlier mentioned factor, there are various fundamental factors as well which influence the climate differently. Solar radiation is one of that factor. The amount of insolation received at a place has a direct impact on the climate, as the temperature is higher near Tropic of Cancer in summer season even more than equator because the suns radiation fall directly on that area creating the ITCZ there. And about 25% of this incoming solar radiation is directly affected by the Milankovitch cycles. This cycle includes Eccentricity, obliquity, and precession, which are based on the shape of Earth's orbit, Earth's angle, and direction of rotation respectively.

Citation: Deepa D. Global Climate Variability: A brief review of climate change from Palaeocene epoch to Holocene epoch. J Environ Sci. 2022;17(12).

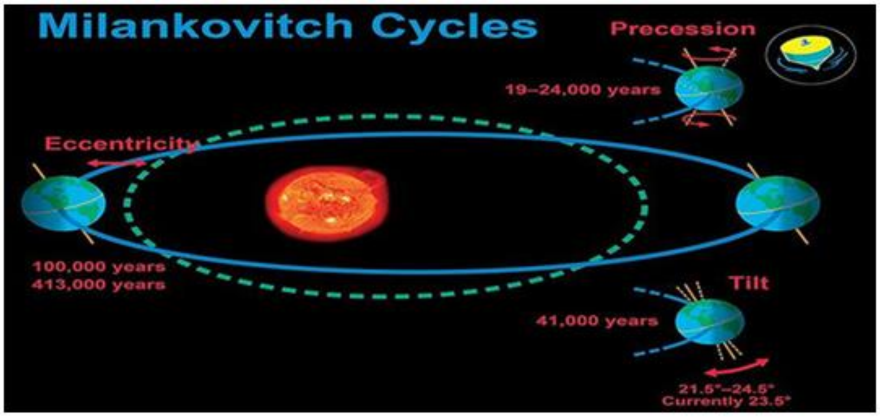

Fig.1. Milankovitch cycle (Earth Observatory NASA)

Literature Review

The middle class is struggling after the 2008 crisis. More and more people feel financially unstable and they have the feeling that their social and economic future will be worse. Populist politicians put the blame on immigrants. As they claim, "immigrants steel our jobs, they don't respect women, they have unacceptable habits and their religion or culture favors violence. Eccentricity is responsible for different lengths of our season and its impact on total global insolation is minimal. Obliquity is responsible for the occurrence of seasons. Earth's angel has changed between 22.1 and 24.5 degrees. Currently, Earth is between its extremes. After 9,800 years, the Earth's angle will be at its minimum and it will lead to mild seasons. The major climate changes over the past 4,50,000 years ago were in correspond with Milankovitch cycles.

In addition, he showed the role of orbital variation in the Glacial and Interglacial periods. It is quiet, not sure how these cycles have started the glacial or interglacial period. However, as these cycles affect the incoming solar radiation on the Earth and if the sunshine drops below a critical value, there will be no melting of ice and snow will accumulate more and more, which leads to the initiation of the ice age. Apart from this concentration of CO_2 also plays a significant role in the glacial and interglacial periods as data from the Antarctic shows that the CO_2 levels were as low as 190 ppm in the glacial time and as high as 280 ppm during the interglacial period. Therefore, it can be inferred that small changes in the Milinkovic cycles amplified the CO_2 concentration, which further might have led to a change in climate along with other regional factors. Different factors were responsible for the past climate change but all of them were natural and these changes cannot explain the present climate change but help in understanding it better.

Objective

As the climate of the world is rapidly changing. It is very important to understand the natural and anthropogenic factors responsible for this.

How paleoclimate data can be very helpful in understanding the present climate as well as predicting the future climate?
This study tries to understand Ocean water circulation and its impact on temperature, CO` levels from the Paleocene epoch to present time. This include various factors like the orbital forcing ,tectonic movement, rotation of the earth, and vegetation during that time.

Result and Discussion

Past Global Variability

The concentration of CO_2, CH_4, sea level, temperature was far high in the past million years as compared to the present times. Various paleoclimate data indicate that the CO_2 level was ranging between 180 ppm to 300 ppm. In addition, these changes in the CO_2 level have even led to climate change in the earlier periods. Pre-quaternary climates prior to 2.6 ma were primarily warmer than these days and associated with higher CO_2 stages. Therefore, they have some similarities with the anticipated future climate. So, let's see the past global variability.

Paleogene Climate Variability

Approximately fifty-five million years ago, the earth was warming after the mass extinction of the Cretaceous period, ocean currents changed their direction. It took 20,000 years to get back to the original state, which implies drastic changes can happen to the planet if global warming continues to increase. Earth's climate system has evolved over years. As this epoch started with the mass extinction of the Cretaceous era, a large amount of CO_2 was released due to the decomposition of the fossils and due to various tectonic activity. This leads to the warming of deep ocean water and rapid decomposition of methane hydrates, which further leads to more CO_2 in the atmosphere. Apart from this CO_2 was released from volcanic activities, and maybe oxidation of certain sediments, which had a high quantity of organic matter. The temperature rises almost by 10°C in a very short period and the CO_2 level was approx. 1400 ppmv. Due to this warm-temperature thick tropical forest, sub-tropical forests were present around the globe and the evidence can be found on a variety of fossil records.

