General Knowledge Today

Environment-6: Climate Change

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Climate Change Concepts

Difference between Climate and Weather

Climate is often defined as 'average weather'. Climate is usually described in terms of the mean and variability of temperature, precipitation and wind over a period of time, ranging from months to millions of years (the classical period is 30 years).

Climate is defined as average weather, and as such, climate change and weather are intertwined. Observations can show that there have been changes in weather, and it is the statistics of changes in weather over time that identifies climate change.

- While weather and climate are closely related, there are important differences. A common confusion between weather and climate arises when scientists are asked how they can predict climate 50 years from now when they cannot predict the weather a few weeks from now.
- The chaotic nature of weather makes it unpredictable beyond a few days. Projecting changes in climate (i.e., long-term average weather) due to changes in atmospheric composition or other factors is a very different and much more manageable issue.

As an analogy, while it is impossible to predict the age at which any particular man will die, we can say with high confidence that the average age of death for men in industrialized countries is about 75. Another common confusion of these issues is thinking that a cold winter or a cooling spot on the globe is evidence against global warming.

Climate Forcing

Earth's climate system includes Oceans, Land surface, Cryosphere (polar ice), Biosphere and Atmosphere. This system evolves in time as per influences of its own internal dynamics. However, external factors also may affect the climate. Any external force / factor that can become a cause of climate change is called Climate Forcing. Such forcing originates from outside the climate system itself. They key examples of Climate Forcing are Albedo (surface reflectivity), Human induced changes in Green House Gases, Atmospheric aerosols due to human activity or volcanic eruption etc. The peculiar feature of all climate forcing is that they influence the balance of the energy entering and leaving the Earth system.

Radiation Balance of Earth

Earth's radiation balance is the equation of the incoming and outgoing thermal radiation. The Radiation Balance is shown by the following equation:

Rb= G-R-AE

In the above equation, G is the total incoming solar radiation, while R is the reflected portion of the incoming radiation which is generally known as Albedo. AE is known as Effective Radiation.

Effective Radiation

The radiation which is incoming is generally shortwave, while the surface and atmosphere of earth radiate back the short waves as well as long waves in the infrared spectrum (long wave radiation). This implies that part of the solar radiation is reflected back while part of it is absorbed by earth's surface which reflects infrared radiation in turn. Out of the total long wave reflected by earth, part is trapped as Green House Effect. Thus,

AE = AO – AG, where

AO = Radiation of the Earth's surface

AG = Radiation trapped as Green House Effect.

Factors influencing the radiation balance

Internal factors include all mechanisms affecting atmospheric composition (volcanism, biological activity, land use change, human activities etc.).

The main external factor is solar radiation. The sun's average luminosity changes little over time.

External and internal factors are also closely interconnected. Increased solar radiation for example results in higher average temperatures and higher water vapour content of the atmosphere. Water vapour, a heat trapping gas absorbing infrared radiation emitted by the Earth's surface, can lead to either higher temperatures through radiation forces or lower temperatures as a result of increased cloud formation and hence increased albedo.

Thus, the radiation balance of the Earth can change by

- By change in the incoming solar radiation (e.g., by changes in earth's orbit or in the sun itself)
- By change in the fraction of solar radiation that is reflected (called albedo'; e.g., by changes in cloud cover, atmospheric particles or vegetation)
- By alternation in the long wave radiation from earth back towards space (e.g., by changing greenhouse gas concentrations).

Implications of Radiation Balance

The Climate responds directly to changes in the Radiation Balance, as well as indirectly, through a variety of feedback mechanisms.

Climate Feedback mechanisms

There are many feedback mechanisms in the climate system that can either amplify ('positive feedback') or diminish ('negative feedback') the effects of a change in climate forcing.

For example, as rising concentrations of greenhouse gases warm Earth's climate, snow and ice begin to melt. This melting reveals darker land and water surfaces that were beneath the snow and ice, and these darker surfaces absorb more of the Sun's heat, causing more warming, which causes more melting, and so on, in a self reinforcing cycle.

Ice-albedo feedback

This feedback loop, known as the 'ice-albedo feedback', amplifies the initial warming caused by rising

levels of greenhouse gases. Detecting, understanding and accurately quantifying climate feedbacks have been the focus of a great deal of research by scientists unraveling the complexities of Earth's climate.

Polar amplification

Climate models generally predict amplified warming in polar regions due to climate feedbacks. This is called Polar amplification. This can be understood by the fact that due to the climate changes, the Arctic has warmed much leading to Arctic Shrinkage. Most simple climate models predict warming at both poles but please note that the Antarctic has not warmed as much as the Arctic.

- Polar amplification has led to the Arctic shrinkage.

Arctic Shrinkage refers to the decrease in size of the Arctic region and is agreed to be a result of global warming. As per the projections, Arctic may be free of the summer ice at anytime between 2060 and 2080. This is the reason that Arctic is often seen as a high-sensitivity indicator of climate change.

