Solar radiation - the major source of energy for almost all environmental flows

Radiation = electromagnetic waves

Different types of heat transfer:

Heat conduction by molecular diffusion (no large-scale transport of mass is needed; think the change of temperature within an iron bar with one end attached to a furnace)

Heat transfer accomplished by mass transport (e.g., convection, turbulent heat transfer in fluids)

Radiative heat transfer - most ubiquitous

Every object in the universe emits radiation according to its temperature

For a "blackbody" in thermodynamical equilibrium, the intensity of radiation is governed by Planck function

$$B_\lambda(T) = \frac{2hc^2}{\lambda^5(\exp^{[\frac{hc}{\lambda kT}]} - 1)}$$

Eq. (A-1) in M&P textbook

h = Planck's constant, k = Boltzmann's constant, c = speed of light,
T = temperature (in degK)

For a given temperature (of the object under consideration),
$B_\lambda(T)$ is a function of the "wavelength" λ (of electromagnetic waves).
The radiation emitted by the object forms a "spectrum".

Example: The sun has a surface temperature of ~ 6,000 K. The following is the "spectrum" of radiation (electromagnetic waves) emitted by the sun, or by any object that has a temperature of 6,000K.

-- The "peak" of the spectrum is in the visible band

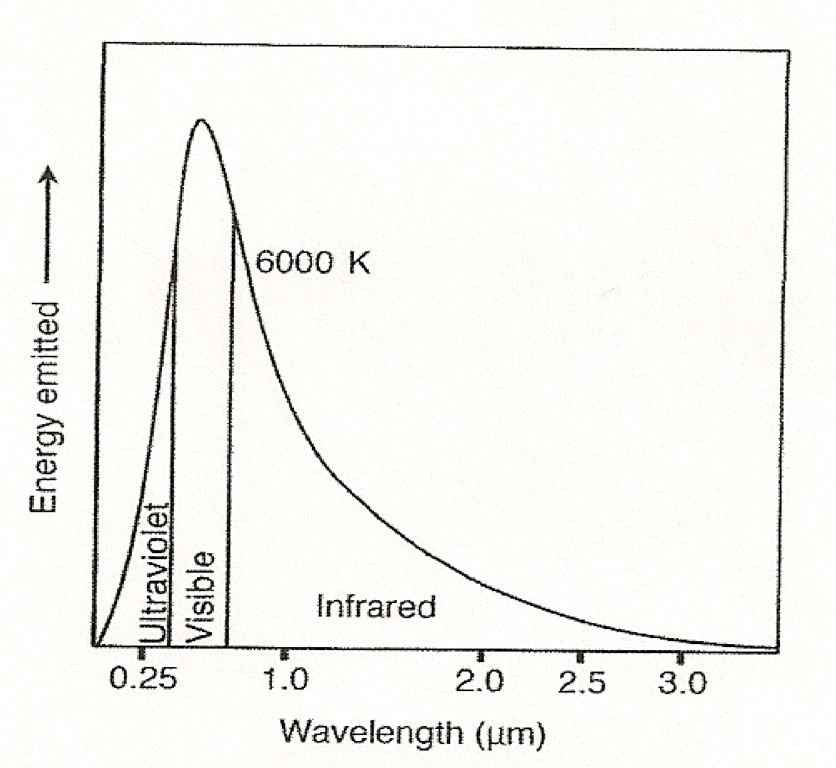

Fig. 2.2 in M&P

Speaking of electromagnetic waves ...

$\lambda \sim 0.01\ \mu m$ X-ray

$\lambda < 0.3\ \mu m$ Ultraviolet radiation (harmful to humans)

$0.3\ \mu m < \lambda < 0.7\ \mu m$ Visible light (that human eyes can "see")

$\lambda > 1.0\ \mu m$ Near-infrared, Infrared

$\lambda \sim 10000\ \mu m$ (1 cm) Microwave

[0.3 μm - 0.7 μm] : [purple, blue, green, yellow, red]

The peak of the radiation spectrum shifts to longer wavelength as temperature decreases

