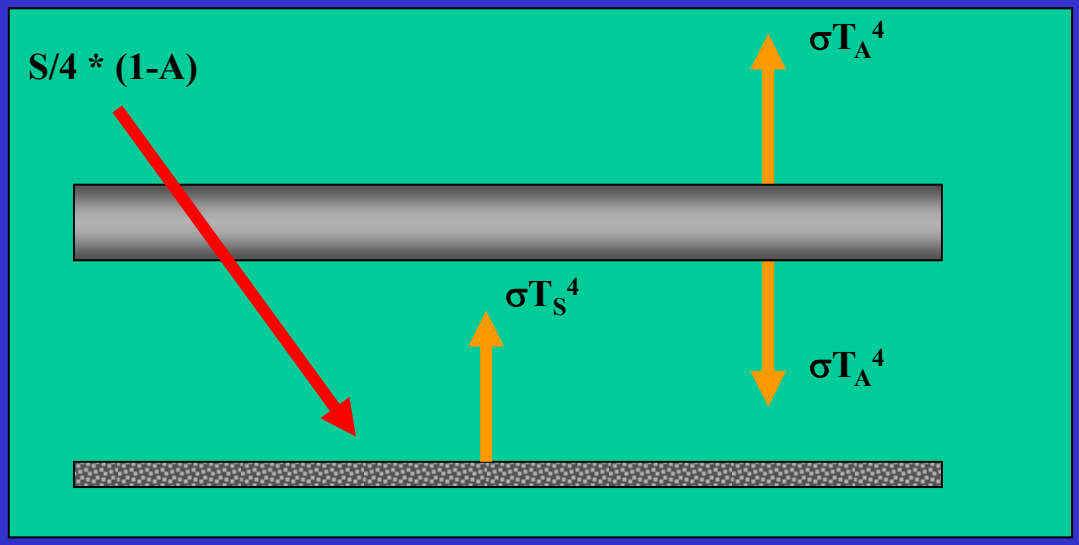
# *Lecture 5:* Greenhouse Effect

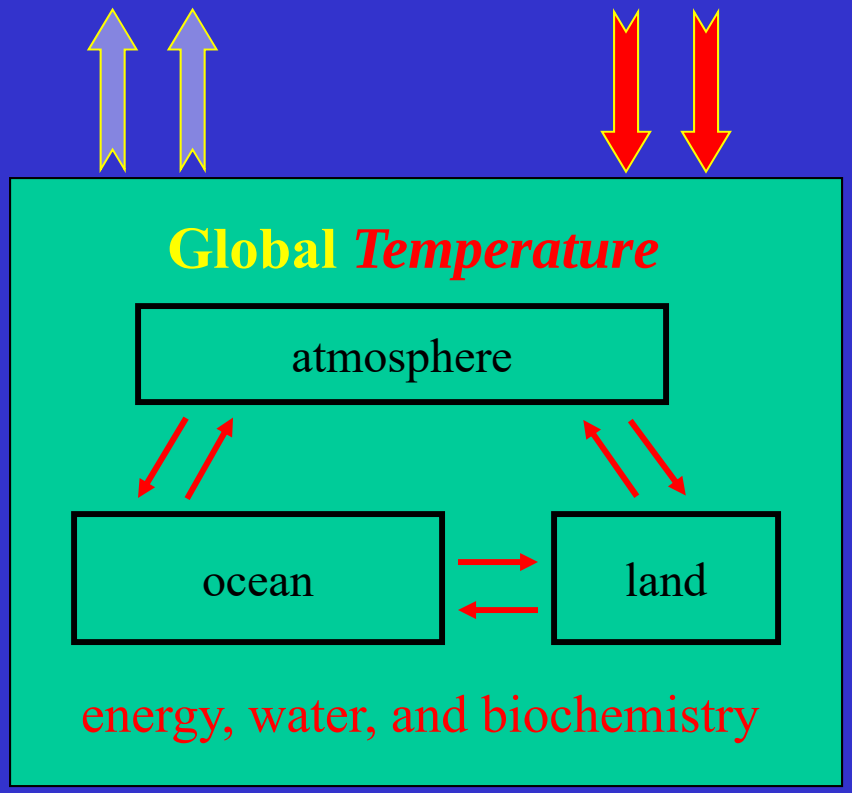



- Wien's Law
- Shortwave and Longwave Radiation
- Selected Absorption ➔ Greenhouse Effect

