CLIMATOLOGY OF THE LOWER AND MIDDLE ATMOSPHERE

BY

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Abstract

Climate change is one of the defining issues of our time. It is now more certain than ever based on many lines of evidence that humans are changing the earth's climate. The atmosphere and oceans have warmed, accompanied by the sea level rise, strong decline in arctic sea ice, and other climate related changes. The evidence is clear however, due to the nature of science, not every single detail is ever totally settled or completely certain nor has every pertinent question yet been answered. Scientific evidence continues to be gathered around the world and assumptions and findings about climate change are continually analyzed and tested. Some areas of active debate and ongoing research include the link between the ocean heat content and the rate of warming estimate of how much warming to expect in the future and the connection between climate change extreme weather events. The focus of this study is aimed to provide a brief over view of climatology at the lower and middle atmosphere, the atmospheric variables the significance of the composition of the atmosphere and their influence on life on the earth's surface and will extremely deal with the climate system, climate system components, observed climate variability and changes. It also focuses on the effect of greenhouse gases, the carbon cycle and atmospheric carbon dioxide, aerosols, their direct and indirect climatic effects in the middle and lower atmosphere.

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Introduction

1.1 Background

The planet earth is different from the other planets of the solar system. The presence of an atmosphere is a unique feature supporting several things on the earth. The air, sea and land constitute are the major portions of the three global spheres.

Climatology is one of the branches of the earth and atmospheric science or it is the science of studying the average atmospheric conditions of a region in long term perspectives.

The primary goal of climatology is to study the unique characteristics of atmosphere in controlling the global climate, origin, types of climate cause and processes influencing the climatic variations, elements of weather and the impact of climate on humans and vice-versa. The earth's atmosphere is an essential component of the climate system. Improving knowledge of the natural variability and trends in atmospheric temperature is of vital importance for the better understanding of the climate change and its causes. Therefore consistent long term observational records of essential climate variables (ECVs) such as upper air temperature are required for the detection and attribution of climate change and for verifying climate model simulation [1].

The middle atmosphere is the region of the atmosphere encompassing the stratosphere from about 10-50 km, characterized by increasing temperatures with height, and the mesosphere from about 50-90 km. It refers to the region of the atmosphere extending from the tropopause to homo pause below which the atmosphere remains relatively well mixed. The mean temperature increases in stratosphere because in this layer the ozone absorbs the greater part of the solar ultra violet radiation and this layer is an absorbing agent that protects life on the earth [2].

The focus of this study is aimed to provide a brief over view of climatology at the lower and middle atmosphere, the atmospheric variables the significance of the composition of the atmosphere and their influence on life on the earths surface and will extremely deal with the climate system, climate system components, observed climate variability and changes. It also focus on the causes and effect of global warming, the greenhouse effect, and atmospheric carbon dioxide, aerosols, their direct and indirect climatic effects in the middle and lower atmosphere. This project work is organized as follows. Chapter two deals with characteristics of the atmosphere. In chapter three we present climate of the earth and in chapter four we discuss temperature climatology. Chapter five describes global warming and finally chapter six is summary and conclusion.

Chapter 2

Characteristics of the atmosphere

The earth's atmosphere is a mixture of different gases that surrounds the earth and absorbs the solar radiation that comes from the sun. In the atmosphere, pressure and temperature change as the distance from the surface of the earth increases to a certain height.

2.1 The evolution of the earth's atmosphere

The earth's atmosphere has been subjected to continuous change since its formation. Its primordial atmosphere starts 4 billion years ago when the material forming the earth coalesced and melted [3]. It organized it self into layers with dense materials at the core and less dense compounds closer to the surface. We know little about the origin of our atmosphere, just as we know little about the origin of our planet. In the absence of any reliable evidence, one can only speculate. According to cosmologists, our planet most likely originated from the sun about 4.6 billions of years ago in the wake of the latter's encounter with a passing star, following a cosmic event, popularly known as the big bang. After its separation from the sun, it started revolving around the sun under the effect of the sun's gravitational pull and rotating about its axis like a fiery ball, surrounded by an extremely hot gaseous envelope which may be called the primordial atmosphere. However, it may be imagined that the primordial atmosphere at that stage must have been at a great upheaval as it hurled through space and its hot gaseous envelope rapidly cooled, condensed and solidified forming a solid crust in the surface layers after giving out considerable amount of volatile hot gases and vapors from the molten material at the surface.

The part of the hot gases and vapors which cooled and condensed into water formed the world's oceans. The remainder formed a gaseous envelope around the planet or was stored in rocks. The atmosphere thus formed had a preponderance of hydrogen and little or no oxygen, so could not support life of the kind that we know on the earth today. However, as the earth cooled down further, complex chemical actions and reactions in the crust and the interactions between the crust and the atmosphere gradually led to the formation of an atmosphere which could support an early form of life such as single celled microbes which required little oxygen for their survival. Such microbial forms of life, also known as blue-green algae, perhaps, first appeared in the oceans where they absorbed carbon dioxide and in the presence of water and sunlight released oxygen by a bio-chemical process known as the green plant photosynthesis. The accumulation of oxygen in the atmosphere facilitated the evolution of more complex and multi-celled forms of life which we observe on our planet today. It is believed that all these developments occurred within the first one billion years of the earth's history and that, since then, our atmosphere has gradually stabilized to its present state [4].

2.2 Structure and composition of the atmosphere

The multilayered gaseous envelope attached to the planet earth is the atmosphere. It is a unique sphere of air, gases and water vapor. Under the study of Climatology, the structure and composition of the atmosphere are studied first, and understanding of the thickness and disposition of different layers like troposphere, stratosphere and mesosphere are needed [5]. The vertical variation in temperature and concentration of gases have a significant impact on global scales. The layer closest to the earth and concerning with weather and climate, is troposphere which contains 80 percent of the atmospheric mass and nearly all water vapor. Atmosphere is composed of three major constituents as gases, water vapor and aerosols and it is composed of about 78 percent nitrogen, 21 percent oxygen, and 0.93 percent argon. The remainder less than 0.1 percent contains trace gases such as water vapor, carbon dioxide, and ozone. All of the trace gases have important effects on the climate. The atmosphere can be divided into vertical layers determined by the temperature changes with altitude.

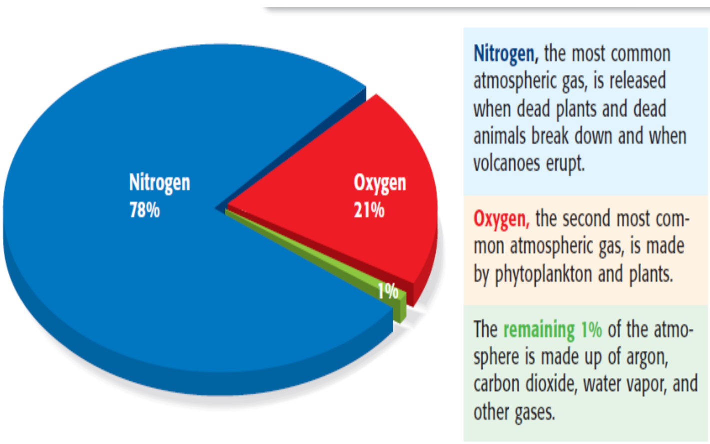

Figure 2.1: Composition of the atmosphere

2.2.1 Atmospheric thermal structure

The atmospheric layers of the Earth are characterized by variations in temperature produced by differences in the radiative and chemical composition of the atmosphere at different altitudes.

With increasing distance from earth's surface, the chemical composition of air becomes progressively more dependent on altitude and the atmosphere becomes enriched with lighter gases. Based on the temperature changes with height, the earth's atmosphere is divided into mainly four zones [6].

