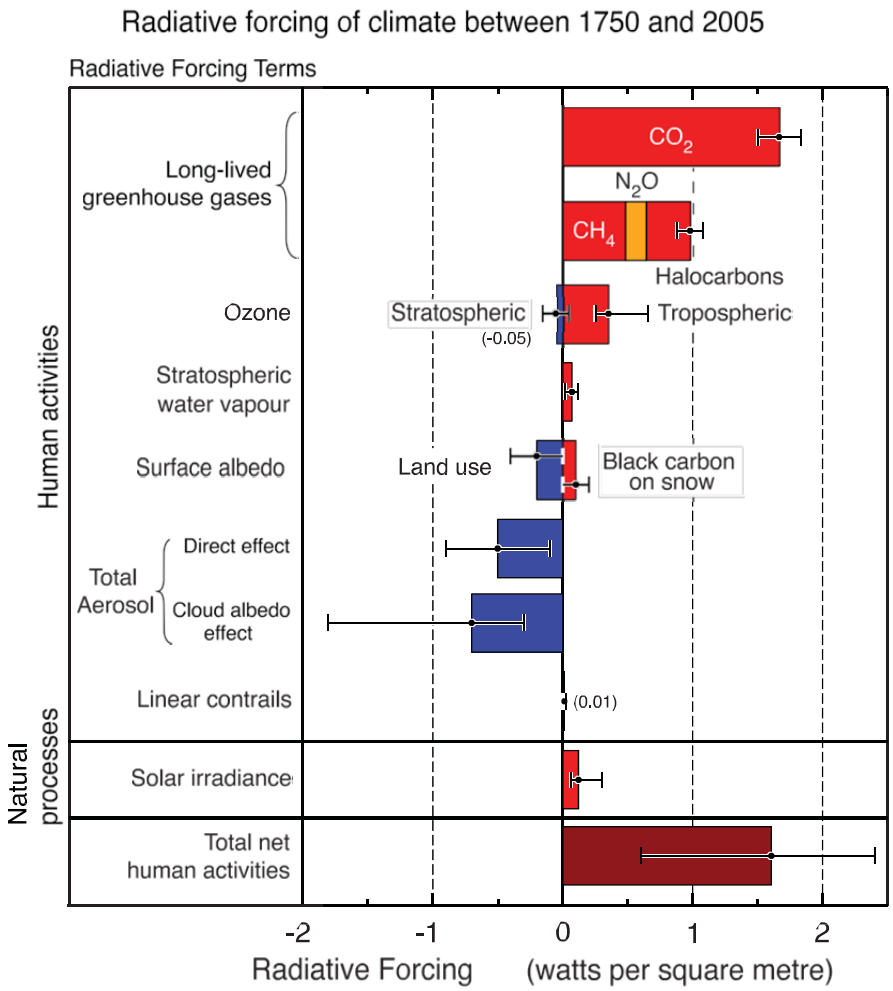
Environmental Science 160 Lab 1: Energy Flow from Sun

One of the big issues when it comes to environmental science is global climate change. There is strong evidence that the earth's temperature is rising and that this is being driven primarily by greenhouse gases released by humans, from the 4th Assessment Report from the International Panel on Climate Change:



FAQ 2.1, Figure 2. *Summary of the principal components of the radiative forcing of climate change. All these radiative forcings result from one or more factors that affect climate and are associated with human activities or natural processes as discussed in the text. The values represent the forcings in 2005 relative to the start of the industrial era (about 1750). Human activities cause significant changes in long-lived gases, ozone, water vapour, surface albedo, aerosols and contrails. The only increase in natural forcing of any significance between 1750 and 2005 occurred in solar irradiance. Positive forcings lead to warming of climate and negative forcings lead to a cooling. The thin black line attached to each coloured bar represents the range of uncertainty for the respective value.*

Measuring the temperature of the earth is a challenging endeavor. In lab today we seek to understand some of the physical mechanisms that drive global climate change, and some of the processes that complicate measuring the temperature of the earth's troposphere at any given time.

