Final Project: The Earth system during the last interglacial

For the last two labs you have developed skills to work with EdGCM (Educational Global Climate Model), plot the data using Panoply and analyze the data with your understanding of the global climate system. You will examine during the final project the relative impacts of orbital forcing (i.e. tilt, precession and eccentricity) and greenhouse gases in driving climate change. Specifically, you will compare the climate of the Eemian, which is the last interglacial period, with the current climate both with and without elevated anthropogenic greenhouse gases. For the final project of this class you will need to focus on one aspect of the Earth System that was influenced by these changes and present your results to the class and provide a write-up discussing the significance. The presentations will be graded as a group but the write-ups will be graded individual. The project needs to include both discussion and interpretation of your own results and also references to at least 2 published papers.

<u>The presentation (50%)</u>

The presentation will be held strictly to 15 minutes and there is an expectation that the talking will be distributed evenly between the members of the group. Your presentation should include the following:

1) A description of the scientific question, the expected results and the motivation for the work
2) A description of the experimental design and why it is suitable to address the question
3) Figures clearly showing the results
4) A comparison of your results with any previous studies that have done something similar
5) A discussion of whether your results were consistent with your expectations.
6) Any thoughts on follow-up or future experiments

You will be graded on your ability to: (1) address those 6 points, (2) the style of your presentation and (3) your ability to meet the time requirements. Please take advantage of figures and images when putting together your presentations. Style and aesthetics go a long way in making a good presentation. Also, practice practice practice!

<u>The write-up (50%)</u>

The write-up needs to be prepared individually. It should not exceed two pages of 1.5 spaced text however, there is no limit on the number of figures or references utilized. References need to be in a bibliography. You can choose the format. **Figures must include captions and must be discussed in the text.** If I find figures that are not actually discussed, this will result in a loss of points. The write-up should address all the 6 points listed above. You must must be VERY concise in order to fit this all in 2 pages. In other words, just get to the point! This is an important skill in scientific writing.

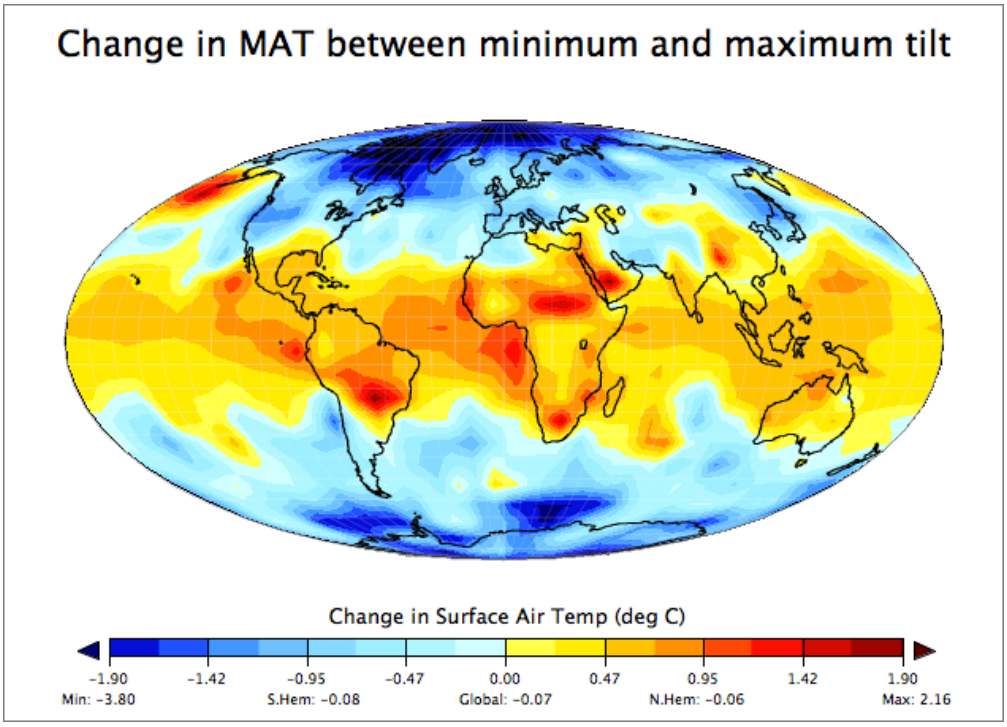
Due Date: Presentations will be during class on April 26 and 28. Papers are due by midnight on April 29.

EdGCM Lab 1: Experimenting with the Earth's climate response to different forcing.

This is a three-part lab, which will culminate the final week of class with group presentations. The work during this week and next week's labs will both be handed in and graded like a normal lab. The purpose of this series of labs is to: (1) learn to use a simplified **Global Climate Model** (GCM), (2) develop a hypothesis regarding how some aspect of the climate will respond to a forcing agent (such as an increase in methane), (3) conduct a series of experiments with the GCM to test this hypothesis and (4) present your results to the class and consider how your results compare to other published literature.

