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Global Climate Change and Changes in Disease Distribution: A Review in Retrospect

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Abstract

Climate is the prevailing weather conditions of a particular place at a given time. It comprises of all the climatic elements including rainfall, temperature, relative humidity, sunshine, precipitation and snow patterns. An obvious change in these global climatic components is termed Global Climate Change which is signaled by a change in the geographic seasonal patterns of these components. These changes are as a result of the increase in the concentration of Green House gases such as CO_2, methane, water vapour, ozone, etc in the atmosphere. An increase in concentration of these Green House Gases causes Global Warming. This occurs as a result of human activities such as burning of fossil fuels, mining, deforestation, intensive use of land for farming, etc. all these have led to a degradation of the environment via pollution, natural disasters, flooding and a change in disease distribution. These diseases range from vector borne, air borne, waterborne and food borne. Malaria, dengue fever, tick borne encephalitis (TBE), borreliosis, salmonellosis, cholera and bluetongue infection are all affected by climate change. Three components of diseases affected by climate change are host, pathogen and transmission. Excessive rainfall and high temperature increases the transmission rate, reproduction rate and the proliferation of the *Plasmodium* species that causes malaria. Increase in temperature shortens the incubation period of the west nile virus that causes dengue fever. Extreme precipitation and rainfall increases the distribution of TBE and Bluetongue infection. Excessive rainfall leads to flooding which in turn increase the epidemics of salmonellosis and cholera due to faecal contamination from sewage. Climate change cannot be completely stopped but can be managed by reducing emission of Green House gases. This in turn can be controlled by the use of alternative sources of energy in the industries, use of solar, electric cars, improving the rate of photosynthesis and genetically engineering microbes to trap CO_2 from the atmosphere and convert it to useful products.

Keywords: Global, climate, Changes, Diseases, Distribution

Introduction

Climate change encompasses the alterations in the climate variables including Temperature, Precipitation, Sunshine, Wind and Rainfall. A change in these parameters can have a negative effect on the survival, reproduction or the distribution of pathogens and host causing diseases (Xiaoxu *et al.*, 2016). The change in climatic variables is as a result of human activities particularly the production of greenhouse gasses from fossil fuel emissions leading to global warming, rising temperatures, rising sea levels, acidity and extreme weather conditions such as droughts, wildfire, floods and powerful storms (www.livescience.com/topics/climate-change).

Infectious diseases can be divided into communicable and non-communicable. Communicable diseases are sub divided into vector borne, food borne, air borne and water borne infections. Pathogen refers to a wide range of disease agents, including virus, bacterium, protozoa, and fungi. The impact of climate change on pathogens can be direct, through influencing the survival, reproduction, and life cycle of pathogens, or indirect, through influencing the habitat, environment, or competitors of pathogens (Xiaoxu *et al.*,2016). As a result, not only the quantity but also the geographic and seasonal distributions of pathogens may change. Change in Temperature affects disease distribution by impacting on the life cycle of the pathogens. First, a pathogen needs a certain temperature range to survive and develop. For example, the two thresholds, maximum temperature of22–23 °C for mosquito development and minimum temperature of 25–26°C for Japanese Encephalitis Virus (JEV) transmission, play key roles in the ecology of JEV (Mellor and Leake, 2000). The development of malaria parasite (*Plasmodium falciparum and Plasmodium vivax*) ceaseswhen temperature exceeds 33°–39 °C. This is as a result of increase in temperature can leads to increase in mortality rate of pathogens (Patz *et al*., 2003). The rising temperature can influence the reproduction and extrinsic incubation period (EIP) of pathogens (Harvell *et al*., 2002). For example, the EIP for *P. falciparum* reduces from 26 days at 20 °C to 13 days at 25 °C. On the contrary, lower ambient temperature is likely to lengthen EIP, which may in turn decrease the transmission of diseases such as dengue because fewer mosquitoes can live long enough. Third, extended periods of hot weather can raise the average temperature of water bodies and food environment, which may provide an agreeable environment for microorganism reproduction cycles and algal blooms. For example, *Vibrio* spp. bacteria, native to the Baltic and the North Sea, showed an increased growth rate during the hot summersin 2006 (Frank *et al*., 2006). Salmonellas is a food-borne disease; the reproduction of the bacteria increases as temperature rises in that range between 7 °C and 37 °C (IWGCCH, 2010). Lastly, rising temperature may limit the proliferation of a pathogen through favoring its competitors. For example, *Campylobacter* spp., the bacteria of food-borne disease was found to be more concentrated in surface water at low temperature and during winter (Jones, 2001); it is believed that warmer temperature supports other bacteria to out-compete *Campylobacter* spp. and that ultraviolet light prohibits the survival of *Campylobacter* (Obiri-Danso *et al*., 2001).

Climate change may cause shifts in precipitation, which affects the dissemination of water-borne pathogens. Rainfall plays an important role in the development of water-borne disease pathogens. Rainy season is related to the increase of fecal pathogens as heavy rain may stir up sediments in water, leading to the accumulation of fecal microorganisms (Jofre *et al*., 2010). However, unusual precipitation after a long drought can result in an increase of pathogens, causing a disease outbreak (Wilby *et al*., 2005). Droughts/low rainfall lead to Lower River flows, causing the concentration of effluent water-borne pathogens to increase. Humidity change also impacts the pathogens of infectious diseases. The pathogens of air-borne infectious disease such as influenza tend to be responsive to humidity condition. For example, absolute humidity and temperature were found to affect influenza virus transmission and survival (Shaman and Kohn, 2009). Lowen *et al.* (2007) proposed that cold temperature and low relative humidity are favorable to the spread of influenza virus. Humidity change also affects the viruses of water-borne diseases. For example, the survival of water-borne viruses near water surface is limited due to the drying effect of surface water (Gerba, 1999). Lastly, virus of vector-borne diseases may be impacted by humidity change. Humidity was found to affect malaria parasite development in Anophelese mosquito (Patz *et al*., 2003).Thu *et al.* (1998)found that the temperature and humidity during rainy season in Yangon and Singapore favor dengue virus propagation in mosquitoes, contributing to the outbreaks of dengue hemorrhagic fever in these regions. Sunshine is one more important climate variable that may affect the pathogens of infectious diseases. For example, sunshine hours and temperature act synergistically during cholera periods to create a favorable condition for the multiplication of *Vibrio cholerae* in aquatic environments(Islam *et al.*, 2009).