# Global *Energy* Balance

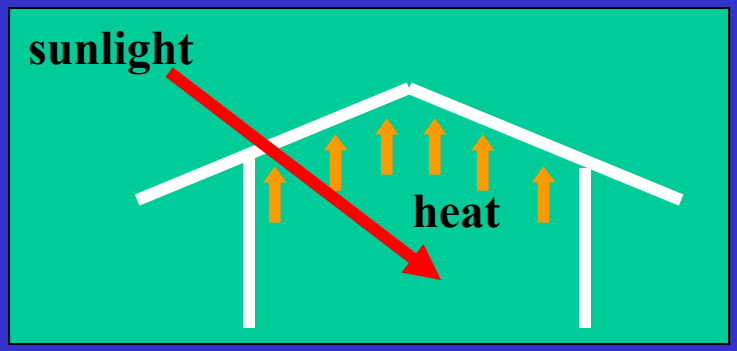
terrestrial radiation cooling

Solar radiation warming

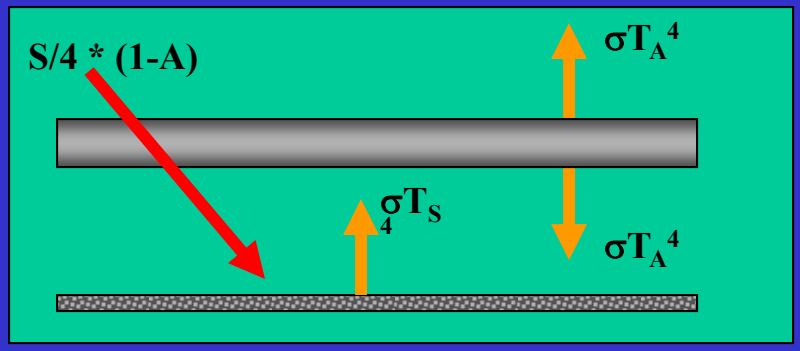



# Why Is It Called "Greenhouse Effect"?

## Greenhouse




## Atmosphere




- allow sunlight to come in
- trap heat in the atmosphere (house)

# Two Key Reasons for the Greenhouse Effect

- Solar and terrestrial radiations are emitted at very different wavelengths.

- The greenhouse gases selectively absorb certain frequencies of radiation.

# Spectrum of Radiation

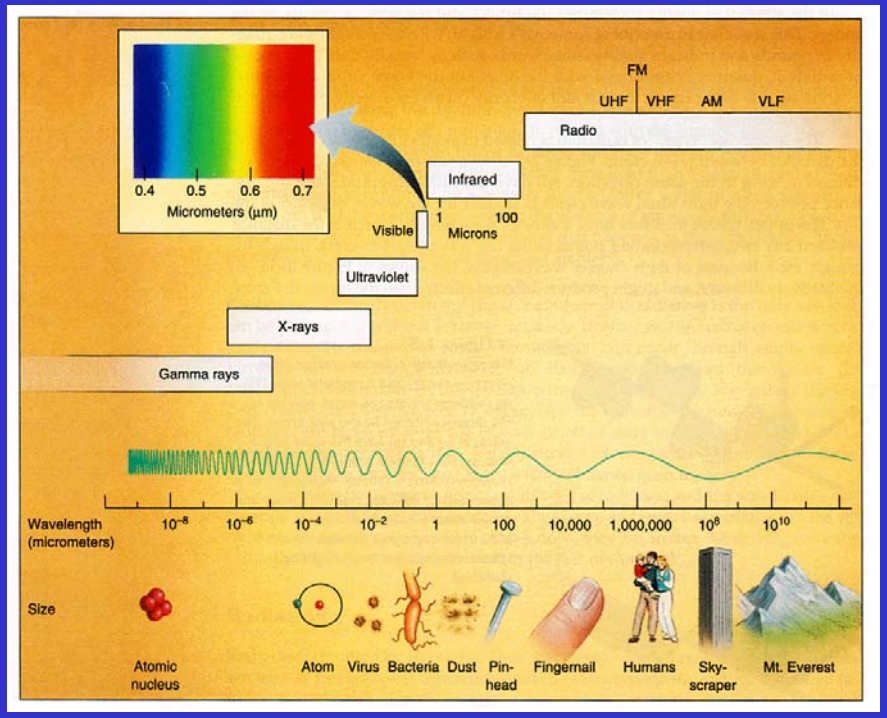



**Table 2–1 Wavelength Categorizations**

| Type of Energy | Wavelength (micrometers) |
|---|---|
| Gamma | <0.0001 |
| X ray | 0.0001 to 0.01 |
| Ultraviolet | 0.01 to 0.4 |
| Visible | 0.4 to 0.7 |
| Near Infrared (NIR) | 0.7 to 4.0 |
| Thermal Infrared | 4 to 100 |
| Microwave | 100 to 1,000,000 (1 meter) |
| Radio | >1,000,000 (1 meter) |

(from *Understanding Weather & Climate*)

- Radiation energy comes in an infinite number of wavelengths.
- We can divide these wavelengths into a few bands.

