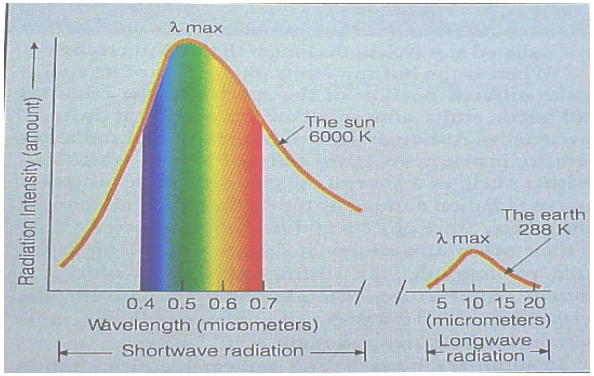
Radiation and the Planetary Energy Balance

- Electromagnetic Radiation
- Solar radiation warms the planet
- Conversion of solar energy at the surface
- Absorption and emission by the atmosphere
- The greenhouse effect
- Planetary energy balance

Spectrum of the sun compared with that of the earth



Blackbodies and Graybodies

- A blackbody is a hypothetical object that absorbs all of the radiation that strikes it. It also emits radiation at a maximum rate for its given temperature.
  - Does not have to be black!
- A graybody absorbs radiation equally at all wavelengths, but at a certain fraction (absorptivity, emissivity) of the blackbody rate

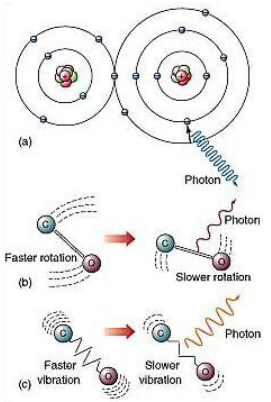
Total Blackbody Emission

- The total rate of emission of radiant energy from a "blackbody":

$$E^* = \sigma T^4$$

- This is known as the Stefan-Boltzmann Law, and the constant σ is the Stefan-Boltzmann constant (5.67×10^{-8} W m^{-2} K^{-4}).
- Stefan-Boltzmann says that total emission depends really strongly on temperature!
- This is strictly true only for a blackbody. For a **gray body**, $E = \varepsilon E^*$, where ε is called the emissivity.
- In general, the emissivity depends on wavelength just as the absorptivity does, for the same reasons: $\varepsilon_\lambda = E_\lambda / E^*_\lambda$

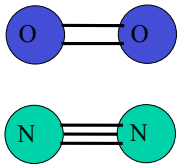
Atoms, Molecules, and Photons



- Atmospheric gases are made of molecules
- Molecules are groups of atoms that share electrons (bonds)
- Photons can interact with molecules
- Transitions between one state and another involve specific amounts of energy

Dancing Molecules and Heat Rays!

- Nearly all of the air is made of oxygen (O_2) and nitrogen (N_2) in which two atoms of the same element share electrons

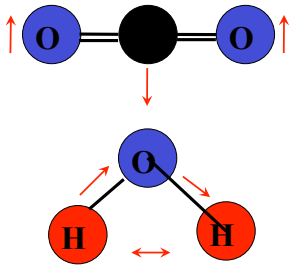


- Infrared (heat) energy radiated up from the surface can be absorbed by these molecules, but not very well

Diatomic molecules can vibrate back and forth like balls on a spring, but the ends are identical

Dancing Molecules and Heat Rays!

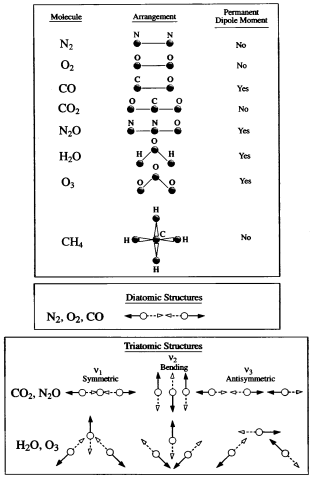
- Carbon dioxide (CO_2) and water vapor (H_2O) are different!
- They have many more ways to vibrate and rotate, so they are very good at absorbing and emitting infrared (heat) radiation



Molecules that have many ways to wiggle are called "Greenhouse" molecules

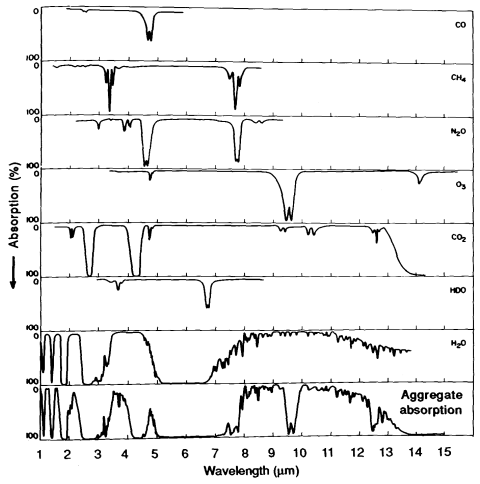
Absorption spectrum of CO2 was measured by John Tyndall in 1863

Molecular Absorbers/Emitters



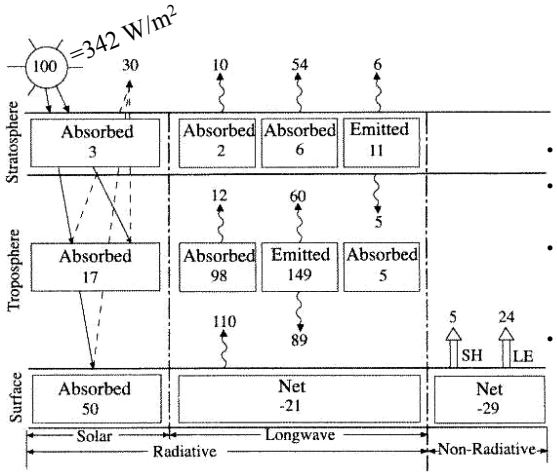
- Molecules of gas in the atmosphere interact with photons of electromagnetic radiation
- Different kinds of molecular transitions can absorb/emit very different wavelengths of radiation
- Some molecules are able to interact much more with photons than others
- Molecules with more freedom to jiggle and bend in different ways absorb more types of photons
- Water vapor (H_2O) and CO_2 are pretty good at this, and abundant enough to make a big difference!
- These are the "greenhouse gases!"

Atmospheric Absorption



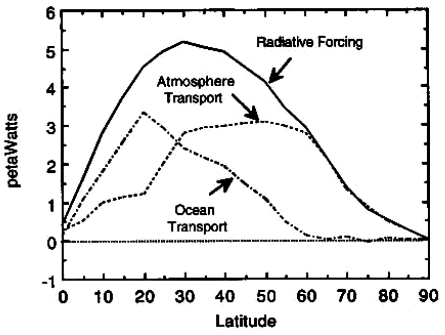
- Triatomic modelcules have the most absorption bands
- Complete absorption from 5-8 m(H_2O) and > 14 m(CO_2)
- Little absorption between about 8 m and 11 m ("window")

Planetary Energy Budget



- 4 Balances
- Recycling = greenhouse
- Convective fluxes at surface
- LE > H

Energy Transports in the Ocean and Atmosphere



- Northward energy transports in petawatts (10^{15} W)
- "Radiative forcing" is cumulative integral of R_{TOA} starting at zero at the pole
- Slope of forcing curve is excess or deficit of R_{TOA}
- Ocean transport dominates in subtropics
- Atmospheric transport dominates in middle and high latitudes

- *How are these numbers determined?*
- *How well are they known?*