AOS 425 EdGCM Project
Fall 2016

Goal

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.columbia.edu) has been designed at NASA's Goddard Institute for Space Studies (NASA GISS) and Columbia University to be user friendly and computationally tractable for use on home computers and in computer labs like ours. 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 150 years on a PC, remember that climate models being used for the current Intergovernmental Panel on Climate Change (IPCC Assessment Report 5, 2013) 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. Students, working as a team, will write a brief report consisting of selected figures and bullet points about model-data comparisons, as well as some summary text.

At the end of Part 1, students will chose a climate problem of their own and formulate hypotheses to test with the model during Part 2. When the Part 1 report is turned in, each group will write a short (one-page) proposal describing their chosen problem, its importance in climate research, a proposed hypothesis, and a summary of the simulations to test it (three to four). Since many students are thinking about applying for jobs, graduate school, and fellowships this time of year, we will use this as an opportunity to gain practice in application writing. In addition to the proposal itself, each student will supply a short Curriculum Vita including a brief interest statement and a proposed timeline for conducting the research with the goal of convincing a review panel to *hire* you to conduct the proposed research. We will convene a mock panel review in class to consider each proposal and offer constructive suggestions for improving the research and fine tuning future applications. Groups will then conduct their experiments, analyze their results, and present their findings (as a team) to the class in early December. A final report (done individually) is due on the last day of presentations.

Key Dates

Part 1 Report and Hypothesis for Part 2 – October 21
Review Panel to Discuss Part 2 – First week in November
Part 2 presentations – December 12-16
Final report – December 16

Getting help with the EdGCM

Reading the EdGCM website, www.edgcm.columbia.edu, and resources found therein can help answer basic questions about how to run the simulations and how to do plotting and analysis. There is also a discussion board on the website for which you can read to see past interchanges, and you can get assistance. You can also see either the Professor or the TA for help.

Plotting Notes

Maps

You will find that there are many mapping options in EVA. 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 (centered on 0.0 N, 0.0 E)
- Orthographic - for regions (use the zoom) or hemispheric plots of the polar regions (set to +-90N)

Additional plotting hints

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

PART I: RUNNING THE MODEL, ANALYSIS, AND INTERPRETATION

Each team will do two runs in this part. The first, Modern_predictedSST, is a 150-year simulation with boundary conditions from 1958, such that you will produce a stable climate that looks similar to modern-day observations. You will compare the results to the second simulation, Doubled_CO2. By comparing these two, you will be able to consider the effects of increased CO_2 on the climate system.

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

Experiments

1. Modern_predictedSST: 1958 – 2100 (NOTE: Output from this simulation will likely be already loaded on many of the computers in 1411. If that is the case, you do not need to rerun the simulation, just use the output to perform the analysis below. If you install EdGCM on your own laptop, you will need to run the case first.)
    a. In this run, the goal is to make sure the climate system is stable with time if nothing is forcing it to vary. We are testing the model's *stability* with this run. If this run illustrates large changes over time then we should suspect the model is not a good representation of the real climate.
    b. There are constant concentrations of CO_2 and other greenhouse gases, and constant solar luminosity (1958 values).
    c. This run provides a basis for comparison to the "Doubled_CO2" run.

2. Doubled_CO2: 1958 – 2100
    a. This run tests the response of the equilibrium climate to a doubling of the atmospheric CO_2 (observed in 1958 was 314.9ppm, so it is set to 629.8ppm). You will run the simulation from 1958-2100.
    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.
    c. In contrast to a more realistic Global Warming simulation in which the atmospheric CO_2 concentration increases gradually over time, this experiment is meant to test the <u>equilibrium</u> response of climate to a CO_2 change.

Plotting and Analysis

For your analysis, you will primarily focus on an average of the last five years of your simulation (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 representative of the climate state.

1. Modern_predictedSST – Plot and compare results to mapped data, found in Marshall and Plumb. Are these results reasonable considering the model and its limitations? What are key areas of difference that you note?
    a. Surface air temperature - monthly means for January and July (Figure 12.2 of M&P)
    b. Annual mean precipitation (compare against Figure 11.6 of M&P)
    c. Net radiation of planet for JJA – compare against lecture notes
    d. East-west ("U") winds – JJA, mapped at the surface; and Vertical Slice (Figure 5.20 of M&P)
    e. Line plot of surface air temperature vs. time (use the Timeseries Tab in Analyze Output). How steady is this with time?
    f. Determine the pole-equator temperature gradients for the northern and southern hemispheres (look at T_SURF under the Zonal Average Tab). Why are they not the same?
    g. Plot Sea Surface temperature for 2096-2100 and compare to the data in Figure 9.3 of M&P. Do this for the annual mean, both mapped and zonal mean plots. Is your result what you expected?
    h. Produce at least two other plots or maps that illustrate that this simulation provides a reasonably constant climate with time.
2. Doubled_CO2
    a. Make a timeseries plot of the surface air temperature from 1958-2100.
    b. Compare the temperature trajectory (i.e. how the temperature is changes over time) to the CO_2 forcing used in this simulation
    c. When does the air temperature come into equilibrium with respect to the CO_2 forcing?
3. Comparing Modern_predictedSST and Doubled_CO2 (use the differencing feature in EVA)
    a. Map surface air temperature in the doubled scenario as a difference from Modern_predictedSST. 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 see dynamical changes in your plots?

