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Research Note

Ecological Significances of Climate Change

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Abstract

Climate change is a long-term phenomenon that gradually changes the weather pattern. A significant number of scientists are now in agreement that the Earth has been gradually warming up. Such changes may have been contributed by both anthropogenic (such as, production of greenhouse gases) and non-anthropogenic (such as, volcanic eruption, cosmological radiation, plate tectonics, etc.) activities. By developing mathematical and computer models, and theoretical approaches, scientists predict that the world will continue to warm in the upcoming centuries, and global warming will be the foremost reason for a fast changing weather pattern. Data suggest that during the past 30 years, the earth's surface has warmed up faster than the base period (1957-1980). Models based on data from 1923 to 2010, predict that rapidly changing weather pattern will lead to widespread drought in the next 30-90 years. Increased earth temperature may also cause glaciers to shrink and sea levels to rise, leading to loss of lands. This is easily comprehensible that such drastic changes in weather condition will cause significant impacts on sea levels and weather patterns, and consequences for ecosystems, human health and the economy.

Keywords: global warming, greenhouse gases, solar variability, climate change, ecology.

1.0 Introduction

The sustainability of all species depends on the interactions among the global ecological communities and the climate they live in. In recent years, continuing changes in global temperature and consecutive changes to global climate are considered to be the major threats to ecological communities (Zarnetske and Wilson, 2013). Global climate changes are also considered to be major threats to ecological conservation (McCarty, 2001) and it is predicted that the effects of climate change will contribute to extinction risks for many species (Maclean and Wilson, 2011).

Over the past century, the earth's climate has warmed up by 0.58^{o}C (McCarty, 2001). Since climate change is a global phenomenon, it has global impacts. This global change in temperature is contributed by different factors, but anthropogenic factors play a major role in it mainly by producing greenhouse gases. Rising levels of CO_2 and other heat trapping gases in the environment have gradually warmed the planet earth leading to wide-ranging impacts, including drought, fires, melting snow/ice, rising sea levels, extreme weather conditions, etc. Studies indicate that greenhouse gases have even affected the climate of one of the earth's most remote regions, the Arctic Region (Pechsiri *et al*., 2010).

2.0 Greenhouse Gases

In 1820s, French mathematician Joseph Fourier determined that the Earth would be a much colder place without having a heat trapping atmosphere (Pierrehumbert, 2004). This greenhouse effect is vital for the existence of living forms. In 1896, Swedish chemist Svante Arrhenius proposed relationships between fossil fuel combustion and global warming, and atmospheric concentration of CO_2 as a greenhouse gas and atmospheric temperature (Enzler, 1998).

Greenhouse gases blanket the atmosphere and trap the infrared and heat energies as they enter the weather occurring part of the Earth's atmosphere. The major greenhouse gases in the atmosphere are water vapor, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (NO_2), and ozone (O_3), causing 36-70%, 9-26%, 4-9%, 6%, 3-7% of total greenhouse effects respectively. Water vapor is the most plentiful greenhouse gas. Water vapor increases as the earth's temperature increases, thus acting as a feedback to the climate. CO_2 is a highly potential heat trapping gas in the atmosphere. It is considered to be the most important greenhouse gas as the atmospheric CO_2 level continues to rise. CO_2 is produced through respiration, volcanic eruptions, and anthropogenic processes such as agriculture, burning of fossil fuels, deforestation, etc. CH_4 is less abundant but more active greenhouse gas as compared to CO_2. It is produced both through anthropogenic and non-anthropogenic processes. The common sources of CH_4 are, waste decomposition, manure production, rice cultivation, etc. NO_2, another strong greenhouse gas, is mostly produced through fossil fuel combustion, use of fertilizers, nitric acid production, etc. O_3 is an effective greenhouse gas in upper troposphere (90%) and lower stratosphere (10%). It also plays an important role in absorbing ultraviolet radiation (NASA, 2015). Along with these naturally occurring greenhouse gases, there are some synthetic potential greenhouse gases such as chlorofluorocarbons, hydro-chlorofluorocarbons and halons that are emitted from a variety of industrial processes. In 2012, EPA estimated that NO_2, CH_4 and CO_2 counted for about 6%, 9% and 82% (6,526 million Metric Tons of CO_2 equivalent), respectively, and fluorinated gases counted for about 3% of the total greenhouse emission (EPA, 2012).

