Week 9 Climate 101

Earth's Energy Flows and Global Climate

Overview of the Week

* In a computer lab, participants use a PCEP interactive and an OSS simulation to explore how energy flows into, within and out of the Earth system.
* Participants build on computer lab experiences to model Earth's energy flows and explain how increased carbon dioxide results in global warming.
* Participants analyze graphs of carbon dioxide concentrations in the atmosphere at different time scales. They analyze evidence linking historic changes in atmospheric carbon dioxide concentration with changes in global climate, and obtain a long-term perspective on the current rapid increase in atmospheric carbon dioxide.
* Instructor and participants review prior weeks of the course in preparation for the "mid-term" post-test.

Before Teaching this Week:

* Make sure computer lab can be available for the first session and that the computers there can run both the PCEP Earth's Energy Flows interactive and the OSS greenhouse effect simulation.
* Note that we are not printing or using Investigation Notebook Unit 3 since the Climate 101 course uses only a few parts of Unit 3, and has changes to those parts.
* For Day 1, make copies for each participant of the Energy Interactive Handout (double-sided is preferable), Simulation Handout, and Heat-Trapping Gases Handout (page 12 of the Unit 3 Investigation Notebook).
* For Day 2, make double-sided copies of the How Scientists Know reading (see provided pdf obtained from pages 8-9 of Unit 3 Investigation Notebook), and the two pages from the 400,000 Years Handout.
* Make a color copy for each participant of Slide 21 (Energy Flows and the Earth System).
* Review the write-up below for each day, the slides in the power point including the notes for each slide, and the participant handouts.

Day 1: Computer Lab

Participants will explore two different computer resources. About half the time will focus on the PCEP interactive titled "Earth's Energy Flows and Climate." The other half of the time will focus on the Greenhouse Effect simulation from the OSS Session 3.3. The slides in the file ComputerLab Energy.pptx include notes to guide this day. Begin the session by **Showing Slides 1 through 3** to quickly set the context of the three interactives, especially the focus on this middle interactive.

Participants should work in teams of two. Distribute the Energy Interactive Handout for participant teams to take notes while exploring the interactive (if possible best to provide as double-sided rather than two separate sheets of paper). **Show Slides 4 through 6** to facilitate their use of the interactive, especially beginning with the Tropical Island and then transitioning to the Global View. Emphasize that the atmosphere is part of the Earth System and marks the boundary with Outer Space.

After half the time has elapsed, the teams should transition to exploring the simulation. **Show Slides 7 and 8** to mark the transition in the computer lab from the PCEP Interactive to the Simulation. They should follow directions to guide their use of the simulation, especially beginning with trying different atmospheres and later transitioning to the Photon Simulation part. Help them start by giving each participant a copy of the Greenhouse Effect Simulation handout and a copy of the Heat-Trapping Gases handout (if possible as double-sided rather than two separate sheets of paper). If there is not enough time, the instructor can help everyone experience the main features of the simulation on Day 2 back in the regular classroom. If they have more time, they can explore other features of the simulation.

Day 2: Connecting Carbon Dioxide and Global Warming

If participants did previous week's optional activity (designing a control for the photosynthesis BTB activity), have them describe procedures, results and conclusions. Summarize whether these experiences help confirm that the change in BTB color by the plant exposed to sunlight is due to photosynthesis.

Using the main Power Point for this week, **Show Slides 9 and 10** to review their experience with the Earth's Energy Flows interactive. Each of the slides has notes that can help guide this session. Distribute the "Heat Energy Moves in Three Ways" handout and **Show Slide 11 (Heat Energy Moves in Three Ways)** to guide their small group discussion and work in filling out this handout. **Slide 12** can be used to help summarize the distinctions among conduction, convection and radiation. **Slide 13 (Electromagnetic Spectrum)** can be used to help provide a common background with respect to the electromagnetic spectrum in general, and specifically the very narrow visible band and the nearby infrared region.

Use Slides 14 through 16 to transition to the global view and help establish about the nature of greenhouse gases and their effect on climate. With Slide 14, reinforce the concept that infrared radiation is the only way that heat energy can leave the Earth System. Try to elicit the correct conclusions by participants sharing the results of their observations from the interactive and the simulation. Then use **Slides 17 through 19** as background for participants to begin working in groups to create a model system diagram of the flows of energy into, within and out of the Earth system.

After the groups have the beginnings of diagrams to share, have them post their diagrams to where people can view them. Each group then walks around the room to look at what others have done. Nobody stays with their own poster. As each group examines and discusses a different group's poster, they can add a green Post-It to write about something that they like about that group's diagram; a yellow Post-It to write about anything that they wonder about or are confused by in the diagram; and a blue Post-It if they have a specific suggestion of something to add or change. They can also write a note to themselves about something that they might want to change about their diagram based on what they have just seen. Each group should look and discuss at least two other groups' diagrams.

Each group then goes back to its own poster to look at the comments that they received. Each group then has time to discuss and make any changes based on the comments they received and their reactions to seeing the other diagrams. During this entire process, instructors play a vital role in making sure that misconceptions are not being propagated and also in seeding ideas for improvements. If necessary, refer to slides 20 and 21 for ideas.

After groups have revised their diagrams, convene the class to **View and Discuss Slides 20 and 21.** Help participants identify key features distinguishing where energy flows into the Earth system, within the Earth system, and out of the Earth system. Compare the two versions, for example with respect to specifically showing atmosphere in Slide 20, and also with respect to identifying in **Slides 21 and 22** that climate is a property of the whole system that arises from the interactions of the system parts with the incoming sunlight and with each other.