Report (5% of your final grade for AOS 425)

The basic form of the report will be Figures (in color) and 2-3 bullet points about each Figure that focus on (1) evaluating the Modern_predictedSST against observational data and (2) comparing the Modern_predictedSST and Doubled_CO2 runs. You and your partner will write and submit a single report together and will receive the same grade for it. <u>You will be evaluated primarily on the degree to which you've carefully thought about your results, and on the clarity and brevity of the presentation of those results.</u>

Your report should have the following format:

- Abstract (max ½ page, single-spaced), where you provide a concise overview
  - See the abstract of a peer-review scientific paper for an example.
- Figures (select a maximum of 20 that capture your key points) with 2-3 bullets (max 2 sentences each) for each figure
  - Compare Modern_predictedSST to the data
  - Discuss how things change with Doubled_CO2
- Summary (max 1 page, single spaced, 12pt) –
  - ***What does model performance as you have evaluated it, tell you about the usefulness of this model as a tool for climate experimentation?***
    - Refer back to specific figures to illustrate your points.
  - ***What are the impacts of Doubled_CO2 on this modeled climate? What conclusions can you draw about impacts on the real Earth's climate?***
    - Refer back to specific figures to illustrate your points.

Additional Instructions

- <u>Analysis</u> of your results means going beyond description to the provision of mechanistic explanations.
  - e.g. "Jet stream winds are too slow" (description) vs. "Slow winds in the jet stream are due, in part, to the model's coarse grid" (mechanistic)
- You should make all plots and consider all questions in the "Plotting and Analysis" section, however, you cannot reasonably include all these plots in your report. You will need to decide which plots best make the points you need to make (i.e. bold italics above). You are also encouraged to explore alternative comparisons that you feel will best make your points.
- Your report should <u>include no more than 20 images</u> (multi-panel images each count as one of the 20). There will be few pages of bullet points.
  - Bullets can come below the figures or on separate pages. Either way,your report must be well-organized and well-labeled so figures and associated points can be easily connected.
  - Clearly, you will have to make some decisions about what to include and what to not include. Include what you think is most important. Justify this with your text in the abstract, bullets and summary.
- Word, LaTEX, or other word processing software that allows you to embed *png (exported from EVA) graphics is recommended. Figures may also be attached at the end of the report.
- Color printouts are required.

<u>DON'T FORGET PROPOSALS FOR PART 2 ARE DUE AT THE SAME TIME AS THIS REPORT (SEE NEXT PAGE)!!!</u>

FORMING YOUR OWN HYPOTHESES – GETTING READY FOR PART II

Each group will form its own unique hypothesis to test with the EdGCM in Part II. When you turn in your Part 1 report, you also need to turn in a **proposal** (1 page, single-spaced, 12 pt) that presents the hypotheses that you would like to test using at least 3 EdGCM model runs. Please present **specific ideas for your 3-4 EdGCM modeling experiments**. These ideas will be better developed if you study the EdGCM Setup Simulations window so as to acquaint yourself with the things EdGCM allows you to change. In one or two separate sentences briefly describe an alternative hypothesis that you could test in case there are already too many groups pursuing similar ideas to yours, or if your primary hypothesis simply can't be tested using EdGCM. The model experiments for the alternative hypothesis need not be explained in great detail since the focus should be on describing your primary hypothesis.