# Micrometer (μm)

**1 micrometer (μm) = $10^{-6}$ meter (m)**

# Blackbody Radiation

- Blackbody

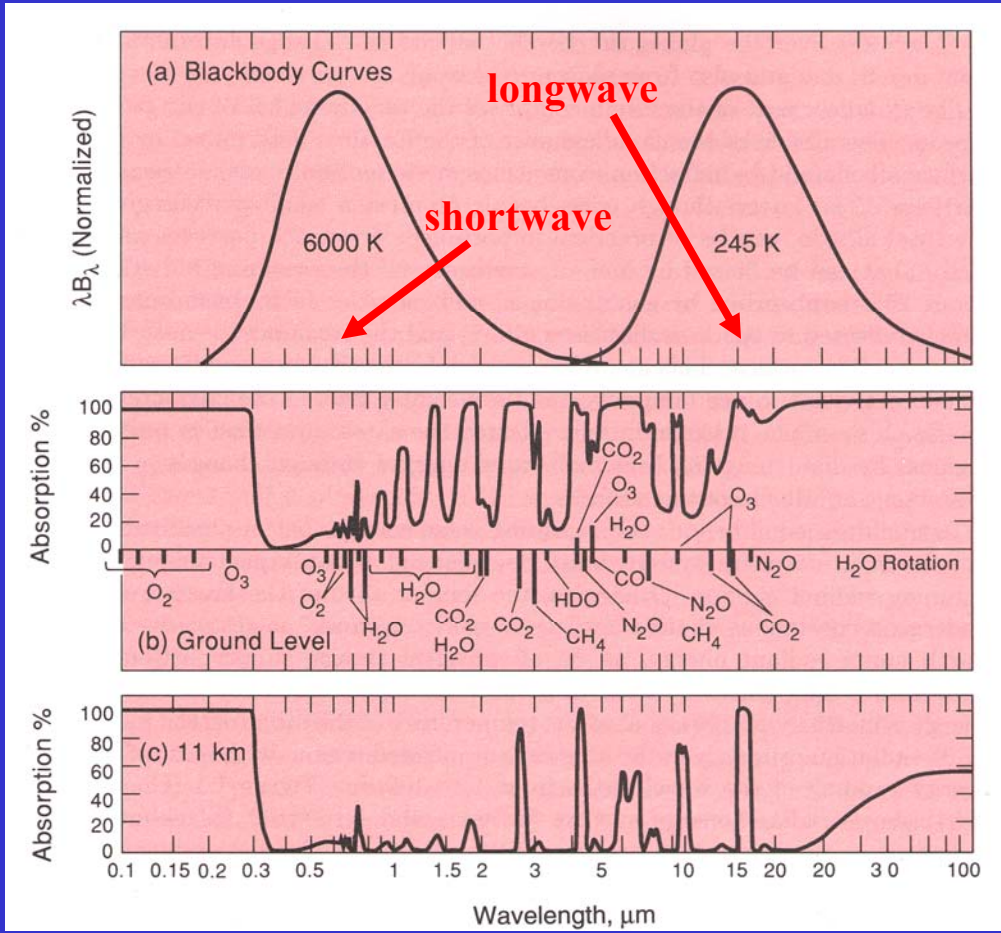
  A blackbody is something that emits (or absorbs) electromagnetic radiation with 100% efficiency at all wavelength.

- Blackbody Radiation

  The amount of the radiation emitted by a blackbody depends on the absolute temperature of the blackbody.

# Different Wavelengths of Solar and Earth's Radiation

## Normalized Planck Function




(from *Climate System Modeling*)

## Planck Function

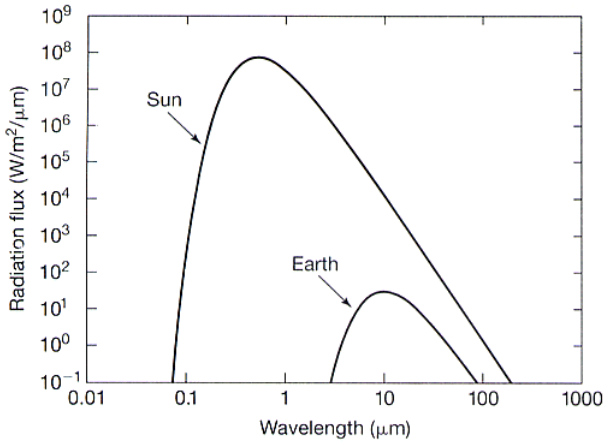



**FIGURE 3-8**
Blackbody emission curves for the Sun and Earth. The Sun emits more energy at all wavelengths.

(from *The Earth System*)

ESS15
Prof. Jin-Yi Yu

# Stefan-Boltzmann Law

$$E = \sigma T^4$$

E = radiation emitted in $W/m^2$

$\sigma = 5.67 \times 10^{-8}$ $W/m^2 * K * sec$

T = temperate (K ← ***Kelvin degree***)

- The single factor that determine how much energy is emitted by a blackbody is its temperature.
- The intensity of energy radiated by a blackbody increases according to the fourth power of its absolute temperature.
- This relationship is called the Stefan-Boltzmann Law.

