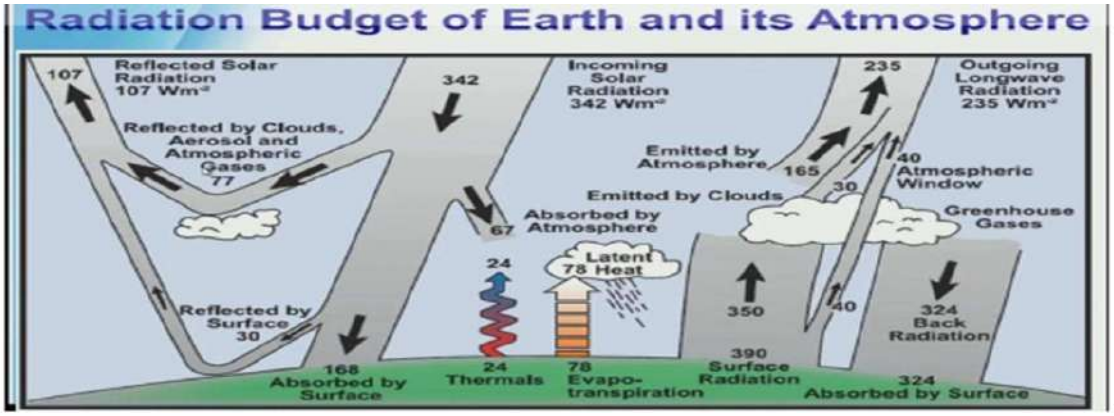
E-Book

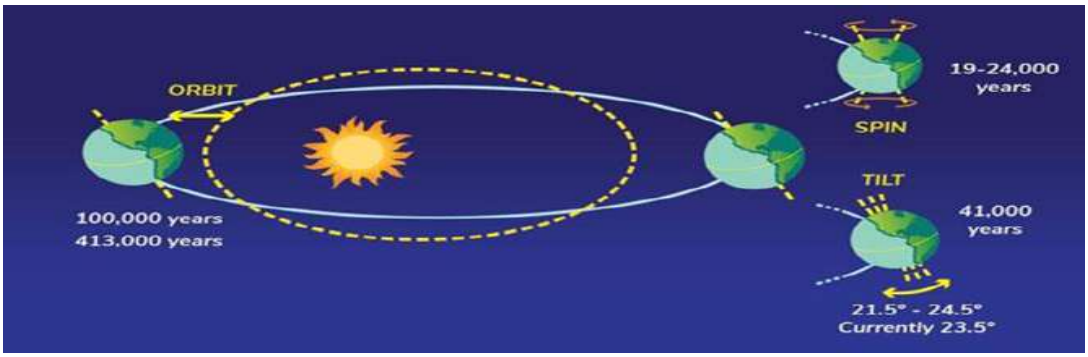
An Ensemble of Surround Physics

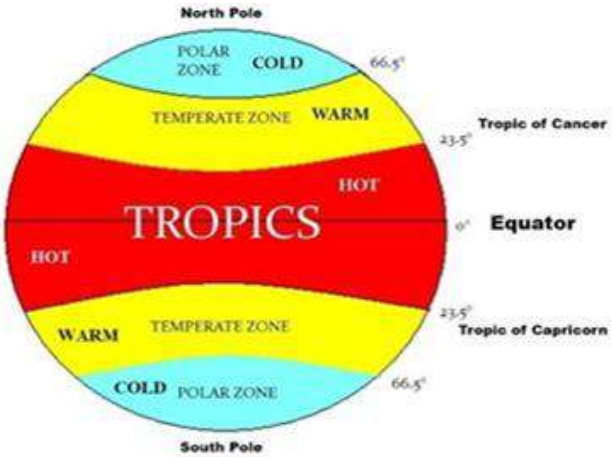
[Volume-2]

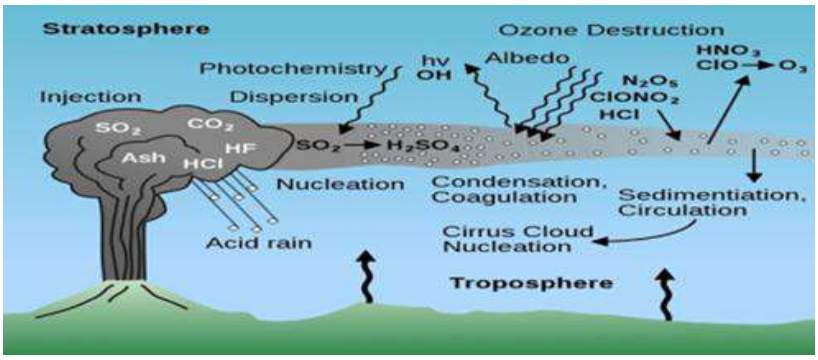
(A collection of awarded Essays in NCEWP – 2022)

PHYSICS BEHIND THE CLIMATE CHANGE









FOREWORD

Second volume of **An Ensemble of Surround Physics**, a collection of essays awarded in National Competition of Essay Writing in Physics (NCEWP) 2022, on *Physics Behind Climate Change,* is out. It is focused on a topic of concern to each one of us who are living on this unique planet on which life exists with all the means to sustain it. But it is sad to find how climate change is impacting every aspect of sustainability raising red flags for rising temperature (greenhouse effect), agriculture, availability of water, shifting of climate patterns, change in microclimate of every nook and corner of this blue planet. Unfortunately, we the homo-sapiens are responsible for this degradation to alarming proportions. Essays written by the participants in this collection provide us an interesting perspective from the physics point of view on climate change in the form of case studies both locally and globally. I would like to congratulate them for their hard work and spirit of sharing beautiful studies with a wider audience. These essays also provide us an opportunity to see how Scientific Community is providing evidence to this change which cannot be swept under the carpet and requires global and local efforts to mitigate effects all around us. Each of these essays is a good e-resource to discuss these issues in the class rooms of our Universities, Colleges and Schools.

Prof. Santosh Joshi and his team has very painstakingly conducted this competition and made a huge effort to archive it in a time bound manner for not only physics community but to every concerned citizen with a scientific temperament. In the words of actor environmentalist Leonardo DiCaprio: *You are the last, best hope of earth, we ask you to protect it, or we, all living things we cherish, are (going to be) history.*

I am sure this collection will also encourage students and teachers to become part of this world-wide effort.

Congratulations IAPT for such competitions and their valuable outputs which this collection represents.

Prof. P. K. Ahluwalia
President IAPT
12.02.2023

PREFACE

Writing makes one perfect, essay writing more so……

NCEWP is one of the three national competitions being held by IAPT every year. The competition is open to participants in two categories viz., students and teachers (including Science Communicators).

Category A - students of Higher Secondary /Jr. College, UG and PG levels;
Category B - teachers of Higher Secondary/Jr. College, UG and PG institutions, also Science Communicators working in recognized institutions.

From 2019, due to Covid Pandemic, NCEWP was conducted by submitting the essays through E-mail. Subsequently, an idea of E-Book containing the collection of selected essays was given by our President IAPT Prof. P. K. Ahluwalia. I am extremely thankful to our President for this novel suggestion.

On 25th September 2022, we have already uploaded the first volume of E-Book containing the awarded essays from the year 2019 to 2021 on IAPT Website. Now, we have decided to display the prize-winning essays in the form of an E-Book on **yearly** basis. This most recent volume thus includes 9 essays on the topic **"PHYSICS BEHIND CLIMATE CHANGE".**

This time total **41 Essay entries** were received. The essays were evaluated by three experts and aggregate marks were considered towards the final results. All entries were checked for plagiarism by me. Negative marks were assigned by the evaluators for copy-paste instances. We are very much thankful to the expert evaluators Prof. V. N. Potbhare, Dr. D. A. Deshpande, Dr. Sapna Sharma, Prof. S. B. Welankar, Dr. A. P. Deshpande and Dr. Usha Singh for their voluntary services in this competition.

I am extremely thankful to our GS Prof. Rekha Ghorpade. I sincerely thank all EC Members, Office bearers of RCs, all Vice Presidents IAPT, Prof. B. P. Tyagi and Prof. U. S. Kushwah. Apart from this I am also thankful to my committee members Dr. Himanshu Pandey and Dr. Shivanand Masti for their help.

Big thanks to Kanpur Office Dr. Sanjay Sharma, Dr. D. C. Gupta and Vinod ji for their excellent help in the Prize Distribution Ceremony. It is a long list to mention all individual names. Finally, I am thankful to all the participants of Essay competition and those who helped me in conducting this event directly or indirectly.

As editor, I have only tried to rectify language errors and a more consistent formatting. The basic content of the essays has been kept as it is. In the end, I am very much thankful to Sambodhi Translation and Computer Services, Indore for their professional services in getting this E-book (volume-2) out in the current shape.

In the last part of this E-book, the Guidelines for Essay Writing and Developing Skills for Science Communication as well as the Announcement of Essay Competition NCEWP-2023 have been included as an **Appendix**.

Prof. S K Joshi
Coordinator NCEWP &
Editor of E- Book

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PHYSICS BEHIND THE CLIMATE CHANGE

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Pace Junior Science College, Thane (Maharashtra)

Key words: Climate, Global warming, Radioactive imbalance, Greenhouse gases, Alternate energy.

Climate change and its impact

Climate change has always been the topic of deliberation, but it should be addressed more often. People, in general, are frustrated by the rise in temperature but are not aware of why that happens. They do not realize that they are partially responsible for this situation. The term "climate change" was a popular search term on Google from mid-April to the last week of May this year, i.e., when it was extremely hot in our country. This shows that common people care about climate only when they are affected by it the most. We should be vigilant about this phenomenon at all times of the year to understand and improve it more.

Global Warming

Climate change has a direct link to Global warming. Global warming is essentially the temperature rise of land, oceans, and the atmosphere. It alters precipitation patterns, wind patterns, storm patterns, cloud formation and catalyzes natural disasters. Global warming has two primary aspects: the exchange of energy and matter in the Earth-Sun system and the mechanism of Greenhouse gases (GHGs) in the temperature rise. Some of the major GHGs are Carbon dioxide (CO_2), water vapour (H_2O), Methane (CH_4), etc. Although there are various drivers for global warming, the most potent substance is CO_2 because it is directly affected by human activity.

Energy Balance

As mentioned before, a crucial aspect of global warming is the exchange of energy. This exchange is associated with the Earth-Sun system's emission of electromagnetic (EM) energy. All bodies in the universe have EM radiation, hence, so does Earth. According to the Stefan-Boltzmann Law, aka., black body radiation, an object emits radiant energy proportional to its temperature to the fourth power. Earth emits infrared energy (frequency= 10^3 to 10^4 Hz) whereas the sun emits infrared, visible (4×10^{14} to 8×10^{14} Hz), and ultraviolet radiant energy. According to thermodynamics, the incoming and outgoing energy should be equal to reach an equilibrium. This balance of energy is called the Earth-energy balance model. According to the Stefan-Boltzmann Law,

$$(1 - \alpha)S\pi r^2 = \sigma T^4 4\pi r^2$$

Here, the Stefan-Boltzmann Law has been modified to understand global warming. In the equation, S is the solar flux (the amount of solar energy available at the Earth's distance from the Sun). This energy is approximately 1362 Watt per meter squared or 1362 J s^{-1} m^{-2}. Though the energy value is 1362 J s^{-1} m^{-2}, it was once said to be 1366 J s^{-1} m^{-2}. The reason for this is the satellite components TIM, SORC, ACRIM1, ACRIM2, and ACRIM3. They started at 1366 W m^{-2} but when they were replaced with newer instruments, the measurement was less by about 4 J s^{-1} m^{-2}. The value we get now is roughly 1361.0 ± 0.2. Along with that, the Sun's output has gone down by almost 0.073%.

However, the solar flus has been modified because the total received energy is not completely absorbed by the Earth. Almost 30% of the total incident energy is reflected in space. This is known as the Albedo effect, represented by α (alpha). The flux is multiplied by 1-α (aka, the reflectivity of an object) to depict the total energy which warms the Earth. The value of albedo is directly proportional to the temperature. For example, the polar ice caps melt if there is less albedo, which means less reflected energy and thus higher temperature on Earth due to more absorption of the incident energy.

We multiply this value by πr^2, which is the area of the Earth that receives direct sunlight. Though the Earth is considered a sphere, the area which receives the sunlight directly is equal to the cross-sectional area of the Earth. Hence, by substituting all values of the variables given in the Stefan-Boltzmann law equation, we get-

$$(1 - 0.3)1362\pi(6400000)^2 = \sigma T^4 4\pi r^2$$

Which is equal to 1.23×10^{17} watts. This is the value we get for the left-hand side of our equation. Since the Left- hand side is equal to the right-hand side, equating both would give us the average temperature of Earth requiredto reflect all the incoming flux. Thus,

$$1.23 \times 10^{17} = \sigma T^4 4\pi r^2$$

Where, σ is the Stefan-Boltzmann constant, which relates the emitted energy to the temperature raised to the fourth power. The value of this constant is 5.67×10^{-8} W m^{-2} K^{-4}. Now, we simply cancel the common term πr^2 from both sides to find the temperature. Hence, the equation we are left with is-

$$(1 - \alpha)S = \sigma T^4 4$$

With some modification, we get –

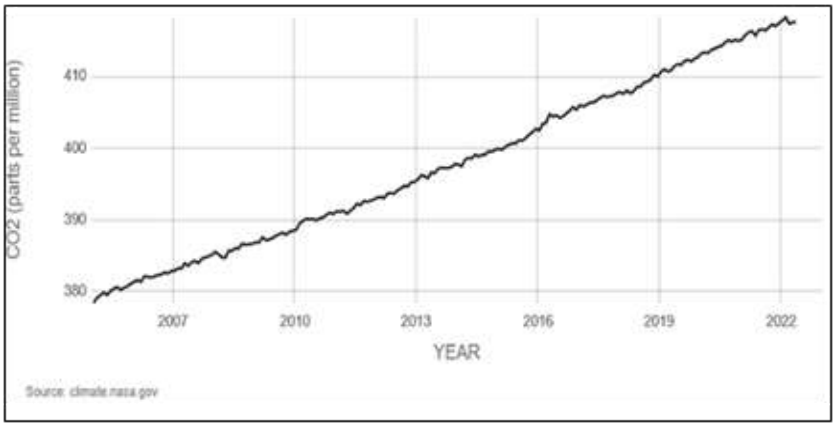
$$\sqrt[4]{\frac{(0.7)s}{4\sigma}} = T$$

Therefore, by substituting all the values, we get the value of temperature as approximately 254.629 kelvin whichis -18 ˚C or 0˚F. However, the current average temperature is about 288 kelvin or 15˚C or 59˚F. We can noticethat the Earth would have to have a way lesser average temperature to attain the energy balance. -18˚C is the temperature of the Earth if we remove all GHGs. Removing all GHGs would freeze majority of life forms on Earth.

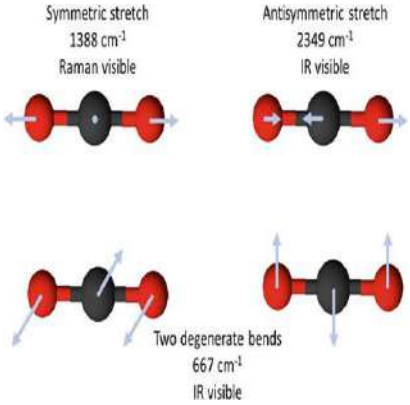
Effect of Greenhouse Gases

The major GHGs are carbon dioxide, water vapour, methane, nitrous oxide, and ozone. Fluorinated gases ($C_2F_3Cl_3$) also as act as GHGs. Though, the most potent GHGs are CO_2 and H_2O. Most changes happen due to CO_2. H_2O is a more potent gas in comparison to CO_2, but it is not affected directly by human activities.

The atmospheric concentration of CO_2 has been on the rise since the industrial era. In 2022, the concentration of CO_2 is about 418 parts per million (ppm) which is 0.041% of total atmospheric molecules. This value has risen considerably since 1870 when it was 0.028%.



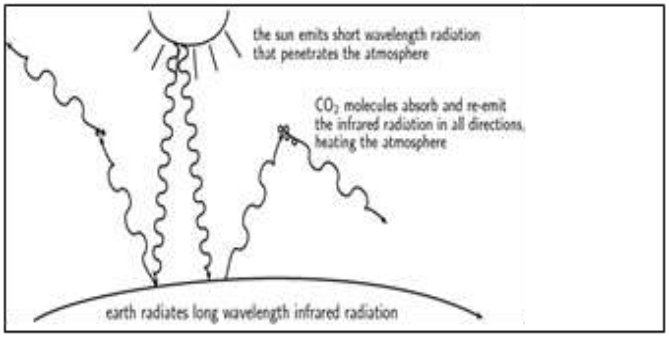
If we apply the ideal gas equation, we get about 2.56×10^{22} molecules per litre in 1870 and about 2.55×10^{22} molecules per litre in 2022. This gives us 0.768×10^{19} CO_2 molecules per litre concentration in 1870 and 1.05×10^{19} molecules per litre in 2022. We can notice a 1.5 times increase in the concentration of CO_2 molecules over about a hundred years. To put it simply, carbon dioxide absorbs and emits infrared energy, which is essentially how the greenhouse effect works. The mechanism of this process can be understood by quantum mechanics. Let's consider a carbon atom of a CO_2 molecule. This atom has electrons spinning in its multiple orbitals. When any electromagnetic radiation is incident on the particle, the electron either gets excited or stays at the same energy level. This is because energy



received is in discreet values called quanta. The atom lets the EM waves pass if the electron receives either more or less energy than the required excitation energy. Similarly, a band of infrared energy matches the energy of excitation of CO_2 molecules. CO_2 in its resting state is a non-polar molecule (the dipole moment of the particle = 0), but it has temporary dipoles in unsymmetrical vibrational modes. This generates different vibrational frequencies of the molecule which must be equal to some frequency in the infrared region.

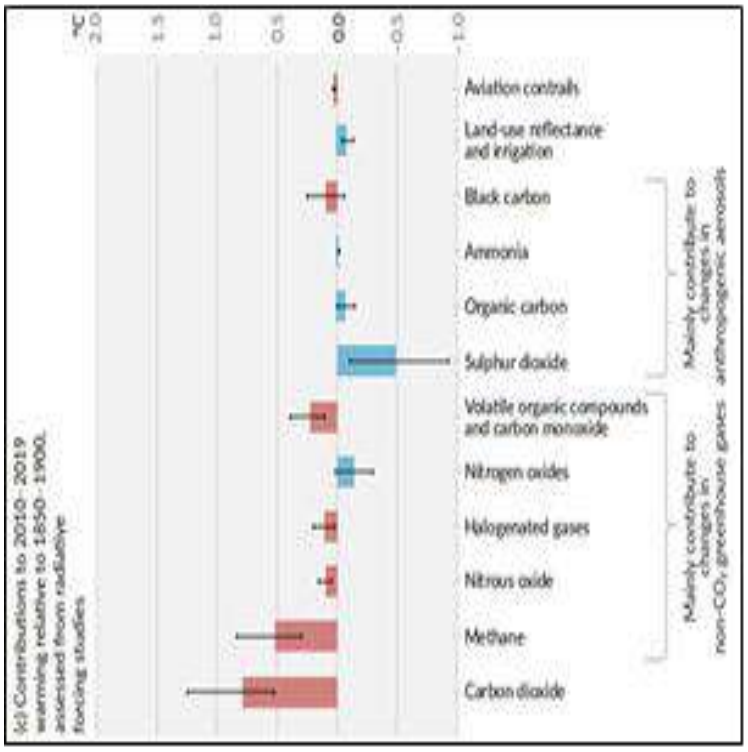
$$\frac{1}{2\pi c}\sqrt{\frac{k}{\mu}} = \frac{c}{\lambda}$$

The left-hand side of the above equation is the formula for the vibrational frequency of a molecule where c is the speed of light in vacuum, k is the force constant in erg-cm-2 and μ is the reduced mass of the molecule in grams. Here, the force constant is obtained by diagonalization of the mass-weighted Hessian matrix. The right-hand side is the equation for the frequency of an EM wave in a vacuum



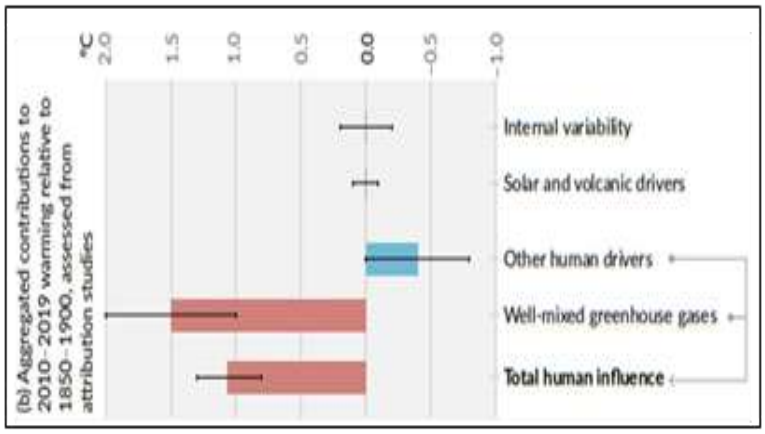
Here, c is the speed of light in vacuum and λ is the wavelength. Carbon dioxide absorbs energy from wavelengths 2,000 nm to 15,000 nm. Multiple CO_2 molecules in the atmosphere thus absorb and emit infrared energy, without letting it reflect straight back into space.

This redistributes the infrared energy in the lower atmosphere. Several absorptions and emissions in all directions have essentially two final results — either the emission is finally reflected into space or it is reabsorbed by the Earth to start the entire process again. For this energy to be lost into space, the CO_2 molecule has to be at a certain minimum altitude. Due to gravity, the concentration of CO_2 molecules is higher close to the surface and it gradually decreases as we increase the altitude. The higher density near the surface emits and absorbs the IR energy multiple times and gradually becomes less as the reflected energy travels upwards. This is where the concentration of CO_2 in the atmosphere is significantly low such that almost all upward reflected



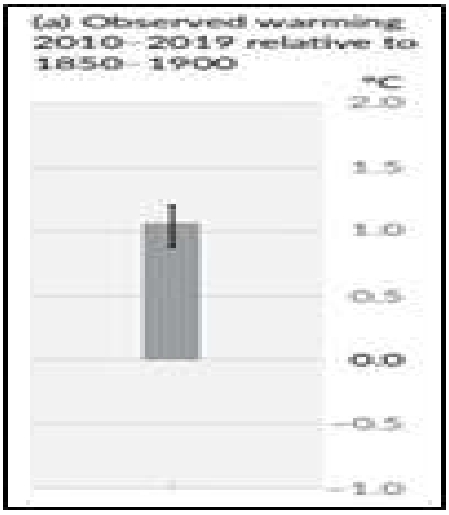
IR rays bounce back into space, thus exiting the Earth's atmosphere. This altitude or height is known as the emission height which was measured to be around 5.4 km before 1870 (industrialization period).

As we go higher up the altitude, the temperature gradually drops because of the expansion of gases and the loss of kinetic energy. This temperature change rate concerning height is called lapse rate, which is about 6˚C/km. The temperature at the emission height is found to be -18˚C or 255 K, which is the exact temperature we need to satisfy the Earth-Energy balance equation. This implies that the surface in the Earth-Energy balance equation is actually at the altitude of 5.4 Km from the actual surface of the Earth. If we look at the figures today, the concentration of CO_2 has risen significantly due to the burning of fossil fuels. The emission height of 5.4 km before 1870 has increased to 5.5 km. This is in correspondence to the observed temperature change from 1880, which is about 1.01˚.

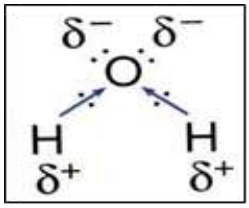


This increase shifts the emission height higher, thus making the global average temperature drop to less than 255 K. By the energy balance equation, the emitted radiant energy decreases as it is directly proportional to the average temperature of Earth.

Thus, the outgoing IR energy < incoming IR energy. The difference between the incoming and outgoing energy IR energy stays trapped in the Earth's system and is called Radioactive forcing. This radioactive forcing causes global warming and climate change. According to the equation, the new average temperature is supposed to be 287 K, but we also know that the Earth's surface warms more than about one kelvin. This gives an average temperature of 287.6 K. But where did the 0.6 come from? To help us bridge this value gap, we also consider water vapour as a contributor to the distribution of IR energy. Unlike the CO_2 molecule, H_2O has a permanent dipole. This dipole is strong, with more electron density towards the oxygen atom, giving it a partial negative charge. This accumulation of charges allows the H_2O molecule to absorb and emit IR Energy.



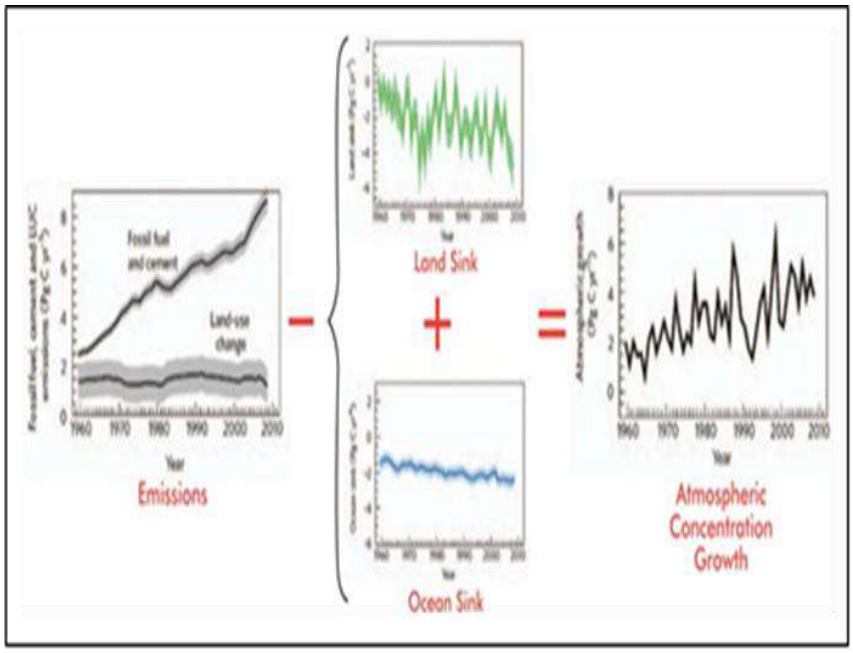
Water vapour absorbs more frequencies of infrared energies, making it more potent GHG than CO_2, but why is H_2O not the major GHG? H_2O in its vapour form acts as a GHG and its concentration in air is about 0 – 4% of all atmospheric gases, depending on the temperature and



other factors. A higher concentration causes water vapour to condensate. The temperature of the atmosphere is directly proportional to the concentration of water vapour in the atmosphere. Hence, it creates a positive feedback loop between H_2O and the atmospheric temperature and CO_2 and H_2O. The carbon dioxide from industrialization increased the temperature, which in turn increased the concentration of H_2O in the atmosphere. Increased H_2O again increased the temperature and the cycle went on until Earth-energy balance was achieved. However, the constant temperature increases due to the constant increase in the atmospheric carbon dioxide makes the water vapour temperature feedback loop occurs multiple times. This increase in H_2O and other GHGs (methane, CFCs) further increases emission height. We have already seen that not all of the Sun's radiant energy incident upon earth is emitted by the Earth. This difference in energy is manifested as kinetic energy in the atmospheric molecules. If any colder air molecules collide with warmer surfaces, then kinetic energy is transferred and the air molecules near the Earth's surface increase in temperature. This is called heat transfer via conduction. Thus, higher kinetic energy at the Earth's surface from absorbed solar energy results in higher Earth surface temperature and kinetic energy transfer to air molecules which raise air temperature. This higher temperature is required to maintain the Earth-energy balance.

Although temperature rise is a significant part of climate change, how does it affect storms, floods, and several other natural calamities? To understand that, we need to think about H_2O. 1 gram of liquid H_2O requires 2267 joules to evaporate. This means that the water condenses and releases 2267 joules into the atmosphere. With more condensed water vapour, it gives rise to more violent storms. Higher temperature if the atmosphere melts the polar ice caps, increasing the water levels globally and causing floods. More water decreases the reflectivity (albedo) of the Earth, thus trapping more energy into the atmosphere.

Impact of Climate Change



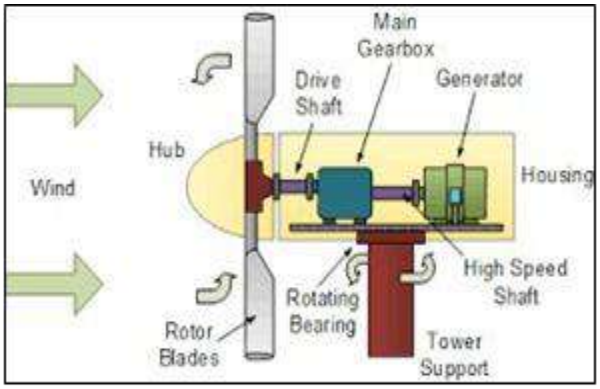
Climate change has a serious effect on our livelihood and economy. It affects almost all sectors of our economy such as agriculture, infrastructure, health and productivity, tourism, business, and the market. Storm and excessive rainfall damage crop and alters yield. Floods drown livestock. People lose their assets, homes, and even lives because of severe floods. Increasing temperature hinders the growth of certain crops like corn, soybean, wheat, rice, cotton, and oats as they do not grow well enough above a certain temperature threshold. Farmers and the agricultural sector take the major. They face severe droughts and floods, ruining the crops. Such conditions cause the prices of crops and livestock to rise, causing severe inflation. Infrastructure is at high risk due to floods, which may cause a loss of assets worth thousands of crores. Water pipes, sewers, and oil pipelines may require increased maintenance as they are subjected to varying harsh conditions. Humans and other living beings are at a risk due to increasing environmental temperature. Increased warmth and precipitation add to the risk of a potential increase in waterborne diseases. Tourism is affected due to unpredictable weather patterns. Business and the financial market take a hit because of fluctuations occurring in the primary and secondary sectors.

Global warming enhances the effect of natural calamities like the severity of tropical storms, ocean acidity, sea levels, and melting of glaciers. It shifts the location of viable agriculture, harms the ecosystems and animal habitats, and changes the timing and magnitude of the water supply. However, about half of actual global warming to date is being masked by cooling aerosol particles (particles causing air pollution). Thus, the clean- up of air would cause the masked global warming to unmask. The land is a source as well as a sink for GHGs. It plays a crucial role in the exchange of energy, water, and aerosols between the land and the atmosphere. Land-surface sink is estimated to remove about 29% of annual CO_2 emissions. Oceans act as a sink via a two-step process. First, CO_2 dissolves in the surface water. Afterward, the ocean's overturning circulation distributes it deep into the ocean's interior, where it accumulates over time as a part of the carbon cycle. Oceans absorb about 20-30% of atmospheric CO_2. Unfortunately, the increased CO_2 concentration is hazardous to marine life. It dissolves the coral reefs made of Calcium Carbonate ($CaCO_3$). At this stage, the rate of

increase in CO_2 is significantly larger than the rate of land and ocean's combined capacity to act as sinks. but it is severely hazardous. Therefore, we need alternative energy sources to not increase the production of GHGs. A few technologies for addressing and lessening the effect of global warming are as follows: Solar photovoltaics (PVs), concentrated solar power (CSP), Wind, Geothermal, Hydroelectric, Wave, and Tidal, Nuclear, Coal-carbon capture and storage, Corn and cellulosic ethanol, etc. Although we can access so many alternatives to conventional fossil-fuel-generated energy (which increase the concentration of GHGs), not all are feasible. Thus, important alternative energy technology is the sufficient resource available to power the technology, and resources can be accessed and used with minimal effort.

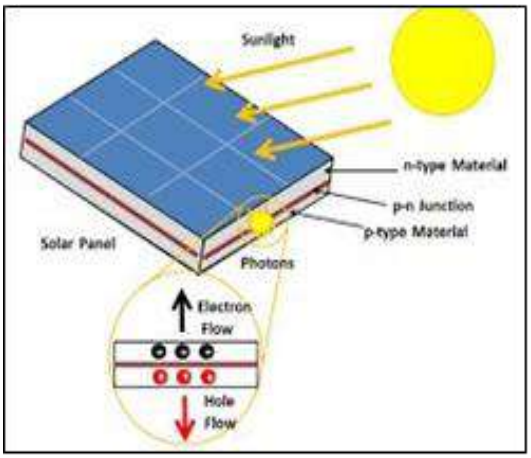
Alternate Energy Sources

Wind turbines transform kinetic energy into electrical energy. A gearbox turns the slow-turning turbine's rotor faster, which converts this mechanical energy into electricity. This instantaneous power produced by turbines is directly proportional to the cube of instantaneous wind speed.



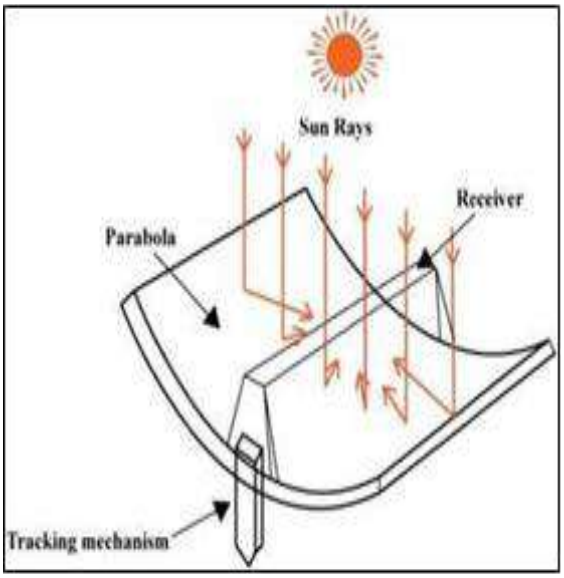
The efficiency of wind power generation increases with an increase in altitude. Larger turbines are usually placed on flat lands. However, small turbines are convenient for use near residential areas. Wind turbines have a very low lifecycle CO_2e (CO_2e is Carbon dioxide equivalent). A 5MW turbine operating for 30 years under average standard conditions results in 2.8-7.4 $gCO_2e\ kWh^{-1}$ and the energy payback time (the amount of time taken for an energy system to generate the amount of energy equivalent to the amount that took to produce the system) is 1.6 months to 4.3 months. The time to plan and operate a wind farm also includes developing as construction months. period. Thus, the overall time to construct and operate a wind farm is about 2-5 years. The pollution that arose while using this technology is only due to and during the time of construction. No further pollution arises after the construction.

Solar Photovoltaics are cell arrays containing a material that converts solar radiation into direct current electricity. Materials used for PVs nowadays are amorphous silicon, polycrystalline silicon, microcrystalline silicon, cadmium telluride, and copper indium selenide or sulphide.

