EOSC 112: THE FLUID EARTH

RADIATION, ENERGY BALANCE AND THE GREENHOUSE EFFECT

E12

Read: Kump et al. Chap.3, p. 34-43

Check: Key Terms, Review Questions.

Objectives:

1. To describe the spectrum of electromagnetic radiation
2. To calculate the energy balance of a planet devoid of atmosphere
3. To calculate the magnitude of the greenhouse effect

1. Spectrum of electromagnetic radiation

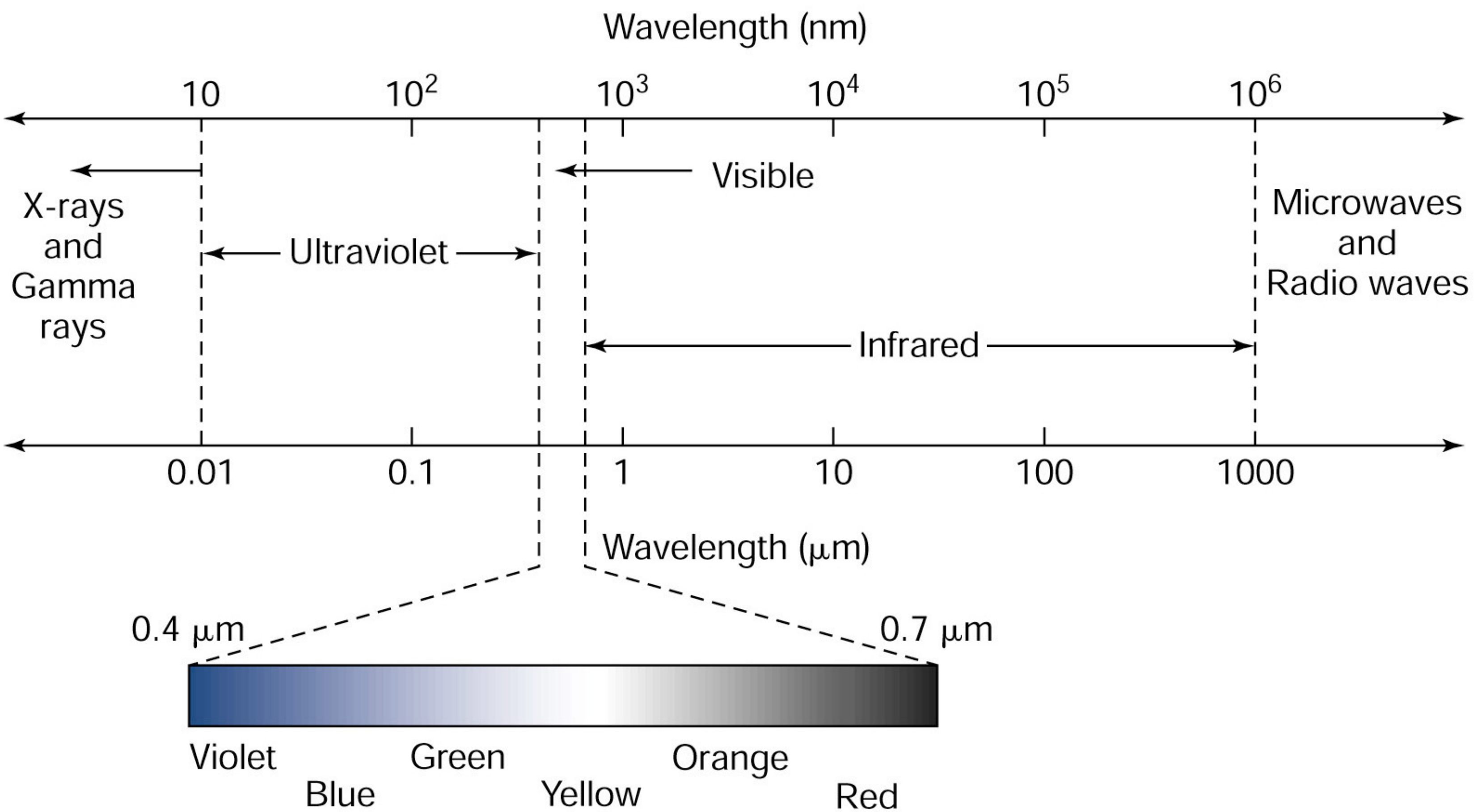
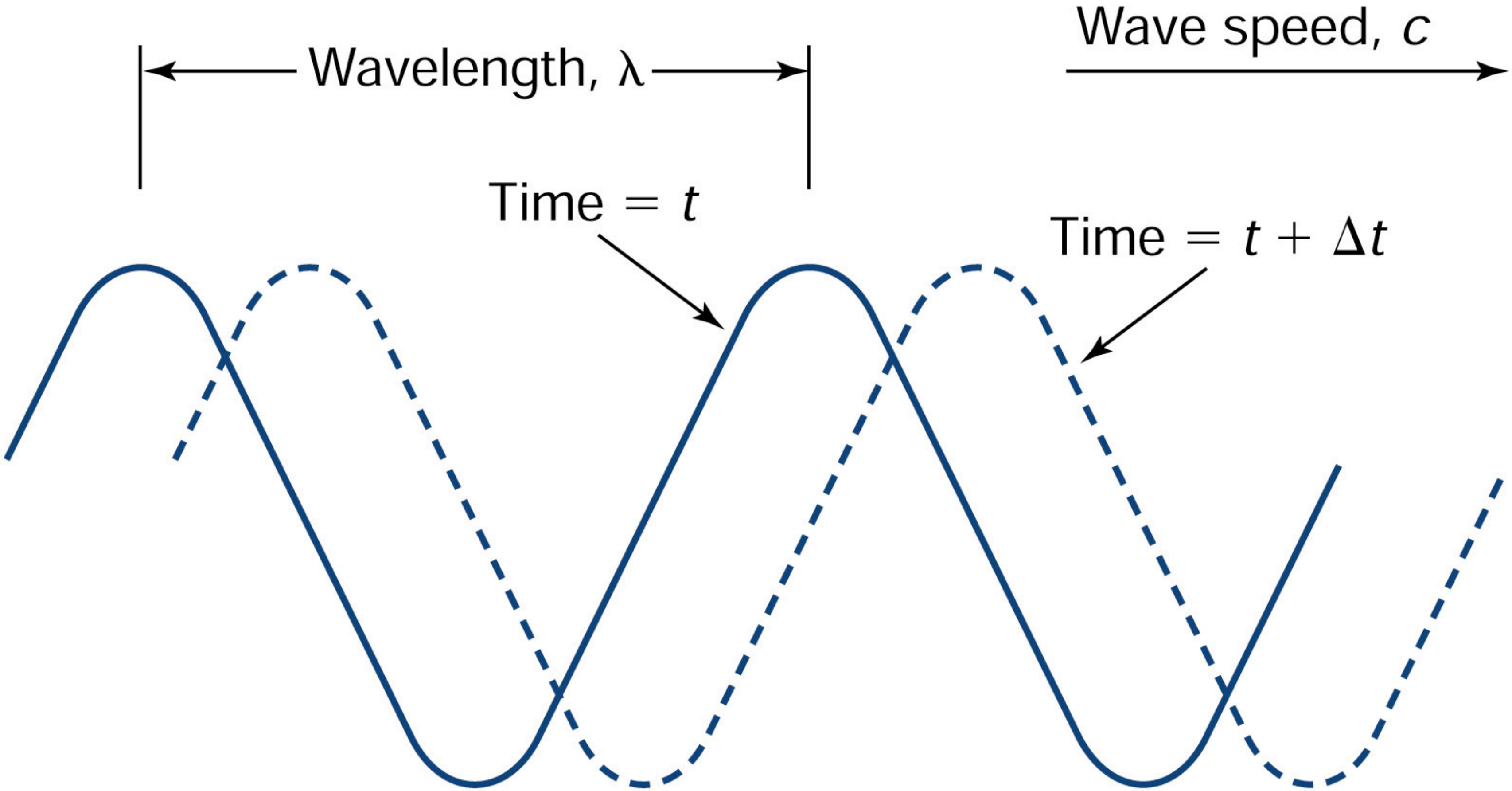