# Wien's Law

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

$\lambda_{max}$ = wavelength (micrometers)

W = 2897 μm K

T = temperate (K)

- Wien's law relates an objective's maximum emitted wavelength of radiation to the objective's temperature.
- It states that the wavelength of the maximum emitted radiation by an object is inversely proportional to the objective's absolute temperature.

# Apply Wien's Law To Sun and Earth

- **Sun**

  $\lambda_{max}$ = 2898 μm K / 6000K

  = 0.483 μm

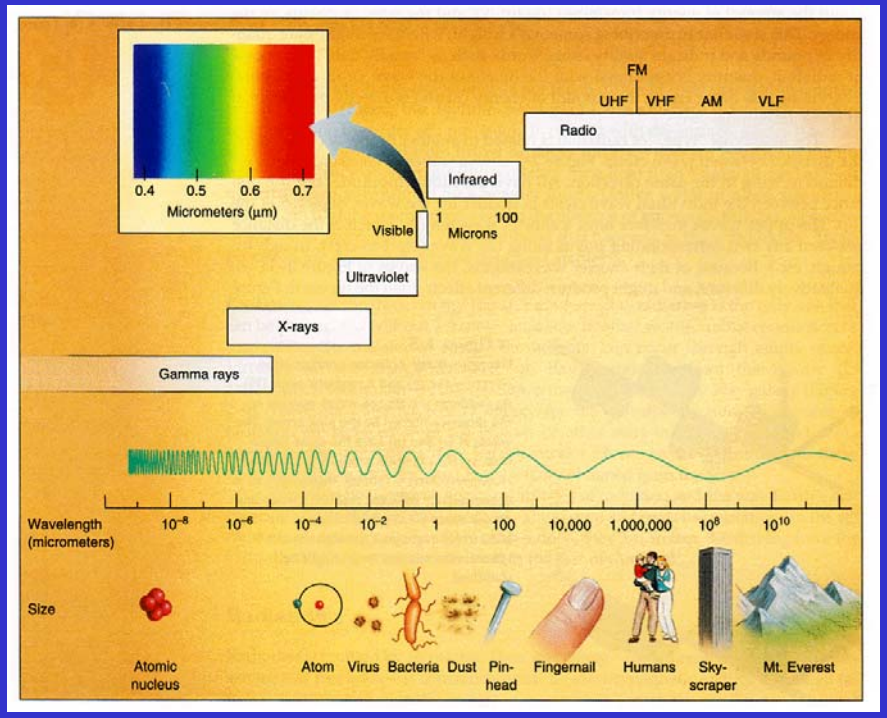
- **Earth**

  $\lambda_{max}$ = 2898 μm K / 300K

  = 9.66 μm

- Sun radiates its maximum energy within the visible portion of the radiation spectrum, while Earth radiates its maximum energy in the infrared portion of the spectrum.