A Global Climate Model is a computer program intended to capture the physics of the climate system using a series of numerical equations. These programs are incredibly complex, often including 100,000's of lines of computer code and taking decades to develop. Currently, there are close to 20 different climate models in the world each with their own unique strengths and weaknesses. In general, because of how computationally demanding these programs are they can only be run on super-computers however, a simplified GCM was developed by the Goddard Institute of Space Studies called EdGCM (Educational GCM). This program has many of the critical elements of a state-of-the-art GCM but has been simplified so it can be run on a personal computer. However, don't be mistaken, even though this is fairly simple for a GCM, it is still very complicated and pushes the computational power of a normal personal computer. I encourage you to read more about EdGCM here: http://edgcm.columbia.edu

Below is an example of the sort of results you will be expected to produce. This map shows the difference in average annual temperatures when the axial tilt of the planet is shifted between 24 and 21 degrees. The results from this experiment (a simulation run with EdGCM) suggest the tropics get warmer with less axial tilt but the poles get cooler. *Why might that be?*



During the first week of the lab you will be expected to (1) familiarize yourself with how the program works, (2) conduct a set of assigned experiments and (3) answer a few questions on the results of these experiments, which will be handed in and graded as a normal lab.

The Program is available on the lab computers but if you want to set it up on your own computer go through Part 1 below, otherwise skip to Part 2.

1) Downloading and setting up EdGCM:

Getting started with EdGCM can be a bit time consuming and frustrating the first time so feel free to ask myself or the TA for assistance. **There is very useful quick start guide here: http://edgcm.columbia.edu/documentation which you will need use in order to figure out how to make maps and interpret the results.**

Here are the links to download the software for Windows:
http://tinyurl.com/EdGCM-Win-b926

and Mac:
http://tinyurl.com/EdGCM-Mac-4b3

There are additional software updates that are needed to make the software work. These can be found here.
http://edgcm.columbia.edu/download-edgcm/software-updates/

Additional downloads may be necessary depending on supporting software you already have on your computer. Please consult this post if you are having issues: http://forums.edgcm.columbia.edu/showpost.php?p=2846&postcount=1

2) Setting up your first experiment

The first experiment you will run is going to be a "control". This means you will run the climate model with conditions equivalent to those that were present in 1958. This means the atmosphere will have greenhouse gas concentrations, luminosity and orbital parameters similar to those in 1958. You will compare the results from the "control" run to all your additional experiments. So, for example, if you want to know how temperature varies if carbon dioxide doubled you would first run a control and then a "doubled CO2" experiment and see how the results between these two simulations differ.

1. Start EdGCM
2. Find the Simulation called "Sample_Control_Run" in the Simulation Library
3. This simulation cannot be modified so you will need to Duplicate it before it can be modified.
4. Give this experiment a new name, for example "Control". Type in an Author name and in the "Comments" section write a brief description of the experiment.
5. Change the length of the simulation from 1958-1963. (**This is critical, if you fail to make this adjustment, the simulation will take many many hours to run**)
6. Press the "Play" button to start the simulation. The software will run one timestep to make sure there are no problems with how it was set up. Press the "Play" button a second time to start the full simulation. The screen will show you the progress of the simulation. Assume it will take 10-15 minutes to run depending on the speed of the computer. When the simulation finished there will be a blue circle next to the simulation. This means the outputs are complete and can be analyzed

Assignment (these questions need to be answered and handed in):

1a. Make a plot showing the 5-year annual average (a) wind speeds, (b) surface temperature and (c) precipitation for the control simulation.
1b. What is the average temperature for Chicago in the simulation? How does it compare to reality.
1c. What is the approximate latitude and longitude of the grid cell that receives the most precipitation?

3) Testing the influence of greenhouse gases on the climate

In this experiment you will run a 5-year simulation where you double the concentration of methane, carbon dioxide and nitrous oxide in the atmosphere. You will then compare how temperature, wind and precipitation were affected by these changes.

1. Duplicate the "Control simulation" from the first experiment
2. Give this experiment a new name, for example "DoubledGHG". Type in an Author name and write Comments to describe this experiment.
3. Scroll down to the area called "***Forcings***" and double the concentrations for CO2, CH4 and N2O.

4. Press the “Play” button to start the simulation. It will run one timestep to make sure there are no problems with the setup. Press the “Play” button a second time to start the full simulation. The screen will show you the progress of the simulation. Assume it will take 10-15 minutes to run depending on the speed of the computer.

