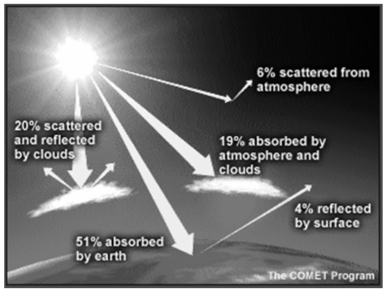
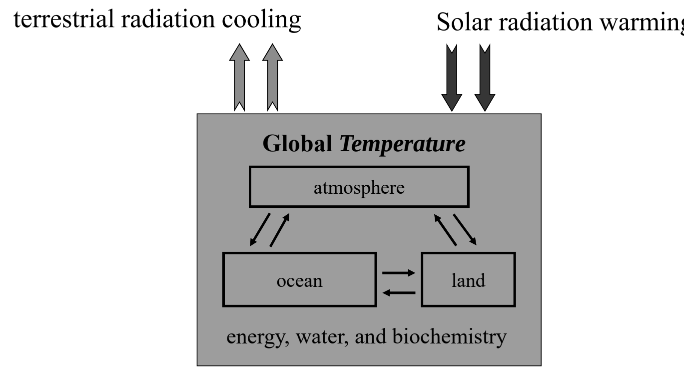
Lecture 6: Radiation Transfer



- ❑ Vertical and latitudinal energy distributions
- ❑ Absorption, Reflection, and Transmission

Global *Energy* Balance



Atmospheric Influences on Insolation

❑ **Absorption**

- convert insolation to heat the atmosphere

❑ **Reflection / Scattering**

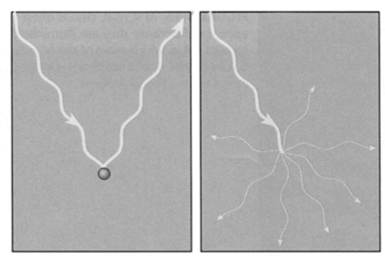
- change the direction and intensity of insolation

❑ **Transmission**

- no change on the direction and intensity of insolation

Reflection and Scattering

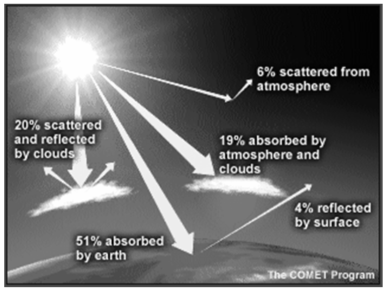
Reflection   Scattering



(from *The Atmosphere*)

- ❑ Reflection: light bounces back from an objective at the same angle at which it encounters a surface and with the same intensity.
- ❑ Scattering: light is split into a larger number of rays, traveling in different directions.
- ❑ Although scattering disperses light both forward and backward (backscattering), more energy is dispersed in the forward direction.

Where Does the Solar Energy Go?



(from NCAR/COMET website)

Incoming solar energy (100)

- 70% absorbed

  50% by Earth's surface (ocean + land)

  20% by the atmosphere and clouds

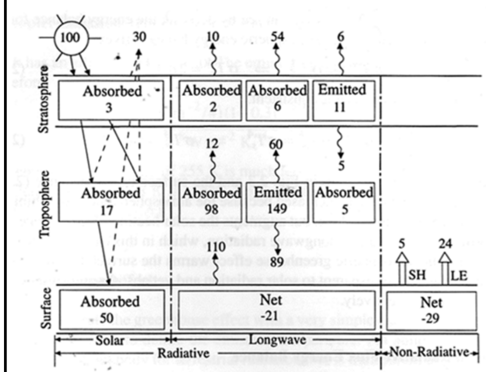
- 30% reflected and scattered back

  20% by clouds

  6% by the atmosphere

  4% by surface

Vertical Distribution of Energy



(from *Global Physical Climatology*)

Incoming solar energy (100)

- 70% absorbed

  50% by Earth's surface

  20% by atmosphere

  3% in stratosphere (by ozone and O_2)

  17% in troposphere (water vapor & cloud)

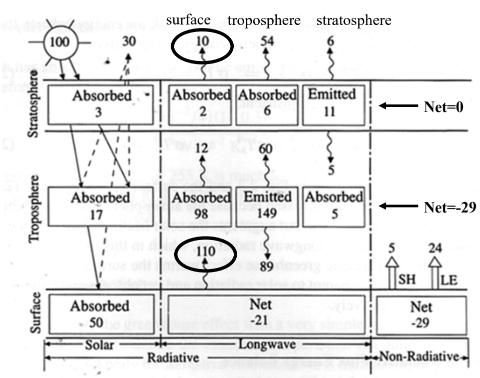
- 30% reflected/scattered back

  20% by clouds

  6% by the atmosphere

  4% by surface

Vertical Distribution of Energy



(from *Global Physical Climatology*)

Outgoing radiation (70 units)