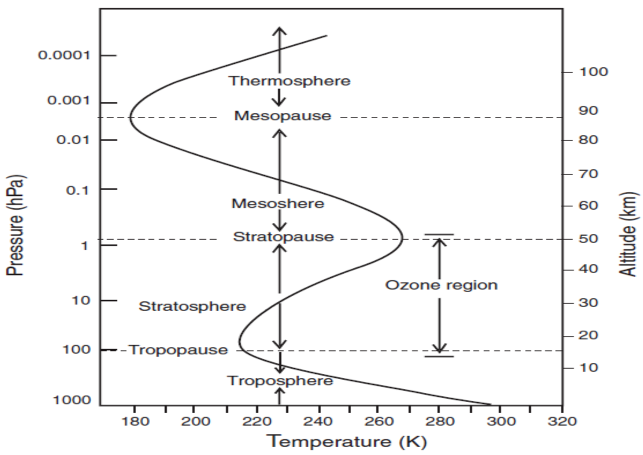

Figure 2.2: Vertical thermal structure of the earth's atmosphere [3]

2.2.2 Troposphere

The troposphere contains over 80 percent of the mass of the atmosphere, along with nearly all of the water vapor. This layer contains the air we breathe, the winds we observe, and the clouds that bring ours rain. All of what we know as weather occurs in the troposphere, the name of which means "changing sphere". All of the cold fronts, warm fronts, high and low pressure systems, storm systems, and other features seen on a weather map occur in this lowest layer. Severe thunderstorms may penetrate the tropopause. The troposphere is the lowest part of the atmosphere and is closer to the earth, and extends about 8 km above the poles and 18 km over the equator. It is the densest part of the atmosphere which contains almost all the water vapor, clouds, and precipitation. Temperature generally decreases with height in the troposphere at about 6-7 degree Celsius per kilometer in the lower half and 7-8 degree Celsius per kilometer in the upper half. Because of the general decrease of temperature with height and the presence of weather systems, the troposphere is often characterized by fairly significant localized vertical motions, although these are generally much smaller than horizontal motions. Sometimes shallow layers may be present in the troposphere in which temperature increases with height and these inversions inhibit vertical motion. The earth's surface is the major source of heat for the troposphere, although nearly all of that heat comes from the sun and the soil, the rock, and water absorb the sun's light and radiate it upward in the form of infrared heat. About 90 percent of the infrared heat radiated from the earth is then absorbed by the greenhouse gases in troposphere. The presence of water vapor, clouds, storms, and weather, contributes to the significance of the troposphere. Water vapor plays a major role in regulating air temperature because it absorbs solar energy and thermal radiation from the planet surface. The troposphere contains 99 percent of the water vapor in the atmosphere. The water vapor content, however decreases rapidly with altitude, thus reflecting the change in temperature [6].

2.2.3 The stratosphere

The stratosphere is the second layer of the atmosphere of the earth, located above the troposphere and below the mesosphere [7]. It is an atmospheric layer composed of stratified temperature layers, with the warm layers of air in the high the sky and the cool layers of air in the low sky, close to the planetary surface of the Earth. The increase of temperature with altitude is a result of the absorption of the Sun's ultraviolet (UV) radiation by the ozone layer. The temperature inversion is in contrast to the troposphere, near the earth's surface, where temperature decreases with altitude. Between the troposphere and stratosphere is the tropopause border that demarcates the beginning of the temperature inversion [8].

2.2.4 Mesosphere and thermosphere

The mesosphere is the region of the atmosphere located between the stratosphere, between 50 and 90 km in which temperature decreases with height, because there are few gas molecules in this layer of the atmosphere to absorb the sun's radiation, and the coldest temperature in the earth's atmosphere (-90 degree Celsius) are found near the top of this layer and the heat source for this region is the stratosphere below it [9]. The air in this layer has extremely low density as a result the air pressure is very low. The thermosphere is another atmospheric region from about 85 - 500 km in altitude containing ionosphere which is characterized by increasing temperature and variability, in response to changes in ultraviolet radiation and solar driven geometric activity. The upper mesosphere and the lower thermosphere contain charged atoms and molecules (ions) in a region known as the ionosphere. The atmospheric constituents at this level include nitrogen gas, atomic oxygen, and nitrogen (O and N), and nitric oxide (NO). All of these are exposed to strong solar emission of ultraviolet and x-ray radiation, which can result in ionization, knocking off an electron to form an atom or molecule with a positive charge. The ionosphere is a region enriched in free electrons and positive ions. This charged particle affects the propagation of radio waves.

2.3 Air pressure and temperature

Air pressure is the pressure caused by the gravitational pull earth. Both air pressure and temperature have significant influence on the earth's atmosphere. Atmospheric pressure is caused by the gravitational attraction of the earth on the atmospheric gases above the surface and is the function of the mass of the planet, the radius of the surface, the amount and composition of the gases and their vertical distribution in the atmosphere. The temperature has different characteristics at different layers of the atmosphere [3, 10].

2.4 Atmospheric pressure changes with altitude

Gravity pulls gas molecules in the atmosphere toward the earth's surface. As a result, there are a lot of air molecules near the earth's surface, and when a large number of air molecules are contained in a small space, those molecules exert a lot of pressure on one another and on the surface around. The distribution of atmospheric pressure is controlled by altitude, temperature, air circulation, earth's rotation, water vapor and other factors. The air pressure at any point in the atmosphere is equal to the weight of the air directly above that point and it is greatest at the earth's surface because there are a lot of air above the earth's surface. Near Earth's surface the pressure decreases with height at a rate of about 3.5 millibars for every 30 meters (100 feet). However, over cold air the decrease in pressure with altitude can be much steeper because its density is greater than warmer air. The pressure at 270,000 meters (10-6 mb) is comparable to that in the best man-made vacuum ever attained and at heights above 1,500 to 3,000 meters (5,000 to 10,000 feet), the pressure is low enough to produce mountain sickness and severe physiological problems unless careful acclimatization is undertaken. The pressure at any point in the atmosphere may be interpreted as the total weight of air above a unit area at any elevation. At higher elevation, there are fewer air molecules above a given surface than a similar surface at the lower levels. For example there are fewer molecules above the 50 km surface than are found above 12 km surface which is why the pressure is low at 50 km. Since most of the atmosphere's molecules are held close to the earth's surface, by the force of gravity, air pressure decreases rapidly at first than more slowly at higher levels. To derive how pressure depends on height h over sea level in the gravitational field of the earth, consider an arbitrary gas column with intersection area, A and height, h. Then the weight of this column is

$$F = mg \tag{2.4.1}$$

where F is weight of the column, m is the mass of the air column and g is acceleration due to gravity. The pressure exerted is the force per unit area

$$P = \frac{F}{A} = \rho g h \tag{2.4.2}$$

Where P is pressure exerted on the column of air with cross sectional area A and density ρ. Now consider a column in the atmosphere and separate a thin layer of air with height dh. Then the value of the pressure change is given by;

$$dP = -\rho g dh \tag{2.4.3}$$

The negative sign indicates that the air pressure decreases with altitude. Now consider atmospheric air as an ideal gas, so we can use the ideal gas law to express the density ρ through pressure P.

$$PV = nRT \tag{2.4.4}$$

where $n = \frac{m}{M} \Rightarrow P = \frac{mRT}{MV}$ n represents the number of moles.

$$P = \frac{\rho RT}{M} \tag{2.4.5}$$

Here V is volume of the gas, T is absolute temperature, R is universal gas constant, equal to 8.314 J/K.mol, M is molar mass which is for air is equal to 0.029 kg/mol, and n is the number of mole of the gas. It follows from the above equation that the density of the air is given by;

$$\rho = \frac{MP}{RT} \tag{2.4.6}$$

Substituting equation (2.5) in to equation (2.2) gives

$$dP = -\frac{MP}{RT} g dh \tag{2.4.7}$$

$$\frac{dP}{P} = -\frac{Mg}{RT} dh \tag{2.4.8}$$

Integrating both sides of the equation;

$$\int \frac{dP}{P} = -\frac{Mg}{RT} \int dh \tag{2.4.9}$$

$$\ln \frac{P}{P_0} = -\frac{Mgh}{RT} \tag{2.4.10}$$

$\Rightarrow \frac{P}{P_0} = \exp\left(-\frac{Mgh}{RT}\right)$

$$P = P_0 \exp\left(-\frac{Mgh}{RT}\right) \tag{2.4.11}$$

This equation shows the dependence of atmospheric pressure on altitude.

As $h \rightarrow \infty, P_0 \rightarrow 0$

Where standard temperature is equal to 288.15 K, which corresponds to the initial standard, g is acceleration due to gravity equal to 9.807 m/s^2

Density is directly proportional to pressure and inversely proportional to temperature. As pressure increases, with temperature constant, density also increases. Conversely when temperature increases, with pressure constant, density decreases. The air density depends on its temperature, its pressure and how much water vapor is in the air.

Chapter 3

Climate of the earth

Climate is the long term pattern of weather in an area typically averaged for a long period of time while the weather is a mix of events that happens for short period of time, which refers to the sum total of short term variations in atmospheric conditions in terms of temperature, pressure, wind, water vapor, clouds, precipitation and visibility in the atmosphere [11]. It is known that weather and climate have a profound influence on life on the earth. they are a part of the daily experience of human beings and are essential for the health, food production and well-beings. As the climate has influence on life on the earth, human beings also have a great influence on the climate change. Some of the elements of climate and weather includes temperature, air pressure, wind, humidity, precipitation, cloudiness and these elements are controlled by various factors like latitude, altitudes, unequal distribution of land and water, air-sea interface, ocean water circulation and geomorphological conditions. There are a lot of different types of climate on the earth. For example hot regions are normally closest to the equator which implies that the climate is hotter there because the sun is almost directly over the head at the equator and the north and the south poles are cold because the sun and heat is least direct there.