Wind is a key factor affecting the pathogens of air-borne diseases. There is a positive correlation between dust particle association/attachment and virus survival/transporting (Chen *et al*., 2010). It has been reported that the presence of desert dust in the atmosphere during Asian dust storms (ADSs) is associated with increased concentration of cultivable bacteria, cultivable fungi, and fungal spores (Griffin, 2007; Schlesinger *et al.,* 2006). Chen *et al*. (2010)found that the concentration of influenza A virus was significantly higher during the ADS days than normal days. Studies further suggested that the viruses of infectious diseases be transported across ocean by dust particles (Chung and Sobsey, 1993; Cox, 1995; Griffin, 2007), which may facilitate the transmission of viruses between distant

The Climate

Climate is defined as the prevailing weather conditions of a region such as temperature, air pressure, humidity, precipitation, sunshine, cloudiness, and winds throughout the year averaged over a series of years (Houghton, 2011).

It can also be seen as the general or average weather conditions of a certain region at a given period of time including temperature, rainfall and wind (Houghton, 2011). Climate is mostly affected by latitude, the tilt of the Earth's axis, the movement of the Earths wind belts, the differences in temperature of land and sea, topography and human activities especially relating to depletion of the ozone layer (Houghton,2011).

Climate is the statistics of weather over a period of time and it is determined by assessing the changes in the climatic components such as temperature, humidity, rainfall etc (Planton, 2013).

Components of the Climate

- Hydrosphere
- Atmosphere
- Lithosphere
- Cryosphere
- Biosphere

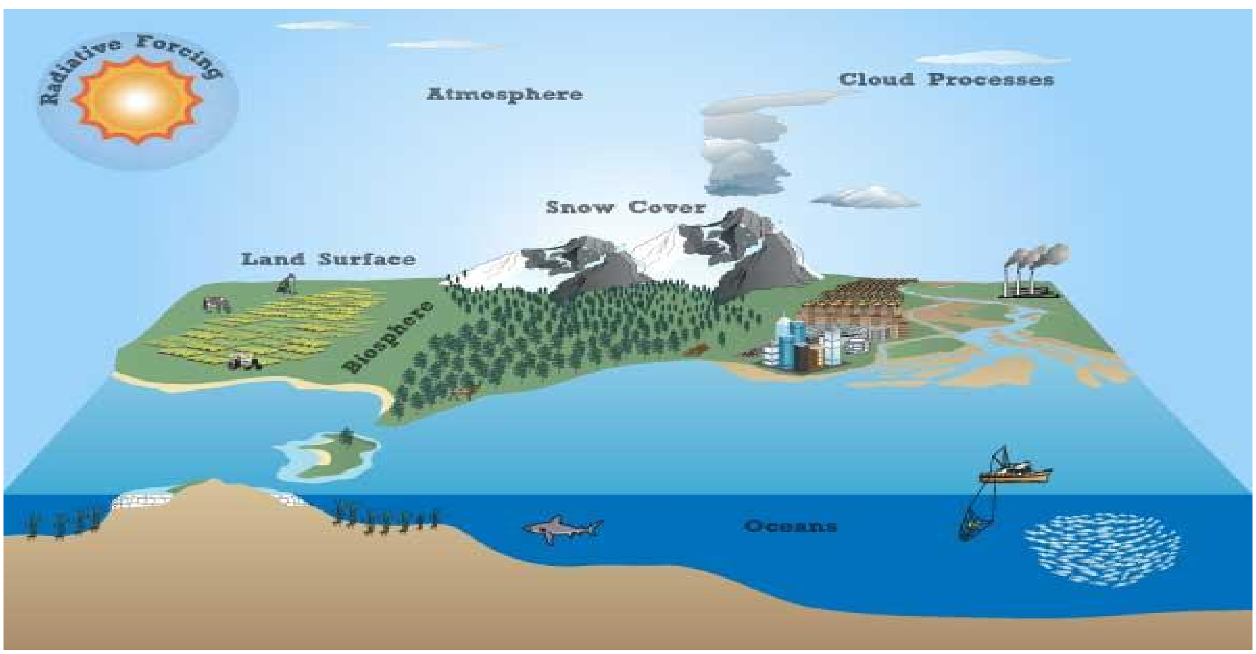

Figure 1: components of the climate system
Source: integration and Application Network,
University of Maryland center for Environmental Science

The earth and its original form

The earth began to form over 4.6 billion years ago and it is the only planet that can support life as it is the home to billions of living organisms that share a common evolutionary track. The atmosphere and the ocean were formed by the volcanic outgassing. The earth was in molten form due to frequent collision which led to extreme volcanism. Over time the earth cooled causing the formation of crust and allowing liquid on the surface forming the ocean and the seas (Borenstein,2013).The natural background level of carbon dioxide varies on time scales of millions of years due to slow changes in out gassing through volcanic activity. 1000 million years ago during the cretaceous period, CO_2 concentrations appear to have been several times higher than today but over the past 700,000 years CO_2 has varied over a small range in association with the earth's orbit. In the 21st century, CO_2levels reached 384ppm which is 37 percent and it has continued to increase and has reached 410ppm by 2018 (Micheal, 2018).