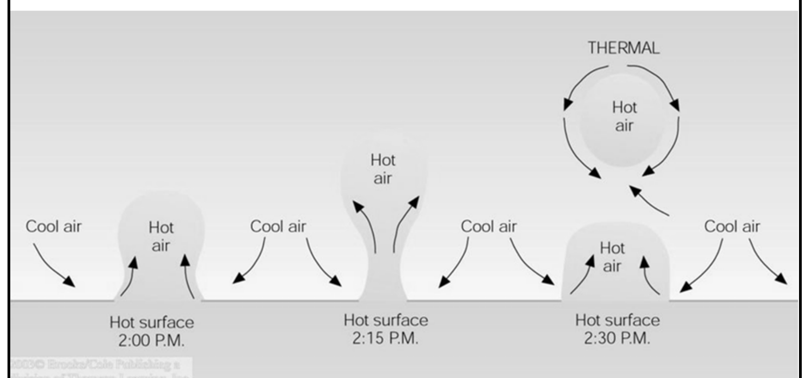
- 10 units by the surface
- 60 units by the atmosphere

  54 units by troposphere

  6 units by stratosphere

- Greenhouse effect (89 units) from the atmosphere back to the surface
- Water vapor and cloud provide 80% of the greenhouse effect

Convection in the Atmosphere.



Convection is heat energy moving as a fluid from hotter to cooler areas. Warm air at the ground surface rises as a thermal bubble, expends energy to expand, and therefore cools.

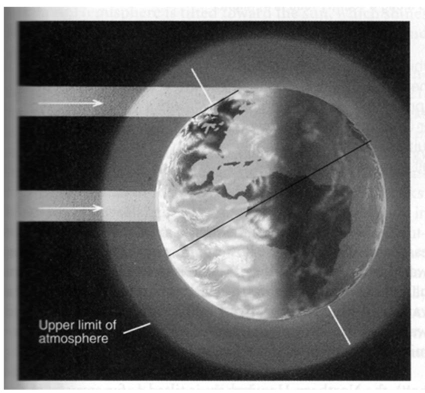
Supercell Thunderstorms

Courtesy of Bruce Lee

- ❑ Supercell thunderstorms are the most intense thunderstorms in Earth's atmosphere.
- ❑ Supercell thunderstorms always rotate.
- ❑ They account for most severe tornadoes, damaging winds, and most large hails.

❑ Most of the solar radiation is absorbed by (a) stratosphere (b) troposphere (c) Earth surface.

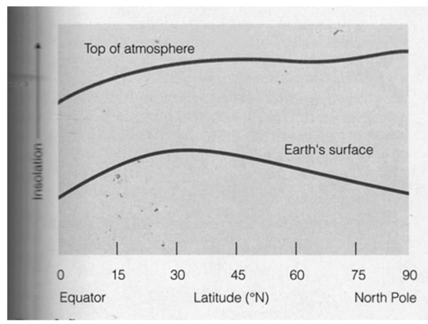
Thickness of the Atmosphere



(from *Meteorology Today*)

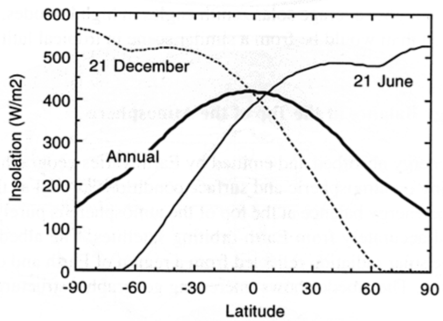
❑ The thinker the atmospheric layer, more sunlight can be reflected or scattered back to the space.

Insolation in Summer Solstice



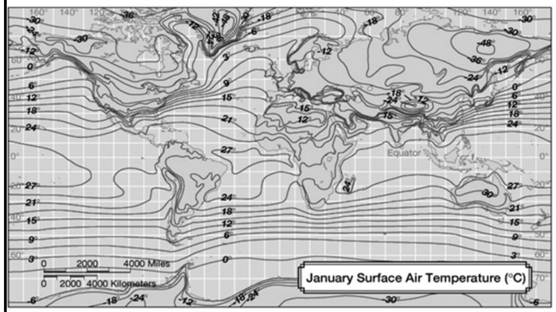
(from *Meteorology Today*)

Insolation at Top of Atmosphere



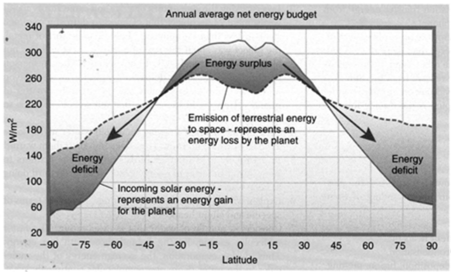
(from *Global Physical Climatology*)

The controls of Temperature



- ❑ Latitude
- ❑ Sea/land distributio
- ❑ Ocean currents
- ❑ Elevation

Latitudinal Variations of Net Energy

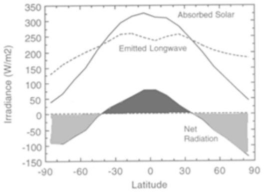


(from *Meteorology: Understanding the Atmosphere*)

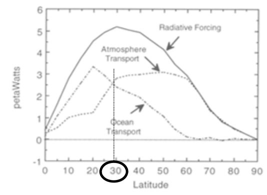
- ❑ Polarward heat flux is needed to transport radiation energy from the tropics to higher latitudes.

