CLASS EXERCISE: GLOBAL ENERGY BALANCE

1. EARTH

$$\bar{I} = \frac{1}{4}(1 - \bar{\alpha})S$$

With S = 1360 W-m^{-2} and α = 0.305, I = 236 W-m^{-2}. This is slightly different from the value on the class slide (238 W-m^{-2}), which used α = 0.30.

$$\bar{I} = \sigma\left(\bar{T}_{RAD}\right)^4$$

Using the "perfect black-body" emission relationship, we can compute an effective radiative temperature for the planet. Recognizing that σ = 5.67 x 10^{-8} W-deg^4-m^{-2}, where T is in Kelvins, and using I = 238 W-m^{-2}, we get

$T_{RAD} = (I/\sigma)^{1/4} = (238/5.67 \times 10^{-8})^{1/4} = 254$ K

The average surface temperature of the earth = $T_s \approx 288$ K $\neq T_{RAD}$, indicating the greenhouse effect.

2. OTHER PLANETS

S varies with distance from the sun. In particular, S $\propto$ (distance)$^{-2}$. We can use the sun-earth distance as 1 unit, often called 1 Astronomical Unit (A.U.).

(a) Venus

S(Venus)/S(Earth) = (distance to Earth)^2/(distance to Venus)^2 = (1)^2/(0.72)^2 = 1.93

Thus, for Venus, S = 2623 W-m^{-2} and α = 0.76, I = 157 W-m^{-2} and T_{RAD} = 230 K.

The average surface temperature of the Venus = $T_s \approx 755$ K ($\approx$ 900 F!) $\neq T_{RAD}$, indicating the greenhouse effect.

Note: T_{RAD} for Venus is colder than for Earth. Also, the outgoing radiation I is smaller for Venus than for Earth. Because of the balance, this means that Venus is absorbing

less solar energy than the Earth, even though its surface is hotter, indicating that the greenhouse effect is stronger for Venus.

(b) Mars

S(Mars)/S(Earth) = (distance to Earth)^2/(distance to Mars)^2 = $(1)^2/(1.52)^2$ = 0.43

Thus, for Mars, S = 589 W-m^{-2} and α = 0.16, I = 124 W-m^{-2} and T_{RAD} = 216 K.

The average surface temperature of the Mars = $T_s \approx$ 216 K (≈ - 71 F!) ≈ T_{RAD} , indicating that there is virtually no greenhouse effect.