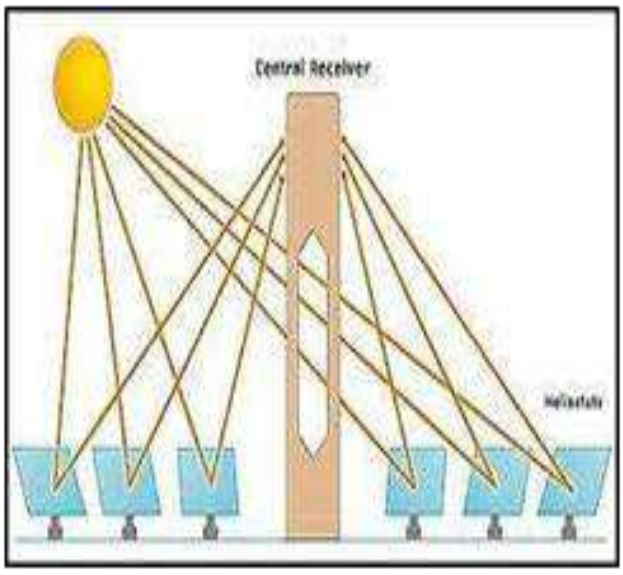


This material is doped to increase the (p-type) and negative (n-type) charge carriers. The resultant semiconductors are combined to form p-n junctions which allow the generation of electricity when illuminated. There is a performance decrease if the cell temperature exceeds the threshold of 45°. About 1700 TW of solar power is theoretically available over land for PVs. This includes exclusion zones of competing land zones or high latitudes where the solar insolation is low. Even a 1% capture of this energy would suffice the world's power needs. The maximum capacity factor (The ratio of the electrical energy produced by a generating unit for the period considered to the electrical energy that could have been produced at the continuous full-power

operation during the same period) is 0.2, regardless of location. The energy payback time for PVs is usually longer than other renewable energy sources, but it depends on solar insolation. The old PVs had a payback time of about 1-5 years. The latest systems consisting of Cadmium Telluride, silicon ribbon, multi-crystalline silicon, and mono crystalline silicon have a payback time over a 30-year PV module life of 1-1.25, 1.7, 2.2, and 2.7 years, respectively. This results in emissions of 19-25, 30, 37, and 45 g of CO_2 e kWh^{-1}, respectively (CO_2 e: emissions of CO_2 plus those of other greenhouse gases multiplied by their global warming potentials). Solar-PV power plants are about 2-5 years. When this technology is paired with BEVs (battery electric vehicles), the carbon generation goes down significantly.



Another technology used as an alternative to fossil fuels is concentrated solar power (CSP). The light is focused by mirrors or reflective lenses to heat a fluid at high temperatures. This heated fluid (pressurized steam, synthetic oil, molten salt) flows from the collector to a heat engine where a part of the heat (at most 30%) is converted to electricity. There are several types of collectors. One has a set of parabolic-trough (long U-shaped) mirror reflectors that focus the light into the pipe to heat the oil which flows through a chamber to heat water for steam generators that finally produce electricity. The second type of collector is made by a central tower receiver with a field of mirrors surrounding it.

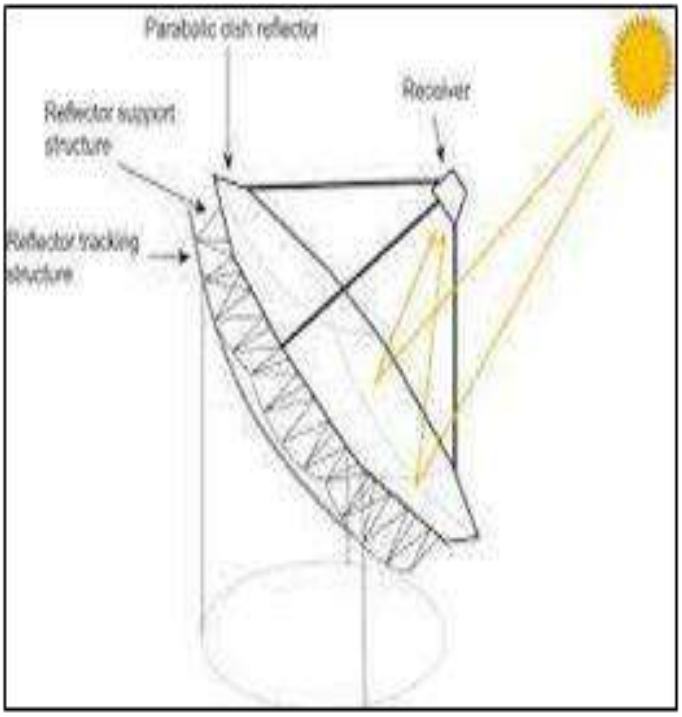


The focused light heats the molten nitrate salt which produces steam for steam generators. By storing this heat in thermal storage media, such as pressurized steam, concrete, molten sodium nitrate ($NaNO_3$) or potassium nitrate (KNO_3), or purified graphite. These are within an insulated reservoir before producing electricity. The parabolic trough and central tower CSP plants can reduce the effects of solar intermittency by producing electricity at night. The third type of CSP is a parabolic dish-shaped reflector that rotates to follow the Sun and reflects light onto a receiver which then transfers the energy to hydrogen in a closed loop.

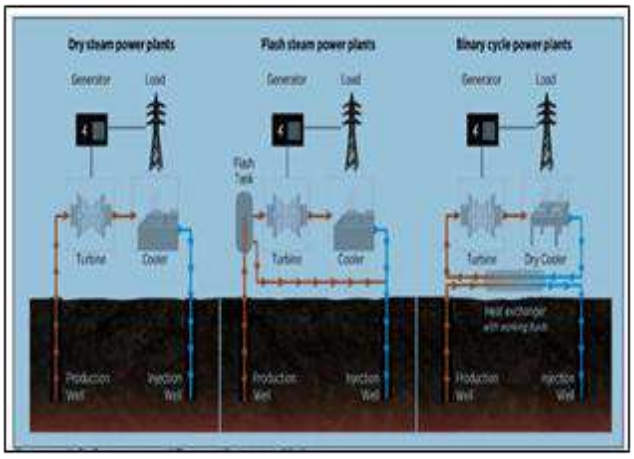
Hydrogen expands against a piston or a turbine to produce mechanical energy used to run a generator to produce electricity. The total energy available worldwide for this technology is 1/3rd

less than that for solar PVs. This is due to the more land requirement for CSP than for solar farms. Almost more 1/3rd area is required for CSP than solar PV.

The capacity factor ranges from 13-25%. This technology, like wind and solar-PVs, has climate-relevant emissions only during its construction period. CSP has an energy payback time of about 5-6 months and a lifetime of 40 years, which results in an emission rate of 8.5-11.3 g CO_2e kWh^{-1}. The planning to operation time for a CSP plant is about 2-5 years, which is the same as solar-PV power plants. Concentrated solar power with parabolic trough technology requires the heating of water to produce steam. Since the process is closed-looped, the water is not lost but needs to be condensed to be reused. This is generally done by combining the steam with cooler water in a cooling tower or by air cooling. Water- cooled CSP is the most efficient alternative.

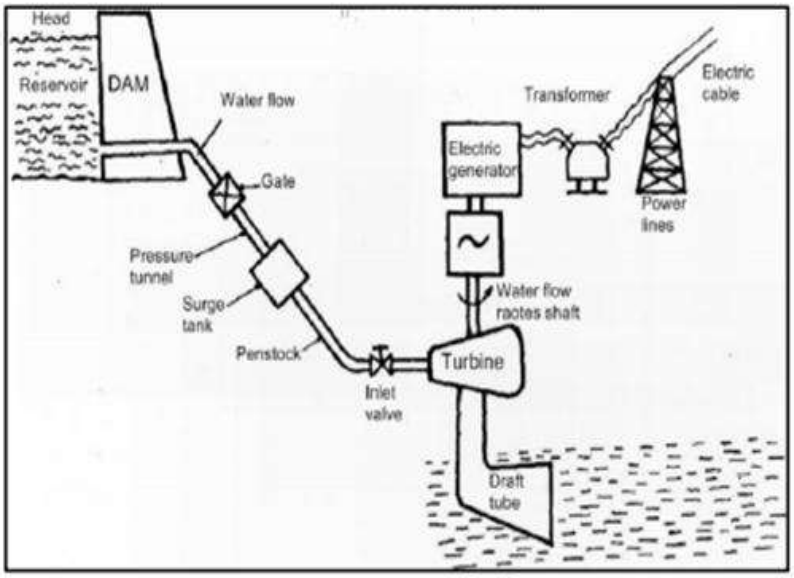


Carbon capture and storage (CCS) is the diversion of CO_2 from point emission sources to underground geological formations. Even today, CO_2 has been diverted underground following its separation from mined natural gas in several operations. However, no large power plant currently captures CO_2. One model for electricity generation with CCS technologies integrate gasification combined cycle technology is used to gasify coal and produce hydrogen. Although this method does create as many emissions as classical air pollutants the emissions are still significant. Another CCS method requires an injection into the deep ocean and the production of carbonate minerals, which results in ocean acidification. Thus, this energy alternative is not completely efficient.



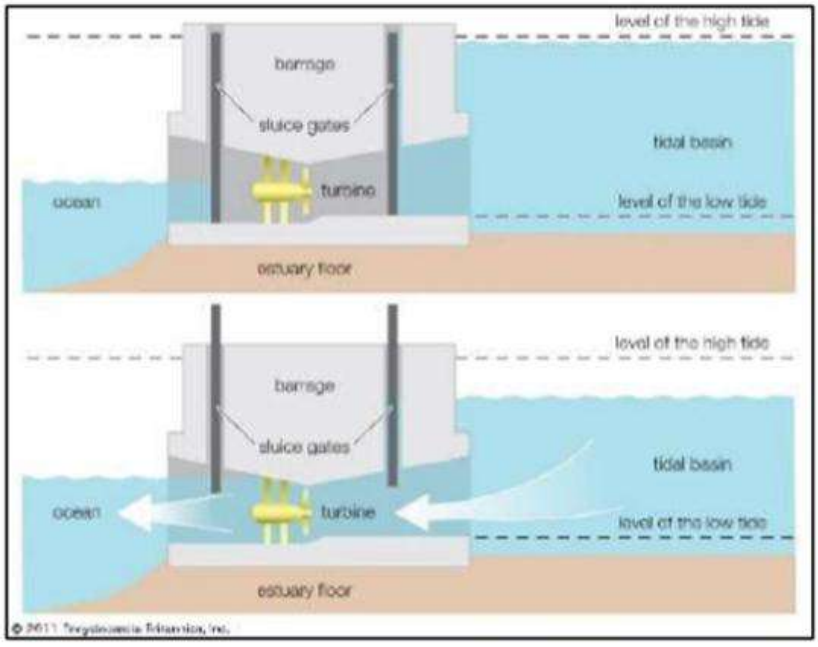
Geothermal energy is the energy that is extracted from hot water and steam below the Earth's surface. Hot water and steam have been used to generate electricity in geothermal power plants. The three major types of plants are dry steam, flash steam, and binary. A dry and flash steam plant works where geothermal reservoirs' temperatures are 180-370˚C or higher. Boreholes are drilled, one for steam alone (for dry steam) and another for liquid water and steam (for flash steam) to flow up, and the second for the condensed water to return after it has passed through the plant. Geothermal plant lifecycle

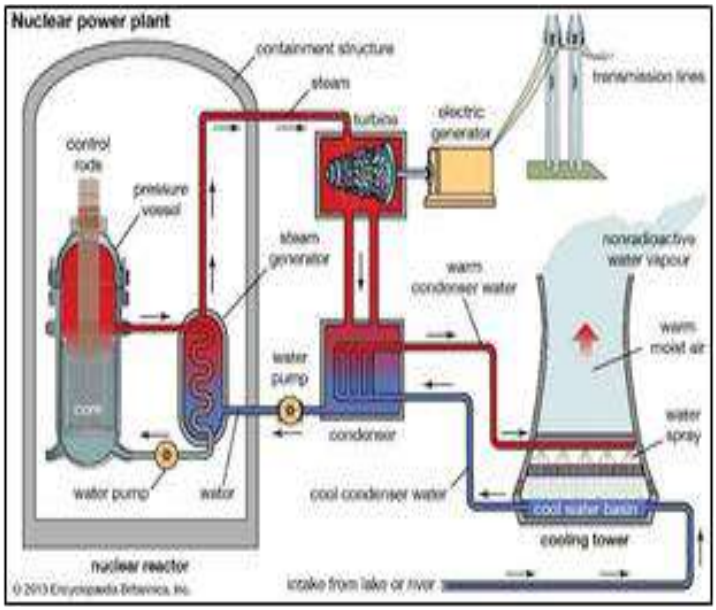
emissions are approximately 15 g CO_2e kWh^{-1}. The evaporative emissions are about 0.1 g CO_2e kWh^{-1} for binary plants and 40 g CO_2e kWh^{-1} for non-binary plants. The total planning and operation time for a large geothermal plant is about 3-6 years.



Hydroelectricity power is currently the largest installed renewable source of electricity globally. Water produces electricity when it drops on a turbine, providing it with mechanical energy which is then converted into electrical energy. These plants last for around 50-100 years and have very less lifetime emissions, about 17-22 g CO_2e kWh^{-1}.

A tidal turbine is similar to a wind turbine. It consists of a rotor that turns when water is dropped on it during a tide. A generator in the turbine converts the mechanical energy into electricity. These turbines are usually mounted on sea floors. Since tides run about six hours in one direction before switching directions for six hours, they are fairly predictable. Tidal power generates about 14 g CO_2e kWh^{-1} and has a payback time of 3-5 months.





Nuclear power plants today generate electricity by splitting heavy elements during fission. The products formed during fission collide with water in a reactor which releases energy. The water boils, producing steam whose pressure turns a turbine to generate electricity. Usually, Uranium-235 and Plutonium 239 are used for fission. When a slow-moving neutron hits Uranium-235, the neutron is absorbed which generates Uranium-236. Uranium-236 splits into Krypton-92, Barium-141, three free neutrons, and gamma rays When the gamma rays and other particles collide with water in a reactor, they convert their electromagnetic and kinetic energy to heat the water to form vapours. The lifetime emissions of a nuclear power plant are 9-70 g CO_2e kWh^{-1}. However, this source of energy also possesses a threat to society in the form of nuclear terrorism.

The connection between nuclear power plants and nuclear weapons and wars is the availability of radioactive material.

These are a few alternative solutions to conventional fossil fuel energy resources. With the correct implementation of these, we can reduce the amount of GHGs produced, which will in turn not create temperature hikes.

Conclusion

Climate change needs to be addressed more often and with more severity. As discussed above, we need to take crucial and efficient actions. We, as common citizens can also contribute to a better environment. We can use public transit more often, not burn garbage, use energy-efficient appliances, plant more trees, discourage deforestation, etc. A small step from all of us would surely impact our climate and Earth positively.

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PHYSICS BEHIND THE CLIMATE CHANGE

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Key words: Greenhouse Gases, Physics of Climate Change, Ice ages, Effects of Climate change.

"Earth provides enough to satisfy every man's need but not every man's greed."

-Mahatma Gandhi

Introduction: The phrase climate change consists of two words, 'Climate' and 'Change', so in order to understand the meaning of climate change first we have to understand the word Climate. The word climate can be defined as follows:

"The average course or condition of the weather at a place usually over a period of years as exhibited by temperature, wind velocity, and precipitation is known as the climate of that particular or specific place."

Or in simple words we can say that the 'climate' is the long term average of a region's weather events.

So, now as we have the understanding of the word climate, we can define the climate change. **"Climate Change means a change of climate which is attributed directly or indirectly to the human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods."**

In other words the phrase, 'Climate Change' refers a change in the long term weather patterns. Climate change is not a change of weather in a particular day.

We can understand this by a simple example, it is possible that a winter day in Himachal, could be sunny and mild, but the long term average weather conditions (Climate) tells us that winters in Himachal will mainly be cold and include snowfall but if there is a significant change in the pattern of Himachal's winter from the usual or normal pattern than this condition represents an epitome of climate change.

The climate change is the biggest threat for the future of mankind as well as for our home planet, for the survival of the human species we must conquer over this threat.

We humans are fortunate enough to get one mighty tool against this catastrophe and the tool is '**Physics'**. Physics is helping us in numerous ways such as; finding the causes and impacts of climate change and threats and challenges for the upcoming generation. Physics has also suggested us some alternative ways through which we can dodge this threat.

Further, we are going to know more about climate change and try to understand how physics is helping humanity against this threat.

Discovery of Climate Change: The discovery of this dejected yet shocking and interesting phenomenon dated as back as the discovery of **'The Discovery Of Global Ice Ages'**.

The credit of this important discovery goes to the famous Swiss scientist duo scientists Johann von Charpentier (1786-1855) and Jean Louis Agassiz (1807-1873).

Charpentier and Agassiz took a trip through Alps mountain range in 1836, at that time Charpentier was convinced by the idea that the marks of the glacier in the Alpine Valley is left by previous larger glaciers. This theory had developed by a Swiss engineer named Ignace Venetz (1788-1859), Venetz expanded this idea and was able to convince Charpentier. During the Alps trip Agassiz got to know about the Venetz's theory, he not only accepted the theory but also expanded and modified that. Later he suggested that in addition to the expansion of Alpine glaciers, other glaciers descended from the north to cover virtually all of Europe and North America. Agassiz's theory suggests that earth has undergone many ice ages. Perhaps the single most important outcome of this theory, however, is the realization that Earth's climate does change dramatically over time.

The next breakthrough in the field of climate change had occurred when famous Swedish scientist and Nobel laureate **'Svante August Arrhenius'** predicted that changes in atmospheric carbon dioxide level could substantially alter the surface temperature of earth through the greenhouse effect, in one of his seminal paper which he presented in 1896. In 1936 English steam engineer **Guy Stewart Callendar** connected the carbon dioxide level in earth's atmosphere and global warming. Studies in 1950's showed something which was quite interesting that CO_2 released in the earth's atmosphere was not immediately got absorbed by oceans. Oceans have the limited capability to absorb CO_2.

In 1960 Charles David Keeling gave the concept of **'Keeling Curve'** and showed that the level of CO_2 is rising in earth's atmosphere. In the year 1967 **Syukuro Ivanabe** and **Richard Wetherald** made a first detailed calculation of the greenhouse effect incorporating convection (the "Manabe-Wetherald one- dimensional radiative-convective model") and showed that a doubling of carbon dioxide from the current level would result in approximately 2°C increase in global temperature.

John Sawyer published the study Man-made Carbon Dioxide and the "Greenhouse" Effect in 1972 and he accurately predicted the rate of global warming for the period between 1972 and 2000.

In the year 1979, World Climate Conference (12 to 23 February) of the World Meteorological Organization finally concluded by stating the fact that "it appears plausible that an increased amount of carbon dioxide in the atmosphere can contribute to a gradual warming of the lower atmosphere"

There is a famous quote, **'Truth is strengthen by observation and time'** and these observations were enough for mankind to realize the fact that, we have done something horrible to our planet and now it is changing our surroundings day by day.

Scope of Study: 'Bhopal', what comes in your mind when you hear this word, a beautiful city full of natural beauty and lakes. No wonder Bhopal is known as 'City of Lakes', there are more than 15 major and minor lakes in this amazingly nature rich city. The geographical location of the Bhopal City lies within North Latitude 23°16' and East Longitude 77°36'. City has an average elevation of 500 meters (1401 ft) and is located in the central part of India, just north of the upper limit of the Vindhya mountain ranges. Located on the Malwa plateau, it is higher than the north Indian plains and the land rises towards the Vindhya Range to the south. The city has an area of 463 km², with population around 2,505,000. The Climate of Bhopal is **Humid Subtropical**, with cool and dry winters and hot summers, the monsoon mainly be humid. The average annual rainfall of Bhopal district is about **1126.7 mm**, while based on IMD station at Bairagarh; the annual normal rainfall of Bhopal is **1260.2 mm**.

Map-A: Credit Google

Rainfall patterns and change in maximum and minimum temperature throughout the year is the most promising feature to detect the effect of climate change. So now we are going to see rainfall patterns of the last 10 -12 year of Bhopal and try to find out how these things are affecting the climate of the city.

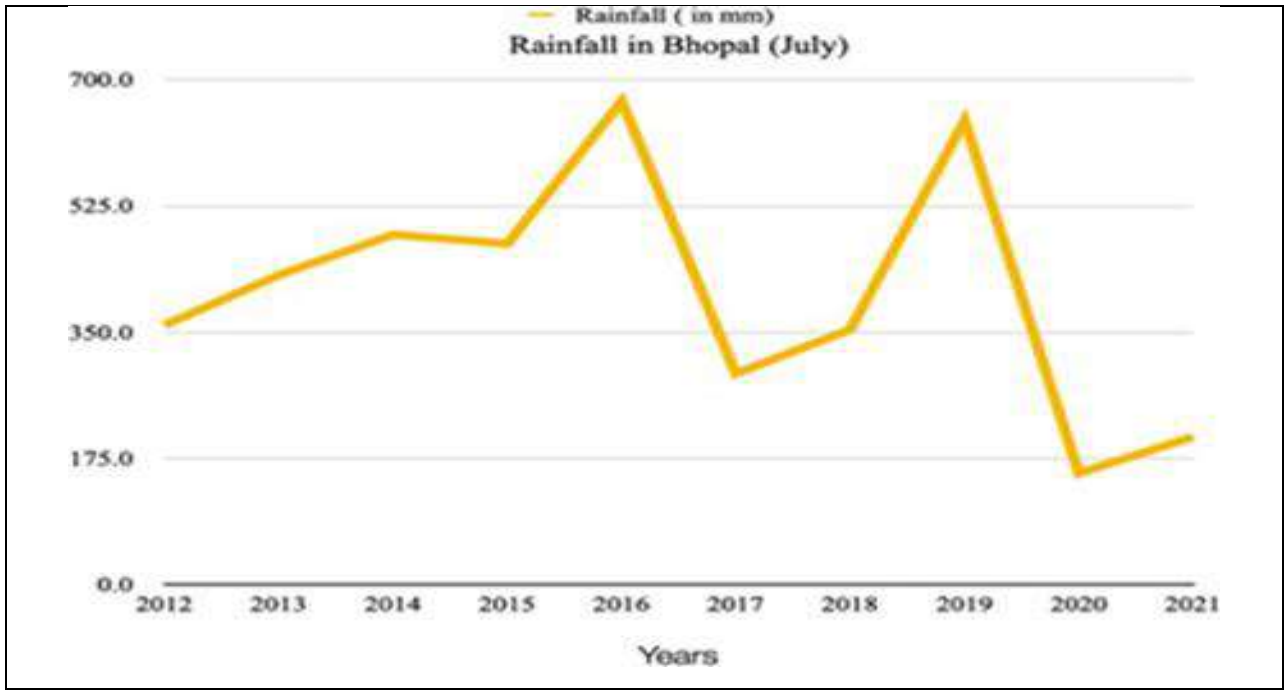
The data here we are using is the rainfall data of July month because the July is the peak time of monsoon in Bhopal. July is the month when southwest monsoon has already set in the area.

The table below represents the rainfall of last 10 years (2012- 2021) in mms.

YEAR	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Rainfall in mms	360.0	429.1	485.5	472.7	670.2	292.6	354.0	643.1	154.7	205.1

Table: A (Credit IMD Bhopal)

By taking a look at the table: A one can easily figure out that the rainfall pattern is pretty unusual and unpredictable, in year 2015 the rainfall in month July is around 472.7 mms while in 2016 it got increased to 670.2 mms. The major fact is here that the arrival of monsoon is not definitive it is changing continuously over the last 10 years. In some year there was the early or on time arrival of monsoon, in such years we got sufficient rain or more rainfall than the required parameter but in some years , for instance in the year 2020 we got less than 200 mms of rainfall because the monsoon was delayed.



This abnormal pattern of rain is indicating to the fact that the climate of the city is changing slowly.

The temperature variation of a place is as important as the rainfall patterns. The table:B below represents the highest and lowest temperatures recorded in last 10 years in July month.

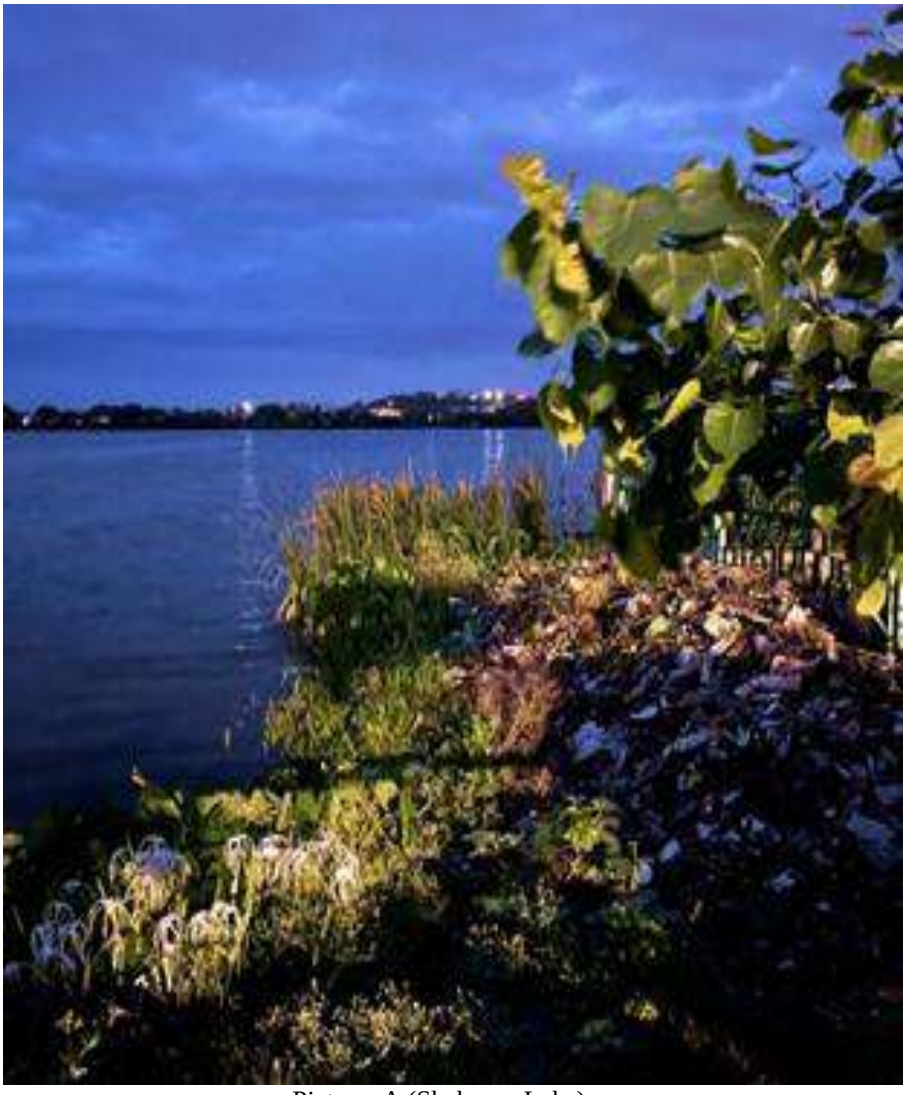
The lowest temperature have increased since 2012, however it was the lowest temperature ever recorded in last 50 years but the fact is the lowest temperature have also increased from 21.4 in 2013 to 22.5 in 2021. The change is very small but we are looking at only 10 years data and for 10 years this thing is no less than an alarming event.

	उच्चतम अधिकतम Highest Maximum(दिनांक Date)	निम्नतम न्यूनतम Lowest Minimum(दिनांक Date)
2021	37.8(8)	22.5(28)
2020	36.3(2)	22.8(25)
2019	36.3(25)	21.7(1)
2018	35.6(3)	22.4(12)
2017	36.1(8)	21.4(26)
2016	34.7(1)	22.3(7)
2015	35.7(5)	21.6(27)
2014	39.3(3)	21.5(21)
2013	32.4(1)	21.4(2)
2012	38.3(1)	19(30)

Table: B (Credit:IMD,Bhopal)

Bhopal is the city of lakes and the condition of water bodies can also tell us the effect of climate change over the city or in other words if the water bodies are getting affected then this will eventually lead towards the imbalance of eco systems around them and at the end it will surely led to a negative effect on climate of the city.

The most of the lakes of city are not in good condition, almost all the lakes are contaminated with a large part of the city's sewage, chemical and toxic waste. The Upper Lake of Bhopal also known as 'Bada Talab' is the major source of city's drinkable water but the lake is filled with 7,500 cubic metric million litre of sewage. Another major lake known as Shahpura Lake also facing the same threats, in the summer season the water level of lake dropped down drastically, the lake is filled with polythene bags and different types of non-biodegradable wastes. This picture (Picture A) of Shahpura lake tells us the poor condition of this beautiful lake. The situation is threatening and alarming, almost all the lakes are getting more and more polluted day by day and dying a slow death.



Picture: A (Shahpura Lake)

Causes of Climate Change: Now as we are well aware of the seriousness as well as the vast impact of climate change, let us try to find out the major causes behind this catastrophe.

We can divide the causes into two categories, which are:

I. Natural Causes of Climate Change

II. Man-made causes of Climate Change

Firstly we are going to discuss about the natural phenomenon which are affecting the health of our planet.

I. **Natural Causes of Climate Change:** The causes from which the climate is getting affected and which are entirely generated by the nature are known as the 'Natural causes of Climate Change'. Climate Changes which had happened prior to the Industrial Revolution in the 1700s can be explained by studying the natural processes. Some of the major Natural causes are as mentioned below:

a) **Changes in the Earth's Orbit and Rotation:** A tiny change in the earth's orbit or in its axis of rotation can lead to a huge change in climate. For example the different seasons we experience today are just because of the axis of rotation. Another is the happening of Ice Ages. Studies have shown us that the ice ages was happened because the amount of summer sunshine got affected by the changes in planet's orbit, this thing increased the winter period and earth had experienced the long period of cold temperature which ultimately lead to the origin of several ice ages.
Even today this factor is playing an important role in the determination of the climate. We can easily understand this by Figure: A that how different heat zone are generated because of the tilt in the axis of rotation.

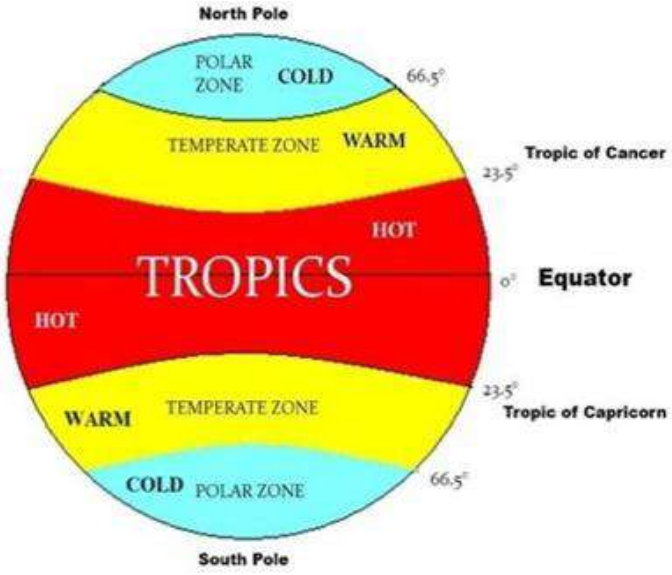


Figure: A Credit: Google

b) **Variation in Solar Activity:** Changes in the sun's energy output can affect the intensity of the sunlight that reaches the earth's surface which directly affect the heat absorbed by the atmosphere and surface of the planet, this factor has a countable effect over the climate. However some satellite measurements have shown us that the energy output of sun is almost constant since 1978 and the global temperature is rising.

c) **Volcanic Activity:** Volcano can affect the climate at a noticeable level. Volcanic eruptions release the large quantities of CO_2 in the atmosphere. Some explosive volcano can throw particles (e.g. SO_2) into the upper atmosphere, where the particles can reflect enough sunlight back to space and cool the surface of the planet for several years.

d) **Changes in Naturally Occurring CO_2 Concentration:** The heating and the cooling of earth's surface vastly depends upon the level of CO_2. Thus the change in the concentration of CO_2 can affect the temperature immensely. In past also the CO_2 levels varied in tandem with the glacial cycle's means level was higher and lower during the warm and cold interglacial period respectively.

These are some of the major Natural phenomenon which affect the climate of our planet, Human activity is playing more crucial role in the climate change.

II. **Man-made causes of Climate Change:** One of the greatest scientific mind of all time, Albert Einstein once said, "Mankind invented the atomic bomb, but no mouse would ever construct a mousetrap." But what if one is not enough we humans have created another equivalent of a mouse trap known as 'Climate Change'.
"The direct or indirect activity performed by the human which has contribution in the change of the climate is known as the man-made causes of the climate change."

The following are some of the biggest man-made causes of climate change:

a) **Emission of Greenhouse Gases:** Greenhouse gas emission is major human made cause of climate change. The main sources of emission include transportation, electricity production, burning of fossil fuels in industries, commercial and residential application, agricultural activities. CO_2 and other greenhouse gases accumulate in the atmosphere, blocking the heat from escaping, thus warming the planet and afterwards the result is the change of climate.

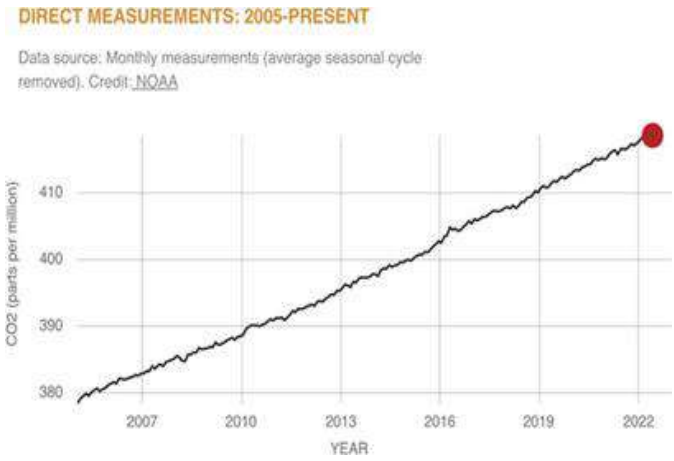


Figure: B Credit: NASA

The level of CO_2 (A major heat trapping Greenhouse gas) in earth's atmosphere has increased significantly. The Figure shows the level of CO_2 in January 2005 and current level of CO_2.Methane, Nitrous Oxide, CFC, Sulphur Hexachloride are some other major Greenhouse Gases.

b) **Deforestation:** Trees can be considered as the lungs of the mother nature; they take in CO_2 and release oxygen to the atmosphere during photosynthesis apart from that they also help in the regulation of regional rainfall. When we cut trees, their stored CO_2 gets emitted to the atmosphere, which contributes to the global warming and changes the climate of the earth. Deforestation also leads to increase in absorption of energy by the surface of earth and warm the planet.

c) **Agricultural Activities:** The modern agriculture practices and methods of food production are great contributor in global warming and climate change. Also the large scale farming leads to the problem of deforestation and machine intensive works, which contributes in the greenhouse emission at a great degree. Food is most basic human need but this is a sad fact to know that every stage of food production (e.g. packing, transportation etc.) is releasing the substantial amount of Greenhouse gases in the upper atmosphere.

d) **Industrialization:** Industrial revolution is associated with adverse environment effects that cause climatic changes. With recent innovations, human labor has been replaced with machinery that uses fossil fuels as the source of energy. Industrialization leads to the urbanization which give the birth another alarming phenomenon known as 'Heat Islands'. In this effect urban centers get warmer than the surroundings, less populated areas.