# Spectrum of Radiation

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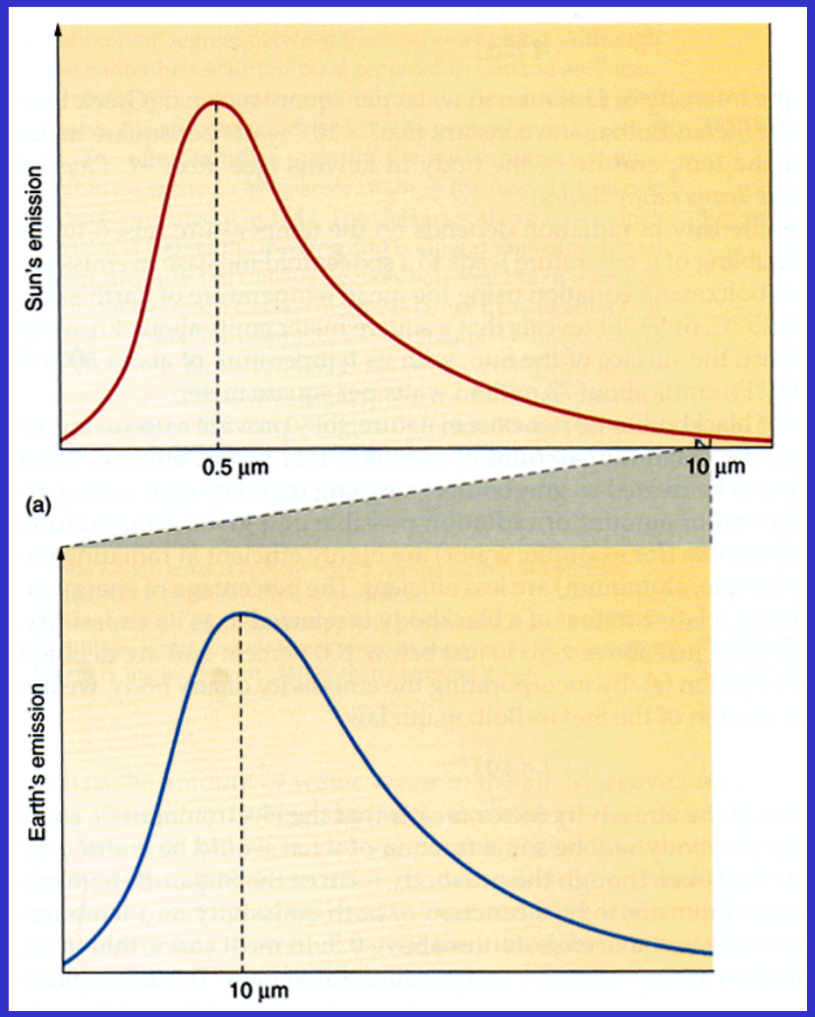
(from *Understanding Weather & Climate*)

- Radiation energy comes in an infinite number of wavelengths.
- We can divide these wavelengths into a few bands.

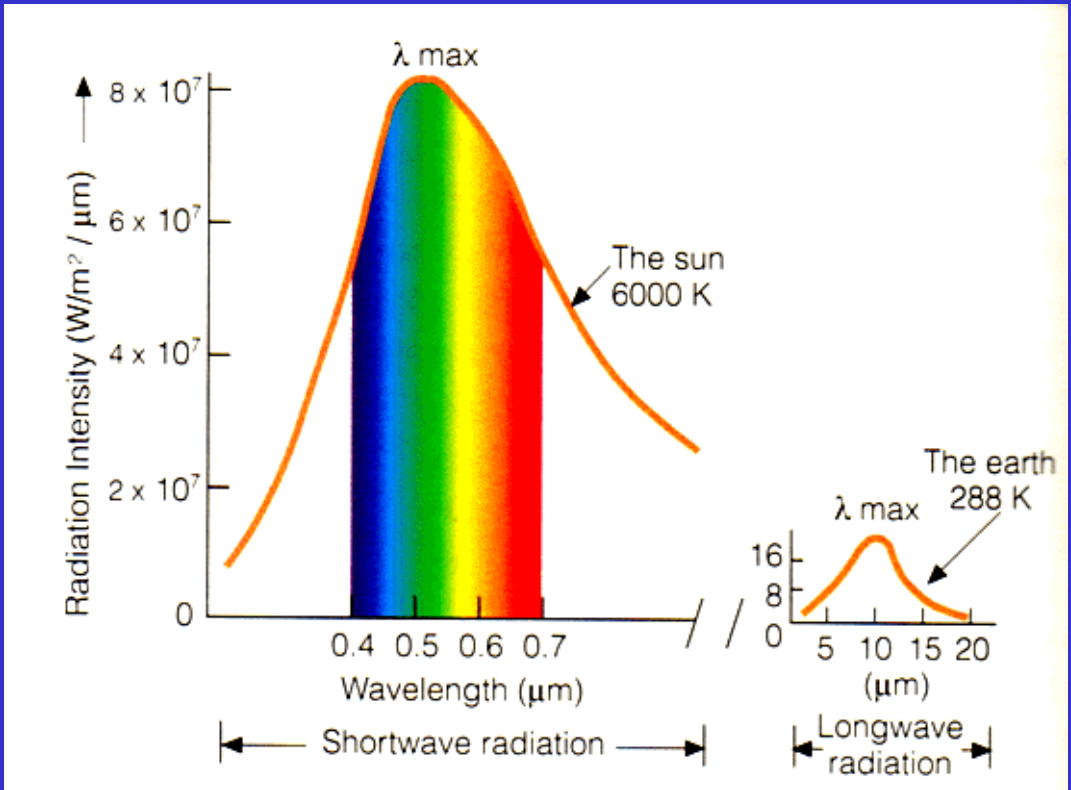
# Solar and Terrestrial Radiation




(from *Understanding Weather & Climate*)

- All objectives radiate energy, not merely at one single wavelength but over a wide range of different wavelengths.
- The sun radiates more energy than the Earth.
- The greatest intensity of solar energy is radiated at a wavelength much shorter than that of the greatest energy emitted by the Earth.

