EOSC 112: Lecture Summary: Wednesday, September 19

Text Coverage: Earth's Global Energy budget. pp. 49 - 50, plus feedback loops/Daisy World pp. 19-25.

Review: Last lecture we covered the vertical distribution of pressure and temperature in the atmosphere (current climate). Important points: 1) the *stratosphere* consists of heavy air under light air (i.e. it's stably stratified). Very little vertical mixing. This increasing temperature profile is due to ozone heating. 2) Underneath the stratosphere is the *troposphere*, where we live. It is continually stirred by convection due to surface heating. 3) The temperature decreases with height in the troposphere because internal energy (heat) is turned into potential energy as air rises from the surface. 4) The pressure decreases with height in the entire atmosphere because pressure is a measure of the mass of air above a particular level. 5) Much of the energy transport from the surface of the planet actually occurs by vertical convection of water vapor (*latent heat*). 6) It takes 2.5 Million Joules of energy to turn one kg of liquid water into vapor. 7) Condensing that vapor back into clouds releases that energy back into the atmosphere, causes thunderstorms, tornadoes, hurricanes, and in fact all weather.

Earth's Global Energy Budget: Figure 3-19 summarizes the energy flow between radiation, thermal convection and evaporation. Note the notation – the earth receives 100 "units" (really 240 $\mathrm{W\,m^{-2}}$) in the shortwave, and then spreads it around and recycles it in the longwave and as thermals (*sensible heat*) and evaporation. Some important points:

- Note that the atmosphere and ocean absorb 70 units (45 + 25) but shed (via thermals, evaporation and radiation) twice that (5 + 24 + 104 = 133). This is because 88 units are sent back down to the surface via the greenhouse effect.
- If the planet was dry, then the temperature would be much higher, because we couldn't shed 24 units as evaporation and would have to shed them as thermals.
- There is currently a very intense debate about the correct value of the atmospheric absorption, which may be as much as 20% higher than the 25 units shown in Figure 3.19. It is important to figure out what the right value is, because it is the energy difference between the surface and the atmosphere that drives the planetary winds.

New topic: Feedback – Chapter 2

- Why does the one layer model give such a small temperature increase for a 4 $\mathrm{W\,m^{-2}}$ increase in surface heating?
- More complicated models are in general agreement that the temperature increase will be at least 3 °C. Click here to see a summary of this.
- What's missing is the idea of *feedback*, i.e. there's no connection between the surface temperature T_{sfc} and the absorption. There actually is a strong feedback, since the higher the temperature of the ocean, the more water vapor is released, and the more water vapor in the atmosphere, the more absorption. (see Figure 4-23, p. 75).

- A system that is not changing with time is said to be in an *equilibrium state*. If this state is created by a negative feedback loop, then the the equilibrium is *stable*. If the state is created by a positive feedback loop, then the equilibrium is *unstable* (see p. 22)
- A system can be moved from an equilibrium state by a *perturbation* (short time scale) or *forcing* (long time scale). Examples: a volcanic eruption is a perturbation, industrial pollution is a forcing.
- Jimmy and Rosylyn and their blanket provide an example of an unstable equilibrium with positive feedback (Figure 2-2).
- Why doesn't the positive water vapor feedback runaway and evaporate all water on Earth? Clouds form from the vapor and act as shade umbrellas, while removing vapor as rain and sending it back to the surface.

Daisyworld:

- Daisyworld (p. 26) provides a good example of negative and positive feedbacks.
- Two characteristic curves (Fig 2-10):
  - Daisy coverage as a function of temperature – Daisies don't like it too cold or too hot.
  - T_{sfc} as a function of daisies – the more daisies, the higher the albedo, and the lower the surface temperature.
- The result is one stable, and one unstable equilibrium (Figure 2-11).
- Figure 2-11 shows the response to one type of forcing – removal of daisies. Figure 2-13 shows the response to another type of forcing – an increase in the solar constant.
- Many climate modeling studies report the *feedback factor* for various processes, given by:

$$f = \frac{\text{temperature change with feedback}}{\text{temperature change without feedback}} = \frac{\Delta T_{eq}}{\Delta T_0} \tag{1}$$

- In the lab this week you found ΔT_0 for a 4 $\mathrm{W\,m^{-2}}$ radiative forcing with no feedbacks, As explained on p. 51, most models give $\Delta T_0 \approx 1.2$ °C for a 4 $\mathrm{W\,m^{-2}}$ radiative forcing. When feedbacks are turned on, these same models give $\Delta T_{eq} \approx 3 - 5$ °C, so f for these models is about 3-5.