SYSTEMS ENRICHMENT EXERCISE

Understanding Climate Momentum

Students use a simple computer simulation to explore how time scale affects climate change.

Objectives

After completing this exercise, students will be able to

- describe the delay between climate mitigation measures and climate response, and
- explain the time scale involved with climate change.

Materials

- Understanding Climate Momentum student page and access to computer with Internet

Introduction

In this exercise, students work with a user-friendly climate simulation in order to gain a better understanding of the time scales involved with climate change. As discussed in Activity 2, one of the reasons people exhibit complacency regarding climate change is that they think that we do not need to address climate change until conditions become sufficiently bad to warrant a major response. This wait-and-see approach is unwise for numerous reasons, including that the climate system will not respond to changes immediately. It takes time to turn a large ship around and get it moving in another direction, and the climate system is a very large ship indeed.

A simple example of a delay can be the time between planting a seed in the ground and seeing it sprout. We know the seed was planted, but it may be days or weeks until it germinates and we see the plant start to appear above ground. The delay involved with getting a sunburn works as another good analogy. Fair skinned people can be in the sun for several hours without noticing a problem, yet the next day they may have a painful burn. Avoiding such a burn requires understanding the delay involved and taking proactive measures to prevent it, such as staying in the sun for only a short time, using sunscreen, avoiding midday sun, or wearing protective clothing. All of these are perhaps

A simple example to help explain the concept of delay is the time between planting a seed in the ground and seeing it sprout.

inconvenient, but each has positive results for mitigating damage from the sun. Addressing climate change requires a similar approach.

Doing the Exercise

1. Distribute the student page as homework or at a time when students have access to a computer lab. This is a relatively simple simulation for students to manipulate, and it helps them practice reading graphs and recording results. Students will use the slider tool below the graph to explore different scenarios for addressing climate change. As they move the slider from one scenario to another, they can read the different measures for mitigating climate change included in each scenario and see the resulting changes in CO_2 emissions, atmospheric CO_2 levels, global temperature, and sea level rise. Note that answers are provided for both the tables and the discussion questions. Keep in mind that these responses are merely guidelines. Students may enter slightly different values in the table since they must use the online figures to estimate these numbers. Also, students will likely not answer the discussion questions with the level of detail provided here. This detail is provided so that you can supplement student comments during discussion with more nuanced explanations. Depending on what other systems thinking exercises you have covered, you may need to provide your students with assistance on the discussion questions.

2. This exercise helps students see the big picture. However, you may need to remind students of the connections between climate and forests and land-use change. To do this, direct students back to the "80% Reduction" setting and have them read the description: "An 80% reduction of global fossil fuel plus a 90% reduction in land use emissions by 2050." If the students have already learned about the role of forests in carbon storage, then you might ask students what "land use emissions" might refer to. If the students have not covered this concept yet, you can explain that you will cover this in more detail in Section 3 of the module (Activities 7 and 8).

Understanding Climate Momentum (1 of 2)

NAME DATE

Directions: In this activity, you will work with Climate Interactive's Online Climate Momentum Simulation. To begin this exercise, go to the following website: http://climateinteractive.org/simulations/climate-momentum-simulation

When you load the webpage, you will see a figure with four graphs illustrating sea level rise since 2000 (in millimeters), temperature change over pre-industrial levels (degrees Celsius or °C), atmospheric carbon dioxide (CO_2) levels (in parts per million, ppm), and global CO_2 emissions per year (in tons).

You will also see a slider under the bottom graph that can be moved to mimic reductions in CO_2 emissions. This first setting on the left represents Business as Usual. The other five settings are as follows:

1. **March 09 Proposals** assumes that every country meets its publically stated proposal for addressing climate change (as of March 2009).
2. **Flatten Emissions** assumes that annual CO_2 emissions have leveled out by 2025.
3. **Modest Decrease** assumes that total greenhouse gas emissions decrease to 29% below 2009 levels by 2050.
4. **80% Reduction** assumes an 80% reduction in fossil fuel emissions and a 90% reduction in land use emissions by 2050.
5. **95% Reduction** assumes total CO_2 emissions decrease by 95% by 2020.

Fill in the following table and answer the questions by manipulating the slider on the bottom and reading the corresponding results for the year 2100 from the graphs. Keep in mind as you answer these questions that scientists have suggested 350–450 parts per million (ppm) and a temperature increase of 2° C as the maximum safe limits to avoid severe negative effects of climate change. These values are indicated on the Climate Interactive graphs with solid lines indicating the goal or goal range.

SCENARIOS	Sea Level Rise Since 2000 (mm)	Temperature Change over Pre-Industrial Levels (° C)	Atmospheric CO_2 Levels (ppm)	Global CO_2 Emissions (tons C/year)
Business as Usual				
March 09 Proposals				
Flatten Emission				
Modest Decrease				
80% Reduction				
95% Reduction				

Understanding Climate Momentum (2 of 2)

1. Under March 09 Proposals, when do global CO_2 emissions begin to level off?

2. Which conditions show atmospheric CO_2 concentrations leveling out or decreasing by the year 2100?

3. Which conditions show sea level rise leveling off by the year 2100?

4. Which conditions would allow us to keep atmospheric CO_2 concentrations under 450 ppm?

5. Under 95% Reduction conditions, would global temperatures level off? If so, by how much would the maximum increase?

6. Under 95% Reduction conditions, how much do atmospheric CO_2 concentrations drop between 2020 and 2100? What does this indicate about the processes that decrease atmospheric CO_2?