Eocene: This epoch experienced global surface temperature about 13°C higher than the pre-industrial era. Major attraction of this epoch are no permanent ice, CO_2 levels were approximately 1400 ppmv. Palaeocene Eocene Thermal Maximum was the warmest period of the Cenozoic Era. The temperature of the arctic was 22°C. Warm seas throughout the world including the poles. Extreme changes in the climate and carbon cycling were observed during this epoch.

Early Pliocene and Mid Pliocene (5-3 Ma)

One of the first scientists who proposed that the Pliocene climate could be analog to the mid-Twenty first century were Zubakov and Borzenkova. During that time CO_2 levels were nearly double as compared to the pre-industrial era. Many proxy techniques have been used to study the climate of this period.

The deep ocean basin of the Central American seaway was closed during mid-Miocene and the 200 m Shallow Ocean existed. However, during 4.8-4 ma, it reached its critical threshold, which had a huge impression on ocean circulation and global climate. The shutdown of this seaway leads to the formation of the Panamanian bridge between the North American continent and the South American continent. This re-routed current in both the Atlantic and the Pacific oceans. Atlantic currents moved northward, and eventually created a new current that is known as Gulf Stream.

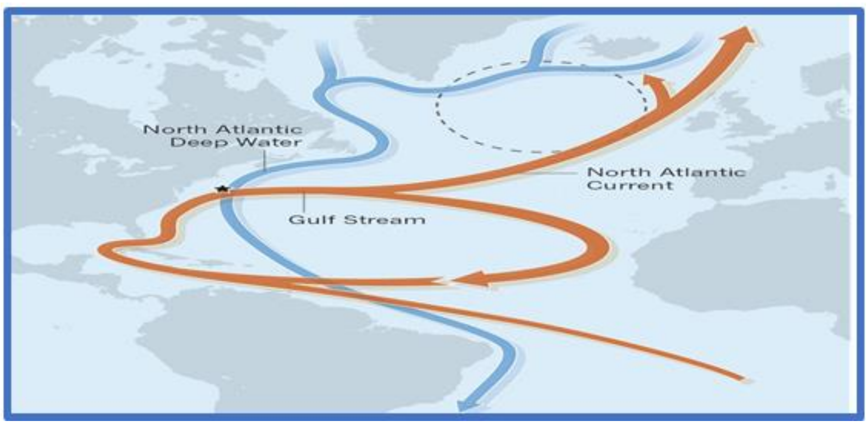

Fig.2. North Atlantic Meridional Overturning Circulation

It is responsible for the warming of north Western Europe. SST gradient difference between the North Hemisphere and South Hemisphere in Atlantic diminished and supported the Atlantic Meridional Overturning Circulation especially the upper AMOC. It also leads to the cooling of the Tropical Pacific by cooling the thermocline. It strengthened deep-water formation and favoured the warming of the Northern Hemisphere during the early Pliocene. Records also suggest that surface temperature gradient near-equatorial pacific were similar to present-day El Nino conditions. And early Pliocene was a permanent El-Nino state which implies that there was a weak atmospheric circulation. However, the temperature of the Western Equatorial Pacific remains debated among the paleoclimate scientist community.

The present geographical configuration of the continents and oceans is nearly the same as of mid-Pliocene time. CO_2 level was around 360 to 400 ppm and sea level was around 15 to 25 m more than the pre-industrial values. Elevation in the CO_2 level was responsible for additional radiative forcing which could increase tropical Sea Surface Temperature by 1°C-3°C.

Due to the increase in temperature ice sheets started melting. But it is to be noted that higher latitudes experienced warmer climate when compared to tropical areas. Coupled atmosphere-ocean experiment which has taken into account 400 ppm of CO_2 has predicted that northern North Atlantic was warming around 3°C to 5°C above pre-industrial time and tropics were warming 1°C to 3°C. One of the reasons cited for this due to enhanced thermohaline circulation or the heat exchange through oceans increased. Arctic summer SST was warmer than modern, seasonal free ice was existing but seasonally ice-free as well. The warm Pliocene climate even at the higher latitudes in Northern Hemisphere like Lake E Siberia was warmer than 8°C than the modern times.