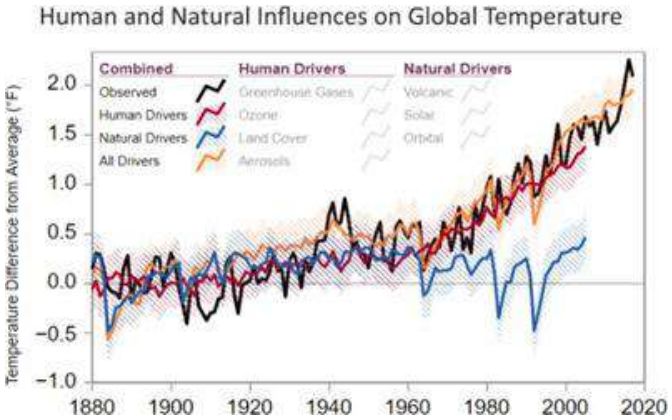
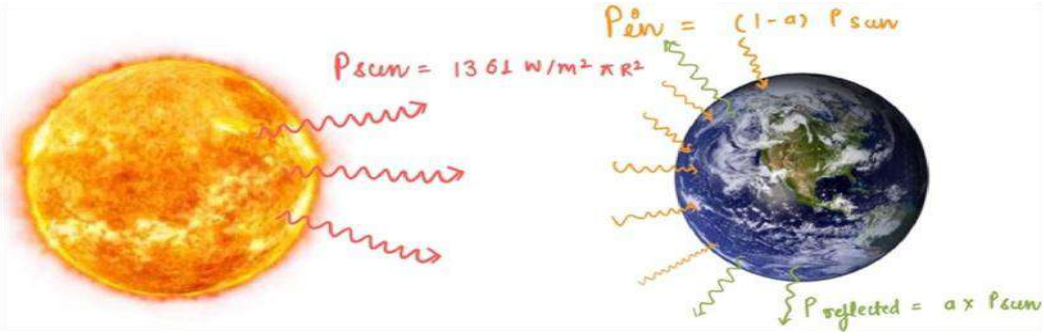


Figure: C, Credit EPA

The figure (Figure-C) shows us the comparison of different causes in the climate change.

Physics behind the Change: Climate Change can be explained by the simple laws of Physics. Let us try to understand the causes of climate change:



Picture-B

Let us consider here,

$$P_{sun} = 1361 W/m^2 R^2$$

$$P_{reflected} = a \times P_{sun}$$

$$\therefore P_{in} = (1 - \alpha) P_{sun}$$

$$\approx 10^{17} \text{ Watts}$$

Here, P_{sun} is the heat emitted by the sun, $P_{reflected}$ is the heat reflected by the earth and P_{in} is the heat absorbed by surface and atmosphere of the earth.

Now for the condition of the equilibrium, so the temperature of the planet remains constant, it is important that,

$$P_{in} = P_{out}$$

Here, P_{out} is the heat radiation emitted by the earth. But we know that according to the laws of thermodynamics a blackbody emits heat in the form of kT^4, here 'T' is the temperature of that body and 'k' is a constant. So the heat emitted by the surface of the earth can be expressed as follows.

$$P_{out} = 4 \pi R^2 x \, kT^4$$

Now, the equation $P_{in} = P_{out}$ gives us a quite surprising result. This equation was solved by the famous mathematician Fourier in 1824 and the value of temperature obtained was:

$$T_{earth} \approx -18℃$$

Here T_{earth} is the average temperature of the earth's surface which is not the case as we know that the value of T_{earth} is around ≈ +15℃, this leads us to the conclusion that the value of P_{out} is not equal to the value of P_{in} , means earth is absorbing some part of the radiation which is keeping the earth warm. This process of absorption is known as the **'Greenhouse Effect'.**

Now if the P_{earth} is the amount of radiation absorbed by the earth, then

$$P_{out} = (1 - b) P_{earth}$$

Means,

$$P_{earth} = p_{out/\,(1-b)>} P_{out}$$

Here the value of (1-b) is less than one so the value of $p_{out/(1-b)}$ will be greater than the P_{out}
So finally we can see how the temperature of the earth depends upon the value of heat radiation absorbed.
So,

$$T_{earth} > -18℃$$

But value of 'b' is increasing because of the increasing amount of Greenhouse gases in earth's atmosphere so this heat equilibrium is getting disturbed and this is the cause behind the increase of global temperature.

Effects of Climate Change: The Climate change is the global crisis, almost every living organism is getting affected with it. Some effects of climate change are mentioned below:

a) Effects on Bio-diversity: The environmental changes being driven by climate change are disturbing the natural habitats and species in numerous ways. Wild fires incidents in Amazon forest and Australian forests are the greatest example of it. Rising global temperatures can also alter the functioning of the ecosystems which can affect the vegetation and living species in them.

b) Effects on Economy: Climate change is one of the biggest threats for the developing as well as developed economies. Droughts, hurricanes, cyclones and other natural disaster is taking place because of the climate change which are affecting the economies of nations. Monsoon patterns are also getting affected which can prove disastrous for a country like India, where farming is the main source of income for people and farming is mainly dependent on the monsoon.

c) Effect on Social Factors: According to a latest report by the World Bank, Climate Change is deeply intertwined with global patterns of inequality. Female-headed households, children, persons with disabilities, indigenous people and ethnic minorities, landless tenants, migrant workers, displaced persons, sexual and gender minorities, older people and other socially marginalized groups are particularly vulnerable to this global crisis. The irony is that the most vulnerable are often also disproportionately impacted by measures to address climate change.

How to Dodge Climate Change: Famous Visionary and one of the leading social activist, Bill Gates suggested in his famous book, 'How to Avoid a Climate Disaster', there is only one way left to avoid or slow down the effect of climate which is attaining the 'zero percent emission of carbon'. We have to follow a two-step path in order to achieve this goal. We can define these two steps on the basis of their working, first of them is **'short term actions',** these are the actions everyone must apply in their lifestyle in order to slow down the effect of climate change some of them are as follows:

- Save energy, electricity is much more valuable than the amount you are paying for it.
- Minimize the use of things which produce non-biodegradable waste and encourage recycling.
- Plant as much trees as you can, try to grow a terrace garden and discourage the unnecessary use of paper.
- Avoid the unnecessary use of vehicles and try to take a walk if your destination is at shorter distance, use public transport in place of your private car or two-wheeler to reduce your carbon footprint.
- There are many eco-friendly concepts which are coming in the market, such as footplates, cups and spoons, which are edible; we can use these items in place of plastic utensils.

These are some short term actions but this is not enough to stop the climate change we must take some big and bold moves in order to achieve this goal. There are some 'long term actions' which we must apply in order to secure our future, some of these are mentioned below:

- We must move to the renewable energy sources and we have to achieve this goal in upcoming 12 to 15 years because according to the IPCC (Intergovernmental Panel on Climate Change) after this the climate change will become irreversible.
- Governments should pass policies and make some strict rules in order to stop the production of the products which are producing the harmful and non-biodegradable wastes and should provide the subsidy on renewable energy sources.
- Every nation must establish some organization on central and state level to spread awareness about the climate change, its harmful impacts and solutions.
- The vehicles which are currently being used in the public transportation should be changed with the electric vehicles.
- In order to reduce the emission of greenhouse gases to the minimum level, we must establish a plan which can improve the farming techniques at ground level so that agricultural emissions of greenhouse gases can be minimized.

These are some key points which every human being must know and follow in order to conserve earth. Remember this earth belongs to the upcoming generation and we should pass it on to them in the best condition possible.

Conclusion: No challenge possesses a greater threat to future generations than the climate change. Famous writer **'David Wallace – Wells'** says in his bestseller book, **'The Uninhabitable Earth'**, that the "Climate change is no more remain as Arctic or Antarctic region incident which is happening remotely." according to him this is a global crisis, which is among us and all of us are feeling it. He has stated in the first line of the same book, "It is worse, much worse than you think. The slowness of climate change is a fairy tale."

Former U.S. president Obama also said in his speeches, "We are the first generation to feel the impact of climate change and only generation that can do something about it." Our planet is on fire we must act or we are all going to burn.

We are human, the most intelligent species of this planet, we got tools to understand this catastrophe, we have capability to defeat climate change and we must have do so because this is the only home for us there is no planet **'B'**. The earth has always protected and nurtured us and now it's our turn to save our mother earth.

The world is too much with us; late and soon,
Getting and spending we lay waste our powers;

--William Wordsworth

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PHYSICS BEHIND THE CLIMATE CHANGE

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Key words: Global warming, fossil fuels, sun radiation and temperature variation in climate.

Over several years, science has progressed in tremendous ways. Technology has advanced into many areas of our lives, making information more accessible, improving communication, changing transportation, and the list goes on. While it is easy to sit back and benefit from plethora of technological advancements, it is crucial we do not become blind to its effects on society.

As these technology advancements have started resulting into "Global Warming" and to be precise "Climate Change" and that what the essay is all about but with some cooperative touch of physics. Let's know about climate change. People say it is crisis of our time, well to be honest, it is. The science is dense and the politics gets in the way. Well let's see it with some basic science.

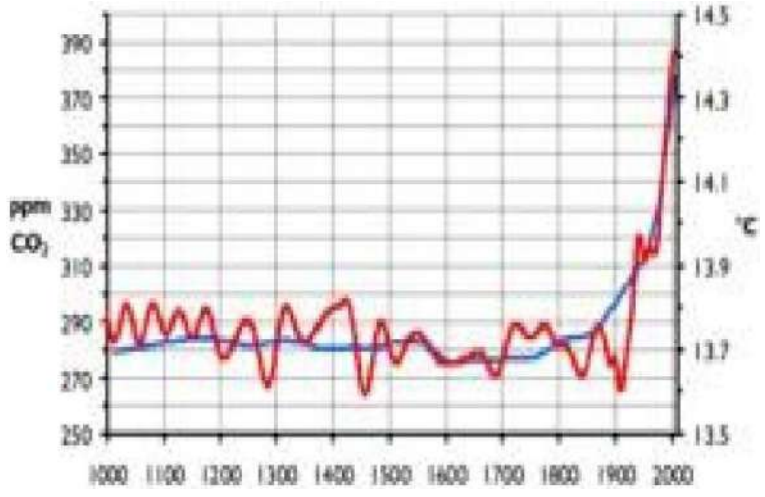

Figure 1: Graph of CO_2 over thousands of years

The graph shows that these are the levels of carbon dioxide in our atmosphere over hundreds of thousands of years. But 1950's spike in carbon dioxide at almost the end. That took off during the industrial revolution. We the humans, started breaking CO_2 records in 1950, and we haven't stopped since. Why? Because scientists say there's a 95% chance that human activity is the cause.

As we have been burning more and more like oil and coals, which release CO_2, to power our homes, factories, airplanes and cars. There's also a lot more of us. The global population has tripled in the past 70 years and we're consuming more products from animals that release another pollutant called methane. So, all those gases are in the air, and when sunlight gets into the earth's atmosphere, some of the heat gets trapped, and the planet gets warmer. That's why we call it the "Greenhouse Effect". But the concern is not only this that earth is getting warmer but it is happening far too quickly.

Johan Rockström, Director, Potsdam institute for climate impact research said, "It's actually the warmest temperature on earth since the last Ice age since Ten thousand years ago."

The UN says, our world is about 1 degree hotter, right now, than pre-industrial times. That's around the year 1800, which is okay. In fact, the UN says if we warm by 1.5 degrees before the end of the century, we should

be fine. The UN even says 2 degrees would 'probably' be alright. But again, the problem is speed, because right now, we are on track to hit 1.5 degrees in only ten years and if we don't slowdown that warming up, it could mean Catastrophe within my lifetime and maybe yours too. Sea levels are rising about 3mm a year because seawater expands as temperatures get warmer. Melting ice sheets and glaciers also add trillions of tons of freshwater into our oceans. People in our country and around the world are already losing their homes. Entire coastal cities could be underwater within 80 years.

Well, here's the politics, Malcolm **Roberts**, Australia Senator One Nation Party said "The ground base temperature data has been messaged to show an increase but the satellite data shows no increase."

But no wonder, there is a positive momentum. There's more awareness and some countries including India, Morocco and the Gambia have massive renewable energy projects. But according to experts, what's needed now is an even bigger push to change everything about the way we run our world.

"You can't have infinite growth on a finite planet."

It can be done by shifting to renewable energy, reducing the use of cars, use trains more, cycle more, eat less meat, consume a bit more carefully. So where does that leave us? Well, there's only so much bike- riding and light-bulb replacing you and I can do every day. But the truth is that it's those everyday things that are going to change anyway. Even tea could run out if farmers can't grow it. So, what's the expert advice? Is that it's down to all of us, to change our ways and shake things up or climate change is going to do it for us as instead of us it will start adjusting.

Well! We all only see climate change in terms of geography or environment but there are some parts where physics plays a vital role. So, here's the cooperative part of physics. As I said further that CO_2 is warming the earth, but how does it work? We say gases trap the heat and don't let it go back to space but how? Is it like the glass of a greenhouse or like an insulating blanket? Well quite similar but not entirely, as its answer includes a bit of quantum mechanics, but to make it simple to understand, rainbow is the best way. So, if we look closely at sunlight separated through a prism, we see dark gaps where bands of color go missing. Well! Where did they go? It is that before reaching our eyes, different gases absorbed those specific parts of the spectrum. For example, oxygen snatches away some of the dark red light, and sodium grabs two bands of yellow. But why do these colors absorb specific colors of light? So, this is where quantum realm enters, every atom and molecule have a set number of possible energy levels for its electrons. To shift its electron from the ground state to a higher level, a molecule needs to gain a certain amount of energy. "No More, No Less." It gets that energy from light, which comes in more energy levels than you could count. Light consists of tiny particles called photons and the amount of energy in each photon corresponds to its color. Red lights have lower energy and longer wavelengths. Purple lights have higher energy and shorter wavelengths.

Sunlight offers all the photons of the rainbow, so a gas molecule can choose the photons that carry the exact amount of energy needed to shift the molecule to its next energy level. When this match is made, the photon disappears as the molecule gains its energy, and we get a small gap in our rainbow. If a photon carries too much or too little energy, the molecule has no choice but to let it fly past. This is a way glass is transparent. The atom in glass does not pair well with any of the energy levels in visible light, so the photons pass through.

Well, this was whole theory type introduction, but now about our climate change. So which photons does carbon dioxide prefer? Where is the black line in our rainbow that explains global warming? Well, it's not

there. As we know that carbon dioxide doesn't absorb light directly from the sun, it absorbs light from a totally different celestial body.

One that doesn't appear to be emitting light at all: "Earth".

If you are wondering why our planet doesn't seem to be glowing, it's because the earth doesn't emit visible light. It emits infrared lights. The light that our eyes can see, including all of the colors of the rainbow is just a small part of the larger spectrum of electromagnetic radiation, which includes radio waves, microwaves, infrared rays, x-rays, and gamma rays. It may seem strange to think of these things as light, but there is no fundamental difference between visible light and other electromagnetic radiation. It's the same energy, but at a higher or lower level. In fact, it's a bit presumptuous to define the term visible light by our own limitations. As we are part of kingdom animally too, every animal sees different lights and different electromagnetic radiations. For e.g., Infrared rays are visible to snakes, and ultraviolet light is visible to birds, and if we take ourselves as the example and if our eyes were adapted to see light of 1900 megahertz, then a mobile phone would be a fresh light, and cell phone tower would look like a huge lantern. Earth emits infrared radiation because every object with a temperature above absolute zero will emit light. This is called as Thermal Radiation. Th hotter an object gets the higher frequency the light it emits. For e.g., when you heat a piece of iron, it will emit more and more frequency of infrared light, and then a temperature of around 450° C, its light will reach the visible spectrum. At first, it will look red hot, and with even more heat, it will glow white with even more heat, it will glow white with all of the frequencies of visible light. This is how traditional light (tungsten light) bulbs were designed to work and that's why they are so wasteful. As 95% of the light it emits is invisible to our eyes. It's wasted as heat.

Earth's infrared radiation would escape to space if there weren't greenhouse gas molecule in our atmosphere. Just as oxygen gas prefers the dark red photons, CO_2 and other greenhouse gases match with infrared photons. So, they provide the right amount of energy to shift the gas molecules into their higher energy level. Shortly, after a carbon dioxide molecule absorbs an infrared photon, it will fall back to its previous energy level, and spit a photon back out in a random direction. Some of the energy then returns to earth's surface, causing warming. The more carbon dioxide in the atmosphere, it is likely that infrared photons will land back on earth and change our climate.

- **CASE STUDY: "ANAND"**

The rainfall and temperature are the most fundamental physical parameter among the climate as it determines the environmental factors of the particular region which affect the agricultural productivity. Global warming/climate change is one of the most important worldwide issues talked among the scientists and researchers. Attempts have been made to study the temporal variations and trends in monthly, seasonal and annual temperature over Anand (middle Gujarat). Analysis has been carried for four temperature indices, namely - minimum temperature (T_{min}), maximum temperature (T_{max}), mean temperature (T_{mean}) and diurnal temperature range (DTR). Non-parametric Mann-Kendall (MK) test was used to detect the trends and the magnitude of the trends were determined with Sen.'s estimator of slope. The present study is the warming trends in T_{min}, T_{max} and T_{mean} temperatures and decreasing trends in DTR over City of Anand. At the site, the total numbers of statistically significant values in three temperature indices - T_{min}, T_{max} and T_{mean} are more than total number of non-significant values on annual, seasonal and monthly timescale. The trend in T_{min} variable is increasing at the station on annual, seasonal and monthly scale. These increasing trends in T_{min} are significant at annual, seasonal and monthly scales over January, July August and December over Anand, it is significant at annual, seasonal (winter, monsoon, post-monsoon). In general, the magnitudes of rate of change

in T_{min} are higher as compared to other variables on all time scale at the station. The increasing trends in T_{max} at Anand are significant on annual scale, monsoon season as well as in February, March, May, June, August, and October to December at Anand. The similar trends are observed in T_{min} and T_{max}, T_{mean}, this shows significant increasing trends on annual, seasonal (monsoon and post-monsoon) and monthly (except January) scale over Anand timescale. DTR shows significant decreasing trends on annual scale, winter season, post - monsoon season and in April month at Anand.

Geographically, it is located at Anand (Lat - 22°.35' N and Long- 72° 58'E) station is located in Middle Gujarat Ago-climatic zone-3. It has an average elevation of 39 meters from the mean sea level. The Annual Rainfall at Anand is ranged between 286.9 to 1693 mm. The Data used in this paper are the monthly, seasonally and annual means of temperatures (Max and Min) and DTR during 1958-2016 (i.e., 50 years (approx). The four seasons in India as defined by IMD are: winter season (January - February), pre-monsoon season (March to May), monsoon season (June to September) and post-monsoon season (October to December) based on the climatology of the region. The annual average T_{max} is around 33.2 °C. The annual T_{min} is 19.7 °C, T_{mean} is 26.4 °C and DTR is 13.6 for Anand.

***Annual maximum, minimum, mean temperature and DTR graphs for Anand.**

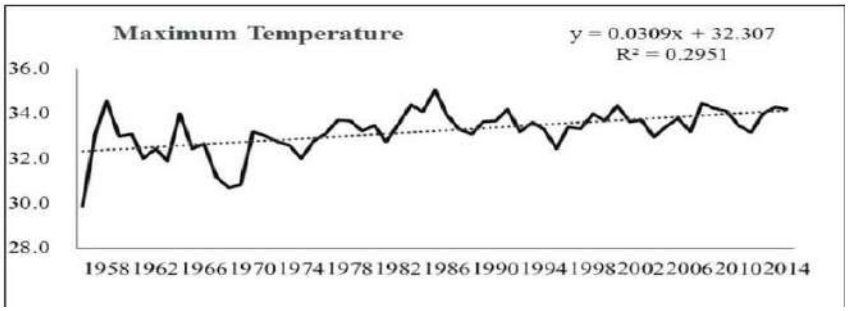

Figure 2: Maximum temperature in Anand

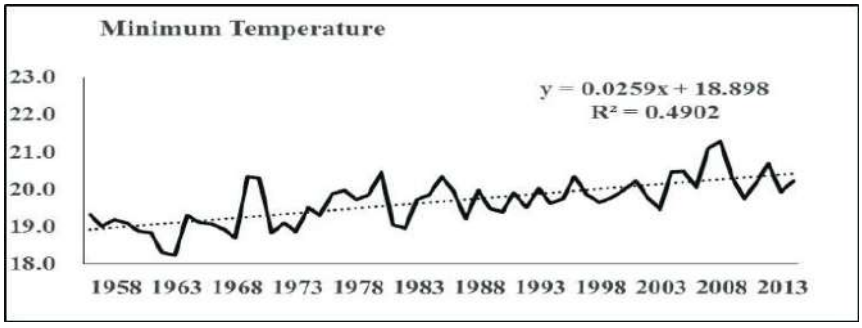

Figure 3: Minimum temperature in Anand

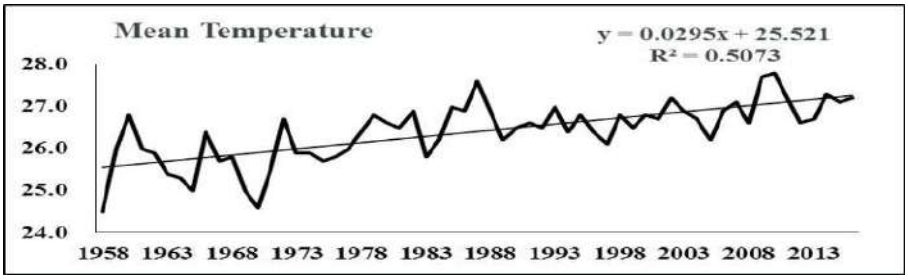

Figure 4: Mean temperature in Anand

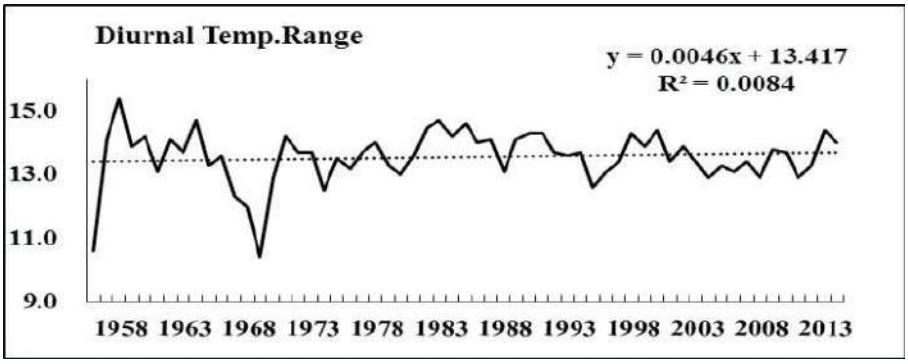

Figure 5: Normal day temperature range in Anand

The seasonal T_{max} is highest (37.3 °C) during the pre-monsoon season and lowest (28.9 °C) during the winter season. The seasonal T_{min} is lowest (11.7 °C) during the winter season and highest (25.4 °C) during the monsoon season. The seasonal average T_{mean} temperature varies from 20.3°C to 29.3°C and the highest (29.3°C) is experienced during the monsoon season. The seasonal mean DTR are also found highest (17.3°C) during the winter season and lowest 7.9 °C during the monsoon season. The highest values (28-29°C) of monthly T_{mean} are observed during pre-monsoon season and monsoon season. The monthly T_{mean} is maximum during May-September period and June-September period respectively. The monthly T_{max} is highest in May and lowest in January. The highest monthly T_{max} observed in May are 39.0°C at Anand. During pre-monsoon season and monsoon season, i.e., from March to September months the maximum temperature varies from 32.5°C to 38.0°C at Anand. January is the coldest month for Anand station with monthly minimum temperature at around 10.9°C. The monthly T_{min} are highest (24.0°C to 26.0°C) during June-to-September months (monsoon season) over Anand. The DTR values are highest during January-February months (winter season) and lowest during June-September months (monsoon season). At Anand, DTR is highest in January (16.7 °C) followed by February (17.8°C). During June-September months (monsoon season) DTR varies from 6.3°C to 10.0°C.

The present study is the warming trends in T_{min}, T_{max} and T_{mean} temperatures and decreasing trends in DTR over the City of Anand. At the site, the total numbers of statistically significant values in three temperature indices - T_{min}, T_{max} and T_{min} are more than total numbers of non-significant values on annual, seasonal and monthly timescale. The trend in T_{min} variable is increasing at the station on annual, seasonal and monthly scale. These increasing trends in Tmin are significant at annual, seasonal and monthly scales over January, July, August and December over Anand, it is significant at annual, seasonal (winter, monsoon, post-monsoon). In general, the magnitudes of rate of change in T_{min} are higher as compared to other variables on all time scale at the station. The increasing trends in T_{max} at Anand are significant on annual scale, monsoon season as well as in February, March, May, June, August and October to December at Anand. We must protect and restore wild nature in our country, region, and community. This means mobilizing private individuals to take action in their neighborhoods and cities as well as influencing elected leaders to do a better job at protecting public lands and expanding those protections to include critically important areas threatened by the imminent potential for destruction.

For example, the places like Vidyanagar, AV Road, Town hall areas, etc., are quite important in educational field but apparently hazards for our nature earth. As for P.G., hostels, institutions, campus area, lot harm has been happening in such areas, without any concern for it. So, as being the youth and the future of our nation, it's our duty to be the effective change for our regions, not for whole country but for our regions. As we know that every revolution starts with a small step. Every day we make choices in our lives that affect the environment, the climate and other species. From what we eat to how many children we decide to have, there's a lot we can do to "choose wild" and reduce our environmental footprint to leave more room for wild animals and plants.

- Think twice before shopping.
- Make sure your big purchases have big environmental benefits.
- Go Plastic Free.
- Boycott products that endanger wildlife.
- Pay attention to labels.
- Be water wise.
- Drive less, drive green.
- Green your home.
- Choose Wild Energy.
- Take Extinction Off Your Plate.
- Choose to have a smaller family.
- Use your voice and your vote.

"If the earth bursts where we will get birth, reduce heat, and save the earth."

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PHYSICS BEHIND THE CLIMATE CHANGE

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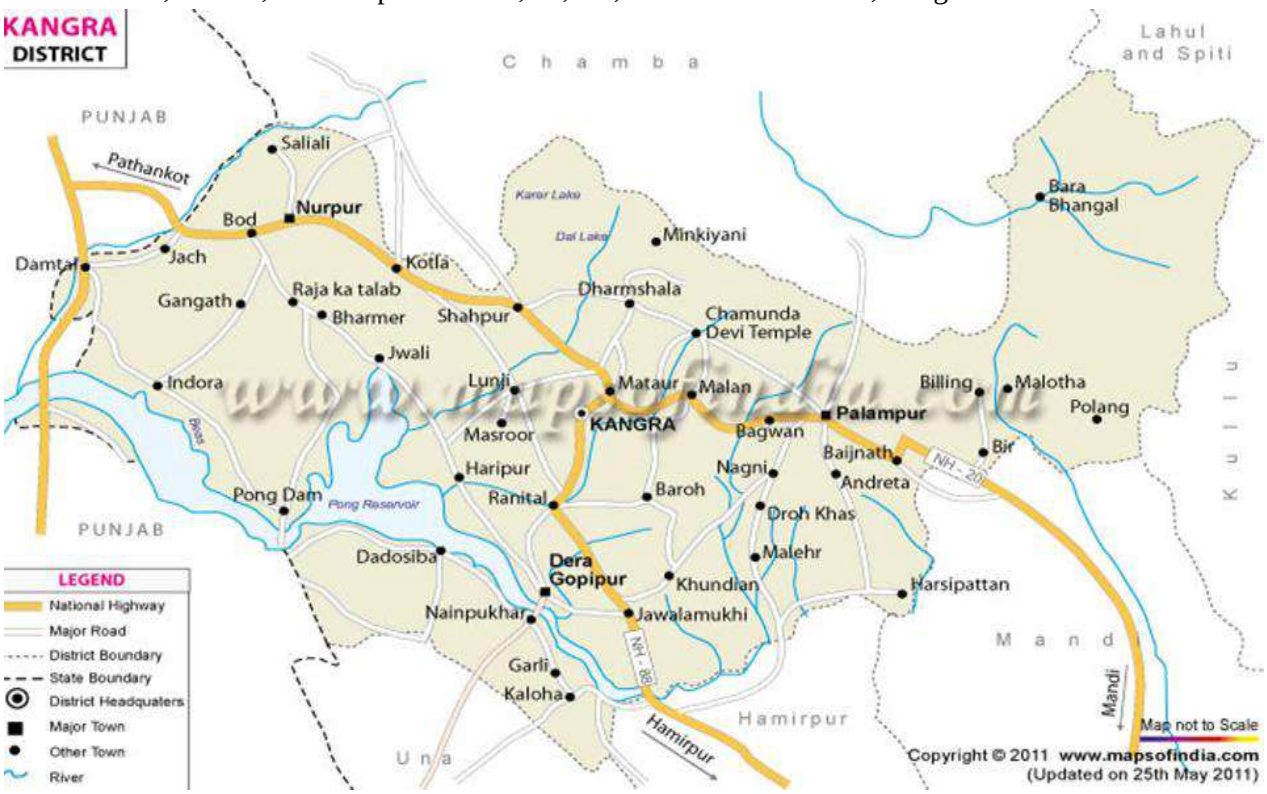
I. Scope of study: District Kangra, Himachal Pradesh

Area: 5,739km^2; Total Population: 15, 10,075; Latitude: 32.0669°N; Longitude: 76.2691° E

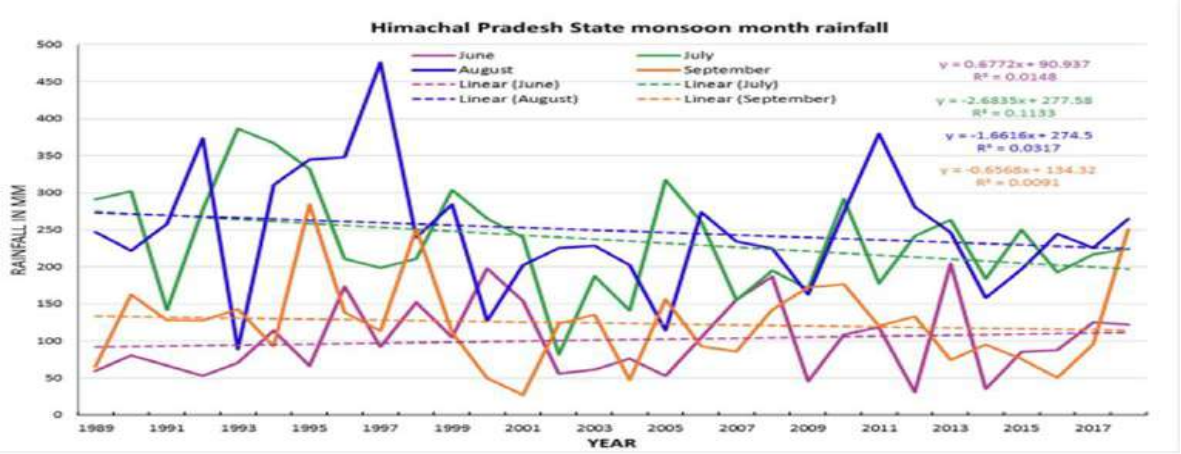


Here, this is the map of district Kangra of Himachal Pradesh, India which is also my residential area. The area covered by district Kangra is 5,739km2. The total population is 15, 10,075. The state may be broadly divided into 3 geographical regions: outer Himalayas, the lesser Himalayas and the greater Himalayas or the Alpines. The outer Himalayas include the districts of Bilaspur, Hamirpur, Kangra, Una and the lower parts of Mandi, Sirmour and Solan. The lesser Himalayas include the parts of Mandi, Sirmaur and parts of Chamba, Kangra and Shimla.

II. DATA

- Rainfall variation (from 1989-2017)

  Highest rainfall (June and July) is received in the year 2013(203.9mm) and 1993(386.9 mm) respectively while highest rainfall of 476.1 in August received in the year1997 and of 284.5mm in September received in the year 1995.Highest annual rainfall of 1493.9 mm is received in theyear 1995 and highest southwest monsoon rainfall of 1028.6 mm received in the year 1995.

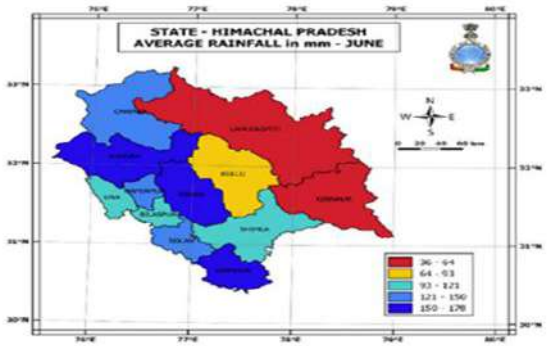


Here, in this graph rainfall in monsoon months is depicted which includes June, July, August, September. It can be seen that the highest rainfall (35%) of south west monsoon season rainfall is in August month while there is 33% of the south west monsoon rainfall in July month. June and September receive 14% and 17% of south west monsoon rainfall respectively. Also more than 61% of annual rainfall is received during the southwest monsoon season.

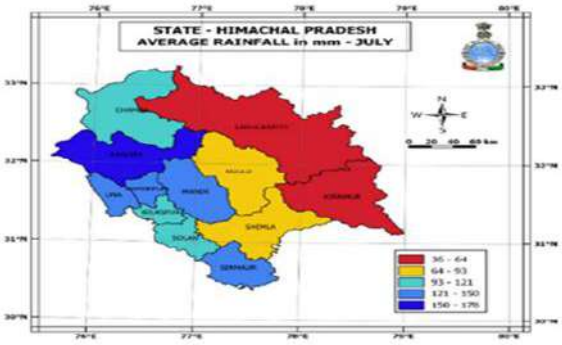
It can be seen that four districts viz. Hamirpur, Mandi, Sirmaur and Kangra receive highest rainfall over other districts during the whole season.

Coefficient of variation (CV) =Standard Deviation/Mean × 100

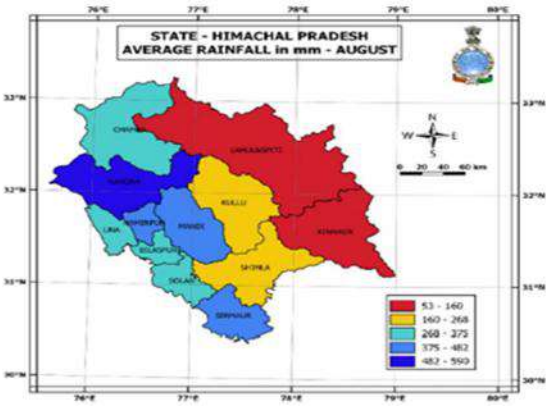
DISTRICT	JUNE		JULY		AUGUST		SEPTEMBER		MONSOON		ANNUAL	
	MEAN	CV	MEAN	CV	MEAN	CV	MEAN	CV	MEAN	CV	MEAN	CV
BILASPUR	100.5	287	257.6	36	327.8	88	147.1	80	833.0	74	1096.2	90
CHAMBA	121.5	177	290.4	51	310.8	93	140.3	160	863.0	63	1590.8	66
KANGRA	177.7	58	508.2	28	589.0	31	204.8	47	1479.8	22	1860.4	21
KINNAUR	35.0	124	51.1	65	52.7	67	49.8	74	188.6	45	611.3	41
KULU	85.8	239	173.5	44	167.6	49	93.5	75	520.3	60	1016.5	40
LAHUL AND SPITI	49.7	540	97.4	298	105.7	115	91.8	238	344.7	140	855.5	80
MANDI	169.4	51	382.0	28	400.0	34	160.0	40	1111.3	21	1460.9	20
HAMIRPUR	123.9	237	352.3	27	419.6	33	153.5	67	1049.3	52	1345.2	67
SIMLA	111.5	190	211.5	43	205.6	37	122.1	62	650.8	51	1049.0	39
SIRMUR	167.7	140	415.2	37	383.8	34	193.4	64	1160.1	41	1446.2	37
SOLAN	139.1	58	287.5	42	282.4	42	151.6	61	860.5	23	1156.3	20
UNA	110.2	193	337.2	92	373.4	35	158.0	146	978.8	67	1221.4	66



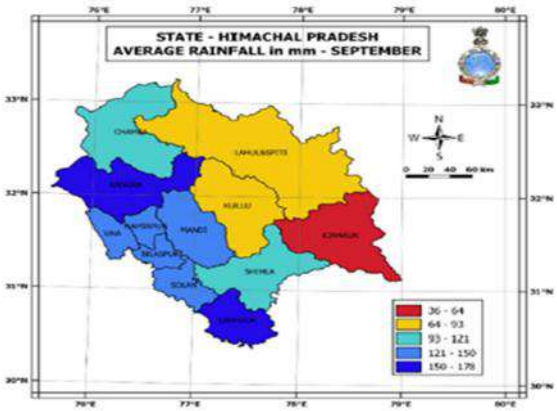
Here, we can see that highest cm rainfall is received in districts of Kangra, Mandi and Sirmaur.