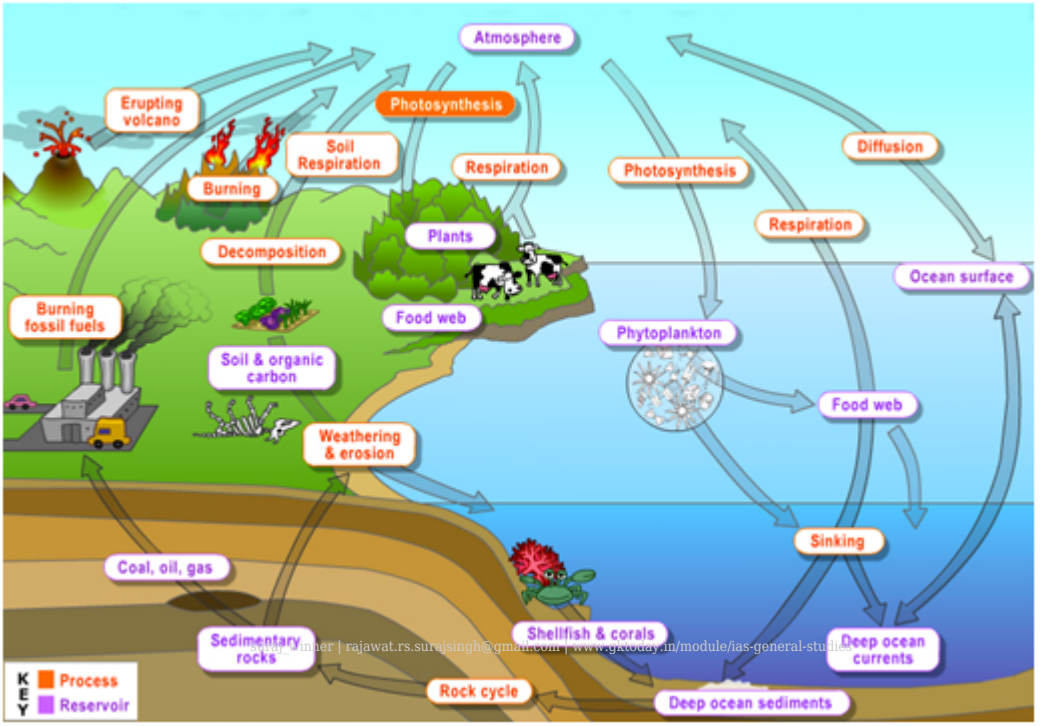
Topics Related to Carbon

Carbon Cycle and Global Carbon Budget

The Carbon Cycle is of two types viz. Organic and Inorganic Carbon cycle. The Carbon Cycle is the interchange of CO2 in the following:

- Atmosphere
- Terrestrial biosphere, including fresh water systems and soil carbon.
- The oceans, including dissolved inorganic carbon and living and non-living marine biota,
- The sediments including fossil fuels.

The Earth's interior, carbon from the Earth's mantle and crust is released to the atmosphere and hydrosphere by volcanoes and geothermal systems.



Global Carbon Budget refers to the balance of the exchanges of carbon between the carbon reservoirs as shown in above graphics. This may refer to one specific pathway such as atmosphere to biosphere or vice versa or many pathways.

Ocean Acidification

Ocean acidification refers to the ongoing consistent decrease in the pH of the Ocean water. When CO_2 dissolved in the Ocean water, it creates Carbonic Acid ($H2CO_3$) and increases the Hydrogen Ion (H^+) concentration in the ocean.

- The Ocean acidification has fastened only after the Industrialization.
- Pre-Industrialization pH of the ocean water was 8.179.
- In the 20th century, it came down to 8.1074, which corresponds to an increase of H^+ ions by 19%.
- **At present the pH of the Ocean water is 8.069** and this corresponds to an increase of 28.8% in the H^+ Ions since Industrialization of the 18th century.

Impacts of Oceanic Acidification

- The absorption of the CO2 by the world's Oceans helps in mitigating the climatic effects of Carbon Dioxide emissions. But the decrease in the pH will give negative impact to the oceanic organisms such as the Calcifying animals.

- The result will be seen in the Ocean ecosystem and food chains.
- The organisms such as corals, echinoderms, crustaceans and mollusks will be severely affected. This is because the falling pH makes the oceans under saturated with the $CaCO_3$, and the result is that rate of dissolution of calcareous material would increase.

The decreased pH may also lead to the **hypercapnia** in the ocean biota. **Hypercapnia** refers to the CO_2 induced acidification of body fluids, which may lead to adverse effects.

Carbon Footprint

Carbon Footprint refers to the GHG emission by an entity, event, product or person. It is expressed terms of the amount of carbon dioxide, or its equivalent of other GHGs, emitted. Most common used unit is CO2 equivalent. The carbon footprint seen as a subset of the ecological footprint.

- When we compare various forms of energy generation: Nuclear, Hydro, Coal, Gas, Solar Cell, Peat and Wind generation technology, we find that **Coal has the largest Carbon footprint among others.** Coal is followed by Oil, Natural Gas and Geothermal Energy. The hydroelectric, wind, and nuclear power always produce the least CO2 per kilowatt-hour of any other electricity sources. That too in construction only and not in operation.

The Kyoto Protocol recognizes 6 GHGs and Carbon footprint considers all six of the Kyoto Protocol greenhouse gases viz. Carbon dioxide (CO^2), Methane (CH_4), Nitrous oxide (N_2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs) and Sulphur hexafluoride (SF_6).

