

AOS/IES 171 Spring 2008 Prof. Hitchman
Quantitative Assignment #2 10 points Due Tuesday, March 11

Be sure to show your work, put your name on each page, and staple together.

1. (1 pt) The radiative equilibrium temperature of a planet is governed by the equation Energy In = Energy Out: $\sigma T^4 = \frac{(1-A)S}{4}$, where A is the albedo, S is the solar constant at its distance from the sun, and $\sigma = 5.7 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$.
 - a) Calculate the radiative equilibrium temperature, T, for the earth using A=0.3 and S=1370 W/m².
 - b) Based on our discussion in class, from about what altitude in the earth's atmosphere is infrared being emitted to space at the temperature you found in a)?
2. (1 pt) a) During the first billion years of the earth's history the solar output was only about 75% of its modern value. Estimate T, keeping A=0.3, for this ancient situation.
 - b) A large volcanic eruption or large continental glacier could increase the earth's albedo. Estimate T for A=0.4, keeping S=1370 W/m².
3. (2 pts) If the earth's orbit were at a different distance from the sun (r') instead of the present value (r), we can estimate the solar intensity at the new distance (S') from $\frac{S'}{S} = \left(\frac{r}{r'}\right)^2$, where S=1370 W/m² and r = 150 x 10⁶ km. How many kilometers *farther* from the sun (r'-r) would the earth's orbit have to be for T to be 15 K colder than at present?
4. (1 pt) If the average surface temperature of the earth is 288 K and the radiative equilibrium temperature of the earth is 255 K, estimate the intensity of radiation emitted from the earth's surface and from the earth to space in W/m².
5. (2 pts) We can include the extra emission of infrared by the atmosphere down to the surface $\epsilon \sigma T_a^4$, where T_a is the atmospheric temperature, and ϵ is the atmospheric emissivity by adding this on the right hand side: $\sigma T_s^4 = \frac{(1-A)S}{4} + \epsilon \sigma T_a^4$, where T_s is the surface temperature.
 - a) For A=0.3, S=1370 W/m², $\epsilon=0.63$, and T_a=255 K, estimate T_s.
 - b) Anthropogenic trace gas increases are leading to an increase in atmospheric absorptivity (equal to its emissivity) in the infrared. Estimate T_s for a future atmosphere with $\epsilon=0.77$.
6. (1 pt) If all of the radiation absorbed by the planet went into evaporating water, how much water could be evaporated in one day from a typical square meter of ocean surface. [1 day $\approx 10^5$ s; it takes 2.5 x 10⁶ J to evaporate 1 kg of water; water density is 1000 kg/m³].
7. (2 pts) Using Wien's Law estimate the wavelength of maximum emission from the surfaces of a) Mars, b) Earth, c) Venus, d) your skin. You will need to use K and microns.