Here, we can see that highest cm rainfall is received in district Kangra.

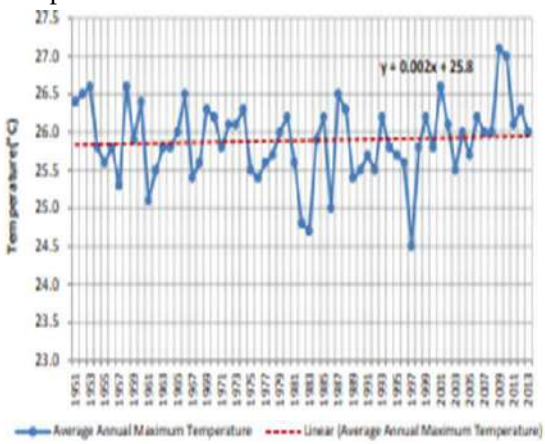


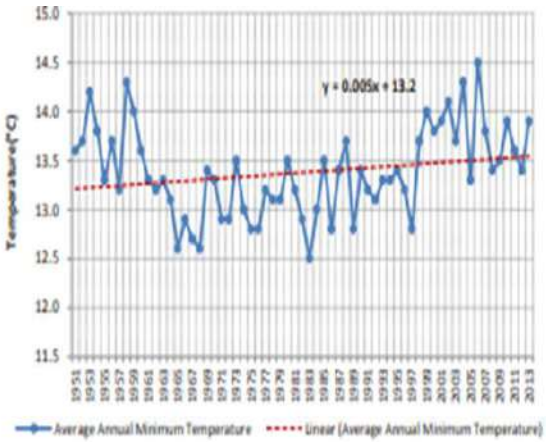
Here, we can see that highest cm rainfall is received in district Kangra.

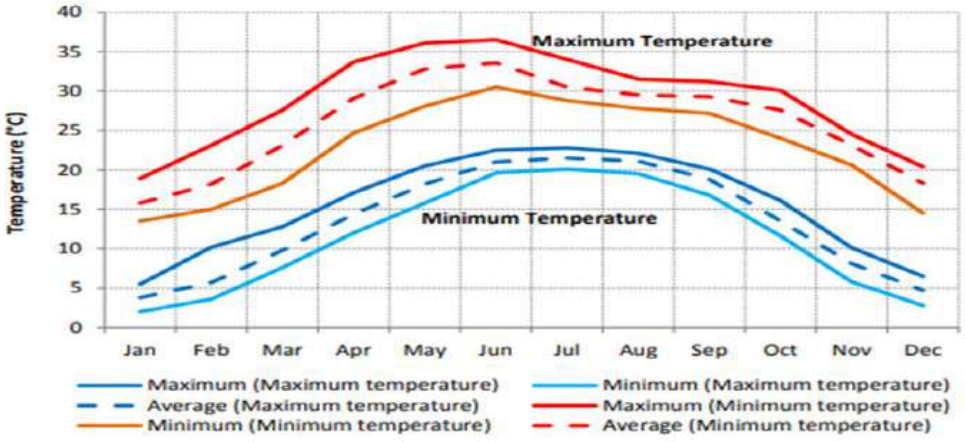


Here, we can see that highest cm rainfall is received in districts of Kangra and Sirmaur.

- Temperature variation: 1951-2013







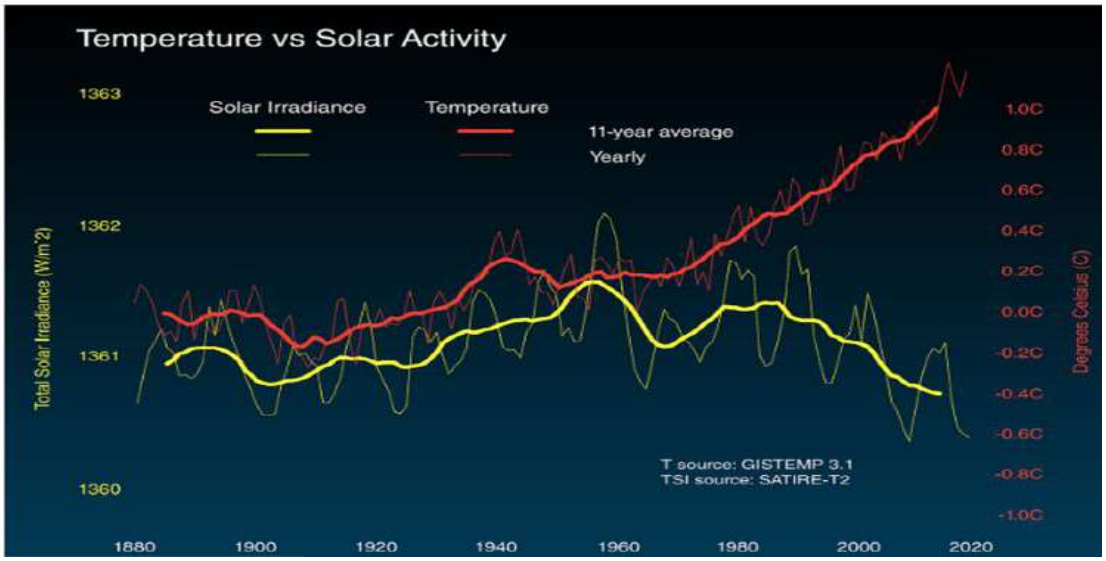
III. CLIMATE CHANGE

- Natural Causes

❖ CAN WE SAY THAT SUN IS RESPONSIBLE FOR IT?

It's according to me a question with both answers yes and no. Let's find why it should be no first.

Maybe it's still a paradox or a mystery which is yet to be discovered; is sun a reason to cause climate change or it is not; even a slight change in sun's energy could disturb the whole climate of earth or is it just the amount of heat trapped by greenhouse gases?
These all questions are still not answered but to every mystery there is solution too, **may be we will only be the ones to find that solution!**



NO, because since 1978, a series of satellite instruments have measured the energy output of the Sun directly. The satellite data show a very slight drop in solar irradiance (which is a measure of the amount of energy the Sun gives off) over this time period. So the Sun doesn't appear to be responsible for the warming trend observed over the past several decades.

The evidences which prove that global warming is not affected by changes in energy of sun are as follows:

i. Since 1750, the average amount of energy coming from the Sun either remained constant or increased slightly.
ii. If the warming were caused by a more active Sun, then scientists would expect to see warmer temperatures in all layers of the atmosphere. Instead, they have observed a cooling in the upper atmosphere, and a warming at the surface and in the lower parts of the atmosphere. That's because greenhouse gases are trapping heat in the lower atmosphere.
iii. Climate models that include solar irradiance changes can't reproduce the observed temperature trend over the past century or more without including a rise in greenhouse gases.

So, it explains us that without increase in greenhouse gases there is no significant change in temperature and climate of earth.

YES, because it's reasonable to assume that changes in the Sun's energy output would cause the climate to change, since the Sun is the fundamental source of energy that drives our climate system.

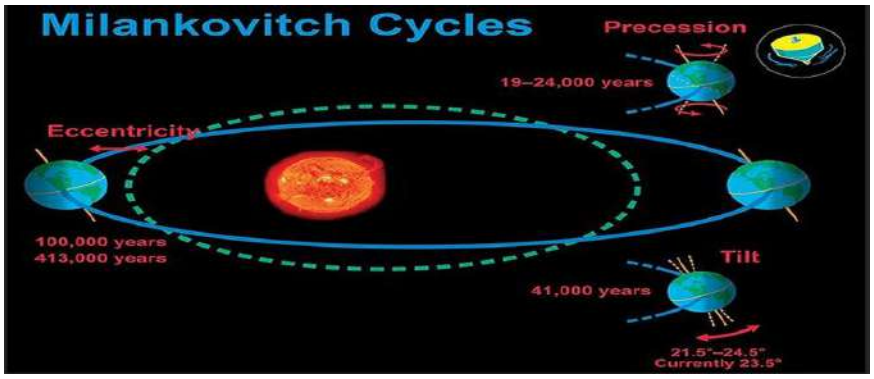
Indeed, studies show that solar variability has played a role in past climate changes. For example, a decrease in solar activity coupled with an increase in volcanic activity is thought to have helped

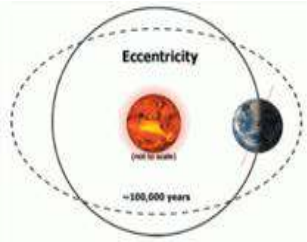
trigger the Little Ice Age between approximately 1650 and 1850, when Greenland cooled from 1410 to the 1720s and glaciers advanced in the Alps.

❖ CHANGES IN THE EARTH'S ORBIT, AXIAL TILT AND PRECESSION

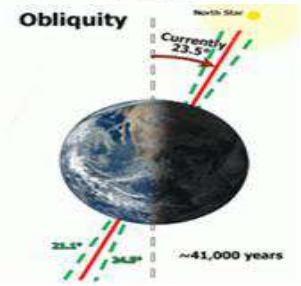
The three changes in the Earth's orbit around the Sun — eccentricity, axial tilt (obliquity), and precession — are collectively called 'Milankovitch cycles'.

According to Milankovitch's theory, these three cycles combine to affect the amount of solar heat that reaches the Earth's surface and subsequently influences climatic patterns, including periods of glaciation (ice ages). The time period between these changes can be tens of thousands of years (precession and axial tilt) or more than hundreds of thousands of years (eccentricity).

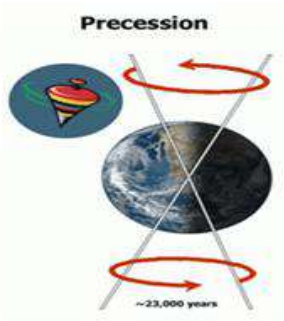




Eccentricity: The shape of Earth's orbit is known as eccentricity.
When the Earth is closer to the Sun, our climate is warmer and this cycle also affects the length of the seasons. The measure of a shape's deviation from being a circle, in this case the Earth's orbit, is called 'eccentricity'.



Obliquity: The angle at which Earth's axis is tilted with respect to Earth's orbital plane is known as obliquity. It varies between 22.1° and 24.5° every 41,000 years. Earth's axis is currently tilted 23.5°. When the tilt is less, the winters are not as cold and the summers are not as warm.



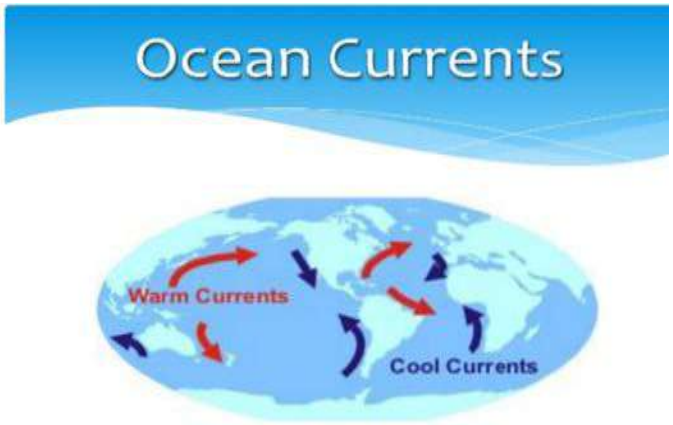
Precession: The direction Earth's axis of rotation is pointed is known as precession.
Each 24 hours, Earth rotates once around its imaginary axis. About every 23,000 years, the axis itself also makes a complete circle or precession, causing Earth to "wobble." This "wobble," causes Earth to be closer to the sun in July instead of January and intensifies the summer temperatures in the Northern Hemisphere.

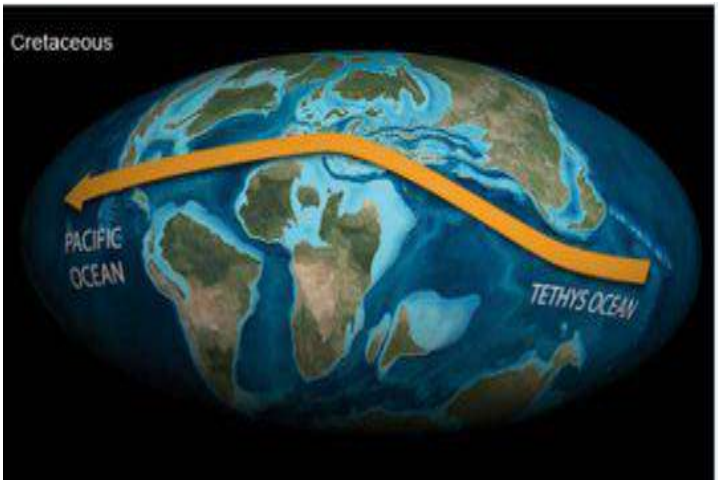
❖ CHANGES IN OCEAN CURRENTS

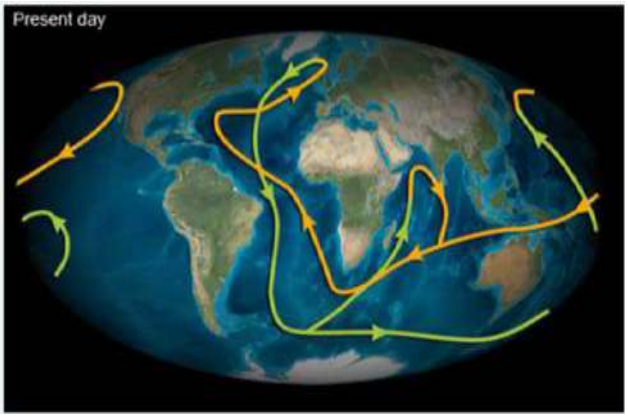
Ocean currents carry heat around the Earth. The majority of radiation from the sun is absorbed by the ocean, particularly in tropical waters around the equator, where the ocean acts like a massive, heat-retaining solar panel. Covering some 71 per cent of the Earth and absorbing about twice as much of the sun's radiation as the atmosphere or the land surface, the oceans are a major component of the climate system. Because they absorb and emit heat more steadily than land, oceans help moderate temperatures in coastal areas, making winters warmer and summers cooler.

Some currents take warm water away from the equator, influencing coastal climates near the poles. Others take colder water from the poles or the deep ocean and move it towards the equator, creating cooler coastal climates.

Ocean currents are located at the ocean surface and in deep water below 300 meters (984 feet). They can move water horizontally and vertically and occur on both local and global scales. The ocean has an interconnected current, or circulation, system powered by wind, tides, the Earth's rotation (Coriolis Effect), the sun (solar energy), and water density differences. The topography and shape of ocean basins and nearby landmasses also influence ocean currents. These forces and physical characteristics affect the size, shape, speed, and direction of ocean currents.

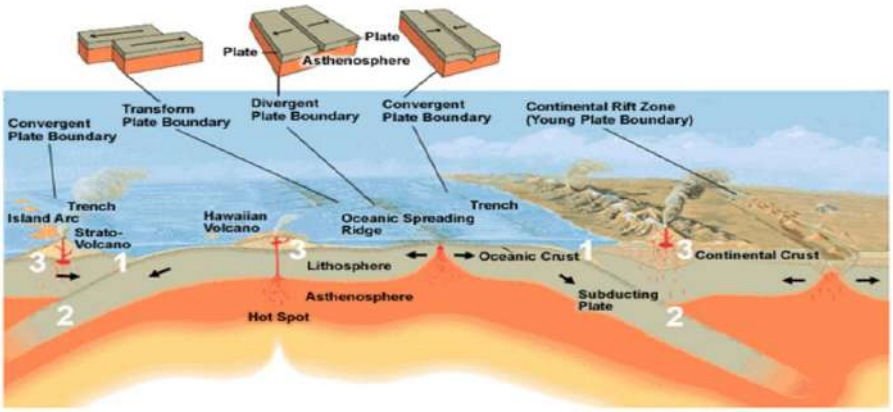






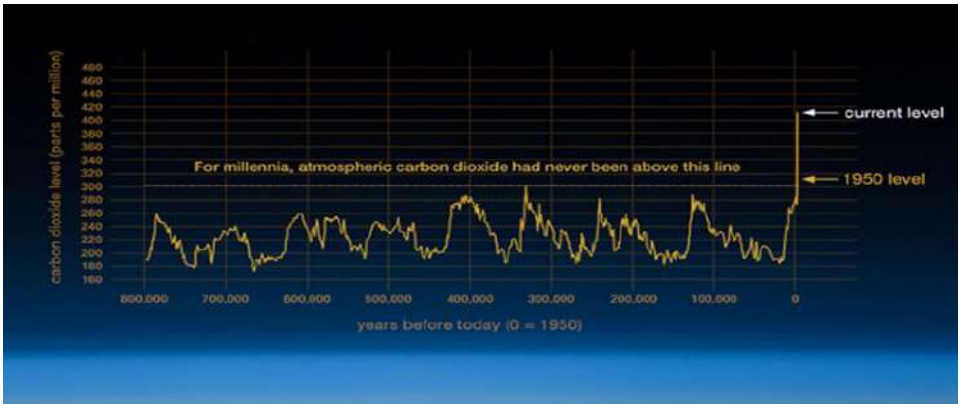
❖ PLATE TECTONICS

Over very long periods of time, plate tectonic processes cause continents to move to different positions on the Earth. For example, Britain was near to the equator during the Carboniferous Period, around 300 million years ago, and the climate was warmer than it is today. The movement of the plates also causes volcanoes and mountains to form and these can also contribute to a change in climate.

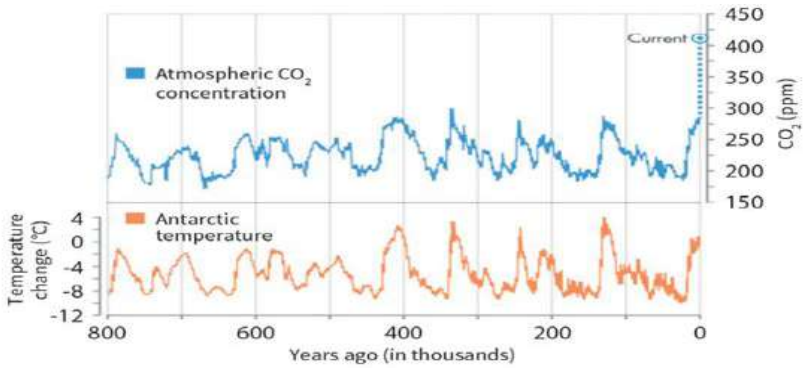


❖ VARIATIONS IN NATURALLY OCCURING CO_2 LEVELS

During warm interglacial periods, carbon dioxide levels were higher. During cool glacial periods, carbon dioxide levels were lower.



During ice ages, CO_2 levels were around 200 parts per million (ppm), and during the warmer interglacial periods, they hovered around 280 ppm.



This shows that when temperature was lower CO_2 levels became low and when temperature was high CO_2 levels became high during thousands of years back.

❖ **VOLCANIC ERUPTIONS**

Volcanoes have played a vital role in climate, and volcanic eruptions released large quantities of carbon dioxide in the past. Some explosive volcano eruptions can throw particles (e.g., SO_2) into the upper atmosphere, where they can reflect enough sunlight back to space to cool the surface of the planet for several years.

Volcanic particles from a single eruption do not produce long-term climate change because they remain in the atmosphere for a much shorter time than greenhouse gases. In addition, human activities emit more than 100 times as much carbon dioxide as volcanoes each year.

- **Man-made causes**

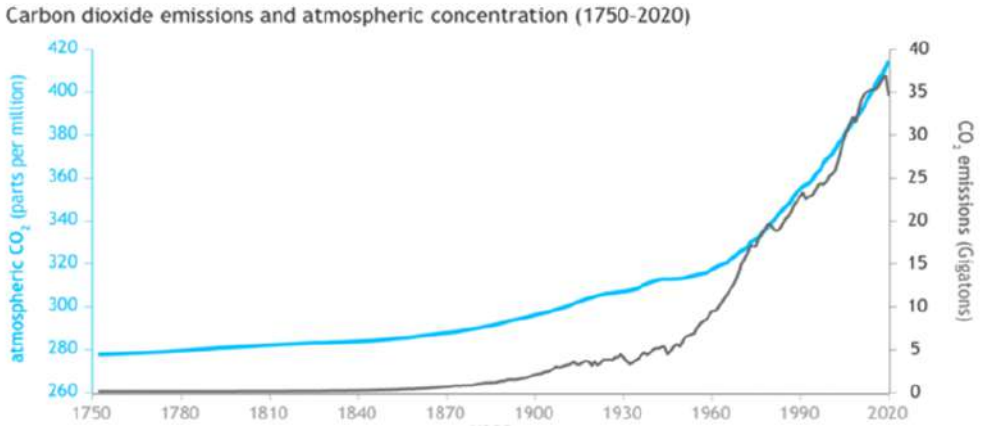
❖ **GREENHOUSE EFFECT**

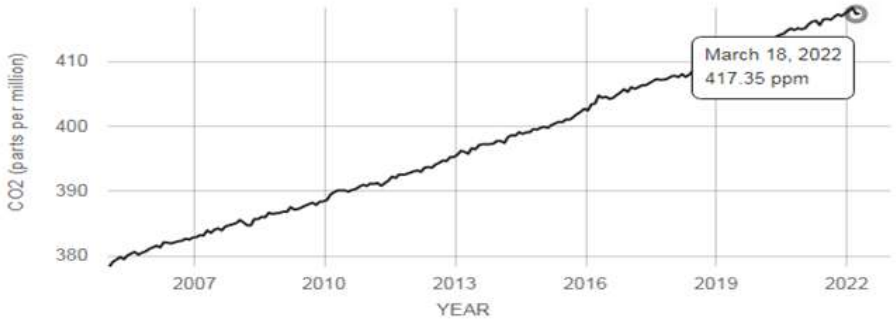
Concentrations of the key greenhouse gases have all increased since the Industrial Revolution due to human activities. Carbon dioxide, methane, and nitrous oxide concentrations are now more abundant in the earth's atmosphere than any time in the last 800,000 years. Scientists attribute the global warming trend observed since the mid-20th century to the human expansion of the "greenhouse effect"- warming that result when the atmosphere traps heat radiating from Earth toward space. These greenhouse gas emissions have increased the greenhouse effect and caused the earth's surface temperature to rise. Burning fossil fuels changes the climate more than any other human activity.
Human activities (primarily the burning of fossil fuels) have fundamentally increased the concentration of greenhouse gases in Earth's atmosphere, warming the planet. Natural drivers, without human intervention, would push our planet toward a cooling period.

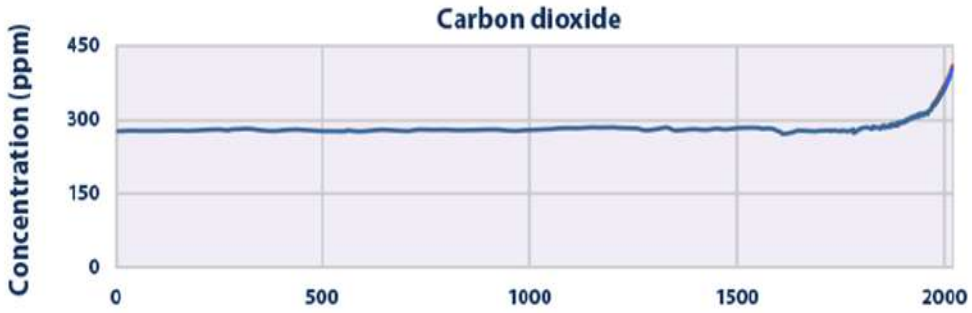
Carbon dioxide: Humans have increased atmospheric CO_2 concentration by 48% since the Industrial Revolution began. Approximately from 280 parts per million (ppm) in the 18^{th} century it increase to 414 ppm in 2020.

Today, we stand on the threshold of a new geologic era, which some term the "Anthropocene", one where the climate is very different to the one our ancestors knew.

Carbon dioxide is the most important of Earth's long-lived greenhouse gases. It absorbs less heat per molecule than the greenhouse gases methane or nitrous oxide, but it's more abundant, and it stays in the atmosphere much longer. Increase in atmospheric carbon dioxide is responsible for about two-thirds of the total energy imbalance that is causing Earth's temperature to rise.



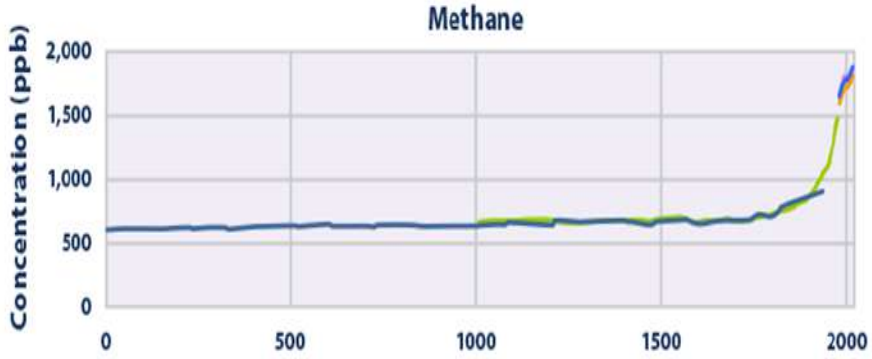




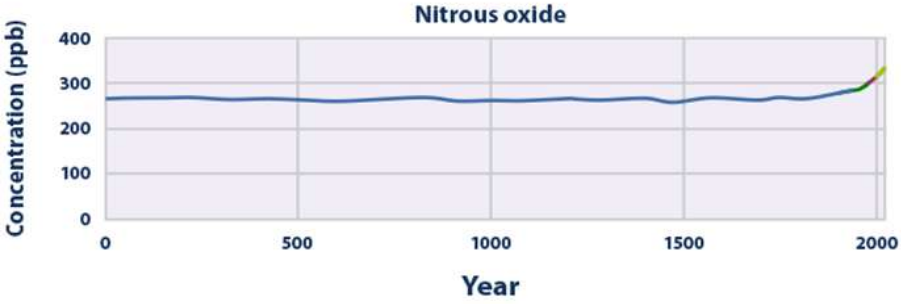
Water Vapour: The most abundant greenhouse gas, but importantly, it acts as a feedback to the climate. Water vapor increases as the Earth's atmosphere warms, but so does the possibility of clouds and precipitation.

Water Vapour is often discussed and recognized as being an important part of the global warming process. The water vapour feedback process is most likely responsible for a doubling of the greenhouse effect when compared to the addition of carbon dioxide on its own.

Methane: Human activities increased methane concentrations during most of the 20th century to more than 2.5 times the pre-industrial level, from approximately 722 parts per billion (ppb) in the 18th century to 1,867 ppb in 2019.



Nitrous Oxide: Nitrous oxide concentrations have risen approximately 20 percent since the start of the Industrial Revolution, with a relatively rapid increase toward the end of the 20th century. Nitrous oxide concentrations have increased from a pre-industrial level of 270 ppb to 332 ppb in 2019.



Chlorofluorocarbons (CFCs): Chlorofluorocarbons (CFCs) are a group of odorless manufactured chemicals. Because they damage the earth's ozone layer, CFCs have been banned since 1996. Depletion of the Ozone Layer will have a negative impact on the biodiversity of the earth itself.

- **CHANGES IN LAND COVER**

  On a global scale, patterns of vegetation and climate are closely correlated.

  A decrease in vegetation cover, via deforestation for example, tends to increase local albedo, leading to surface cooling. Albedo refers to how much light a surface reflects rather than absorbs. Generally, dark surfaces have a low albedo and light surfaces have a high albedo. Ice with snow has a high albedo and reflects around 90 per cent of incoming solar radiation. Land covered with dark-colored vegetation is likely to have a low albedo and will absorb most of the radiation.

- **REFLECTIVITY OR ABSORPTION OF THE SUN'S ENERGY**

  Activities such as agriculture, road construction, and deforestation can change the reflectivity of the earth's surface, leading to local warming or cooling. This effect is observed in heat islands, which are urban centers that are warmer than the surrounding, less populated areas. One reason that these areas are warmer is that buildings, pavement, and roofs tend to reflect less sunlight than natural surfaces. While deforestation can increase the earth's reflectivity globally by replacing dark trees with lighter surfaces such as crops, the net effect of all land-use changes appears to be a small cooling.

❖ **DEFORESTATION**

Deforestation is another major contributor to the Climate change. Rainforests are precious resource in our world. They form part of a delicate ecosystem that has taken millions of years to evolve. Rainforests every year help to absorb almost 20% of manmade CO_2 emissions therefore deforestation can be classed as a major contributor to the causes of climate change. Cutting down rainforests faster than they can be replaced has a devastating effect on the carbon emission cycle producing an extra 17% of greenhouse gases.

IV. PHYSICS BEHIND CLIMATE CHANGE

❖ **RADIATIVE FORCING**

Radiative forcing (or climate forcing) is the change in energy flux in the atmosphere caused by natural or anthropogenic factors of climate change as measured by watts / metre^2. Positive radiative forcing means Earth receives more incoming energy from sunlight than it radiates to space. This net gain of energy will cause warming. Conversely, negative radiative forcing means that Earth loses more energy to space than it receives from the sun, which produces cooling. Radiative forcing varies with solar insolation, surface albedo, and the atmospheric concentrations of radiatively active gases - commonly known as greenhouse gases - and aerosols.

Forcing due to changes in solar irradiance

Approximating Earth as a sphere, the cross-sectional area exposed to the Sun is equal to one quarter the area of the planet's surface. The globally and annually averaged amount of solar irradiance per square meter of Earth's atmosphere is therefore equal to

$$I_0 = 340 \ \mathrm{W\,m^{-2}}.$$

Water vapour is a 'feedback' for greenhouse gases.CO_2, CH_4, O_3 etc. are forcing agents .They stay in the atmosphere whatever and 'force' more heat into the climate system. This effect is measured by 'Radiative forcing constant'. More CO_2 means more warmth which causes more H_2O to be evaporated. Water vapour goes in and out of the atmosphere very quickly. Carbon dioxide is there for ~ 100 years. That makes a very big difference in the way they act.

Annual cycles

Earth follows an elliptical orbit around the Sun such that TSI(Total Solar Irradiance) received at any instance fluctuates between about 1321 W/m^2 (at aphelion in early July) and 1412 W/m^2 (at perihelion in early January), or thus by about ±3.4% during each year. This change in irradiance has minor influences on Earth's seasonal weather patterns and its climate zones.

Sunspot activity

TSI variations associated with sunspots contribute a small but non-zero net forcing in the context of decadal climate changes. Some research suggests they may have partly influenced climate shifts during the Little Ice Age, along with concurrent changes in volcanic activity and deforestation. Since the late 20th century, average TSI has trended slightly lower along with a downward trend in sunspot activity. Sunspots are areas that appear dark on the surface of the Sun. They appear dark because they are cooler than other parts of the Sun's surface.

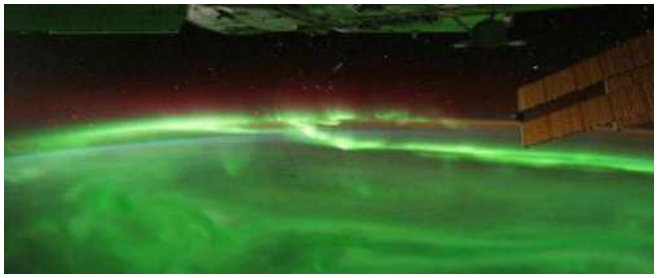
The surface of the Sun is a very busy place. It has electrically charged gases that generate areas of powerful magnetic forces. These areas are called magnetic fields. The Sun's gases are constantly moving,

which tangles, stretches and twists the magnetic fields. This motion creates a lot of activity on the Sun's surface; called solar activity. Sometimes the Sun's surface is very active. Other times, things are a bit quieter. The amount of solar activity changes with the stages in the solar cycle. Solar activity can have effects here on Earth.

Sunspots are relatively cool because they form at areas where magnetic fields are particularly strong. These magnetic fields are so strong that they keep some of the heat within the Sun from reaching the surface. When charged particles from a CME reach areas near Earth, they can trigger intense lights in the sky, called auroras. When particularly strong, a CME can also interfere in power utility grids, which at their worst can cause electricity shortages and power outages.

Coronal Mass Ejection (CME) - A CME contains particle radiation (mostly protons and electrons) and powerful magnetic fields.

AURORAS - If you're ever near the North or South Pole, you may be in for a very special treat. Frequently there are beautiful light shows in the sky. These lights are called auroras. If you're near the North Pole, it is called an aurora borealis or northern lights. If you're near the South Pole, it is called an aurora Australis or the southern lights.



Sun aging

Our Sun has consumed about half its hydrogen fuel since forming approximately 4.5 billion years ago. TSI will continue to slowly increase during the aging process at a rate of about 1% each 100 million years.

- The relationships between the atmospheric concentration of greenhouse gases and their radiative effects are well quantified. Forcing from the long-lived greenhouse gases: carbon dioxide, methane, and nitrous oxide, is presently about 2.5 Watts per meter squared (W/m^2). While changes in solar irradiance may have affected global climate in the last century, 0.15% change irradiance, the order of estimated changes, results in only a 0.36 W/m^2 forcing.

V. EFFECT OF CLIMATE CHANGE ON ECONOMY

The gap between the wealthiest and poorest countries has been steadily declining over the past several decades, but that gap would have closed by an additional 25% if climate change hadn't created a massive economic drag, according to a new study published in the science journal Proceedings of the National Academy of Sciences. The researchers looked at aggregate economic data between 1961 and 2010 and compared it to temperature changes over this period. They found that temperature increases associated with global warming caused marked declines in economic activity. As it becomes hotter, workers become less productive, staple crop yields decline, cognitive functioning decreases, and interpersonal conflict rises.

Depending on underlying assumptions, studies of the economic impacts of a doubling in atmospheric carbon dioxide (CO_2) from pre-industrial levels conclude that this would have a slightly negative to moderately positive aggregate effect (i.e., total impacts across all regions) on the agricultural sector.

The largest impact of climate change is that it could wipe off up to 18% of GDP off the worldwide economy by 2050 if global temperatures rise by 3.2°C, the Swiss Re Institute warns.
The World Economic Forum's Global Risks Report 2021 identified climate action failure as the most impactful and second-most likely long term risk facing the world in a year when populations continued to struggle mitigating the impact of the COVID-19 pandemic.