The survival of all life forms on earth directly or indirectly depends on the solar energy. About half of the sunlight that reaches the earth will radiate back into the space and the other half will pass through the earth's atmosphere. About 10% of this energy that passes through the earth's atmosphere radiates back into the space in the form of infrared heat and the remaining 90% of the energy is absorbed by ocean, plants and the greenhouse gases (NASA, 2015). Greenhouse gases trap heat in the troposphere, the weather occurring part of the atmosphere. They absorb and emit radiation within the thermal infrared range. This process takes place in two steps. First the greenhouse gases let the visible and ultraviolet rays of solar radiation to pass through the atmosphere and reach the earth's surface. Then, when rays are reflected back to the atmosphere as infrared or heat energy, greenhouse gases absorb this heat and warm the earth (Angelle, 2010). This process is the central cause to the greenhouse effect. Figure 1 shows an illustration of solar energy reflection and absorption by the earth's atmosphere. (Solar energy is mostly radiated back into space from upper atmosphere. But in lower atmosphere, it is mostly trapped by greenhouse gases that act as a thermal blanket. Primarily these are water vapor, carbon dioxide, methane, and nitrous oxide.)

Despite the current weather related problems caused by the greenhouse gases, they are vital to maintain atmospheric temperature and without them, the earth surface would be below freezing, about 59 °F below the current average temperature of 57 °F (Karl and Trenberth, 2003). However, since the industrial revolution (since 1750), anthropogenic activities have caused a 40% increase in the atmospheric CO_2 from 280 ppm to 392.6 ppm in 2012 (Blasting, 2014), and reached 400 ppm in the northern hemisphere. If this trend continues, it is projected that by year 2047, every ecosystem of the world will be affected,

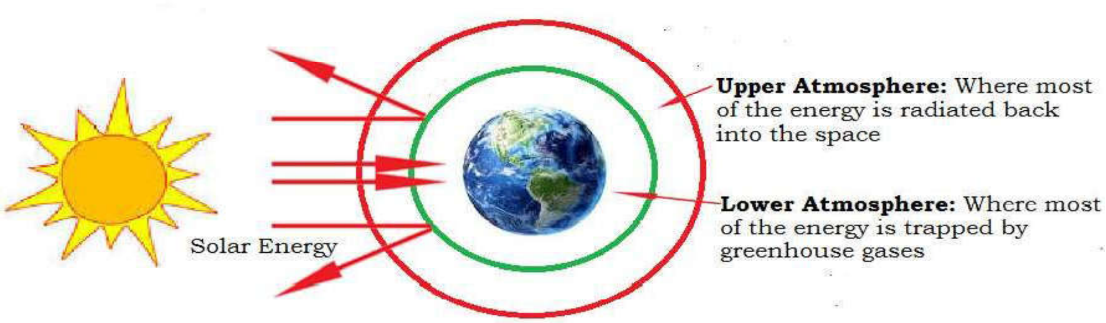

Figure 1: An illustration of solar energy reflection and absorption by the earth's atmosphere.

affecting the livelihood of over 3-billion people over the world (Mora, 2013).

To take an average carbon measurement of earth's whole atmosphere, there are between 70-150 ground based stations around the world that measure atmospheric CO_2. Recognizing that scientists would never have enough ground based stations for a complete assessment of earth's CO_2 status, in 2009, NASA launched "Orbiting Carbon Observatory". But the mission failed due to a rocket malfunction. In July 2014, NASA launched "Orbiting Carbon Observatory-2" (see Figure 2). This satellite is devoted to measuring carbon footprints for earth's whole atmosphere from space, the carbon cycle, and the implications for climate change (Tenenbaum, 2014). NASA scientists are hoping that this new observatory will provide details about where, "every single CO_2 molecule is going."

Figure 2: NASA's Carbon Observatory-2, launched in 2014 to study carbon footprints in the earth's atmosphere (Credit: https://en.wikipedia.org/wiki/Orbiting_Carbon_Observatory_2).

3.0 Solar Variability

Due to variations in internal stellar processes (solar activities), the total radiant energy emitted by the sun may fluctuate. The probable role of solar variability in climate change has long been discussed. Variations in composition and intensity of solar radiations that reach the earth's surface can cause variations in regional and global climates (Haigh, 2011). Scientists have assumed that changes in sun's energy output would influence the climate to change. Studies indicate that a decrease in solar activity may have triggered the "Little Ice Age" between1650-1850 (NASA, 2015).

Studies indicate that an 11-year cycle in solar variability was related to only about 0.1% in solar irradiance (Cubasch, *et al*. 1997). Authors predicted that the solar variations over a longer time period may implicate a larger climate variation. Such climatic changes by natural agents may complicate pinpointing the significance of anthropogenic activities in climate change. However, other studies indicate that current global warming may not be significantly linked to changes in energy from sun. Since 1978, data from satellite instruments measuring solar energy output show that there is a slight drop in solar irradiance over this time period, indicating the sun may not be responsible for global warming trend (NASA, 2015).

