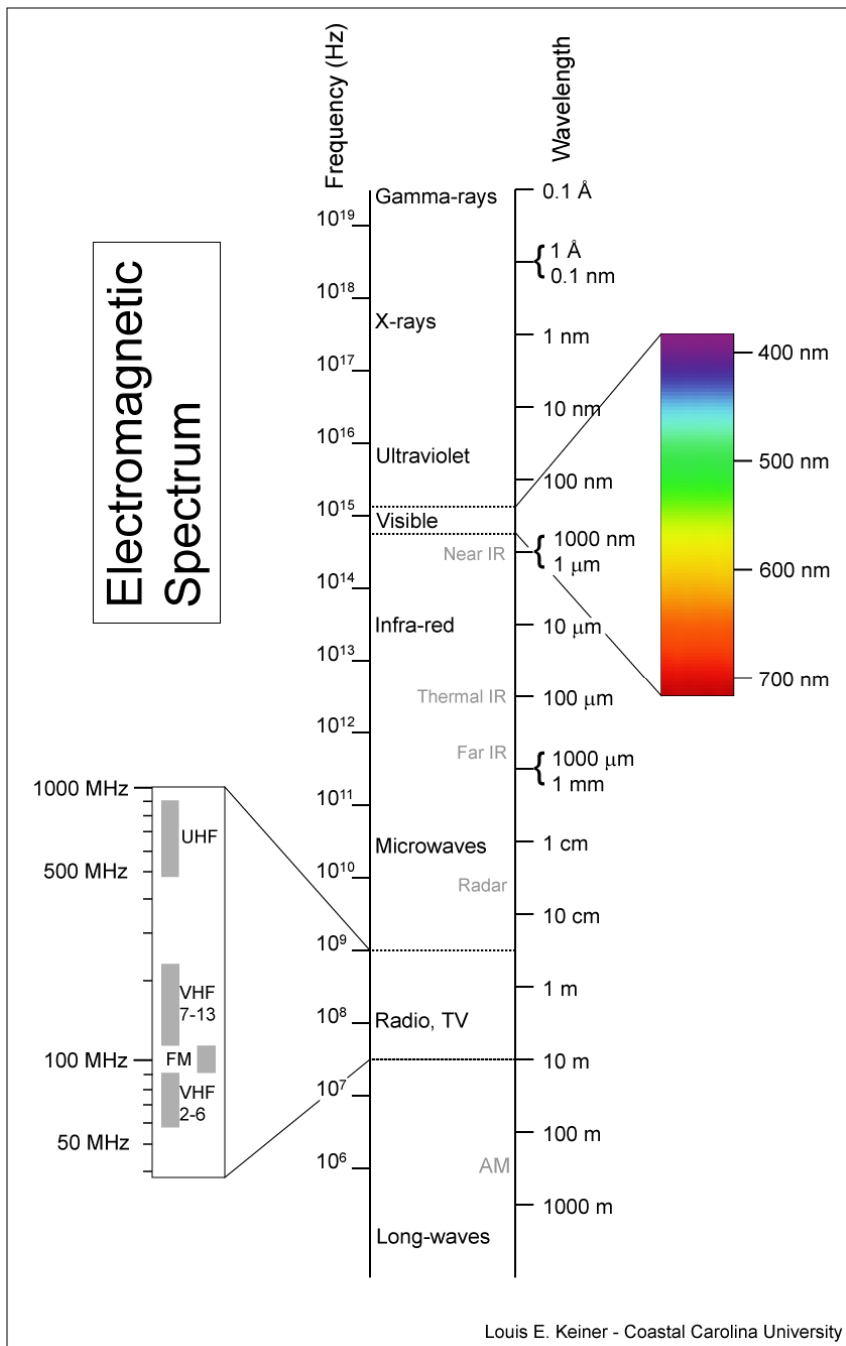


Introduction to
Electromagnetic Radiation
and
Radiative Transfer



Visible light, infrared (IR), ultraviolet (UV), X-rays, γ -rays, microwaves, and radio are all forms of electromagnetic radiation.

Each type has a different wavelength (λ).

The shorter the wavelength, the greater the energy of individual photons (discrete packets of electromagnetic radiation).

