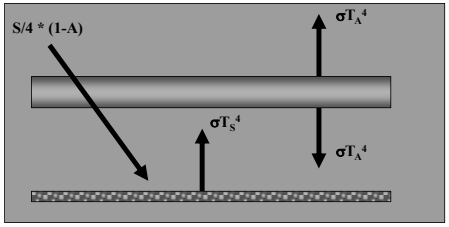
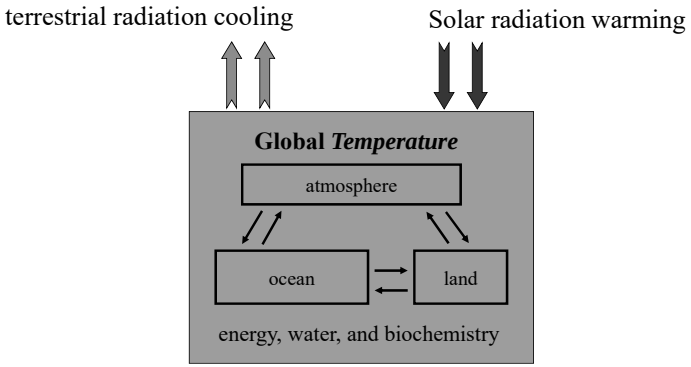
Lecture 5: Greenhouse Effect



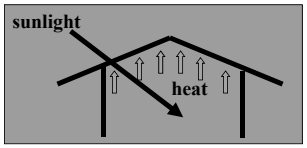
- ❑ Wien's Law
- ❑ Shortwave and Longwave Radiation
- ❑ Selected Absorption ➔ Greenhouse Effect

Global *Energy* Balance

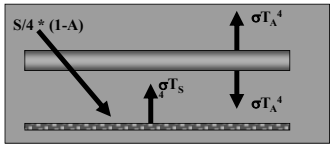


Why Is It Called "Greenhouse Effect"?

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

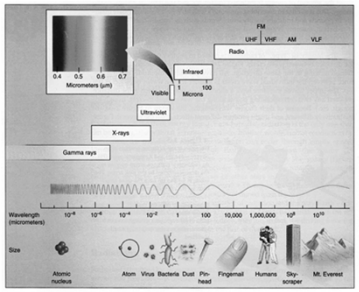


Table 2–1 Wavelength Categorizations

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.

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Micrometer (μm)

1 micrometer (μm) = 10^{-6} meter (m)

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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.

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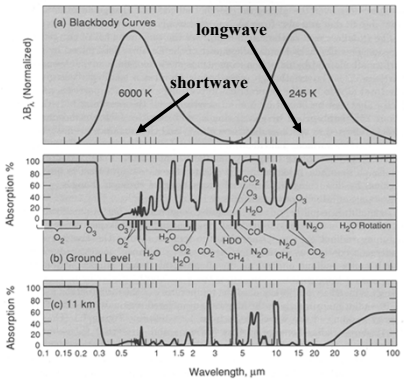
Different Wavelengths of Solar and Earth's Radiation

Normalized Planck Function



(from *Climate System Modeling*)

Planck Function

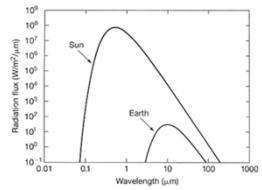


FIGURE 3-8
Blackbody emission curves for the Sun and Earth. The Sun emits more energy at all wavelengths.

(from *The Earth System*)

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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

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

λ_{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**

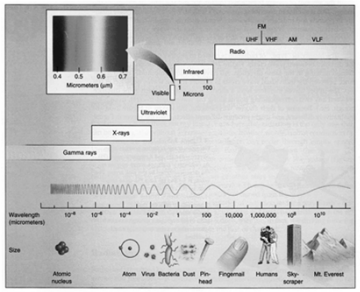
  λ_{max} = 2898 μm K / 6000K
  = 0.483 μm

- **Earth**

  λ_{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*)

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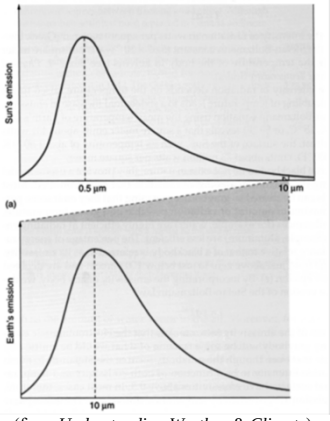
Solar and Terrestrial Radiation



(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.

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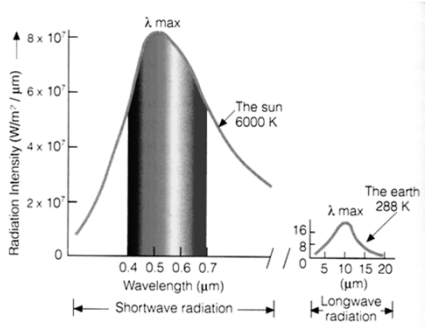
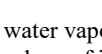
Shortwave and Longwave Radiations



(from *Meteorology: Understanding the Atmosphere*)

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



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Two Key Reasons for the Greenhouse Effect

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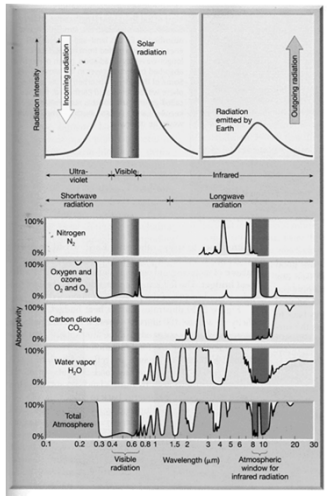
Selective Absorption and Emission



- 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*)

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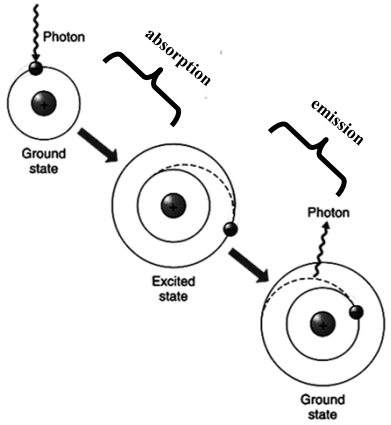
Why Selective Absorption/Emission?



(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.

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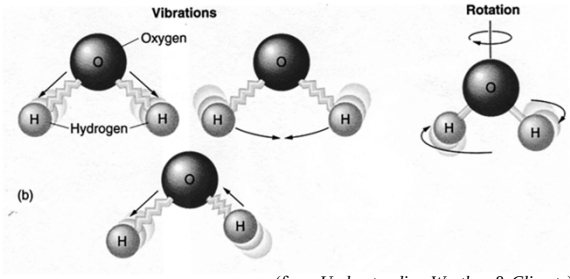
Different Forms of Energy Levels



(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.

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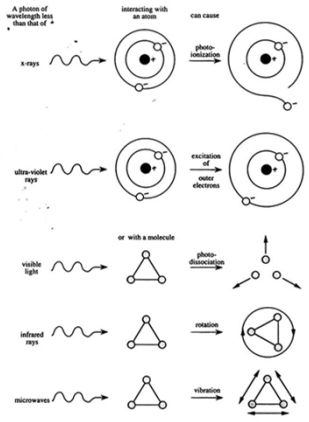
Energy Required to Change the Levels



- 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?*)

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