Measurement of Carbon Foot Print

A carbon footprint is measured in **tons of carbon dioxide equivalent (tCO_2e).** The carbon dioxide equivalent (CO_2e) allows the different greenhouse gases to be compared on a like-for-like basis relative to one unit of CO_2. CO_2e is calculated by multiplying the emissions of each of the six greenhouse gases by its 100 year global warming potential (GWP).

Types of Carbon foot Print

Two types of carbon foot printing. The main types of carbon footprint are:

Organizational

Emissions from all the activities across the organisation, including buildings' energy use, industrial processes and company vehicles.

Product

Emissions over the whole life of a product or service, from the extraction of raw materials and manufacturing right through to its use and final reuse, recycling or disposal.

What are the activities that can help our Carbon footprint?

Examples of the activities that reduce our carbon footprint are as follows:

- Replacing a regular light bulb with a compact fluorescent lamp (CFL)
- Walk instead of using bikes, Use Bicycles, carpool, or mass transit

- Use of recycled products
- Using properly inflated tyres (for better mileage)
- Using cold water instead of hotwater (save energy bills)
- Avoiding the products with lots of packaging
- Planting trees

Carbon Offsetting

Mitigation of carbon footprints through the development of alternative projects is known as Carbon offsetting. The alternative projects may be the solar, wind, Tidal energy or reforestation.

Carbon sequestration

Carbon sequestration refers to the *process of removing carbon from the atmosphere and depositing it in a reservoir*. In simple language, Carbon Sequestration encompasses all forms of carbon storage such as oceans, plants, soil and underground geologic formations. On this basis, Carbon sequestration is of three types as follows:

Terrestrial Carbon Sequestration

- Indirect sequestration whereby ecosystems (e.g., forests, agricultural lands, and wetlands) are maintained, enhanced or manipulated to increase their ability to store carbon.

Geologic Carbon Sequestration

- CO2 can be stored, including oil reservoirs, gas reservoirs, unminable coal seams, saline formations and shale formations with high organic content.
- These formations have provided natural storage for crude oil, natural gas, brine and CO2 over millions of years. Geologic sequestration techniques would take advantage of these natural storage capacities.

Ocean Carbon Sequestration

- Oceans absorb, release and store large amounts of CO2 from the atmosphere.
- There are two approaches for oceanic carbon sequestration which take advantage of the oceans' natural processes. One approach is to enhance the productivity of ocean biological systems (e.g., algae) through fertilization. Another approach is to inject CO2 into the deep ocean.

Soil Carbon and Carbon sequestration

Soil carbon refers to the carbon held within the soil, mainly as organic content. Soil carbon *is the largest terrestrial pool of carbon* (around 2,200 Gigatonnes). Soil carbon plays a key role in the carbon cycle and thus is important in global climate models. It has been shown that 1kg of carbon released from the soil constitutes 3.64kg of Co2 in the atmosphere.

The exchange of carbon between soils and the atmosphere is a significant part of the world carbon cycle, which is extensive both spatially and temporally. Carbon, as it relates to the organic matter of

soils, is a major component of soil and catchment health.

With reference to Carbon sequestration, the soil is one of the largest reservoirs, where carbon could be restored.

What are the Farming Practices that help in Carbon sequestration?

- Mulching →because it helps to retain moisture and organic matter
- Zero Tillage → Does not help directly in carbon sequestration but helps in stopping release of soil Carbon
- Crop Rotation → Helps by increasing soil organic content, so foster Carbon sequestration
- Strip Cropping and Contour Bunding → Increase carbon inputs so help in carbon sequestration
- Switching from Field to Tree crops → Helps to retain carbon and nutrients in soil
- Rotational Grazing and Pasture Management
- Intercropping

Can Organic Farming help in Carbon Sequestration?

Organic Farming is supportive for Carbon Sequestration. One example is Organic Mulch. Organic mulch is basically a type of compost made from decaying plants or trees. It can be one of the ways of sequestering carbon. Organic mulching refers to covering the soil with any organic matter such as applying compost or farm yard manure over the soil surface followed by adding a layer of dry organic matter over it.

Here, the compost contains an array of beneficial microbes, where the dry matter is rich in carbon and the green matter is rich in nitrogenous substances. When decomposition of these components takes place the carbon nitrogen ratio in the soil becomes 10:1, ideal for the proliferation of microbes.

How dumping of Iron can Induce Carbon Sequestration?

Dumping of Iron to the upper ocean can significantly induce the Carbon sequestration in Oceans. This is because introduction of iron to the upper ocean will stimulate phytoplankton bloom. This is due to a phenomena called *"Iron fertilization"*, whereby introduction of iron to the upper ocean to stimulate a phytoplankton bloom is adopted. Like all plants, phytoplankton takes up C02from air and converts it to carbon compounds like carbohydrates. The plant quickly dies and starts sinking, taking the carbon with it. What happens thereafter is the key to the technique's efficacy: If it sinks well below the ocean surface, the carbon would effectively have been put away for a long period (Carbon sequestration). This has led to several experiments in recent times.

