

§1.1 Assignment 1

Topic : What is YOUR stand and understanding on the issue of Global Warming ?

As a high school kid I remember having been deeply affected by the news and our classes educating us about global warming and its effect. Back then, I never questioned the claims being made as it was evident to me from my own experience. Being in an auto rickshaw while traveling to school and getting stuck in Mumbai traffic jams with all the smoke being pushed right down our lungs was all that I needed to get convinced. It seemed natural that man made sources were the primary source causing Global Warming.

Here's what the aspiring inventor high school version of myself thought: few years down the line when the Earth's climate would have changed dramatically, if we would not be able to sustain human life, what's the point of building any other technology? Hence, I was determined to tackle this issue as my primary concern. With my limited knowledge and experience at that time, I believed that carbon dioxide (CO_2) was the major cause of pollution and that eliminating exhausts from automobiles would significantly reduce pollution rates. I set out enthusiastically to make an electric car. I believed that this was the ultimate invention that was needed to save the Earth. After a few months of thinking, I came up with a design for the engine in a car using only electromagnets. When I showed this to my physics teacher, he asked me: but where are you going to get the electricity from? And I quickly answered: from batteries. He asked again, and where is the energy in the batteries going to come from? And I understood the cycle of conservation of energy like never before. We would still have to use fossil fuels to generate electricity. In automobiles where fossils were directly being converted into heat and mechanical energy, in my case there was an additional step of conversion and hence a lower efficiency, that of concerning fossils to electrical and then to mechanical energy. This made me realize how non-trivial the process of energy management was. The root problem was the use of non-renewable energy sources.

However, now I must not give support to claims without due thought, being a practitioner of science, and having taken Quantum Physics classes which show how reality can be counter intuitive. It is also important to identify the major sources to control climate change effectively. In the first week of our ES 200 Course, Prof. Virendra Sethi showed data in support of industries not being the major source of pollution in Chandrapur but roads and combustion being significant contributors. Pollution control boards have mainly been managing industries- green, orange, red categories and large scale, medium scale and small scale. Haryana, Punjab only smoke from chimneys are counted as pollution. A large part of the problem in India is not on the radar such as smoke from chulhas, trucks and buses. In addition, we were told to watch the films "An Inconvenient Truth" and "The Global Warming Swindle" which provide contradictory arguments to establish whether global warming is being caused by humans.

A simple fact that is undeniable is the meteoric rise of carbon dioxide emissions. Just like the human body has to regulate the concentrations of different chemical constituents for regular functioning, the Earth's atmosphere also needs to maintain its composition. However, the rapidly increasing carbon dioxide levels have been too much of an extreme and if not mitigated, will lead to dysfunctioning of the ecosystem. Given my engineering background, estimates and models with data assimilation and analysis need to be done to predict the rate at which things could get worse. Here comes the big issue. The scale of the problem is too large to be modeled and analyzed. In Nonlinear Dynamics

course, Lorenz attractor was simulated to show how simple models for complex systems can cause chaotic dynamics (popularly known as the Butterfly effect, as in the movie Mr. Nobody). Bifurcation theory therein is based on symmetry breaking principle. Here we are breaking symmetry with respect to nature. Nonlinear dynamics taught me that even though there may be deterministic laws governing the dynamics, they could result in unpredictable outcomes over non-trivial time scales. We are conditioned to formulate patterns and take correlation to be causation in order to predict things but in the case of climate of the entire planet, the complexity involved is too large to allow such simplistic prediction models (Kahneman, D., P. Slovic, A. Tversky 1982 Judgment Under Uncertainty: Heuristics and Biases 555pp. Cambridge Un. Press). Time series and regression analysis have also caused misleading factors to be pronounced as primary causes. The problem is that for large numbers, central limit theorem makes noise and dissipation indistinguishable because of approximate Gaussian behaviour of the mean, and two completely unrelated time series, having similar spectral shape also show on average the same number of maxima and minima in any given time interval.

The movie An Inconvenient Truth, shows a graph exhibiting carbon dioxide correlation with temperature increase however in the movie The Global Warming Swindle, scientists claim the converse. They also say that the IPCC is politically biased. Data scientists are needed to do more Investigation of the link. Earth's atmosphere is thin. But is it fragile? Can it sustain, adapt and redevelop? Earth's temperature curve shows a breathing pattern: One simplistic explanation is that when the northern hemisphere is towards the Sun, where most of the vegetation grows and hence carbon dioxide gets consumed and vice versa. Assuming that carbon dioxide affects the global temperature significantly (based on the correlation shown), the temperature also increases and drops. Carbon dioxide being greenhouse gas increases the temperature of Earth by trapping infrared radiation in the troposphere. Roger Revelle first studied in 1958 the carbon dioxide composition in the atmosphere using weather balloons. Data shows increasing levels constantly. Carbon dioxide levels have never gone above 300 ppm before this century but now it has shot up to 412 ppm. However current models fail to explain the slight decrease in temperatures as we rise up in the atmosphere which may imply that greenhouse gasses are not the major cause of trapping heat. Ian Clark on the other hand states that the correlation might be explained by a reverse causation: temperature rise causes higher carbon dioxide in the atmosphere. This based on his data which shows that carbon dioxide concentration increase lags that of temperature increase by 800 years. However the periodicity can create a confusion. Carbon dioxide rise may have an accumulative effect on the increase in temperature after a few hundred years and continue this in cycles. This becomes a chicken and egg problem as carbon dioxide emissions being produced now can persist in the air for centuries, with their effects building over time. Carl Wunsch (MIT Oceanography) explains that the ocean is the primary source of carbon dioxide. Ocean's memory of temperature changes is used to explain the time lag. Use Sun to predict the weather. However recent studies have shown opposite trends. The contribution of human and industry produced carbon dioxide is in single digits percentage. We can detect isotopes of Carbon and get estimates on the industrial carbon vs natural carbon sources as isotope carbon-13 is less commonly found in natural sources whereas its abundant in industrial emissions. Even though small, if the contribution is disrupting the balance of natural carbon cycle, then it may lead to a landslide. Most of the scientists' comments in the second movie were taken out of context. In fact the work of Ian Clark that was mentioned has been proved to be based on false data. Moreover Carl Wunsch even criticized the movie makers for misinforming him.