# Shortwave and Longwave Radiations




(from *Meteorology: Understanding the Atmosphere*)

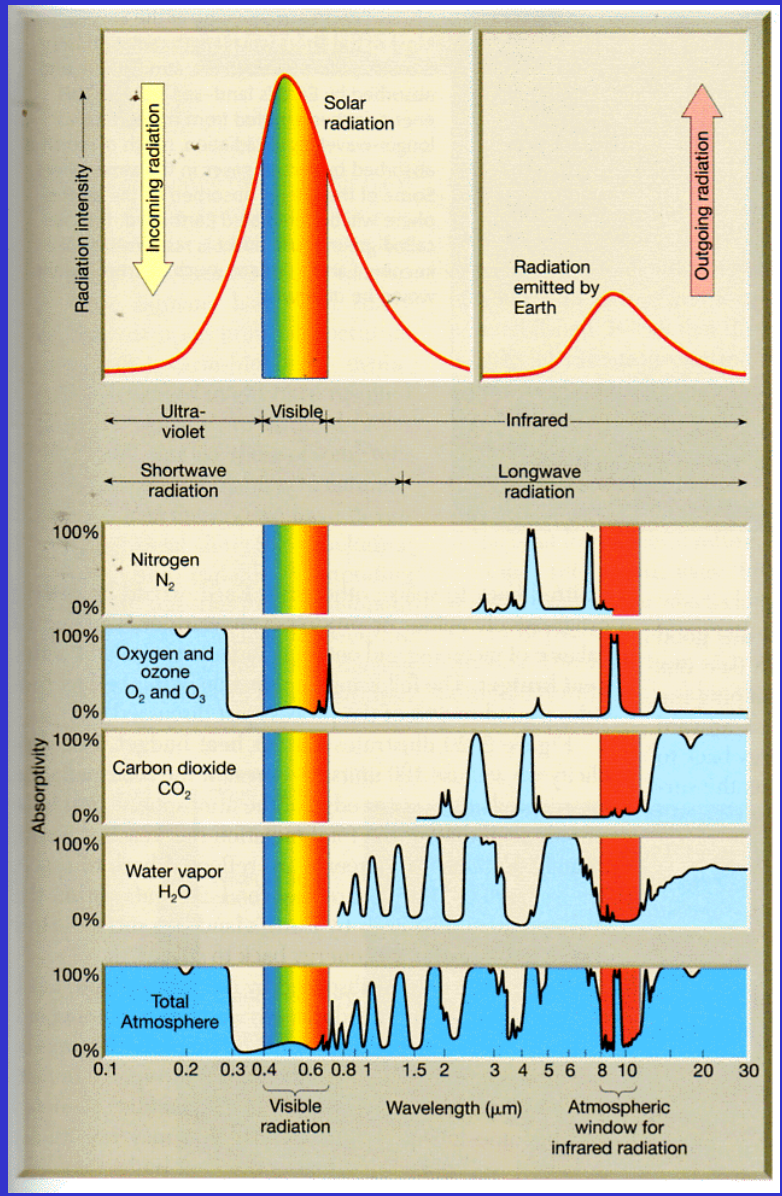
- Solar radiation is often referred to as "shortwave radiation".
- Terrestrial radiation is referred to as "longwave radiation".

# Two Key Reasons for the Greenhouse Effect

- Solar and terrestrial radiations are emitted at very different wavelengths.

- The greenhouse gases selectively absorb certain frequencies of radiation.