As water temperatures increase, water quality could suffer due to more frequent and more intense algae blooms, which can be toxic, thus curtailing recreational water activities and freshwater fishing. More frequent and severe wildfires will worsen air quality and discourage tourism. Sea level rise could submerge small islands and coastal areas, while deforestation and its destructive impacts on biodiversity could make some tourist destinations less attractive.

VI. EFFECT OF CLIMATE CHANGE ON SOCIAL FACTORS

As the climate continues to change, millions of poor people face greater challenges in terms of extreme events, health effects, food security, livelihood security, migration, water security, cultural identity, and other related risks. Impacts such as rising temperatures and increased frequency of extreme weather events put severe pressure on food availability, stability, access and use.
By 2050, more than a billion people in the Asian region (Central, South, East and South-East Asia) are expected to be affected from freshwater shortages due to climate change. Additionally, a great number of people between 75 million and 250 million in the African region are projected to be exposed to increased water stress due to climate change.

The World Health Organization reports that the rising temperatures and variable precipitation due to climate change that has occurred since the 1970s claimed over 140000 deaths. Globally, weather-related natural disasters result in over 60,000 deaths every year, mainly in developing countries.

VII. SOME REMEDIAL SOLUTIONS

- Changing our main energy sources to clean and renewable energy. Solar, Wind, Geothermal and biomass could be the solution.
- Many methods exist to prevent, control and reduce air pollution, in particular by reducing the consumption of fossil fuels, and limiting industry emissions and waste.
- The simplest solution to reduce waste is to adapt our production methods to our consumption patterns. The recycling process must also be taken into account in our consumption habits.
- Our transport methods must be aligned with environmental requirements and reduce their carbon footprint. It is essential to rethink our transport methods from the design stage towards eco-friendly transportation.
- Use the 3 r's of circular economy (Reduce, Reuse and Recycle) to significantly reduce our waste and avoid unnecessary production of new items.
- Oceans and seas are the largest storage of greenhouse gases and are an exceptional support system for life on this planet. Limiting overfishing, unsustainable development activities in coastal areas and the consumption of environmentally friendly products is now essential.

- **TEO Power**

Transparent energy purchase and consumption guarantee for green energy consumption

Energy today represents 2-3% percent in operations costs but up to 20-30% of carbon footprint for industrials. Companies are moving to 100% renewable energy consumption to lower their carbon impact, but today the only mechanism is the 'Guarantee of Origin' scheme, an old system with a green washing reputation. TEO Power guarantees real green energy consumption, 100% production-consumption matched renewable energy. Renewable electricity production and consumption is traced in near real time to let clients target concretely towards 24/7 green energy consumption. Customers are given communication tools to transform their energy purchase cost in image investment.

- **Tracking Water in the Face of Drought**

The "ET" in Open ET stands for evapotranspiration, which is the process through which water leaves plants, soils, and other surfaces and returns to the atmosphere. Warmer temperatures from climate change can even increase the rate at which water evaporates from plants, meaning many farms in the region need to increase irrigation to protect their crops. Evapotranspiration is a crucial measurement for farmers and other water-resource managers, where most of the water used by people goes to irrigate crops and produce food.

- **Tracking Smoke in the Face of Fires**

Used for the first time in summer 2020, when historically large fires in California blanketed vast areas of the state in smoke for days, the technique is now being refined as a way to monitor smoke.

CONCLUSION

The conclusion comes out to be that we as human beings are responsible for all these changes and we are only responsible to avoid these in future and find solutions to stop this to an extent or a point will come when earth would no more remain a place for us to survive on and we need to find other planets where we could survive and the most common planet we all talk about is MARS. Elon Musk is the biggest name in this field. He as an individual living on earth is making all the efforts that he could make to make life at Mars possible and I think we as humans too should do the same, at least few of us.

With the increase in economic and population growth the increase in use of energy is inevitable which the primary source of greenhouse gases is. One of the largest uncertainties in future greenhouse emissions is the effect of technological change. If renewable energy sources become cost-effective, if there are major gains in the efficiency of energy utilization, or if there is a large increase in the use of nuclear energy (fission or fusion), then emissions of greenhouse gases may be substantially restrained. The degree to which the climate will change in the future is still uncertain. However climate change may lead to significant damage to both human and natural systems.

PHYSICS BEHIND THE CLIMATE CHANGE

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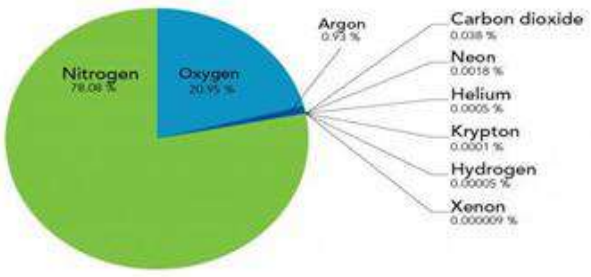
Key Words: Climate, Atmosphere, Radiation.

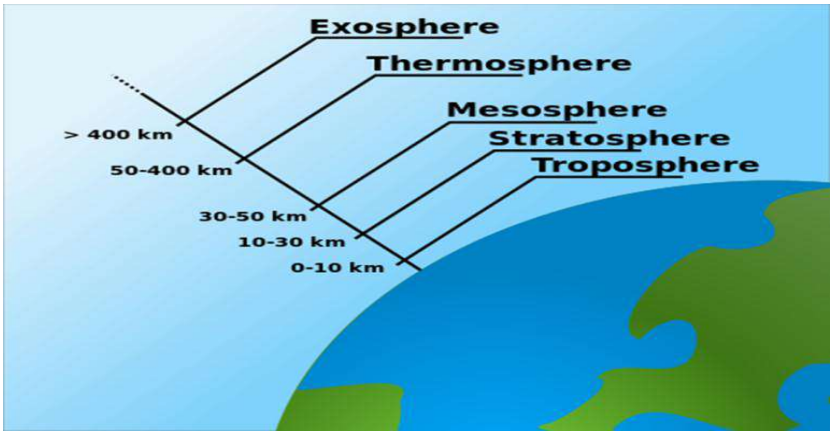
The place where we live has got its own natural environment which supports the lifestyle of ours' in a very conducive way. It exclusively depends on many factors for its steadiness over a region. One of the basic elements that govern the natural environment of a region is the atmospheric conditions prevailing over that particular region or the effects of whose is observed due to abruptions in the nearby regions.

Have we ever thought why the outer environment has impact on us, affects us in almost every dimension? It is because whatever there is outside shows not only its presence outside, but it also resides in each of us subtly. And this subtleness is realized by the one who are very much awaked in a way which is highly aligned with the consciousness of the 'Self' and the nature. The very pedestal of the philosophical talks/ideas are realized to be strongly worth only when there exists a scientific way of knowing the happenings or the process behind the talk. Now let us acquaint yourselves well with the science behind the aforementioned topic, which is "PHYSICS BEHIND THE CLIMATE CHANGE".

To start with it let us first clear our view about the term 'Climate'. What is climate? The answer to it can be phrased as "the long-term pattern of weather in a particular region" is known as the climate for that area. So how do we exactly perceive 'long-term' here? The weather patterns are observed rigorously for about 30 long years. And what are these patterns, so called weather patterns? The degree to which the atmosphere is cold or hot, rainy or dry, stormy or calm, clear or cloudy observed as same for days or weeks, at a time in a year forms the weather pattern of that region. Here we encountered another term – atmosphere. So, what is an atmosphere? An atmosphere may be defined as the envelope of various gases stacked above each other forming layers positioned at different heights due to gravitational pull above the surface of earth. For a planet to have an atmosphere the gravitational pull of it must be high and the temperature must be low so as to avoid the escape of gases into the outer space due to increased thermal activity. If the temperature is low enough the movement of gas particles will almost cease to rest ensuring the thickness of various layers is maintained. The atmosphere of earth is majorly composed of nitrogen (~78%), oxygen (~21%), argon (~0.9%), carbon dioxide (~0.04%) and trace gases. These trace gases include ozone, methane, water vapors, various oxides of nitrogen, helium, neon, etc.



As we have discussed earlier that earth's atmosphere is layered, and each layer of the atmosphere has its specific traits. The atmosphere of earth is mainly divided into four layers: Troposphere, Stratosphere, Mesosphere and Thermosphere. All these layers are separated on the basis i.e., variation of temperature gradient in the respective layers. Every layer plays an important role in preserving the atmosphere in a most unique way to sustain the supportive environment on earth. The various layers of atmosphere are shown below.



As our primary concern here is climate and the climate that we have on our planet earth is due to the disturbances in the lower most layer of the atmosphere which is troposphere. We are now very much curious to know about the happenings in the troposphere resulting in the formation of different weather patterns over any region. This troposphere contains almost three-quarter percent of the total mass of the atmosphere which means that this layer envelopes with majority of the constituent particles which make up the atmosphere. But how can we say that having a greater number of particles/gases can be cause of climate at different places? The solar radiation (sunlight) coming from the outer space through different layers of the atmosphere, when interacts with the troposphere; is mainly scattered in the sky resulting in the blue sky and reddish sky (during sunset and sunrise). During the first interaction almost, no heat is absorbed by the troposphere. These incoming radiations when reach down to the surface, heats the surface resulting in the emission of infrared radiations (as thermal radiation). These infrared radiations or the photons of infrared radiation are then absorbed by the carbon dioxide molecules. The infrared spectroscopic studies on CO_2 molecules have shown that these molecules are the rich absorbers of infrared light. So the thermally radiated photons gets soaked up by CO_2 ultimately resulting in the rise of temperature in the environment. This rise in temperature creates a low-pressure zone. As we are very much aware of the fact that everything in this universe tries to attain a stable state. So, the winds from the high-pressure zone rushes towards the zone having relatively low pressure. These winds are capable of bringing clouds to the low-pressure zones. Therefore, we see monsoon arriving after the scorching summer.

There is one more factor which effects the climate of any region is the latitude of that region. But what is latitude? It may be defined as the angle made with the equatorial plane by the line joining the centre of the earth and the point on the geographic plane. So how does it contribute to climate change? It is as the different latitudes receive different amounts of solar radiation. The regions lying on the equator receives much the sunlight. Days at such places are equally long all around the year and the sun is directly overhead

at midday. The Polar Regions receive the least solar radiation. Nights here lasts for about six months in winters. The Sun never rises very high in the sky. This happens because the sunlight gets filtered through the thick wedge of atmosphere, making up the sunlight feel less intense.

Our country India has mountains to its north having average height of 6000 meters. The Himalayas acts a barrier wall preventing cold winds from central part of our continent entering Indian subcontinents. If the Himalayan Mountains were not present, then the winters might have been much cooler than it used to be now. The weather conditions in our country making up the climate depends on surface winds, pressure, jet streams, tropical cyclones and western cyclonic disturbances. The winds originating from the subtropical high-pressure belt of the northern hemisphere blow to the south but are deflected towards east (towards the equatorial low-pressure area). The question here arises that why there is such deflection? What is causing this deflection? This deflection is due to the rotation of the earth about its axis. As the direction of rotation of our planet earth is from west to east. Due to this rotation a particle in the northern hemisphere experiences a fictious force which tends to move it towards right. This force is known as Coriolis force. In winters cold winds blows from high-pressure zone of northern Himalayas to low- pressure oceanic areas of the southern India. During summers, a low-pressure zone is developed over north-western India which causes a complete reversal of the direction of wind. Air from high-pressure area brings the moisture from southern Indian Ocean to the low-pressure areas of the Indian subcontinents. These are known as southwest monsoon winds.

I live at Medininagar (Daltonganj) city which comes under palamu district in Jharkhand. It is situated at the elevation of about 215 metres from the sea level. My city has humid subtropical type climate.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °C (°F)	34.2 (93.6)	40.6 (105.1)	43.9 (111.0)	46.5 (115.7)	47.8 (118.0)	46.9 (116.4)	43.8 (110.8)	40.2 (104.4)	39.7 (103.5)	40.0 (104.0)	36.5 (97.7)	33.2 (91.8)	47.8 (118.0)
Average high °C (°F)	25.2 (77.4)	28.4 (83.1)	33.9 (93.0)	39.3 (102.7)	40.8 (105.4)	37.8 (100.0)	32.8 (91.0)	32.0 (89.6)	32.3 (90.1)	31.9 (89.4)	29.5 (85.1)	26.3 (79.3)	32.5 (90.5)
Average low °C (°F)	9.1 (48.4)	11.9 (53.4)	16.5 (61.7)	22.0 (71.6)	26.2 (79.2)	27.4 (81.3)	25.9 (78.6)	25.5 (77.9)	24.5 (76.1)	20.4 (68.7)	14.3 (57.7)	9.7 (49.5)	19.5 (67.1)
Record low °C (°F)	0.0 (32.0)	0.6 (33.1)	5.6 (42.1)	11.2 (52.2)	17.8 (64.0)	18.6 (65.5)	18.2 (64.8)	20.6 (69.1)	17.2 (63.0)	10.0 (50.0)	5.0 (41.0)	1.7 (35.1)	0.0 (32.0)
Average rainfall mm (inches)	11.9 (0.47)	19.6 (0.77)	15.6 (0.61)	9.4 (0.37)	24.8 (0.98)	151.6 (5.97)	285.2 (11.23)	288.6 (11.36)	179.0 (7.05)	49.5 (1.95)	8.4 (0.33)	6.3 (0.25)	1,049.8 (41.33)
Average rainy days	1.1	1.6	1.8	0.9	1.9	7.0	14.9	13.5	9.4	2.9	0.6	0.7	56.2
Average relative humidity (%) (at 17:30 IST)	50	41	32	24	30	52	77	79	76	62	57	57	53

[Source: India Meteorological Department]

Daltonganj has been ranked among the cities having highest temperatures in summers. In summers temperature here can go up to 49 degrees Celsius and in winters it can go as low as 5 degrees Celsius. It is situated on the bank of river Koel. This river is a type of seasonal river. The hydro-meteorological studies show that the city falls under unassured rainfall zone and hence receives monsoon rain during June to September. The average annual rainfall of the city is less than 1200 millimeters as it comes under rain shadow area. More than 80% of the precipitation is received during the monsoon months. Talking about the annual rainfall of Palamu district it is 1163.4 millimeters of which 85% is received between June and October. The city is characterized by warm climate (as stated above) in March to June and later there is gradual decrease in the temperature from October onwards to December. Here January is the coldest month

of the year. The city experiences dust storms between March and June associated with low humidity, high temperature, and fast blowing winds. During Winter season the city records temperature between 6 to 18 centigrade whereas in summers the temperature increases beyond 47 degrees centigrade.

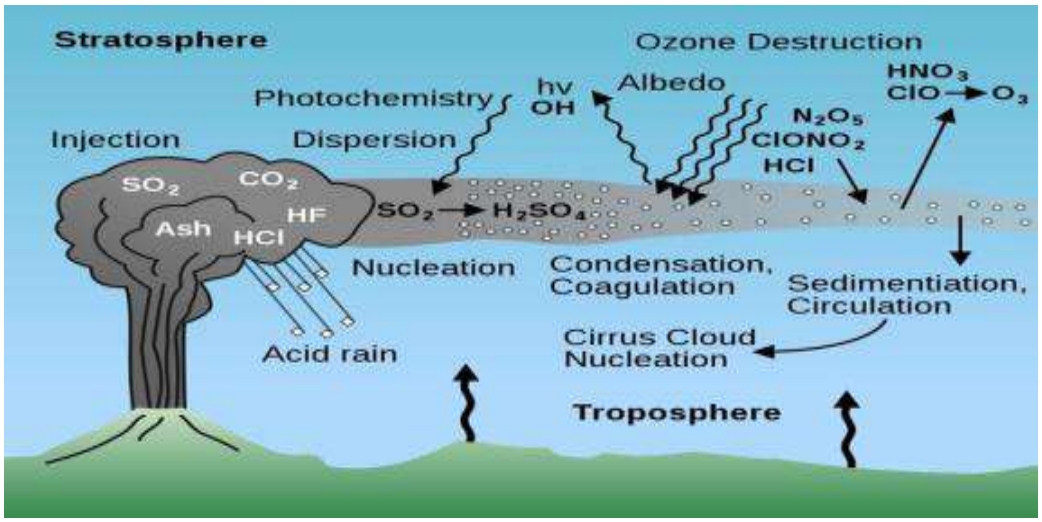
The topography of Palamu district is characterized by highly rugged landscape with green forest all over the area. The elevation of the hill ranges in southern part of the district varies from 360- 1110 meters above minimum sea level. The master slope of the area in general tends towards north and east. In terms of the physiography the district shows the following four broad categories of landforms - East-West trending hill ranges, consisting of crystalline and metamorphic rocks in the southern part, Flat topped hills in the south-eastern, the sub-plateau area lying south of the plains are separated by narrow valleys in parts of Bishrampur block, Narrow valleys along the course of the major rivers.

Three soil orders namely Entisols, Inceptisols and Alfisols were observed in Palamu district. Alfisols were the dominant soils covering 53.9 percent of total gross area followed by Entisols (21.5 %) and Inceptisols (20.0 %). Alfisols amongst which Red sandy soils are common and Ultisols of which red and yellow soils are common.

Natural Causes of Climate change

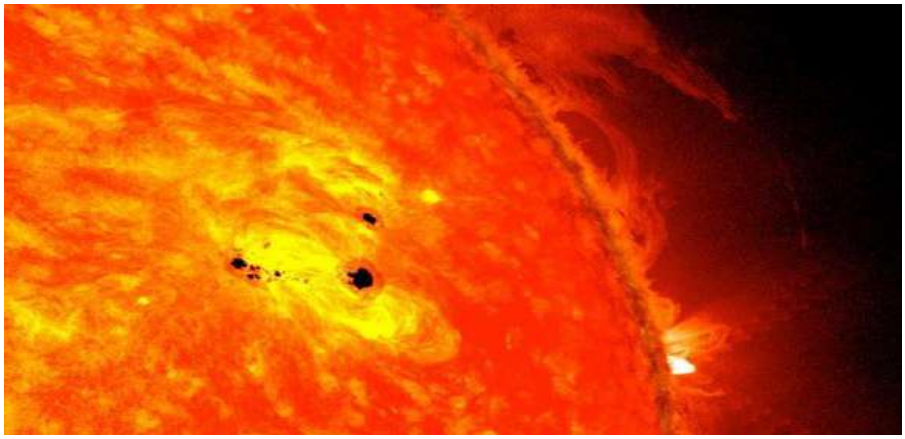
Out of other naturally occurring causes the two - volcanic eruptions and variation in Solar radiation is better observed in one's lifetime.

Volcanic eruptions: The earth's crust has got many things in molten form called the lava. Volcano is like a vent for the lava to escape to the environment from the crust. When there happens to occur disturbance in the tectonic plates, the lava from the volcano escapes, or we better say it as there is eruption in volcano. Whenever the volcano erupts not only there comes out the lava but also aerosols, carbon dioxide and Sulphur dioxide gases are discharged. These aerosols are capable of reflecting back the incoming solar radiation in the outer space causing slight lowering in the temperature of that region. But the discharged Sulphur dioxide combines with the water vapors in the atmosphere resulting in the formation of Sulphuric acid ultimately causing acid rains and much adverse effect on our environment.



Variation in solar radiation: Solar radiation is the radiation of electromagnetic wave emitted out by the sun in the space. These radiations are very much important to support life on earth. The variation in the solar radiation depends on the number of sunspots on the sun's surface.

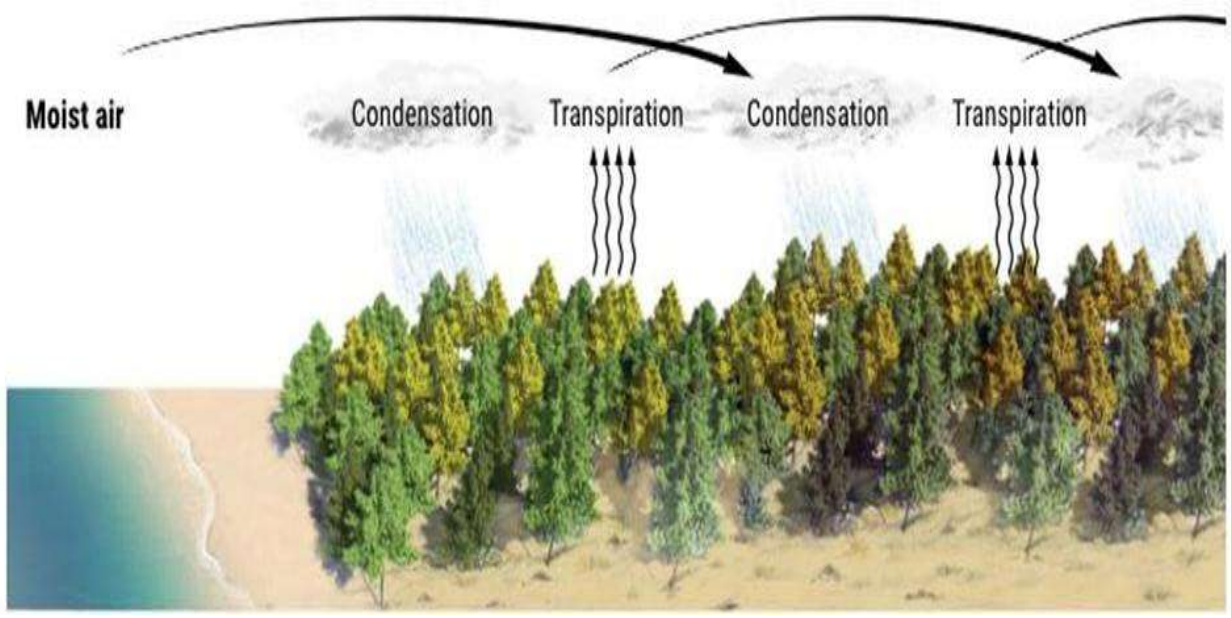
What are these sunspots? Sunspots are the dark patch formed on the surface of sun when intense magnetic fields restrict the flow of heat from the interior of sun to its surface. These spots appear dark because it has got relatively less temperature than those nearby. In almost every 11 years, the number of sunspots changes from maximum to minimum. As these sunspots appears to suppress heat inside the sun's surface resulting in the bright glow of the surrounding area. This means that when there are a greater number of sunspots more-and-more heat will be radiated by the sun. This would cause a warmer global climate. Whereas a smaller number of sunspots is associated with relatively cooler global climate.



Man-made causes of Climate change: There are many such man-aided activities which are causing the change in the climate. The two of the main activities are "Greenhouse Gas Emission" and "Deforestation". Let us discuss them briefly.

Greenhouse gas emission: These are gases which are rich absorber and emitter of thermal infrared radiation, causing greenhouse effect. The main constituents of greenhouse gases are water vapor, carbon dioxide, methane, nitrous oxide, and ozone. Water vapors accounts for the largest percentage of the greenhouse effect by amplifying the effects of other greenhouse gases. According to Clausius-Clapeyron equation we get to know that at higher temperatures more number of water vapors will be present. Another major contributor is carbon dioxide. Despite accounting for only about 0.04% of the atmosphere it is known as the major additive to greenhouse effect because it has long lifetime in atmosphere and rich absorber of infrared radiation. When hydrocarbon is burnt carbon dioxide along with water vapors are released in the atmosphere. The bond arrangement of carbon dioxide molecule is such that it vibrates in all three directions to emit or absorb infrared radiation. This is how the thermal radiations from the earth's surface is absorbed by CO_2 molecule and it is emitted in all directions. It is due the increased concentration of carbon dioxide which prevents the infrared radiation escaping to outer space. The next one is methane which is almost 3-4 times stronger than carbon dioxide. Methane oxidizes itself to form more CO_2 molecules with the formation of H_2 gas. Another gas is nitrous oxide which has about 265 times more ability of absorbing heat than carbon dioxide. These are released into the atmosphere mainly by the agricultural practices. It is involved in the thinning of ozone layer. All these gases are producing greenhouse effect ultimately causing global warming.

Deforestation: Another major cause of climate change is cutting down of trees at very large scale, clearing-up the forest areas termed as deforestation. These tress and forest regulate the rainfall of a place. Rainfall follows forest. The trees maintain the oxygen levels in the environment and are an important part of carbon cycle. The roots of the trees hold the soil tightly so as to prevent soil erosion. According to the theory of biotic pump which predicts the importance of forests in the water cycle. They are useful in determining the level of rainfall a region will receive.



Effect of climate change on economy

Climate conditions affect the economy of a country or region to a great extent. According to the Swiss Re Institute, largest impact of climate change is that it could clear off about 18% of the GDP from the world economy by 2050 if global temperatures rise by 3.2 degree centigrade. With the adverse climatic conditions, the agriculture, tourism, health and productivity, etc., will be affected badly. The very backbone of economy of any country must be strong so as to stand tall. This can only be possible when we put some effort to keep our atmosphere/environment clean and healthy.

The Nature is called the Mother Nature. Why is so? It is because anything that nurtures without any bias has a grace of mother despite any gender. The Mother Earth is mother of all that we have today. There is no substitute for healthy environment, tress, forests, air, water, etc. These are just irreplaceable and the most benevolent to us – the reckless inhabitants. Just like 'light', there is no substitute for it. Only the light can dispel the darkness which glorifies the light in its absence. We must put our conscious efforts to protect our environment because we are from 'environment'. Afforestation must be done at very large scale. We must look for nature friendly useable and must adapt nature friendly habits. The matter particles which have made up this giant planet is also constituted in us. So, there is an inevitable dependence of us on our environment making up a supportive climate.

TEACHERS' ESSAYS CATEGORY (B)

YEAR 2022

PHYSICS BEHIND THE CLIMATE CHANGE

Starting on the next pages…

PHYSICS BEHIND THE CLIMATE CHANGE

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Keywords: Albedo, Emissivity, Stefan-Boltzmann Law, Clausius-Clapeyron eq., Band-saturation

Abstract
Carnot regarded the Earth as a heat engine, in which fluid acting as working substance transports heat from hot to cold places, thereby producing the kinetic energy of the fluid itself. To a climatologist, climate is the work done by this stupendous solar powered heat Engine. Differential heating of equator and poles drives the atmospheric and oceanic circulation. This corroborates Carnot's observation about Earth. All heat engines have a certain limit for the conversion rate of the heat energy into the kinetic energy and this limit is inevitable for any natural system including the Earth's atmosphere. Radiative forcing is the change in energy flux in the atmosphere caused by natural or anthropogenic factors. Global warming is the result of Positive Radiative forcing when earth receives more energy than it gives back to space and Global cooling results from Negative Radiative forcing when the outgoing energy is greater. A net zero radioactive forcing ensures stable planetary equilibrium temperature. A forcing generally triggers feedbacks that intensify or weaken the original forcing. Earth's climate is warming up to catastrophic levels. Attributing global warming to human behavior by Svante Arrhenius (1896) was a wake-up call that got ignored. No wonder, Swedish Activist Greta Thunberg rightly says "It's not the world that's on fire. It's my house."

Natural causes of Climate Change

Milankovitch orbital cycles: Long-term collective effects of changes in Earth's position relative to the sun drive earth's long-term climate and are responsible for triggering the beginning and end of glaciation periods i.e., ice ages. The cyclical orbital movements, called the Milankovitch's cycles cause variations up to 25% in the amount of incoming insolation at Earth's mid-latitudes. Current trend in the Milankovitch cycle is towards a gradual global cooling. The Milankovitch's cycles include:

Eccentricity: Eccentricity measures deviations in the Earth's elliptical (elongated) orbit from a symmetrical, circular orbit. If eccentricity is zero, an orbit is circular. As an orbit becomes more elliptical, its eccentricity gets closer to one. When Earth's orbit is at its most elliptic, about 23 percent more incoming solar radiation reaches Earth at the perihelion than it reaches the aphelion. Currently, Earth's eccentricity is near its least elliptic (most circular) and is very slowly decreasing in a cycle that spans about 100000 years.

Obliquity: If the angle of the Earth's axis, called its obliquity equals to zero (no tilt at all), the Earth would have no seasons because no variation in temperature would occur. The tilt varies from 22 to 24.5 degrees, with respect to Earth's orbital plane. The greater Earth's axial tilt angle, the more extreme our seasons are, as each hemisphere receives more solar radiation during its summer, when the hemisphere is tilted toward the Sun, and less during winter, when it is tilted away. Larger tilt angles favour periods of deglaciation (the melting and retreat of glaciers and ice sheets). As obliquity decreases, it gradually helps

make our seasons milder, resulting in increasingly warmer winters, and cooler summers that gradually, over time, allow snow and ice at high latitudes to build up into large ice sheets. As ice cover increases, it reflects more of the Sun's energy back into space, promoting even further cooling. Earth's axis is currently tilted 23.4 degrees, and this angle is very slowly decreasing in a cycle that spans about 41000 years. It was last at its maximum tilt about 10,700 years ago and will reach its minimum tilt about 9,800 years from now.

Precession: Precession describes the slight wobble in the Earth's axis caused by the moon and other planets in the solar system. The trend in the direction of this wobble relative to the fixed positions of stars is known as axial precession. Lasting 26,000 years, it changes the timing of perihelion and aphelion. Axial precession makes seasonal contrasts more extreme in one hemisphere and less extreme in the other. Currently perihelion occurs during winter in the Northern Hemisphere and in summer in the Southern Hemisphere. This makes Southern Hemisphere summers hotter and moderates Northern Hemisphere seasonal variations. But in about 13,000 years, axial precession will cause these conditions to flip, with the Northern Hemisphere seeing more extremes in solar radiation and the Southern Hemisphere experiencing more moderate seasonal variations. Not only does the Earth's axis wobble, but Earth's entire orbital ellipse also wobbles irregularly, due to its interactions with massive gravitational effects of Jupiter and Saturn. The cycle of this apsidal precession spans about 112,000 years. The combined effects of axial and apsidal precession result in an overall precession cycle spanning about 23,000 years on average.

Geophysical Fluid Dynamics: Oceans are called the flywheel of climate. Driven by temperature, wind and salinity, Thermohaline Circulation (THC), transports tropical heat to the poles and sends colder water back, southwards in deep ocean currents. In the Atlantic, it is called Atlantic meridional overturning circulation (AMOC). The warm and swift, wind driven Gulf stream in the Atlantic moving poleward gets cooled, gains more salt content due to evaporation enroute. Near the poles, ice bergs are formed, salt is released and cold dense saline water, sinks down (down-welling) to the level of slow-moving deep ocean currents, that travels southwards. THC is thus, the giant conveyor belt of the oceans redistributing heat across the globe. Near the equator eddies and gyres stir up contents from the deep by convective heat transfer (upwelling), while atmospheric winds and Ocean currents steer moisture and heat around the globe by advection. THC also facilitates storing CO_2 in oceans as Carbonates (Ocean Solubility pump) Too much of atmospheric CO_2 causes ocean acidification, in accordance with Le-Chatelier Principle and this harms the marine ecosystems, as they are unable to make shells and sequester carbon naturally.

Another conveyer belt, the Global atmospheric circulation, ensures that the three distinct cells Polar, Hadley and Ferrel circulate the air through the entire depth of the troposphere in each hemisphere. The prevailing wind in each cell, caused by Earth's spin is affected by Coriolis effect, the pseudo force that deflects the movement of wind and particles due to spinning of the earth. Air moves anti clockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere

ENSO (El Nino and La Nina): The periodic reversal of pressures in tropical south Pacific Ocean and tropical Indian Ocean leads to Southern Oscillation. The creation of high-pressure conditions in Indian Ocean usher drought. El Niño and La Niña are opposite phases of El Niño-Southern Oscillation (ENSO), out of which El Nino is more common.

While the warm phase, El Nino is detrimental to Indian Monsoons, the cold phase La Nina is beneficial. These recurring climate patterns alter tropical rainfall, wind patterns and surface temperatures leading to

drought, floods and forest fires at various places and also change the vertical as well as thermal structure of oceans. The positive and negative phases of yet another oscillation i.e. Pacific Decadal Oscillation (PDO) strengthen and weaken the Indian summer monsoons respectively. The warm and cold phases of Atlantic Multi decadal Oscillation (AMO) do the same.

Types of clouds: Clouds absorb and emit like black bodies through-out the thermal IR. Higher the cloud, lower the temperature from which emission takes place and lower is the energy emitted. Thin, wispy cirrus clouds near the stratosphere have the strongest warming effect and low -lying stratus clouds have a weaker warming effect. Optically thick clouds, carrying icy particles cause Tyndall effect and increase the Earth's albedo and have a negative feedback effect on planetary warming.

Tectonic Shift: Movement of tectonic plates over geological timescales, carry landmasses to different positions and latitudes. This affects global circulation patterns of air and ocean currents. The southern Hemisphere, having less percentage of Earth's landmass, is cooler than the Northern Hemisphere due to the high heat capacity of the oceans.

Omega Block patterns: They are areas of high pressure that remain nearly stationary and therefore block the movement of other weather systems. Blocking patterns can stay in place for up to a week, leading to countries beneath them experiencing prolonged periods of hot weather, such as heat waves.

Volcanic degassing: Volcanic CO_2 can cause warming (+ feedback) but SO_2 can cause cooling (- feedback).

Solar Activity: Solar energetic particles and cosmic rays could reduce ozone levels in stratosphere, altering the behavior of atmosphere below it and pushing solar storms. Peaks in sunspot cycles have been linked with increased precipitation and above normal sea level pressures also. Yet, the effect is far from being enormous. Quoting Solar physicist Greg Kopp," Sun could be an 800-pound gorilla in climate but thankfully it is pretty placidly lazy."

Chemical weathering: It is caused in rocks by Carbonic acid ($CO_2 + H_2O$) in the atmosphere weakens Green-house effect and acts as a negative-feedback. The calcareous shells of eukaryotic phytoplankton Coccolithophores in oceans increases the sinking velocity of photo synthetically fixed CO_2 by ballasting organic matter thus managing marine carbon cycle. This bio-sequestration of carbon is also a negative-feedback.

<u>Man-made causes of climate change</u>

"We are running the most dangerous experiment in history right now, which is to see how much carbon dioxide the atmosphere can handle before there is an environmental catastrophe" -Elon Musk, CEO Tesla & Space X Over. Population and Consumerism are the basic causes which give birth to all others factors of environmental collapse. The Kaya Identity, developed by Yoichi Kaya quantifies the CO_2 emission due to anthropogenic causes and expresses it as a product of Human population, GDP per capita, energy intensity (per unit of GDP) and carbon intensity (emissions per unit of energy consumed). In order to keep the global temperature rise limited to 1.5^oC, net emissions in 2030 need to reduce by 45% from 2020 levels and in 2050, they need to be down to zero. Anthropogenic factors are listed below:

1. Deforestation: Cooling effect caused by evapotranspiration disappears, when trees are cut down.

2. Burning of fossil fuels and industrialization causing pollution: This positive forcing has multiple feedbacks that enhance its deleterious effects. GHGs, Refrigerants and CFCs (Freon) slow down the rate of heat loss from the Earth's surface just like a blanket that slows down the rate at which our body loses heat. The earth gets warmer, same way as our body does.

3. Animal farming: Methane burps by cattle accelerate global warming, although to a small extent.

4. Methane release: This from Permafrost could lead to intense heat waves and faster de glaciation. The enhanced rate of iceberg calving and melting of sub ice methane clathrate can reinforce the vicious-irreversible cycle of global warming.

5. Plastic pollution: GHGs released during manufacture of plastics creates a positive-feedback.

6. Black carbon: The soot released from incomplete fuel combustion absorb and scatter incoming solar radiation. It reduces the albedo as it lands on snow clad areas and produces positive radiative forcing. Sulphur dioxide released from burning fossil fuels get oxidized in the atmosphere to sulphur trioxide and ultimately form hygroscopic sulphuric acid molecules and salts that act as nucleation sites for tiny water droplets. The aerosol-sulphate particle rich clouds, thus formed have a greater reflectivity, so increase albedo and produce negative radiative forcing.