To expose students to the peer review process and provide an opportunity to start crafting interest statements and CVs for future job, fellowship, and grad school applications, the Part II proposals will be evaluated as a group in a mock review panel. In addition to the proposal, each group member will also submit a brief **interest statement**, a one page **Curriculum Vita (CV)**, and a proposed **timeline** for conducting the research with the goal of convincing your peers to *hire* you to conduct the proposed research. The interest statement can be thought of as your cover letter. It should consist of 4-6 sentences describing your interest in your chosen problem, your future goals, and any skills or experiences you have that will benefit both this research project and your career path in general. The abbreviated CV (less than 1 page, see template at the end) should immediately follow the interest statement summarizing your background, education, relevant work history (only what you feel comfortable sharing), skills, activities, awards, etc. Finally, the timeline takes the place of a budget that often accompanies proposals. Here, you should attempt to budget the amount of time it will take to complete the various stages of the research project such as learning how to run EdGCM, performing test experiments, running full simulations, plotting and analyzing the results, etc. through to compiling your presentation at the end of the semester. You should also summarize the dates of a few key milestones in your project. Remember the goal of this exercise is to try to convince the panel to hire you to conduct the research. Both the CV and the interest statement should be targeted to achieve that goal wherever possible. Do not share personal information such as your home address for this in-class exercise.

Each student will then be asked to review and comment on three other research proposals during a mock panel review that will be conducted in class in late October. Here we will exchange ideas for improving both the projects as well as sharing constructive suggestions for making future applications stronger. This exercise will also ensure that a wide range of issues are covered by the class' investigations, and will help you to refine your designs to fit with the capabilities of EdGCM. You need to come to this review prepared to (1) present and discuss your comments on the three proposals you were asked to review, (2) articulate and defend the experiments you proposed to do to the panel, and (3) discuss your alternative hypothesis should the panel decide that it might be a better choice. The proposal and peer review exercise will be worth **5% of your final grade** for the course.

Here are some initial ideas to get you started, but you are strongly encouraged to go beyond these! Carefully-thought, original and tractable ideas will add to your grade!

- 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 US agricultural regions?
- 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?
  - Would cutting other gas emissions a way to control climate 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.
- Ideas of your own

PART II: PRESENTATION AND FINAL REPORT

Presentation (5% of final grade)

The presentation to the class should include no more than 6 Powerpoint slides (suggested: 1 with title; 1 with motivation; 1 with experimental setup; 1-2 with results; 1 with conclusions). The presentation should be developed and presented with your partner, and will both receive the same grade. Your presentation should be no more than 10 minutes long, and you should be prepared for about 2 minutes of questions.

Guidelines for Final Report (10% of final grade)

Reports should be no longer than 8 double-spaced pages in 12pt font (including graphics and references). Students will be graded on the 'big picture' motivation behind the problem they choose, the design of the specific simulations to answer the relevant science questions, and their presentation and interpretation of the relevant results.

Writing is a fundamental to ANY professional or academic career. ***Ability to write efficiently and effectively is a key determinant of success in all fields.*** The goal here is to gain experience in research methods and practice in conveying this information to colleagues. The final report needs to be prepared individually. You are encouraged to discuss your motivation, methodology, results and conclusions in detail with your partner, but you need to write it all up in your own words. Also the foci of the written report should not be identical between you and your partner, even though the model runs will be. So you can each focus in different regions or on different feedbacks, etc.

Students are encouraged to discuss any aspect of this process with their peers or the professor at any time. Students are also encouraged to explore the excellent writing resources provided by the UW Writing Center (http://www.wisc.edu/writing).

Format

Students should model their reports after the scientific articles found in meteorological journals such as Geophysical Research Letters or Nature Geosciences. Critical elements include:

- Title, corresponding author, and academic affiliation, including street address and e-mail
- An Abstract summarizing the most important findings from the article (single-spaced, 5-8 sentences that concisely summarize your motivation, methodology, and findings)
- An Introduction giving a 'big picture' overview of the subject, summarizing any previous work done on this issue, and outlining your hypothesis. The introduction will be section 1.
- The main body containing the main findings organized into a set of consecutively numbered logical sections each with its own heading. Examples might be:
    - A few words on EdGCM

  - The setup and execution of your experiments
  - Results (What did you find?)
  - Discussion (How did your findings relate to previous work and to your hypothesis?)
- A final Conclusion or Summary section summarizing key findings
- Acknowledgements (if necessary)
- References: these should be primarily from peer-reviewed journals. Books, conference abstracts, web resources and other references should be used sparingly. See: http://www.agu.org/pubs/AuthorRefSheet.pdf for an example.
- Figures and tables should be included where necessary to illustrate important points. The following guidelines should be followed:
  - All figures and tables should be embedded within the text
  - All figures should have appropriate captions describing the figure and drawing attention to key features
  - Figures should be numbered sequentially and referenced in the text by this number (eg. "Fig. 3 shows…").
  - All characters, labeling, and lines should be LARGE and DARK enough to be clearly legible.
  - All tables should have appropriate captions describing the data contained and any relevant units.
  - Tables should be assigned their own set of sequential numbers and be cited in the text accordingly.
- SI units are preferred (m, kg, s, K) but deviations from these can be made where appropriate to the particular subject.

