Project #2 – Climate Change Projections and Impacts

Introduction

The observed and projected effects of anthropogenic (human-caused) climate change impact every aspect of Earth's physical geography. Class lectures have touched on many aspects of these impacts. In this project, you will examine climate change processes in greater depth. In the first section, you will explore the impacts of climate change on surface air temperature in different places. In the second section, you will look at the impacts of changing climate conditions on ecosystems, focusing on the forest ecosystems of the eastern U.S.

Objectives

1. To become familiar with process of projecting future climate conditions using general circulation models.
2. To examine the predictions of the IPCC general circulation models (GCMs) for future climates, looking at different models, different emissions scenarios, different time periods, and different regions.
3. To investigate the use of climate and ecological models to predict the influence of climate change on forest ecosystems.

Part 1: Background reading

Read pp. 308-317 in the textbook on Global Climate Change and answer questions 1-4. You may also want to look at other resources, such as the IPCC website (www.ipcc.ch), or the College of Earth & Mineral Sciences' video on climate change: (http://www.youtube.com/watch?v=LdIORWLd_wk)

Part 2: Projected Future Temperatures

For this section, you will use a webpage that allows you to map and download projected temperatures from the general circulation models used by the IPCC. Use this link to reach the webpage: http://www.ipcc-data.org/cgi-bin/ddcvis/gcmcf.

This page uses data from the IPCC Third Assessment Report (TAR) (2001). Many other data products are available at http://www.ipcc-data.org, including another mapping interface that allows you to map data from the Fourth Assessment Report (AR4) (2007). We will be using the TAR data because that page is easier to use for our purposes, but take a minute to explore the other resources on this site—they will help you get a better picture of how climate modeling and forecasting works and help you better answer the questions in this section.

To use the mapping interface, you need to select a number of specifications (see figure 1):

- Variable (a): this page will map a number of climate variables, but we will only be using the **Mean Temperature** option.

- Map type (b): **Land only**, or **land + oceans**. When we analyze the data from the models, we will use both options.

- GCM / Scenario (c): This selection combines your choice of one of six GCMs and one of several scenarios for future greenhouse gas emissions. Basic information about the models is available through various websites; a summary of the different scenarios is available here: http://www.ipcc-data.org/sres/ddc_sres_emissions.html; more background on the scenarios here: http://sedac.ciesin.columbia.edu/ddc/sres/.

- Time slice (d): This choice specifies how far into the future you wish to project. As indicated at the top of the page, each slice represents a 30-year average; thus, the "2020s" time slice will be the averages of model projections from 2010-2039, and so on.