7. Change in land use pattern: Urban centers formed due to human settlements, resource extraction, agriculture, road and building-construction change the reflectivity of earth and aggravate the effect of heat waves and dust storms. These centers act as Heat islands and contribute to climate emergency.

8. Breaking up of polar vortex out of the Arctic: It is a feedback which results from the warming up of the Arctic region. The polar jet stream meanders north and south making the polar vortex wobble and visit the mid-latitudes.

The parity between natural emissions of carbon-dioxide from oceans and vegetation and natural absorptions is healthy for the planet but the anthropogenic release of excessive GHGs makes the earth's energy budget go haywire. The rise in temperature following a doubling of CO_2 conc. is called Climate sensitivity abbreviated as ΔT_2x. Most of the climate models predict the value of climate sensitivity to be between 2 to 5^oC. The delay before global surface temperature changes significantly, is due to the thermal inertia of the oceans, land and cryosphere as water has a high heat capacity. ΔT_2x can be used to calculate the temperature change ΔT after a few centuries.

$\Delta T = \Delta T_{2x} \times \ln(\text{new } pCO_2 / \text{original } pCO_2) / \ln(2)$ where ln is the natural log. The Intergovernmental Panel on Climate Change (IPCC), aided by historical and Paleoclimate records, Climate models calculate ΔT_{2x} to be 1.76^oC. The atmospheric concentration of carbon dioxide has already increased from 280 ppm to 420 ppm and Average global temperatures have increased about 1.1^0C since the industrial revolution. The tipping point has been breached. Expecting a rise of 1.76^oC at 560 ppm appears inevitable. (Figure 4: Keeling Curve). The jagged red line in the Keeling curve shows the natural oscillations caused by plant growth cycles in autumn and spring while the black line shows the anthropogenic increase in CO_2 levels. The energy intensity goes up proportionally to the log of CO_2 concentration rather than proportionally to the CO_2 concentration. The logarithmic dependence means the radiative effect of increasing partial pressure of CO_2 from 10 to 20 ppm is about the same as going from

100 to 200 ppm or 1000 to 2000 ppm. Guy Calendar (1939) estimated that doubling the amount of CO_2 in the atmosphere could raise the global mean surface temperatures by 2^oC.

The Physics of Climate change

The inverse Square Law implies that solar irradiance is inversely proportional to the square of the distance away from the Sun. This accounts for the natural causes of Climate. The earth manages to handle this pretty well with various counterpoises. The anthropogenic causes are the ones that throw a spanner in management of Earth's energy budget. A planet is said to be in radiative Equilibrium when the incoming solar radiation is balanced by an equal flow of heat to space. Anything that increases or decreases the amount of incoming or outgoing energy disturbs the radiative equilibrium and global temperature rises or falls in response. This Radiative forcing varies with solar insolation, surface albedo and the atmospheric concentrations of aerosols and green House gases. The Incoming solar radiations from the Sun absorbed by the Earth's surface are in UV / visible region and are emitted as long wavelength thermal IR, in accordance with Wein's Displacement Law since earth is at a much lower temperature. Sun's peak emission is at 0.5 microns compared to earth whose λ_{max} lies in far IR region of electromagnetic spectrum (Figure 2 below) Earth's average albedo 'α' is 0.3 i.e., almost 30% of the incident solar energy is reflected back into space by Clouds and aerosols in Earth's atmosphere. Taking Solar Irradiance (Solar constant) 'S' to be 1365 watts m^{-2} , and area ofcircular disc of earth receiving the solar energy as πR^2,

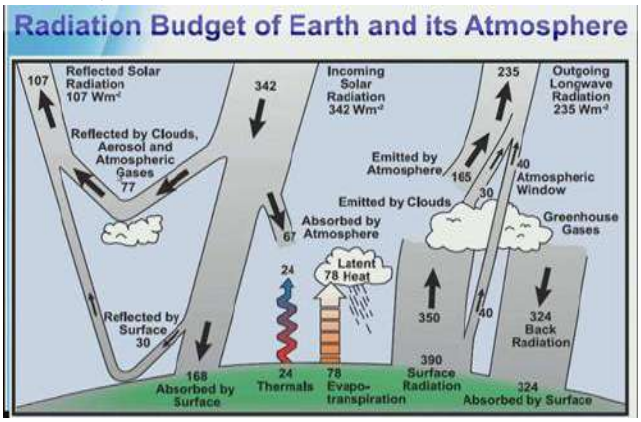


Figure 1: Earth's Energy Budget

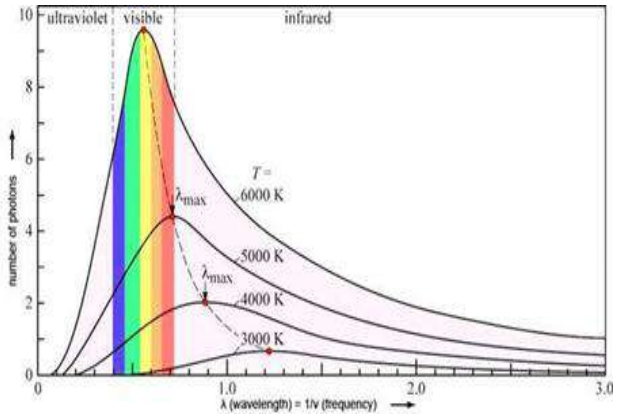


Figure 2: Peak emission of Sun

Solar energy incident on Earth = $\pi R^2 S$ (R = Radius of the Earth).
Solar energy absorbed by Earth (Input intensity) = $\pi R^2 S (1-\alpha) \rightarrow ①$
Energy emitted by Earth = $4 \pi R^2 F$ where F is the flux of long range IR emitted by Earth having surface area $4 \pi R^2$.

Stefan Boltzmann Law gives us $F = \rho \varepsilon T_e^4$ where ρ is Stefan Boltzmann Constant equal to 5.67×10^{-8} watts $m^{-2} K^{-4}$ and T_e is the Effective temperature of the earth's Surface.

Out-put intensity = $4 \pi R^2 \rho \varepsilon T_e^4 \rightarrow ②$
According to Planck's law of Thermal radiation, Radiative equilibrium requires Input intensity = output intensity $\pi R^2 S (1-\alpha) = 4 \pi R^2 \rho \varepsilon T_e^4$

Simplifying this equation, $S(1-\alpha)/4 = \rho \varepsilon T_e^4 \rightarrow ③$

CASE 1- Bare Rock Model: Assume earth to be a black body with emissivity 'Ɛ' equal to 1 and having no atmosphere. Simplifying and plugging the values in equation ③, gives T_e = 255 K, called the Black body temperature of earth (-18^{o}C = 0^{o}F). This temperature is quite low to support the diverse life forms as earth will turn into a frozen ball of ice. Earth would then follow the Kirchoff's law of thermal radiation and would maintain its temperature constant.

CASE 2 - Layer Model: However, earth has an atmosphere and it is not actually a perfect black body The Earth along with its atmosphere is a grey body due to the presence of Green House gases. Some of the outgoing radiation does get absorbed by the grey atmosphere and reemitted. Some of the radiation flux passes through the grey atmosphere into the outer space as well. The Greenhouse molecules like CO_2, N_2O, CH_4 and water vapors vibrate at various frequencies, that match (are in phase) with those of photons of IR range. The asymmetric bending (more significant) and stretching vibrational motion of atoms in CO_2 and CH_4 generate dipole moment, where-as N_2O and water vapors are permanent dipoles. The GHG molecules absorb the Long-range IR radiations and emit them in all directions. The homo nuclear diatomic molecules in atmosphere like N_2 (78%) and O_2 (21%) do not absorb IR as their vibrational mode does not generate a dipole moment due to non-polarity i.e., no imbalance in electric field is created when their bonds vibrate. The presence of GHGs in the atmosphere drops the emissivity to 0.6 approx. Plugging the values of emissivity (0.6), S, α and ρ in equation ③, the observed Surface temperature of the earth 'Ts' comes out to be 287 K (14^{o}C or 59^{o}F) Infra-red energy is lost to space only if the emitting GHG is high enough in the atmosphere, otherwise the energy will keep bouncing about between the GHG molecules in the lower atmosphere. At a height of about 5.4 Km, the concentration of GHGs is low enough, and any upward release of IR energy is lost directly to space. This height, called the emission height corresponds to the pre-industrial revolution period. At this height, temperature is 255 K, the lapse rate being $\Delta 6^o$ per Km. Thanks to the Natural green House Effect in action, in favour of survival and sustenance of life. French Mathematician Joseph Fourier (1827) was the first person to suggest that atmosphere acts like an insulator, keeping us warm. (Figure 1 above)

CASE 3: It has almost been 150 years now, since the industrial revolution took place. The release of GHGs in the atmosphere, by fossil fuel combustion and resource extraction have pushed the emission height to 5.5 km above the Earth's surface. The IR energy is now lost to space at this greater height. Temperature decreases due to adiabatic cooling as atmospheric height increases. That makes temperature at which IR is lost lower than 255 K, due to lapse rate. Increased emission height means less IR energy will be lost to space due to lower temperature at that height. (Figure 3 below) This is in accordance with Stefan Boltzmann Law (The amount of heat radiated by a surface is proportional to the fourth power of its absolute temperature.). The IR loss is less due to GHGs but the incoming solar energy remains same. Earth loses its radiative equilibrium since Energy gained > Energy lost. Hence the positive Radiative Forcing leading to global warming. (Figure 5)

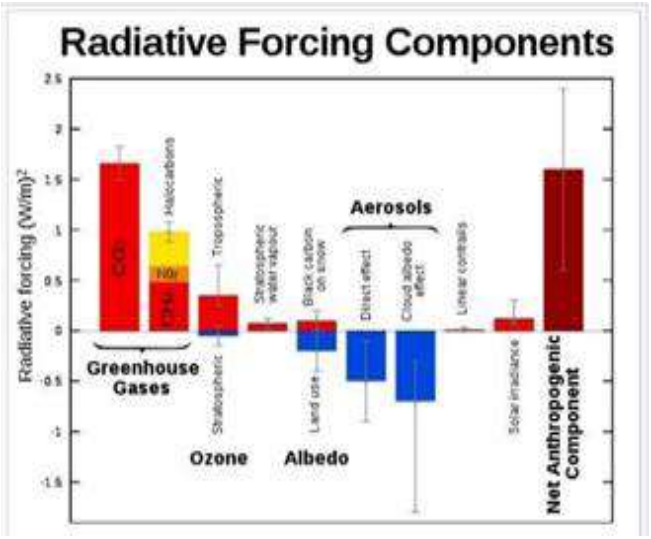


Figure 3 - Emission Height

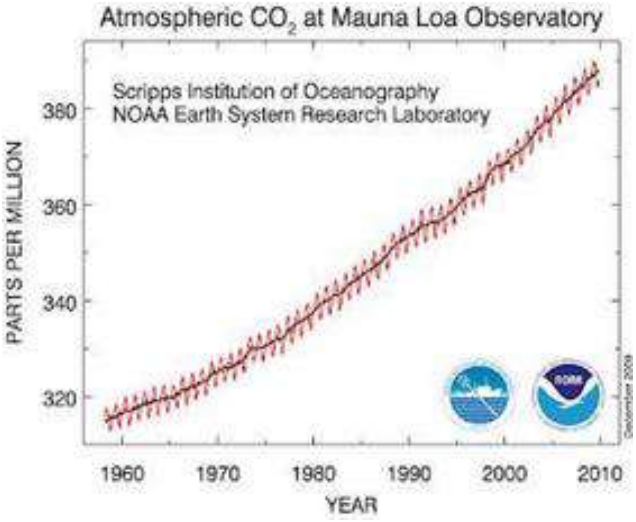


Figure 4 - Keeling Curve

If temperature of earth doubles, radiated energy increases by a factor of 16 (2 to the 4th power). Higher temperature will make the planet rapidly emit an increasing amount of heat to space. Even small changes in temperature will make large difference in the energy radiated.

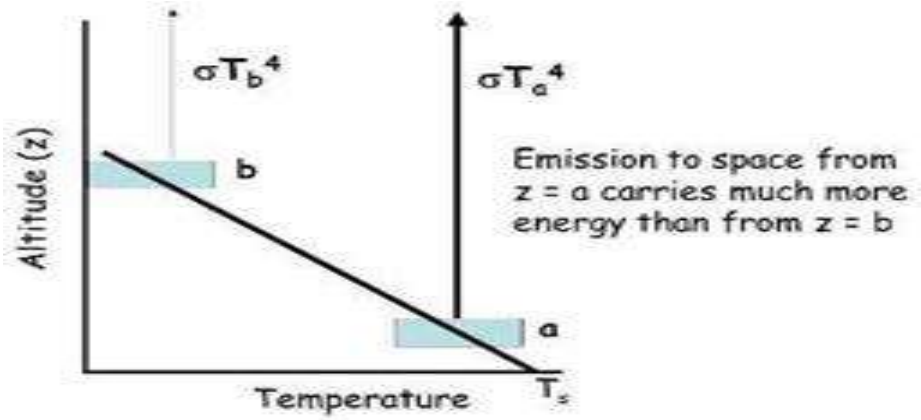
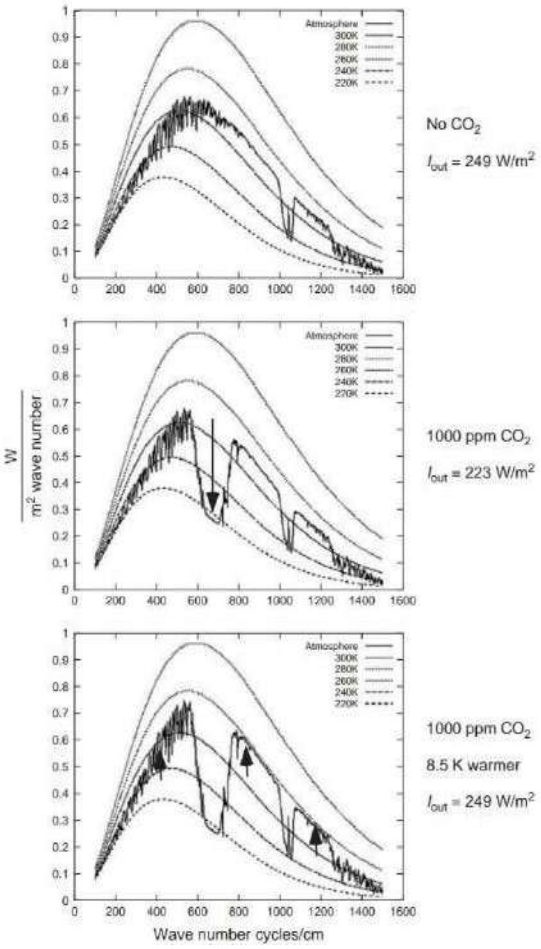


Figure 5 – Radiative Forcings (- and +)

If we are able to stabilize the concentration of GHGs, the Earth's atmosphere will again achieve equilibrium, but the thermostat- global average surface temperature will be set at a higher temperature than it was before the industrial revolution. This large increase in heat loss in response to a relatively smaller increase in temperature—referred to as radiative cooling—is the primary mechanism that prevents runaway global warming on Earth, the unfortunate fate suffered by Venus, the hottest planet of the solar system Global warming potential (GWP) is a dimensionless number to compare the global warming impact of GHGs. It measures how much energy one ton of a GHG will absorb over a period (generally 100 years) relative to the emissions of 1 ton of CO_2. GWP value for CO_2 is 1 and all values are calibrated according to it.

Parameter ↓ GHG →	CO_2	CH_4	N_2O	NF_3	SF_6
Change in concentration in ppmv (1748-2018)	120	1.08	0.05	1×10^{-6}	5.6×10^{-6}
Radiative efficiency in Wm^{-2} $ppbv^{-1}$	1.37×10^{-5}	3.63×10^{-4}	3.0×10^{-3}	0.20	0.57
Lifetime in years	50-200	12	121	500	3200
Total Radiative forcing in Wm^{-2}	1.82	0.48	0.17	2×10^{-4}	4.1×10^{-3}
Global warming Potential	1	28	265	16100	23500



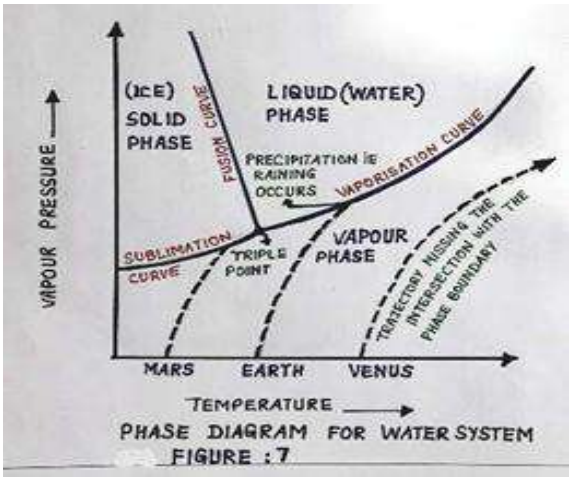
The area under the curve in the Earth-light spectrum (figure 6) is proportional to outgoing energy flux. The atmospheric window is 900 to 1000cm^{-1}, where no GHG absorbs or emits IR. CO_2 takes a bite out of the black body spectrum of the Earth's surface at 700 cm^{-1}, almost on top, thus decreasing the area and also the outgoing energy flux. To restore the outgoing energy flux, to its initial value, the remaining curve bulks up to compensate, thus increasing emission height, also called the skin altitude. Poor earth tries to achieve its radiative equilibrium and ends up getting heated up. With increase in conc. of CO_2 the absorption band spreads out, called the band saturation effect. Spreading or smearing out of Absorption band of CO_2 occurs due to pressure broadening (Gas at high pressure will absorb almost all frequencies like solids and liquids without being choosy) and Doppler shifting (Molecule moving away from IR radiated by earth absorbs slightly longer wavelength.) The off-peak location of absorption band of methane in the Earthlight spectrum coupled with its low concentration ensures that is does not undergo band saturation.

A GHG has a stronger effect on the radiative balance of the earth, if it interacts with IR in the middle of the earthlight spectrum like CO_2.

The second Law of Thermodynamics (Kelvin -Planck Statement) justifies the global warming as some amount of energy is always lost as heat when doing irreversible work. This lost heat leads to increase in the entropy of the system, and that's exactly what's happening to the atmosphere. Natural global warming is good but the enhanced Global warming caused by pollutants has increased the free energy available to drive weather so variance of climate has increased accordingly.

A warming climate alters precipitation pattern in accordance with the Clausius-Clapeyron Equation. Rise

of almost 1.5^{o}C temperature increases the atmospheric moisture content to 9%, leading to higher precipitation causing amplification of global hydrological cycle. An intensified water cycle would mean flooding, stronger hurricanes, heat waves, tornadoes. 'Wet places get wetter and dry get dryer. The fresh is getting fresher and the salty is getting saltier'- opine the climatologists. Figure 7, depicting phase diagram for water system explains the water vapour feedback.



The ubiquitous water vapours set the stage for so called the stratospheric water vapour feedback. Water vapour is a positive-feedback, not a forcing. It supercharges the warming caused by other GHGs. It is thankfully limited, on earth as the vapour pressure Vs. Temperature curve intersects with the phase boundary of liquid water, in the phase diagram by the stabilising effect of hydrological cycle (negative feedback) Increased evaporation causing increased ocean salinity can also make oceans take up greater heat to greater depths.

Surface warming can then decrease. The closer proximity of Venus to the Sun made all its water vaporize due to high temperature and its Vapour pressure vs Temperature curve missed intersecting the phase boundary for liquid water making a one-way street and hence the runaway green House effect.

Principles of Physics also explain the slowing down of AMOC. Melting Glaciers at the poles, due to global warming, adds up more fresh water to incoming saline water from the equator so sinking of dense water slows down at the poles. Slow movement of ocean conveyor belt could lead to harsh weather in Europe besides endangering species as upwelling at the equator and down welling at the poles depends on temperature and salinity. Recent studies have shown that AMOC is getting a jump start from the warming up of Indian Ocean. Low pressure above Indian Ocean makes moisture laden winds move towards it and cause precipitation. Decrease in salinity of Indian Ocean and Increase in the Salinity of Atlantic-ocean gives a jumpstart to AMOC.

Effect of climate change on economy

It is a negative global externality—one country's emissions affect all countries by adding to the stock of GHGs in the earth's atmosphere, putting countries with low income into greater peril. Climate volatility could deplete stocks of social, environmental, institutional and economic capital, thus mounting national and international tensions.

1. Damage to infrastructure: Warmer temperatures, sea level rise and extreme weather will damage property and critical infrastructure. Factory productivity will suffer as the environment in which technologies were designed to operate change and resources will get diverted away from R&D toward efforts to deal with climate impacts.

2. Dwindling water supply due to drought: This will limit power generation and adversely affect agriculture. Diminishing food supplies and water can stem ethnic strife, Arms Race, wars, ultimately disrupting world peace.

3. Tourism: Less snow and ice can jeopardize winter recreational facilities. Warm waters induce algal bloom, thus curtailing freshwater fishing. This also breaks down the symbiotic relationship between corals and zooxanthellae algae. The corals lose their color and die due to decalcification of their skeletons and compromised immune systems. Iconic reefs like Great Barrier reef have undergone bleaching to a great extent. Devastating wildfires will worsen air quality while deforestation, inundation and its destructive impacts on biodiversity could make some tourist destinations less attractive.

4. Business and the financial market: Extreme weather can disrupt transport and supply chain operations, thus setting up economic malaise. Uncertainties will multiply in production and insurance sector.

5. Fishery and Aquaculture output: El Niño alters oceanographic features like sea surface temperatures and unwilling events thus affecting fish distribution by way of composition and abundance of fishes. The Indian Ocean Dipole (IOD), i.e. Indian-Niño, is an irregular oscillation of sea surface temperatures in which the western Indian Ocean becomes alternately warmer (positive phase) and then colder (negative phase) than the eastern part of the ocean, hence the dipole. The positive phase of IOD, gives a boost to monsoon winds. Thus, a strong positive phase of IOD counters the negative effects of El Nino.

6. Heat waves: They make us less able to work and reduce productivity and cause loss of labour hours. Smog- Classical as well as photochemical cause serious health issues and impairs human efficiency.

7. Forestry: Climate change could aggravate the frequency of intense fires, trigger growth of pests and pathogens, cause species redistribution or even extinction. The livelihood of Indigenous communities is at stake.

Effect of climate change on social factors

1. Food security and water supply: Shifting weather patterns affects food availability and access by impacting crop yield, water holding capacity of soil, water availability, soil fertility, pH, crop pests and diseases. Water is intertwined with health, industry transportation, livelihood and ecosystems so all these tend to fall in the risk of getting adversely affected. Limited supply and increased competition for access to basic amenities is expected to create a wider social divide and abet civil conflict, rioting and social unrest.

2. Melting of glaciers, polar Ice caps and Ice shields: This would raise the level of seas by over 230 feet, swamping ports and sea coasts and submerging low lying land. With little ice cover to reflect back the solar radiance, the earth will heat up faster- feedback that intensifies the original forcing. Geological changes like Iceberg calving and collapsing ice shelves can increase the incidence of earthquakes, both submarine (underwater) and aerial (above ground) landslides and volcanic eruptions which, in turn, can exacerbate the threat of tsunamis. Changes in the stress to the Earth's crust causes a phenomenon called "isostatic rebound" – the long-term uplift of land in response to the removal of ice sheets. Coastal erosion caused by ocean acidification would create make coastal storms like hurricanes and typhoons more frequent. Rapid intensification of storm causes bombogenesis (cyclone bombs) leading to tremendous loss of life and property All these disasters will lead to habitat destruction.

3. Health and productivity: Temperature rise and unpredictable rainfall encourages the proliferation of

malaria and dengue -spreading mosquitoes. The diseases like Zika, Lyme West Nile will expand to new territories. The risk of water, food and vector borne diseases and allergies will increase manifolds. Direct and indirect exposures can cause death, disability, mental issues and eco-anxieties. Ill-health increases vulnerability and reduces the capacity of individuals to adapt to climate change, ushering an existential threat in society.

4. Higher financial burden on poor household: Carbon pricing may lead to higher public transport fares which can impact poor households more. Variation in the length of the crop growing season and higher frequency of extreme events adversely affect the farmer's net income. Water scarcity would amplify the situation further. The solastalgia (existential distress caused by environmental collapse) sets in faster.

5. Loss of biodiversity: Melting permafrost spells trouble for wildlife like walruses, arctic foxes, penguins, polar bears and reindeer. More frequent man- animal conflicts are expected with the loss of their natural habitat. Coral reefs that buffer shorelines against waves, storms, erosion and floods get bleached due to thermal stress. Destruction of the fragile coral reef ecosystem, harbouring the highest biodiversity, has wide repercussions on fishing, subsistence food, tourism and livelihood.

Remedial solution

It took a rise of 5 degrees over 5000 years, to take earth out of ice age. The past century alone saw a rise of 0.7 degree and the climate models predict the rate of warming to be at least 20 times faster. Big trouble ahead. Evidences left in Tree rings, coral reefs, ocean sediments and ice bubbles trapped in glaciers indicate that experiencing climate change is nothing new to earth but this time, it is unusually drastic. Unbridled carbon genie will certainly create havoc. SDG13 calls for urgent action to combat climate change and its impacts.

Transition sprint towards Circular global economy: With only 8.6% of global economy being circular, the resource extraction is at the threshold limit. The linear economy of "take, make, waste" is wreaking havoc on biosphere. Let's reimagine a future without single use plastics. Vote for decarbonization and make a paradigm shift to circularity by following nature- positive solutions i.e. Reduce, Reuse, Recycle and Recover – also known as R^4.

1. **Embrace Environmentalism and Activism:** Sustainable farming, forestry protection, sustainable land use, smarter urban developments, more compact, connected and coordinated cities, decentralized, digitized electrification technologies, Green Chemistry, clean energy, Eco friendly Process system engineering techniques will make humanity survive longer on this planet. Carpooling, shunning plastic, using CFL instead of incandescent bulb, responsible consumption and production, minimal wastage, phasing out fossil fuels can mitigate climate emergency.

2. **Control Population:** Population pressures undermine food security, poverty alleviation, natural resource conservation so it has to be controlled to avoid straining the environment.

3. **Carbon Pricing:** This policy instrument aims to pass the cost of emitting on to emitters. Based on "polluter pays" principle, its broad goal is to discourage the use of fossil fuels and meet national and international climate agreements. A well-designed carbon pricing policy offers triple benefits-

protecting the environment, driving investments in clean technologies, and raising revenue. Carbon offsetting means compensating for the carbon dioxide pollution that we make by preventing the same amount of pollution from happening somewhere else.

4. **Geo-engineering:** It is the deliberate intervention in Earth's natural systems to combat climate emergency. Cloud seeding is one such method that involves spraying AgI (silver iodide) aerosols on clouds to cause artificial rain. Other Geo-engineering techniques involve:

Solar Radiation Management (SRM): SRM techniques aim to enhance Earth's albedo by reflecting a bigger proportion of the Sun's energy back into space.

1. Stratospheric sulfur injections: An artificial aerosol layer of sulfur particles shot into stratosphere by cannons or dispersed from balloons would scatter the incoming solar radiation and so less of it would be absorbed by the troposphere. Partial blocking of sun by suspended aerosol is called Global dimming.

2. Cloud whitening (brightening): Tall spraying devices on land and also mounted on ocean bound vessels would expel a mist of pressurized sea water droplets and dissolved salts to altitudes upto thousand feet. The evaporation of these water droplets would leave behind bright salt crystals to reflect incoming solar radiation. Not only this, these would also act as condensation nuclei, forming new water droplets thus increasing marine cloud coverage.

3. Orbital mirrors and sunshades: Placing several million small reflective objects beyond Earth's atmosphere at a stable Lagrange point between the Sun and Earth, could partially redirect incoming solar radiation.

Greenhouse Gas Removal (GGR) or Carbon Geo-engineering: GGR techniques aim to extract carbon dioxide from the atmosphere, changing into other forms of carbon through photosynthesis and artificial 'scrubbing.' Locking up the carbon genie back into its bottle is basically sequestering carbon for which the proposed methods are:

1. Global scale Afforestation and Reforestation*:* It is most effective and practical way to mitigate climate emergency.

2. Carbon geo sequestration burial: The carbon capture, utilization and storage (CCUS) involve the pumping of pressurized carbon dioxide into suitable geological structures for storage.

3. Ocean fertilization: This bio/geo engineering technique, would involve dissolving nitrates into the surface waters of ocean to induce phytoplankton bloom. These microscopic plants would die and sink to the ocean floor carrying the Carbon compounds with them that they had photosynthesized into their tissues.

4. Biochar: The pyrolysis of animal wastes and plant residues would rapidly decompose the material with little or no CO_2 release and Bio char mixed with soil serves as fertilizers thus increasing the carbon sequestration potential of plants.

5. Direct air capture: Constructing a series of sticky, resin covered filters would act as scrubbing towers, also called artificial trees. Air would be funneled into them by wind driven turbines followed by

spraying with NaOH, KOH and Ca $(OH)_2$ to precipitate out carbonates (Soda ash) that are then made to react with water to form weak acids. These could then be piped to permanent safe storage locations such as gaps between basalt rocks where they mineralize into carbonate rocks. The crux here is Fossilization of carbon i.e. putting it back where it came from.

6. **Ocean Alkalinity Enhancement (OAE) and Enhanced Weathering:** Anthropogenic CO_2 equilibrates among various reservoirs over a timescale of few centuries. Almost 50% of CO_2 returns to solid earth by very slow weathering process colloquially called the long tail of CO_2 in the atmospheric CO_2 decay curve. Spreading finely ground silicate rock or basalt on to land or sea accelerates the chemical reaction between rocks, water and air, cutting the long tail short, thus CO_2 gets permanently stored in solid carbonates or as ocean alkalinity.

Conclusion

Most of the countries have already exceeded the Earth's bio capacity of 1.5 gha/person (global hectares/person). The perturbed carbon cycle, the so-called battery of the biosphere is clamouring to get recharged. The UN Climate Change Conference in Glasgow (COP 26) saw 120 world leaders reaffirm the Paris agreement goal of limiting the increase in the average global temperature to well below 2^oC above pre industrial levels and pursuing efforts to limit it to 1.5^oC. The clock is ticking. The beautiful big blue- green marble is worth fighting for, every day, not just on 22nd April. Reducing our ecological footprint is the only solution. Let's follow the principle of Kaitiakitanga – guardianship and protection of our Mother Earth, lest life on earth recedes into oblivion.

https://drive.google.com/file/d/1uCOwVuAIR-cu2s5-dmkDt8FQzw0MAmBA/view?usp=sharing: Temperaturetrends of Ludhiana (Punjab) culled from Climate Time Series Browser.

PHYSICS BEHIND THE CLIMATE CHANGE

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Keywords: Climate Change, Greenhouse gases, Albedo, Stefan-Boltzmann Law, Earth's Temperature.

Climate Change Studies as Interdisciplinary Education: Need, Relevance and Implementation for our unique blue dot.

Today the Earth is host to a multitude of life forms, including ourselves, and is known to be a unique planet which has evolved to sustain life from its history of ~ 4.6 billion years. It is a scientific curiosity that in a lifespan of less than a century we have been able to explore our past and we can now witness other planetary systems through the aid of telescopes and many other technological advances. Whilst we are trying to search for life on other planets and their moons in our solar system, and a bleak signal of water or oxygen gives a glimmer of hope of life there, we are ultimately neglecting our own source of life. We may be thrilled at the concept of finding future Earths, but what about our sustainability on Mother Earth? There is compelling evidence to show that the global temperature of the Earth is on the rise and many challenges are presented due to global warming and climate change [1]. It is important for us all to understand what climate change is, what evidence scientifically supports its occurrence and what steps should be taken to combat its effects.

We live in a very fragile ecosystem in which the interdependence of multiple factors and the influences of individual components in our environment are difficult to comprehend. However, through the monitoring of data, studying of patterns and analysing the effects of various natural and anthropogenic factors, we can build a better understanding of the role of the contributing factors of climate change and begin to unravel the complexities. One such factor with a great influence is greenhouse gases, of which carbon dioxide, methane and water vapour are prominent examples. As we begin to explore this further, it is worth mentioning that a thorough analysis of this topic requires skills across many disciplines including physics, chemistry, biology, geography, engineering and economics, and as such we need to consider a broader perspective to tackle these issues.

Greenhouse Gases in our Solar System: Some Insights

The distance of a planet from the Sun is one of the decisive factors in how much heat flux it receives. By inspecting the data of the planets of our solar system as shown in Table 1, it can be seen that the Solar Constant depends on the Luminosity (Lum) of our star i.e. the Sun and it decreases for the planets from Mercury to Neptune as Inverse Square of the distance from the Sun ($1/d^2$) (Eq.1) where

$$S = \frac{Lum}{4*\pi} * \left(\frac{1}{d^2}\right) \qquad \text{(Eq.1)}$$

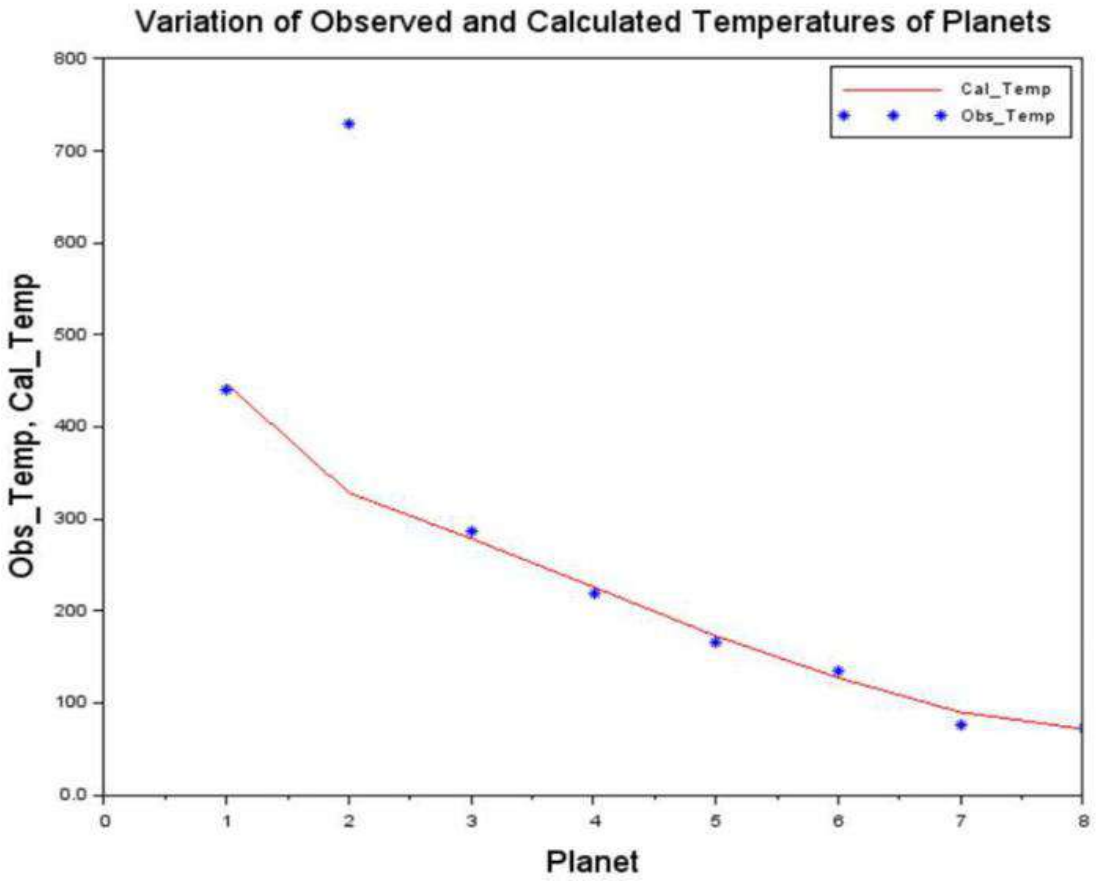
$$\frac{S}{4}(1 - A) = \sigma T_{Cal}^4 \qquad \text{(Eq.2)}$$

S can be used to obtain the calculated temperature using the Stefan-Boltzmann law (Eq.2), where A is the Albedo of a planet, having a value between 0 and 1, and has an average value of ~ 0.30 for Earth.

$$\Rightarrow T_{Cal} = \left(\frac{S(1-A)}{4\sigma}\right)^{0.25} \qquad \text{(Eq.3)}$$

Where σ is the Stefan-Boltzmann constant ($5.68 \times 10^{-8}\ Wm^{-2}K^{-4}$) and T_{Cal} is the calculated temperature of the planet [2]. A deviation between the observed temperature of a planet and the calculated temperature can be attributed due to the greenhouse gases, which has been seen on planets such as Venus and Earth. A better fit of data can be obtained by incorporating many other factors in Eq.3. Furthermore, there are complexities in modeling such as system due to temperature variations between locations and dynamic changes over time.

