Exercises

A. In the blackbody model, how much would the Earth’s surface temperature change if the surface albedo was 0.4 instead of 0.31?

B. What is the relative GWP (Global Warming Potential) of CO₂?

C. Explain what causes the annual rise and fall of [CO₂] shown in Figure 22.3 of the 2nd and 3rd editions of the textbook?

D. How many kg of CO₂ does a person’s driving produce in one year, if they drive 12,000 miles/year at 25 miles/gallon. Treat gasoline as C₈H₁₈ with ρ = 0.7 g/ml.

E. List two feedback mechanisms related to CO₂ concentration.

F. What is the mechanism by which some particles exert a direct negative radiative forcing? What is the mechanism by which some particles exert a direct positive radiative forcing? What is the mechanism by which particles may exert an indirect radiative forcing?

G. Consider the statement “The climate in Syracuse today is warm for this time of year.” From your reading of Section 1.2 of the text, explain what is wrong with the statement.

H. Consider Species A absorbs at λ₁ in the IR with a cross-section of 1 × 10⁻¹⁹ cm²/molecule. Species B absorbs at λ₁ with a cross-section of 4 × 10⁻¹⁸ cm²/molecule. Compute the %Transmittance (aka %T) and %Absorbed (%A = 100-%T) at λ₁ for a path-length of 10 km for the following conditions:
   a) an atmosphere with only species A, and [A] = 2.5 × 10¹³ molecules/cm³
   b) an atmosphere with [A] = 2.5 × 10¹³ molecules/cm³ and [B] = 2.5 × 10¹¹ molecules/cm³

I. On the graph on the next page:
   i) what is the instantaneous radiative forcing of compound Y at t=10 years (the first data point)
   ii) what is the AGWP of compound Y for a time horizon of 10 years? (in W years m⁻² kg⁻¹)

J. In the handout I gave you on energy balances, what energy flux of IR emitted from the Earth’s surface passes the atmosphere to escape into space?

Problems

1. The figure on the next page shows the instantaneous radiative forcing (IRF) for substances X and Y. The units of IRF are W m⁻² kg⁻¹.
   A) Calculate (approximately) the GWP of X relative to Y for a time horizon of 200 years.
   B) Estimate the time at which the relative GWP of X equals 1.0 (relative to Y)

   HINT: Start by calculating the lifetime, τ, of each species from the data in the graph and the equation \( \ln([X]_t/[X]_0) = -t/\tau_X \) and then using the equations for AGWP and relative GWP. Use the calculus formula employed in lecture. Alternatively, you can get the AGWP of X and Y by adding up the areas of a bunch of polygons to get the area under each curve.
2. Does the GWP of CFC-115 increase or decrease with increasing time horizon? Why?

Type of Answers: Quantitative reasoning.

3. Given the molecules and results from Exercise H, and:
Species B also absorbs at $\lambda_2$ in the IR with a cross-section of $1 \times 10^{-18}$ cm$^2$/molecule

Question: Does this addition of species B to an atmosphere already containing A have a greater effect on the amount of energy of the Earth’s IR emission by the atmosphere at $\lambda_1$ or at $\lambda_2$?

(Assume the emission power, $I_0$, from the Earth’s surface is the same at $\lambda_1$ and $\lambda_2$, and that these are the only absorbers one need account for.)

Prompt a) Which quantity in Exercise H is proportional to the radiative forcing of these compounds at $\lambda_1$ and $\lambda_2$: Absorbance, %T, or %A?

Prompt b) What is the baseline at $\lambda_1$ to determine the effect of adding compound A? At $\lambda_2$?

Type of Answer: Calculation. Note: this is really a question about window regions!

4. Use the data in the file HW09.xls (from the Homework web page) to determine the total concentration of particles, the total particle surface area concentration (in $\mu$m$^2$/cm$^3$ air), the total particle volume concentration (in $\mu$m$^3$/cm$^3$ air), and the distribution $n_s^p(\ln D_p)$. Email me your spreadsheet.