EdGCM Climate Modeling Assignment
Global Climate Process (ATM OCN 425) – Fall 2005
Professor McKinley

Goals:
The goal of this project is to introduce students to running and analyzing results from a Global Climate Model (GCM). Students will use the GCM to test their own hypotheses about climate under different perturbation scenarios.

The EdGCM
The EdGCM (www.edgcm.org) has been designed at NASA's Goddard Institute for Space Studies (NASA GISS) to be user friendly and computationally tractable for use in our computer lab. Please spend some time reading through this website to learn more about the model.

While our runs may seem long – taking on the order of 1 day to run on a PC, remember that climate models being used for the current Intergovernmental Panel on Climate Change (IPCC) assessment can take up to 6 months to run on a supercomputer with 150+ processors!

Plan of work:
In Part 1, students will perform a set of standard, pre-established simulations with the model. They will analyze this output to answer a set of questions about current climate and expected future change in climate. At the end of Part 1, students will form hypotheses that they will be able to test with the model. Students will write a report using the eJournal capability of EdGCM and have a meeting with the professor to discuss their plans for Part 2. This report will be prepared as a team.

In Part 2, students will design experiments to test their hypotheses, execute the appropriate experiments, and then analyze their results. They will write a final report (individually) and present their results to the class.

Due dates;
Part 1 – Report due on October 18.
Meeting with professor on October 20-21.
Part 2 – Presentations on December 13.
Final report due December 15.

Plotting Notes
Maps
You will find that there are a vast array of mapping options in Panopoly. Cartography is a science of its own, but we will not have time to explore it. For this class, please use only:

- Mollweide - for full Earth maps
- Equirectangular (Regional) - to zoom in on a region of interest
- Orthographic - for hemispheric plots of the polar regions (set to +-90N)

Line plots – "Timeseries"
In the current PC version of EdGCM, there is not a line-plotting program. You will need to export your data to Excel to make these plots. If you do not know Excel, please see the Help section to learn.

Getting your plots from Panoply into the eJournal via the Image Browser
Save your plots in Panoply as a *.png file. Then go to the Image Browser in EdGCM 4D. Here, find the "Import" function from the toolbar to bring in your plot saved from Panoply. Your plot will show up in the Image Browser window, and then you can drag it into place in the eJournal.

A few additional plotting hints

- When you compare plots, be sure to use the same color scale.
- Look at the difference between an interpolated and un-interpolated plot, particularly when you compare coarse-grid of the model fields to data.

Getting help with the EdGCM

Reading the EdGCM manual and looking at the Quicktime tutorial videos, both available from www.edgcm.org, can help answer basic questions about how to run the simulations and how to do plotting and analysis. Use these resources first if you need help.

You can see Professor McKinley for additional help. Office hours (Mondays 4:45-6:15) are the best time. Ana Marti (AOS&S 1515a) is knowledgeable about using the model and is also willing to answer questions.

Please do not expect the developers at NASA GISS to provide support on this project. If you believe you've found a bug with the program, please discuss it with the professor before contacting them.

PART 1: RUNNING THE MODEL, ANALYSIS, AND INTERPRETATION

Each team will do three runs in this part. The first, Modern_specifiedSST, is short and is done to check if the model is reasonable and will provide an atmospheric circulation and temperature patterns that are like that which is observed. The second, Modern_predictedSST, is a 150-year simulation and is used to compare to results of the third simulation, Global_Warming01. By comparing these two, you will be able to consider the effects of increased CO_2 on the climate system.

These three runs are already set up in the EdGCM installation. You should study the options that have been picked, but should not change them.

Experiments:

1. Modern_specifiedSST: 1958-1968
   a. This run uses a specified annual cycle of sea surface temperature (SST) that does not change over the course of the model run.
   b. Run to make sure that the model is working, and create a few plots to check against those posted on the web to make sure things are working correctly.
2. Modern_predictedSST: 1958 – 2100
   a. This run is a "calibration" run. It allows SST to vary in response to heat fluxes from the atmosphere over the course of the run.
   b. Constant CO_2 concentration and constant solar luminosity (1958 values).
   c. This run provides a basis for comparison to the "Global_warming_01" run.
   d. Performing this run is a key way of testing the model. Despite constant forcings, if this run illustrates large changes over time in climate then we should be suspicious of the model's output.
3. Global_Warming01: 1958--2100
   a. This run includes .5 ppm linear change in CO_2 from 1958-2000 and then has a 1% exponential increase in CO_2 from 2000-2100.
   b. Since the only difference from the Modern_predictedSST is the change in CO_2 forcing, changes in climate between the two simulations are the climate impact of that CO_2.

Plotting and Analysis:
For your analysis, focus on an average of the last five years of your simulation (i.e. 1964-1968 or 2096-2100). If you want to compare to the beginning of your simulation, also use a five-year average (i.e. 1958-1962). Averages are used to avoid short-term anomalies (also known as the "weather"!) that are not truly representative of the climate state.