Figure 1: Variation of observed and calculated temperatures of planets (in Kelvin). Planet numbers correspond to 1 = Mercury, 2 = Venus, 3 = Earth, 4 = Mars, 5 = Jupiter, 6 = Saturn, 7 = Uranus, 8 =Neptune. An anomaly for Venus (Planet 2) is evident.



Planet No.	Planet Name	Distance from Sun (AU)	S = Solar Constant (W/m^2) [4]	Albedo of different planets	Calculated Temp. at the top of the atmosphere of the planet (K) (Eq.3)	Observed Temp. (K) [5]	Prominent Gases in Atmosphere	Increase in Temperature due to Greenhouse Effect
1	Mercury	0.387	9121	0.12	434	440.15	Sodium, Hydrogen, Helium	Negligible
2	Venus	0.723	2635	0.75	232	737.15	Carbon Dioxide, Nitrogen	Acute greenhouse effect due to 96% CO_2
3	Earth	1	1366	0.30	255	288.15	Nitrogen, Oxygen, Argon	Mild greenhouse effect currently
4	Mars	1.52	591	0.16	216	208.15	Carbon Dioxide, Nitrogen, Argon	Mars has 95% CO_2, but a negligible atmosphere.
5	Jupiter	5.20	51	0.34	110	163.15	Hydrogen, Helium, Methane	Methane contributes in upper atmosphere
6	Saturn	9.57	15	0.34	81.2	133.15	Hydrogen, Helium, Methane	Methane contributes in upper atmosphere
7	Uranus	19.17	4	0.30	59.2	78.15	Hydrogen, Helium, Methane	Methane contributes in upper atmosphere
8	Neptune	30.18	1.5	0.29	46.5	73.15	Hydrogen, Helium, Methane	Methane contributes in upper atmosphere

Table 1: Summary of astronomical and atmospheric calculations for planets in our solar system. [2-7]

We note that Venus is not the closest planet to the Sun but its measured surface temperature is quite different to that expected for a planet at a distance of 0.72 AU from the Sun with one of the reasons being the prevalent runaway greenhouse effect on Venus. From Figure 1, we see that the temperature anomaly on Venus provides compelling evidence to demonstrate how the greenhouse entities play a vital role in the observed temperature and on the other interdependent factors such as the planetary heat budget, cloud dynamics, albedo and various other factors.

The presence of greenhouse gases on Venus gives us a glimpse into the fate of a planet when the production of greenhouse gases is excessive thereby leading to enhanced temperatures. Using this, we can say that in the absence of greenhouse gases on Earth the temperature of our planet would be much lower. However, we need to consider why we should even worry about greenhouse gases and their role on the Earth's atmosphere. If we

examine the atmosphere of the Earth, we observe an abundance of gases such as Nitrogen and Oxygen which are homo nuclear diatomic gases and collectively constitute 99% of the total atmosphere. Meanwhile other gases such as CO_2, CH_4, and water vapour are hetero nuclear and make up less than 1% of the total atmosphere [6]. We mentioned earlier that these three gases in particular are some of the greenhouse gases on Earth. So why are these gases, which occur in scanty amount, such a matter of concern?

Why the greenhouse gases a concern for Earth's atmosphere?

The key difference between non-greenhouse gases and greenhouse gases is their chemical structure, particularly how they respond to Infrared (IR) radiation. Homo nuclear molecules such as O_2 and N_2 lack any dipole moment and don't absorb IR radiation. Comparatively, the vibrational modes in CO_2, CH_4 and H_2O can be excited by IR radiation and they absorb these radiations emitted from the Earth and re-emit it in all directions, thus trapping the heat within the Earth's atmosphere. This was shown by John Tyndall who demonstrated that carbon dioxide and water vapour both absorbed and re-radiated heat. [8]

These greenhouse gases act as an insulating envelope such as glass, an idea proposed by Fourier [9] stating how the Earth's atmosphere is responsible for increasing the planet's temperature. Further to this, Arrhenius linked CO_2 levels with temperature changes. According to his calculations, doubling and halving CO_2 concentrations led to an increase of 5-6 ºC and decrease of 4-5 ºC respectively [10]. His work was later pursued by many other scientists and the implications of raising CO_2 levels are still being studied.

Apart from CO_2, the heat budget (which is the balance of incoming and outgoing heat) of the Earth is delicate as well as complex, that can be affected by both natural and man-made sources. Natural sources that can affect the heat budget of the Earth include luminosity of our star, Milankovitch cycles (causing changes in the Earth's shape and orbit), and abrupt volcanic eruptions. However, it is human activities that are of major concern as these can cause unprecedented increases to greenhouse gas concentrations. [11].

To illustrate the impact we are having to our atmosphere, we can consider the Keeling curve – a graph of CO_2 concentrations in the Earth's atmosphere from 1958 to the present day (Figure-2 shows the data from 1968 to 2021 [12]) with measurements taken at the Mauna Loa Observatory in Hawaii, first monitored by Charles David Keeling.

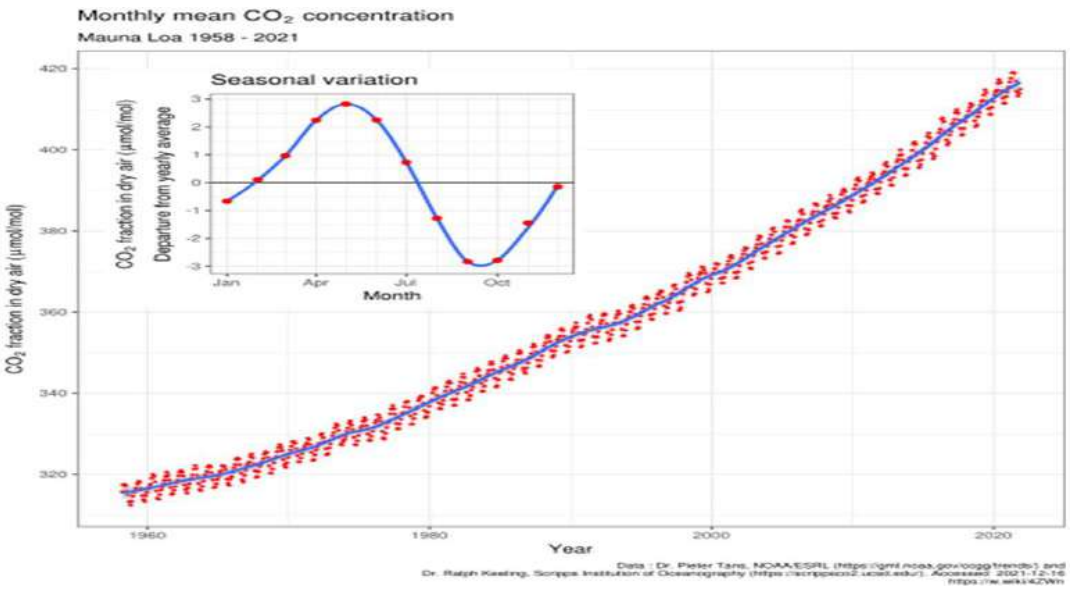


Figure-2: Atmospheric CO_2 concentrations 1958-2021 [12]

An impetus to the study of greenhouse gases was given by Charles Keeling when the measurements at the Mount Loa were conducted in 1957. The rate at which carbon dioxide is accumulating on our planet is 2 parts per million per year equating to 4 billion tons of carbon per year. There are also systematic seasonal changes (Figure-2) in the atmospheric carbon dioxide which shows intake of it by terrestrial vegetation during the growing period and release from the biosphere due to the decay of microbes in the non–growing period. However, a reversal of this cycle is observed in the southern hemisphere.

The data showed the effects of vegetation and other activities on the atmospheric CO_2 globally. The burning of fossil fuels and cement production are huge sources of its production as well. The major losses to the atmosphere are the uptake by land and ocean biospheres, with geological losses acting on much longer timescales. The increase in temperatures which may arise due to any reason such as increasing greenhouse gases have triggering effects on the melting of glaciers as well as ice caps and result in thawing of the permafrost on the Earth [13]. It can be easily noticed that the amount of heat reflected will change if the ice caps are shrunk due to a change in the albedo as well as changes in cloud dynamics. Clouds play a very important positive and negative role in the planetary budget of the Earth. They can reflect the radiation and their formation is dependent on aerosols and pollutants which act as the nucleating centres and, depending on their types, can scatter or absorb the radiation [14].

Variation in Temperature and climate in Delhi: Case Study

There has been an enormous variation in maximum temperatures, minimum temperatures along with average temperatures in many places worldwide, including Delhi. To explore the effects that climate change can have on a local scale, we will consider the temperature variation in Delhi. We obtained data from CPCB (Central Pollution Control Board) specifically for the monitoring station at Shadipur (Latitude: 28.6514781, Longitude: 77.1473105), which can be seen in Figure 3 [15].

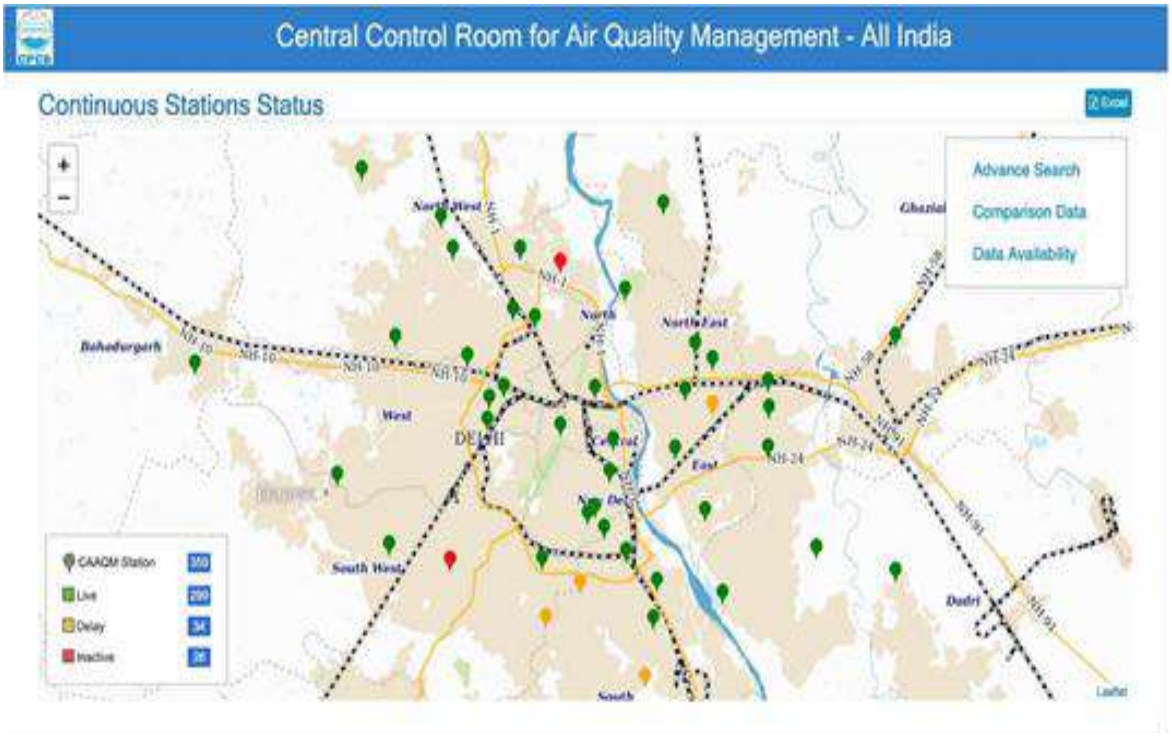


Figure 3: Shadipur Station in Delhi [15]

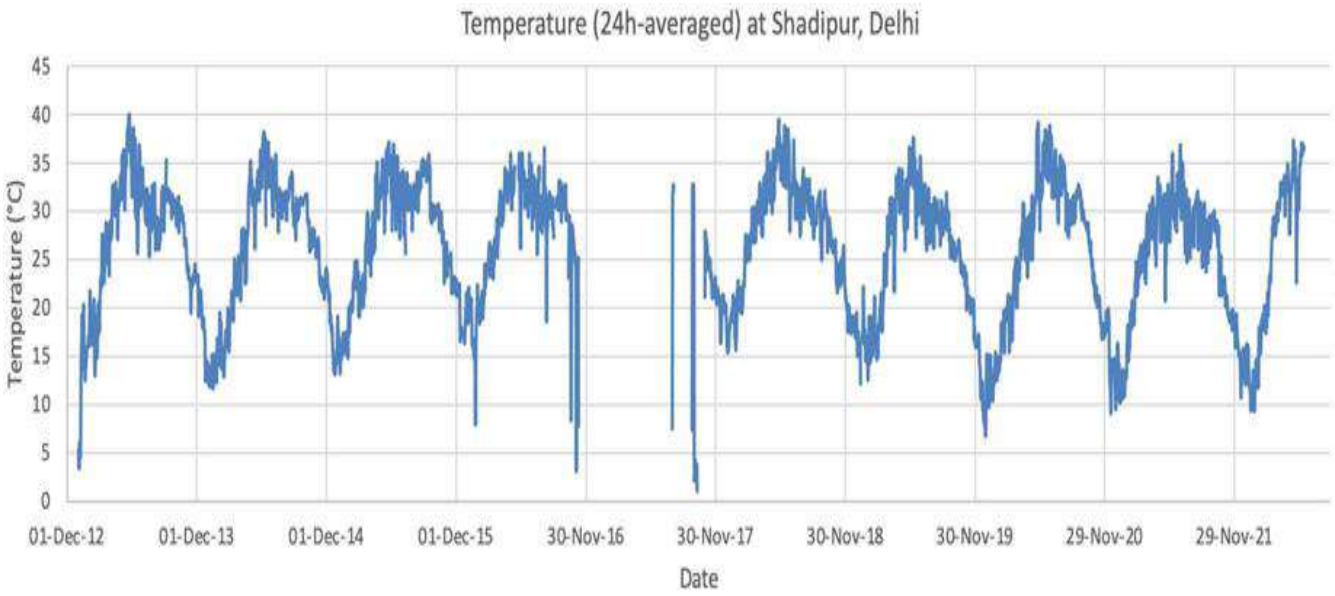


Figure 4: Temperature (24h-averaged) at Shadipur, Delhi [15]

This data (as shown in Figure 4) ranges from 2 January 2013 to 14 June 2022 and displays 24 hour-averaged temperature measured at the Shadipur station. The main observation we can see from this representative graph is that there is a continuous increase in the minimum temperature from 2013 to 2017. The average temperature of the whole of Delhi will be quite different from this particular station. According to Indian Metrological Department (IMD), in April 2022, an average maximum temperature of 40.2 degrees Celsius was recorded in Delhi, which is the highest average maximum temperature seen in the month of April since 2010 [16].

On the other hand, April 2020 was observed to be one of the coldest Aprils where we witnessed cooler temperatures and an improvement in air quality which can be attributed to the Covid-19 pandemic which led to a reduction in the use of transport, emissions and production of greenhouse gases. It should be addressed that between November 2016 and November 2017, hardly any data was available for the 24-hour averaged temperature for this station. As a result, we have disregarded this year when forming a trend within the data. Moreover, the years of 2019 – 2021 can be seen to not fit the general trend that we outlined above which may be associated with the Covid-19 pandemic having the effects mentioned above.
According to a report, the temperature in Delhi is forecasted to rise by approximately 5 degrees Celsius by the end of the century [17]. An enhancement in the occurrence of heat wave days demonstrates that the frequency of such conditions is increasing amongst many other extreme weather events. The extreme changes in the climate are increasingly affecting different people in different ways due to socio- economic, psychological and other contrasts in the society. The enhanced energy demands for combating these effects will also escalate these effects and hence need more concentrated efforts which are discussed below.

The Way Forward for Climate Change Education

Climate change is the most pressing problem of recent times and needs to be addressed by adopting an integrated approach. It is posing grave concerns not only for flora & fauna, biodiversity, ecological balance, extinction of species, heat budget of the planet and temperature of our habitat amongst an endless list but

also challenging our survival on the blue planet. It is difficult to gauge its causes and more so the effects due to its complexity and interdependence of multiple factors. It is the need of the hour to create proactive awareness about this issue. Incorporating case studies, assessing and evaluating the multiple factors contributing to it, simulation, modeling and above all, training and capacity building of skilled manpower can help to understand its causes for possible action plans for sustainable development.

Other than integrating climate change education within the curriculum [18] there is a worldwide emphasis on novel techniques and methodologies where energy demands and usage is minimized and furthermore, renewable sources of energy are adopted. A lot of research, resources, infrastructure, capital investments, private and public partnerships are needed for replacing conventional techniques and materials with cleaner and greener alternatives. This will also have a major impact on the economy. A lot of awareness and emphasis on long term benefits and incentivisation by governments from around the world is also needed for replacing alternate methods and techniques for a better environment. It is worth to highlight that the younger generation can pave way for a more sustainable world if they are trained for finding innovative solutions and tackling upcoming challenging problems. In this regard, sensitization and awareness camps, personal counseling and willingness to adopt changes can be beneficial in an individual and collective manner. This will ensure a lovely and enjoyable life for all the stakeholders on this blue planet if we constructively work towards the goals for sustainability.

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PHYSICS BEHIND THE CLIMATE CHANGE

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Climate in a narrow sense is usually defined as the "average weather," or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period ranging from months to thousands or millions of years. The World Meteorological Organization (WMO) describes "climate normals" (CN) as "reference points used by climatologists to compare current climatological trends to that of the past or what is considered typical. A CN is defined as the arithmetic average of a climate element (e.g. temperature) over a 30-year period. A 30 year period is used, as it is long enough to filter out any inter-annual variation or anomalies, but also short enough to be able to show longer climate.

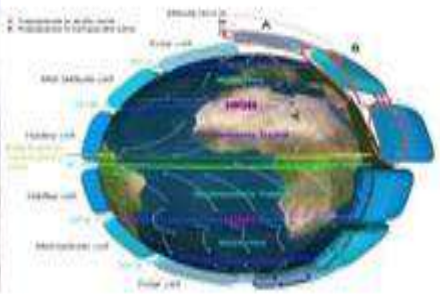
The difference between climate and weather is usefully summarized by the popular phrase "Climate is what you expect, weather is what you get. Over historical time spans, there are a number of nearly constant variables that determine climate, including latitude, altitude, proportion of land to water, and proximity to oceans and mountains. All of these variables change only over periods of millions of years.

1. INTRODUCTION: The physics of climate change. Weather and climate are driven by the absorption of solar radiation and the subsequent re-distribution of that energy through radiative, advective, and hydrological processes.

2. NATURAL CAUSES OF CLIMATE CHANGE: The earth's climate is influenced and changed through natural causes like volcanic eruptions, ocean current, the earth's orbital changes and solar variations.

Volcanic Eruption

Volcanic eruptions discharge carbon dioxide, but they may also emit aerosols, such as volcanic ash or dust, and sulfur dioxide. Aerosols are liquids and solids that float around in the air. They may also include soot, dust, salt crystals, bacteria, and viruses. Aerosols scatter incoming solar radiation, causing a slight cooling effect. Volcanic aerosols can block a percentage of sunlight and cause a cooling that may last for 1-2 years.



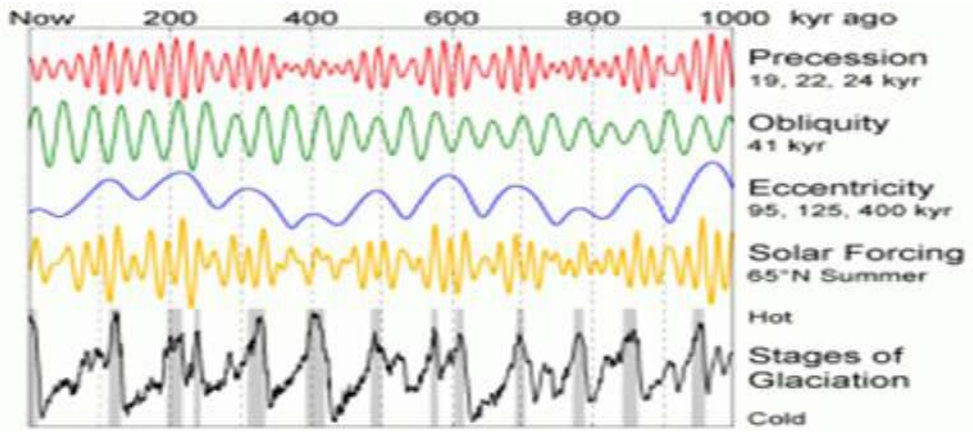
GLOBAL WIND PATTERN

In violent eruptions, volcanoes release ash particles and sulfur dioxide (SO_2) into the stratosphere. The larger particles settle after a few days while the sulfur dioxide combines with water vapor to from sulfuric acid (H_2SO_4) and sulfate particles, known together as sulfurous aerosols. Winds transport these sulfurous aerosols around the planet in easterly or westerly directions. For this reason, volcanoes that erupt at lower latitudes (closer to the equator) are more likely to cause hemispheric or global cooling. Volcanoes that erupt at higher latitudes (closer to the poles) are less likely to cause cooling because the sulfurous aerosols are confined to wind patterns surrounding the poles.

Ocean current - Ocean currents move vast amounts of heat across the planet. Winds push horizontally against the sea surface and drive ocean current patterns. Deep ocean circulation of cold water from the poles towards the equator and movement of warm water from the equator go back towards the poles. Without this movement the poles would be colder and the equator warmer. The oceans play an important role in determining the atmospheric concentration of Carbon dioxide. Changes in ocean circulation may affect the climate through the movement of CO_2 into or out of the atmosphere.

Earth orbital changes - The earth is tilted at an angle of 23.5° to the perpendicular plane of its orbital path. Changes in the tilt of the earth can lead to small but climatically important changes in the strength of the seasons, more tilt means warmer summers and colder winters; less tilt means cooler summers and milder winters.

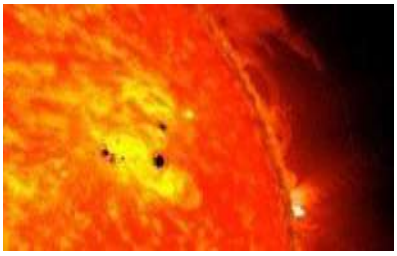
Milankovith cycles over the past 1000000 years. Source: Global Warming



The Milankovitch Theory explains the 3 cyclical changes in Earth's orbit and tilt that cause the climate fluctuations that occur over tens of thousands of years to hundreds of thousands of years. You have learned about these orbital changes in the Temperature over Time module. These fluctuations include changes in the shape (eccentricity) of Earth's orbit every ~100,000 years, the tilt (obliquity) of Earth's axis every ~41,000 years, and the wobbling (precession) of Earth's axis about ~23,000 years. Milankovitch proposed that glacial periods began when the three cycles align to favor an extended period of more solar radiation in the winter and less solar radiation in the summer at a latitude of 65°N. These conditions for the northern latitudes favor somewhat higher temperatures, but also more water vapor in the air – causing more snowfall. A relatively cool summer for the northern latitudes favors less melting of winter snow and glacier formation. The figure above shows the alignment of each of the orbital changes to the glacial and

interglacial periods. The interplay of the three orbital cycles affects the amount of solar radiation received at different latitudes over the year. The amount of solar radiation reaching the Northern Hemisphere at 65°N seems to control the advance and retreat of glaciers and ice sheet

Solar Variation: Although the Sun's energy output appears constant from an everyday point of view, small changes over an extended period of time can lead to climate changes. As the sun is the fundamental source of energy that is instrumental in our climate system it would be reasonable to assume that changes in the sun's energy output would cause the climate to change. Current global warming however cannot be explained by solar variations. Some examples are evidenced such as since 1750, the average amount of energy coming from the Sun either remained constant or increased slightly. If global warming was caused by a more active sun, then scientists would expect to see warmer temperatures in all layers of the atmosphere. They have only observed a cooling in the upper atmosphere, a warming at the surface and in the lower parts of the atmosphere. This is due to greenhouse gases capturing heat in the lower atmosphere. Also climate models that include solar irradiance change.



The total amount of solar radiation varies by very small amounts. The energy emitted by the sun only varies by 1.3 W/m^2.

This change in solar radiation is related to the number of sunspots. Sunspots are darker areas on the sun's surface. A sunspot develops where an intense magnetic field weakens the flow of gases that transport heat energy from the sun's interior. Sunspots appear dark because their temperature is lower than the surrounding area. Approximately every 11 years, the number of sunspots changes from a maximum number to a minimum number. The sun emits slightly more radiation during active periods of sunspots. Because the sunspots are suppressing heat, the heat flows to surrounding areas causing these regions to be brighter than normal, radiating more heat.

Movement of Crustal Plates

As tectonic plates move over geological timescales, landmasses are carried along to different positions and latitudes. These changes affect global circulation patterns of air and ocean water and the climate of the continents. One form of evidence for plate tectonics and an example of how plate tectonics affects climate is the location of coal mines. Coal mines were formed over millions of years ago in tropical areas, yet are found at higher latitudes today. You also learned in the Temperature over Time module that, since the industrial revolution, the Northern Hemisphere has warmed more than the Southern Hemisphere. This is because the Northern Hemisphere has a larger percentage of Earth's landmass compared to ocean than the Southern Hemisphere. Remember that landmasses warm faster than oceans due to the high heat capacity of the ocean.

3. MAN MADE CAUSES OF CLIMATE CHANGE: The climate is changing due to man-made greenhouse gases. We are already committed to future substantial change over the next 30 years and change is likely to accelerate over the rest of the 21st century. The Industrial Revolution in the 19th century saw the large-scale use of fossil fuels for industrial activities. Fossil fuels such as oil, coal and natural gas supply most of the energy needed to run vehicles generate electricity for industries and households. The energy sector is responsible for about 3/4 of the carbon dioxide emissions, 1/5 of the methane emissions and a large quantity of nitrous oxide. Carbon dioxide is undoubtedly, the most important greenhouse gas in the atmosphere. Changes in land use pattern, deforestation, land clearing, agriculture, and other activities have all led to a rise in the emission of carbon dioxide.

Methane is another important greenhouse gas in the atmosphere. It is released from animals such as dairy cows, goats, pigs, buffaloes, camels, horses and sheep. Methane is also emitted during the process of oil drilling, coal mining, leaking gas pipelines, landfills and waste dumps. The certainty of global warming can be seen through some of the natural phenomenon like the effect on crops and extreme weather conditions around the world. It is especially clear in the dramatic change of the polar caps, i.e. the Arctic ice cap is shrinking and the Antarctica ice shelf is melting.

There are other elements of people's homes that contribute to climate change indirectly. Everything, from furniture to computers, from clothes to carpets, all use energy when it is produced and transported – and this causes carbon emissions to be released. The three main causes of the increase in greenhouse gases observed over the past 250 years have been fossil fuels, land use, and agriculture.

Agriculture has been shown to produce significant effects on climate change, primarily through the production and release of greenhouse gases such as carbon dioxide, methane, and nitrous oxide. Another contributing cause of climate change is when agriculture alters the Earth's land cover, which can change its ability to absorb or reflect heat and light. Land use change such as deforestation and desertification, together with use of fossil fuels, are the major anthropogenic sources of carbon dioxide. Deforestation is another major contributor to the Climate change. Rainforests are precious resource in our world. They form part of a delicate ecosystem that has taken millions of years to evolve. Rainforests every year help to absorb almost 20% of manmade CO_2 emissions therefore deforestation can be classed as a major contributor to the causes of climate change. Cutting down rainforests faster than they can be replaced has a devastating effect on the carbon emission cycle producing an extra 17% of greenhouse gases. Forests reduce greenhouse gas emissions to combat global warming. 20% of global greenhouse gas emissions result from deforestation and degradation of forest, more than all the world's cars, trucks, ships and planes combined. Fossil fuels release carbon dioxide into the atmosphere contributing to global warming and climate change. Forest alleviates this change by converting carbon dioxide to carbon during photosynthesis. The world's forests contain about 125 percent of the carbon found in the 100 atmosphere. This carbon is stored in the form of wood and vegetation through "carbon sequestration".

The atmospheric carbon dioxide concentration in the pre-industrial era was 280 ppm. Now the level has risen to 375 ppm, a 30% increase. It is predicted that the level will be 450 ppm in 2050 resulting in 1.8 to 3^0 C increase in temperature eventually. Therefore, global warming will produce a sharp upswing followed by a deep plunge into a glacial period several thousand years from now.

Scope of Study- Ratlam

Ratlam is one of the districts of Madhya Pradesh in India, having population in 2022 as 1,627,276 The latitude for Ratlam is: 23°20'N and a longitude of 75°2'E

Weather averages Ratlam

The variation in the precipitation between the driest and wettest months is 340 mm | 13 inch. During the year, the average temperatures vary by 13.4 °C | 24.2 °F. Ratlam, like most of Madhya Pradesh, has humid subtropical climate zone. Three distinct seasons are observed: summer, monsoon and winter. Summers start in mid-March and can be extremely hot from April through June. Highs can reach 112 °F (44 °C), although the humidity is extremely low. Average annual temperature: 24 °C (75 °F) Avg. winter temperature: 16 °C (61 °F)

The least amount of rainfall occurs in April. The average in this month is 2 mm | 0.1 inch, with an average of 342 mm | 13.5 inch, the most precipitation falls in July.

The best time of year to visit Ratlam is during the month of December and January

Other facts from our historical climate data

- It has high temperatures all year ranging between 26°C&40°C.
- Most rainfall (rainy season) is seen in July, August and September.
- The months January, February, March, April, May and December are very dry.
- May has an average maximum temperature of 40°C and is the warmest month of the year.
- The coldest month is January with an average maximum temperature of 26°C.
- May is the sunniest month with an average of 327 hours of sunshine.

4. THE PHYSICS OF CLIMATE CHANGE: The average temperature of the Earth is essentially determined by the balance between incoming solar radiation and outgoing 'heat' ' radiation. A change in this radiative balance is termed as radiative forcing, which is measured in Watts per square meter.

Water vapour is a 'feedback' for greenhouse gases. CO_2, CH_4, O_3 etc. are forcing' agents .They stay in the atmosphere whatever and 'force' more heat into the climate system. This effect is measured by 'Radiative forcing constant'.

According to Intergovernmental Panel on Climate Change(IPCC),"The radiative forcing of the surface troposphere system due to the perturbation in or the introduction of an agent (say, a change in greenhouse gas concentrations) is the change in net (down minus up) irradiance (solar plus long-wave; in Wm-2) the tropopause AFTER allowing for stratospheric temperatures to readjust to radiative equilibrium, but with surface and tropospheric temperatures and state held fixed at the unperturbed values".

Oxygen and Nitrogen molecules respond to high energy EMR in UV region. The relationships between the atmospheric concentration of greenhouse gases and their radiative effects are well quantified. Forcing from the long lived greenhouse gases: carbon dioxide, methane, and nitrous oxide, is presently about 2.5 Watts per meter squared (W/m^2). Of this total, 1.6 W/m^2 is from carbon dioxide alone. The total anthropogenic forcing is uncertain, particularly because the magnitude of the negative forcing associated with sulfate aerosols is unclear. While changes in solar irradiance may have affected global climate in the last century, a 0.15% change irradiance, the order of estimated changes, results in only a 0.36 W/m^2

forcing. There are still significant uncertainties in moving from greenhouse gas emissions, particularly those of carbon dioxide, to atmospheric concentrations. It is the balance between positive and negative feedbacks which will determine the net effect of increased greenhouse gases.

THE ECONOMIC IMPACTS OF CLIMATE CHANGE

These vary geographically and are difficult to forecast exactly. Researchers have warned that current economic modeling may seriously underestimate the effects of climate change, and point to the need for new models that give a more accurate picture of potential damages. A 2018 study found that potential global economic gains if countries implement mitigation strategies to comply with the 2 °C target set at the Paris Agreement are in the vicinity of US $17 trillion per year up to 2100 compared to a very high emission scenario.

Global losses reveal rapidly rising costs due to extreme weather events since the 1970s. Socio-economic factors have contributed to the observed trend of global losses, such as population growth and increased wealth. Part of the growth is also related to regional climatic factors, e.g., changes in precipitation and flooding events. It is difficult to quantify the relative impact of socio-economic factors and climate change on the observed trend. The trend does, however, suggest increasing vulnerability of social systems to climate change.

The total economic impacts from climate change are difficult to estimate. For instance, total damages are estimated to be 90% less if global warming is limited to 1.5°C compared to 3.66°C, a warming level chosen to represent no mitigation. One study found a 3.5% reduction in global GDP by the end of the century if warming is limited to 3°C, excluding the potential effect of tipping points. Another study noted that global economic impact is underestimated by a factor of two to eight when tipping points are excluded from consideration. In the Oxford Economics high emission scenario, a temperature rise of 2 degrees by the year 2050 would reduce global GDP by 2.5% – 7.5%. By the year 2100 in this case, temperature would rise by 4 degrees, which could reduce the global GDP by 30% in the worst case.

SOCIAL IMPACT ON CLIMATE CHANGE

There are many direct and indirect social and cultural impacts of climate change.

Food systems

Impacts such as rising temperatures and increased frequency of extreme weather events put severe pressure on food availability, stability, access and use. Availability of agricultural products is affected by climate change directly through impacts on crop yields, crop pests, diseases, soil fertility and soil water-holding properties. There is a well-accepted prediction that climate change will – and already has – caused severe regional water shortages. As water stress increases, we will likely experience much more unstable global food production along with decreased biodiversity, and damaged ecosystems.

Water

One of the most serious impacts of climate change is how it is affecting water resources around the world. Water is intimately tied to other resource and social issues such as food supply, health, industry, transportation and ecosystem integrity.

Glacial melting is one of the most striking and visual signs of the impacts of climate change. Glaciers store snow like bank accounts store money; they hold snow in the winter and release water when it's most

needed, during hot, dry summers and periods of drought. However, global warming is cashing in on a bank account that has been built over thousands of years but isn't being replenished.