Shortest to longest wavelength: γ -rays, X-rays, UV, visible, IR, microwave, radio

When a photon hits a molecule (gas, liquid, or solid), one of the following events will occur:

- The photon continues in the same direction (transmission)
- The photon goes in a new direction (scattering/reflection)
- The photon is destroyed, and its energy goes to the molecule (absorption)

The individual probabilities for transmission, scattering, or absorption depend on the molecule and the wavelength of the photon

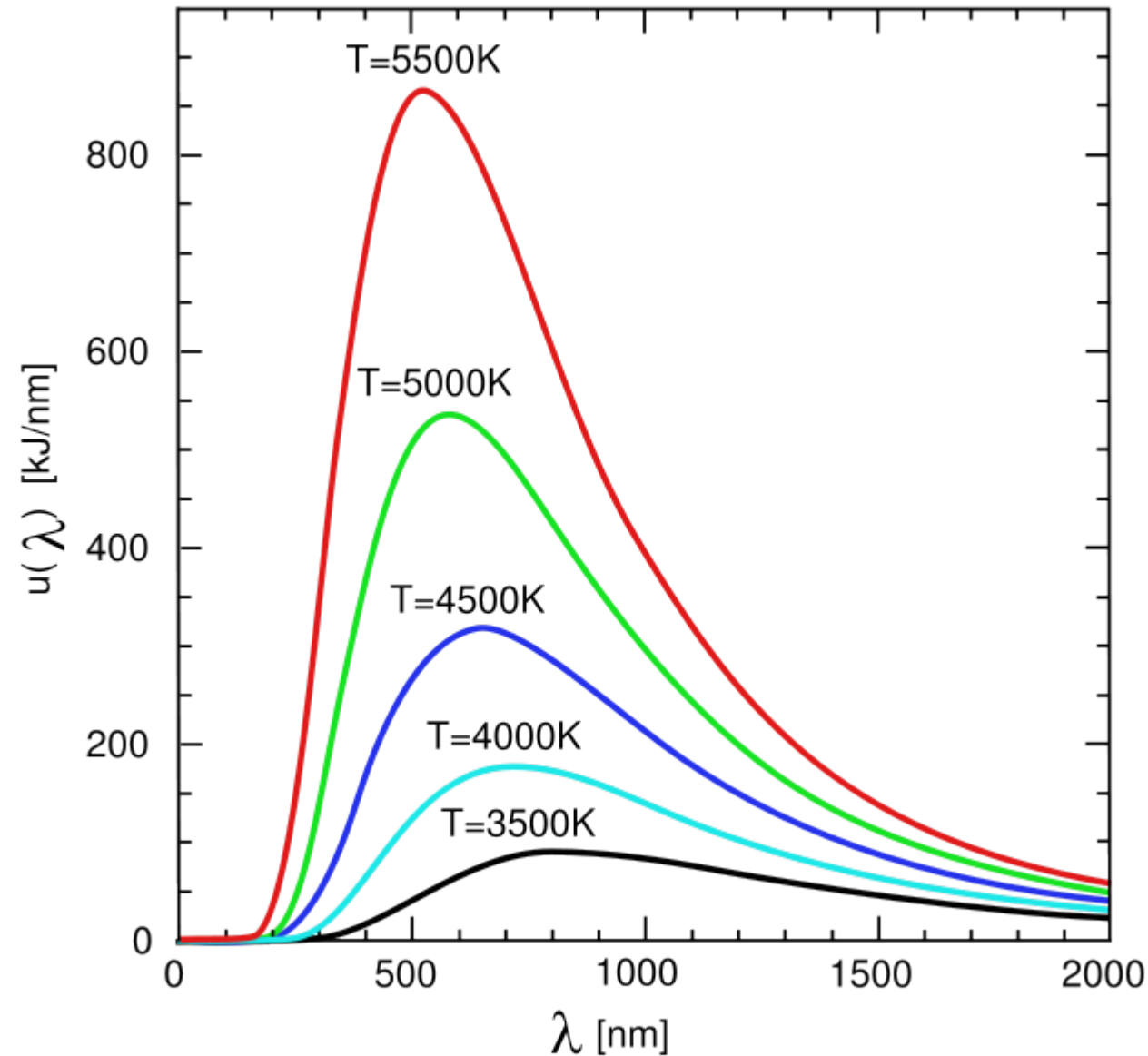
- A UV photon hitting a nitrogen molecule will probably be scattered
- A UV photon hitting an ozone molecule will probably be absorbed
- An IR photon hitting a nitrogen molecule will probably be transmitted
- An IR photon hitting a water molecule might be transmitted or might be absorbed