Extreme of anything is detrimental. There needs to be a balance otherwise disastrous effects can be seen such as glaciers and Ice melting. Land based ice vs sea based ice have different effects. Sea level rise is a major issue of concern. Especially for the polar regions. However, a recent paper published in Geophysical Research Letters (Marine ice cliff instability mitigated by slow removal of ice shelves by Clerc, Fiona and Minchew, Brent M and Behn, Mark D), based on their simulations of mechanical properties, based on Maxwell's model for viscoelasticity for behavior of ice, reports that for a 90-meter ice cliff to collapse, the ice shelves supporting the cliff would have to break apart rapidly, in a few hours , which has not been observed till date.

Population explosion and Industrial revolution has completely gone out of control. Contribution of developing vs developed nations based on lifestyle is evident. Carbon footprint of an average US citizen is five times more than the average in rest of the world. Hurricane Katrina, heat wave in Europe, temperatures in India and Pakistan reaching extremes during summer, very recent events including the forest fires in Australia and China and the wildfires in California are clear examples that a significant increase in such fires is one of the expected effects of a warmer planet with more frequent and deeper droughts. I saw a movie which had a line that stuck with me for a long time: "What will you say to your kids when they ask you how did you allow this to happen to the Earth?" Later, I read the book Sapiens (A Brief History of Humankind) in which, Yuval Harari's explanation on what makes humans so distinct from other species was that it is the ability to give reality to abstract things such as notions of money and nationality. Our superiority as a species is also based on this power- its what makes possible organizing millions of humans in one nation, an unprecedented event at the scale of species in the history of Earth. However, this has also separated our ideology so far from the rest of natural forms on the planet that we seldom take their existence into account. Rather, we have exploited every other resource in order to develop our species more and more. This is what makes our activities depart from the way of nature. The way of nature is usually assumed to be the best path (most of modern physics is now reformulated in terms of the least action principle that says the minimum energy path is always taken). We act not in harmony with nature but against it. There's a natural time for everything. Season's, rains, winter and autumn come and go periodically. However, human tendencies change rapidly. We want to get to places faster, experience things that are not in our reach quicker, go much ahead of the natural time of doing things, which is what technology is mainly used for. These activities have upset the ecosystem's balance s well. We experience rains at times of the year when it should be dry, there's heat in months that used to be cold. The question is not whether to go back to the Stone Age lifestyle but can we optimize our activities so as to minimize the damage being done to the planet and hence save ourselves?

Personal and social decisions matter. I didn't own any electronic device other than a mobile and a calculator in undergraduate and it in fact helped me immensely to live a peaceful life. Walking with friends and having important discussions instead of rushing to and from classes in auto rickshaws helped me benefit from my amazing peers that are here. I remember cannoning in a national park in Canada, away from the city. The natural calmness in the area was itself much more refreshing than any other activity in the city. Last decade has seen the Maximum number of hottest years recorded in our history.

Identifying the real causes and handling them effectively. We may misdirect our efforts and energy to work on factors that are not so important. For instance a formal method to assess the relative importance of controlling carbon dioxide vs. short-lived greenhouse

gases such as methane. With a large number of leading experts working on combating the climate change problem and Elon Musk even having a plan to make Mars a viable option for life sustenance, there's no doubt that the problem is to be critically addressed. Not to form opinions based on social media or any other forms of hearsay, but to rely on scientists (people who are proven investigators of these issues). Dicaprio's documentary in collaboration with National Geographic titled Before the Flood also depicted concerns rising worldwide and the attempts by nations to join forces and take action. He himself had to film for the Revenant in the extremes of Northern Canada, where their shoot halted many times because of bad weather. Also education plays an important role, data science needs to be included in the core curriculum. Modern techniques of machine learning to predict based on huge datasets can be used to give estimates. For instance, En-ROADS climate solutions simulator, a new online interface that simulates 100 years of energy, land, and climate data to identify solutions in less than a second was released by MIT Sloan Sustainability Initiative, which can be used by high school students to see the effects of various factors.

Economic factors also pitch in. Industries are in opposition to concerns of global warming as it impedes the rate of growth and expansion. However, the recent plastic ban was an indication that the government will not shy away from taking drastic measures to save the planet even if it is at the cost of industrial development. In fact we have supposedly left the Holocene era and entered the Anthropocene era of which global warming is just a part of the process. Human civilization must stop treating nature as a distinct entity. Even for economic growth, soil erosion in conventionally plowed agricultural fields is nearly 100 times that of the natural background rate. Most carbon dioxide stays in the air for over a century. Now that renewable technology has advanced, we can replace coal sources by solar, wind and nuclear, use modern equipment to increase efficiency. Global warming is a real and major issue for our society today, and I intend to see to it throughout my career that modern technology improvements can be made environment friendly and help optimize our activities to be in harmony with the ecosystem.