EBM3 Project 3, 4 Dec 2023

Begin with $EBM3_{HF}$ with HF = 0.287Q.

Problem 1.

a. Calculate the temperatures if the tropospheric (level 2) *solar* albedo (reflectivity), ρ_2, increases by steps of 0.002 from 0.245 to 0.265. While doing so, reduce the *solar* absorptivity, α_2, by the same amount.

What is the effect on surface temperature of increasing the solar reflectivity of the troposphere (show a plot of surface temperature vs. ρ_2)?
What physical changes in the real atmosphere could this represent?
What is the rate of surface temperature change relative to a change in ρ_2 over this range (i.e. total surface temperature change for total $\Delta\rho_2$ of 0.020)?

b. Repeat part (a) but rather than the tropospheric layer, increase the stratospheric reflectivity (ρ_1) by increments of 0.002 from 0.038 to 0.058. Reduce solar transmission in layer 1 (τ_1) by the same amount.

What is the effect on surface temperature of increasing the solar reflectivity of the stratosphere (show a plot of surface temperature vs. ρ_1)?
What physical changes in the real atmosphere could this represent?
What is the rate of surface temperature change relative to a change in ρ_1 over this range?

Problem 2.

It has been proposed that to mitigate the theorized extra warming in the troposphere/surface from increases in greenhouse gases, that reflective aerosols should be added to the stratosphere to reflect incoming sunlight.

(a) simulate the extra warming of the enhanced greenhouse effect by increasing the tropospheric thermal absorptivity, a_2, (similar to problem 3 of Homework 2) that would *increase* the *surface* temperature by 2.0 K over what is the base case of $EBM3_{HF}$. In other words, increase a_2 while decreasing t_2 until the surface temperature is warmer by 2.0 K. What are the new a_2 and t_2?

(b) With these coefficients set (i.e. the a_2 and t_2 that create 2.0 K more surface warming), by trial and error find the increase in ρ_1 (stratospheric solar reflectivity while reducing τ_1) that would reduce the *surface* temperature back to the original value from $EBM3_{HF}$.

How much does the stratospheric albedo need to change to compensate for a 2.0 K increase in the surface? What is the relationship between changes in surface temperature and ρ_1, i.e. what is $\Delta T_3/\Delta\rho_1$?

Problem 3

Low and middle clouds, in general, increase the reflectivity of the Earth and thus cool the planet. Using the results from the 2(a) above in which the surface temperature is warmer by 2.0 K vs. that of $EBM3_{HF}$, allow the value of ρ_2 to *increase* (reducing τ_2) and reduce the surface temperature back to the original value from $EBM3_{HF}$. [Note: this is different that problem 2(b) which dealt with changes in ρ_1]. How much must ρ_2 increase? What is the relationship between changes in surface temperature and ρ_2, i.e. what is $\Delta T_3/\Delta\rho_2$?

Problem 4

Satellite measurements indicate that, in general, when humans develop the surface of the earth the *solar* reflectivity of the surface increases, i.e. ρ_3 increases and thus α_3 decreases. Using the results from the 2(a) above in which the surface temperature is warmer by 2.0 K vs. that of $EBM3_{HF}$, allow the value of ρ_3 to increase and reduce the surface temperature back to the original value from $EBM3_{HF}$. How much does ρ_3 increase? What is the relationship between changes in surface temperature and ρ_3, i.e. what is $\Delta T_3/\Delta\rho_3$?

To which layer's reflectivity is the surface temperature (T_3) most sensitive, i.e. which layer's reflectivity changes the least to produce the same change in temperature, ρ_1 (#2(b)), ρ_2, (#3) or ρ_3 (#4)?