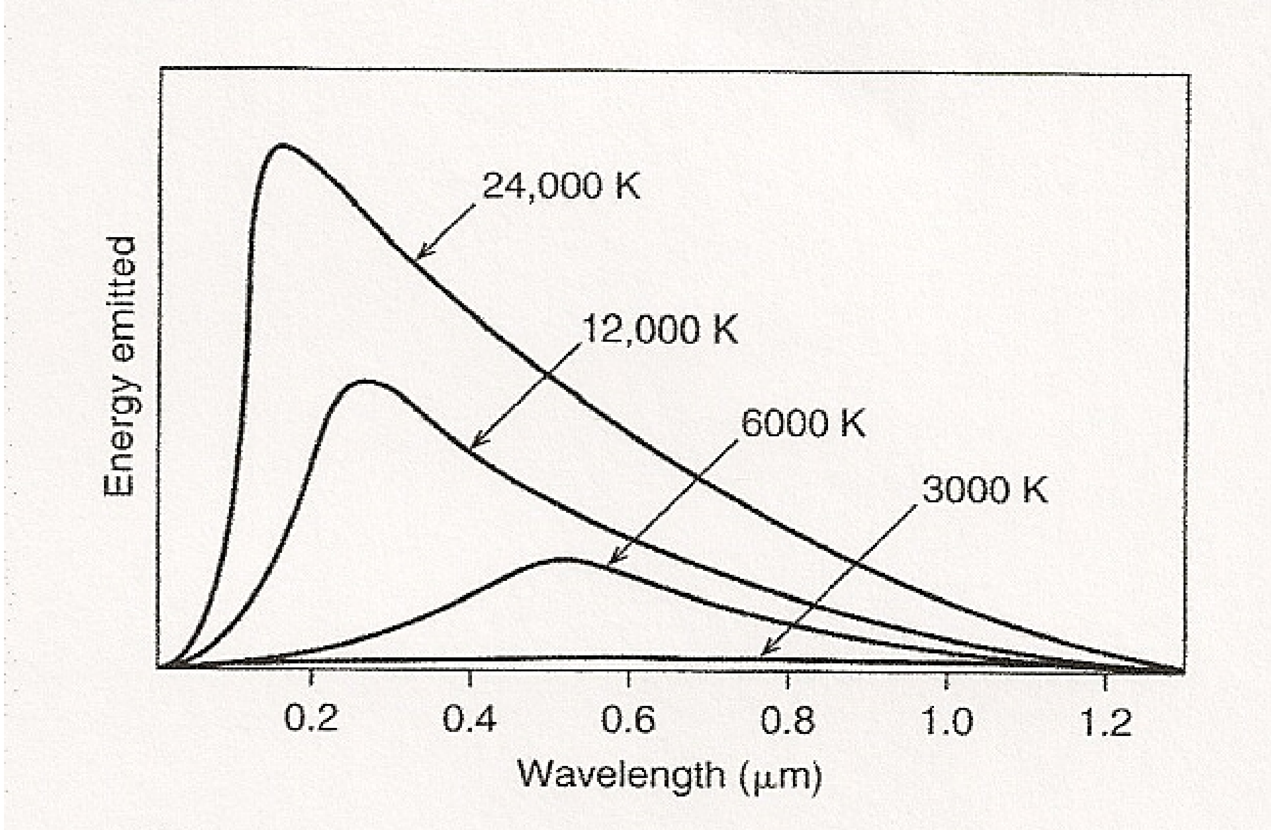

Fig. 2.3 in M&P

A star with a surface temperature of 10,000K would look more blue, while a star with surface temperature of 4,000K will look more red.

This behavior is anticipated from Planck's function

$$B_\lambda(T) = \frac{2hc^2}{\lambda^5(\exp^{[\frac{hc}{\lambda kT}]} - 1)} \ .$$

The peak of the spectrum occurs at the wavelength λ where

$$\frac{\partial B_\lambda(T)}{\partial \lambda} = 0 \ .$$

Straightforward math would lead to a formula of the peak wavelength as a function of temperature (sometimes called "Wien displacement law"), which would readily corroborate the behavior shown in the previous slide. We will leave this to a homework.

What about the Earth?

