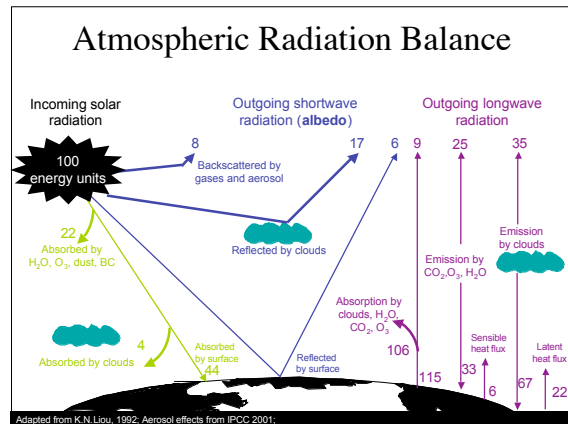
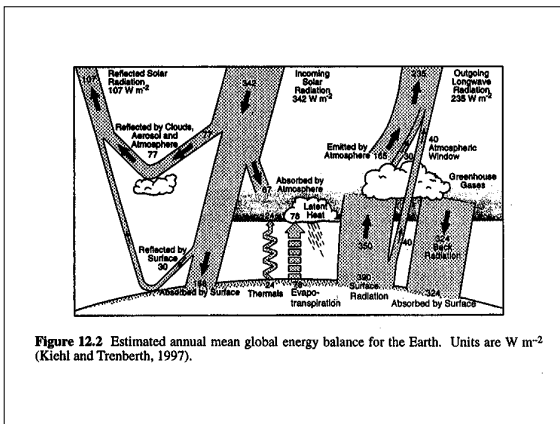
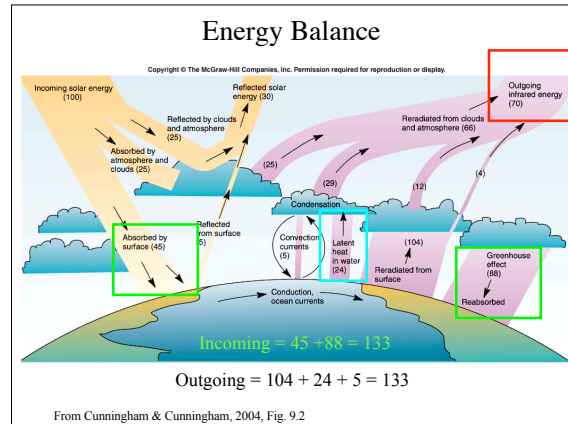


Lecture Ch. 3b

- Simplified climate model
 - Assumptions
 - Calculations
 - Cloud sensitivity
 - Effect of an atmosphere
- Absorption coefficient
- Optical thickness
- Heat transport

Curry and Webster, Ch. 3; Ch. 12 pp. 331-337; also Liou, 1992
For Tuesday, 10/14: Read Ch. 4

For Tuesday, 10/14: Homework Ch. 3, pp.94-95: 1,2,3



Simplified Climate Model

- Atmosphere described as one layer
 - Albedo $\alpha_p \sim 0.31$: reflectance by surface, clouds, aerosols, gases
 - Shortwave flux absorbed at surface $F_s = 0.25 \cdot S_0 (1 - \alpha_p)$
- Earth behaves as a black body
 - Temperature T_e : equivalent black-body temperature of earth
 - Longwave flux emitted from surface $F_l = \sigma T_e^4$

Curry and Webster, Ch. 12 pp. 331-337; also Liou, 1992

Absorption and Emission

Note that whereas the disposition of solar radiation is dominated by absorption and scattering, thermal radiation is dominated by emission and absorption.

The rate of transfer of energy by electromagnetic (em) radiation is called *radiant flux* (units are joules per second, $J s^{-1}$, or watts, W). The radiant flux incident on a unit area is called the *irradiance* ($W m^{-2}$), denoted by E . The irradiance per unit wavelength interval, centered on wavelength λ , is denoted by E_λ ($W m^{-2} \mu m^{-1}$).

- Emissivity – the irradiance from the body divided by the irradiance from a blackbody at the same temperature
- Absorptivity – the amount of irradiance absorbed divided by that absorbed by a blackbody (perfect absorber).

Absorption by Molecules

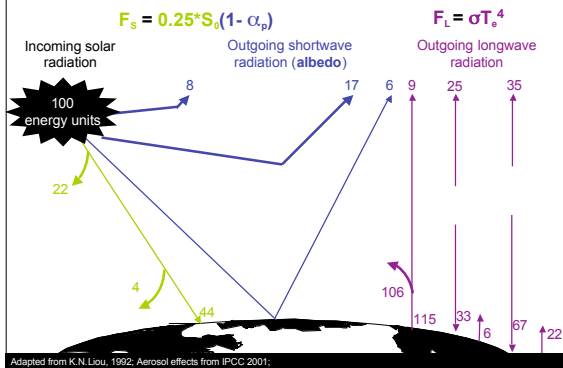
- Occurs only when incident photon has same energy as difference between two energy states
 - States may differ in rotation, vibration or electronic
 - Result may not be chemical, e.g. heating (GHGs)

Consequences of Absorption

- Molecules may lose absorbed photon's energy by several mechanisms
 - Dissociation (breaks apart)
 - Direct reaction (excited molecule reacts with other molecule)
 - Isomerization (internal rearrangement of bonds to make more stable)
 - Collision (losing energy to other molecules w/o chemical changes)
 - Internal energy transfer
 - Luminescence (fluorescence or phosphorescence: emission of a photon)
 - Photoionization (ejection of an electron to form an ion)