However, during 4-3 ma, due to change in the tectonic activity of the Indonesian region, the warm southern pacific was replaced by fresh and cold north pacific water. This freshening of the sub-surface eastern Tropical Indian Ocean resulted in weak AMOC .This weak AMOC was responsible for climate change like aridity in North-western Australia and Africa and had other impacts. This freshwater was the result of the melting of ice covers which significantly changed the surface albedo. And this surface albedo change along with CO_2 contributed significantly to the warm mid-Pliocene. The cause of Mid Pliocene warming can be partitioned between CO_2 (36%-61%), vegetation (21%-27%), ice sheets (9-13%), and orography (0-26%), Although the involvement of ice sheets is less on the global level but very significant in the warming of the Southern Hemisphere. Because of this warmness major Trans Arctic migration of mollusks, ostracodes happened as the Bering Strait opened. Shifting of the taiga forest, temperate forest toward northward led to the reduction in Tundra vegetation and increased Coniferous forest.

Table 1. Global climate variability of various epoch from Cenozoic Era.

Time	Events	Global mean surface temperature(°C)	CO_2(ppmv)	Sea level	Major reason for climate change
6 ka	Mid Holocene	0.7°C higher than pre-industrial	260 ppmv	2-3 meter high than pre industrial	Jomon Trangression Japan, Isostatic rebound
20ka	Last glacial	3°C-5°C cooler	199 ppmv	120 m below	Orbital forcing, amplification
129-116 ka	Last interglacial	0.8-1.3°C higher than pre-industrial	280-300 ppmv	4-6 m above	Glacial isostasy
3.3-3 Ma	Mid Pliocene	1.8-3.6°C higher than pre-industrial	~400 ppmv	22 m above	Atlantic Ocean Circulation
~50 Ma	Paleocene-Eocene Thermal Expansion	13°C higher than pre-industrial	1400 ppmv	Data not available	Mass extinction of cretaceous period

Glacial and interglacial periods

Earth has witnessed series of glacial and interglacial periods but the last 430 kyr have been best documented.

Last interglacial (125ka)

During this interglacial time, the temperature rose between 0.8°C to 11.3°C higher than in the pre-industrial era. During the first half of this period, there was increase in insolation due to orbital forcing. There was significant decrease in the size of Greenland and Antarctica ice sheets with 3°C to 5°C increase ,warmer sea surface waters in Mediterranean Sea, Indian Ocean and Pacific Ocean and Artic ocean. During the last interglacial period, the global sea level increased between 4 to 6 m higher due to the retreat of ice sheets, the south Greenland Ice Sheet and arctic field contributed 2 to 4 m of sea level.

Most recent Glacial period (116KA)

The reason for the initiation of this glacial period was Orbital Forcing. Ice sheets started growing, sea-level fall which build the Last Glacial Maximum (21ka). And these periods are widely studied because of the availability of boundary conditions, radiative forcing, etc. The evergreen forest was reduced and the tundra forest expanded. And because of the reduction in vegetation, the concentration of the aerosols increased. The records from the pollen grains indicate that the tropical temperature in the lowland was 2℃ to 3℃ cooler. North Atlantic had an extensive ice sheet as compared to the present, and there was a large expansion of the winter ice sheet in Antarctica. More cooling was observed in the mid to high latitude due to change in the ocean circulation and less cooling in the tropics. Over mid and high latitude, as vegetation decreased and shifted southwards, permafrost expanded over Northwest Europe.

Comparison of variation in Greenhouse gases from glacial and interglacial period to Industrial Era

The past millennium concentration of CO_2, CH_4, N_2O fluctuated only within 4%,4%, and 7% respectively. But in the last 200 years ago it has exceeded by 25%, 120%, 9% for CO_2, CH_4 and N_2O respectively. In the radiative forcing, CO_2 concentration plays a significant role and the increase of CO_2 level during the industrial era is comparable to the CO_2 level during the transitions from glacial to interglacial. But the rate of the increase of CO2 level, in the industrial era, is not comparable to 650kyr. And also the rate of increase of CO_2, CH_4, N_2O has been maximum in the industrial era than in the last 16kyr. From 1960 to 1999, the increase in CO2 level was 5 times more when compared to any 40 years of the 2 millennia. Similarly, the rate of increase of CH_4 was 6 times, and for N_2O minimum of 2 times higher in the past 2 millennia. And the combined radioactive forces of all these gases were 6 times higher from 1 AD to 1800AD.

Since CO_2 is more soluble in cold water, so any change in the temperature of deep ocean circulation will impact the atmospheric CO_2 concentration. And the southern ocean plays a very important role in the thermohaline circulation. So, changes in the Antarctic temperature impacts the CO_2 concentration.

Current Interglacial period

In the present interglacial period, Earth orbit experienced changes that resulted in the modulation of latitudinal and distribution of insolation. The associated ice sheet albedo has been modulated because of orbital forcing. Ice core analyses have helped in the estimation of atmospheric trace gases during Holocene. The concentration of CO_2 decreased from 11 to 8 ka about 7pppm and then increased by 20ppm till the industrial revolution. There was a decrease in NH to about 730ppb, 580ppb around 10ka and 6ka respectively. Then, increased to 730ppb until 2002. The same trend can be seen in the concentration of the N_2O. So, the climate had been changing drastically. Now, let's discuss the variation in greenhouse gas, glacier and the abrupt changes in climate.