3.1 The tropical climate

This type of climate is characterized by predictable temperature patterns where its average temperature is greater than 18 degree Celsius and above year round, found at the middle band along the equator between the tropic of cancer in the northern hemisphere and the tropic of capricorn in the southern hemisphere and are not without variety and change place to place. These climates are classified depending on the koppen climate classification system which is most widely used for classifying the world climate [12]. There are two major climate in the tropical climate zone; the tropical wet climate and tropical dry climate zones. The tropical wet regions give rise to rise to tropical rain forest whenever the tropical dry regions varies between the semi desert and savanna. The two climates in the tropical zone have significance in relation to how the earth rotates around the sun. The tropic cancer and capricorn are located at 23.5 degrees north and south of the equator determined, because they mark the maximum over head sun on June 21^{st} and December21^{st} respectively. There are three basic types of the tropical climate group; the tropical rain forest, the tropical monsoon climate, and the tropical dry and savannah climate which are distinguished by the annual precipitation and precipitation level of the driest month in those regions.

3.1.1 The tropical rain forest climate

The tropical climate is one of the world's most threatened biomes, despite being home to some of most diverse and unique species on the planet. It is usually found within 10 to 15 degrees latitude of the equator. These regions experience high mean temperatures, small temperature ranges and rain that falls throughout the year. In this region all months have an average precipitation of 60mm and referred to as the lowland equatorial evergreen rain forest and the true rain forest are typically found between 10 degrees north and south of the equator. The tropical rain forest biome has four main characteristics. Very high annual rain fall, high average temperatures and nutrient-poor soil and high level of bio diversity. The climate of tropical rain forest biome is perfect for plants and animal growth. The hot and humid conditions create an ideal environment for the growth of bacteria and other microorganisms [12, 13].

3.1.2 The tropical monsoon climate

The tropical monsoon climate is found in the countries in the south and southeast Asia region between the latitude of 10 degrees north and the tropics of cancer. It is characterized by distinct wet and dry seasons associated with seasonal reversal of winds. Flood in wet seasons and drought in dry seasons are common in this climate region. It has small annual temperature range, high temperature and plentiful precipitation. There are generally two versions of the tropical monsoon climates. First less pronounced dry seasons are regions with variation of the tropical monsoon climate typically see copious amount of rain during the wet seasons usually in the form of frequent thunderstorms, however, unlike most tropical savanna climates, a sizeable amount of precipitation also falls during the dry seasons [14]. In essence, this version of the tropical monsoon climate generally has less pronounced dry seasons than the tropical savanna climate. Second extraordinarily rain wet seasons and pronounced dry seasons. this variation features pronounced dry seasons similar in length and character to dry seasons observed in tropical savanna climates. However this is followed by sustained period of extraordinary rain fall. In some instance, up to and some times in excess of 100 mm of precipitation is observed per month for more consecutive months. The tropical savanna climates generally do not see this level of sustained rain fall [15].

3.1.3 The tropical savanna climate

The tropical savanna climate have monthly mean temperature above 18 degree Celsius in every month of the year. In this area the dry season can be severe and often drought conditions prevail during the course of the year. Tropical savanna climates often feature tree-studded grass lands, rather than thick jungle. It is this widespread occurrence of tall, coarse grass (called savanna) which has led the wet climate and the tropical savanna climates often being referred to as tropical savanna. This climate regions typically pronounced, dry season with the driest month having precipitation less than 60 mm of precipitation. In essence, a tropical savanna climate tends to either see less rain fall than a tropical monsoon climate or have more pronounced dry seasons than a tropical monsoon climate. The tropical savanna climates are most commonly found in Africa, Asia and south America. The average temperature in this region is 25.4 degree Celsius and the warmest month, on average is August with average temperature of 27.7 degree Celsius. On the other hand the coldest month on average is February with average temperature of 22.8 degree Celsius. The average amount of precipitation for the year in this region is 434.3 mm and the month with the most precipitation on average is December while the month with least precipitation on average is June with an average of 7.6 mm [16].

3.2 The dry climate zone

The dry clime zone which covers about 26 percent of the world's area comprises the regions that are characterized by the dry climate. These are arid and semiarid areas has three characteristics; very low precipitation, high evaporation rates that typically exceed precipitation and wide temperature swings both daily and seasonally [17].

Precipitation:- Low and unpredictable precipitation is the primary characteristic of a dry climate. The lowest rainfall occurs in arid, or desert, areas where precipitation averages less than 35 cm (14 inches) per year, and some deserts have years with no rainfall at all. Semiarid, or steppe, regions are comprised of grasslands characterized by short grasses and scattered small bushes or sagebrush. They receive slightly more rainfall than deserts and can receive up to 70 cm (28 inches) per year. However, most semiarid regions have less than 50 cm (20 inches) of average annual precipitation.

Evaporation:- Another characteristic of a dry climate is that evaporation is often greater than precipitation. This results in a climate that lacks ground moisture due to the low average rainfall and rapid evaporation of the precipitation that does fall. For example, arid regions in the middle east average less than 20 cm of rainfall per year, but annual evaporation rates of more than 200 cm can be ten times that of precipitation. The extreme evaporation contributes to dry, coarse soils that support little plant life. Semi-arid regions with slightly more precipitation will support some grass and small bushes.

Temperature:- The third common characteristic of dry climates are wide variances in seasonal and daily temperatures. Deserts are usually found in the rain shadows of mountain ranges and have hot summers, cool nights and moderate winters. However, in cold deserts, winters can be extremely frigid. In dry climates, the sun's rays are more direct, due to the lack of humidity, and this results in extreme daily temperature swings. Desert highs can approach 40 degrees Celsius (104 Fahrenheit) or more, and in some areas, winter lows can drop well below freezing [18].

3.3 The temperate climate zone

Temperate climates of the earth are characterized by relatively moderate mean annual temperatures, with average monthly temperatures above 10 degree Celsius in their warmest months and above -3 degree Celsius in their colder months. Most regions with a temperate climate present four seasons, and temperatures can change greatly between summer and winter. Most people live in temperate zones, and human population densities in coastal regions are about three times higher than the global average. Globally, nearly all temperate coastal regions experienced net immigration during the last century, and the increasing population associated with rapid economic growth has led to extensive conversion of natural coastal wetlands to agriculture, aquaculture, and silviculture, as well as industrial and residential uses. Humans both influence and depend on the extensive ecosystem services that temperate coastal wetlands provide, sustained by biological populations and their dynamic interaction with physical and chemical properties of the environment. The interaction of biota, hydrology, and sediments is clearly evident in the ecological and geomorphologic characteristics of temperate coastal wetlands. Living organisms respond to abiotic factors such as tidal inundation, climate, groundwater, accommodation space (the space between sediment surface and mean sea level), and sediment dynamics, as well as human interventions. Based on the climate condition there are five temperate zones of the earth known as geographical zones. These are the north frigid zone, the tropics, the south frigid zone and the south temperate zone.

3.4 The continental climate zone

The continental climate zone which is characterized by variable weather pattern exists where cold air masses infiltrate during the winter and warm air masses form in summer under the conditions of high sun and long days. They tend to occur in the middle latitudes (40 to 55) degrees north./,/,It mainly occurs in the northern hemisphere which has large masses of land necessary for this type of climate to develop and where temperature is not moderated by any water body such as sea or ocean and the prevailing wind over head. Such a regions experience colder winters and hot summers since there is no water body to keep the climate milder in winter and cooler in summer. This is because rocks and soil have a lower heat capacity compared to water and also lose heat much faster. Thus, the continental climate is relatively dry as air masses that originate from the oceans far away lost before reaching the location and it is characterized by a moderate amount of precipitation, mostly concentrated in the warmer months. The precipitation is derived from the frontal cyclone and conventional showers during the summer months when the maritime tropical air pushes northwards behind retreating polar front. Most areas show distinct summer precipitation maximum with only few areas. The figure below shows the different climate zones of the earth [19, 20].

3.5 The polar climate zone

The polar climate regions surround earths north and south poles. The area around the north pole is called the arctic. The area around the south pole is called Antarctica. These regions have unique climates and they are very cold regions, because they get less direct sunlight than other places on earth. The earth rotates around the sun, but the sun doesn't reach all parts of the earth in the same way. However the area around earths equator gets a lot of sunlight in a small area. Sunlight hits the polar regions at a shallow angle [21]. This means the same amount of light is spread out over a larger area because they receive less concentrated sunlight, polar regions are much colder than other parts of the planet. In the summer, the average temperature at the north pole is zero degree Celsius and in the winter, the average temperature drops to -40 degree Celsius. The south pole is even colder. The average temperature in the summer is -28.2 degree Celsius and in the winter its -60 degree Celsius [22].

3.5.1 Land forms in polar region

We often think of deserts as being hot, but parts of polar regions are also classified as deserts too. The air in polar regions is very dry, because of the very cold temperatures of the region. Since there is not much moisture in the air, there are not many clouds or rain and snow in the region. Some polar regions get less than 25 cm of precipitation per year and this is what makes them deserts. Near the north and south poles, the temperatures can be so low that, when snow does fall, it doesn't melt. Instead, the snow builds up slowly over millions of years. In some places, the weight of many years of snow compresses it into large masses of ice. These are called glaciers. Glaciers flow, or move at very slow speeds, because they contain so much ice [23].