Blue Carbon

The 2014 study financed by central government has found that the Sundarbans Mangrove Forests are fast losing their capacity to absorb the CO2 from the atmosphere due to an array of reasons including salinity of water, rampant deforestation and pollution. The report says that Sundarbans

flora and fauna is losing its capability to store the so called "**Blue Carbon**" Blue carbon refers to the carbon captured by living organisms in oceans and stored in the form of biomass and sediments from mangroves, salt marshes and seagrasses.

El-Nino and La Nina

A recurring characteristic of the climate is called Climatic Pattern. The gap between two recurrences may be from one year to as long as tens of thousands of years. Some of the events are in regular cycle, while some are not. When they recur in the form of regular cycles of fluctuations in climate parameters, they are called **climate oscillations**. The term **oscillation** is used because such fluctuations are *not perfectly periodic.* For example, we say that El Nino returns every four and half years. But actually it may or may not return. Or it may return too early or too late. So, El Nino is quasi periodic.

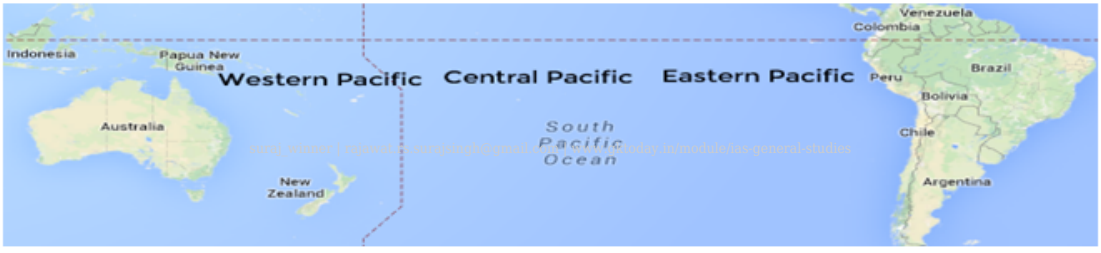
El Niño

El Niño was originally recognized by fisherman off the coast of **Peru** in South America. The ocean off the coast of Peru is one of the world's richest fisheries regions. In most years trade winds flow from the southeast push warm surface water **away** from the coast. In its place, the cold water comes up on the surface *due to upwelling*. This cold water is full of nutrients and provides nourishments to planktons. These planktons serve as food for fishes. Fishes in turn provide food to the sea birds. Due to all this, not only there is a good catch of fishes but also good collection of the **Guano**, the bird excreta, used as a valuable fertilizer. This is what that made Peru number one fishing nation in the world by the early 1970s.

Pattern of flow of warm winds off the coast of Peru

However, every few years, there is a change in the pattern of air circulation. It changes in such a way

that the trade winds reverse direction, blowing from west to east. Due to this reversal, the upwelling of the cold water gets weakened. The surface water is warm. This lowers the nutrients available to fish and thus poses problems to the economics of fisheries. The problems don't end here. The accumulation of large mass of warm water allows formation of more and more clouds and this would bring destructive rains that occur in normally dry areas of Peru and Chile. The same is also responsible for bring outbreaks of Malaria and Cholera in some parts of South America. Peru , as you may know is a **Hispanophone** country as many people speak Spanish out there. The above mentioned reversal of the winds occurred during Christmas times (Please note that we have Christmas in winter, but Peruvians have in summer, because they are in southern hemisphere), so they named it El Niño or "Christ Child" or "The Little Boy" in their own language. Before, you read further, please understand the location of Eastern, Central and Western Pacific on the map, otherwise it would be too confusing (earth is round…after all)



Now, here is how it affects the entire tropical region.

- Off the coast of Peru (read in Eastern Pacific and Central Pacific), there is normally cool surface water. But El Niño makes it go warm. When the water becomes warm, the tread winds, which otherwise flow from East to west, either reverse their direction or get lost. The warm water causes lots of clouds getting formed in that area, causing heavy rains in Peruvian desert during El Niño years.
- Due to this warm water, the air gets up and surface air pressure above Eastern Pacific gets down. On the other hand, the waters cool off in western pacific and off Asia. This leads to rise in surface pressure over the Indian Ocean, Indonesia, and Australia
- So, while there is raining (read flooding) in Eastern Pacific; the drought sets in over Asia as high pressure builds over the cooler ocean waters.
- The net result is:
- Normal or high rainfall in eastern / central pacific.
- Drought or scant rainfall in western pacific / Asia.

Although El Niño originally referred to local conditions off the coast of Peru and Ecuador, the use of the term has been broadened by many scientists to represent all surface temperature warming in the

eastern and central Pacific. The impacts of El Niño , which have been well documented include the following:

- Heavy rains in Ecuador and Peru.
- Heavy rains in southern Brazil but drought in north East Brazil
- Drought in Zimbabwe, Mozambique, South Africa, Ethiopia
- Warm winter in the northern half of the United States and southern Canada
- Drought, Scant rains off Asia including India, Indonesia, and Philippines etc.
- Coral bleaching worldwide
- Drought in eastern Australia

La Niña

La Niña, which means "The Little Girl" or "El Viejo" or "anti-El Niño" or simply "a cold event" or "a cold episode is the cooling of water in the Eastern Pacific Ocean. Here is what happens in La Niña.