Variation of atmospheric greenhouse gases in the Holocene period

The decrease in the concentration of CO_2 in the early Holocene can be attributed to the increase in forest cover. As the ice melted, vegetation found its way in those areas and there was forest regrowth which was covered by ice sheets in the previous ice age. Recent studies based on carbon isotope had suggested the concentration of CO_2 was rather stable in the last 7kyr till industrial era. And it may have been because of the carbon storage in peatland in the northern hemisphere. So, atmospheric CO_2 should have remained below 290 ppm without human-made interference. And based on the Vostok ice core data, CO_2 concentration should have dropped by 20 ppm naturally in the past 8 kyr but we have seen an increase by 20 ppm. And the reason stated is the release of CO_2 and CH_4 from prehistoric agriculture in the Holocene.

This increase in Greenhouse gas emission has blocked the beginning of glaciation in high altitude areas by the late Holocene. But this hypothesis has also been challenged because apart from an increase in GHGs, there is no orbital forcing like previous interglacial periods and the concentration of CO_2 was even higher in many interglacial periods when compared to today. The evolution of temperature over the Holocene has been established for numerous different territories, often with centenary resolution proxy data more sensitive to particular seasons. At higher latitudes of the North Atlantic and Adjoining Arctic, there was a propensity for summer temperature maxes to happen in the initial Holocene (10-8 ka), indicating the direct effect of the summer insolation maximized on sea ice area. Climatic restoration for the middle northern latitudes shows a long-term Decrease in SST from the hot early to middle Holocene to the cool preindustrial era of the late Holocene, most likely in response to yearly mean and summer orbital enforcing at these latitudes.

Forest, as well as substantial glacier retreat. Hotter conditions at middle and elevated latitudes of the NH in the initial to middle Holocene are stable with deep borehole temperature profiles. Further early hotter periods were recognized in the Antarctic equatorial region and western Pacific region.

Abrupt Climate Change during the Current Interglacial

High-resolution continental proxy data records record an abrupt cooling of 2°C to 6°C identified as an important feature of ice cores in Greenland at 8.2 ka in European countries and North America. A huge decrease in atmospheric methane levels (tens of parts per billion, shows us the widely spread signature of the sudden '8.2 ka event' associated with large-scale atmospheric circulation change data recorded from the Arctic to the tropical region with relation to dry episodes.

Around 5 and 4 ka, several rapid events were happening at a various latitudes like Immediate increase of ice cover in the Northern Hemisphere, Greenland deuterium decreased, the hydrological cycle was changed. And the reason for these sudden changes has not been understood. But these changes in the climate suggest that climate can change abruptly even there is a slight change in orbital forcing. Few examples of abrupt changes due to present climate change.

A) The Record of Past Atlantic Variability

Climate change over the North Atlantic region is related to changes in the North Atlantic Oscillation and the Atlantic Multidecadal Oscillation. From 1980-1995, the North Atlantic Oscillation tended to abide by in single extreme phase and support for a significant part of the warming in winter over northern Eurasia and Europe. The North Atlantic region has an exclusive amalgamation of longer instrumental observations, any recorded data, and multiple sources of proxy data. However, it remains difficult to record past differences in the presiding modes of climate change in the region, including the North Atlantic region, due to problems of setting up proxy data for the pressure of the atmosphere, as well as the absence of immobile in the NAO frequency and in tracking storms. Many reformations of NAO have been suggested.

Though the various reconstructions are different in various aspects, yet there is a common tendency for negative NAO indices in the 17th and 18th centuries rather than in the 20th century, which indicates that the decrease in temperature was the result of a zonal atmospheric pattern. The most freezing European winter in 1708/1709, and the vigorous warming trend around 1684 and 1738, and negative NAO index and the response of NAO to increase in radioactive forcing. A few temporal resolved models which employ GCMs show that the solar forcing and volcanic forcings were responsible for the warming of continents which was associated with a relocation in direction of high NAO index. An increase in solar irradiance at the termination of the 17th century and the beginning of the next century might have resulted in relocation in the direction of a high NAO index. It is established that NAO is responsible for a strong impact on winter temperature and rainfall in Europe, though the stability of this relationship can alter in time and with the region.