1. Modern_specifiedSST – Plot and compare to data figures found on Learn@UW to make sure you're on the right track. You can also download these data files and plot them against your model results. Are these results reasonable considering the model and its limitations? What are key areas of difference that you note?
    a. Surface air temperature - annual mean, DJF (DecJanFeb) and JJA (JunJulAug)
    b. Precipitation – annual mean
    c. East-west ("U") winds – JJA, mapped and zonal mean
    d. Line plot of surface air temperature (export data to Excel and plot). How steady is this with time?
    e. Determine the pole-equator temperature gradients for the northern and southern hemispheres. Why are they not the same?

2. Modern_predictedSST – Since this simulation maintains current forcings, climate shouldn't vary that much over the course of the 150-year run.
    a. Show with a plot that the surface air temperatures are basically constant with time from 1958-2100.
    b. Plot Sea Surface temperature for 2096-2100 and compare to the data. Do this for the annual mean, both mapped and zonal mean plots. Is your result what you expected?
    c. Produce at least two other plots or maps that illustrate that this simulation provides a reasonably constant climate with time.

3. Global_Warming01
    a. Make a timeseries plot of the surface air temperature from 1958-2100.
    b. Plot the CO_2 forcing. How does this trajectory compare to the temperature trajectory?

4. Comparing Modern_predictedSST and Global_Warming01
    a. Map surface air temperature in the global warming scenario as a difference from the Modern_predictedSST result
        i. Where are the changes the largest? Why?
    b. Map ice and snow cover. How have they changed in comparison to Modern_predictedSST?
    c. Map the zonal wind at the jet level and discuss any changes.
    d. What are the impacts of increased CO_2 on SST?
    e. Plot clouds cover changes - Total, High, Low. What are the implications for the radiation balance?
    f. How does the Earth's albedo change? Can you relate these changes to other changes you've investigated above?

g. How does precipitation change? What might be the local impact to people in specific regions of the world?
h. Have the pole-equator temperature gradients changed? If so, what are the dynamical implications implied? Can you observe any such changes?

Reporting

Using EdGCM's eJournal capability, construct a multi-section, multi-plot report that details your simulations and explains what you have learned from them. As in a scientific paper, it is adviseable to choose your figures first, and then to construct your text around them. Any figures presented must be discussed in the text.

- The very first section will be your abstract. Here, provide a concise overview of your findings. (See the abstract of a peer-review scientific paper to get an idea of how this should be done.)
- Then, illustrate that the model you are using is functioning in a reasonable way, producing a climate like the observed when modern-day forcings are applied.
- Explain the difference in the setups of the Modern_specifiedSST and Modern_predictedSST simulations. What are the implications for climate?
- Explain / illustrate the change made to the simulation setup in the Global_Warming01 as compared to Modern_predictedSST.
- Illustrate the impacts of the CO_2 forcing on climate.
- Focus on analysis of your results. Provide mechanistic explanations wherever you can. Explain how changes in forcing create changes in climate.
- The limitations of the model need to be kept in mind when considering these results. Be specific about how the limitations impact your mechanistic interpretations.
- Include at least 20 figures in your report.
- Both respond to the specific questions presented to you in the "Plotting and Analysis" section, and also include your own thoughts about what you're finding.
- When your report is complete, publish it on your MyUW website. Also print out a copy to turn into the professor and provide the complete URL for access to the website. You do not have to turn in color figures on paper, as these can be viewed on the web.
- You and your partner will write the report together and will receive the same grade for it.

Forming your own hypotheses – getting ready for Part 2:

At the end of your Part 1 report, present hypotheses that you would like to test using the EdGCM in Part II. Plan to do at least 3 modeling experiments for Part 2 – you are encouraged to present specific ideas for new modeling experiments in your report. Each group will form its own unique hypotheses to test with the EdGCM. Present at least two areas of investigation that are interesting to you. Discussions with the professor will help to ensure that a wide range of issues are covered by the class' investigations, and will help you to refine your designs for your investigations.

Some topics that you might explore include:

- Solar constant
    - What are the climate impacts of a changing solar constant?
    - How much would the solar constant have had to change to explain recently observed warming patterns? Is the consistent with observed solar changes in the recent past? Over geologic timescales?
- CO_2 emission scenarios
    - How would the climate system react if we stopped burning fossil fuels tomorrow? How would the climate react if we started burning fossil fuels more and more quickly?
    - How might different IPCC scenarios for future emissions impact climate?
- Global warming impacts
    - With expected global warming, what will be the impact on SST in hurricane-formation regions?
    - What will be the impact on soil moisture in agriculturally-important regions of the United States?
- Other atmospheric constituents
    - How large is the impact of emissions of other gases (e.g. N_2O, CH_4, CFCs) on climate in relation to expected impacts of CO_2?
    - Perhaps cutting emissions of those gases will be easier on society than cutting CO_2 emission. Would this be a feasible way to control global warming?
- Paleoclimate
    - What was climate like in the past in comparison to today? Consider changed topography, the impact of ice sheets on albedo and the radiation budget, etc.