Using a Global Climate Model – Assignment 1:
Running Climate Model Simulations and Examining Global Changes Through Time

Assignment overview

- Use a web-based climate simulator to examine the difference between climates in a modern climate simulation vs. two global warming simulations: 1) a simulation with double the mid-20th century atmospheric carbon dioxide level and 2) a simulation with gradually increasing atmospheric carbon dioxide that is representative of a scenario that is projected to be underway currently on our planet.

- Complete the Reflection Questions and submit them, with your time series plots of several climate variables to the Week 3 assignment page.

Introduction:
This week you will begin the analysis of three climate simulations using a web-based climate modeling tool developed at NASA. Next week, you will examine in greater depth a climate model simulation conducted for the IPCC (Intergovernmental Panel on Climate Change) 4th Assessment Report, a study that earned the Nobel Peace Prize in 2007 for the science teams that conducted the research. The goal for the next two weeks is for you to become familiar with the steps involved in climate modeling and how scientists use these types of models to study future climate change.

In this assignment, the three climate model simulations we will begin to explore include: 1) a mid-20th century (“Modern”) climate simulation, which serves as a control experiment, 2) a simplistic global warming simulation (“Doubled CO2”) and 3) a more realistic future climate change experiment (“IPCC_A1FI_CO2”). The modern simulation represents the Earth’s climate prior to any major effects of greenhouse gas increases, while the Doubled CO2 global warming run is one that climate scientists use to gauge model sensitivity for comparison to other models. We will discuss the third simulation, “IPCC_A1FI_CO2,” in greater detail during Week 4.

The model you will be using was developed at NASA’s Goddard Institute for Space Studies (GISS) in New York and is one of the nation’s primary climate model development and research centers. The simulations designed with this model are identical to those used for comparisons with models developed by other international
climate modeling institutions. Such model comparisons and analyses form the core of
the international research studies that guide government policy decisions on climate
change.

Read all the steps carefully in the assignments for Week 3 and 4. If you have any
questions as you work, please post them in the special “Help Forum” sections for either
Week 3 or Week 4 of the course.

Simulating Future Climate Change Using
A Global Climate Model: Part I

(EzGCM: Web-based Version)
Step 1 – Constant Vs. Transient Greenhouse Gas Forcings

One important distinction in how climate forcings are applied in computer models is whether or not the simulations use constant or transient values of greenhouse gases (transient = changing over time).

**Constant Greenhouse Gas Forcings:** If a simulation begins with climate conditions that are similar to modern, including a modern level of greenhouse gases (a simulation has to start somewhere, after all) we would expect that the simulation would reproduce something like the modern climate. That is, if no other major changes are imposed during a simulation and presuming that the model’s equations are accurate, the resulting climate would have no reason to change – except for some natural variation around the mean. On the other hand, if the same model were run with increased or reduced levels of greenhouse gas the resulting climate would no longer be like the present climate. In most cases the climate would adjust and eventually reach a new equilibrium. In our assignments, the constant forcing simulations are called **Modern_PredictedSST** and **Doubled_CO2**, which is also a constant forcing simulation but, as the name implies, has twice as much CO₂ in the atmosphere. Look for these runs as you use EzGCM.

**Transient Greenhouse Gas Forcings:** The use of transient greenhouse gases is very important when scientists are trying to simulate, as accurately as possible, the climate changes that have occurred over the past 200 years (and that will continue to occur during the coming century). With CO₂ levels rising continuously as a result of fossil fuel burning, the Earth is undergoing a shift in its climate state associated with a transient forcing. In our assignments the climate model run called **IPCC_A1FI_CO2** is one example of a simulation that includes a transient atmospheric CO₂ trend that is close to the path we are currently following in the real world. We will examine the climate effects caused by that CO₂ trend in next week’s assignment but, for now, let’s just examine the constant and transient CO₂ forcing trends used in a variety of experiments.

Examine the line plot at the right and use it to help answer the reflection questions on the following page.
Reflection Questions

1. Which of the CO\textsubscript{2} forcings shown on the line plot on page 4 are constant forcing and which are transient forcing? For each simulation what are the beginning and ending CO\textsubscript{2} values?

2. Which simulations do you think would equilibrate at colder temperatures than the Modern_PredictedSST run? Which would equilibrate at temperatures warmer than that run?

3. Assume the Modern_PredictedSST simulation resulted in a global surface air temperature of 14°C. Discuss how you might estimate the temperatures that would result from the other scenarios and make a rough estimate of the temperature at year 100 for the Ice Age LGM run, the Doubled CO\textsubscript{2} run, and the IPCC_A1FI_CO2 run. The objective is to have you think about how scientists might have estimated global temperatures before climate models existed – we are looking for good reasoning, not a “right” answer. You will be running these simulations later with the climate model and will be able to check your estimates at that time.