Figure representing a wave in motion



•The regions of the spectrum that are most important to climate and life are: the *visible*, the *infrared*, and the *ultraviolet* (fig.).

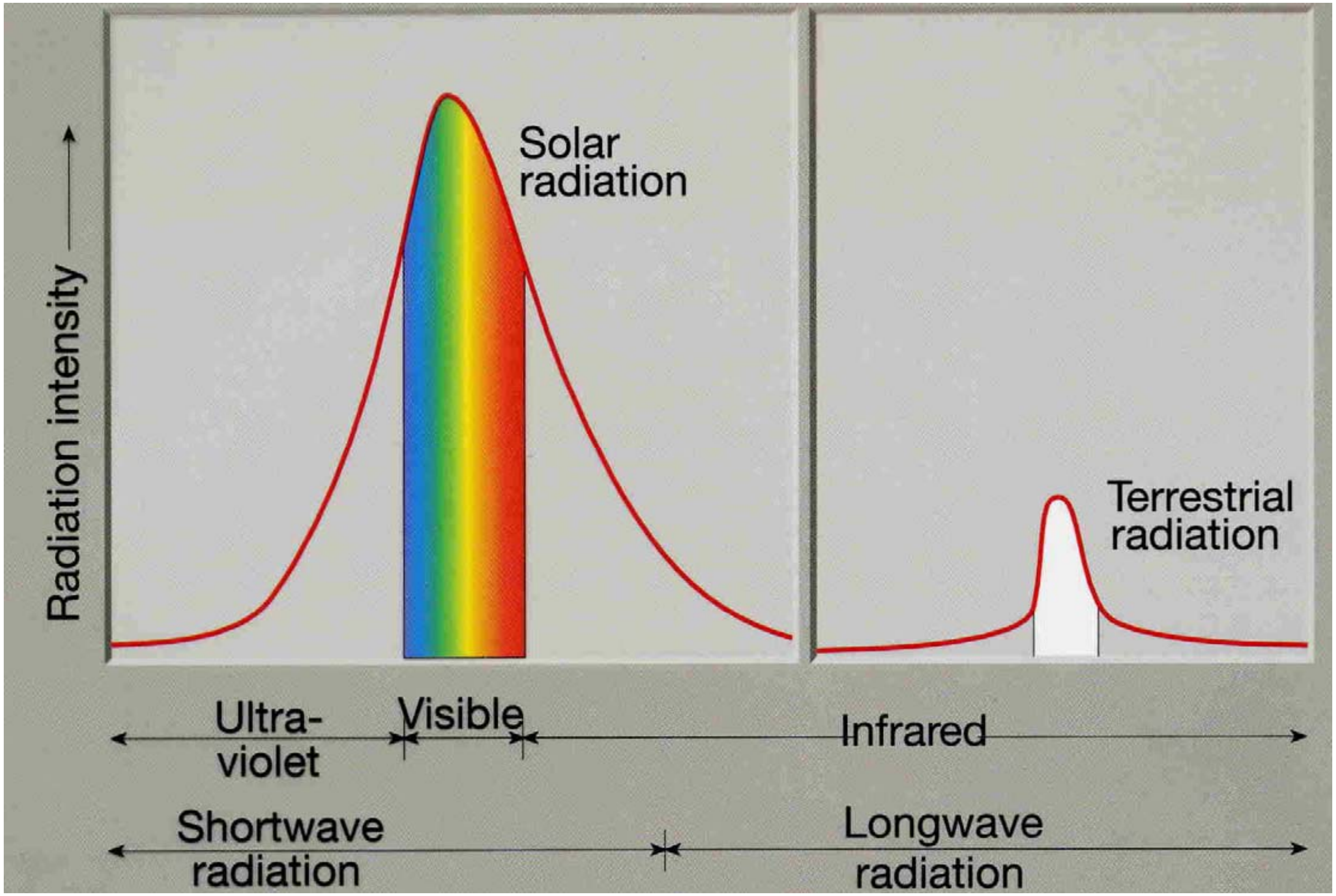
•The Sun radiates energy in all of these spectral regions, while Earth emits in the infrared (fig.).

•Stefan-Boltzmann law:

$$F = \sigma T^4$$

where, **F = energy flux (Watts/m^2),**
T = temperature (Kelvins), and
$\sigma = 5.67 \times 10^{-8}$ W/(m^2K^4).

