Radiative efficiency of trace gases

February 8, 2014

Problem 0.1 *Radiative efficiency of trace gases*

There are a number of gases which are present in the atmosphere in only extremely small amounts (often at the level of a few parts per trillion), but which nonetheless have radiative forcing which is not completely negligible. These are sometimes called *trace greenhouse gases*. Because these gases have such low concentrations, they generally act in the weak absorption limit, so that the OLR reduction (radiative forcing) is linear in concentration. Because the line centers are not saturated, the radiative forcing per unit concentration (or molecule) added is very large, though the net radiative forcing itself is quite small. The radiative forcing (OLR reduction) per unit of gas is called the *radiative efficiency*. It is usually measured in $W/m^2/ppb$

In this problem, you will use HITRAN data to compute the radiative efficiency of sulfur hexafluoride (SF_6). This molecule has hundreds of thousands of lines in the infrared, taking a half gigabyte to list, but most of these lines are too weak to be significant at the ppt concentrations in which the gas is present. The data file `30_hit08.par` is a *subset* of the full HITRAN database, but still contains some tens of thousands of closely spaced lines. Note that the line data for this molecule is very incomplete, e.g. all the line widths in the current version seem to be set to the same value; the lower state energy is also poorly known, making it hard to compute the temperature dependence.

Download this file and edit the data path on Pytran so that it will be able to find it. You may also need to add the line

```
molecules['SF6'] = [30,146.,QGenericNonLin]
```

to the other molecule name definitions in Pytran, so that the molecular weight and molecule index number is known. Given that the filename is a bit different, you will also need to edit the lines

```
if molNum < 10:
    file = hitranPath+'0%d_hit04.par'%molNum
else:
    file = hitranPath+'%d_hit04.par'%molNum
```

to replace 04 with 08.

Once you have done that, make some plots of the absorption cross section and have a look at where SF_6 absorbs strongly. Make sure to zoom in and have a look at the fine structure of the absorption features, which consist of a large number of closely-spaced overlapping lines. Next plot the transmission function for a mass path corresponding to a concentration of 10 ppt, and show that at this concentration, SF_6 is in the weak-line limit.

Finally, use this data, together with the weak line approximation, to compute the radiative efficiency of SF_6, assuming the temperature profile is the dry adiabat. Look up the IPCC value and compare with your result. Your result should be somewhat larger than the IPCC value, because of the use of the dry adiabat instead of the actual atmosheric temperature profile.