- Finally, the right-hand column of choices allows you to consider only part of the year, or the whole year. We will only be using the "season" choices (e), ignoring the month selections below it (f).
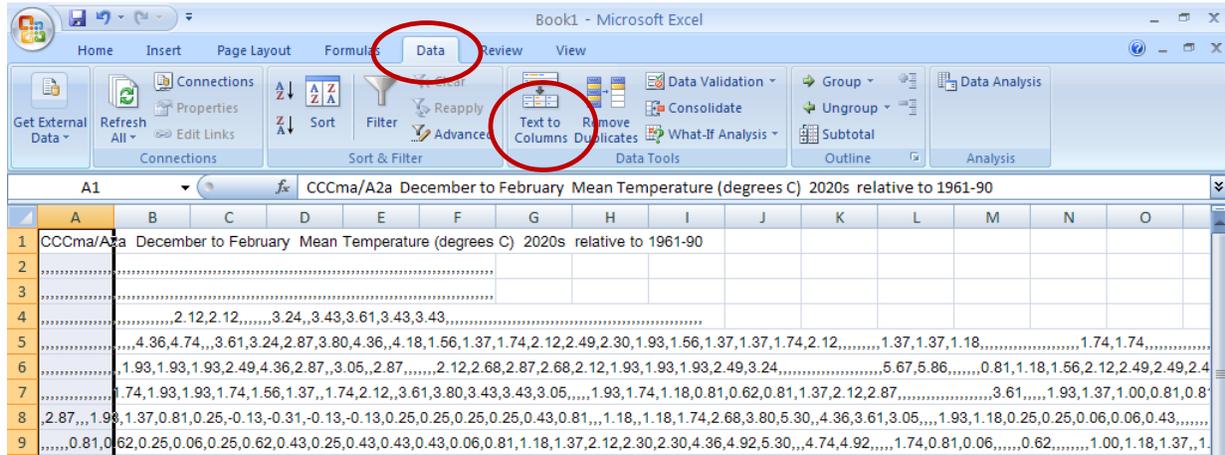
FIGURE 1:
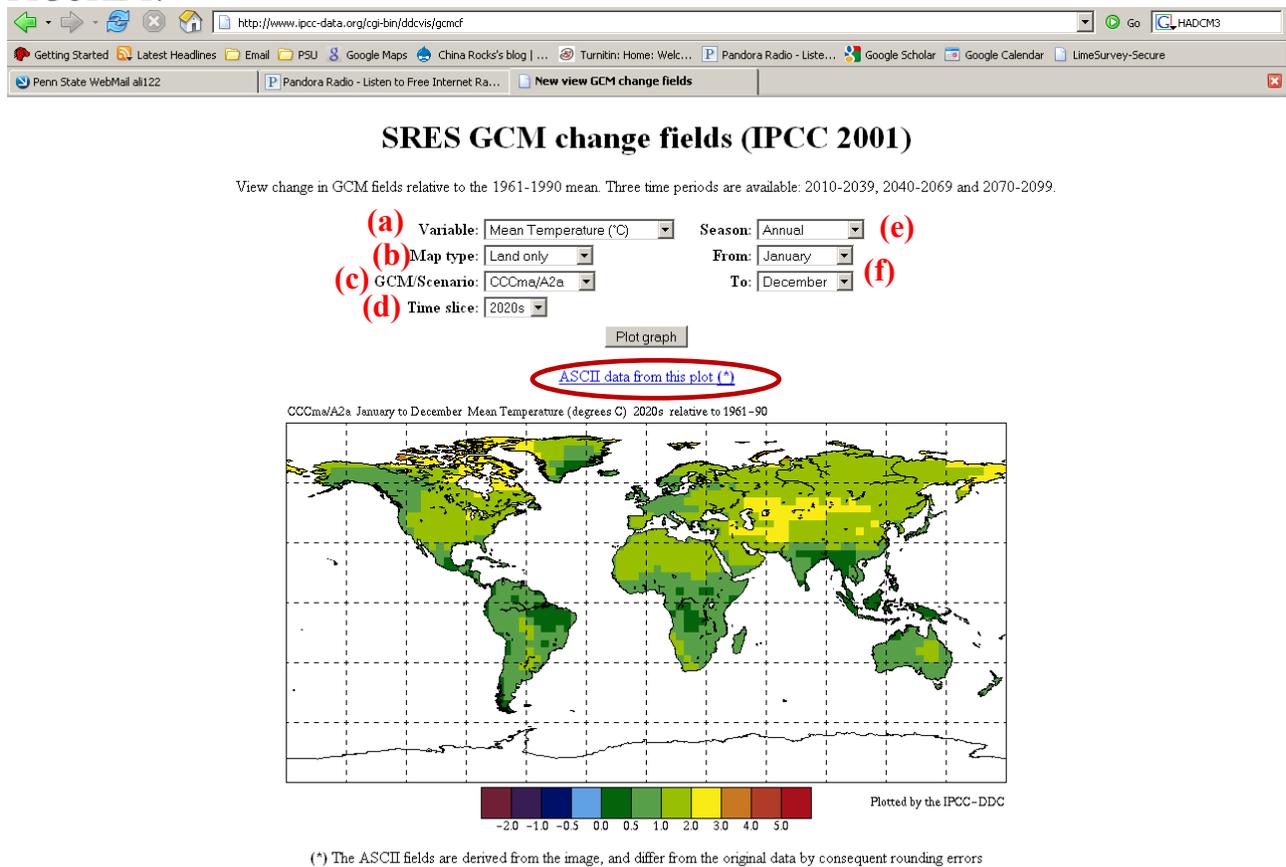
Once you have selected all of your choices, click on "plot graph" to see the model output for those selections. As noted just above the map, the colors indicate the difference between projected temperatures for the selected time period and the observed average temperatures for 1961-1990. The color key at the bottom shows how much temperatures are projected to

