Attachment 2: Lab Handout 1

A. Objectives

- Become familiar with the Educational Global Climate Model (EdGCM)
- Learn about Svante Arrenhius's 1896 work on doubled atmospheric CO_2
- Begin using EdGCM to pose your own questions about climate change

B. Background

Global climate models (GCMs) are one of the primary tools used today in climate research. Because of computational requirements these models were originally developed and housed at national laboratories run by the government science agencies. NASA's climate modeling lab, the Goddard Institute for Space Studies (GISS), is located at Columbia University in New York City (this is also where EdGCM was developed). NOAA's lab, the Geophysical Fluid Dynamics Laboratory, is located in Princeton, New Jersey, while NSF funds the National Center for Atmospheric Research (NCAR) in Boulder, Colorado.

As a result of their complexity, these models are not well understood by the general public. Today's lab will give you the opportunity to more fully understand the process and potential of climate modeling through a hands-on interaction with an educational version of climate modeling software. This educational version of the software differs from the original climate modeling software only in that it is designed to run on school computers, which are generally smaller and have less computing power than the supercomputers used by national labs.

Useful resources for background knowledge:
Weather and Climate Basics
http://www.eo.ucar.edu/basics/index.html
Earth Lab: Degrees of Change:
https://koshland-science-museum.org/explore-the-science/earth-lab
Global Warming Facts and Our Future:
https://www.koshland-science-museum.org/teacher-resources/webquests/climate-change

C. Exploring EdGCM

Be careful not to change the scenarios that come installed with EdGCM by unlocking the lockbox at the top. Instead, try duplicating them or making your own.

1. Can you open 4D?
2. How do the menu/buttons change as you click on different things?
3. What do the DVD-like controls do?
4. Can you start one of the existing scenarios running? Pause it? Stop it?
5. What does clicking on the pencil do? The folder? The colorful blob? The image of Earth?
6. Can you run more than one simulation at once?
7. What happens to the circles next to each simulation name as the model runs?
8. When you have the setup simulation tab open, what do the "open all sections" and "close all sections" buttons do?
9. If you wanted to write a scientific article complete with maps and graphs produced by EdGCM, how would you do it?
10. What do we need to do to analyze our output? What is output? (*Note: We do not yet have any output.)*
11. What is EVA for? What does Panoply do? How do they work?

D. Svante Arrhenius and Doubling Atmospheric CO_2

Known as the father of climate change theory due to his publication in 1896 of the paper "*On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground,*" Svante Arrhenius worked in a time before GCMs existed. In this part, you must work through each question to learn

more about Arrhenius before also exploring how EdGCM can be used to look at his ideas. Be sure to write complete answers to each question. You may use the internet to help find answers to these questions.

1. Who was Svante Arrhenius and when did he live?
Svante August Arrhenius (19 February 1859 – 2 October 1927) was a Nobel-Prize winning Swedish scientist, originally a physicist, but often referred to as a chemist, and one of the founders of the science of physical chemistry.

2. What was the main idea of the paper he wrote? How did he explore his theory? What conclusions did he arrive at?

In this paper, Svante Arrhenius posits that the presence of heat-absorbing gases in the atmosphere can affect the mean temperature of the surface (or ground) of the planet. In particular, he lays the foundation for his work calculating that a doubling of the amount of such gases could increase temperatures in the Arctic region by 8 or 9 degrees Celsius.

3. Compare Arrhenius predictions to those being made today using GCMs. How do they differ? How are they the same?

The Doubled_CO_2 run of EdGCM simulates the math experiment that was conducted by Svante Arrehenius. Try running this scenario and, in the next lab, learn how to plot a time-series graph that will answer this question.

Now open EdGCM.
1. Click on the setup simulation window for the **Doubled_CO_2** run. What happens in this simulation?

Total atmospheric concentrations (no the rate of increase) of CO_2 are instantly doubled as a boundary condition at the start of this run.

2. Do *initial* or *boundary* conditions vary in this run? How do you know?

As stated before, CO_2 is taken as a boundary condition. It does not change during the simulation.

3. What other details do you notice about this simulation?

Students can answer this question a variety of ways. Anything that's correct, noting details from the setup scenario pain, deserves full credit. If details are missed (and even if not), the instructor should point out each section of the setup scenario window of EdGCM when he or she walks students through EdGCM.

4. Now open the setup simulation window for the **Global_Warming_01** scenario. What is different about this simulation? Which simulation do you think better represents what's taking place now with global greenhouse gas emissions and climate change?

This scenario represents a rate-wise increase in CO_2 emissions, representative of yearly emissions (and their increases) in the world today.

5. Finally, look at the both the **Modern_PredictedSST** and **Modern_SpecifiedSST** scenarios. What's different about these? What do you think are the purpose of these scenarios? *(Don't worry if you can't fully answer this last question as it will be the focus of our next EdGCM lab.)*

These scenarios are control runs for EdGCM. They proceed as if current conditions were extrapolated out into the future year specified. SST stands for Sea Surface Temperature, a common term used due to the fact the oceans cover more than 70 percent of the globe.

Open Exploration

For the remainder of this lab, you will be designing your own experiment using EdGCM. Here are the steps you may wish to follow.

1. Do some research online about climate change and determine a research question and hypothesis you are interested in.
2. Find specific background information on the question you are interested that include specific levels of greenhouse gases, other climate forcings, or how a particular species might be impacted by climate change.
3. Flag-down your teacher and ask them to look at your research question and ensure that it makes sense. Make any revisions they suggest.
4. Click on the **Doubled_CO_2 run** and hit setup scenario. Down below, hit the "Duplicate" button.
5. In the "General Info" section fill in the information about your simulation that's necessary for someone else to understand what you plan to do.
6. In the appropriate sections ("Forcings" and GHG "Trends") manipulate initial conditions you want to include in your simulation.
7. Try out starting forcings at different years and see what happens.
8. Try out different types of trends and view the graphs. Compare them.
9. Ask your teacher about why you might want to vary the solar trend.
10. See if you can find explanations of "Eccentricity," "Axial Tilt," and "OmegaT."

Sources:

Youngman, B., Chandler, M., Sohl, L., Hafen, M., Ledley, T., Ackerman, S., & Kluge, S. (2015). Envisioning Climate Change Using a Global Climate Model. Earth Exploration Toolbook. The Science Education Resource Center at Carleton College, Norh Field, MN.