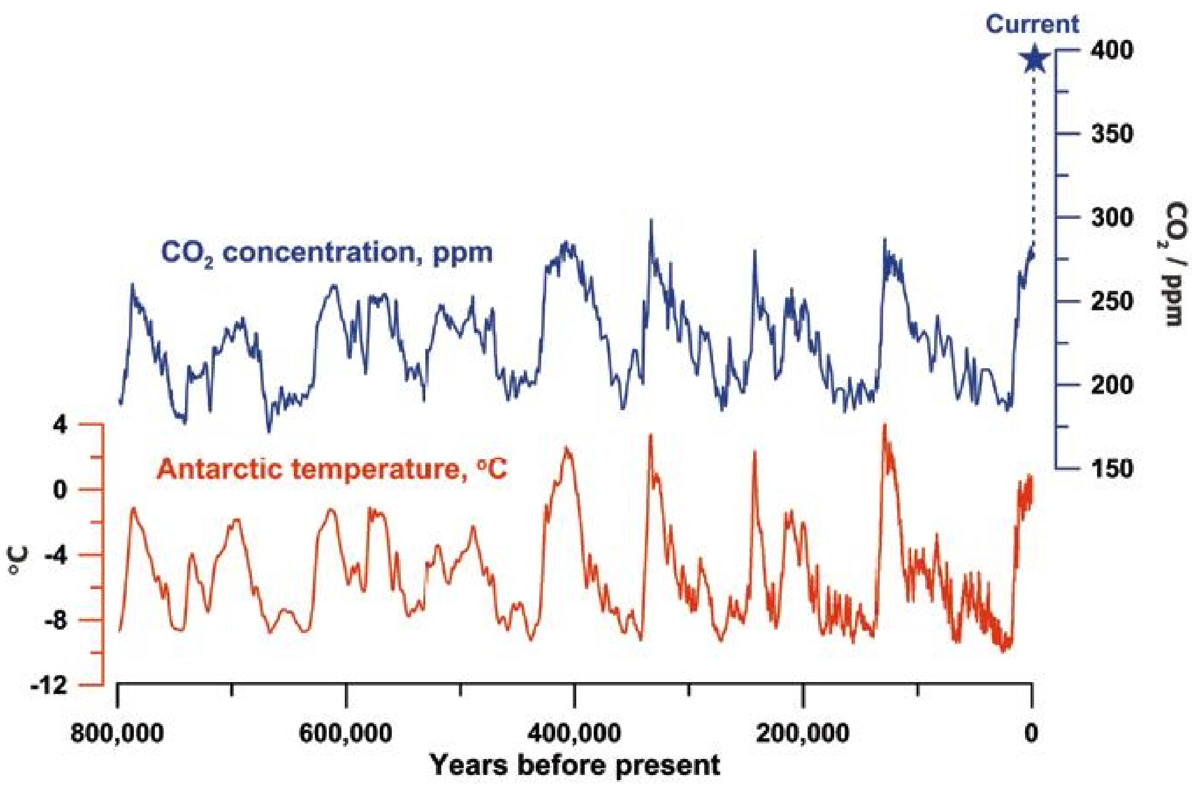

Figure 2: Measurement of CO_2 levels years before and present
Jeremy (2008)

Data from ice cores have been used to reconstruct Antarctic temperatures and atmospheric CO_2 concentrations over the past 800,000 years. Temperature is based on measurements of the isotopic content of water in the Dome C ice core. CO_2 is measured in air trapped in ice, and is a composite of the Dome C and Vostok ice core (luthi*et al.,* 2008). The current CO_2 concentration (blue star) is from atmospheric measurements. The cyclical pattern of temperature variations constitutes the ice age/ interglacial cycles. During these cycles, changes in CO_2 concentrations (in blue) track closely with changes in temperature (in red). As the record shows, the recent increase in atmospheric CO_2 concentration is unprecedented in the past 800,000 years (Jouzel *et al.,* 2007).

Global Climate Change

An obvious change in the patterns of the different components of the climate such as change in temperature, Rainfall, wind pattern, snow patterns that lasts for longer period and is lethal to human health and affect other living creatures is termed climate change. A number of factors contribute to climate change but not limited to human and natural factors (American EPA,2010).

Causes of Global Climate Change

A number of factors can be said to be responsible for climate change. Scientists have proved that the main cause of current global change is global warming. Warming is due to the human expansion of greenhouse effects. This warming results when the atmosphere traps heat radiating from the earth towards space(IPCC, 2014).

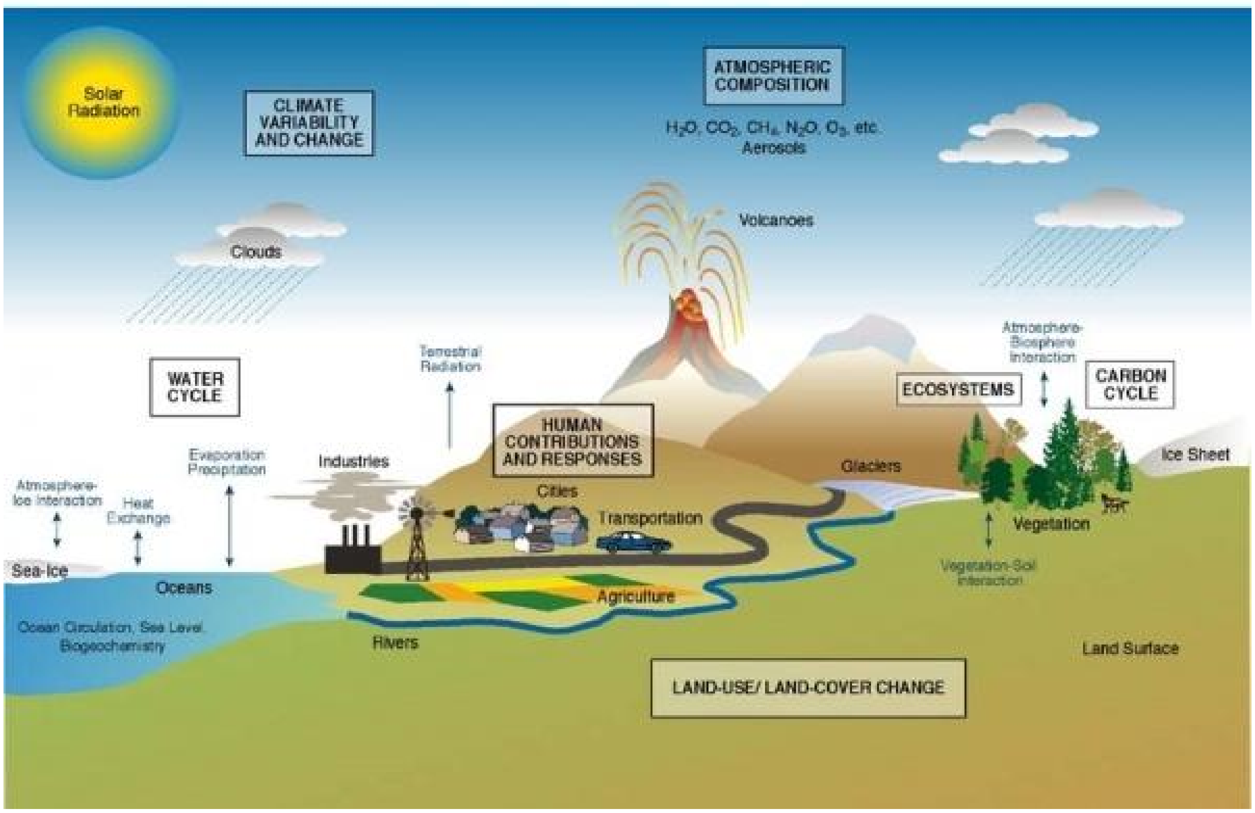

Figure 3: components of the climate system
Source: integration and Application Network,
University of Maryland center for Environmental Science

Global Warming

Global warming is a natural process by which the atmosphere retains some of the sun's heat, it is primarily caused by greenhouse effects. Global warming can also be perceived to be a situation that occurs as a result of the increase in the earth's temperature causing glaciers to melt, rise in sea levels, cloud forests to die and also causing the scrambling of wildlife to keep peace. Global warming has resulted to changes in the earth's climate and even long weather patterns that varies from place to place. As the earth spins each day, the new heat swirls with it picking up moisture over the oceans rising at a particular place and settling elsewhere (National Geographic, 2018).