As greenhouse gases are increasing at a very significant rate, the Atlantic meridional circulation is very important for carbon sequestration and absorbing anthropogenic heat, which helps in modulating the climate. But this circulation started slowing down around 1850, probably because of the increase in the freshwater influx from the arctic due to the melting of ice with an increase in the temperature .A weakening AMOC means the Gulf Stream will transport less heat into the atmosphere. The collapse of AMOC is unlikely, but the RCP8.5 model predicts a 34 % weakening of AMOC by 2100 for a high GHG emission. The slowdown was about 15% (since the mid-twentieth century) and was most prominent during winter resulting into the decrease in temperature and harsh cold winters in Western Europe. In the Southern Ocean, Antarctic Circumpolar Current is required to shift poleward later on. This dislodging is relied upon to result in upgraded warming in between 40 ºS and 60 ºS and expanded equatorward Ekman transport, expanding the upwelling of generally warm profound water masses. Because of temperature-driven abatements in thickness, the development of Antarctic Bottom Water soaking in the northward course towards the worldwide chasm is relied upon to debilitate.

B) Changes in the El Niño-Southern Oscillation System

A keen interest in the ENSO system inspired various attempts in the reconstruction of its palaeoclimate. These efforts include a Siberian winter reconstruction of the Southern Oscillation Index (SOI), which is based on tree ring indicators that are ENSO sensitive. The records of coral Fossil from Palmyra Island in the Pacific Ocean also gives data of changes in ENSO in the past 1.1kyr. At last, a 600 year remodel of Nino-3 SST from December to February has been developed, and that is more accurate than the previous. Yet not independent, these paleo records depict significant changes greater than 30% in their cross-validation period, which indicate a comparatively in tune with El Niño in past centuries. Many of the coral records from regions like the western Pacific Ocean and the Indian Ocean indicate the increase in temperature is unparalleled over 100 to 300 years. Still, it is not advisable to completely rely on records from coral. Remodelling of temperatures and atmospheric circulation of the extratropical region is in agreement with the estimate of tropics, which assist the evidence from the Pacific from the last 3 to 4 centuries. The radiative forcing by solar radiation and volcanic eruption might have altered the ENSO over the last thousand years. In addition, remodels further suggest that La Nina resulted from the increased SST gradient, which was further in response to dominant trade winds.

When we compare paleo data and various remodels of the last thousand years, it suggests that warmer climate was in association with ENSO variation. In addition, these experiments further suggest that ENSO played a significant role in past climate change which happened due to radiative forcing. The low-frequency alteration in both variability and average state suggested by ENSO remodelling from Palmyra corals was in co-relation with the changes of volcanic radiative forcing in tropics from the last 1 kyr which played the primary role. While solar forcing played the secondary role. Various records indicate that ENSO’s impact on global climate has evolved. Notably, ENSO to drought relations occur constantly in the southwestern USA, but the strength of humidity penetration into the continent differs substantially. On Comparing reconstructed Niño three SST with global mean temperature patterns indicated that few characteristics are robust throughout timelines, such as the warming of eastern Pacific and western coasts of Northern and Southern America, whereas connection into The Atlantic, North America, and Eurasia are inconstant. The spatial correlation model for the period between 1801-1850 provides important proof of non-stationarity in ENSO teleconnections, displaying a clear absence of the normal pattern of warming in the tropical Pacific region.

El-Nino is portrayed by enormous SST anomalies in the eastern pacific until the twenty century, but in the late twentieth century, it is portrayed by enormous SST anomalies in the central Pacific Ocean. This new type of El- Nino is also called as Central Pacific-El Nino is less incessant now and CP-El Nino is incessant which is also called as El- Nino Modoki.

Impacts of this CP-El Nino

CP-El Nino is responsible for drought like conditions in the areas of India, Australia, Indonesia, and central Pacific Island.
The air that rose above heated water of the central pacific sank in the surface at higher latitude with more than usual intensity and resulted in cyclonic activities in the Pacific and less in the Atlantic.

Drought like conditions in Amazon and south-eastern part of South America, which created ideal conditions for forest fires. It is estimated that there was an increase of 36% in the forest fire of Amazon in the 2015-2016 El Nino.

SST anomalies of the Eastern Pacific

El Nino is formed on Eastern Pacific .Whereas SST anomalies during the CP- El Niño are formed on Central pacific.

