Current Climate Studies 7: CLIMATE MODELS: LARGE SCALE AND PREDICTABLE

1. Print this file (and associated linked images if any). Also answer the "Concept of the Week" questions in the *Weekly Climate News* File. (Check for additional *News* updates during the week.)

2. Complete the Investigation by responding to the *Chapter Progress Questions* (*Study Guide*) and the Investigations 7A and 7B from the *Climate Studies Investigations Manual*, and this *Current Climate Study*.

Notice: A course requirement is to prepare a *Plan of Action* for your climate science resource teacher activities following the course completion. If you have not already, click to download the guidelines for that Plan of Action. Consult your LIT leader or mentor if you have questions.

Essential to modern climate science and climate change research is **climate modeling**. A **model** is an approximate representation or simulation of a real system, incorporating only the essential features (or variables) of a system while omitting details considered neither needed nor predictable. **Figure 1** displays the features of climate models, which are essentially systems of mathematical equations representing the basic laws of physics, fluid motion, and chemistry. Computer-based numerical climate models are either empirical or dynamic.

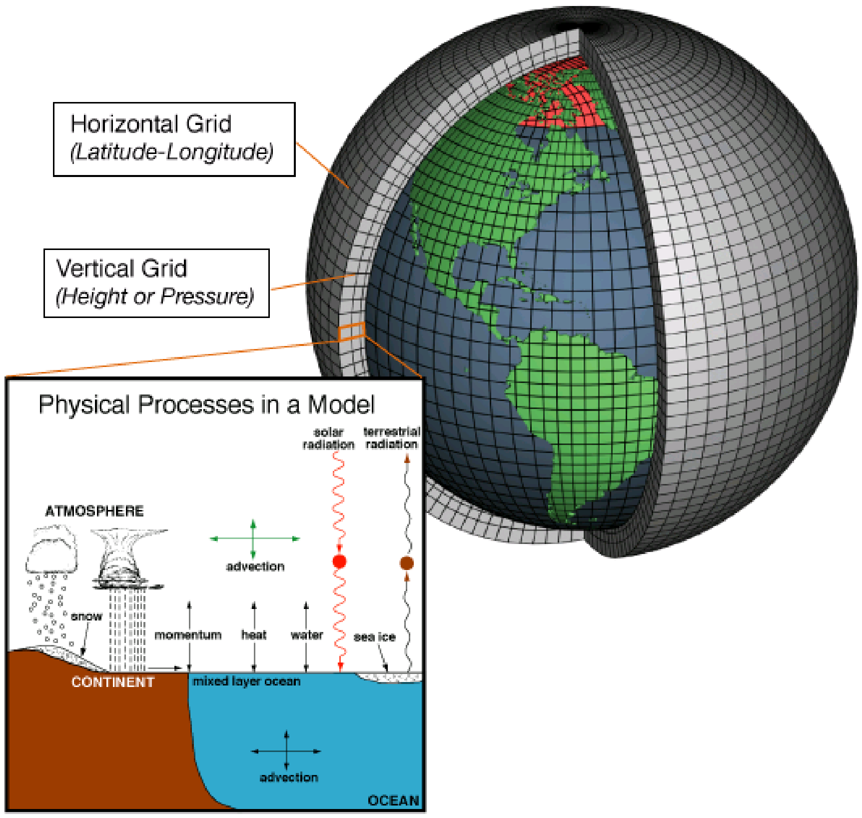

Figure 1. Features of three-dimensional climate models that are systems of mathematical equations. [NOAA]

Empirical climate models, based on actual observational data, are especially useful in predicting and interpreting climate variability. Dynamic climate models, based on interacting forcing mechanisms both internal and external to the climate system, are employed to predict climate change.

In recent decades, dynamic computer models of Earth's climate system have increasingly demonstrated their potential to realistically model past and simulate future climate. The USGCRP's 2009 second National Climate Assessment, *Global Climate Change Impacts in the United States* report, (page 22) points out that climate models are extremely important, because:

- Current climate models accurately portray many important aspects of today's weather and climate.
- Models capture not only the present-day climate, but also key features of the observed climate changes over the past century.
- Many large-scale observed climate changes are driven by very basic physics, which is well-represented in models.
- Climate models can be used to predict changes in climate that can be verified in the real world.

- Models are the only tools that exist for trying to understand the climate changes likely to be experienced during the course of this century (and beyond).