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have increased or decreased for each cell of the model. If you have selected "land only," only land surfaces will be colored (as in the screenshot above); if you select "land + ocean," the whole map will be colored.

Once you have created a map, you can also access the raw data that was used to generate the map. Click on the link for "ASCII data from this plot **(*)**" (circled in screenshot), and you will see a data table, in which each entry indicates the projected temperature change (in °C) for one cell on the map (figure 2):

FIGURE 2:

In this case, many cells are left blank, because the map type was set to "land only." If you select "land + water," every cell will be filled in with a number.

Before going on to the analysis section, take a minute to try different combinations of selections and familiarize yourself with how the map works.

Now that you are familiar with the interface, you will use this application to investigate projected temperature changes for different emissions scenarios and time periods. Choose one GCM and two scenarios. For each scenario, plot maps for annual, N. hemisphere winter, and N. hemisphere summer, for both the short term (2020s time slice) and longer term (2080s time slice), and also for both "land only" and "land + ocean."   You do not need to use the 2050s time slice, as it generally falls between the other two. Then, import the data for each map into a spreadsheet and calculate the average change for each latitude (i.e., each row in the data). Use the maps and spreadsheets to explore the seasonal and latitudinal variation in climate change impacts for each scenario and time period.

Step-by-step instructions are below. Using your results, answer questions 5-10:

1. Choose one of the GCMs and find out basic information about the model. The IPCC website, the textbook, and other websites are good places to look. The textbook has an extensive list of links, and search engines can also locate much useful material.

2. Choose two of the IPCC scenarios (make sure that the mapping application supports your scenarios with the model you have selected). As noted above, descriptions of each scenario are can be found here: http://www.ipcc-data.org/sres/ddc_sres_emissions.html, as well as in your textbook and elsewhere.

3. Map projected annual temperature change for your model and one of your scenarios for 2010-2039.

    a. Choose the appropriate "GCM /scenario."

    b. Choose map type as "land only."

    c. Choose time slice as "2020s."

    d. Choose season as "annual."

    e. Click "plot graph."

    f. ***Insert the map into a separate Word document, making sure to label it clearly.***

4. Analyze the raw data in a spreadsheet.

    a. Click on "ASCII data from this plot **(*)**"

    b. Select all the data in the table (using CTRL+A, or by clicking and dragging), and copy it.

    c. Open Excel, select the upper-left cell, and paste the data.

    d. Now, each row of data is entirely contained in the cells of Column A. To spread this data across all the columns, use the "Text-to-columns" feature (figure 3). Choose "delimited," and on the next page, check the box next to "comma" (since the data points are separated by commas). Click NEXT, then FINISH, and your data should be nicely spread throughout the spreadsheet.

FIGURE 3:

    e. Scroll all the way to the right until you find the last column with any data in it. In the next column to the right, use the $\sum \blacktriangledown$ tool to calculate the average of all the data points in each row (figure 4). Make sure your range includes all of the data points in the row (in this case, A2:CR2).