Earth's global mean surface/atmospheric temperature is $T \sim 255$ K

-- The peak wavelength of the radiation emitted by
the Earth is $\lambda \sim 10\ \mu$m , in the infrared range not visible
to human eyes

That Earth is at all visible from space is because it reflects sun light, which contains a substantial visible band

Human body ($T \sim 300$K) also emits infrared radiation not visible to human eyes; We cannot "see" each other at night (unless aided by artificial light, or by a pair of infrared goggles)

The atmosphere absorbs solar and terrestrial radiation in a highly wavelength-dependent manner. This has many important implications for Earth's global environment and life on earth in general.

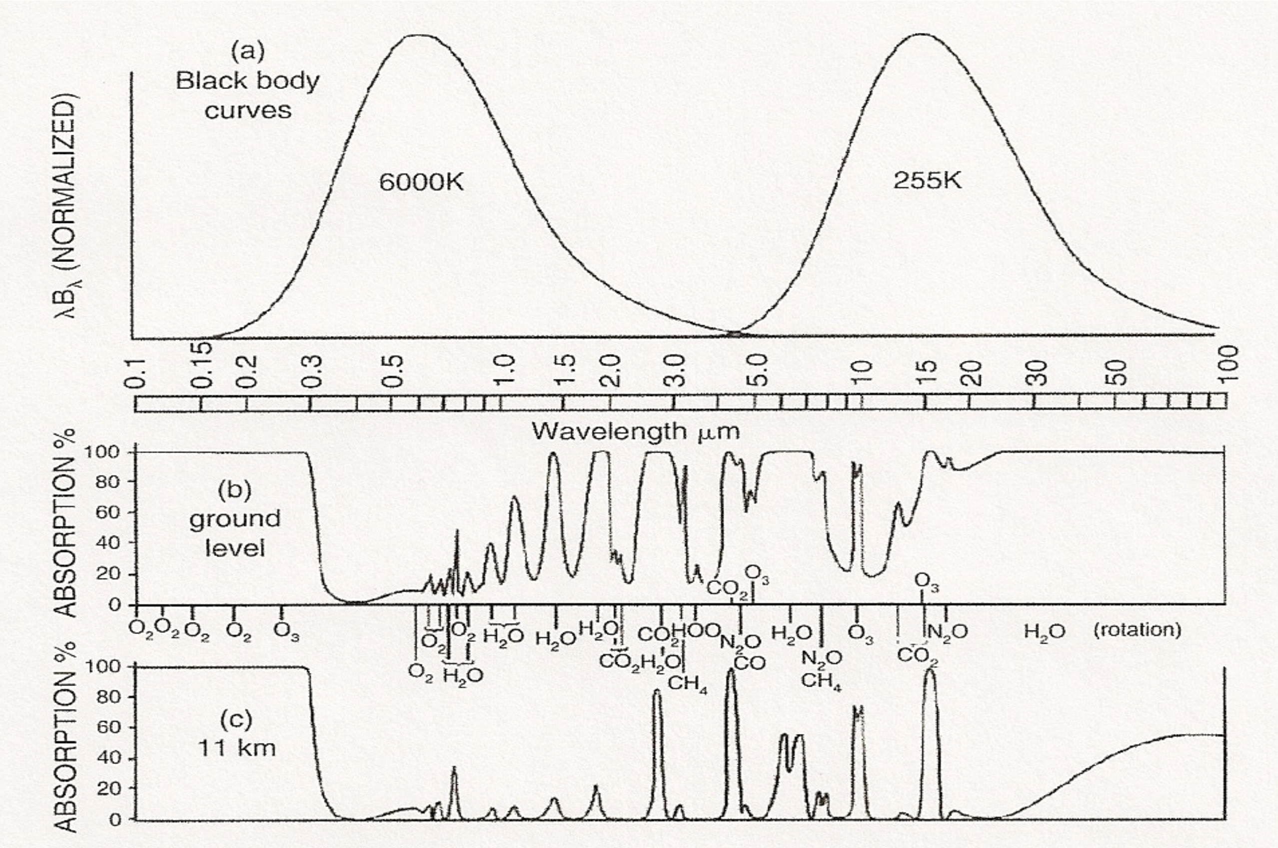

Fig. 2.6 in M&P

Beware that the radiation spectra in the top panel are "normalized". In actuality, solar radiation is much stronger than terrestrial radiation.