1. A climate model that predicts temperature changes resulting from projected increases in atmospheric heat-trapping gases would be a(n) ________ model.

   [ ] empirical
   [ ] dynamic

You have already been introduced to a simple dynamic climate model, the ***AMS Conceptual Climate Energy Model*** **(*AMS CCEM*)**. Dynamic climate models use mathematical expressions of physical processes and known initial conditions which can lead to model calculations of responses to forcings. Such forcings fundamentally result from changes in: 1) the rate of incoming solar radiation, 2) the fraction of solar radiation that is reflected (albedo) back to space, and 3) the rate of radiation emitted by the climate system to space. The *AMS CCEM* is a one-dimensional model that varies only in the vertical and assumes everything else is uniform or homogeneous, thereby focusing on how these changes would impact the flow of energy to and from an imaginary planet's climate system. *AMS CCEM* is conceptual in that it presents interactions (determined by a set of rules) among components of a system, and these interactions can be considered analogous to what happens in the real world (e.g., an energy unit absorbed by an atmospheric molecule has an equal chance of subsequently radiating an upward or downward component relative to the planet's surface). While the AMS *CCEM* is rudimentary, it presents basic understandings about energy flow that are integral to even the most sophisticated dynamic climate models.

2. In *Current Climate Studies 3*, you compared energy budgets of the AMS CCEM when an imaginary planet having atmospheric concentrations of CO_2 of none (0), equivalent to the current amount (1X) in Earth's atmosphere, or double the current amount (2X). When comparing the planet with no CO_2 in its atmosphere to one with CO_2, you determined that the addition of CO_2 which absorbs outgoing infrared (heat) radiation ________ the amount of energy retained in the planetary climate system. This retention can be expected to have a related effect on the climate system's temperature.

   [ ] increases
   [ ] decreases

3. The addition of a heat-trapping (greenhouse) gas in a planet's atmosphere produces feedback in terms of energy flow. A ***feedback*** occurs when part of an output returns to serve as an input again, so that the net response of the system is altered. The feedback may amplify (positive feedback) or dampen (negative feedback) the output. The addition of heat-trapping gas (e.g., CO_2) in the atmosphere causes absorption of infrared radiation emitted from the planet's surface. Some of the absorbed energy is emitted by the greenhouse gas molecules in the downward direction and returned to the planet's surface as an input again, thereby amplifying the output. This is an example of ________ feedback.

[ ] negative
[ ] positive

Aside from changing the atmospheric concentration of heat-trapping CO_2, the *AMS CCEM* allows adjustments in the Sun's Energy and Albedo. Here, we will look at the impact of albedo. *Albedo* is defined as the amount of radiant solar energy reflected by a body to the amount incident upon it, commonly expressed a percentage. An albedo of 0% means a body or surface absorbed all the radiant energy striking it. An albedo of 50% means half of the incident energy is reflected. Go to the *RealTime Climate Portal* and in the "**Extras**" section, click on <u>AMS Conceptual Climate Energy Model</u>. Then click on *Run the AMS CCEM*.

4. Before running the model with the default settings that are pre-selected, change <u>only</u> the **Cycles** setting to "200". With the albedo set at 0% (meaning no incoming solar energy is reflected by the planet's surface), the mean energy in the planet's climate system from Cycles 51 to 200, reported below the planetary view, is ________ units.

   [ ] 2.5
   [ ] 2.9
   [ ] 4.3
   [ ] 5.3

5. Now change only the Albedo value from 0% to 50% (meaning half of the incoming solar energy is reflected). With this setting, the mean energy in the planet's climate system during Cycles 51 to 200, is ________ units.

   [ ] 2.5
   [ ] 2.9
   [ ] 4.3
   [ ] 5.3

6. The *AMS CCEM* shows that with a(n) ________ in the albedo there is a related decrease in the energy retained in the planet's climate system. Typically, reflection and scattering by clouds and the planet's surface are most responsible for determining the albedo value.

   [ ] decrease
   [ ] increase

The *AMS CCEM* is a useful tool to learn the basic concepts of climate modeling. An understanding of Earth's climate system can provide a broad quantitative estimate of a globally averaged variable but with very little detail. The simulation of Earth's actual climate system and its changes require a much more sophisticated and detailed approach. Such computer-based numerical models are greatly needed as they are the only tools that can provide quantitative estimates of future climate changes.