Green House Gas

A greenhouse gas is any gaseous compound that is capable of absorbing heat energy (infrared radiation) emitted from the sun and reradiate it back to the earth thus causing greenhouse effect (Micheal, 2018).
Examples of such gases include;

- Carbondioxide
- Methane
- Water vapour
- Ozone
- Nitrous gases
- Fluorinated gases (Micheal,2018).

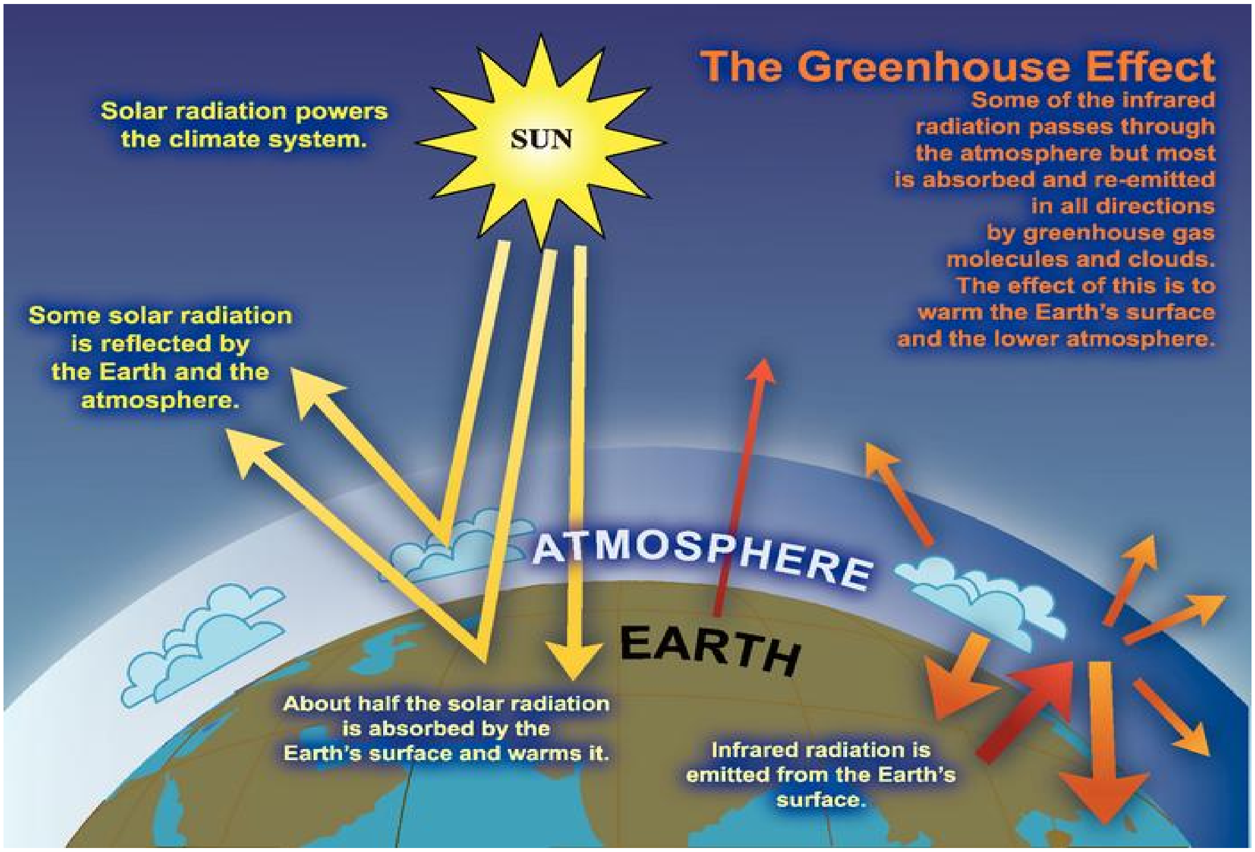

Figure 4: Greenhouse Effect
Source: IPCC Fourth Assessment Report (2007)

Carbon Dioxide(CO_2)

Carbon dioxide is the most significant of all the greenhouse gases that has accumulated in the atmosphere at an average of 2.0 parts per million between 2005 and 2018. It is obtained from out gassing of volcanoes, aerobic respiration, combustion of fossil fuels, and decomposition of natural decay or organic matter (Micheal, 2018). The CO_2 in the atmosphere is balanced by some physical, chemical and biological processes such as photosynthesis, assimilation by phytoplanktons, solubility pump which involves the descent of the surface sea water containing dissolved CO_2 and assimilation into the soil, which take up CO_2 from the environment by carbon sink (Micheal,2018). Human activities have distorted this balance since the evolution of industrialization. Of such activities include burning of fossil fuels such as oils, coal, and natural gas. Other anthropogenic activities such as clearing of land and the burning of forest have also contributed to these effects. There are majorly two methods by which CO_2 is emitted:

- The natural method of emission -This is occurs by the deforestation and clearing of land which accounts for the release of about sevengigatons of carbon in the atmosphere which in turn accounts for the 3% CO_2 emission into the atmosphere
- Industrial emissions which accounts for up to ten gigatons of carbon released into the atmosphere(Micheal, 2018).

Methane (CH_4)

Methane is another greenhouse gas that has the ability to absorb infrared and reradiate the earth. Its concentration in the atmosphere is quite lower than that of CO_2. It has a very short residence time in the atmosphere than CO_2. Its sources include tropical and northern wetlands, methane oxidizing bacteria, seapage vents of sea floor in region with high organic sediments and methane hydrates. Methane natural sinks is the atmosphere itself as it reacts readily with hydroxyl radicals (OH^-) in the troposphere to form CO_2 and water vapour.