3.6 Climate change in the middle and lower atmosphere

The middle and the lower atmosphere are the region of the atmosphere encompassing the troposphere and the stratosphere layers characterized by increasing temperatures with height, and also includes mesosphere which ranges from about 50-90 km, where temperature decreases with height in this region. The stratosphere has received a lot of attention during the past few decades due to the depletion of the earths ozone layer. It is known that the climate change is one of the defining issues of our time [18]. It is now more certain than ever, based on many lines of evidence, that humans are changing the earths climate. The atmosphere and oceans have warmed, accompanied by sea-level rise, a strong decline in arctic sea ice, and other climate-related changes. There is no doubt that mankind contributes to climate change through activities connected with emissions of climatically relevant gases such as, use of fossil fuels with high emissions of carbon dioxide and other climate gases, especially in transportation and traffic, industrial production and application of substances (which are climate gases of extremely high warming potentials), agricultural activities (such as animal husbandry and rice cultivation) leading to emissions of methane or nitrous oxide, and methane emissions from landfills caused by ineffective waste management [24]. To control the situation, reduction measures of climate changing gases and other relevant actions, are urgently necessary on all levels. This is understood by the public and by policy makers. Climate related activities thus are high ranking on the political agenda. They are implemented into the political programmes on UN level, internationally and single countries, but also on communal levels by climate initiatives of cities or NGOs. Examples are the so-called Kyoto Protocol reducing climate gas emissions in industrialized countries, bans of halogenated hydrocarbons, shifting of energy sources from fossil to renewable and international CO_2 emission trading. It is but obvious, that the efforts must be strengthened, to reduce the risks of a dangerous interference with the climate system [25].

3.7 Climate change and health

Geological record shows that there have been a number of large variation in the earth's climate. These have been caused by many natural factors. The main cause of the climate change includes: human activities, burning fossils fuels such as (oil, gas and coal) have fundamentally increased the concentration of greenhouse gases in the earth's surface warming the planet [26]. The best evidence for warming the earth's surface comes from wide spread thermometer records that in some places extend back to the late 19^{th} century and today temperatures are monitored at many thousands of location. There are a lot of factors that influence the climate change. These are elevation or altitude, prevailing global wind patterns, topography, effect of geography, Surface of the earth and, the climate change over time. The above factors generally are influences for the climate change. Global climate change is therefore the most factor to the spectrum of environmental health hazards faced by humankind. The climate change together with human activities and other natural factors, challenges has great influences on human health and deaths in different ways. Some existing health treats will intensify and new health will emerge. In general even though the climate change at different times has some localized benefits such as fewer winter death in temperate climates and increased food production in a certain areas, the overall health effect of a changing climate are very high compared to its benefits [27].

3.8 Climate change and vegetation

We human beings need plants for our survival. Everything we eat consists of plants or animals that depend on plants somewhere along the food chain. Plants also form the backbone of natural ecosystems, and they absorb about 30 percent of all the carbon dioxide emitted by humans each year. Rising levels of CO_2 in the atmosphere drive an increase in plant photosynthesis. Because plants take up carbon dioxide from the atmosphere and convert it into food, forests and other similar ecosystems are considered to be some of the planets most important carbon sinks. In fact, the United States and many other countries that participated in UN climate change conference have made nature-based solutions critical feature of their carbon dioxide mitigation framework under the Paris agreement. As human activities cause more carbon dioxide to be emitted into the atmosphere, scientists have debated whether plants are responding by photosynthesizing more and sucking up even more carbon dioxide than they already do and if so, it is a little or a lot more. Since carbon dioxide stays in the atmosphere decades longer than other greenhouse gases driving global warming, efforts to reduce it are critical to mitigating climate change [2, 28]. Plants, through photosynthesis, and soils sequester roughly a third of carbon dioxide emissions released into the atmosphere each decade from the burning of fossil fuels. During photosynthesis, plants open tiny pores on their leaf surfaces to suck carbon dioxide from the air and produce their own food and to measure this photosynthetic activity, scientists can put a leaf in a closed chamber and quantify the dropping carbon dioxide levels in the air inside; but its far more difficult to measure how much carbon dioxide an entire forest takes up. Photosynthesis is the process by which green plants and certain other organisms transform light energy into chemical energy. During photosynthesis in green plants, light energy is captured and used to convert water, carbon dioxide, and minerals into oxygen and energy-rich organic compounds.

Chapter 4

Temperature climatology

4.1 Temperature

The vertical distribution of temperature and wind structure of the lower and middle atmosphere has been studied extensively for several decades using a variety of techniques. A large number of measurements have been made by using balloons, aircrafts, radiosonde, rocket and satellite observations, both spatially and temporally, on a global scale. Based on the global observations, and modeling information, stratospheric process and its influence on climate has prepared a reference climatology of the middle atmosphere. measurements of global surface air temperature show substantial increases over the past several decades. In the early 1990s, data from the national oceanic and atmospheric administration's (NOAA's) polar orbiting satellites were analyzed for multi-decadal trends. These initial analysis indicated that global-mean temperatures in the troposphere showed little or no increase, in contrast with surface air measurements from ships, land-based weather stations, and ocean buoys. This result led some to question the reality and or the cause of reported global-mean surface temperature increases, on the basis that human influences, thought to be important contributors to observed change, were expected to increase temperatures both at the surface and in the troposphere, with the largest increases expected in the tropical troposphere. This led to an intensive effort by climate scientists to better understand the causes of the apparent differences in the reported rates of temperature changes between the surface and the troposphere [29].

4.2 Temperature lapse rate

In the lowest part of the earth's atmosphere, air temperature generally decreases with altitude and the temperature lapse rate is the rate at which the temperature of the atmosphere falls with altitude. it corresponds to the vertical component of the spatial component of the atmosphere. The decrease in atmospheric temperature with height, is expressed as the negative of the rate of temperature change with altitude.

$$\Gamma = -\frac{dT}{dZ} \tag{4.2.1}$$

where Γ is lapse rate in temperature per altitude, T is temperature and Z is altitude.

The origin of lapse rate can be understood on the bases of fundamental thermodynamics.

4.2.1 Dry adiabatic lapse rate

From ideal gas equation

$PV = nRT$

where n represents the number of mole for one mole of a gas, P is pressure of the gas, V is the volume, T is temperature, and R is the molar gas constant and differentiating it, we get

$$PdV + VdP = RdT \tag{4.2.2}$$

From the first law of thermodynamics

$$dU = dQ - PdV \tag{4.2.3}$$

Where U is the internal energy,and the heat transferred. For adiabatic process, there is no heat transfer into and out of the system and hence,

$dU = C_v dT$.

$$C_v dT = -PdV \tag{4.2.4}$$

$$dT = -\frac{PdV}{C_v} \tag{4.2.5}$$

$$PdV + VdP = -\frac{RPdV}{C_v} \tag{4.2.6}$$

$$PdV\left[1 + \frac{R}{C_v}\right] = -VdP \tag{4.2.7}$$

$$PdV\left[\frac{C_v + R}{C_v}\right] = -VdP \tag{4.2.8}$$

$$PdV = \frac{C_v}{C_p}VdP \tag{4.2.9}$$

where $C_p = \frac{-1}{C_v+R}$

$\gamma = \frac{C_p}{C_v}$

C_p is the specific heat capacity at constant pressure and C_v is specific heat capacity at constant volume.

here C_v is the heat capacity at constant volume and C_p is specific capacity at constant pressure.

$$PdV = -\frac{VdP}{\gamma} \tag{4.2.10}$$

$$PdV = -C_v dT \tag{4.2.11}$$

$$C_v dT = \frac{VdP}{\gamma} \tag{4.2.12}$$

$$C_v = mc_v \tag{4.2.13}$$

Where c_v is specific heat capacity and m is mass of the gas.

$$mc_v dT = \frac{VdP}{\gamma} \tag{4.2.14}$$

$$c_v dT = \frac{V}{m}\frac{dP}{\gamma} \tag{4.2.15}$$

$$c_v dT = \frac{\alpha dP}{\gamma} \tag{4.2.16}$$

Where α is specific volume

$$\gamma c_v dT = \alpha dP \tag{4.2.17}$$

$$dT = \frac{\alpha}{c_p}dP \tag{4.2.18}$$

where α is specific volume. Assuming that an atmosphere in hydrostatic equilibrium, we have

$$dP = -\rho g dZ \tag{4.2.19}$$

where g is standard gravity, ρ, is density of the gas, and z is altitude. Combining equations (4.18) and (4.19) to eliminate the pressure we arrive at a result for dry adiabatic lapse rate.