State-of-the-Art Climate Models:

State-of-the-art climate models include interactive representations of the atmosphere, ocean, land, hydrologic and cryospheric processes, land and ocean carbon cycles, and atmospheric chemistry. The comprehensive models employed by climate scientists are highly complex systems of mathematical equations that are solved by using a three-dimensional grid over the globe. To simulate climate, the major components of the climate system are represented in sub-models, along with the processes that go on within and between them.

These models have demonstrated simulations in close alignment with recent climate and past climate change. As reported by the IPCC, there is considerable and growing confidence that Atmosphere-Ocean General Circulation Models (AOGCMs) provide credible quantitative estimates of future climate change, particularly at continental and larger scales. In its 2013 Fifth Assessment Report, the IPCC detailed the major AOGCMs from around the world. Also, USGCRP's NCA3 development included the use of climate models. If you wish, you can view the NCA3 animations of models covering annual winter and summer North America in two scenarios during the 21st century, at: http://svs.gsfc.nasa.gov/vis/a000000/a004000/a004029/temp_mosaic.m4v.

We will look at products from the *National Center for Atmospheric Research Community Climate System Model* (*NCAR CCSM*), a recognized U.S. climate model. Go to: http://www.vets.ucar.edu/vg/IPCC_CCSM3/index.shtml to view an animation of *NCAR CCSM* products.

7. Play the animation and view the changes that occur as the *NCAR CCSM* depicts simulated global surface temperature change from 1870 to 2100. Simulated and observed temperature changes to the Year 2000 show close agreement. In the lower panel, note the several curves generated after 2000 that show warming based on different atmospheric CO_2 concentration scenarios. [Note: The CO_2 concentration is currently very close to 400 ppm.] Also, note in the lower panel the impact of major volcanic eruptions that lowered the average global surface temperature. The eruption impacts typically last only for a couple of years. ________ was the most recent major eruption evidenced in the temperature curve.

   [ ] Krakatau
   [ ] Pinatubo
   [ ] Agung

8. Replay the animation. Using the control bar, stop the animation at the Year 2000 (when 2000 appears to the lower right on the global map). The value appearing to the right of the year notation indicates the global surface temperature change relative to the 1870-1899 baseline. It is ________ C degree(s).

[ ] 0
[ ] +1.0
[ ] +1.5
[ ] +3.3

9. Continue the animation. As the year seen on the global map advances, follow the **green** curve depicting temperature change under the IPCC A1B mid-level emissions scenario (in which the atmospheric CO_2 concentration is programmed to stabilize at 720 ppm). In this scenario, at Year 2050 the temperature change is projected to be ________ C degrees relative to the 1870-1899 baseline.

[ ] +1.0
[ ] +1.5
[ ] +2.5
[ ] +3.3

10. Continue the animation to the Year 2100. **Figure 2** is the 2100 view at the end of the animation. The 2100 view shows the CCSM prediction of surface temperature changes relative to the 1870-1899 baseline. As seen on the graph, the Scenario A1B average global surface temperature change relative to the 1870-1899 baseline will increase about ________ C degrees by 2100.