Style

The present tense should be used when discussing results ("I/we conclude…") or scientific truths ("The Earth is round."). If you are discussing methodology, the past tense is appropriate ("I/we measured…"). The passive voice is more acceptable in science writing than in most genres, but should not be overused. Acronyms must be spelled out before being used ("..quasi-geostropic potential voriticty (QGPV)…") . You should avoid superlatives, exclamation points, and colloquial language. Narratives on the development of your thoughts are not appropriate. Remember, this is scientific writing, not a short story. Again, reading the literature will help you to recognize what is an appropriate scientific writing style.

Though technical aspects of writing (i.e. grammar) are not the focus of a science course, the reality is that, as in all real-world applications, proper grammar is a fundamental requirement for effective communication. You are expected to use proper grammar, to transition effectively between paragraphs and sections, and to avoid run-on sentences, etc, as taught in English classes. If you need extra help, please access the great resources available to you from the Writing Center http://www.wisc.edu/writing/.

Academic Integrity

As with all research projects of this kind, this project is subject to the University academic misconduct policy (www.wisc.edu/students/saja/misconduct/UWS14.html). Academic misconduct may lead to automatic failure for the course and may be reported. The official policy states:

"Academic honesty requires that the course work (drafts, reports, examinations, papers) a student presents to an instructor honestly and accurately indicates the student's own academic efforts. UW-Madison [...] defines academic misconduct as follows:

Academic misconduct is an act in which a student:

- seeks to claim credit for the work or efforts of another without authorization or citation
- uses unauthorized materials or fabricated data in any academic exercise
- forges or falsifies academic documents or records
- intentionally impedes or damages the academic work of others
- engages in conduct aimed at making false representation of a student's academic performance
- assists other students in any of these acts.

Examples include but are not limited to: cutting and pasting text from the web without quotation marks or proper citation; paraphrasing from the web without crediting the source; using notes or a programmable calculator in an exam when such use is not allowed; using another person's ideas, words, or research and presenting it as one's own by not properly crediting the originator; stealing examinations or course materials; changing or creating data in a lab experiment; altering a transcript; signing another person's name to an attendance sheet; hiding a book knowing that another student needs it to prepare an assignment; collaboration that is contrary to the stated rules of the course, or tampering with a lab experiment or computer program of another student. If you are accused of misconduct, you may have questions and concerns about the process. If so, you should feel free to call SAJA"

Plagiarism

"Plagiarism means presenting the words or ideas of others without giving credit. You should know the principles of plagiarism and the correct rules for citing sources. In general, if your paper implies that you are the originator of words or ideas, they must in fact be your own. If you use someone else's exact words, they should be enclosed in quotation marks with the exact source listed. You may put someone else's idea in your own words as long as you indicate whose idea it was (for example, "As Jane Smith points out, . . ."). If you are unsure about the proper ways to give credit to sources, ask your instructor or consult the Writing Center at 6171 Helen C. White Hall (phone: 608/263-1992, e-mail: writing@wisc.edu) for a copy of their handout "Acknowledging, Paraphrasing, and Quoting Sources""

Sample CV:

Tristan S. L'Ecuyer
Assistant Professor
University of Wisconsin-Madison

a. Education (include current degree and anticipated graduation date)

Colorado State University	Atmospheric Science	Ph.D. 2001
Dalhousie University	Physics	M.S. 1997
Dalhousie University	Physics	B.S. 1995

b. Professional Experience (work history)

Aug. 2011 – present;	Assistant Professor, University of Wisconsin-Madison
July 2002 – July 2011;	Research Scientist, Colorado State University
Sep. 2001 – June 2002;	Postdoctoral Fellow, Colorado State University

c. Relevant Skills and Expertise (a bullet list summarizing things like computer skills, prior research projects, specific courses taken, etc. is acceptable but an opening statement can also be included)

Dr. L'Ecuyer has 15 years expertise in the development satellite retrieval algorithms and planning field campaigns for evaluating satellite datasets. Specific experience relevant to the proposed research includes:

- Mission Scientist: GPM Cold Season Precipitation Experiment (GCPEx), Barrie, Canada February 2012
- Project Scientist: Light Precipitation Validation Experiment (LPVEx), Helsinki, Finland Sept-Oct 2010
- Lead developer CloudSat 2B-FLXHR-LIDAR radiative flux and heating rate dataset
- Co-chair NASA Energy and Water cycle Study (NEWS) Energy and Water Cycle Climatology working group

d. Activities (bulleted list of other activities, sports, etc. if applicable – especially any that demonstrate leadership or relate to job being applied for)

e. Awards (bulleted list if applicable)