Γ_d = -$\frac{dT}{dZ}$

$\Rightarrow \Gamma_d = (\frac{\alpha \rho g dZ}{C_p dZ})$

$$\Gamma_d = \frac{\rho \alpha g}{C_p} \tag{4.2.20}$$

4.2.2 Moist adiabatic lapse rate

The presence of water within the lower atmosphere complicates the process of convection. water vapor contains latent of vaporization. As parcel of air rises and cools, it eventually becomes saturated; that is the vapor pressure of water in equilibrium with liquid water has decreased as temperature has decreased to the point where it is equal to the actual vapor pressure of water. With further decrease in temperature the water vapor in excess of equilibrium amount condenses, forming cloud and releasing heat. Before saturation, the rising air follows the dry adiabatic lapse rate and after saturation the rising air follows moist adiabatic lapse rate. the release of latent heat is an important source of thunderstorms [30]. To find how the temperature changes as we move up from the surface, we begin with the first law of thermodynamics.

$$C_p dT - \alpha dp = dQ = -L dW_s \tag{4.2.21}$$

The heat exchange between the air parcel and its environment is zero, but heat is released within the air parcel by the phase change from water vapor to liquid water (ice). As vapor is converted to liquid water, $W = W_s$ decreases and $dQ = -L dW_s$ and $dW_s < 0$.

where L is latent heat of vaporization and W_s is mixing ratio.

$$C_p dT - \alpha dP = -L\left(\frac{\partial W_S}{\partial T} dT + \frac{\partial W_s}{\partial P} dP\right) \tag{4.2.22}$$

$$\left(C_p + L\frac{\partial Ws}{\partial T}\right) dT = \left(\alpha + L\frac{\partial W_S}{\partial P}\right) dp \tag{4.2.23}$$

$$\frac{dT}{dp} = \frac{\alpha + L\frac{W_s}{P}}{C_p + L\epsilon\frac{LW_s}{R_d T^2}} \tag{4.2.24}$$

$$\frac{dT}{dP} = \frac{\alpha}{C_p}\left[\frac{1 + \frac{LWs}{R_d T}}{1 + \frac{\epsilon L^2 W_s}{C_p R_d T^2}}\right] \tag{4.2.25}$$

We know that

$$\Gamma_s(T, P) = -\frac{dT}{dZ} = \rho g\frac{dT}{dP} \tag{4.2.26}$$

$$\Gamma_s(T, P) = \frac{g}{C_p}\left[\frac{1 + \frac{LW_s}{R_d T}}{1 + \frac{\epsilon L^2 W_s}{C_p R_d T^2}}\right] \tag{4.2.27}$$

This means that the moist adiabatic lapse rate is not constant, but a function of temperature and pressure. Notice that the denominator differs from the numerator by $\frac{\epsilon L}{C_p T}$ which is roughly larger than unity, so the denominator exceeds the numerator so $\Gamma_s < \Gamma$. This means that the temperature changes more slowly along a moist adiabatic than along a dry adiabatic. The reason is the release of latent heat by the condensation of vapor to liquid water. It can be shown that $\frac{LW_s}{R_d T}$ increases with increasing temperature (because W_s increases with T), so Γ_s decreases with increasing temperature. Also, because Ws decreases with increasing pressure, Γ_s increases with increasing pressure. The slope of a moist adiabatic increases and approaches that of a dry adiabatic as pressure and temperature decreases. While the dry adiabatic lapse rate is constant, however the moist adiabatic lapse rate varies strongly with temperature.

4.3 Temperature variation between troposphere and stratosphere

The troposphere is heated from the ground, so the temperature decreases with altitude. The reason is that the troposphere's gases absorb very little of the incoming solar radiation. Instead the ground absorbs this radiation and then heats the tropospheric air by conduction and convection. In stratosphere, temperature increases with altitude. The stratosphere contains the ozone layer which protects the planet from the suns harmful UV radiation. The reason why the stratosphere is warmer than the troposphere is that ozone molecules in the layer absorbing energy ultraviolet (UV) light from the sun, converting the UV energy in to heat. Unlike the troposphere, stratosphere actually gets warmer the higher we go and that trend of rising temperatures with altitude means that air in the stratosphere lacks the turbulence and updrafts of the troposphere beneath [31].

4.4 The ozone in atmosphere

Ozone is formed throughout the atmosphere in multi-step chemical processes that require sunlight. In the stratosphere, the process begins with an oxygen molecule (O_2) being broken apart by ultraviolet radiation from the Sun. In the lower atmosphere (troposphere), ozone is formed in a different set of chemical reactions involving hydrocarbons and nitrogen-containing gases. Ozone is a gas that is naturally present in our atmosphere. Each ozone molecules contains three atoms of oxygen and denoted chemically as O_3. It is found in two regions of the atmosphere. about 10 percent of the atmospheric ozone is in the troposphere (the region closest to the earth from 10-16 km above the surface of the earth), while the remaining ozone about 90 percent resides in the stratosphere between the top of the troposphere (tropopause) and about 50kms altitude. The large amount of the ozone in stratosphere is known as the ozone layer [32].

4.4.1 Tropospheric ozone production

Near earths surface, ozone is produced in chemical reactions involving naturally occurring gases and gases from pollution sources. Production reactions primarily involve hydrocarbon and nitrogen oxide gases and require sunlight. Fossil fuel combustion is a primary pollution source for tropospheric ozone production. The surface production of ozone does not significantly contribute to the abundance of stratospheric ozone. The amount of surface ozone is too small in comparison, and the transport of surface air to the stratosphere is not effective enough. As in the stratosphere, ozone in the troposphere is destroyed in naturally occurring chemical reactions and in reactions involving human-produced chemicals. Tropospheric ozone can also be destroyed when ozone reacts with a variety of surfaces, such as those of soils and plants.

4.4.2 Stratospheric ozone production and depletion

Stratospheric ozone is naturally formed in chemical reactions involving ultraviolet sunlight and oxygen molecules, which make up 21 percent of the atmosphere. In the first step, sunlight breaks apart one oxygen molecule (O_2) to produce two oxygen atoms ($2O$). In the second step, each atom combines with an oxygen molecule to produce an ozone molecule (O_3). These reactions occur continually wherever ultraviolet sunlight is present in the stratosphere. As a result, the greatest ozone production occurs in the tropical stratosphere. The production of stratospheric ozone is balanced by its destruction in chemical reactions. Ozone reacts continually with a wide variety of natural and human produced chemicals in the stratosphere. In each reaction, an ozone molecule is lost and other chemical compounds are produced. Important reactive gases that destroy ozone are those containing chlorine and bromine. Some stratospheric ozone is transported down into the troposphere and can influence ozone amounts at Earths surface, particularly in remote, unpolluted regions of the globe [33].

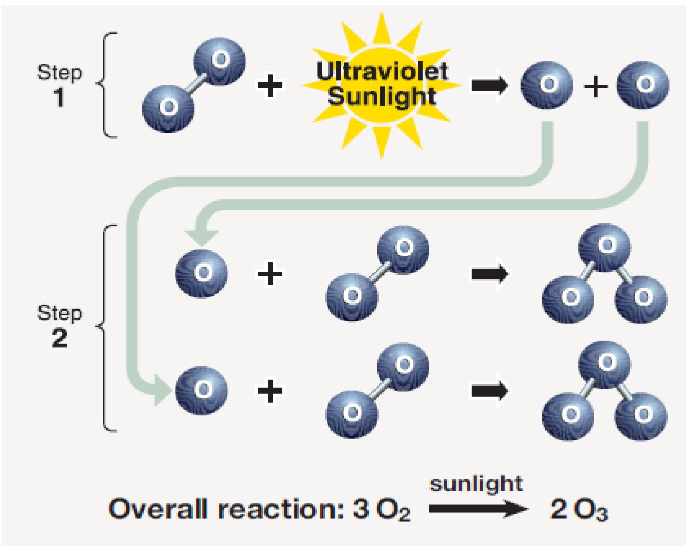

Figure 4.1: Production of ozone in stratosphere

Stratospheric ozone(O_3) is produced by combination of oxygen atom with oxygen molecule(O_2) and the reaction is expressed as

$O_2 + UV \rightarrow O + O$

$2O + 2O_2 \rightarrow 2O_3$ The above process shows the ozone production in the atmosphere. On the other hand UV radiation also involved destruction of ozone molecule(O_3). It is expressed as

$O_3 + UV \rightarrow O + O_2$

$O + O_3 \rightarrow 2O_2$

The net reaction is;

$2O_3 + UV \rightarrow 3O_2$ If there are no ozone depleting gases in the atmosphere, nature will keep this ozone production and ozone destruction processers in balance.