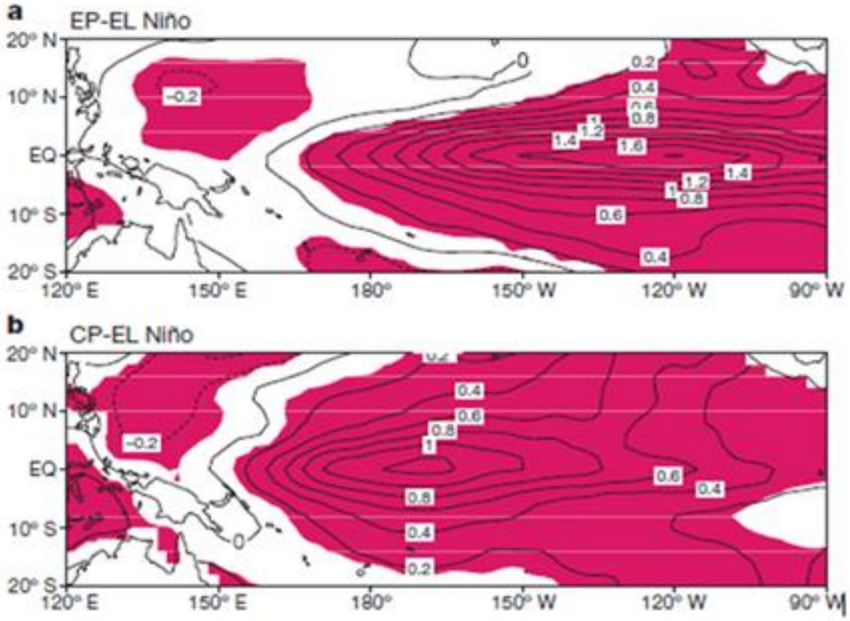

Fig.3a. SST anomalies of Eastern Pacific - El Nino
Fig.3b. SST anomalies of Central Pacific - El Nino

Tropical regions of South America, Arica, and Indonesia released 2.5 gigatons more carbon in 2015-16 El Niño as compared to 2011. Using 20 climate models, scientists have estimated that extreme El Niño events occur in every 20 years but now its frequency will increase and will occur roughly in 10 years. The growth rate of CO_2 decreases during La Niña as conditions are reversed during that time. As the world climate is changing, events like ENSO are changing and are affecting the global climate at a very large scale.

Change in monsoon because of climate change

As per precipitation data, the summer monsoon was enhanced in parts of Africa, India, and Asia during the early to middle Holocene. The reason for this enhancement is again orbital forcing which resulted in an increase of temperature and changes the position of ITCZ. So, there were wetter conditions in the Mediterranean Sea which changed the climate of the nearby area.

Comparison between climate changes from history to present times

Change in Climate on all timelines in Earth's history. Few aspects of the current climate change are not very uncommon, but many are. The concentration of carbon dioxide in the earth's atmosphere has outreached a record high comparative to more than it was in the past half-million years and has done so at an unusually faster rate. Current earth temperatures are warmer than they have ever been in the last five hundred years, certainly even for more than one thousand years. If warming continues incessantly, the consequential climate change within the last one hundred years is Very uncommon in geological terms. Another uncommon feature of current climate change is its cause, the climate changes in the past were having natural origins, whereas the majority of the global warming of the last 50 years is due to anthropogenic activities.

When we compare the recent global climate change to past global climate changes, natural ones, three dissimilarities must be concluded. First, it must be clear which variable is being compared: is it global greenhouse gas concentration or Global temperature variation (or any other climate change parameters), and is it their absolute value or their rate of change? Second, local changes must not be confused with global changes. Local climate changes are often much larger than global ones since local factors (e.g., changes in oceanic or atmospheric circulation) can shift the delivery of heat or moisture from one place to another and local feedbacks operate (example sea ice feedback). Large changes in global mean temperature, dissimilarity, needed some global forcing (similarly as a greenhouse gases concentration level variation or solar activity).

Third, it is needed to differentiate between various time scales. Climate changes observed over millions of years can be much bigger & have various causes (like continental drift) as compared to climate changes that lasted for 100 years on the time scale. The major reason for the current worry about global climate change is the rise in earth's atmospheric carbon dioxide concentration levels (also a few other greenhouse gases), which is very uncommon for the period from about 2.5 million years ago to the present. The concentration of carbon dioxide is currently known precisely for the past 650,000 years from ice cores in the Antarctic. During this time, carbon dioxide levels vary between a lowest of 180 ppm during the freezing global glacial times period and a highest of 300 ppm during hotter interglacial. In the last 100 years, it quickly rose well out of this range and is now it is nearly 379 ppm. For comparison, the approximately rise in carbon dioxide concentration levels is 80-ppm at the end of the previous ice ages which normally took over five thousand years.

Higher values than at present have only taken place many millions of years ago. The global Temperature is a more difficult variable to reconstruct than carbon dioxide (globally a very well-mixed gas), as it does not have the same value all over the earth so that a single record (for example an ice core) is only of limited value. Local temperature fluctuations, even those over just a few decades, can be few degrees Celsius, which is greater than the global warming signs of the past 100 years of about 0.7°C. More significant for global changes is an evaluation of large-scale averages, where many of the local variation averages out and variability is smaller. Adequate coverage of instrumental records goes back only about 150 years.

