Greenhouse Gases

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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.

Reading Notes:

Undergraduates need only understand band saturation qualitatively (i.e., you don't need to worry about equations 4.1–4.3). Graduate students do need to know and be able to apply these equations.

You should understand why molecules with many atoms are more powerful greenhouse gases than molecules with fewer atoms. Can a single atom (e.g., noble gases such as helium) act as greenhouse gases? What about nitrogen (N_2) and oxygen (O_2) molecules, which make up almost 99% of the atmosphere?

What is the "atmospheric window," that spans the range of about 800–1250 cycles/cm (wavelengths of 8–12 μm)?

Understanding emissions spectra seen by satellites

This is important: The key to this section is understanding diagrams, such as Fig. 4.3 and 4.5. These diagrams show the brightness of infrared light emitted at different frequencies. The smooth lines correspond to the radiation a perfect blackbody would give off at different temperatures. Hotter bodies give off more energy and cooler bodies give off less.

The jagged line is the actual radiation given off by the atmosphere, as seen by a satellite in space. Because the atmosphere is cooler higher up, emissions that follow a cooler blackbody curve for some part of the spectrum mean the infrared at those wavenumbers is emitted by greenhouse gases higher in the atmosphere. Brighter emissions that follow a hotter blackbody curve for some part of the spectrum means hotter temperatures, and hence emission at those wavenumbers comes from gases closer to the ground.

As you add more of a gas, it absorbs more infrared light, so the emissions from the ground or from lower in the atmosphere can't get through—they're absorbed by higher layers of the atmosphere—and thus, the only emissions that get out to space come from higher (and thus colder) layers. This is why you see lower emissions (colder temperatures) for the wavenumbers at which powerful greenhouse gases, such as CO_2 and ozone, absorb.

Here are some review questions to check whether you understand this material well:

- Water vapor is a powerful greenhouse gas. Why do you suppose we don't see extremely cold temperatures for the part of the spectrum (100–600 cycles/cm) where *it* absorbs?
- If greenhouse gases make earth warmer, why does adding CO_2 in make the emissions temperatures become smaller in Fig. 4-5?

Band saturation

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?