Molecules can also emit photons

- Molecules that are good absorbers at a particular wavelength are also good emitters (potentially) at that wavelength
- The probability of emission also depends on the temperature of the molecules

Characteristics of a blackbody:

- A blackbody is a substance with 100% absorption at every wavelength (no transmission or scattering)
- A blackbody emits the maximum amount of radiation possible
- Warm blackbodies emit more radiation than cold blackbodies
- The wavelength with the most emission is shorter for warmer blackbodies



Author: 4C

$$F = \sigma T^4$$

F = radiation energy flux summed over all wavelengths (units are W m^{-2})

T = temperature (units are K)

$$\sigma = 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$$

$$\lambda_{max} = b / T$$

$$b = 2898 \text{ } \mu\text{m K}$$

Approximate the Sun as a blackbody:

- Temperature at surface is about 5800 K
- Using $F = \sigma T^4$, flux at surface is about $6.4 \times 10^7 \text{ W m}^{-2}$

(This is equivalent to more than 1 million 60W light bulbs every square meter)

- Using $\lambda_{max} = b / T$, wavelength of most emission is about $0.50 \text{ } \mu\text{m}$

(This is in the middle of the visible spectrum)

Approximate the Earth as a blackbody:

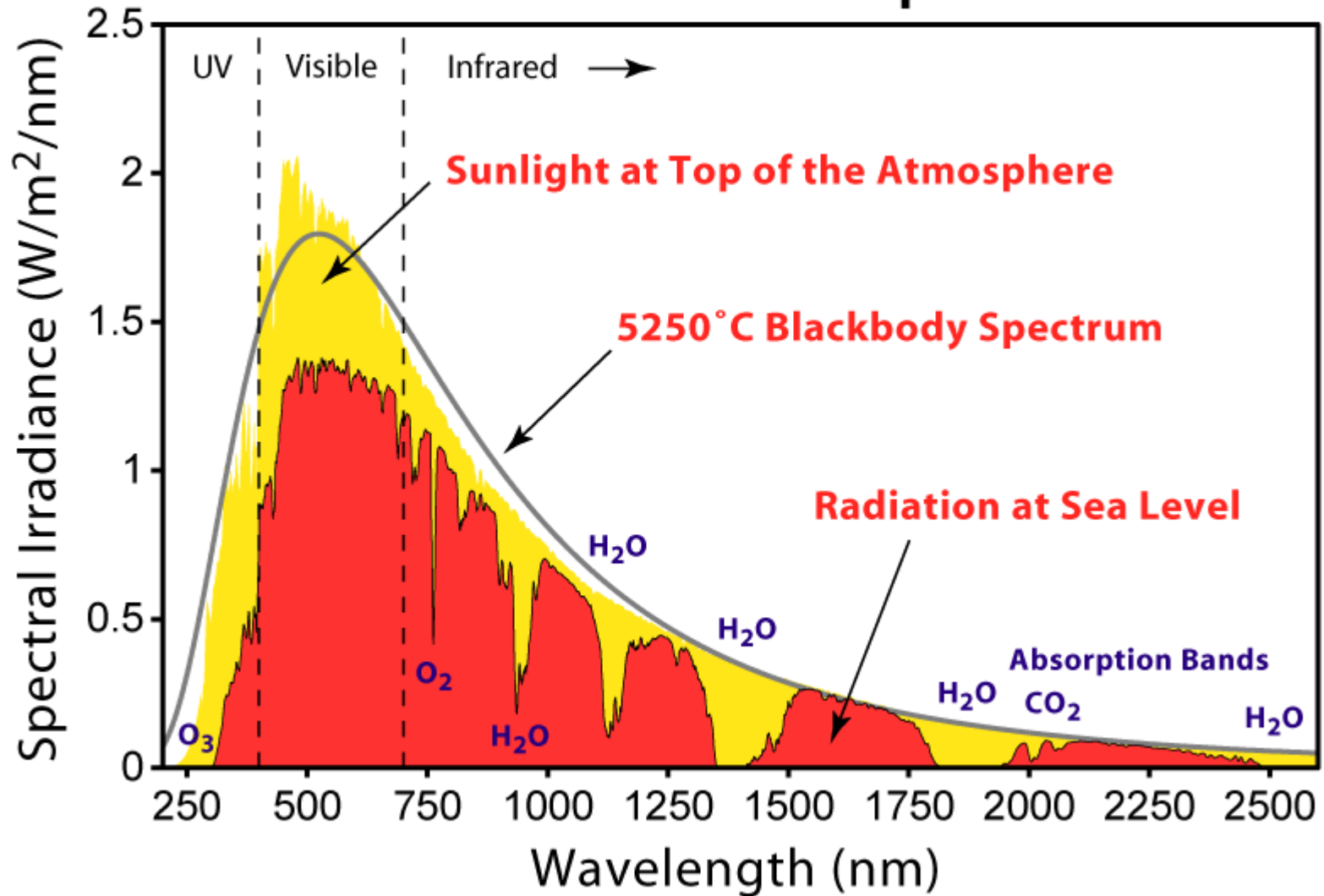
- Temperature at surface is about 288 K
- Using $F = \sigma T^4$, flux at surface is about 390 W m^{-2}