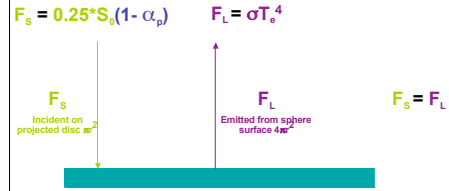
Photolysis -- general word describing chemical changes from reactions initiated by light, regardless of the detailed mechanism

Atmospheric Radiation Balance



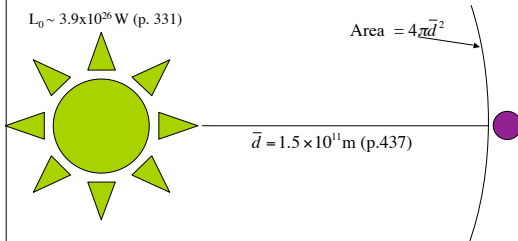
Simplified Climate Model

- Incoming shortwave = Outgoing longwave
- Energy absorbed = Energy emitted



Solar Constant

- Luminosity of the sun
- Irradiance at earth $S_0 = L_0 / (4\pi d^2) = 1.4 \times 10^3 \text{ W/m}^2$

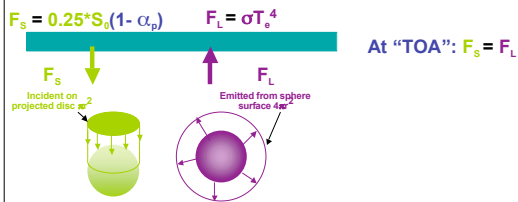


Simplified Climate Model: First 2 Assumptions

- Atmosphere described as one layer
 - Albedo $\alpha_p \sim 0.31$: reflectance by surface, clouds, aerosols, gases
 - Shortwave flux absorbed at surface $F_s = 0.25 * S_0 * (1 - \alpha_p)$
- Earth behaves as a black body
 - Temperature T_e : equivalent black-body temperature of earth
 - Longwave flux emitted from surface $F_L = \sigma T_e^4$

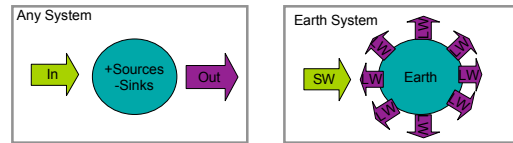
Simplified Climate Model

- Incoming shortwave = Outgoing longwave
- Energy absorbed = Energy emitted



Energy Balance

$$\text{Energy In} = \text{Energy Out} + \text{Sources} - \text{Sinks}$$



- As a 1st approximation, there are no continuous sources or sinks of energy on Earth (only temporary storage, e.g. ocean)
 - Energy In (Shortwave) = Energy Out (Longwave)

Thermal Equilibrium is the name of this assumption

Simplified Climate Model

- At thermal equilibrium (what happens if not?)

$$F_s = F_L$$

$$0.25 \cdot S_0 (1 - \alpha_p) = \sigma T_e^4$$

$$T_e = [0.25 \cdot S_0 (1 - \alpha_p) / \sigma]^{0.25}$$

$$T_e \sim 255K$$

- Observed surface temperature $T = 288K$
- What's missing?

Sensitivity to Albedo

- What if albedo changes?

$$T_e = [0.25 \cdot S_0 (1 - \alpha_p) / \sigma]^{0.25}$$

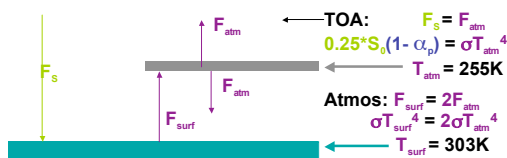
$$\alpha_p = 0.31, T_e \sim 255K$$

$$\alpha_p = 0.30, T_e \sim ?$$

- 1% decrease in albedo warms temperature 1K
- 1% increase in albedo cools temperature 1K

Add an Atmosphere!

- Atmosphere is transparent to non-reflected portion of the solar beam
- Atmosphere in radiative equilibrium with surface
- Atmosphere absorbs all the IR emission



What's (still) wrong?

- With no atmosphere, $T_{surf} = 255K$
- With "atmosphere", $T_{surf} = 303K$
- From observations, $T_{surf} = 288K$
- Real atmosphere:
 - Not perfectly transparent to incoming solar (20 unit absorbed by atm.)
 - Not perfectly opaque to infrared (12 unit "window")
 - Not in pure radiative equilibrium with surface (23 units latent heat)
- Three assumptions were wrong -- but we got very close by adding the greenhouse effect of the atmosphere.

2008 ROAST Topics

Constrained self-assembly rule: Each group needs at least 4 people before any group can have 5 people.

Group A: Recent Advances in Measuring Cloud Albedo with Satellites. C&W 3, 5, 12.

Group B: Recent Advances in Simulating Cloud Albedo with GCMs. C&W 3, 5, 12.

Group C: Recent Advances in Satellite Measurements of Aerosol Albedo. C&W 3, 5.1-5.2, 8.1.

Group D: Recent Advances in Geoengineering Ideas for Controlling Cloud Albedo. C&W 3, 5, 12.

N.B. Your 1st step is to refine these topics as a group, and you are encouraged to ask me questions in this process.