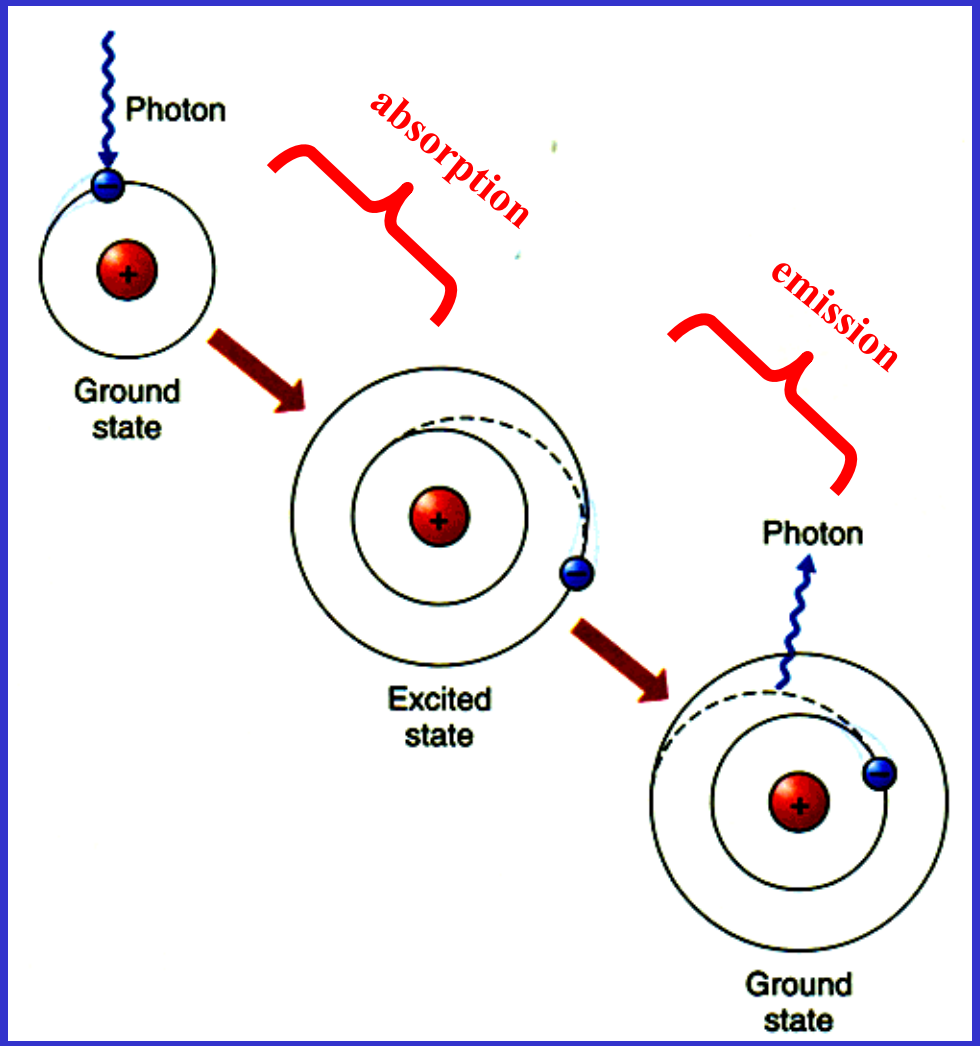
# Selective Absorption and Emission




- The atmosphere is not a perfect blackbody, it absorbs some wavelength of radiation and is transparent to others (such as solar radiation). ➔ Greenhouse effect.
- Objective that selectively absorbs radiation usually selectively emit radiation at the same wavelength.
- For example, water vapor and CO2 are strong absorbers of infrared radiation and poor absorbers of visible solar radiation.

(from *The Atmosphere*)