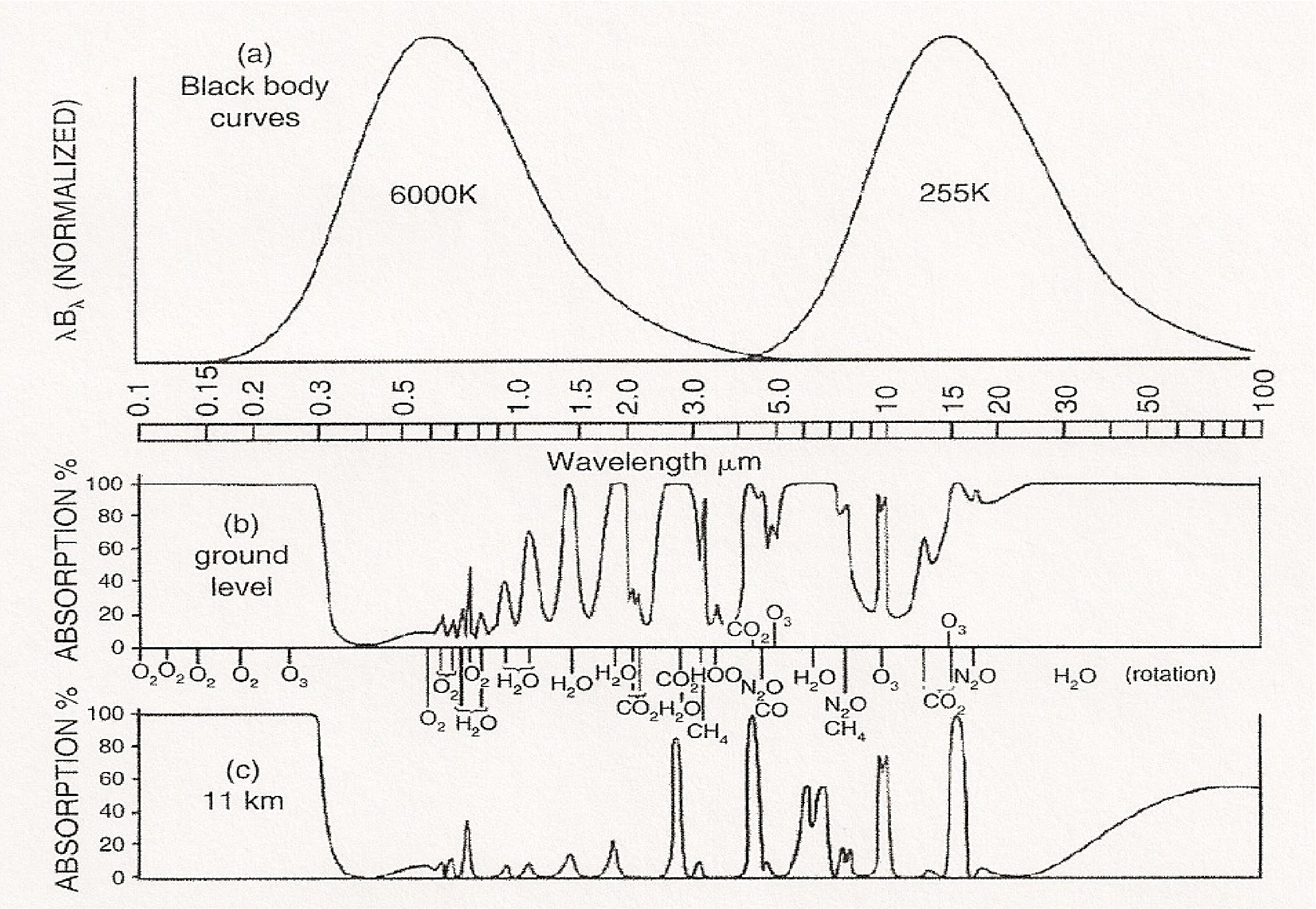

Fig. 2.6 in M&P (repeat)