4.4.3 Use and impacts of stratospheric ozone

The stratosphere is the region of the atmosphere which exists between 10- 50 km above the surface of the earth, and solar wave lengths in the ultraviolet range (180 - 240) nm are absorbed by and break apart oxygen molecules, then some of the resulting unattached pair of oxygen atoms then recombine into triples to form the ozone molecule. A different range of wave lengths of ultraviolet (290 - 300) nm are strongly absorbed by ozone, which breaks down as a result and reforms it into molecular oxygen again, during the production and destruction process. The stratospheric ozone is naturally occurring gas that filters the sun's ultraviolet (UV) radiation [34]. The ozone in this layer is typically regarded as good ozone since it reduce the harmful effects of the UV radiation. A diminished ozone layer allows more radiation to reach the earth's surface and exposure to UV at the surface of the earth has been shown to cause harmful effects in plants and animals, therefore absorption of UV by ozone in stratosphere reduces the amount of UV reaching the earth's surface and generates heat that plays a role in maintaining the temperature structure of the atmosphere. The ozone that that occurs in troposphere is a much smaller proportion of the total planetary ozone and it is regarded as bad ozone, since it reacts easily with other molecules making it highly toxic to all living organisms and it also have a negative impacts on such things as crop production, forest growth, and human health.

Chapter 5

Global warming

Global warming is the gradual increase in the earths temperature generally due to the greenhouse gases which warm the atmosphere by tapping heat which is known as the greenhouse effect caused by increased level of carbon dioxide, CFCs, and other pollutants. Green house effect occurs when gases in the earth's atmosphere trap the sun's heat. The increase in temperature of the atmosphere due to the greenhouse causes global warming. Scientists agree that the earth's rising temperature are fueling longer and hotter heat waves, more frequent drought, heavier rain fall and more powerful hurricanes. This phenomenon has been observed over the past one or two centuries. This change has distributed the climatic pattern of the earth. Scientists have provided relevant data in support of the fact that temperature of the earth is rising constantly. There are two major causes for the global warming. Man-made and natural causes. There are several causes for global warming which have negative effect on humans, plants, and other animals on the earth's surface. The cause of global warming natural or the outcome of human activities. In order to curb the issues it is very important to understand the negative impact of global warming [35].

5.1 Greenhouse gases and their impacts for global warming

Greenhouse gases are the main responsible gases for the greenhouse effect and warms the earth's atmosphere by trapping infrared waves radiated from the earth. Human activities are responsible for almost all of the increase in greenhouse gases in the atmosphere. The primary greenhouse gases in the earths atmosphere are: Water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and ozone (O_3). Without the greenhouse gases, the average temperature of the earth's surface would be -18 degree Celsius rather than the present average of 15 degree Celsius [36].

Carbon dioxide:- Carbon dioxide is in important trace gas in the earths atmosphere. It is also of the greenhouse gas that warms the earths atmosphere by trapping infrared waves emitted from the earth as heat energy. It accounts for about 75 percent of global human caused activities and is the largest contributor for the global warming. When sun light reaches the earth, the earth surface absorbs some of the light energy and reradiates it as infrared waves into the atmosphere which we feel as heat. This infrared travel up into the atmosphere and will escape back into space if unimpeded. Oxygen and nitrogen do not interfere with infrared wave in the atmosphere since they absorb energy that has tightly packed wave length of less than 200 nanometer, where as infrared energy travels at wider and lazier wave length of 700-1000,000 nanometers. This ranges do not overlap with wave length of oxygen and nitrogen. They let the infrared wave freely to the space. However carbon dioxide (CO_2) absorbs the infrared energy at a variety of wave lengths between 2000-15,000 nanometer and can overlaps with infrared wave. As carbon dioxide soaks up the energy, it vibrates and re-emits the infrared energy back to in all directions. About half of it goes to the space and about half returns back to the earth. Carbon dioxide is also an important component of the atmosphere that warms it and keeps the atmosphere extreme cooling. It is released into the atmosphere through natural process such as respiration and volcanic eruptions, and through human activities deforestation, land use changes,and burning fossil fuels [37].

Methane:- Methane is a potent greenhouse gas with warming potential of more than 28 times that of Carbon dioxide. It is hydrocarbon gas produced both in natural sources and human activities in the atmosphere. and is emitted during the production and transport of coal, natural gas, and oil. Methane emissions also result from livestock and other agricultural practices, land use and by the decay of organic waste in municipal solid waste landfills. In 2019, methane (CH_4) accounted for about 10 percent of all greenhouse gas emissions from human activities. Human activities emitting methane include leaks from natural gas systems and the raising of livestock. In addition, natural processes in soil and chemical reactions in the atmosphere help removeCH_4 from the atmosphere. Methane's lifetime in the atmosphere is much shorter than carbon dioxide (CO_2), but CH_4 is more efficient at trapping radiation than CO_2. Methane has relatively short life time to stay in the atmosphere compared to carbon dioxide which stays for hundreds of years. After about 12 years, 80-89 percent of a methane is removed by oxidation with tropical hydroxyl radicals (OH), by a process known as hydroxyl oxidation. As a result of short lifespan, methane is only significant warming our atmosphere for about 12 years and which is why it is considered as short lived climate pollutant gases. It is derived from atmospheric carbon such as carbon dioxide and eventually it returns to the atmosphere as carbon dioxide, making it recycled carbon. Methane is also involved in the ground level formation of ozone, which is an air pollutant and bad for human health.

Nitrous oxide:-Nitrous oxide (N_2O) is an other powerful greenhouse gases which causes global warming in the atmosphere. It is accounted for about 7 percent of all greenhouse gas emissions from human activities. Human activities such as agriculture, fuel combustion, waste water management, and industrial processes are increasing the amount of N_2O in the atmosphere. Nitrous oxide is also naturally present in the atmosphere as part of the Earth's nitrogen cycle, and has a variety of natural sources. Nitrous oxide molecules stay in the atmosphere for an average of 114 years before being removed by a sink or destroyed through chemical reactions. The impact of 1 pound of N_2O on warming the atmosphere is almost 300 times that of 1 pound of carbon dioxide. Globally, about 40 percent of the total N_2O emissions come from human activities. Nitrous oxide is emitted from agriculture, land use, transportation, industry, and other activities.

Water vapor:- Water vapor is the most abundant greenhouse gas in the atmosphere both by weight and by volume. It absorbs longer wave radiation and re-radiate back to the surface of the earth contributing to warming the atmosphere. When compared to other green house gases, water vapor stays in the atmosphere for much shorter period of time. It will generally stays in the atmosphere for a days thus contributing to warming of an extended period of time. Warmer air in the atmosphere is able to hold more moisture. As the climate warms, air temperature rises, more evaporation from water sources and land occurs, thus increasing the atmospheric moisture content. The increase in water vapor of the atmosphere contributes to even more warming.

Tropospheric ozone as green house gas :- Ozone (O_3) is a reactive gas that exists in two layers of the atmosphere: the stratosphere (upper layer) and the troposphere (at ground level and up to 15km). In the stratosphere, ozone protects life on Earth from the suns ultraviolet radiation. In contrast, at lower levels, it is an important greenhouse gas and air pollutant, which is harmful to human and ecosystem health. It is also a major component of urban smog. Tropospheric ozone is a short-lived climate pollutant gas with an atmospheric lifetime of about hours to weeks. Strategies to prevent the formation of tropospheric ozone are primarily based on methane reductions and cutting the levels of atmospheric pollution arising from man-made sources, such as agriculture and fossil fuel production and distribution.

In the troposphere, ozone is the product of the atmospheric reaction of a number of precursor pollutants, which have both natural and man-made sources. Precursor pollutants created by human activities include hydrocarbons and nitrogen oxides, which are largely emitted by cars and other vehicles, fossil fuel power plants, oil refineries, the agriculture sector and a number of other industries.

The climate impact of ozone is, it absorbs radiation and consequently acts as a strong greenhouse gas. Tropospheric ozone affects the climate beyond increased warming, having impacts on evaporation rates, cloud formation, precipitation levels, and atmospheric circulation. These impacts mainly occur within the regions where tropospheric ozone precursors are emitted, and so disproportionally affect the Northern Hemisphere. In the case of human health, Tropospheric ozone is a major component of smog, which can worsen bronchitis and emphysema, trigger asthma, and permanently damage lung tissue. Tropospheric ozone exposure is responsible for an estimated one million premature deaths each year. Children, the elderly, and people with lung or cardiovascular diseases are particularly at risk of the adverse health impacts of ozone.

5.2 Man made causes of global warming

Deforestation:- We know that plants are the sources of oxygen. They take in carbon dioxide and release oxygen thereby maintaining environmental balance. Forests are being depleted for many domestic and commercial purposes. This has led to environmental imbalance consequently this leads to global warming.

Use of vehicles :- The use of vehicles, even for a short distance results in various gaseous emissions. Vehicles burn fossil fuels which emit a large amount of carbon dioxide and other toxins into the atmosphere resulting in surface temperature increases.