- The water in Eastern Pacific, which is otherwise cool; gets colder than normal. There is no reversal of the trade winds but it causes strong high pressure over the eastern equatorial Pacific.
- On the other hand, low pressure is caused over Western Pacific and Off Asia.
- This has so far caused the following major effects:
    - Drought in Ecuador and Peru. Low temperature, High Pressure in Eastern Pacific
    - Heavy floods in Australia; High Temperature in Western Pacific, Indian Ocean, Off coast Somalia and good rains in India.
    - Drought in East Africa (Somalia Drought of 2011 was linked to it)

ENSO

Both **El Nino** and **La Nina** are part of a larger cycle called ENSO, or **El Niño–Southern Oscillation**. The El Niño (warm event) and La Nina (Cold event) both have now established themselves as the integral part of the global climate system. It is a recurrent phenomenon with an average return period of $4^{1/2}$ years, but can recur as little as 2 or as much as 10 years apart. Such events have occurred for millennia, and can be expected to continue to occur in the future.

Impact of El Niño and La Nina on Indian Weather

- El Nino and La Nina are among the most powerful phenomenon on the Earth. These are known to alter climate across more than half the planet and dramatically impact weather patterns.
- Over Indian subcontinent, El Nino during winter results in development of warm conditions. During summer, it leads to dry conditions and deficient monsoon. It also leads to drought in Australia. On the other hand, La Nina results in better than normal monsoon in India. At the same time, in Australia it has caused floods.

- In the recent past, India experienced deficient rainfall during El Nino years 2002 and 2009 whereas monsoon was normal during El Nino years 1994 and 1997. *This so far implies that in about 50 per cent of the years with El Nino during summer, India experienced droughts during monsoon.*
- This implies that *El Nino is not the only factor that affects monsoon in India*. There are other factors that affect India's rainfall pattern. These include North Atlantic SST, Equatorial SE Indian Ocean SST, East Asia Mean Sea Level Pressure, North Atlantic Mean Sea Level Pressure and North Central Pacific wind at 1.5 km above sea level.

Do El Nino and La Nina explain most of the unusual climatic happenings?

It is undeniable that the El Nino has been used to explain unusual climatic changes across the globe. But, modern climatology taken into account various other phenomena also. However, El-Nino has far-reaching and varied effect on climate across the world. The major reason for these unusual climatic happenings is the shifting in tropical rainfall, which in turn affect the wind patterns across the world. When the El-Nino effect causes the rainy areas centered around Indonesia and the Pacific region to move eastward, the subsequent changes result in unseasonable weather in many regions of the world. The El Nino is typically characterized by warm ocean currents and heavy rains, however, it also plays havoc with the normal weather conditions in different areas of the world. Also, the increase in temperatures affects fishing adversely, disrupts local weather and indigenous marine life in the areas concerned, other than having an effect on climatic conditions worldwide. When the linkage between El Nino and climate effects were initially suggested by the British scientist, Gilbert Walker, it was deemed ridiculous that one phenomenon could have an effect on regions as far off as Australia, India etc and Canada. However, the occurrence of El Nino in the past few decades has proved without a doubt, their far-reaching consequences. Some of the effects of El Nino in the past have been causing of droughts and forest fires in South Asia (Indonesia and Philippines) and Australia, floods in the South American countries in the eastern Pacific region, increased rain in certain other areas of the world etc.

Indian Ocean Dipole

Indian Ocean Dipole (IOD) also known as Indian Nino is an irregular oscillation of sea-surface temperature, in which the Western Indian Ocean becomes alternately warmer and then colder than the eastern part of the ocean.

Positive IOD

During the Positive IOD, the eastern equatorial Indian Ocean off Sumatra in Indonesia becomes *colder than normal* while the western tropical part of the Indian Ocean near the African coast becomes *unusually warm*. Such an event has been found to be beneficial for the monsoon.

Negative IOD

In this case the opposite of the above mentioned case occurs. The eastern equatorial Indian Ocean off Sumatra in Indonesia becomes abnormally warm while the western tropical part of the ocean near the African coast becomes relatively colder. This effect obstructs the progression of monsoon over India.

Interplay between IOD and El Nino on Indian Monsoon

Indian monsoon depends upon not only El Nino La Nina but also IOD and other such ocean phenomena. As mentioned above, an IOD can either aggravate or weaken the impact of El Nino on Indian monsoon. If there is a positive IOD, it can bring good rains to India despite of an El Nino year. For example, positive IOD had facilitated normal or excess rainfall over India in 1983, 1994 and 1997 despite an El Nino in those years. Similarly, during years such as 1992, a negative IOD and El Nino had cooperatively produced deficient rainfall.

The positive IOD in 2007 appeared together with La Niña which is a very rare phenomenon that has happened only once in the available historical data (in 1967).

Walker circulation

Walker circulation is a conceptual model of the air flow in the tropics. It is caused by the pressure gradient force that results from a high pressure system over the eastern Pacific Ocean, and a low pressure system over Indonesia, that is why also called Pacific Walker Circulation. When the Walker circulation weakens or reverses, an El Niño results, causing the ocean surface to be warmer than average, as upwelling of cold water occurs less or not at all. An especially strong Walker circulation causes a La Niña, resulting in cooler ocean temperatures due to increased upwelling.