FIGURE 4:
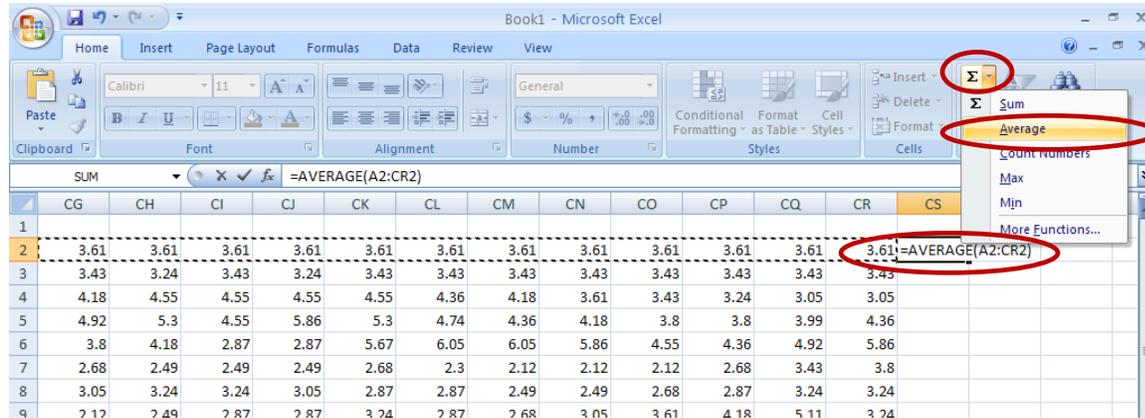
  f. At the bottom of the column of averages, calculate the average of the averages. This number represents the global average temperature change.

  g. Now graph the averages to make them easier to interpret: highlight the whole column and click on "insert chart" (a line graph will probably be the easiest format to read). ***Copy this graph to a separate Word document, making sure to label it so that it is clear what it shows.***

5. Repeat steps 3) and 4), but change map type to "land + ocean."

6. Now, repeat the steps, but this time, select the season to be Dec/Jan/Feb; and then Jun/Jul/Aug. For this and subsequent maps, use the "land + ocean" option unless otherwise specified.

7. Repeat steps 3) and 4) again, this time selecting the second of your scenarios, and choosing the "annual" time frame.

8. Now, set the time slice to the 2080s, and produce maps and graphs for annual averages with both scenarios.

9. As a check on your conclusions about this model's projections under these two scenarios, randomly select one of the graphs you made in steps 6-8, change the map type to "land only," and create a map and graph to compare to the "land + ocean" map and graph. Then select one graph from steps 7 or 8, and create maps for Dec-Feb and Jun-Aug seasons (you can assess this step visually using the map only; you do not need to create graphs).

Part 3: Climate Change Projections and Ecological Impacts

In part 2, you looked at projected changes in temperature over the next century. It can be difficult to imagine how only a few degrees of temperature variation can have a major impact on the physical environment. In part 3, you will explore the effects of projected climate changes on ecosystem and species distribution. Specifically, you will be looking at the distribution of tree species and forest types in the eastern U.S.

All of the exercises are based in the following website, created by the U.S. Department of Agriculture's Forest Service: http://www.nrs.fs.fed.us/atlas/tree/tree_atlas.html.

Forest types:

First, you will look at predicted changes in overall forest composition. Click on the button for "Combined Species Outputs." On the next screen, click the tab for "modeled future forest types," then "potential changes by forest types" (figure 5).

FIGURE 5:

On the next page, you can compare maps of current forest types and projected future forest types based on climate models. Click on "View summary of changes" to see several different maps side-by-side on the same page. Click on the ? icon and a "help" window will pop up. This window has an explanation of the maps and links for more information. Click on "background" within this window for more information on the modeling process.

Explanatory note: The maps include two versions of current conditions, one called "FIA," and the other called "RF current" (or, "modeled current" in other places). The FIA values are based on actual on-the-ground observation of tree species, but the RF values are based on inputting current climate conditions into a computer model. This same model is then used with future climate projections that come from the GCMs.

Once you have explored the "help" information and you understand how the maps work, answer questions 15-19.