Further back in time, analysis of proxy data from tree rings, ice cores, etc., go back more than a thousand years with the descending trend of spatial coverage for earlier periods. While there are differences among those reconstructions and significant uncertainties remain, all published reestablishment find that temperatures were hotter during medieval times, cooled to lowest values in the 17th - 19th centuries, and warmed rapidly after that. The medieval level of warmness is undetermined but may have been reached again in the middle of the 20th century, only to likely be outreach since then. Various existing climate models support these conclusions. Earlier two thousand years ago, temperature differences have not been orderly compiled into large-scale averages, but also they do not provide proofs for warmer present global annual mean temperatures going back through the Holocene period (in the last 11,600 years). There are very rigid signs that a hotter climate, with much reduced global ice cover and higher sea level, succeeded till approximately three million years ago. Hence, current warmth appears uncommon in the relation of the past kilo annum, but not uncommon on a longer timeline for which changes in tectonic activity become relevant.

The highest temperature variation of the past million years is the glacial cycles, during which the global mean temperature increased by 3°C (which is changed by 4°C to 7°C) between ice ages and hotter interglacial periods. However, the recorded data indicate that global warming at the end of the ice age was a moderate process taking about five thousand years. So now it's clear that the current global climate change rate is much faster and very uncommon in the context of changes in the past. The much-discussed current climate shifts during glacial times are not counter-examples, since they were likely due to variation in ocean heat transport, which would be very uncommon to affect the global mean temperature levels. Additionally back in time, beyond data of ice core, the time resolution of sediment cores and other archives does not resolve changes as quickly as the present warming situation.

Conclusion

Climate change is not a new phenomenon. Across all models, the mid-Pliocene climate is best suited for the prediction of future climate as it is similar to the present climate. According to the RCP (8.5) future climate will resemble the climate of mid-Pliocene by 2030 CE, and then to the Eocene climate by 2050 CE. Paleo climatic data explains how change in AMOC affected the global climate. We have observes abrupt climate changes in the past. CO_2 level, temperature, sea level rise were high as compared to the present times. However, during that time all these changes happened due to natural cause and took thousands of year. This gave Earth the time to adapt to these changes. However, all these changes during glacial and interglacial transition were because of orbital forcing and amplified due to increase in greenhouse gases. None of the records indicates that the increase in greenhouse gases initiate the climate change. However, the temperature is rising at a very rapid rate in the current period due to the anthropogenic activities.

References

1. Alexander MA, Blade I, Newman M, et al. The atmospheric bridge: The influence of ENSO teleconnections on air-sea interaction over the global oceans. J clim. 2002;15:2205-2031.
2. Ashok K, Behera SK, Rao SA, et al. El Nino Modoki and its possible teleconnection. J Geophys Res. 2007;112:C11007.
3. Brook EJ, Harder S, Severinghaus J, et al. On the origin and timing of rapid changes in atmospheric methane during the last glacial period. Global Biogeochem. Cycles, 2000:14,559-572.
4. Burke KD, Williams JW, Chandler MA, et al. Pliocene and Eocene provide best analogs for near-future climates. Proc Nat. 2018;115:13288-13293.
5. Caesar L, Rahmstorf, S, Robinson A, et al. Observed fingerprint of a weakening Atlantic Ocean overturning circulation. Nature. 2018:556;191-196.
6. Chiang J.C.H., Sobel A.H. Tropical tropospheric temperature variations caused by ENSO and their influence on the remote tropical climate. J Clim. 2002;15:2616-2631.
7. Collins M., Knutti R., Arblaster J., et al. In Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, pp. 2013:1029-1136
8. Cook E.R., D Arrigo R.D., Mann M.E., et al. A well verified, multiproxy reconstruction of the winter North Atlantic Oscillation index since AD 1400. Journal of Climate. J Clim., 2002:15;1754-1764.
9. Cronin T.M., Cronin M.A. Biological response to climate change in the Arctic Ocean: the view from the past. arktos. 2015;1:1-8.
10. Davis B.A., Brewer S., Stevenson A.C., et al. The temperature of Europe during the Holocene reconstructed from pollen data. Quat Sci Rev., 2003:22;1701-1716.
11. Dickens G.R., Castillo M.M., Walker J.C.G., et al. A blast of gas in the latest Paleocene: Simulating fi rst-order effects of massive dissociation of oceanic methane hydrate. Geo, 1997:25, 259-262.