In a research paper, Haigh (2011) from the Grantham Institute for Climate Change argued that the impacts of solar variations on regional climate could be significant, but much smaller on a global scale. NASA indicated that since 1750, the average energy coming from the sun either remained constant or varied slightly. Moreover, if global warming was due to increased solar activities, it would affect all layers of the atmosphere, not only the lower parts of the atmosphere where greenhouse gases are trapped (NASA, 2015).

4.0 Points of Concern

- Global climate change is already showing observable effects, such as shrinking glaciers, premature breaking of ice on rivers and lakes, shifting in plant and animal ranges, premature flowering, etc.
- Intergovernmental Panel of Climate Change (IPCC) that includes more than 1,300 scientists from around the world, are forecasting a temperature rise of 2.5 to 10^0 F over the next century.
- Scientists are predicting an accelerated rise of sea levels, intense heat waves and an increase in tropical cyclone activities.
- A decrease in precipitation in subtropical lands along with a decrease in water resources in semi-arid areas, but heavy precipitations in high latitudes.
- IPCC scientists have reported to the United Nations that the Earth's climate is undoubtedly getting warmer.

- Climate change and its impacts appear to be accelerating faster than the predictions of the scientific community.
- Data indicate since 1980, US is experiencing extreme weather conditions.
- Data also indicate that the US experienced 14 extreme weather conditions in 2011 costing human lives and an economic impact of $55 billion.
- July 2012 was the hottest ever month in the US since the recordkeeping started in 1895.
- Two-third of the US experienced severe drought in summer of 2012.
- Between 1990 and 2009, Washington State experienced four "100-year" and one "500-year" floods costing the state millions in economic impacts (DOE, 2012; NASA, 2014).

5.0 Conclusions

Climatologists predict that global warming trend will continue and even may accelerate, posing threats to various ecosystems and natural resources. Dai (2013) developed models based on data from 1923 to 2010 and predicted that there will be widespread droughts in the next 30-90 years because of decreased precipitation and/or increased evaporation. Hansen *et al.* (2012) studied the global warming trends and suggested that during the past 30 years, hot extreme covered about 10% of the earth's surface as compared to 1% base period (from 1951-1980).

According to NASA climatologist Gavin Schmidt, the earth is warming. The current decade is warmer than the past decade and that decade was warmer than the decade before. He also suggested that the reason is anthropogenic as we are introducing increasing amounts of CO_2 in the environment (DOE, 2012).

The impacts of global warming in different parts of the globe could be very different. The IPCC has made the following forecast on the regional impacts of climate change: The North America will experience decreasing snowpack, increasing and increasing heat waves. The South America will experience loss of tropical forests, biodiversity (species loss) and water resources. The Europe will experience flash floods, coastal flooding, soil erosion, decreased food production, and loss of biodiversity and glaciers. Africa will experience increased water stress and loss of agricultural production. Asia will be affected by shortage of fresh water, increased flooding in coastal areas, and droughts (NASA, 2014).

Scientists are indicating that the climate change is occurring at a faster pace (Solomon *et al*., 2007; Marcott *et al*., 2013) than predicted earlier. In 2007, IPCC scientists predicted that by year 2100, global warming could cause a 7-23 inches rise in sea levels and affect the coastal populated communities and infrastructures. Some areas could be flooded and in some areas, shoreline would move miles inland (Department of Ecology, State of Washington, 2012).

Scientists reveal with confidence that CO_2 is the principal anthropogenic greenhouse gas that bears the major burden of responsibility for a fast climate change. Currently, human activity produces more CO_2 (35-40 billion tons annually) than any other greenhouse gas. From Earth's atmosphere, CO_2 is partly absorbed into the ocean or by plants. Studies show that about half of the CO_2 that enters Earth's atmosphere, stays in the atmosphere. The scientists are yet to find out if the other half is being absorbed by the oceans or vegetation on land (Tenenbaum, 2014).

It is a growing concern that we are losing the time to reverse the impacts of global warming. Humans and policy makers around the globe must take bold steps to reduce the greenhouse gas emissions before the situation goes completely beyond our ability to reverse these worsening conditions. Gavin Schmidt of NASA (CBC, 2015) stated that reversing global warming effects is not a short-term solution. It will require sustained efforts across the world to see a difference by 2080-2100.

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