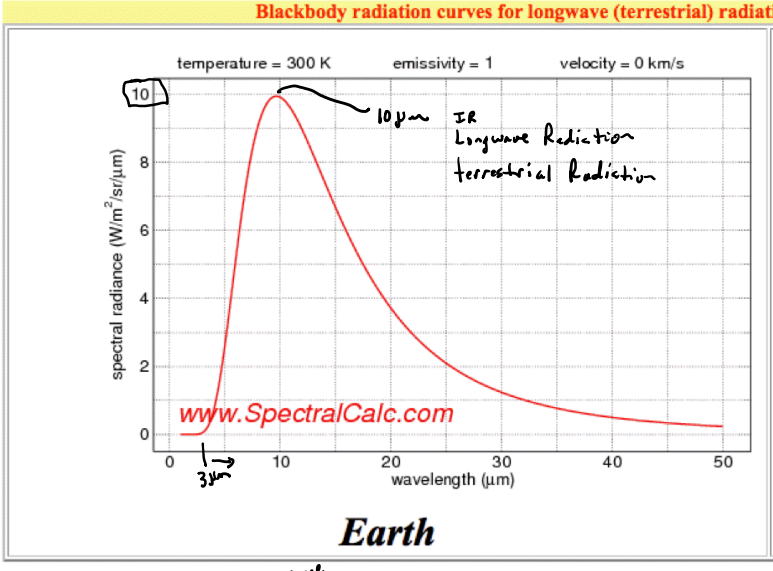
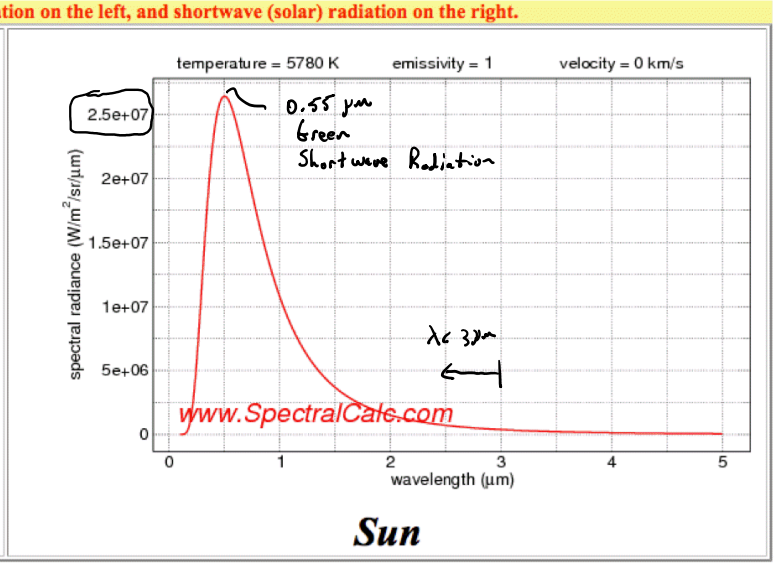
Earth Astronomical Radiation Balance

Friday, November 5, 2021 7:54 AM

Blackbody radiation curves for longwave (terrestrial) radiation on the left, and shortwave (solar) radiation on the right.



Earth



Sun

incoming I_0 = Irradiance Albedo outgoing I

Clouds

$$A = \frac{I}{I_0} = \frac{\text{reflected radiation}}{\text{incident radiation}} = \text{reflection coefficient}$$

$$\frac{\text{R radius}^2}{\text{Sun-Earth distance}^2}$$

Surface	Albedo	
Ocean	0.04	Normal incidence
Desert Region	0.3-0.5	
Fresh Snow	0.95	550 nm.
Glacier or old Snow	0.3-0.6	550nm
Clouds Marine Stratus	0.9	550nm

Astronomical Radiation mon balance -

Solar I Watts/m² Radiation $I = 1368 \frac{\text{watts}}{m^2}$ incoming irradiance

IR out to space

IR E

"In Forced Greenhouse Effect" $T_s \sim 285$ K

P_s = Solar Power Absorbed = Watts = P_e IR outgoing Power

$$\pi R^2 I(1-A) = 4\pi R^2 \sigma T_e^4$$

A: Absorptivity σ: Stefan Boltzman constant $\sigma = 5.67 \times 10^{-8} \frac{W}{m^2 \cdot K^4}$

$$T_e = \left[\frac{I}{4}\frac{(1-A)}{\sigma}\right]^{1/4}$$

$A = 0.3$

$T_e = 255$ K

Problem 4.21

Climate Change.

A) $I(r_{se})$ variability of Solar Radiation.

sun r earth $r \sim 3.5\%$ Variability

Let I_0 = average solar irradiance

r_0 = avg. sun-earth distance.

B) **Albedo Change**

$$C = \left(\frac{I}{4\sigma}\right)^{1/4}$$

Then $T_E = C(1-A)^{1/4}$

$$\frac{\partial T_E}{\partial A} = -\frac{1}{4} C (1-A)^{-3/4} \frac{(1-A)^{1/4}}{(1-A)^{1/4}}$$

$$\frac{\partial T_E}{\partial A} = -\frac{T_E}{4}\frac{1}{1-A}$$

$$dT_e = \frac{\partial T_e}{\partial I} dI + \frac{\partial T_e}{\partial A} dA = \frac{\partial T_e}{\partial I}\frac{\partial I}{\partial r} dr + \frac{\partial T_e}{\partial A} dA$$

Sensitivity

Solar model

$$I(r) = I_0 \frac{r_0^2}{r^2} \qquad \frac{\partial I}{\partial r} = -2\frac{I_0 r_0^2}{r^3} = -\frac{2}{r} I(r)$$

Term $\frac{\partial T_e}{\partial I}$: $B = \left(\frac{1-A}{4\sigma}\right)^{1/4}$ so $T_E = I^{1/4} B$

$$\frac{\partial T_E}{\partial I} = \frac{1}{4} I^{-3/4} B \cdot \frac{I^{1/4}}{I^{1/4}} = \frac{1}{4} B \frac{I^{1/4}}{I} = \frac{T_E}{4I}$$

$$\frac{\partial T_E}{\partial A} dA = \left(-\frac{T_E}{4}\frac{A}{1-A}\right)\frac{dA}{A}$$

$dA \Rightarrow$ A goes from 0.305 to 0.315

First Term

$$\frac{\partial T_E}{\partial I}\frac{\partial I}{\partial r} dr = \frac{T_E}{4I}\left(-\frac{2}{r} I\right) dr = -\frac{T_E}{2}\frac{dr}{r}$$

$$dT_E = -T_E\left(\frac{dr}{2r} + \frac{A}{4(1-A)}\frac{dA}{A}\right)$$