When it reaches the stratosphere it is destroyed. Another natural sink or methane is the soil where methane is oxidized by bacteria. Even though these natural sinks tend to offset the concentration of methane in the atmosphere, the human activities tend to increase its concentration faster than it can be offset. Anthropogenic sources of methane are rice cultivation, livestock farming, burning of fuels, natural gas and coal, combustion of biomass and the decomposition of organic matter in landfills. Increase in methane concentration led to an increase global temperatures by 4-8^{0}C over the past years (Micheal, 2018).

Water Vapour

Water vapour is seen as a climate feedback that is a response within the climate system that causes the continued activity of the climatic system. The amount of water vapour produced is not dependent on human activities but directly determined by air temperatures. The higher the temperature of the atmosphere the greater the evaporation rate of water from the surface. Increase in evaporation leads to an increase in concentration of water vapour in lower atmospheres capable of absorbing infrared radiation and emitting it back to the earth (Micheal, 2018).

Surface level Ozone (O_3)

Surface ozone is as a result of air pollution. Its sources include photochemical reactions involving the atmospheric pollutant carbon monoxide. It also arises from the subsidence of stratospheric ozone from the upper atmosphere. The concentration of surface ozone in the atmosphere is 50ppb and the net radiative forcing due to anthropogenic emissions of surface ozone is approximately 0.35watt per square meter (Micheal, 2018).

Nitrous Oxide and Fluorinated gases

These are trace gases emitted from industrial activities.The fluorinated gases include sulphur hexafluoride, hydroflourocarbons and perflourocarbons. Nitrous oxides are gotten from natural biological reactions in soil and water while fluorinated gases are from industrial processes (Micheal, 2018).

Factors that Contribute to Climate Change

Human Factor: Man in a bid to explore new technologies as a result of rising needs for better ways of life through globalization and industrialization has engaged in so many activities that has endangered the mother earth. These activities include burning of fossil fuels, industrialization, cutting down of trees (deforestation), and developing land for farms, cities, and roads. These activities all release greenhouse gases (CO_2) into the atmosphere which in turn leads to global warming at an increased amount (American EPA, 2010).

Natural Factors: The earth is always changing its orbit but this change in orbit also leads to climate change. Human activities have led to the increase in greenhouse gases which deplete the ozone layer thus increasing the intensity of the sun, which in turn has led to the melting of ice at the Arctic regions (glaciers), this then leads to the filling of the oceans thus affecting aquatic life and also causing over flooding, increase atmospheric temperatures and increased volcanic activities.

Although the Earth's climate has changed many times throughout its history, the rapid warming seen today cannot be explained by natural processes alone (American EPA, 2010).

Signs of Climate Change

There are clear evidence that the climate is warming with the recent mishaps ranging from over flooding, increase in temperature and the general shift in the earth's equilibrium. Some of the obvious signs include

Increase in CO_2 Concentrations in the Atmosphere

Prior to industrial revolution in the eighteenth century, the earth's CO_2content was about 280ppm and this has risen exponentially to about 400 ppm. CO_2 is a greenhouse gas and as such its increase in the atmosphere will surely lead to global warming. This is because greenhouse gases such as CO_2 have the ability to trap heat from the earth surface and this leads to global warming which in turn leads to climate change and invariably affect distribution of disease. Also the greenhouse gas will increase water retention from vapour in the atmosphere which causes the glaciers to melt increasing the sea level and causing overflowing global climate change(Kieran, 2013).

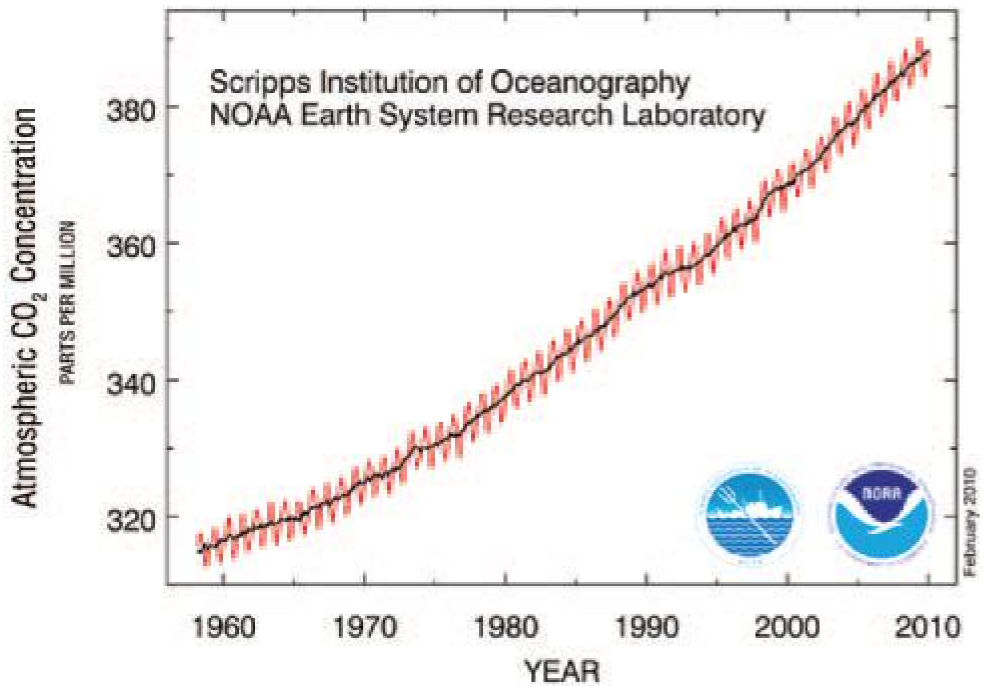

Figure 5: Graph showing increasing CO_2 Concentration
Source: Scripps Institution of Oceanography
NOAA Earth System Research Laboratory

Increasing Temperatures

The clearest evidence for surface warming comes from widespread thermometer record. Temperatures are monitored at many thousands of locations over both the land and ocean surface. Indirect estimates of temperature change from such sources as tree rings and ice cores help to place recent temperature changes in the context of the past. In terms of the average surface temperature of Earth, these indirect estimates show that 1983 to 2012 was probably the warmest a 30-year period in more than 800 years.Global surface temperatures have risen by 1.3 degrees Fahrenheit (ºF) over thelast 100 years. Worldwide, the last decadehas been the warmest on record. Earth's average surface air temperature has increased by about 0.8 °C (1.4 °F)since 1900. The rate of warming across the globe over the last 50 years (0.24ºF per decade) is almost double the rate of warming over the last 100 years (0.13ºF per decade) (Ralph and Paul, 2016).

