Spectrum of Atmospheric Radiation

2023-01-23

Contents

Notice:

If you have a laptop or tablet that you can bring to class and connect to the internet, I recommend you do so today so you can work along with me in using the MODTRAN model.

Reading:

Required Reading (everyone):

- Understanding the Forecast, Ch. 4, pp. 34-40.

Reading Notes:

Band saturation

You only need to understand **band saturation** qualitatively (i.e., you don't need to worry about equations 4.1–4.3).

This is important for understanding why some greenhouse gases are more powerful than others

- What is **band saturation**?
- Why does increasing CO_2 from 10 to 100 parts per million or from 100 to 1000 parts per million have much less effect than increasing it from 0 to 10 parts per million?

Think by analogy. Suppose you smear a tablespoon of black ink all over a white piece of paper. How much will that affect its brightness? Now suppose you smear four more tablespoons of ink on the stained paper. Which has the bigger effect on the whiteness of the paper: the first spill of ink, or the second (much bigger) one?

Now, looking at the atmosphere with the current amount of greenhouse gases, can you speculate why adding a million molecules of methane to the atmosphere will produce 20 times more warming than adding a million molecules of CO_2?

Examine figure 4-5 closely. What does it show you about the saturation of absorption by carbon dioxide? How does this figure relate to Figure 4-6?

Greenhouse Gases in the Atmosphere

A crucial piece of this chapter is understanding why adding more greenhouse gases makes the Earth warmer. Figure 4-8 shows this.

- If we add greenhouse gases, they absorb outgoing longwave radiation.
- When greenhouse gases absorb outgoing radiation, that means less radiation is going out to space, so $F_{\text{out}} < F_{\text{in}}$.
- What happens to the temperature of the earth and its atmosphere when $F_{\text{out}} < F_{\text{in}}$?
- What happens to outgoing radiation when the earth and its atmosphere heat when the temperature rises?
- Eventually, the temperature rises enough that $F_{\text{out}} = F_{\text{in}}$ with the higher concentrations of greenhouse gases.
- This temperature change is **global warming** due to adding greenhouse gases.

You should understand **climate sensitivity**: Every time you double the amount of CO_2 in the atmosphere, the temperature rises by the **climate sensitivity**.

Important: I don't ask you to memorize many numbers but I want you to know by heart that the earth's climate sensitivity is roughly 3.0°C and that the concentration of CO_2 in the atmosphere today is a bit more than 400 parts per million (as of January 2023, it's 419 ppm, but you don't need to memorize that detail).

Review Questions

Think about these questions to check whether you understand the important points in this chapter. You do not have to write them up and turn them in.

- What makes some greenhouse gases more powerful than others?
- How does band saturation work? How can you recognize saturation in spectra like Fig. 4-5?
- Look at Fig. 4-6. What does band saturation have to do with the shapes of the curves showing the relationship between temperature and CO_2 concentration? Why are they curved instead of straight lines?

Go to https://climatemodels.jgilligan.org/modtran/ or http://climatemodels.uchicago.edu/modtran/ and play with the MODTRAN computer model, which calculates the outgoing radiation from the top of the atmosphere for different concentrations of greenhouse gases.

For now, leave all of the settings at their default values and try changing the "CO_2 (ppm)" value and observing what happens to the outgoing longwave radiation ("Upward IR Heat Flux", near the bottom left). The default value of CO_2 is 400 ppm (parts per million). What happens to the outgoing heat flux if you cut this in half or double it?

I will explain this model in a lot more detail in class on 2.