Assignment:
2a. Make a plot showing the **difference** between the 5-year annual averaged wind speed, temperature and precipitation for the *DoubledGHG* and the *Control simulation*. This map should show areas the regions where the climate was most influenced by the change in Greenhouse gases.
2b. How much was Chicago influenced by this change in GHGs?
2c. What region was affected most in terms of (a) Temperature, (b) Precipitation and (c) windspeed

4) Testing the influence of axial tilt and eccentricity

In this experiment you will run a 5-year simulation where you will change eccentricity to its maximum value and axial tilt to its minimum value. You will need to look up maximum and minimum values for axial tilt and eccentricity in your book or on the internet. Greenhouse gas concentrations will be set to the original values from the control simulation so you will only test the orbital influence on the climate system. As with part 3, you will then compare how temperature, wind and precipitation were affected by these orbital changes.

1. Duplicate the “Control simulation” from the first experiment
2. Give this experiment a new name, for example “Orbital”. Type in an Author name and Comments.
3. Scroll down to the area called “Forcings” and change tilt and eccentricity to minimum and maximum values, respectively.
4. Press the “Play” button to start the simulation. It will run one timestep to make sure there are no problems. Press the “Play” button a second time to start the full simulation. The screen will show you the progress of the simulation. Assume it will take 10-15 minutes to run depending on the speed of the computer.

Assignment:
3a. Make a plot showing the difference between the 5-year annual average wind speeds, temperature and precipitation for the “Orbital” and the Control simulation. This map should show areas how much the climate was influenced by this change in orbital shifts and show you where the changes were most severe.
3b. How much was Chicago influenced by these orbital changes?
3c. What region was affected most for (a) Temperature, (b) Precipitation and (c) windspeed
3d. Did the change in GHG or orbital forcing have an overall larger influence on the climate?

EdGCM Lab 2: The Earth system during the last interglacial

Anthropogenic emissions of greenhouse gases have contributed significantly to the recent rise in Earth's temperatures. However, 125,000 years ago during a period called the Eemian, temperatures were almost as warm as today yet greenhouse gas concentrations were much lower. This is because orbital configurations were such that climate was warm despite the relatively low greenhouse gas concentrations. The Eemian is a very important period in Earth's history because it represents the last time Earth was warmer than it is today. So, this time period provides our best insight into how things like the Greenland Ice Sheet or forests will respond to expected future warming. In this final project you will look at the climate under the following four scenarios:

1) Eemian climate (orbital forcing)
2) Preindustrial climate ("control")
3) Modern climate (greenhouse gas forcing)
4) Modern+Eemian (greenhouse gas+orbital forcing)

Experiment	Eccentricity	Obliquity	Precession	CO2	CH4	N2O
Predindustrial	0.0167	23.44	102.04	260	600	270
Eemian	0.039	24.04	275.4	270	630	160
Modern	0.0167	23.44	102.04	410	1823	327
Modern+Eemian	0.039	24.04	275.4	410	1823	327

Although each group will run, more or less, the same set of simulations each group will focus on a specific aspect of the climate system that is influenced by changes in orbital, greenhouse gases or both. For example, how would changes in orbital forcing during the Eemian influence the expansion of the Sahara or Mojave Deserts? How did Arctic sea ice change in response to these changes? Were there differences in extreme rainfall or wind? Was there more or less snowfall in the mountains of the western US?

During the first week of this lab you familiarized yourself with the EdGCM and Panoply software and did a few brief experiments to gain experience with these tools. During this week's lab you will set up the four experiments for your final project by setting the correct greenhouse gas, orbital configurations and time span. Although you will not have the time to run all these experiments today, you will run a series of short test simulations to make sure you have properly set up your experiments. You will have an additional lab period to complete the simulations or they can be run at home if you have setup the software on your own computer.

Step 1: Set up the four simulations in your simulation library and run short 1 year test simulations. Some factors such as orbital configurations are listed in the table above but other factors can be set specifically by your group. For example, it is important to decide how long you want to run your experiment for. If you run your experiment too short, you might not get a stable answer but obviously if you run your experiment for 100 years, it will take too long. Please check with the TA or Prof. Berkelhammer to make sure the four simulations have been setup correctly.

Step 2: Decide on what questions you would like to address with these simulations. Have a discussion with your group and decide what you would like to look at. Fundamentally, you are all asking how the Earth system responds differently to changes in greenhouse gases vs. orbital forcing but specifically you will need to hone in on something smaller and more targeted. Some examples are listed above such as changes in extreme rainfall, sea ice or perhaps how ecosystems or habitat may have shifted under these changes. This is the time for you as a group to focus on something that most interests you. Perhaps there is a region of the world you are interested in or a type of phenomenon such as heat waves. Be creative and pick something exciting. Feel free to look up articles to help you decide.

Step 3: Decide on the tasks needed to completed. This will include running the simulations, preparing figures and finding relevant papers. To get this done on time, it is necessary to make sure different people are responsible for different tasks. You will have one more complete lab period to work on this and perhaps another hour of class time. **To hand in by the end of the lab period from each person is a paragraph describing what topic/questions the group will be working on and the specific tasks you are responsible for.**