(This is equivalent to more than four and a half 60W light bulbs every square meter)

- Using $\lambda_{max} = b / T$, wavelength of most emission is about $10 \text{ }\mu\text{m}$

(This is in the middle of the thermal IR spectrum)

Solar Radiation Spectrum



From <http://www.globalwarmingart.com>

Earth's atmosphere and solar radiation:

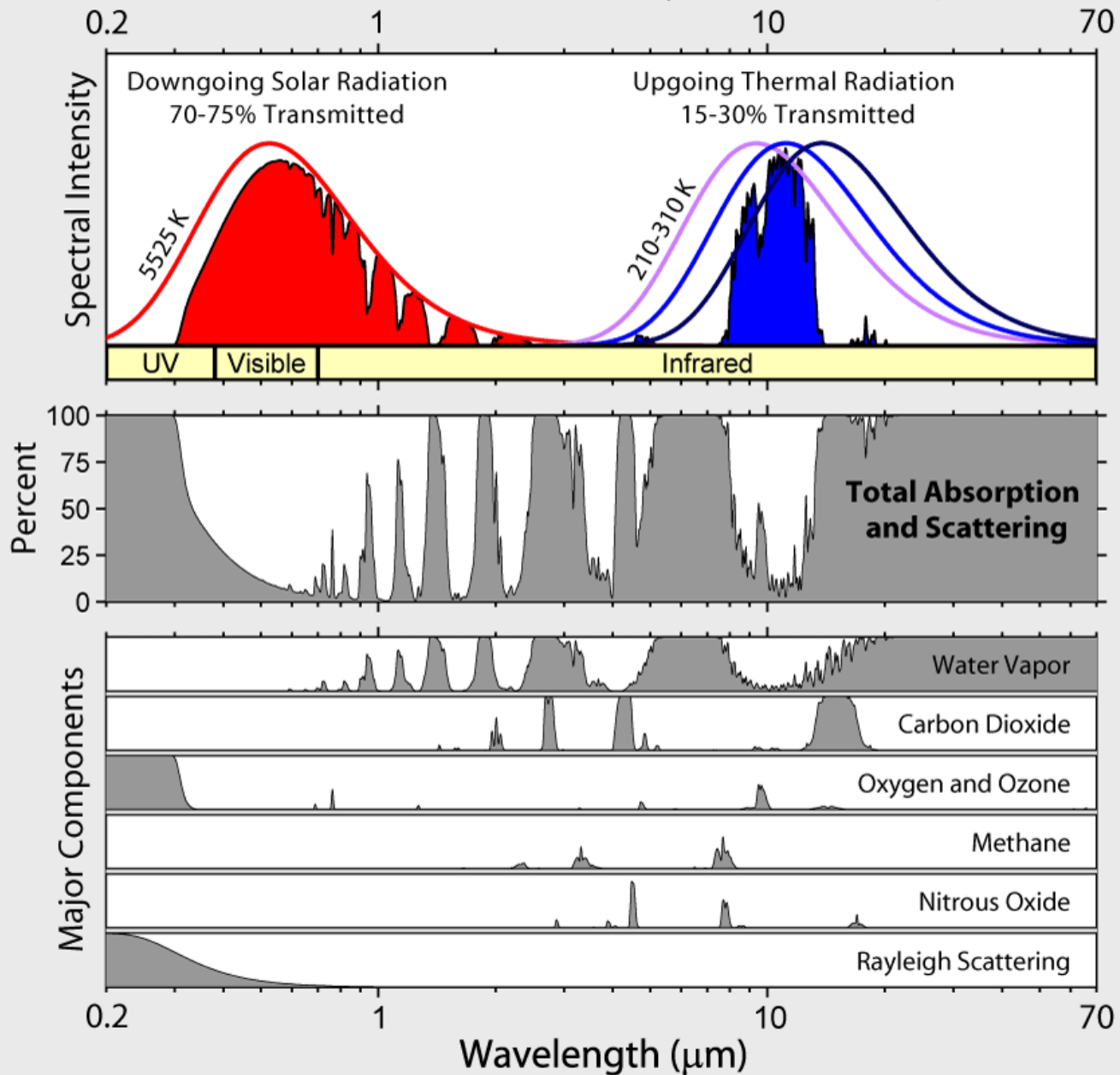
- Scatters UV and blue light (all gases)
- Absorbs most UV (ozone)
- Transmits most visible radiation (all gases)
- Scatters some visible radiation (clouds)
- Absorbs some near IR (water vapor and clouds)