A wide range of other observations such as reduced Arctic sea ice extent and increase ocean heat content and indications from the natural world such as poleward shiftsof temperature sensitive species of fish, mammals, insects, etc all thesetogether provides an obvious evidence of planetary-scale warming.The evidence of climate change extends well beyond increases in global surface temperatures (Ralph and Paul, 2016). It also includes:

• Changing precipitation patterns.
• Melting ice in the Arctic.
• Melting glaciers around the world.
• Increasing ocean temperatures.
• Rising sea level around the world.
• Acidification of the oceans due to elevated carbon dioxide in the atmosphere.
• Responses by plants and animals, such as shifting ranges (Ralph and Paul, 2016).

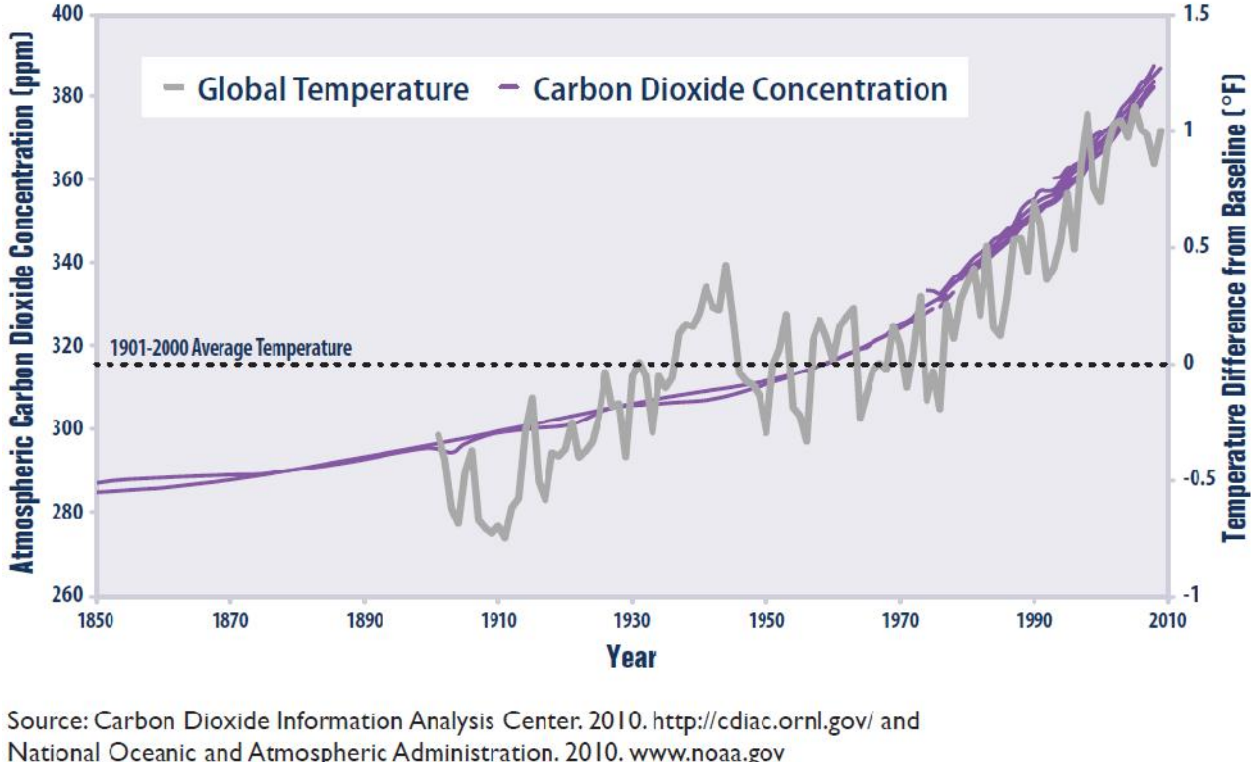

Figure 6: Increased Global Temperatures and Carbondioxide

General impact of Climate Change on Infectious Diseases

The climatic condition of a particular region affects the disease distribution of that particular geographical area. This is so because most of the diseasesare caused by microorganisms and transmitted through vectors and the distributions of these vectors are in turn affected by climatic conditions at a particular period of time.Changes in climatic conditions may affect the survival, reproduction or distribution of the disease, their means of transmission as well as the host susceptibility to the disease(Xiaoxu*et al.*,2016). The effects of climate changeon disease distribution are characterized by shifts in the geographic and seasonal patterns ofhuman infectious diseases, changes in their outbreak frequencyand severity of the disease (Xiaoxu*et al.*,2016). For example, ancient Romans retreated to cooler hillside resorts in the summer to avoid malaria since hotterconditions can help the mosquitoes breed more (WHO, 2010).