7. Under 95% Reduction conditions, how is the global temperature changing between 2020 and 2100? Explain this behavior in the context of the slight decrease in CO_2 concentrations during this same period noted in Question #6.

8. If reducing CO_2 emissions by 95% would still result in decades more of increased global temperatures and increased sea level rise, then why bother trying to decrease atmospheric CO_2 concentrations at all?

Understanding Climate Momentum (1 of 2)

SCENARIOS	Sea Level Rise Since 2000 (mm)	Temperature Change over Pre-Industrial Levels (° C)	Atmospheric CO_2 Levels (ppm)	Global CO_2 Emissions (tons C/year)
Business as Usual	900	4.6	950	31 billion
March 09 Proposals	810	3.9	750	21 billion
Flatten Emission	810	3.4	600	12 billion
Modest Decrease	710	2.9	500	7 billion
80% Reduction	590	2.3	400	1 billion
95% Reduction	590	2.0	360	0.5 billion

1. Under March 09 Proposals, when do global CO_2 emissions begin to level off?

   Between 2080 and 2090

2. Which conditions show atmospheric CO_2 concentrations leveling out or decreasing by the year 2100?

   80% Reduction and 95% Reduction both indicate leveling of atmospheric CO_2 concentrations. Modest Decrease still shows a slight increase in atmospheric CO_2 concentrations from 2090 to 2100.

3. Which conditions show sea level rise leveling off by the year 2100?

   None. Even 95% Reduction indicates sea level continuing to rise between 2090 and 2100.

4. Which conditions would allow us to keep atmospheric CO_2 concentrations under 450 ppm?

   Both 80% Reduction and 95% Reduction keep CO_2 concentrations below 450 ppm.

5. Under 95% Reduction conditions, would global temperatures level off? If so, by how much would the maximum increase?

   Yes, temperatures would level off by 2100 at 2° C over pre-industrial levels.

6. Under 95% Reduction conditions, how much do atmospheric CO_2 concentrations drop between 2020 and 2100? What does this indicate about the processes that decrease atmospheric CO_2?

   Although CO_2 emissions are held very low from 2020, the atmospheric concentrations of CO_2 only decrease from about 390 ppm to about 360 ppm. This indicates that the global processes that decrease atmospheric CO_2 levels work very slowly.

Understanding Climate Momentum (2 of 2)

7. Under 95% Reduction conditions, how is the global temperature changing between 2020 and 2100? Explain this behavior in the context of the slight decrease in CO_2 concentrations during this same period noted in Question 6.

   Many students might expect to see a decrease in atmospheric CO_2 concentrations to be accompanied by a corresponding drop in temperature. Therefore, they are surprised by the continuing increase in global temperatures. To understand this behavior we need to consider the system in terms of stocks and flows. The global temperature indicates a stock of heat energy in the global system. More energy is constantly flowing into the system from the sun and radiating out of the system into space. Atmospheric CO_2 inhibits the outflow of energy from the Earth, just like a sweater inhibits the flow of heat from our bodies.

   The problem is that current CO_2 concentrations are the equivalent of wearing several sweaters. Therefore, taking the first one or two sweaters off would not decrease our temperature. Rather, it would cause us to increase our temperature more slowly than before. That is what is happening in the model. Initial decreases in CO_2 concentrations slow down the increase in temperatures. However, it takes several decades for CO_2 concentrations to decrease to levels low enough to allow heat to radiate off the planet at roughly the same rate the Earth receives energy from the sun.

8. If reducing CO_2 emissions by 95% would still result in decades more of increased global temperatures and increased sea level rise, then why bother trying to decrease atmospheric CO_2 concentrations at all?

   This model drives home two important lessons. First, in order to address climate change in a serious way, reductions in CO_2 emissions must be more significant than many students may realize. Second, the positive impacts of our efforts to mitigate climate change will take a long time to have a discernible impact. These two points can be discouraging. There are numerous ways to address these lessons. The following are just a few.

   First, in previous exercises, students learned about reinforcing feedback loops. People often focus on feedback loops that reinforce unwanted changes. We call these loops "vicious cycles." However, these loops can also reinforce desired changes. These are called "virtuous cycles." A virtuous cycle might look something like this: the school tree-planting project goes so well that it generates a lot of positive publicity for the school. Other schools see that result and decide to start similar projects. Local community leaders and politicians see the excitement generated across the county by these programs and turn it into a regional affair. Climate mitigation efforts become a point of regional pride, which encourages numerous private businesses to add to mitigation efforts in their own ways. These efforts receive national coverage and spark communities all over the country to institute their own climate mitigation programs.

   This may seem like an unrealistic series of events, but this is how change happens. Ecologists and social scientists have documented many examples of small-scale change being reinforced into broader scales of influence. We are more accustomed to observing negative examples of escalating change. However, there are positive examples as well. Perhaps the most famous is in the context of civil rights. Recall that by refusing to move to the back of a bus, Rosa Parks affected national changes in racial equality. As anthropologist Margaret Mead once said, "Never doubt that a small group of thoughtful, committed citizens can change the world. Indeed, it's the only thing that ever has."

   What about the second point? Decreasing atmospheric CO_2 concentrations is still going to take a really long time. That's true, but slowing down the rate at which climate change is occurring still has short-term value. The slower we experience climatic changes, the better our chances for successfully adapting to those changes become. In addition, some people believe that we should feel a sense of responsibility to future generations. When someone living a hundred years from now asks why we did not do more to mitigate climate change, we probably would be ashamed to answer, "It just seemed like it would take a really long time."