Earth's atmosphere and terrestrial radiation:

- Transmits a small amount of IR
- Absorbs most IR (clouds, water vapor, CO₂, CH₄, and other greenhouse gases)
- Emits IR (clouds, water vapor, CO₂, CH₄, and other greenhouse gases)

N₂, O₂, and Ar (99% of atmosphere) are not greenhouse gases (do not absorb IR)

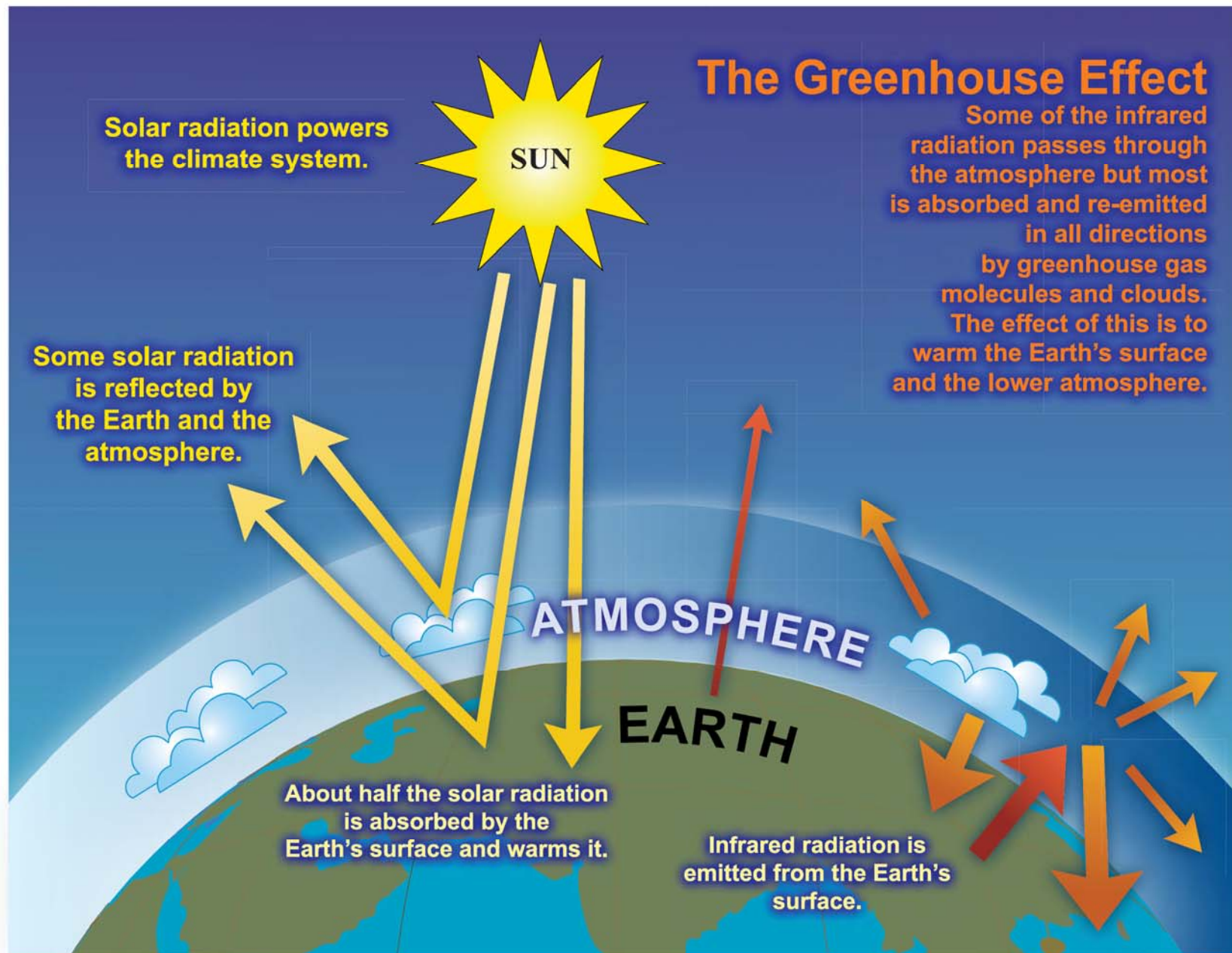
Radiation Transmitted by the Atmosphere



From <http://www.globalwarmingart.com>

Earth's atmosphere and terrestrial radiation:

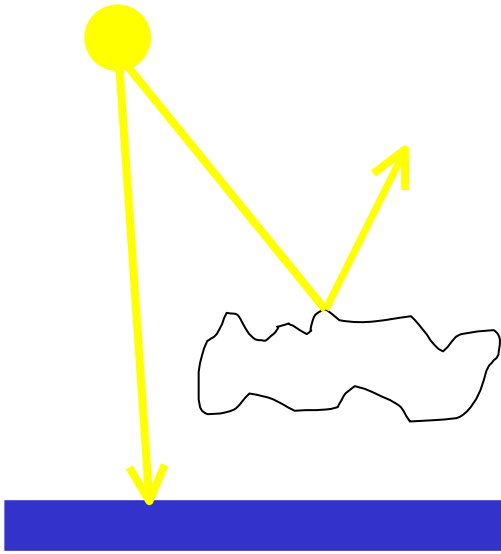
- Most IR radiation emitted by the surface is absorbed by clouds and greenhouse gases
- Clouds and greenhouse gases emit less IR radiation than the surface because they are colder
- High clouds are colder than low clouds
- The reduction of radiation emitted to space acts to warm the Earth (greenhouse effect)