Clorofluorocarbons:- Chlorofloro carbons (CFCs) are synthetic compounds entirely of industrial origin used in a number of applications but nowadays largely regulated in production and release to the atmosphere by international agreement for their ability to contribute to destruction of the ozone layer in the stratosphere. They are greenhouse gases composed of carbon, hydrogen, chlorine, and fluorine once used widely as aerosols, propellants, refrigerants, solvents and with the extensive use of air conditions and refrigerators. Humans have been adding CFCs into the environment which affects the atmospheric ozone layer. The ozone layer protects the earth surface(life on the earth) from harmful incoming solar radiation emitted by the sun. The CFC has led to ozone layer depletion making way of the ultraviolet rays thereby increasing the temperature of the earth.

Industrial development:- Industrial development is another cause for global warming. With the advent of industrialization, the temperature of the earth has been increasing rapidly. This is because the harmful emission from the factories leads to the increasing temperature of the earth. In 2013 Inter governmental panel for climate change(IPCC) reported that the temperature is widely increasing.

Agriculture:- Agriculture activities produce carbon dioxide and methane gases. This adds to the greenhouse gases in the atmosphere as a result increase the temperature of the earth. Agriculture activities produce carbon dioxide and methane gases. This adds to the greenhouse gases in the atmosphere as a result increase the temperature of the earth.

5.3 The El Nino oscillation

The El Nino Southern Oscillation (ENSO) is an irregular periodic variation in winds and sea surface temperatures over the tropical eastern Pacific Ocean, affecting the climate of much of the tropics and subtropics. The warming phase of the sea temperature is known as El Nino and the cooling phase is called La Nina. By influencing global temperatures and precipitation, the El Nino Southern Oscillation (ENSO) significantly impacts the Earths ecosystems and human societies. El Nino and La Nina are opposite extremes of the ENSO, which refers to cyclical environmental conditions that occur across the Equatorial Pacific Ocean. These changes are due to natural interactions between the ocean and atmosphere [38].

Sea surface temperature, rainfall, air pressure, atmospheric and ocean circulation all influence each other. An El Nino condition occurs when surface water in the equatorial Pacific becomes warmer than average and east winds blow weaker than normal. The opposite condition is called La Nina. During this phase of ENSO, the water is cooler than normal and the east winds are stronger. El Ninos typically occur every 3 to 5 years.

An El Nino southern oscillation (ENSO) is just one of many oscillations in Earths ocean and atmosphere that occur naturally over different time and geographic scales. El Nino, Spanish for "the little boy" or "the Christ child," was named by Peruvian fishermen when they noticed changes in anchovy populations around Christmas more than 100 years ago caused by uncharacteristically warm surface water in the eastern tropical Pacific Ocean. Much later, scientists realized that El Nino was part of a much larger, recurring phenomenon that can bring about abnormal and often severe changes in temperature and precipitation throughout the tropics.

5.3.1 The El Nino oscillation and its impacts on the climate change

We know that El Nino is characterized by unusually warm ocean temperature in the equatorial pacific, as opposed to La Nina, which is characterized by usually cold ocean temperatures in the equatorial pacific. El Nino Southern Oscillation (ENSO) is a powerful climate phenomenon that exerts profound impacts on the global climate and accounts for the major skill source of seasonal to inter annual climate prediction. Episodic shifts in winds and water currents across the equatorial Pacific can cause floods in the South American desert while stalling and drying up the monsoon in Indonesia and India. Atmospheric circulation patterns that promote hurricanes and typhoons in the Pacific can also knock them down over the Atlantic. Fish populations in one part of the ocean might crash, while others thrive and spread well beyond their usual territory.

During an El Nino event, the surface waters in the central and eastern Pacific Ocean become significantly warmer than usual. That change is intimately tied to the atmosphere and to the winds blowing over the vast Pacific. Easterly trade winds (which blow from the Americas toward Asia) falter and can even turn around into westerlies. This allows great masses of warm water to slosh from the western Pacific toward the Americas. It also reduces the upwelling of cooler, nutrient-rich waters from the deepshutting down or reversing ocean currents along the equator and along the west coast of South and Central America.

The circulation of the air above the tropical Pacific Ocean responds to this tremendous redistribution of ocean heat. The typically strong high-pressure systems of the eastern Pacific weaken, thus changing the balance of atmospheric pressure across the eastern, central, and western Pacific. While easterly winds tend to be dry and steady, Pacific westerlies tend to come in bursts of warmer, moister air.

During normal conditions in the Pacific ocean, trade winds blow west along the equator, taking warm water from South America towards Asia. To replace that warm water, cold water rises from the depths a process called upwelling. El Nino and La Nina are two opposing climate patterns that break these normal conditions. During El Nino, trade winds weaken. Warm water is pushed back east, toward the west coast of the Americas.

Perhaps no where is the intricate relationship between the ocean and the atmosphere more evident than in the eastern Pacific. The oceans surface cools and warms cyclically in response to the strength of the trade winds. In turn, the changing ocean alters rainfall patterns. This series of images shows the dance between ocean and atmosphere. Changes in rainfall, right, echo changes in sea surface temperature, left. Many people recognize the extreme ends of the spectrum, El Nino and La Nina, by the severe droughts and intense rains each brings to different parts of the world.

El Nino occurs when warm water builds up along the equator in the eastern pacific. The warm ocean surface warms the atmosphere, which allows moisture-rich air to rise and develop into rainstorms. The clearest example of El Nino in this series of images is 1997. The unusually warm waters are dark purple in the sea surface temperature anomaly image, indicating that waters were as much as 6 degrees Celsius warmer than average. The corresponding streak of dark blue in the rainfall anomaly image reveals that as much as 12 millimeters more rain than average fell over the warmed eastern Pacific. The unusual rainfall extended into northwestern South America (Ecuador and Peru). The disruption in the atmosphere impacts rainfall throughout the world. In the United States, the strongest change in rainfall is in the southeast, the region closest to the pool of warm pacific water. During El Nino years, such as 1997, the southeast receives more rain than average.

5.3.2 The EL Nino in Africa

A wide range of sea surface temperature (SST) expressions have been observed during the El Nino Southern Oscillation events of 1950 2010, which have occurred simultaneously with different global atmospheric circulations. This study examines the atmospheric circulation and precipitation during December March 1950 - 2010 over the African Continent south of 15 degrees south, a region hereafter known as Southern Africa, associated with eight tropical Pacific sea surface temperature expressions characteristic of El Nino and La Nina events. The self-organizing map method along with a statistical distinguishably test was used to isolate the sea surface temperature expressions of El Nino and La Nina.

The seasonal precipitation forcing over Southern Africa associated with the eight sea surface temperature expressions was investigated in terms of the horizontal winds, moisture budget and vertical motion. El Nino events, with warm sea surface temperature across the east and central Pacific Ocean and warmer than average sea surface temperature over the Indian Ocean, are associated with precipitation reductions over Southern Africa. The regional precipitation reductions are forced primarily by large scale mid - tropospheric subsidence associated with anticyclonic circulation in the upper troposphere.

El Nino events with cooler than average sea surface temperature over the Indian Ocean are associated with precipitation increases over Southern Africa associated with lower tropospheric cyclonic circulation and mid-tropospheric ascent. La Nina events, with cool sea surface temperature anomalies over the central Pacific and warm sea surface temperature over the west Pacific and Indian Ocean, are associated with precipitation increases over Southern Africa. The regional precipitation increases are forced primarily by lower tropospheric cyclonic circulation, resulting in mid-tropospheric ascent and an increased flux of moisture into the region.

5.3.3 El Nino in Ethiopia

El Nino is warming of the sea surface temperature of the Pacific Ocean. Extreme flooding, drought, lack of potable water for livestock and domestic use, food insecurity and market imbalance are associated with El Nino and La Nina in Ethiopia. Drought following El Nino caused 50 to 90 percent of crop failure, in the eastern parts of Ethiopia. El Nino episodes are detected using different statistical indices such as Oceanic Nino index (ONI), agricultural stress index system (ASIS) and the southern oscillation index (SOI), with magnitude ranging from weak to strong.

Identifying the El Nino and La Nia seasons it is very important to adopt suitable adaptation strategies, which can resolve and/or reduce the negative impacts. Early warning and immediate support to the impacted areas have been carried out to minimize risks from El Nino animal feed for livestock from other areas has been transported to the vulnerable areas. Planting early maturing and drought resistant crops, supplementary irrigation, early waning information on weather and climate have been exercised as climate change adaptation strategies, early warning mechanisms by the government of Ethiopia. El Nino and La Nina are natural phenomena; however, it is necessary to study the occurrence and distribution of El Nino and La Nina episodes to enable early warning and identify suitable adaptation strategies and policy implications in the country. El Nio in Ethiopia Program observations on the impact of the Ethiopia drought and recommendations for action Ethiopia is facing a massive drought and food insecurity crisis. The impact of failed rains and droughts have been worsened by the 2015 El Nino, which itself has been supercharged by climate change. Urgent humanitarian action is needed to support millions of people who have lost food, water and livelihoods. And long-term investment is needed so that communities can become more resilient and reduce their vulnerability to weather events in the future.