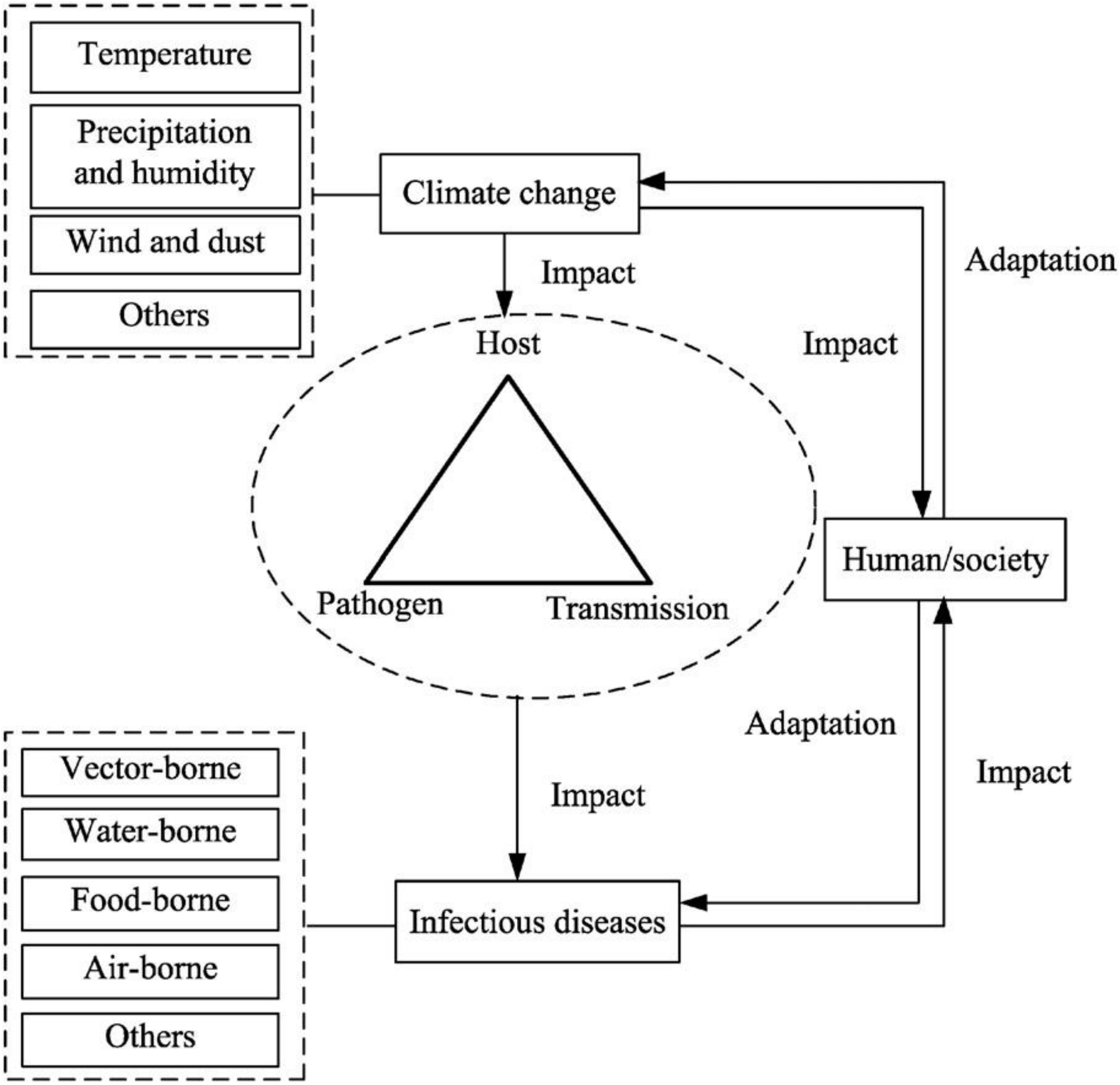

Figure 7: climate change, disease and climate factors (Xiaoxu *et al*., 2016)

Disease Classification

Diseases can be classified according to mode of transmission:

- Communicable diseases
- Non communicable diseases

Based on these assertions, communicable diseases can be classified based on the vehicle of transmission which could be either through air, water, food or animals and these different vehicles of transmission are all affected by global warming and climate change. They include:

Vector Borne Diseases

Vector borne diseases are those disease types mainly transmitted by animals or humans. The animals or humans serve as a vehicle carrying the parasite or cyst that actually causes the infection. Examples of such diseases include malaria, typhus, rickettsial pox, scrub typhus, avian influenza, and rabies. For those infectious diseases transmitted by insect vectors, we know that vectors are more active at higher temperatures (Xiaoxu *et al.*, 2016).

Malaria

Climate change may lead to an increase in malaria in certain spots of the world but in some other places it might have no effect on the mosquito. The climatic factors that influence malaria transmissioninclude temperature and rainfall. These climatic factors affect their life cycle, transmission rates and the proliferation of the *Plasmodium* parasite in the mosquitoes. Some tropical species of mosquitoes such as *Anopheles* require temperatures above 16 °C to complete their life cycles, and malaria parasites are able to develop more rapidly within mosquitoes at higher temperatures (>20 °C). In the case of malaria due to *Plasmodium falciparum*, one mosquito can infect 200 individuals if temperature conditions are ideal, allowing for rapid spread of the disease (Franklin *et al.,* 2017). Vector-borne diseases such as malaria are also thought of as water-borne diseases, since mosquitoes typically thrive in aquatic habitats, where they lay their eggs in water filled containers(Lafferty, 2009, Shuman, 2011). For example, the two thresholds maximum temperature of22–23 °C for mosquito development andminimum temperature of 25–26°C for Japanese Encephalitis Virus (JEV) transmission, play key roles in the ecology of JEV(Xiaoxu*et al.*,2016).

- Excessive heat can increase the mortality rates for some pathogens. The development of malaria parasite (*Plasmodium falciparum* and *Plasmodium vivax*) ceases when temperature exceeds 33°–39 °C(Xiaoxu*et al.*,2016).

- The rising temperature can influence the reproduction and extrinsic incubation period (EIP) of pathogens. For example, the EIP for *P. falciparum* reduces from 26 days at 20 °C to13 days at 25 °C. On the contrary, lower ambient temperature is likely to lengthen EIP, which may in turn decrease the transmission of diseases such as dengue because fewer mosquitoes can live long enough (Xiaoxu *et al*.,2016).

- The extended periods of hot weather can raise the average temperature of water bodies and food environment, which may provide an agreeable environment for microorganism reproduction cycles and algal blooms (Xiaoxu *et al.*,2016).

Dengue Fever

Dengue fever is an important vector-borne viral infectious disease in the world. The abundance of vectors is directly dependent on the climatic conditions at a given time which in turn affects the distribution of the dengue fever disease, that is to say that the abundance of the mosquito vector increases the number of patients (Ichiro, 2010). The epidemics of malaria and dengue fever tend to occur annually during rainy seasons in the tropics and inter-annually after weather events. On the other hand, epidemics of the mosquito-borne West Nile virus infection can occur during times of drought. This happens because mosquitoes and birds the primary hosts of the virus are brought into close proximity at scarce water sources, enhancing transmission of the disease between mosquitoes and birds (and thus to humans). In addition, natural predators of mosquitoes are greatly reduced during times of drought as wetlands dry up (Shuman, 2011).

Lyme Borreliosis

Climate change affects the dynamics of tick borne diseases such as borreliosis caused by the bacterium *Borrelia burgdorferi* and tick-borne encephalitis caused by the TBE virus both carried and transmitted by the tick *Ixodesricinus*. Climate change has led to an increase in daily precipitation, humidity, change in precipitation patterns and extreme increase in temperatures leading to extreme heat. This has led to a 400% rise in cases of TBE in European endemic regions. Warmer winter temperature, longer growing seasons and hotter summers make conditions more favorable for ticks and increase the host populations. By 2040 to 2060, there could be 3.8% growth in the habitat of *Loodesricinus (*European Society of Clinical Microbiology and Infectious Disease).