12. Dolan A.M., Haywood A.M., Hill D.J., et al. Sensitivity of pliocene ice sheets to orbital forcing. Palaeogeogr Palaeoclimatol Palaeoecol. 2011:309;98-110
13. Dowsett, H. J., Robinson M.M., Haywood A.M., et al. Assessing confidence in Pliocene sea surface temperatures to evaluate predictive models. Nat Climate Change. 2012:2;365-371.
14. Dowsett, H.J., Cronin, T.M. High eustatic sea level during the middle pliocene: Evidence from the southeastern U.S. Atlantic coastal plain. Geol. 1990:18;435-438.
15. Du Y, Qu T. Three inflow pathways of the Indonesian throughflow as seen from the simple ocean data assimilation. Dyn atm Oceans. 2010;50:233-256.
16. Evans M.N., Kaplan A., Cane M.A., et al. 2002: Pacific sea surface temperature field reconstruction from coral δ18O data using reduced space objective analysis. Paleoceanogr Paleoclimatol, 2002: 17;1-7.
17. Farrera, I., Harrison S.P., Prentice I.C., et al., Tropical climates at the last glacial maximum: A new synthesis of terrestrial palaeoclimate data I, Vegetation, lake-levels and geochemistry. Clim. Dyn., 1999:15,823-856.
18. Haug G.H., Tiedemann, Ralf. Effect of the formation of the isthmus of panama on atlantic ocean thermohaline circulation. Nature. (1998):393.673-676.
19. Huber, C., Leuenberger M., Spahni R., et al., Isotope calibrated Greenland temperature record over Marine Isotope Stage 3 and its relation to CH4. Earth Planet Sci Lett. 2006:243,504-519.
20. Karas C., Nurnberg D., Bahr A., et al. Pliocene oceanic seaways and global climate. Sci Rep. 2017;7:1-8.
21. Joos F, Gerber S, Prentice IC, Otto-Bliesner BL, Valdes PJ. Transient simulations of holocene atmospheric carbon dioxide and terrestrial carbon since the last glacial maximum. Global Biogeochemical Cycles. 2004;18.
22. Kaplan, M.R., Wolfe A.P. Spatial and temporal variability of holocene temperature in the north atlantic region. Quat Res. 2006:65, 223-231.
23. Karas C., Nürnberg D., Bahr A, et al. Pliocene oceanic seaways and global climate. Sci Rep. 2017:7;39842.
24. Kim J.S., Kug J.S., Yoon J.H., et al. Increased atmospheric CO2 growth rate during El Niño driven by reduced terrestrial productivity in the CMIP5 ESMs. J Clim. 2016;29:8783-8805.
25. Kopp R.E., Simons F.J., Mitrovica J.X., et al. Probabilistic assessment of sea level during the last interglacial stage. Nature. 2009;462:863-867.
26. Larkin N.K., Harrison D.E. On the definition of El Niño and associated seasonal average US weather anomalies. Geophy Res Lett. 2005;32.
27. Lunt D.J., Haywood A.M., Schmidt G.A., et al. On the causes of mid-Pliocene warmth and polar amplification. Earth Planet Sci Lett, 2012;321-332.
28. Luterbacher J. Reconstruction of sea level pressure fields over the Eastern North Atlantic and Europe back to 1500. Clim Dyn. 2002:18, 545-561.
29. Marcott S.A., Shakun J.D., Clark P.U., et al. A reconstruction of regional and global temperature for the past 11,300 years. Sci. 2013:339;1198-1201.
30. Masson Delmotte V. GRIP deuterium excess reveals rapid and orbital-scale changes in greenland moisture origin. Sci. 2005:309,118-121.
31. Monnin, E. Evidence for substantial accumulation rate variability in Antarctica during the Holocene, through synchronization of CO2 in the Taylor Dome, Dome C and DML ice cores. Earth Planet Sci Lett., 2004:224;45-54.
32. Renssen H., Vandenberghe J., Investigation of the relationship between permafrost distribution in NW Europe and extensive winter sea-ice cover in the North Atlantic Ocean during the cold phases of the last glaciation. Quat Sci Rev. 2003:22;209-223.
33. Rind D., Chandler M.A., Increased ocean heat transports and warmer climate. J Geophys Res. 1991:96;7437-7461.
34. Ruddiman W.F., Vavrus S.J., Kutzbach J.E. A test of the overdue glaciation hypothesis. Quat Sci Rev, 2005:24;1-10.
35. Salzmann U., Haywood A.M., Lunt D.J., et al. A new global biome reconstruction for the Middle Pliocene. Glob Ecol Biogeogr. 2008:17; 432-447.
36. Shindell, D.T., Schmidt G.A., Miller R.L., et al. Volcanic and solar forcing of climate change during the preindustrial era. J Clim. 2003:16,4094-4107
37. Spahni R., Schwander J. Flckiger J., et al. The attenuation of fast atmospheric CH4 variations recorded in polar ice cores, Geophys Res Lett. 2003;30:1571.
38. Stevens A.N.P. Factors Affecting Global Climate. Nature Edu Knowledge. 2011:3;1
39. Stocker T.F, Monnin E.R. Past rates of carbon dioxide changes and their relevance for future climate. Pages News. 2003;11:6-8.
40. Wing S.L., Transient floral change and rapid global warming at the Paleocene-Eocene boundary. Sci. 2005:310;993-996.
41. Song Yang, Zhenning Li, Yu, et al. El nino southern oscillation and its impact in the changing climate. Natl Sci Review. 2018;5:840-857.