Climate Change Concepts for Engineers

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Background:

Our Earth's climate has always been dynamic and changing since its inception. It has seen several epochs of extremeties ranging from ice cold temperatures to hotter environment with no ice. As humans we are lucky to be living in an epoch were climate has been conducive to our existence and helped us provide energy and water resources necessary for our survival. Human ingenuity has helped exploit the bounties of nature that exist because of current climate conditions and we have engineered systems that help improve our quality of life. However, these expolitations and improvements have come at a cost. We have, in this process, altered the climate system and our efforts to improve the quality of our life has in many ways threatened our very existence on this planet.

The nature is however resilient and while some of our actions have led to irreversible damages, it still can help us continue to have a wonderful quality of life. However, we are at the stage where the critical carrying capacity of our nature is at its tipping point. We have to make course corrections Just like our body or any engineered machine cannot continue to accelerate perpetually, we cannot think our climate system will continue to function at a high level for ever. We need to ensure, we are taking care of it providing proper maintenence. We need to adapt and start to make small sacrifies for the larger good of the humanity both in the present and into the future.

There is growing evidence that our tinkering of the climate is starting to cause harmful effects such as increased floods and droughts. However, we are not in a position to pinpoint how much of it is due to climate change. This should not dissuade us from going on our business as usual. Not every smoker gets lung cancer, and there are factors other than smoking that cause lung cancer in smokers. However, we know smoking is injurious to health. The climate situation is just the same.

There are several misconceptions related to climate change. The mainstream news and social media are filled with conflicting and confounding information. The science of climate change is inexact though it is strongly rooted in scientific principles. Needless to say, all these factors affect how we view climate change. In addition, climate change is a slow process, even if we think it can be harmful, we tend to justify that our individual effort is too small to make a dent. At the end of the day, nature or this plane does not care if we exist or not. But it is important for us that this planet stay the way it is so we can continue to exist. There is sufficient science to demonstrate that climate is changing and we can also infer what these changes mean to our existence. Just like any other engineering problem, we need to hone in on the basic concepts that drive the climate system and see find ways to mitigate the problem. It is perhaps the largest and the most complex control system problem we can solve and should have a highly vested interest to do so!

Why This Course:

Engineers continue to transform this world and improve our quality of life. However, every engineering process cannot be 100% efficient and tends to have harmful side-effects. It is also the responsibility of engineers to ensure these harmful side-effects are mitigated and minimized. A responsible accounting of an engineering project should not only focus on reducing economic costs and improving profit margins, but also account for likely impacts on the environment and ecosystems. Engineered systems and natural systems integrate to form gaint, interconencted systems of systems (SoS). How do changes in one part impact the others (especially the climate?). What then are the feedbacks from a changed climate system on our engineered system? Questions such these should be part of current engineering thinking.

Building on the above premise, the primary goal of this course is to introduce engineering students to concepts behind the climate system and demonstrate its nexus to both natural and engineered systems related to energy, water, air and agriculture (food). A unique aspect of this course is that we shall employ engineering principles such as mass and energy conservation principles that you have studied in your thermodynamics and fluid mechanics classes to understand climate systems. We shall make use of system-theoretic approaches to study the interactions of climate with other natural and engineering systems. We shall see how we can quantify 'latent' climate phenomena such as drought, floods and heat waves using statistical methods. Finally we shall explore how to make important engineering decisions related to water supply allocations under climate change.

Course Pre-Requisites:

Students should be familar with conservation of mass and energy principles that are commonly taught in engineering thermodyanmics and fluid mechanics classes. Some basic knowledge of statistics and ordinary differential equations taught in the first year engineering curriculum will come in handy.

Students must have access to a strong internet connection. We shall be downloading climate data specific to your location and analyze it.

Some familiarity with computer programming particularly the use of R and Python programming environments is desired but not required. I will be providing some codes in these languages for you to analyze climate data. Both R and Python are free and I shall provide links to download them.

Students must have oral and written communication skills and are expected to write and present a project report. Independent research skills and ability to synthesize information from a variety of sources will be required as part of the course.

Tentative Outline:

Module 1: Introduction to Earth's Climate System. Difference between weather and climate. Historical trends in climate over the history of the Earth. Current climatic conditions, spatio-temporal variability

Module 2: Modeling Earth's climate dynamics. Energy (Radiation) and Water Budgets. Role of atmospheric gases in maintaining Earth's temperature. Natural and anthropogenic influences on the Earth's climate system.

Module 3: Exploring Climate using simple climate models. Hands-on Explorations using R and/or Python programming.

Module 4: Introduction to Global Climate Models (GCMs). Why there are so many? What do these models do? What scenarios do they simulate? Why?

Module 5: How to translate results from large-scale GCM models to smaller scales of interest to us (watersheds, cities)? - A review of downscaling methods.

Module 6: Obtaining downscaled GCM data for your location and evaluating historical trends. (Hands-on Exercise using R programming Environment).

Module 7: Exploring Climate-Water Nexus. How does climate affect water availability. Climate extremes - Floods and Droughts? Characterizing droughts using Downscaled GCM data (Handson Exercise using R programming environment).

Module 8: Exploring Climate-Food Nexus. How does climate directly affect global food security? Is climate change bad for agriculture? Why and Why not. Future trends and potential implications. What is the nexus between climate food and water?

Module 9: Exploring Climate Impacts on Human Health. Role of climate on air-quality, respiratory illnesses, heat-strokes, role of climate on sanitation and water-borne illnesses.

Module 10: Adapting to a changing climate. What should we do?

Bonus Content: Gleaning climate related information using Modern Text Mining Tools (Hands-on example using Python)

Content Delivery:

The course will be conducted in a hybrid format comprising of video lectures and virtual (in-class) presentations. Office Hours will be provided on a regular basis to address student queries.

Course Assessment:

Quizzes: Every module will have quiz associated with it. (15%)
Mini-Projects: There will be 3 mini-projects.
- **Mini Project 1:** Impacts of changing climate in your city. (20%)
- **Mini Project 2:** Water scarcity in your area in the future? How does it compare with the past? (20%)
- **Mini Project 3:** Text mining Literature on a topic related to climate change (topic will be assigned to you) (20%)

Final Presentation: A presentation describing your personal understanding the climate change phenomenon and what you would like to do to combat it (25%)

Venki Uddameri, Ph.D., P.E. is a professor in the department of civil, environmental and construction engineering at Texas Tech where he also serves as the director of the TTU Water Resources Center. His research and teaching interests are in the areas of sustainable water resources management with a particular emphasis on food-energy-water nexus in groundwater-dependent systems. His current research projects are focused on characterization of brackish and other alternative sources of water in arid and semi-arid landscapes. His research has been funded through several federal, state and local agencies including the National Science Foundation (NSF), National Oceanic and Atmospheric Administration (NOAA), United States Department of Defense (DoD), United States Department of Energy (DOE), U.S. Department of Interior (DOI), United States Department of Agriculture (USDA),. He has published extensively in the area of groundwater modeling and management and currently serves as the associate editor of the Journal of American Water Resources Association (JAWRA). He has published extensively in the areas of water resources management and sustainability and edited two journal special issues. He has co-authored two books – Hydraulic Fracturing Impacts and Technology – A Multidisciplinary Perspective (with A. Morse and K. Tindle, CRC Press/Taylor Francis) and GIS and Geocomputation for Water Resources Science and Engineering (with B. Dixon, John Wiley and Sons).