Water- Borne Diseases

Like vector-borne diseases, water-borne diseases are also strongly impacted by climate, particularly the effect of climate on the hydrologic cycle. During times of drought, water scarcity results in poor sanitation and exposure of much of the population to potentially contaminated water. For example, an epidemic of cholera occurred in late 2009 in northern Kenya after a severe drought, with over 4700 cases reported in one month, including 119 deaths (Gettleman, 2009).Excess rainfall and flooding, like drought, can also contribute to epidemics of water-borne infectious diseases, In this case due to poor sanitation resulting from run-off from overwhelmed sewage lines or contamination of water by livestock. An example is the 1993 outbreak of diarrheal disease due to *Cryptosporidium* in Milwaukee, Wisconsin after heavy spring rains (Mackenzie *et al.,* 1994).In this outbreak, there were over 403 000 reported cases, demonstrating how widespread diarrheal disease can be-come when community water sources become contaminated (Mackenzie *et al.,* 1994).

Salmonellosis

Salmonellosis is a disease condition caused by *Salmonella* sp. The distribution and spread of this disease is strongly affected by climate change. This is because of the changes in seasonal patterns such as extreme rainfall, increased flooding, increased average temperatures, and extreme heat and all these affect the dynamics of the disease (Franklin, 2017).

Cholera

Cholera is a food borne infection or water borne infection caused by drinking water contaminated with the bacterium *Vibrio cholerae.*H igh air temperatures and periods of excessive rainfall create environmental conditions that favor bacterial growth. In dry conditions, river levels decrease and bacterial accumulate in dangerously high concentration. During excessive rainfall, flooding can spread bacteria to regions that haven't previously been infected resulting in fast spreading epidemics (Laura, 2014). An increase in rainfall and stormy frequency leads to an increase in flooding and landslides. This can lead to an outbreak of cholera cases. Landslides are often accompanied by distabilities in the infrastructures in the environment (Franklin 2017).

How Climate Change Affects Disease Host and Vectors

Host is any living organism on which a disease pathogen lives in or on. It can be a plant, animal or even human. Vectors are intermediate hosts and they carry and transmit pathogen to living organisms which become hosts. Most known vectors are insects. Climate change causes changes in insect distribution, geographical locations and increases population of insect vectors (Xiaoxu *et al.*, 2016). Thus, climate change may cause changes in range, period, and intensity of infectious diseases through its impacts on disease vectors(Xiaoxu *et al.*, 2016).Temperature affects the spatial–temporal distribution of disease vectors. As temperature continues to rise, the insects in low-latitude regions may find new habitats in mid- or high-latitude regions and in areas of high altitude, leading to geographical expansion or shift of diseases. Recent studies have found that some vector-borne human infectious diseases, including malaria, African trypanosomiasis, Lyme disease, tick-borne encephalitis, yellow fever, plague, and dengue have distributed to a wider range (Harvell *et al*., 2002). Most of these diseases have extended into areas of higher latitude, following the habitat expansion of mosquitoes, ticks, and midge vectors. In China, as the winter temperature continues to rise, *Oncomelania hupensis*, the intermediate host of *Schistosoma japonicum*, extended its geographic distribution into new areas including northern China (Zhou *et al*., 2010). However, temperature change may as well restrict the distribution of disease vectors. For example, *Aedes aegypti* is the mosquito host for yellow fever and dengue fever viruses (Epstein, 2001).Changes in precipitation may impact disease vectors/hosts as well. Many vector-borne infectious diseases are found to be positively associated with rainfall. Larval development of some mosquito vectors accelerates with increased rain and rising temperature (Hoshen and Morse, 2004).Adult Anopheles, vector of malaria, reproduce in small natural ponds of clean water; droughts may limit the quantity and quality of breeding sites for these mosquitoes, resulting in reduction in vector population and disease transmission (Gage *et al.,* 2008). The cocoliztli outbreaks in Mexico proved that rainfall can affect the outbreaks of rodent-borne diseases through its impact on rodent population (Zell, 2004). However, rainfall is not always agreeable for vectors. Excessive precipitation may have catastrophic impacts on mosquito population because strong rain may sweep away their breeding sites (Kuhn *et al*.,2005). On the contrary, drought in wet regions may decrease flow velocity in brooks and provide mosquitoes with more pools of stagnant water as breeding places (Kovats *et al*., 2003). The primary carrier of West Nile virus is a type of mosquito named Culex, which usually breeds underground in the nasty water pools in city drains and catch basins. Drought allows for rotten organic

materials to accumulate in those pools, forming favorite condition for Culex; heavy precipitation would wash the drains and water down the pools (Epstein, 2001), limiting he spread of West Nile virus.
Many disease hosts tend to respond strongly to humidity change. Relative humidity affects malaria transmission through impacting the activity and survival of mosquitoes. When wet and warm weather is intersected by dry-spells, the mosquito vectors carrying West Nile virus and Lyme disease may move into non-traditional areas such as Canada and Scandinavia (Senior, 2008). Low humidity can negatively affect the adult survival of *A. aegypti*, therefore reduce denguedisease transmission (Christophers, 1960). Generally speaking, low humidity, especially when coupled with high temperature, forms unfavorabl econdition for ticks and fleas (e.g. grasslands or forestlands),limiting the spread of the related infectious diseases (Gage and Kosoy,2005).

Projections of Climate Change

At the current rate, the Earth's global average temperature is projected to rise from 3 to 7°F by 2100, and it will get even warmer after that. As the climate continues to warm, more changes are expected to occur, and many effects will become more pronounced over time. For example, heat waves are expected to become more common, severe, and longer lasting. Some storms are likely to become stronger and more frequent, increasing the chances of flooding and damage in coastal communities. Climate change will affect different regions, ecosystems, and sectors of the economy in many ways, depending not only on the sensitivity of those systems to climate change, but also on their ability to adapt to risks and changing conditions. Throughout history, societies and ecosystems alike have shown remarkable capacity to respond to risks and adapt to different climates and environmental changes. Today, effects of climate change have already been observed, and the rate of warming has increased in recent decades.

For this reason, human-caused climate change represents a serious challenge one that could require new approaches and ways of thinking to ensure the continued health, welfare, and productivity of society and the natural environment.

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