Polarward Energy Transport

Annual-Mean Radiative Energy



Polarward Heat Flux



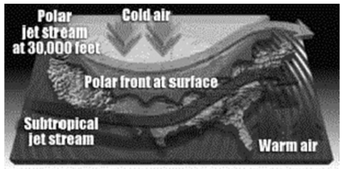
Polarward heat flux is needed to transport radiative energy from the tropics to higher latitudes

The atmosphere dominates the polarward heat transport at middle and high latitudes. The ocean dominates the transport at lower latitudes.

(figures from *Global Physical Climatology*) **(1 petaWatts = 10^{15} W)**

How Do Atmosphere and Ocean Transport Heat?

Atmospheric Circulation



(from USA Today)

Ocean Circulation

(top from *The Earth System*)
(bottom from USGCRP)

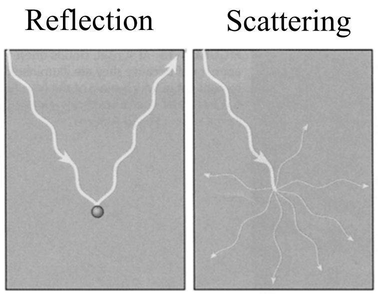
Atmospheric Influences on Insolation

- **Absorption**
  - convert insolation to heat the atmosphere

color of the sky

- **Reflection / Scattering**
  - change the direction and intensity of insolation
- **Transmission**
  - no change on the direction and intensity of insolation

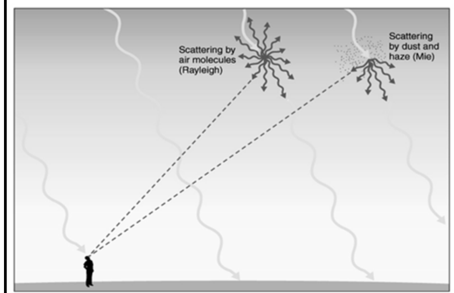
Reflection and Scattering



(from *The Atmosphere*)

- ❑ Reflection: light bounces back from an objective at the same angle at which it encounters a surface and with the same intensity.
- ❑ Scattering: light is split into a larger number of rays, traveling in different directions.
- ❑ Although scattering disperses light both forward and backward (backscattering), more energy is dispersed in the forward direction.

Scattering

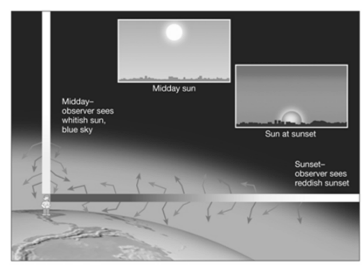


- ❑ Scattering is a process whereby a beam of radiation is broken down into many weaker rays redirected in other direction.
- ❑ Gases in the atmosphere effectively scatter radiation.
- ❑ Characteristics of scattering are dependent upon the size of the scattering agents: (1) Rayleigh Scattering, (2) Mie Scattering, (3) nonselective Scattering.

Rayleigh Scattering (Gas Molecules)

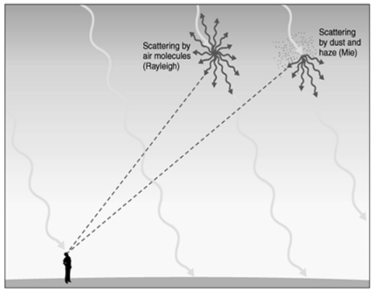
- ❑ Involves gases, or other scattering agents that are smaller than the energy wavelengths.
- ❑ Scatter energy forward and backward.
- ❑ Violet and blue are scattered the most, up to 16 times more than red light.
- ❑ Responsible for (1) blue sky in clear days, (2) blue tint of the atmosphere when viewed from space, (3) why sunsets/sunrises are often yellow, orange, and red.

Scattering and Colors



- ❑ Short wavelengths (blue and violet) of visible light are scattered more effectively than longer wavelengths (red, orange). Therefore, when the Sun is overhead, an observer can look in any direction and see predominantly blue light that was selectively scattered by the gases in the atmosphere.
- ❑ At sunset, the path of light must take through the atmosphere is much longer. Most of the blue light is scattered before it reaches an observer. Thus the Sun appears reddish in color.

Mie Scattering (Aerosols)



- Larger scattering agents, such as suspended aerosols, scatter energy only in a ***forward*** manner.
- Larger particles interact with wavelengths across the visible spectrum.
- Produces hazy or grayish skies.
- Enhances longer wavelengths during sunrises and sunsets, indicative of a rather aerosol laden atmosphere.

- The blue sky is caused by the

(a) absorption (b) reflection (c) scattering (d) transmission of solar radiation.