# Why Selective Absorption/Emission?

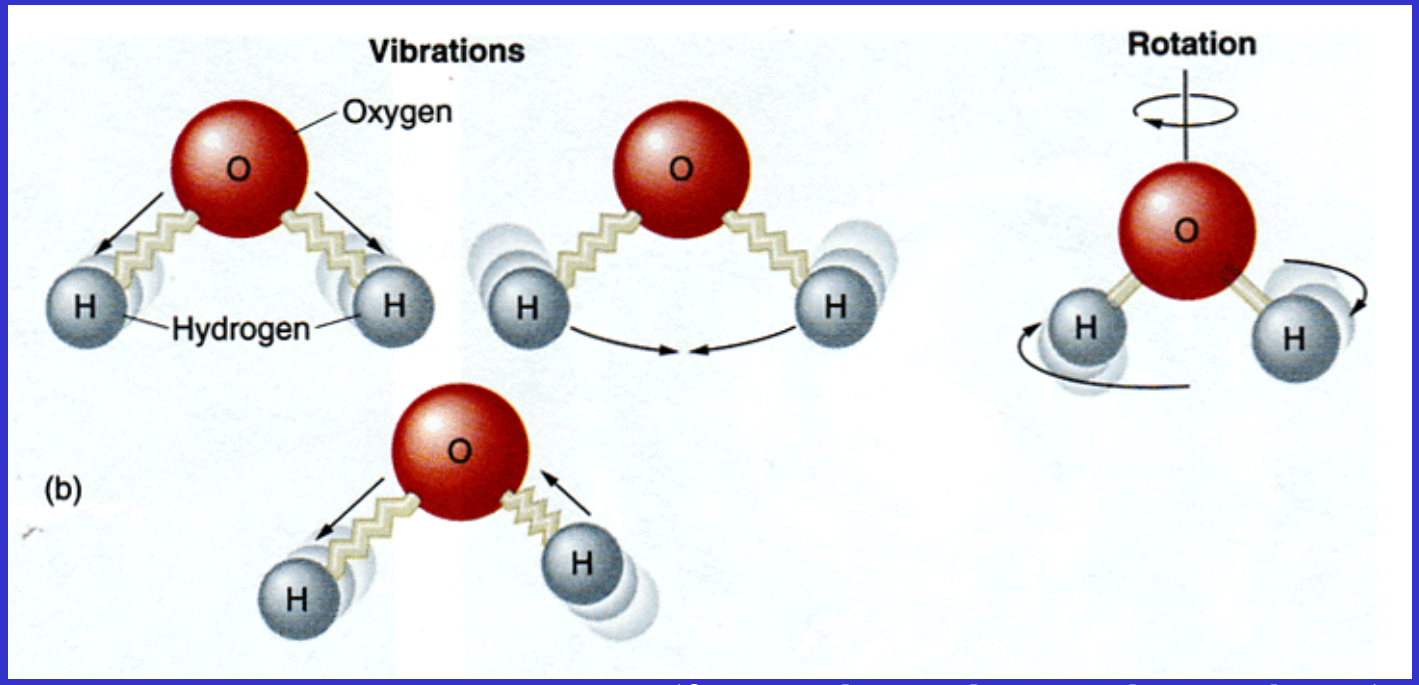



(from *Understanding Weather & Climate*)

- Radiation energy is absorbed or emitted to change the energy levels of atoms or molecular.
- The energy levels of atoms and molecular are discrete but not continuous.
- Therefore, atoms and molecular can absorb or emit certain amounts of energy that correspond to the differences between the differences of their energy levels.

➔ Absorb or emit at selective frequencies.

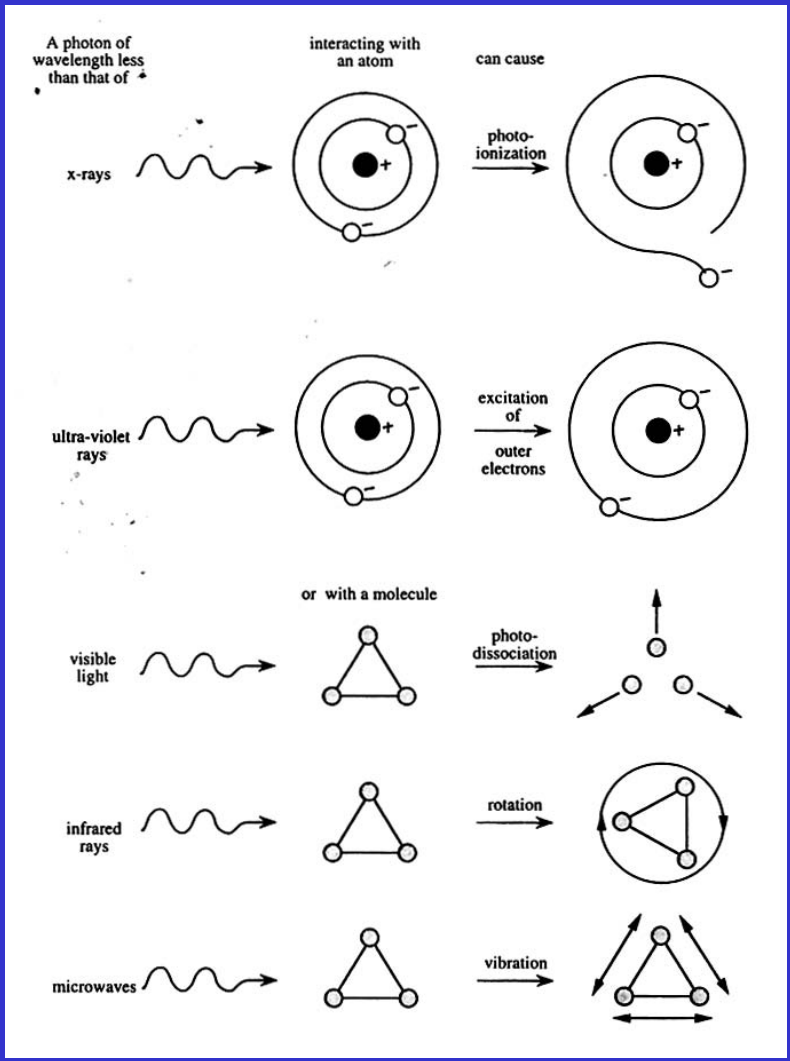
# Different Forms of Energy Levels




(from *Understanding Weather & Climate*)

- The energy of a molecule can be stored in (1) translational (the gross movement of molecules or atoms through space), (2) vibrational, (3) rotational, and (4) electronic (energy related to the orbit) forms.

# Energy Required to Change the Levels




- The most energetic photons (with shortest wavelength) are at the top of the figure, toward the bottom, energy level decreases, and wavelengths increase.

(from *Is The Temperature Rising?*)