Distributions of individual species:

Now, go back to main species list on the initial screen of the tree atlas. Choose three species to examine: two that you have observed in the State College area (on field trips, in your observations for the final project, or outside of class activities), and one that is not present in State College. For each of the three species, click on the species' name, which will take you to that species' page. Browse the links at the top of the page for "Life History and Disturbance Response," "Silvics Manual," and "Plant Photos" to learn basic information about the species. Then select "Abundance Change Maps" from the Modeled Future Habitat box (figure 6):

FIGURE 6:
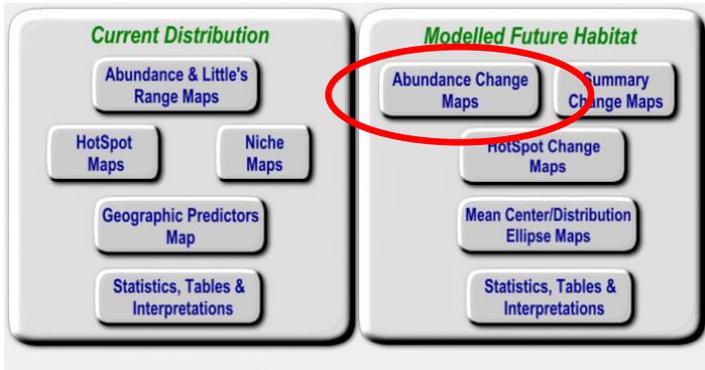
On the next screen, use the dropdown menu in the upper left corner of each map to set that map to show either the current range of the species (either FIA- or model-generated), or projected future abundance based on one of the GCMs and one of two emissions scenarios (figure 7). The title on each map indicates which option is currently selected. You can also click on "animate scenarios" to view an animated map which changes from current to modeled future conditions.

Explanatory Notes: IV stands for Importance Value, and it is a number from 0-100, indicating how dominant a species is in a patch of forest. If the IV=100, it is the only species present; if the IV=0, the species is not present. Half of the value is determined according to the number of trees, and half according to the sizes of trees. Also, the maps have a blue line that shows the boundary of "Little's range" for each species. This is the species range as published in the _Atlas of United States Trees,_ by biogeographer Elbert L. Little, Jr.

FIGURE 7:
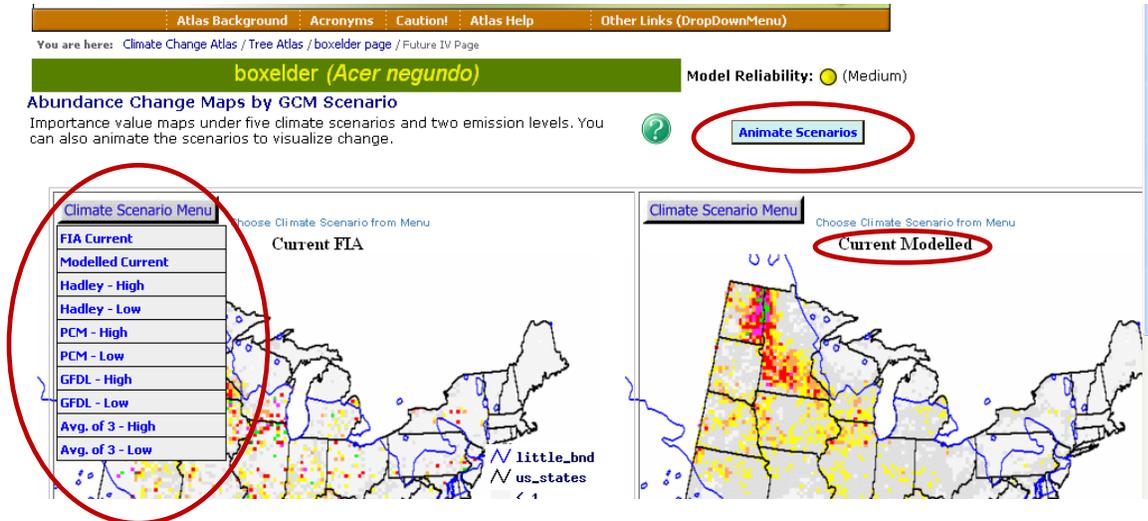
Experiment with different settings for these maps until you have a good sense of the projected future range of the species, and then answer questions 20-23.