Impact on India Monsoon

The researchers in the Potsdam Institute for Climate Impact Research and Potsdam University concluded that Walker circulation, on average, brings more high pressure over India and suppressing the monsoon, especially in spring when the monsoon begins to develop.

The recent studies find that the increasing temperatures and a change in strength of the Pacific Walker circulation in spring could cause more frequent and severe changes in monsoon rainfall.

Madden-Julian Oscillation

Madden-Julian Oscillation is a major fluctuation in tropical weather on weekly to monthly timescales of 30-60 days or 40-50 days. The MJO can be characterized as an eastward moving “pulse” of cloud and rainfall near the equator that typically recurs every 30 to 60 days and is a feature of the tropical atmosphere. MJO effects are most evident over the Indian Ocean and western equatorial Pacific. It influences the timing, development and strength of the major global monsoon patterns, including the Indian and Australian monsoons. In the tropics weather is not as predictable as in mid-latitudes.

In 1971 two scientists, Roland Madden and Paul Julian stumbled upon a 40-50 day oscillation when

analysing zonal wind anomalies in the tropical Pacific. They used ten years of pressure records at Canton south of Pacific and upper level winds at Singapore. The oscillation of surface and upper-level winds was remarkably clear in Singapore which became known as the Madden and Julian Oscillation (MJO).

Pacific Decadal Oscillation

The "Pacific Decadal Oscillation" (PDO) is a long-lived El Niño-like pattern of Pacific climate variability.

Both PDO and ENSO have similar spatial climate fingerprints yet the major difference is that PDO persists for 20-30 years while the typical ENSO persists for 6 to 18 months.

The primary climatic fingerprints of the PDO are most visible in the North Pacific/North American sector, while secondary signatures exist in the tropics. On the contrary, the primary climatic fingerprints of the ENSO are visible in tropics while secondary are visible in North Pacific/North American sector.

The PDO has two cycles, viz. Cold Cycle and Warm Cycle, very much similar to La Nina and El Nino of the ENSO cycle.

Major changes in northeast Pacific marine ecosystems have been correlated with phase changes in the PDO; warm eras have seen enhanced coastal ocean biological productivity in Alaska and inhibited productivity off the west coast of the contiguous United States, while cold PDO eras have seen the opposite north-south pattern of marine ecosystem productivity.

Reasons

PDO is under studies. Causes for the PDO are not currently known. Potential predictability for this climate oscillation are also not known.

Influences

The PDO has a major influence on Alaskan and for those matter global temperatures. The positive phase favors more El Ninos and a stronger Aleutian low and warm water in the north Pacific off the Alaskan coast. The negative phase more La Ninas and cold eastern Gulf of Alaska waters. Note the strong similarity of the positive phase with El Nino and the negative with La Nina.

PDO is responsible for bringing colder surface water temperatures and thus beginning the overall cooling effect in recent times in Alaska. This oscillation has brought a weakening of the 'Aleutian Low', the breeding ground for storms that end up regulating weather systems in the rest of the 48 states. With a less active Aleutian Low, cold winter storms have been sticking around Alaska longer and keeping the temperatures chilly.

Climate Change Negotiations

Brief Historical Background

Earth Summit 1992 was the first major global summit on environment held June 1992 at Brazilian city of Rio de Janeiro. Outcome of this summit were five documents viz. Rio Declaration, Agenda 21, Convention on Biological Diversity (CBD), Forest Principles and UN Framework Convention on Climate Change (UNFCC).

Rio Declaration

The Rio Declaration consisted of some 27 principles focusing on major topics related to human role in protection of the environment. The declaration was comprehensive and was hailed by some as *Third Generation Human Rights.*

Agenda-21

Agenda 21 was a voluntary action plan and a comprehensive blue print with 40 points for role to be played by local, national and global organizations in every area in which humans directly affect the environment. For implementation of these points, a *Commission on Sustainable Development* was established.

Forest Principles

The forest principles came as non-legally binding document that makes several recommendations for conservation and sustainable development forestry.

Convention on Biological Diversity

The CBD came out as a legally binding treaty with three clear objectives viz. Conservation of biological diversity (or biodiversity); Sustainable use of its components; and fair and equitable sharing of benefits arising from genetic resources. It was followed up by two protocols viz. Cartagena Protocol and Nagoya Protocol.

United Nations Framework Convention on Climate Change

UNFCC was signed as a non-legally binding framework agreement to *stabilize greenhouse gas concentrations* in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Later, Kyoto Protocol was adopted as a legally binding protocol under UNFCCC. The Kyoto Protocol is to be replaced by newly agreed Paris Agreement.

UNFCCC

The United Nations Framework Convention on Climate Change (UNFCCC) was one of the five outcomes of the Rio Summit 1992. Its objective was to *stabilize greenhouse gas concentrations* in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.

The convention itself was not a legally binding agreement and did not set any mandatory limits on green house gas emissions for individual countries. Neither it contained any enforcement mechanism. But it set that its protocols would be legally binding enforcements. One such protocol

was the Kyoto Protocol.

This convention has been ratified by 197 countries and sub-national entities which includes all United Nations members. Its secretariat is located in Bonn, Germany.

