Chapter 10 Homework Answers

2023-03-01

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Exercise 10.1: Long-term fate of fossil-fuel CO_2

Use the online geologic carbon cycle model at https://climatemodels.jgilligan.org/geocarb/. Use the default setup of the model, and notice that the CO_2 weathering rates, etc., for the transient state are the same as for the spin-up state. So, if there were no CO_2 spike at all, there would be no change in anything at year 0. (Go ahead, make sure I am not lying about this.) Release some CO_2 in a transition spike, 1000 Gton or more or less, and see how long it takes for the CO_2 to decrease to a plateau. There are two CO_2 plots in the output, one covering 100,000 years and one covering 2.5 million years. How long does it take for CO_2 to level out after the spike, according to both plots?

Answer to 10.1

Even after 1 million years (the longest we can plot with the new version of the Geocarb model), CO_2 hasn't quite returned to its original value.

At the end of spinup, CO_2 was 272.6 parts per million, and 1 million years after the spike, it's 273.1 ppm.

Exercise 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?

Answer to 10.4(a)

After the spike, methane immediately begins to drop, and by about 35 or 40 years later, it’s pretty much back to where it was before the spike.

After the spike, CO_2 continues to rise for 35–40 years, and then gradually falls over the next million years.

When methane falls during the first 50 years or so, it is removed from the atmosphere by chemical reactions that oxidize it and convert it to CO_2 and water vapor. CO_2 continues to rise after the initial spike because the initial spike of methane is being converted to CO_2.

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.

Answer to 10.4(b)

After 1 year, the warming due to methane is 0.029 degrees C. After 10 years, it’s 0.09 degrees.

After 1 year, the warming due to CO_2 is 0.001 degree, and after 10 years, it’s 0.006 degrees.

At 1 year, the ratio of methane warming to CO_2 warming is $0.029/0.001 = 29$. At 10 years, the ratio is $0.09/0.006 = 15$.

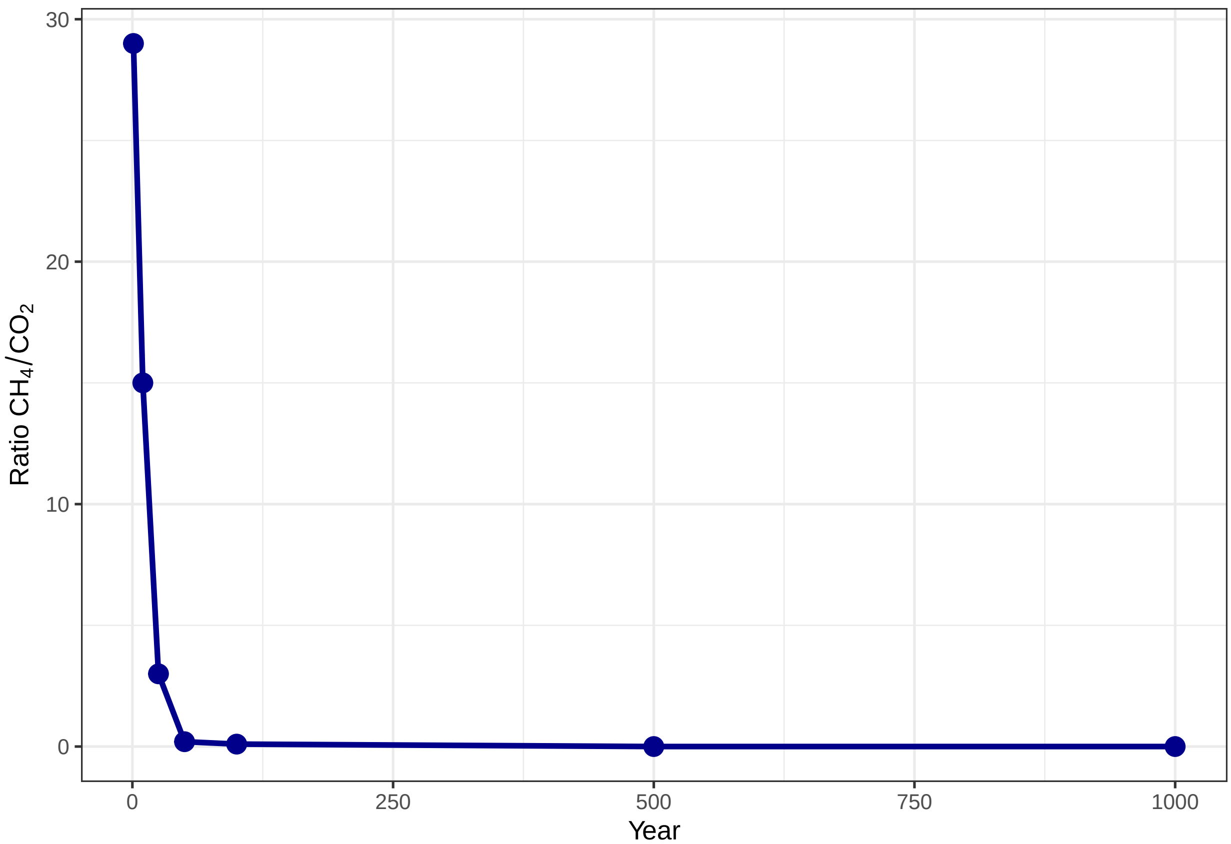
c) Change the time scale to show 25, 50, 100, 500, and 1000 years. Make a table showing the warming due to each gas and the ratio of methane-warming to CO_2-warming at 1, 10, 25, 50, 100, 500, and 1000 years.

Answer to 10.4(c)

Year	Methane warming	CO2 warming	Ratio CH4/CO2
1	0.029	0.001	29.0
10	0.090	0.006	15.0
25	0.030	0.010	3.0
50	0.002	0.010	0.2
100	0.001	0.010	0.1
500	0.000	0.009	0.0
1000	0.000	0.007	0.0

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

Answer to 10.4(d)



e) Why does the ratio change with time?

Because methane is a much more powerful greenhouse gas than CO_2, but it has a much shorter lifetime in the atmosphere, so over time, the methane goes away while the CO_2 remains for thousands of years.

Answer to 10.4(e)

Because methane is a much more powerful greenhouse gas than CO_2, but it has a much shorter lifetime in the atmosphere, so over time, the methane goes away while the CO_2 remains for thousands of years.

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.

Answer to 10.4(f)

In terms of long-term warming, the move from burning coal to burning methane is a big improvement because less than half as much CO_2 will be released into the atmosphere.

However, in the short term (the next 50 years or so), the leaking methane from the gas wells will produce a lot of warming. It's possible that enough methane could leak out of the wells to create more warming in the short-term than the coal would have done.

However, this methane will disappear from the atmosphere in the next several decades, whereas the CO_2 from burning coal would remain in the atmosphere for many thousands of years.