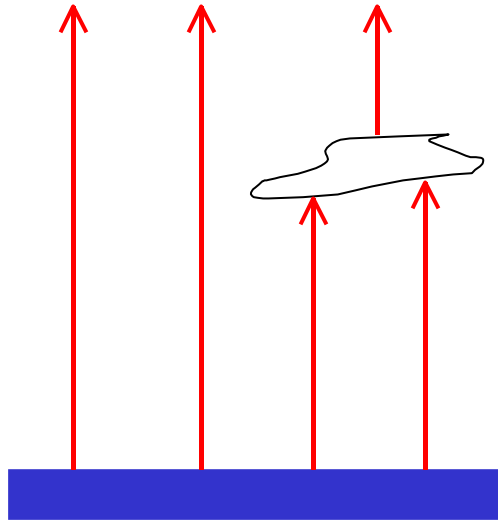
FAQ 1.3, Figure 1. An idealised model of the natural greenhouse effect. See text for explanation.

IR radiation emitted by the surface reaches space if...

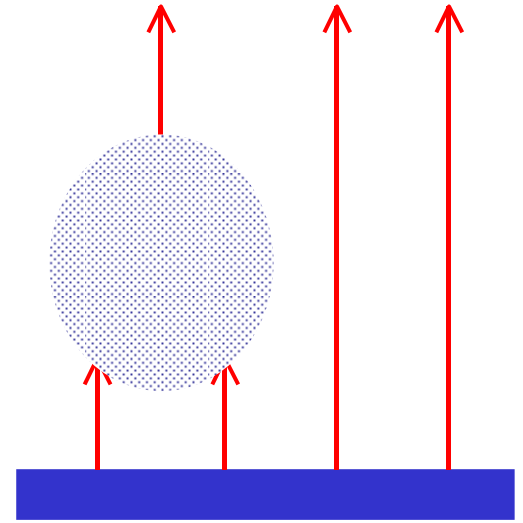
- it has a wavelength where water vapor does not absorb (water vapor window channel)
- it has a wavelength where water vapor does absorb (water vapor channel) but there is little water vapor present



visible



infrared (water
vapor window)



infrared (water
vapor)

Satellite Images

- Visible (VIS): white indicates large radiation flux, dark indicates small radiation flux
- IR water vapor window (IR): white indicates small radiation flux, dark indicates large radiation flux
- IR Water vapor (WV): white indicates small radiation flux, dark indicates large radiation flux