GEOL/ENVS 3520 Homework no. 2
Due in class: Thursday 5 February 2009

Part 1 (6 pts.) The warming potential of methane vs. CO_2:

For these exercises we are going to use a simple on-line model made available by your textbook author. This model calculates the spectrum and amount of outgoing infrared radiation for different conditions in the atmosphere and at the surface. We will use the model (which we have already seen in class) to investigate the impact of two different greenhouse gases on the outgoing infrared radiation, which is a measure of the relative strength of the associated greenhouse effect.

Begin by pointing your browser to http://forecast.uchicago.edu/Projects/modtran.html. Let's start by clicking and opening the "Gases" window and noting the default values for atmospheric CO_2 and methane (CH_4). Next, click on the "Settings" window and set the "Locality" to "1976 U.S. Standard Atmosphere" using the scroll-down menu. Also, to keep track of your work choose a label for the experiment. Now you are ready to hit "Run". The simulation will take a few seconds. You can now open the window with the label you just specified in order to view the simulated infrared spectrum compared to spectra for blackbodies radiating at different temperatures. The values shown in the upper right are the total amount of outgoing infrared radiation (I_{out}, or the area under the simulated IR spectrum) and the ground temperature in Kelvins. Note that the horizontal axis is given as "wave number" which equates to cycles/cm (number of waves per cm), so shorter wavelengths are to the right. Record the greenhouse gas concentrations specified (in ppm etc.) and the model's outgoing infrared radiation (I_{out}). Now perform a series of experiments in which you add 10 ppm (for the same "Settings") of CO_2 <u>or</u> 10 ppm of methane. Record the change in I_{out} for each case. When doing the methane experiment, remember to return CO_2 to its original value, so that you are only changing one gas at a time. Repeat the experiments, now for additions of 20 ppm for each gas.

Build a table showing the gas concentration vs. the outgoing radiation and the change in outgoing radiation (i.e. the change with respect to the value obtained in the first simulation at default gas concentrations). We might guess that the amount of greenhouse warming will scale directly to the change in outgoing radiation. Using this assumption, how much more "warming" would methane deliver compared to CO_2, for the two cases studied (i.e. what is ratio of the change in I_{out} for methane vs. for that for added CO_2)?

NOTE: You need refresh the model web page after every 5 runs. You will need to reinstate the "gases" and "settings" each time the page is refreshed (otherwise the models default values and parameters will be used).

Now let's check our assumption that the temperature response will scale to the change in outgoing infrared radiation (I_{out}) by performing the same type of model exercise we did in class last week. To do this, use a trial and error method to determine by how much you need to increase the ground temperature ("Ground Temperature Offset" under "Settings") in order to bring the outgoing radiation associated with an additional 20 ppm of CO_2 or methane back up to the value of I_{out} associated with the models default concentrations (i.e. I_{out} for the combination 375 ppm CO_2 and 1.7 ppm methane). What is the temperature change associated with the additional methane compared to that for the additional CO_2 (i.e. what is the ratio of ΔT for added methane vs. that for added CO_2)? Does this square with what we learned in class about the Global Warming Potential of methane vs. CO_2? If so (or not) explain.

This exercise follows the bathtub analogy we used in class. We are asking what the level of the tub has to be in order to get as much water out of the partially blocked drain as we did before. Since CO_2 and methane block the drain to differing degrees, the water level (temperature) adjustment may be different for the two. The difference in warming potential would be the ratio of "warming from methane " vs. "warming from CO_2".

Note that I did not ask you to increase each gas on a percentage basis (i.e. add 10% to the original CO_2 or methane amount, etc.). While that might seem a more even-handed experiment, it is not physically meaningful, since our aim is to evaluate warming potential on a molecule vs. molecule basis.

Part 2 (4 pts): Water vapor feedback

Of course, this simple model does not represent many of the feedbacks we have discussed in class. However, water vapor is represented in a simple way in the model. To quantify the water vapor feedback, try the following experiment. As a "control" case, run the model for pre-industrial levels of CO_2 (280 ppm) and methane (0.7 ppm), using the same type of atmosphere ("Settings") as before. Record the simulated outgoing flux of radiation, I_{out}. Now double the CO_2 concentration only, record the outgoing radiation, and use trial and error to determine the "ground temperature offset" needed to get the outgoing radiation back to its "control" value. Record your answer.

While specifying the "ground temperature offset" you may have noticed a default setting saying "constant vapor pressure". That means that the model held the water vapor content of the atmosphere constant even though you changed the temperature. We learned in class that that isn't likely since the vapor pressure of water goes up quickly with temperature (by about 5%/°C). So, now repeat the trial and error exercise of determining the "ground temperature offset" needed to get the outgoing radiation back to its "control" value, but this time select "constant relative humidity". This lets the water vapor content change with the temperature. What is the temperature adjustment needed to restore the outgoing radiation to its control value now? How much bigger is it than the result for constant vapor pressure? That is the water vapor feedback…. Record you answers.