Conference of Parties

The parties to the convention meet annually since 1995 in Conferences of the Parties (COP) to assess progress in dealing with climate change. Till now 21 Conferences have been concluded. The Kyoto Protocol was concluded and established at COP-3 in 1997 as a legally binding obligation for developed countries to reduce their green house gas emissions.

Classification of Parties

To reduce the GHG emissions, the UNFCCC primarily targeted the industrialized countries. Accordingly, the UNFCC divided the countries into three groups viz. Annex-I, Annex-II and Developing countries.

In Annex-I, 40 industrialized economies including US, UK, Australia, Germany, France, Japan, Russia, Canada and countries of European Union were kept.

The Annex-2 was created as a subgroup of 23 Annex-I countries which *could play financial role in the development of the developing countries and pay the cost of development.* These included Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, United States of America.

Rest of the countries were kept in developing category and did not require to reduce emission levels unless the developed countries supply enough funding and technology for their development.

Rationale for no emission targets for Developing countries

The rationale for not imposing reduction targets for developing countries was that it would hamper their development. Since emissions are strongly linked to industrial capacity, emission cut requirements should be there for Industrialized nations. This is how the world was divided into two factions of developed and developing countries on climate change negotiations issue. The developed countries alleged that this convention created an unfair split because both the developing and developed countries need to reduce their emissions unilaterally.

Kyoto Protocol

Kyoto Protocol was adopted in 1997 and came into force in 2005. It is currently in force, however, its first committement period had expired on 31 December 2012. It was signed and ratified by 192 countries including all UN member states except Canada, South Sudan, United States and Andorra. Out of 40 Annex-I Countries, 37 signed it but only 7 ratified it. Those who signed and ratified committed for reduction of six GHG gases viz. carbon dioxide, methane, nitrous oxide, sulphur hexafluoride, hydrofluorocarbons and perfluorocarbons. The agreed target was to reduce emissions

by 5.2% from the 1990 levels.

Position of US and Canada

The United States signed but did not ratify the Protocol and Canada withdrew from it in 2011. United States was responsible for 36.1% of the 1990 emission levels of Annex I countries. It was required to reduce its total emissions an average of 7% below 1990 levels. To reduce these emissions, they needed to almost halt their highly polluting industries. This was not possible and thus they rejected it outrightly calling it "economically irresponsible". Almost same was the case with Canada.

Position of India, China, Brazil

India, China and Brazil are the most advanced developing countries. Since they did not fall in annex-I, they did not have any binding obligations to reduce or limit the CO_2 emissions.

Kyoto mechanisms

The Kyoto mechanims are mechanisms which define how the developed countreis would support the developing countries while reducing thier emission targets. There are three kinds of mechanisms viz. Emission Trading, Joint Implemenation and Clean Development Mechanism.

Emission Trading

The concept of emission trading (also called Cap & Trade) is simple – *the polluter pays while those who don't pollute get rewarded.*

In this, the governments launch schemes in which they set limit (called emission permit) on pollutants that can be emitted by the industries. The industries need to buy the emission permits to be eligible to emit specific volume of pollutants. The industries that pollute more need to spend more on such permits. Thus, it is a self regulatory system that results in pollution control by increasing cost of causing pollution. The emission permit represented the so called Carbon Credit or Kyoto Units. One Kyoto Unit referred to one tonne of Carbon dioxide or the mass of another greenhouse gas with a carbon dioxide equivalent to one tonne of carbon dioxide.

Joint Implementation

Article 6 of the Kyoto protocol provided that any Annex-I country can invest in emission reduction projects in any other Annex I country as an alternative to reducing emissions domestically. The idea is to lower the cost of complying with their Kyoto targets by investing in greenhouse gas reductions in an Annex I country where reductions are cheaper, and then applying the credit for those reductions towards their commitment goal.

Clean Development Mechanism

Under the Clean Development Mechanism, the annex-I countries can implement an emission-reduction project in developing countries and thereby earn saleable certified emission reduction (CER) credits, each equivalent to one tonne of CO_2, which can be counted towards meeting Kyoto targets. This has been by far the most popular Kyoto Mechanism. It helps the Non-Annex parties in achieving sustainable development and Annex parties to achieve compliance with their quantified

emission limitation and reduction commitments.

Extension of Kyoto Protocol Beyond 2012

First commitment period of Kyoto Protocol lasted from 2008-2012. Second commitment (2013-2020) period was agreed in 2012 as *Doha Amendment to the Kyoto protocol*. However, many annex-I parties started saying that they would withdraw from the Kyoto Protocol because of the forced target commitments. Since 2007, extension of Kyoto Protocol has been an issue in all UNFCCC annual conferences. In 2015, the Paris Agreement has been signed as a separate instrument under the UNFCCC rather than an amendment / update of the Kyoto Protocol. As of now, the Paris Agreement is not in force.

Paris Agreement on Climate Change

On 12 December 2015, the Paris Agreement was adopted as an agreement within the UNFCCC framework. As of January 2016, this agreement is not in force. It is to replace the Kyoto Protocol after its second commitment period ends on 31 January 2020.

Objectives of Paris Agreement

The Paris Agreement sets an over-arching target of keeping the emissions in control so that either the rise in global temperature remains below 2°C by the turn of 21st century or as low as 1.5°C. To achieve this goal, the countries will need to peak their emissions and then bring them down. The other purposes of Paris Agreement are as follows:

- Increasing ability to adapt to the adverse impacts of the climate change and foster climate change resilience
- Making finance flows consistent with the pathway towards low greenhouse gas emissions and climate-resilient development.

