Carbon-Cycle

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Contents

Homework

Homework Exercises:

- *Forecast*, Ch. 8, Ex. 1–2
- *Forecast*, Ch. 10, Ex.~1
- **Do the following exercise (call it 10.4):** Using the SLUGULATOR model at https://climatemodels.jgilligan.org/slugulator/ or http://climatemodels.uchicago.edu/slugulator/, compare the impact of methane and CO_2 on timescales of 1, 10, 25, 50, 100, 500, and 1000 years.

  The SLUGULATOR model simulates releasing a large amount of CO_2 and methane and then calculates what happens over time. At time zero, the concentration of each gas is the natural level from shortly before the industrial revolution: 280 ppm of CO_2 and 1.6 ppm of methane. At one year, a large amount of each gas is released instantly (after this, there are no further emissions of either gas).

  a) Run the model using the default model input parameters, setting the left graph to "Concentrations" and the right graph to "Surface T Anomaly". Set the time scale on the bottom to show 10 years.

     Move your mouse over the graphs to measure the exact values (a "tooltip" will pop up next to the cursor telling the time in years and the value of the line on the graph: concentration of CO_2 or methane, or the warming due to that gas). Be aware that on the concentration graph, the concentration of CO_2 is plotted against the left axis while methane is plotted against the right axis.

     What happens to the concentrations of methane and carbon dioxide? Why does the concentration of CO_2 continue to rise after the first year, when methane is falling?

  b) What is the warming due to methane at 1 year and at 10 years? What is the warming due to CO_2 at 1 and 10 years? (Use the mouse to examine the time-dependent temperature plotted on the graphs, not the "Time-integrated temperature" in the table at the top of the page). Calculate the ratio of methane-warming to CO_2-warming at each time.

  c) Change the time scale to show 25, 50, 100, 500, and 1000 years. Make a table showing the warming due to each gas and the ratio of methane-warming to CO_2-warming at 1, 10, 25, 50, 100, 500, and 1000 years.

  d) Plot the ratio of methane-warming to CO_2-warming over time.

  e) Why does the ratio change with time?

f) Generating electricity by burning natural gas (methane) releases less than half as much CO_2 than generating the same amount of electricity by burning coal.

"Fracking" has dramatically lowered the cost of natural gas, and this has made coal-fired electrical generation uneconomical, so about half of the coal generation plants in the United States have shut down in the last 10 years.

Many people think replacing coal generation with natural gas generation will reduce CO_2 emissions significantly, but gas wells that use fracking also leak a lot of methane directly into the atmosphere.

Comment on the significance of this homework exercise to the debate over whether fracking is helping or hurting the problem of global warming.

Notes on Homework:

The GEOCARB model has two time periods: First, it runs for 5 million years with the "Spinup" settings in order to bring the carbon cycle and climate into a steady state. Then, at time zero, it abruptly changes the parameters to the "Simulation" settings and also dumps a "spike" of CO_2 into the atmosphere and runs for another 2 million years with the new parameters to see how the climate and carbon cycle adjust to the new parameters and the CO_2 spike.

Notice that some of the graphs show short-time behavior (the first 100,000 years after the transition) and some show the long-time behavior (two million years after the transition).

The quantities that are graphed include:

pCO2 is the concentration of CO_2 in the atmosphere, in parts per million.
WeatC is the amount of CO_2 weathered from carbonate rocks and moved to the oceans.
BurC is the amount of carbonate converted into limestone and buried on the ocean floor.
WeatS is the amount of SiO_2 weathered from silicate rocks and moved to the oceans.
Degas is the amount of CO_2 released to the atmosphere by volcanic activity.
tco2 is the total CO_2 dissolved in the ocean, adding all its forms:

$$\text{tco2} = [\text{CO}_2] + [\text{H}_2\text{CO}_3] + [\text{HCO3}-] + [\text{CO}_3{}^{2-}].$$

alk is the ocean alkalinity: the total amount of acid (H^+) necessary to neutralize the carbonate and bicarbonate in the ocean. The detailed definition is complicated, but to a good approximation,

$$\text{alk} = [\text{HCO}_3{}^-] + 2\,[\text{CO}_3{}^{2-}].$$

This is not crucial for this homework assignment.
CO3 is the concentration of dissolved carbonate ions ($CO_3{}^{-2}$) in the ocean, in moles per cubic meter.
d13Cocn is the change in the fraction of the carbon-13 (^{13}C) isotope relative to the more common carbon-12 (^{12}C) isotope in the various forms of carbon dissolved in the ocean water.
d13Catm is the change in the fraction of ^{13}C relative to ^{12}C in atmospheric CO_2.
Tatm is the average air temperature.
Tocn is the average water temperature of the oceans.

In this homework, you mostly just look at pCO_2, but in exercise 2 in chapter 8, you also have to look at the weathering.

Details about the assignment:

Chapter 8, #1: Run the model with "Transition CO_2 spike" set to zero and change the CO_2 degassing rate in the "Simulation" box. Examine how changing in the degassing rate affects the atmospheric concentration of CO_2, the time it takes to equilibrate (how can you tell when the atmospheric CO_2 has reached equilibrium?), and how weathering changes to produce this new equilibrium.

If you can't see both the red line and the green line, that's because the two lines are identical and the red line is hidden behind the green line.

Chapter 8, #2: I recommend approaching the exercise as follows:

- First, run the simulation with the transition spike set to zero, the degassing rate set to 7.5 in both the spin-up and the simulation and the
  "Geologic setting" set to 0 (meaning the present).
- Then press "Save model run to background," which lets you compare this run to a different run.
- Next, run the model with the geologic setting at 500 million years ago. The sun was substantially dimmer then. How did this affect the temperature and pCO_2?

  The original run that you saved (present-day conditions) is labeled as "Alt" in the graphs and the current model run is shown without the "Alt" label.

  The simulation is supposed to reflect a steady state, so if you see pCO_2 changing, take a careful look at how much it changes during the two million years the graphs cover (it should not change very much, if at all).

  How does the average value of pCO_2 compare to today? Why is there such a difference?

Chapter 10, #1: Run the model with year = 0, degassing set to 7.5 for both the spin-up and the simulation, and a spike of 1000. If you want, feel free to run it several times with different values for the spike. You're looking for how long it takes pCO_2 to level out and how long it takes pCO_2 to return to its original value (before time zero).