PS7.1: Harte II.13.1

Verify that Eq. 5 yields the result: T_0 = 255 K.

$$\left[\frac{(1-\alpha)\Omega}{4\sigma}\right]^{\frac{1}{4}} = \left[\frac{(1-0.3)\left(1372\,\frac{W}{m^2}\right)}{4\left(5.67\cdot 10^{-8}\,\frac{W}{m^2K^4}\right)}\right]^{\frac{1}{4}} = 255\,K$$

PS7.1: Harte II.13.2

- Blackbody temperature of 98 K assumes solar in = infrared out = $\sigma T^4 = \sigma(98)^4$
- Measured infrared out = $\sigma T^4 = \sigma(130)^4$
- Difference between measured infrared out and solar is due to internal energy of Jupiter:

$$\left[5.67\cdot 10^{-8}\,\frac{W}{m^2K^4}\right]\left[(130\,K)^4-(98\,K)^4\right] = 11\frac{W}{m^2}$$

- Earth: $$\frac{(20\text{ to }40)\cdot 10^{12}\ W}{5.1\cdot 10^{14}\ m^2} = 0.04\text{ to }0.08\ \frac{W}{m^2}$$

PS7.1: Harte II.13.3

- A 1 K increase in T_0 would require Ω of:

$$T_0 = \left[\frac{(1-\alpha)\Omega}{4\sigma}\right]^{\frac{1}{4}} = \left[\frac{0.7(1370)}{4\left(5.67\cdot 10^{-8}\right)}\right]^{\frac{1}{4}} = 255.0\,K$$

$$\Omega' = \frac{4\sigma\left(T_0+1\right)^4}{1-\alpha} = 1391.6\,\frac{W}{m^2}$$

- The Earth would have to get closer to the Sun to increase solar flux from 1370 to 1392 W/m2.

PS7.1: Harte II.13.3

- Ω is the power of Sun, P, divided by area of sphere with radius equal to Earth-Sun distance, R (1.49 x 10^{11} m):

$$\Omega = \frac{P}{4\pi R^2}$$

$$P = 4\pi R^2\Omega = 4\pi\left(1.49\cdot 10^{11}\ m\right)^2\left(1370\,\frac{W}{m^2}\right) = 3.82\cdot 10^{26}\ W$$

$$R' = \sqrt{\frac{P}{4\pi\Omega}} = \sqrt{\frac{3.82\cdot 10^{26}\ W}{4\pi\left(1391.6\,\frac{W}{m^2}\right)}} = 1.478\cdot 10^{11}\ m$$

A decrease of 1.2 million km, or 0.8 percent

PS7.1: Harte II.13.4

- The power of the Sun, P, was computed above as 3.82 x 10^{26} W; this is radiated to space by thermal radiation over the Sun's surface area at temperature T_S:

$$P = \left(4\pi R_s^2\right)\sigma T_s^4 \qquad T_s = \left[\frac{P}{4\pi R_s^2 \sigma}\right]^{\frac{1}{4}}$$

$$T_s = \left[\frac{3.82 \cdot 10^{26}\ \text{W}}{4\pi\left(6.96\cdot 10^{8}\ \text{m}\right)^2\left(5.67\cdot 10^{-8}\ \frac{\text{W}}{\text{m}^2\text{K}^4}\right)}\right]^{\frac{1}{4}} = 5768\ \text{K}$$

PS7.2: Two-Box Model

$$T_s = \left(\frac{2}{(2-\varepsilon)}\frac{(1-\alpha)\Omega}{4\sigma}\right)^{1/4}$$

Ω	α	ε	T_s	ΔT_s
1370	0.30	0.75	286.8	
1374	0.30	0.75	287.0	0.2
1370	0.29	0.75	287.8	1.0
1370	0.30	0.77	288.0	1.2

PS7.3: Radiative Forcing

A. The solar forcing today is:

$$\frac{(1-\alpha)\Omega}{4} = \frac{(1-0.3)}{4}\left(1370\frac{\text{W}}{\text{m}^2}\right) = 239.7\frac{\text{W}}{\text{m}^2}$$

$$\approx 240\frac{\text{W}}{\text{m}^2}$$

0.1% increase = (0.001)(240) = +0.24 W/m^2

PS7.3: Radiative Forcing

B. A change in albedo from 0.3 to 0.31:

$$\frac{(1-\alpha)\Omega}{4} = \frac{(1-0.31)}{4}\left(1370\frac{\text{W}}{\text{m}^2}\right) = 236.3\frac{\text{W}}{\text{m}^2}$$

$$236.3 - 239.7 = -3.4\ \text{W}/\text{m}^2$$

C. A doubling is a doubling, regardless of the initial concentration. Going from 275 to 550 ppmv is 3.7 W/m^2; going from 550 to 1100 ppmv adds another 3.7 W/m^2, for a total of 7.4 W/m^2.