[ ] 1.4
[ ] 3.3
[ ] 4.8

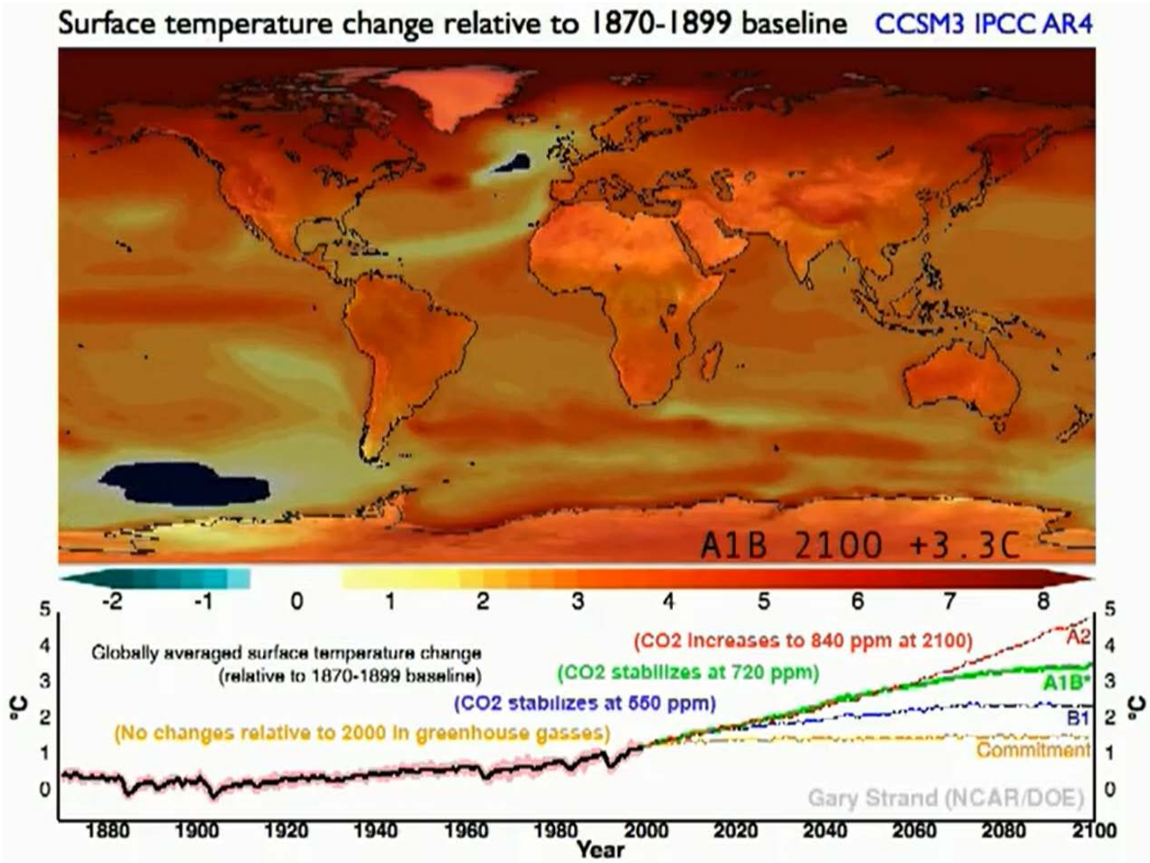

Figure 2. NCAR CCSM prediction of global temperature change from 1870-1899 baseline following IPCC emissions scenarios with different CO2 concentrations up to Year 2100. [NCAR]

11. Note the gold curve extending from Year 2000 onward. This shows the projected temperature change if atmospheric concentrations of CO_2 remained at 2000 levels. Referring back to Item 8 for the temperature change as of the Year 2000, the curve shows that without a change in the concentration of atmospheric CO_2, the average annual global temperature from 2000 to 2100 would ________. This is referred to as a ***commitment*** because it would happen even if we could return and stabilize atmospheric CO_2 concentrations at 2000 levels. Such stabilization is highly unlikely under current national and worldwide energy policies.

[ ] decrease
[ ] remain the same
[ ] increase

12. Figure 2 shows projected temperature changes under several scenarios. The blue Scenario B1 curve with atmospheric CO_2 concentrations stabilizing at 550 ppm, indicates the projected average global surface temperature change this century relative to the 1870-1899 baseline (by comparing Figure 2 temperature change values for the years 2000 and 2100) will be about ________ C degrees. Comparing this temperature change with those of the other

scenarios demonstrates the extent to which curbing CO_2 emissions can have major impact on future climate.

[ ] +1.3
[ ] +2.4
[ ] +3.3
[ ] +4.8

Summary:

Computer climate models are essential scientific tools for understanding and predicting natural and human-caused changes in Earth's climate. They are the only tools that exist for trying to understand and predict climate changes likely to be experienced in the future. Climate models are limited by our ability to understand and describe complicated atmospheric, oceanic, and chemical processes mathematically, as well as by computer capacity constraints. Numerous current climate models demonstrate considerable success in simulating past and current climate, thereby strengthening confidence in their predictions of future climate.

Instructions for Communications with Mentor:

Transmit this week's work to your LIT mentor by Monday, 24 October 2016, or as coordinated with your mentor. Include:

- **Chapter Progress Response Form** from the *Study Guide* or the *RealTime Climate Portal* website.
- **Investigations Answer Form** for 7A and 7B from the *Study Guide* or *RealTime Climate Portal* website.
- **Current Climate Studies Answer Form** from *RealTime Climate Portal* website.