Emission Reduction Action

Under the Paris Agreement, developed countries will have to take emission reduction targets and actions but unlike the Kyoto Protocol – where such targets were mandatory; they shall be able to determine the nature and quantum of these targets nationally. Thus, each individual country is to contribute individually in the form of so called *Nationally Determined Contributions* (NDCs). As of now, the first set of such actions has been provided by more than 180 countries in the form of "Intended Nationally Determined Contributions (INDCs). When the Paris Agreement becomes operation in 2020, these targets will be called *Nationally Determined Contributions* (NDCs).

Climate Finance

Similar to Kyoto Protocol, the developed countries will need to provide finance to the developing countries for emission reduction actions as well as adaptation. The amount set by Paris Agreement is at least USD 100 billion per year from 2020 onward. However, as of now, *there is no consensus on what*

exactly makes climate finance. The countries will have to demarcate the details of these. Further, the Paris Agreement also provides that the developing countries can also voluntarily fund other developing countries.

Climate Change Adaptation

One of the objectives of the Paris Agreement is to increase the ability to adapt to the adverse impacts of the climate change and foster climate change resilience. The developing countries shall be able to seek funds from developed world in this direction.

Review Mechanism

The Paris Agreement provides that every five year, there shall be an assessment of how the emission reduction actions of all the countries are able to succeed towards achieving the goal of keeping global temperatures under control. Every fifth year, the assessment will also be made on kind and volume of funds.

Technology Mechanism

Paris agreement has set up a technology mechanism, which would help the countries to cooperate in developing and deploying clean technologies. However, this would face some issues of intellectual property rights of existing clean technologies.

Market mechanism

Countries are open to become part of existing global market-based mechanisms to reduce the emissions. The agreement would allow a global carbon-trade which shall provide the countries chance to take credit for emission reduction by making payments for the same in the countries where reduction is cheaper to achieve. The difference between Kyoto Protocol and Paris Agreement in this context is that earlier / currently, such trade exsists in limited regions and countries and Paris agreement might have a chance to make it a global market place.

Transparency

As per the Paris Agreement, a uniform system will be built for the countries to report what they have been doing towards the fight against climate change. It will also track the achievements of the countries towards Nationally Determined Contributions. However, there are no punitive actions for non-compliance of such reporting.

Loss and Damage

Prior to the Paris Agreement, a Warsaw International Mechanism for Loss and Damage associated with Climate Change Impacts (called Loss and Damage Mechanism) was adopted at Warsaw in COP-19 in 2013. Objective of this L&D mechanism is to address the loss and damage associated with the impacts of the climate change, including the extreme events such as hurricanes, heat waves etc and slow onset events such as desertification, ocean acidification etc. This mechanism provides technical assistance in case of loss and damage.

Under the Paris Agreement, this L&D would continue. However, the practical issue is that there is little money. Countries also do NOT have right to file for compensation or liability.

Key Issues on Paris Agreement

There are three key issues looming large over the Paris Agreement viz. maintaining the difference between developing and developed countries; issue of climate finance and loss & damage; and mitigation.

Maintaining the difference between developing and developed countries

The world is divided into two factions or rich and poor / developed and developing countries over climate change negotiations. An important principle in this context called common but differentiated responsibility (CBDR) was enshrined in the Principle 7 of the Rio Declaration. This principle implies that the interest of all countries towards sustainable environment are common, but due to the historical reasons, the developed countries have done more damage to the climate and thus, the responsibility towards climate change is "differentiated". It implies that *while all countries should take sustainable development actions, the developed countries have to take the leading role in environmental protection, as they have contributed the most to environmental problems.*

Also they *should support developing countries with finance and technology in their sustainable development efforts. India has always held that the eradication of poverty should be the overarching goal of sustainable development.* India together with other developing countries has played an instrumental role in establishing CBDR as a principle.

In the Paris agreement, definition of CBDR has been expanded and it now includes the phrase "in the light of different national circumstances". It appears to have diluted the notion of hitherto "historical responsibility" of the developed countries. How this is going to break the wall between developed and developing countries, is yet to be seen.

Issue of Climate Finance and Loss & Damage

The Paris Agreement maintains that the developed countries would keep providing support to the developing countries through the finance, technology and capacity building to the tune of at least USD 100 billion per year from 2020 onward. Further, the developed countries are required to provide transparent information also on support to developing countries and biennially communicate their plans for mobilisation of additional finance. The onus to mobilize these funds cannot be placed entirely on bilateral assistance and the Green Climate Fund. The developing countries would need to virtually de-link the greenhouse gas emissions from economic growth and devise innovative ways to mobilize funds.

Mitigation

Towards mitigation, the developed countries are needed to take lead in setting absolute emission reduction targets. However, the developing countries are "encouraged to move over time towards

economy-wide emission reduction or limitation targets in the light of different national circumstances". Under this so called "enhanced transparency framework", all the countries are required to provide updates on their achievements towards NDCs. There might be some practical problem in the periodical review or global stocktake for developing and least developed countries.