5.4 Natural causes of global warming

The forest fire:- Deforestation by nature is another leading cause of global warming. Natural forest fires are usually televised on news, showing the devastation of mountain homes and communities. While this loss is tragic ,the effect of this natural occurring forest fires pose a problem for the earths air. Forest fires emit carbon filled smoke into atmosphere, and on other new forests is slow and not stable enough to produce much needed oxygen into the newly suffocating carbon air. The natural forest fires will eventually run their course, but left in the ashes are polluting gases that get trapped in the atmosphere. Forest fires create global warming by emitting the green house gases, like carbon dioxide, smoke, ash and by heat conduction from the burning bushes to the atmosphere.

Permafrost :- Permafrost is a permanently frozen layer on or under Earth's surface. It consists of soil, gravel, and sand, usually bound together by ice. Permafrost usually remains at or below zero degree Celsius for at least two years. Permafrost can be found on land and below the ocean floor. It is found in areas where temperatures rarely rise above freezing. This means permafrost is often found in Arctic regions such as Greenland, the U.S. state of Alaska, Russia, China, and Eastern Europe. Permafrost thickness can range from one meter (about three feet) to more than 1,000 meters (about 3,281 feet). Permafrost covers approximately 22.8 million square kilometers (about 8.8 million square miles) in Earth's Northern Hemisphere. Frozen ground is not always the same as permafrost. A layer of soil that freezes for more than 15 days per year is called "seasonally frozen ground". A layer of soil that freezes between one and 15 days a year is called "intermittently frozen ground". Permafrost is frozen for two years or more. Permafrost does not always form in one solid sheet. There are two major ways to describe its distribution: continuous and discontinuous. Continuous permafrost is just what it sounds like; a continuous sheet of frozen material. Continuous permafrost extends under all surfaces except large bodies of water in the area. The part of Russia known as Siberia has continuous permafrost. When frozen soil, constituting about 25 percent of the northern hemisphere, increases, it keeps in the carbon and methane gases. So, while thinking about how it can be global warming when we are still freezing in Tibet, the permafrost is actually leaking carbon into the earth's atmosphere. While scientists cannot stop permafrost from emitting these gases, the earth's melting icecaps at incredibly fast rates are causes for concern.

Sunspots :- The Sun is a highly active and complicated body. Its behavior does change over time and this can affect our climate. But these impacts are much smaller than those caused by our burning of fossil fuels and, crucially, they do not build up over time. The main change in the Sun is an 11- years Solar cycle of high and low activity, which initially revealed itself in a count of sunspots. Sunspots have been observed continuously since 1609, although their cyclical variation was not noticed until much later. At the peak of the cycle, about 0.1 percent more Solar energy reaches the Earth, which can increase global average temperatures by 0.05-0.1 degree Celsius. This is small, but it can be detected in the climate record. It's smaller than other known sources of temperature variation, such as volcanoes (for example, the large eruption of Mt Pinatubo, in the Philippines in 1991, cooled Earth by up to 0.4 degree Celsius for several years) and the El Nio Southern Oscillation, which Causes variations of up to 0.4Celsius. According to the environmental protection agency(EPA), sunspots are increasing the global temperature. Sunspots restrict the passing of solar plasma which in turn gives off radiation. Sunspots and solar flares are powerful and unstoppable. They can change the energy radiating to the earth's atmosphere, and thus increase the climate temperature. Solar flares, however have been naturally occurring event for millions of years. If only sunspots and solar flares were to blame, the world's recent increased would barely move.

5.4.1 Impacts of global warming

The perceptible warming of the earth over the past 150 years has been caused by an increase in the emission of gases such as carbon dioxide, which imply the greenhouse effect and increasing global temperature are causing a broad range of changes. sea levels are rising due to thermal expansion of the ocean. In addition to melting Inland ice, amounts and patterns of precipitation are changing. The total annual power of hurricanes has already increased markedly since 1975 because their average intensity and average duration have increased. In addition there has been a high correlation of hurricanes power with tropical sea-surface temperature. Changes in temperature and precipitation patterns, increase the frequency duration, and intensity of other extreme weather events, such as floods, drought, heat waves and tornadoes. The other effects of global warming includes higher or lower agricultural yields, further glacier extinction, on the other hand further effects of global warming causes diseases like malaria. Although global warming is affecting the number and magnitude of these events, it is difficult to connect specific events to global warming.

5.5 Solutions for global warming

The evidence that humans are causing climate change, with drastic consequences for life on the planet, is overwhelming, but the question of what to do about it remains controversial. Economics, sociology, and politics are all important factors in planning for the future. A global conversation that began with concern over warming has now turned to the broader term climate change, preferred by scientists to describe the complex shifts now affecting our planet's weather and climate systems. Climate change encompasses not only rising average temperatures but also extreme weather events, shifting wildlife populations and habitats, rising seas, and a range of other impacts. All of these changes are emerging as humans continue to add heat-trapping greenhouse gases to the atmosphere. Countries around the world acknowledged the imperative to act on climate change with the Paris Agreement in 2015, making pledges to reduce greenhouse gas pollution.

The Intergovernmental Panel on Climate Change (IPCC), which synthesizes the scientific consensus on the issue, has set a goal of keeping warming under 2 degrees Celsius (3.6 Fahrenheit) and pursuing an even lower warming cap of 1.5 degrees Celsius (2.7 Fahrenheit). Addressing climate change will require many solutions. There's no magic bullet Yet nearly all of these solutions exist today, and many of them hinge on humans changing the way we behave, shifting the way we make and consume energy. The required changes span technologies, behaviors, and policies that encourage less waste and smarter use of our resources. For example, improvements to energy efficiency and vehicle fuel economy, increases in wind and solar power, bio fuels from organic waste, setting a price on carbon, and protecting forests are all potent ways to reduce the amount of carbon dioxide and other gases trapping heat on the planet. Scientists are also working on ways to sustainably produce hydrogen, most of which is currently derived from natural gas, to feed zero-emission fuel cells for transportation and electricity. Other efforts are aimed at building better batteries to store renewable energy; engineering a smarter electric grid; and capturing carbon dioxide from power plants and other sources with the goal of storing it underground or turning it into valuable products such as gasoline. Some people argue that nuclear power despite concerns over safety, water use, and toxic waste should also be part of the solution, because nuclear plants don't contribute any direct air pollution while operating While halting new greenhouse gas emissions is critical, scientists have also emphasized that we need to extract existing carbon dioxide from the atmosphere. More fanciful ideas for cooling the planet so-called "geoengineering" schemes such as spraying sunlight reflecting aerosols into the air or blocking the sun with a giant space mirror-have largely been dismissed because they may pose more environmental risks than proven benefits.

Chapter 6

Conclusion

Earth our home planet is one of the unique planet from the other solar system. The existence of air that surrounds the earth (the atmosphere) makes living things to survive on the earth. The study of climatology in the lower and middle atmosphere is one of an important issue to know the effect of climate on living things and how it can be controlled.

In this project work, different activities in the lower and middle atmosphere, the atmospheric conditions of regions, characteristics of the atmosphere in controlling the global climate, the origin and types of climate, causes and processes influencing the climate change as well as the climate variations and their impacts for global warming are deeply discussed.

The atmosphere of the earth is characterized by different mechanisms starting from its origin and the evolution of the earth.Atmospheric air is a mixture of gases and aerosols which has weight and therefore the air exerts pressure which is maximum at sea level and it is characterized by its compositions, the temperature variation with altitude, density pressure of air in different layers of it. Temperature has different variation in each layer of the atmosphere. It decreases with altitude in troposphere and the pattern of the temperature increase with height in stratosphere is the result of solar heating as ultra violet radiation in the wave length range of 0.2 to 0.242 micrometer dissociates the diatomic oxygen. In mesosphere the temperature tends to fall with altitude because of there are few gas molecules to absorb the sun's ultra violet radiation and the thermospheric temperature increase with altitude due to the absorption of highly energetic solar radiations. Unlike the temperature which has different changes in each layer of the atmosphere, the density and pressure of the atmospheric air decreases exponentially with altitude in each layer. The climate of the earth is affected by both natural and human activities which leads to change it all over the world consequently, the variation of the climate has positive and negative impacts for living and non-living things on the earth.

Generally in this project work we deeply discussed the climate change of the earth and how this affects the atmosphere, global warming and its consequences,the ozone layer and the mechanism of temperature variation in the atmosphere. Global warming which refers to the increase in the global surface temperature and atmospheric temperature affects the global radiation balance. The ozone depletion due to various environmental factors including the release of greenhouse gases are the major causes of global warming. The climate of the earth which is changing from time to time, is one of the most alarming issue and unless it is regulated through different mechanisms it will results a great infliction on life on the earth's surface.

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DECLARATION

I, hereby declare that this project is my original work and has not been presented for a degree in any other university, and that all sources of materials have been duly acknowledged.

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