Step 2 – Generate Time Series Plots of Key Climate Variables

2.1 We will now compare time series for three different climate model simulations, including Modern_PredictedSST, which is a simulation of the mid-20\textsuperscript{th} century climate. This simulation will serve as our “control” experiment, which provides a baseline that represents Earth’s climate prior to the effects of anthropogenic greenhouse gases. We can use this control simulation to compare to altered climate simulations, such as the constant forcing run Doubled_CO\textsubscript{2}, in which CO\textsubscript{2} levels are instantly doubled at the start of the run, and the transient forcing run IPCC_A1FI_CO2, where CO\textsubscript{2} levels increase gradually over the entire length of the run. Both of these simulations are global warming scenarios used by the IPCC in previous international reports (2001, 2007).

2.2 Open a web browser (sorry, EzGCM is only compatible with Safari, Firefox or Chrome). Go to the website: http://ezgcm.org and login. If you do not already have an EzGCM account read the instructions document that was provided separately by your instructor. It contains the Course Activation Code you will need to create your EzGCM climate modeling account for this course.
After you log in you will be on your personal MyGCM page. Click on the **Week 3 button** to go to the first assignment.

Refer to the document *MyGCM_in_EzGCM.pdf*, which you can download from the Documents section of your MyGCM page (click on the document to download it to your computer).

The Week 3 button will take you to a brief introduction. Read over the introduction and when you are finished click the **Run Experiment** button at the bottom of the web page (you may need to scroll down to see it).
2.3 You will now find yourself on the Run Simulations page of EzGCM. Note that there are four simulations available in the Simulations section. Select the first 3 simulations (Modern_PredictedSST, IPCC_A1FI_CO2, Doubled_CO2) by holding down the shift key while clicking on each of them. Below the simulations is a list of Climate Variables. Select Surface Air Temperature (it may be selected by default in some browsers).

2.4 Begin loading the simulations by clicking the Play button above the Simulations list. A GCM log window will appear on the left and the time series plots of the selected Surface Air Temperature will begin plotting in the panel on the right.

2.5 After the simulations are complete (when the lines reach year 2100) roll your cursor over the plot to see the legend. The legend indicates which line represents which simulation along with the values of each at any given year of the run.

2.6 Use the Save Image button (the plus sign in the upper right corner of the plot) to save the Surface Air Temperature plot to your MyGCM page. From the MyGCM page you can download the image and submit it along with the answers to the reflection questions.

2.7 Click the Stop button then repeat steps 2.3-2.6 for the climate variable: Atmospheric Carbon Dioxide.

2.8 Click the Stop button then repeat steps 2.3-2.6 for the climate variable: Ocean Ice Cover.
Explore EzGCM’s line plotting options:
You can select any number of simulations AND multiple climate variables (hold down the shift key or the control key while clicking to select multiple variables) and EzGCM will animate up to 4 time series plots simultaneously in the right-hand panel. To see how this works, try selecting all 4 simulations then select 2 climate variables, for example Atmospheric Carbon Dioxide and Surface Air Temperature. This should produce 2 plots, each plot with 4 lines. EzGCM can create up to four climate variable plots at a time.

2.9 Using the plots on the website or your saved images, answer the following reflection questions.

**Reflection Questions**

4. Approximately what year does the CO₂ level in the IPCC_A1FI_CO2 simulation equal the Doubled CO₂ amount?

5. What is the CO₂ level in the IPCC_A1FI_CO2 simulation at year 2100? What year would you predict that atmospheric CO₂ in that scenario will reach 4X the modern level of CO₂? Explain how you made your estimate.

6. How do the three surface air temperature trends differ?

7. Are the temperatures that you predicted in Step 1, Question 3 for the two global warming simulations (Doubled_CO2 and IPCC_A1FI_CO2) similar to what you now find in the surface air temperature plot created by the climate model?

8. How does the ocean ice cover change in the Doubled_CO2 simulation compared to the IPCC_A1FI_CO2 simulation?

9. Explain how the change in ocean ice cover could be related to what happened to the surface air temperature.

10. Next week (Week 4) we will create visualizations to compare Surface Air Temperatures from two scenarios, one of which has stable greenhouse gases, the other having increasing CO₂ levels. What differences do you think you will see? Suggest some other physical characteristics of the climate system that you would expect to change and hypothesize how those components might be altered, qualitatively, as CO₂ increases. (We will explore several climate variables in next week’s assignment).

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Submit your answers to the reflection questions (1-10) to the Week 3 assignment page.
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