Figure representing the solar and terrestrial spectra



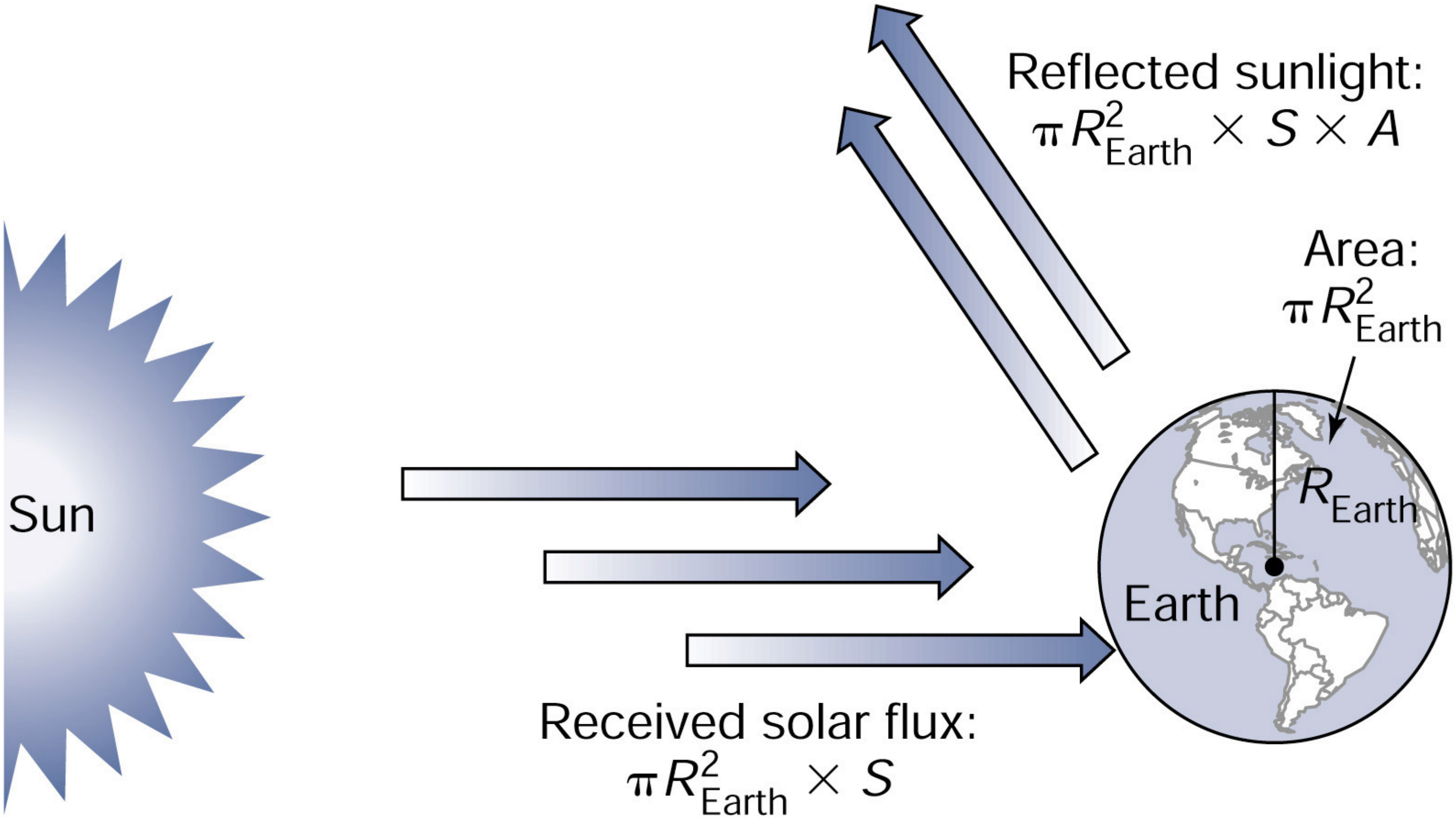
2. Energy Balance

- The principle to apply to determine the surface temperature of a planet: **Energy Balance**.
- For a planet without atmosphere, the surface T depends on 2 factors:

  1) the solar flux available at the distance of the planet's orbit, and

  2) the reflectivity of the planet. (See box titled Planetary Energy Balance)

Figure representing the calculation of Planetary Energy Balance



Calculation of Planetary Energy Balance

ENERGY EMITTED BY EARTH = ENERGY ABSORBED BY EARTH

ENERGY EMITTED = $4\pi R^2_{earth} \times \sigma T_e^4$

EN. ABSORBED = EN. INTERCEPTED – EN. REFLECTED

= $\pi R^2_{earth} \times S - \pi R^2_{earth} \times SA$

Introducing the above expressions into our top equation yields:

$$4\sigma T_e^4 = S \times (1 - A)$$

or

$$T_e = \sqrt[4]{(S/4\sigma)(1-A)}$$

where, $S = \sigma T_{sun}^4 \times \left(\dfrac{\text{radius}_{sun}}{\text{distance}_{sun-earth}} \right)^2$

and using, T_{sun}= 5780K, radius$_{sun}$= 695 000km,

distance$_{sun\text{-}earth}$= 1.496x10^{8}km

then, S = 1366W/m^2; A = 0.3

$\Rightarrow$ T_e = 255K = -18°C. But, T_s = 15°C.

For Venus, T_e = -53°C, T_s = 457°C

For Mars, T_e = -61°C, T_s = -55°C.

3. Magnitude of the Greenhouse Effect

For a planet with an atmosphere, the surface T also depends on the greenhouse effect (that is, the amount of warming provided by the atmosphere):

$$\Delta T_g = T_{surface(actual)} - T_{surface(calculated)}$$

Earth: $\Delta T_g = 15 - (-18) = 33^\circ C$

Venus: $\Delta T_g = 457 - (-53) = 510^\circ C$

Mars: $\Delta T_g = -55 - (-61) = 6^\circ C$