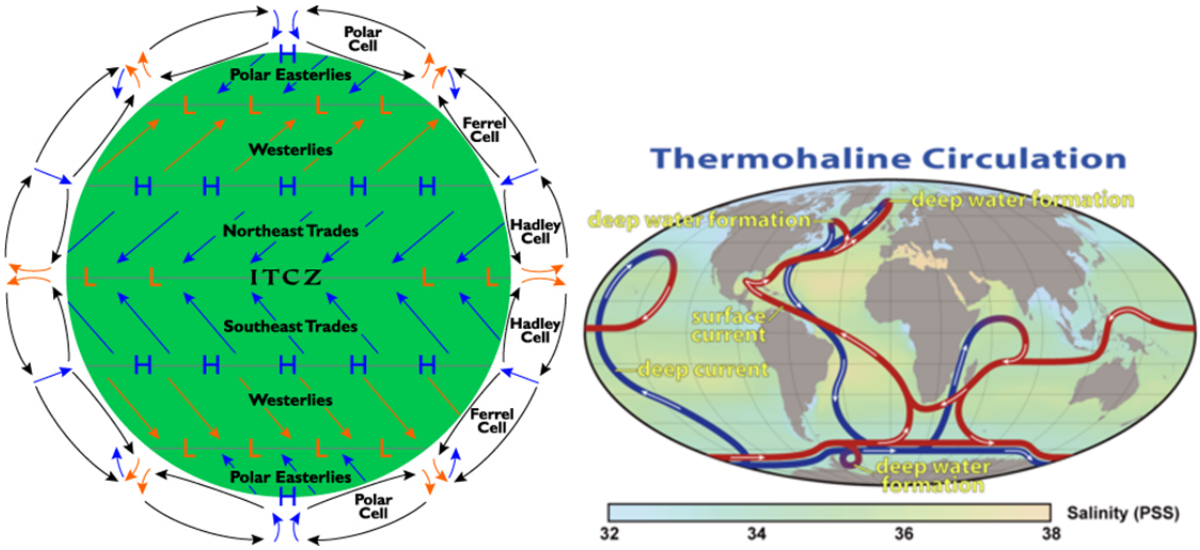
Greenhouse effect

The greenhouse effect refers to the trapping of heat because of the ability of air to trap heat. Energy from different parts of sun light is absorbed at different layers of the atmosphere and by the ground. As a simplified model you will use a lamp to stand in for the sun and a dark piece of wood to stand in for the ground. You will then monitor the rise in temperature during the day (light on) and the fall in temperature at night (light off) under various circumstances

1. No greenhouse: place the lamp 10cm away from the stand mounted thermometer taped to a piece of darkened wood. Press the arrow button on the LabQuest device to start recording temperature and then turn on the lamp. Record the temperature for 10 minutes (600s) with the light on (simulated daytime). You will need to tell the device to continue recording several times (about every 200s), be sure to tell the device to append the new data to the graph. At the end of the 10 minutes of simulated daytime shut off the lamp and continue to record for 10 minutes of simulated nighttime. **Sketch the graph, describe the shape of the graph, and explain why it is the way it is.**
2. Greenhouse filled with air: keep the lamp 10cm away from the stand mounted thermometer taped to the darkened wood. Cover the wood and thermometer with a 500ml inverted Erlenmeyer flask and seal the bottom as best you can with parafilm (once you know how to use it). Use the stylus to tap the file cabinet on the right side of the LabQuest device to save the data run you competed in step one. Tap RUN 2 and select ALL RUNS to show your first data set while you collect your second data set. Start recording run 2, turn on the lamp and record 10 minutes of simulated daytime and then shut off the light and record 10 minutes of simulated nighttime. **Sketch the new graph on top of your first sketch and compare the graph you just collected for the situation with the greenhouse to the previous graph for the situation without a greenhouse. The glass performs two tasks, blocking infrared light, and blocking convection currents. What part of the atmosphere has convection currents due to ground heating and where do they stop?**
3. Greenhouse filled with methane: Carbon dioxide is a potent greenhouse gas, but methane (CH_4) is even stronger (~20x to 70x as strong depending on how you measure it). **You will displace the air in the flask with methane, but to do so you must orient the flask so the methane is trapped. To do this you must calculate the density of methane at STP and compare it to the value we found for air.** Once you have figured out which way to have the flask insert the thermometer, wood, and the rubber tube connected to the gas faucet. Slowly turn on the faucet and purge the air from the flask (~10-15s should do it). Once you have finished remove the tube and seal the flask again with parafilm (should be reusable from before). Make sure the lamp is still 10cm from the thermometer, save RUN 2, show ALL RUNS, then collect 10min of simulated daytime immediately followed by 10min of simulated nighttime. **Sketch this final graph on top of the first two and discuss how the temperature of the wood compares to what you found for the first two situations. Are the differences bigger or smaller than you expected? Given what you know about the relative strengths of carbon dioxide vs methane what would you expect a graph from an experiment with carbon dioxide in the flask to look like? The concentration of carbon dioxide and methane in the atmosphere is much lower than the concentration you tested. What are some key ways in which the atmosphere differs from your experiment?** Once you have finished with your methane, burn it off. I will show you how. But before you do so tell me what the methane turns into when it burns. Do you see any evidence for it?

Convection Cells:

Convection plays an important role in transporting energy around the globe, on the largest scales in convection cells in the atmosphere, and when paired with varying salt concentrations manifest themselves in the form of thermohaline circulation in the oceans.



(from http://minerva.union.edu/failinge/pics/Trade_Winds_fig01.jpg and http://en.wikipedia.org/wiki/Thermohaline_circulation)

The example we will look at today is in water but the same sorts of behavior could be seen in the air with care.

Find one of the aquariums sitting atop two hot plates. You will heat with the right hot plate only, the one on the left is there strictly for support. Turn the hot plate on setting 1. After the plate has been heating for a couple minutes look through the water in the tank over the hot plate, you should see distortions in the water. This is caused by the lower density of the warmed water. Drop one drop of food coloring directly over the center of the cold plate. **Watch what happens for a couple of minutes and describe what you see.** You should do this several times (i.e., take replicates) to get a sense of how reproducible what you saw was**. Comment on how reproducible the behavior was.** Use the thermometer to measure the temperature of the water at several locations. **What is the temperature of the water? Why is this not a simple question to answer/what must you consider in estimating a single number for the temperature of the water in the tank?**

Now turn the right hot plate up to 2 and wait a minute (*Important, if the element starts to glow red, or the tank starts to smoke, turn the hotplate down immediately*). Drop another drop of food coloring over the cold plate. **Watch what happens for a couple of minutes and describe how what you see at setting 2 differs from setting 1.** Again measure the temperature of the water at several locations. **What is the temperature at setting 2? How do these results relate to global climate change?**