Health

The health of human beings is affected by climate change, either directly through changing weather patterns, or indirectly through changes in water, air, food, ecosystems, livelihoods and Infrastructure. Generally, these direct and indirect exposures can cause death, disability and suffering. Ill-health increases vulnerability and reduces the capacity of individuals and groups to adapt to climate change.

The main ways to stop climate change

Fortunately, there are plenty of solutions to climate change they are well understood.

Core to all climate change solutions is reducing greenhouse gas emissions, which must get to zero as soon as possible. Because both forests and oceans play vitally important roles in regulating our climate, increasing the natural ability of forests and oceans to absorb carbon dioxide can also help stop global warming.

- Keep fossil fuels in the ground. Fossil fuels include coal, oil and gas – and the more that are extracted and burned, the worse climate change will get. All countries need to move their economies away from fossil fuels as soon as possible.
- Invest in renewable energy. Changing our main energy sources to clean and renewable energy is the best way to stop using fossil fuels. These include technologies like solar, wind, wave, tidal and geothermal power.
- Switch to sustainable transport. Petrol and diesel vehicles, planes and ships use fossil fuels. Reducing car use, switching to electric vehicles and minimizing plane travel will not only help stop climate change, it will reduce air pollution too.
- Help us keep our homes cozy. Homes shouldn't be draughty and cold – it's a waste of money, and miserable in the winter. The government can help households heat our homes in a green way – such as by insulating walls and roofs and switching away from oil or gas boilers to heat pumps.
- Improve farming and encourage vegan diets. One of the best ways for individuals to help stop climate change is by reducing their meat and dairy consumption, or by going fully vegan. Businesses and food retailers can improve farming practices and provide more plant-based products to help people make the shift.
- Restore nature to absorb more carbon. The natural world is very good at cleaning up our emissions, but we need to look after it. Planting trees in the right places or giving land back to nature through 'rewilding' schemes is a good place to start. This is because photosynthesizing plants draw down carbon dioxide as they grow, locking it away in soils.
- Protect forests like the Amazon. Forests are crucial in the fight against climate change, and protecting them is an important climate solution. Cutting down forests on an industrial scale destroys giant trees which could be sucking up huge amounts of carbon.
- Protect the oceans. Oceans also absorb large amounts of carbon dioxide from the atmosphere, which helps to keep our climate stable. But many are overfished, used for oil and gas drilling or threatened by deep sea mining. Protecting oceans and the life in them is ultimately a way to protect ourselves from climate change.

- Reduce plastic. Plastic is made from oil, and the process of extracting, refining and turning oil into plastic (or even polyester, for clothing) is surprisingly carbon-intense. It doesn't break down quickly in nature so a lot of plastic is burned, which contributes to emissions. Demand for plastic is rising so quickly that creating and disposing of plastics will account for 17% of the global carbon budget by 2050.

It's easy to feel overwhelmed, and to feel that climate change is too big to solve. But we already have the answers, now it's a question of making them happen. To work, all of these solutions need strong international cooperation between governments and businesses, including the most polluting sectors.

CONCLUSION

With the economic and social growth of humans, the requirement of energy is increasing exponentially and the only convenient option right now is fossil fuels. The emission of gases from burning of fossil fuels is the root cause for Greenhouse effect. One of the largest uncertainties in future greenhouse emissions is the effect of technological change. If renewable energy sources become cost-effective, if there are major gains in the efficiency of energy utilization, or if there is a large increase in the use of nuclear energy (fission or fusion), then emissions of greenhouse gases may be substantially restrained.

PHYSICS BEHIND THE CLIMATE CHANGE

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Keywords: Climate Change, Global Warming, Causes of Climate Change.

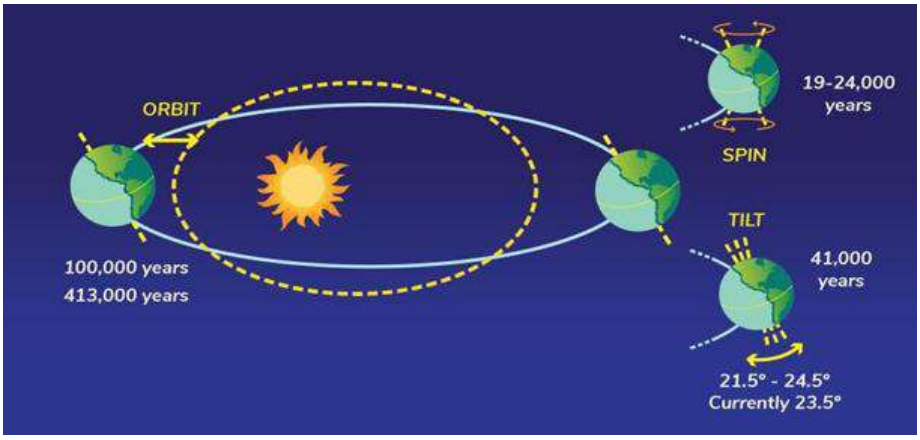
1. Brief Introduction to the topic

Climate change refers to long term change in weather cycle or change in normal weather of the earth as a whole or of a specific place, which is caused by change in environmental factors that may be due to natural or man-made causes. Natural factors that affect environment are volcano, orbital changes, solar output,ocean currents and El Nino. etc., while man-made factors are increased carbon emission, greenhouse gases, deforestation, air pollution etc. Global warming is one such climate change factor which is result of greenhouse gases.

2. Natural Causes of Climate Change

There are also natural factors which contribute to climate change

2.1 Orbital changes - the Earth has natural warming and cooling periods caused by Milankovitch cycles or variations in the tilt and/or orbit of the Earth around the Sun (Wobble, roll and stretch theory). Milankovitch a Serbian scientist put forth the hypothesis of climate change due to earth's position relative to Sun. Tilt of earth22.1 to 24.5 degree cycle is of 41000 years, Precession cycle is of 26000 years and shape of earth's orbit change (eccentricity 0.0034 elliptical to 0.058 circular) cycles is of 100,000 years. Due to these cycles amount of sun radiations absorbed by the earth changes. On this basis Milankovitch explained beginning and end of ice age.



2.2 Volcanic activity - During a volcanic eruption carbon dioxide, ash and dust is spread in the atmosphere which blocks the sunlight causing cooling for a short period. The SO_2 in the debris of volcanic activity forms sulfate aerosol with water vapor which reflects the sunlight causing cooling. These effects last for a few months to a year. In the year 1991 eruption of Mount Pinatubo in Philippines injected 20

million tons of SO_2 in the atmosphere causing lowering of temperature of the earth by 0.5 degree centigrade, according to U. S. Geological Survey.

2.3 Solar output - There can be fluctuations in the amount of radiation from the sun. If there is high amount emitted there will be an increase in Earth's temperatures. During1650 to 1850 there was a decrease in the solar output. It is thought that it triggered the little ice age. Though the solar radiation output is increased slightly in last 150 years but it was not responsible for increased temperature of the earth according to scientific analysis. There was a cooling in the upper part of the stratosphere and increase in temperature near earth's surface. Thus it was only the greenhouse effect responsible for global warming.

2.4 Ocean currents – Ocean currents are caused by mainly Coriolis Effect, planetary vorticity, wind patterns, horizontal and vertical friction. These ocean currents called gyres are of five types – North Pacific, South Pacific, North Atlantic, South Atlantic and Indian Ocean currents. These ocean currents affect the climate of the areas through which they pass. Gulf Stream warms the northwest Europe.

2.5 El Nino and La Nina – El Nino and La Nina are caused by the interaction of atmosphere and sea water. El Nino is caused by the warming of the sea water at equatorial Pacific Ocean and weakening of east winds. La Nina is just opposite, it is caused by cooling of the equatorial Pacific Ocean water strengthening of east winds. These El Nino and La Nina alter the climate of that region. It can result in flood, drought and other secondary effects.

3. Man Made causes of Climate Change

The two main reasons that are responsible for climate change due human activities are:

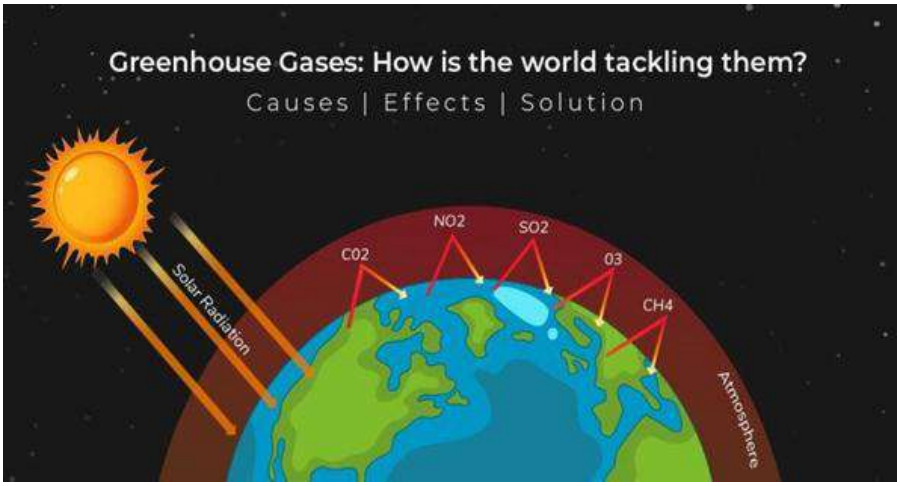
1. Greenhouse Effect and
2. Depletion of Ozone Layer

3.1 Greenhouse Effect - The main man made factor to change the climate is greenhouse effect. Greenhouse effect is caused by some gases like CO_2, CH_4, N_2O, water vapor and fluorinated gases. Main categories of fluorinated gases are — nitrogen trifluoride (NF_3), per fluorocarbons (PFCs), sulphur hexafluoride (SF_6), hydro fluorocarbons (HFCs). These gases allow sunlight (short wavelength radiation) to pass through them but the reflected radiation (long wavelength radiation) from the earth's surface in the form of infrared radiation is absorbed by these gases. Thus these gases prevent earth's heat to go in the space back resulting in the global warming. These greenhouse gases increase on earth due to following human activities

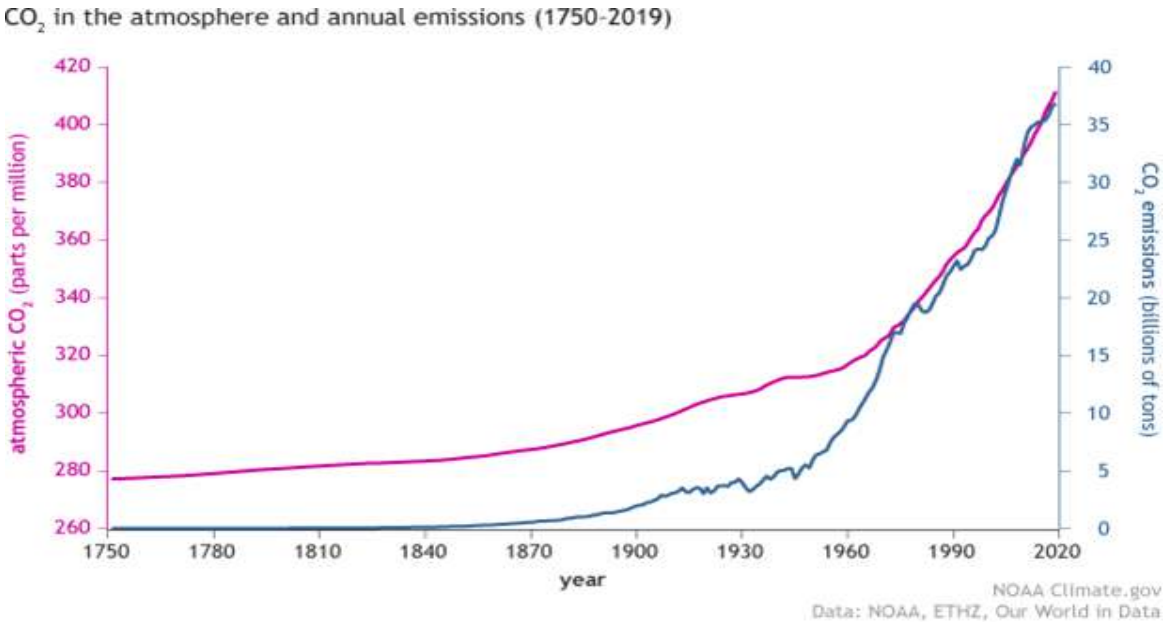
3.11 Burning Fossil Fuels - Burning of fossil fuels like petrol, diesel, coal for auto vehicles, manufacturing machines, power generation etc. produce carbon dioxide which is a greenhouse gas. CO_2 absorbs nearly 90% of the infrared radiation emitted from earth.

3.12 Deforestation – Deforestation causes increase in the amount of carbon dioxide as the trees absorb carbon dioxide during photosynthesis. In the absence of forests amount of carbon dioxide will increase resulting in the global warming.

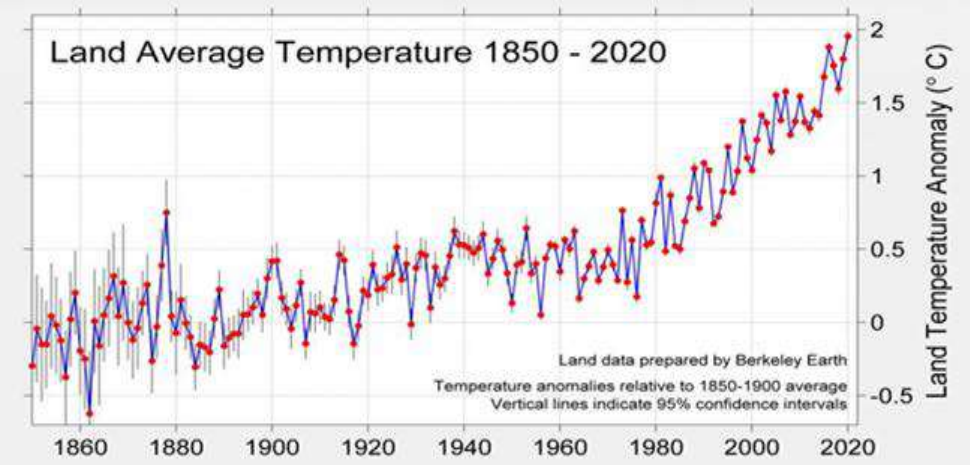
3.13 Dumping wastes in landfills - Waste material is usually dumped in the landfills. After some time this waste material decomposes then methane gas is produced. This is also a greenhouse gas causing global warming.



3.14 Agriculture – Fertilizers are used for farming. These fertilizers contain nitrous oxide that traps heat for plant growth. But In the presence of sun and rain this nitrous oxide is released into atmosphere. This is greenhouse gas causing global warming. Out of the various gases responsible for greenhouse effect the contribution of CO_2 is much more. Relative contribution of the different greenhouse gases in global warming is as follows 60% of water vapor, 26% of CO_2, 5% of CH4, 1% of CFC and 2% of N_2O. The concentration of CO_2 has increased in last few years as

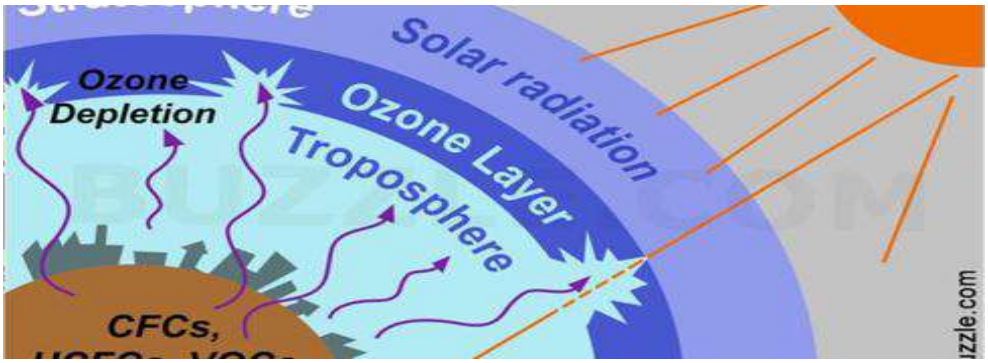


According to world meteorology organization since 2015, the decade was warmer with 2016, 2019 and 2020 as warmest years.



Land average temperature data are due to Berkeley Earth Organization. As compared to 1980 rise in temperature is 1.1 degree centigrade.

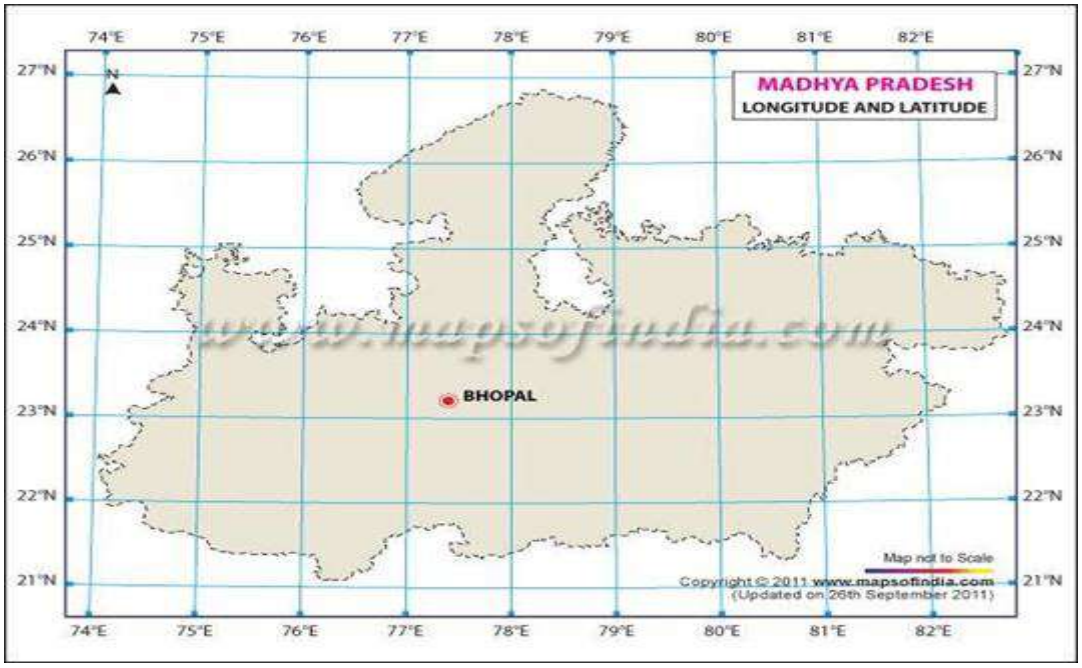
3.2 Depletion of Ozone Layer - Another important cause for climate change is depletion of ozone layer due to choloroflorocarbons and Nitrous oxide. Ultraviolet rays coming from sun hits the upper layer of stratosphere. These are blocked by the ozone layer. Ultraviolet rays break the oxygen molecule into atoms, then these atoms react with oxygen molecule to form ozone. Thus the ozone layer which is at about 10 to 50 Km. height protects us from the harmful ultraviolet rays. Thickness of ozone layer varies with weather. It is maximum in the spring season and minimum in rainy season. In 1985 a team of British scientists found depletion of the ozone layer over Antarctica. For this depletion CFC gases which are used in refrigerators, A.C.'s and plastic foams are responsible. These gases which can last for 80 to 100 years in the atmosphere interact with ultraviolet rays due to which chlorine is released which destroys ozone layer and convert it into oxygen resulting in the depletion of ozone layer. Above the polar region formation of ozone is slow so it is depleted first.



3.21 Effects of ozone layer depletion - Due to hole in ozone layer harmful ultraviolet rays reach to the earth that can cause skin cancer, sun burn, gene mutation, hereditary problems, decrease in plant growth etc.

3.22 Effects of Global warming – These includes Melting of Glaciers, increase in the sea level and river levels, sinking of coastal areas, Floods, Drought, Loss to biodiversity and decrease in growth of crops.

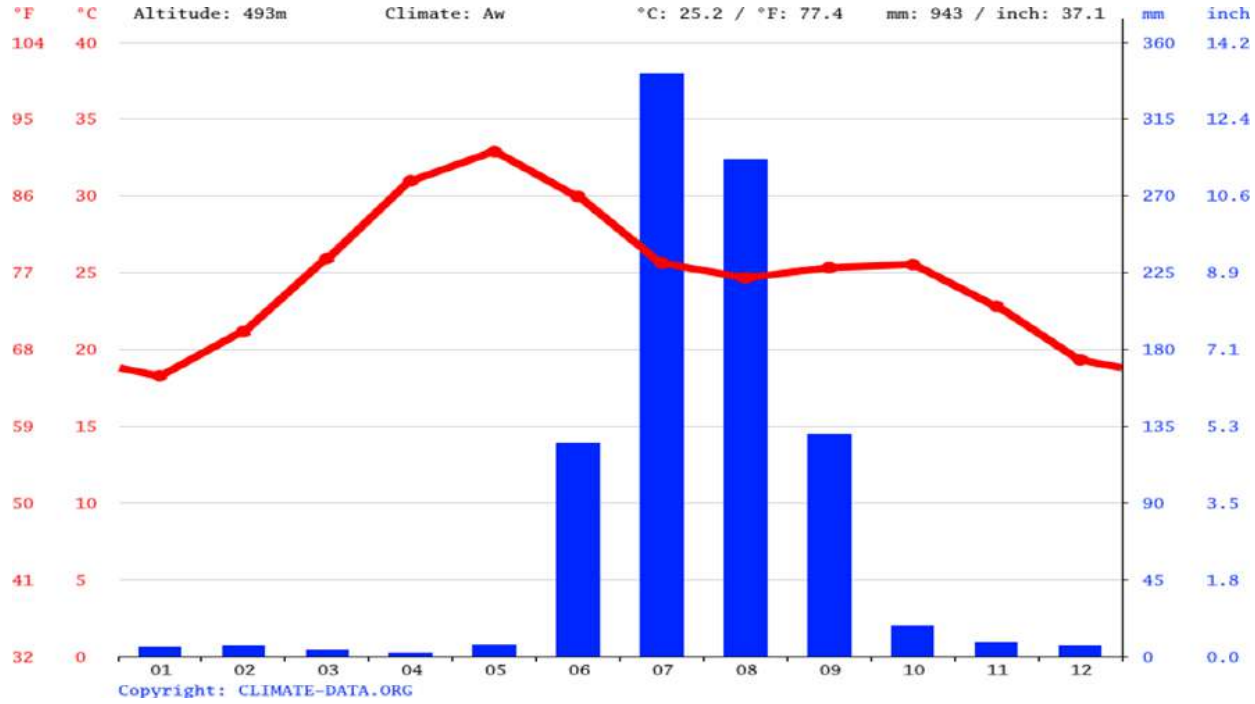
4. Study in reference to Ujjain - Ujjain is an ancient city situated on latitude 23.17 degree North and longitude 75.78 degree East in Madhya Pradesh which is heart of India. Area of Ujjain is 151.8 Square Kilometer. Its elevation is 494 meter from sea level and distance from sea is nearly 550 KM. Population of Ujjain city is nearly 6,17,812.

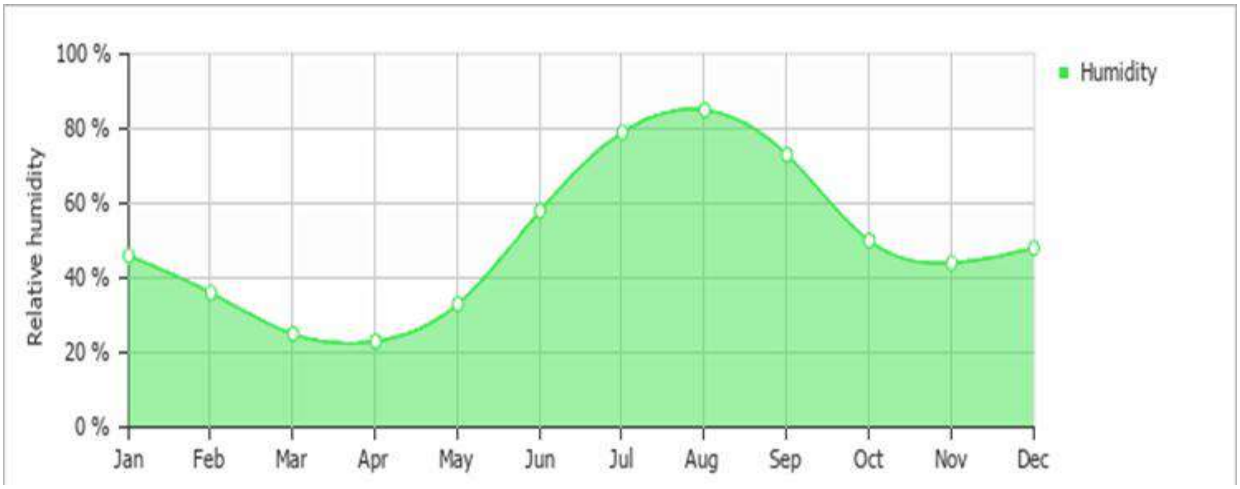


Ujjain is a famous place of pilgrimage. It has one of the 12 Jyotirling Mahakaleshwar. The education place of Lord ShriKrishna Sandipani Ashram is also here. It is situated on the banks of river Shipra. A holy river on the banks of which famous Singhastha fair is organized in every 12 years. Tropic of cancer passes through Ujjain. In ancient times Ujjain was center for time measurement. So it is also called Greenwich of India. It was capital of Maharaja Vikramaditya of Gupta dynasty in 4th century.

4.1 Climate abnormality in Ujjain

In the year 2010 Ujjain observed highest temperature 46 degree centigrade on 21st May. Average rainfall of Ujjain is 943 mm. On 30th May 2019 Ujjain witnessed 43.5 degrees centigrade temperature. A further rise in maximum and minimum temperatures in the coming days took place because of cloud formation due to western coastal disturbance leading to unseasonal rain last week, keeping temperatures low for some days. Ujjain is situated on the tropic of cancer so the weather is generally temperate. The geographical place is known as Malwa Plateau. Due to river Shipra humidity is 46% which is greater than nearby places. For the textile manufacturing humidity is an important factor which determines tensile strength, elasticity and fiber diameter. That's why textile industries flourished in Ujjain in 1960-1970 that are now closed due to other reasons. In the Singhhastha Fair of 2004 when there was rainfall in summer with storms it was guessed that Yagya by the saints created a precipitation but it is to be confirmed by scientific investigation. The extreme weather situations in Ujjain when summers are becoming hotter and winters are becoming colder is the part of global warming it is not local effect.





Average relative humidity in Ujjain month-wise

5. The Physics of Climate Change - The climate change depends on man-made as well as natural causes as described above. Climate of any place mainly depends on height above the sea level, wind patterns, distance from the equator, distance from the sea, latitude and longitude, plain area or mountain area etc. all these are natural causes. Apart from it the man-made causes also described above creating two major factors viz greenhouse effect and depletion of ozone layer. These things lead to global warming and depletion of ozone layer. This global warming changes most of the natural phenomena such as melting of glaciers, rise in average sea level etc.

With the elapse of time new technologies and scientific developments are now posing fresh threats to the environment and climate of the earth. The best example is Covid19 pandemic which lasted for nearly 2 years and still we are facing the consequences of it. It is understood that the pandemic was due to damage to environment and human activity. It is observed that digital revolution also creating a problem of e-waste, so one has to find means to fight these newer things.

6. Effect of climate change on economy - Due to climate change, frequency and potential of floods, droughts, rainfall all these things changes which in turn changes the employment opportunities, growth of plants, crop production, harm in transportation, health problems etc. So Budget of individuals as well as of the government is imbalanced due the climatic conditions. All these lead to price rise and financial problems.

7. Effect of Climate change on social factors - How the climatic conditions affect the social problems is not a new thing. We have seen that any unprecedented situation in our life create a channel of social problems connected to each other. For example the Covid19 created lockdown, that created social distancing in real sense, increased quarrels in the family, problem of employment etc. one by one problems are the result of any change in climate.

Some Remedial Solution - The remedial solution finding is responsibility of individual, society and the government equally. All the governments and UNO are striving hard to fight the natural and man-made causes by imposing rules and framing protocols, but here I would like to mention only the scientific remedies that can be done. Any new technology or scientific invention must be eco-friendly. We should find more ways of green technology. Everything that we manufacture or use must be put to environmental assessment. It should be clearly mentioned that the product or the technology has so much environmental impact factor. We have to find renewable energy sources and improve these technologies so that it can be used at small level as well as at large scale.

Conclusion - Climate change is an alarming situation for the survival of the mankind on earth. The problems that we are facing and will face in future depend on the way how we fight with this problem. Scientific and technological developments must be in a direction to benefit the human life and it should not be limited to personal interest. Anything which is good for one person or community and harmful for the other will definitely prove to be fatal for the whole earth.

Appendix

Guidelines for Essay Writing and Developing Skills for Science Communication

Do you know that the word 'essay' is derived from a Latin word 'exagium', which roughly translates to presenting one's case? Essay is often considered synonymous with a story or a paper or an article. Essays can be formal as well as informal. There are broadly four types of essays.

Descriptive Essays: Here the writer will describe a place, and object, an event or may be even a memory. But it is not just plainly describing things. The writer must paint a picture through his words.

Narrative Essays: This is when the writer is narrating an incident or story through the essay.
Expository Essays: In such an essay a writer presents a balanced study of a topic. To write such an essay, the writer must have real and extensive knowledge about the subject.
Persuasive Essays: Here the purpose of the essay is to get the reader to your side of the argument.

Format of an Essay
As such there is no rigid format of an essay. It is a creative process and should not be confined within rigid boundaries. However, there is a basic structure that is generally followed while writing essays. So let us take a look at the general structure of an essay
Introduction: This is the first paragraph of your essay. This is where the writer introduces his topic for the very first time. You can start with a quote or a proverb. Sometimes you can even start with a definition. Another interesting strategy to engage with your reader is to start with a question.

Body: This is the main crux of your essays. This need not be confined to one paragraph. It can extend to two or more paragraphs according to the content. Usually, we have a lot of information to provide in the body. Write the information in a systematic flow so that the reader can comprehend. So, for example, you were narrating an incident. The best manner to do this would be to go in a chronological order.
Conclusion: This is the last paragraph of the essay. Sometimes a conclusion will just mirror the introductory paragraph but make sure the words and syntax are different Make sure you complete your essays with the conclusion, leave no hanging threads.
In writing an essay on scientific topic, you have to ferret out interesting science themes/dimensions of the subject. Observation, exploration and investigation- things around you and activities you witness on a daily basis. For example if you are mentioning population you may also mention population density (an idea similar to surface charge density) or when mentioning power you may have a graph showing how it has grown over the decades. As a keen scientist you need to share your observations, exploration and investigation. If you are mentioning pollution of air then mention AQI; you may also mention vehicle density. Further you may have a graph showing how the number of vehicles has grown over the decades. Data presented in such an essay particularly in visual format through graphs, diagrams, flowcharts, pictures etc. can add a lot to the comprehension of your article. It is a good idea to do a survey of literature to gather facts, You should never involve in cut and paste business, it is plagiarism and is unethical. Acknowledge the sources in the end by giving a comprehensive bibliography. It is a joy to be part of this process of writing, where one acquires a skill which can become a strong part of the profile of the author and may be launch him as a science journalist.

As a sample we are including the details of NCEWP-2023 of this year containing necessary guidelines for our future participants.

ANNOUNCEMENT

IAPT National Competition on Essay Writing in Physics (NCEWP - 2023)

Writing makes one perfect, essay writing more so……

NCEWP is one of the three national competitions being held by IAPT every year. The competition is open to participants in two categories viz., students and teachers (including Science Communicators).

Category A - students of Higher Secondary /Jr. College, UG and PG levels;
Category B - teachers of Higher Secondary/Jr. College, UG and PG institutions, also Science Communicators working in recognized institutions.

Essay topic for both the categories is: "PHYSICS IN FORENSIC SCIENCE"

Forensic science or forensics is the scientific processing of information found at the crime scene. The facts derived from the analysis can be used as evidence in the justice system. Forensic Physics is the application of physics for purposes of civil or criminal law. General Physics in forensic science involves electrical, mechanical, chemical and laboratory analysis as well as mathematical formulations based on recognized principles of fundamental physics. The fundamental physics like conservation law of momentum, collision and Newton's laws of motion are having a great and vital application in reconstruction of scene of crime. All the fundamental laws of Physics are very much helpful in analyzing available evidence and drawing appropriate conclusion.

Your essay may be written considering the following points:

(i) How Physics is used in crime detection?

(ii) The details of the Instruments/technique used in detection process e.g.,
(a) microscope/electron microscope
(b) the mass spectrometer
(c) use of the photoluminescence phenomenon
(d) use of ultraviolet light
(e) use of X-rays etc.
(f) software-based imaging methods for facial reconstruction etc.
(g) Measurement of density (soil & glass examination)
(h) Refractive index of materials and birefringence for fiber analysis.

(iii) List the types of crimes e.g., road accidents, fire and burns, drowning in water, falling from height, sudden explosion/blast, injuries due to fighting/shooting, other medico-legal cases etc.,

(iv) You may have the data of last five years of various crimes in your area from the Government Hospital / District Police (Forensic) Office, this will give an idea which crimes are having a large no. and what is the growth rate of these during the last five years

(v) Conclusion

General Instructions:

The essay will be limited to 08 pages including figures/tables etc. type-written in the Times New Roman 11-point fonts, with 1.15 spacing. A format is given below:

IAPT National Competition on Essay Writing in Physics: 2023 (NCEWP – 2023)

Topic: -"PHYSICS IN FORENSIC SCIENCE"

Tick the Category: A B

Author's Details (with Affiliation & Signature): Total No. of Words: Key Words (Maximum Five)

Important Changes in the IAPT Essay Competition NCEWP-2023

All the RC's will conduct the regional level essay competition digitally. Students at all the levels i.e. Higher Secondary/UG/PG can submit their essays through e-mails to President/Secretary/EC member of the respective regional council. Only two entries per institution may be submitted in a category.

(1) Students will send their entries duly forwarded through respective school/college/institute to the appropriate Regional Council (RC) with all contact details clearly. The RC's will have the initial scrutiny at their level. They will select 2 best essays from each level. Thus each RC will submit 6 best entries to the national competition. RCs may award certificate etc., for their participants. Even the RCs may issue a certification of Participation to those whose Essays are sent to the National Competition.

(2) For the regional competition, students may write their Essays in Hindi or their regional languages. If such entries are forwarded for the National Competition, then the concerned RCs will translate the Essay in English (with the help of Google translator etc.) Only English Version will be submitted for National Level Competition.

(3) Similarly, Teachers & Science Communicators will send their entries through e-mails duly forwarded directly to the Coordinator/Member. Retired teachers can self-attest their entry. All entries (in English only) will be scrutinized. All entries will be subjected to the online plagiarism test. **All entries will be assessed by three evaluators.**

The last date for essay submission is 30th July, 2023

Final entries for the national competition must be submitted in PDF format by e-mail to any one of the following:

1. Prof. S. K. Joshi, Coordinator, NCEWP, Mail id: joshisantoshk@yahoo.com
2. Dr. Himanshu Pandey, Member, NCEWP, Mail id: himanshukrpandey@gmail.com
3. Dr. Shivanand Masti, Member, NCEWP, Mail id: shivanandmasti@yahoo.co.in

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Prof. S. K. JOSHI (Coordinator, NCEWP-2023)