The last bullet on Slide 22 reminds us that changing a part of a system can profoundly change the system as a whole. **Show Slide 23 (Global Climate Change)** to trace the causal connections again from burning fossil fuels (adding carbon dioxide to the atmosphere) to increased greenhouse effect to global warming to global climate change. Conclude this part of Day 2 by **showing Slide 24 (CO_2 Levels Past 400,000 Years)** and giving the first page of the 400,000 Years Handout to each participant. Have participants identify that the graph shows how much carbon dioxide levels in the atmosphere changed over that very long period of time. Have each person draw a rough graph of how they think the temperature might have changed (or not changed) over that time period. When everyone is ready, **Show Slide 25 (Temperature and CO_2 Past 400,000 Years)** and give out the second page of the 400,000 Year handout. Emphasize the close correlation, but you probably also need to help explain the temperature scale that climate scientists used for that graph.

Show Slide 26 (Tracking Earth's CO_2 through Time) to switch to OSS Session 3.2 for historical data re carbon dioxide and global climate. You can tell participants that we are doing a modified version of Session 3.2 from the Ocean Sciences Sequence curriculum.

Show Slides 27 through 29 to introduce the reading and the literacy jigsaw activity. Make sure that everyone knows what a jigsaw puzzle is and how people can work together to solve a jigsaw puzzle. Ask if anyone has learned or taught using a jigsaw learning activity. If one of more people have, they can explain what it is.

Distribute to everyone a double-sided color copy of the handout "How Do Scientists Know about Carbon in the Atmosphere?". Divide the class into three groups and highlight the three different reading sections (Carbon Dioxide Sensors; Ice Cores; and Plant Leaf Stomata). Keep **Slide 29** projected while participants are doing the complete activity. Note that the first discussions occur within a group where everyone is focused on the same reading. Then the class is redistributed into groups where each group has at least one person from each of the different readings. Conclude with a whole class discussion focused on how scientists know about carbon in the atmosphere. After summarizing the main content ideas, have participants focus on the pedagogy of this jigsaw type learning activity,

especially how they might use this for different types of learning activities (e.g., readings, hands-on activities, project based learning, etc.).

Show Slides 30 through 32 to focus on the units being used to describe the concentration of carbon dioxide in the atmosphere (parts per million, ppm). These slides attempt to help connect and unfamiliar unit of measurement (ppm, which is very useful for very dilute substances) with a more familiar unit of measurement (percentages) which is generally applied to more concentrated substances (1% or more, rather than 0.04%). For **Slide 31** note that each dot represents a molecule of gas in dry air. Of these 10,000 total dots:

7,808 dots represent nitrogen molecules;
2,095 dots represent oxygen molecules;
93 dots represent argon atoms (argon is inert so it does not form molecules; and
4 dots represent carbon dioxide molecules.

Show Slide 33 (CO_2 Levels in Atmosphere Measured at Mauna Loa) to introduce this famous graph. Note that the graph goes up from about 310 ppm in 1958 to more than 400 ppm today. The graph shows data based on direct measurements of the carbon dioxide concentration in the atmosphere taken constantly at the same location (near the top of Mauna Loa, a very high mountain in Hawaii). If anyone asks about the line going up and down each year, you can ask if anyone has any ideas about that. (It is the annual cycle of higher summer photosynthesis decreasing CO_2 in the air followed by higher winter respiration increasing CO_2 in the air.) Note that the most current graph can be accessed at https://scripps.ucsd.edu/programs/keelingcurve/.

Show Slide 34 (CO_2 Levels in Atmosphere Including Recent Ice Core Data) and have participants describe what the graph shows. Note the X-axis (thousands of years) and the Y-axis (ppm from 200 to more than 400). Have participants discuss the graph in small groups to decide what the main conclusions might be. Make sure that the discussion highlights that the level of carbon dioxide has been relatively constant (about 270 ppm) for the last 10,000 years, and that very recently it has increased dramatically. This 10,000 year period corresponds to our comparatively warm interglacial that has enabled human societies to generally prosper.

Show Slide 35 (CO_2 Levels in Atmosphere Including Long-Term Ice Core Data) and have participants discuss this graph in the same groups as before. Facilitate whole class discussion leading to the correlation of the carbon dioxide concentrations with the extreme cooling of the planet during Ice Ages, followed by relative warming during interglacials. The current very high levels of carbon dioxide are already causing significant global warming and associated climate changes that we will be investigating in the rest of this course.

<u>Day 3: Review of Prior Weeks of Climate 101</u>
The main time for this session is to review earlier parts of the course that had focused on local climate and Unit 1 of the Ocean Sciences Sequence curriculum. Participants should have their Unit 1 Investigation Notebook for reference. Remind them that they took a pre-

test at the start of the course. At the beginning of the next week, they will take exactly the same test. All participants need to take the post/test even if they did not take the pre/test.

Show Slides 36 through 49 to help review earlier course sessions. Remind participants of key activities associated with the different sessions. For example, **Slide 44** shows the simulation of balloons filled with different liquids floating in a big beaker. This is from LHS Session 1.6, and you could re-play that simulation during the review.

Homework Assignment is to write about our Two Guiding Reflections (same questions used at the end of every week):

1) Choose a concept of activity from this week. How would you teach this concept or activity with your students?
2) What would be hard for your students to understand about this concept or activity?

Special Homework Assignment: Review Investigation Notebooks and other notes to prepare for Test on Day 1 of Week 10.