Lecture Ch. 12a

- Review of simplified climate model
- Current research
  - Aerosols, precipitation, and evaporation
- Course evaluations

Curry and Webster, Ch. 12
For Tuesday: Read Ch. 13
For Dec 6: Review Past Homework, Quizzes, Reading, Midterm

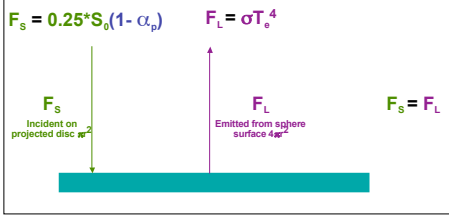
Simplified Climate Model

- Atmosphere described as one layer
  - Albedo α_p~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 $F_L=\sigma T_e^4$

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

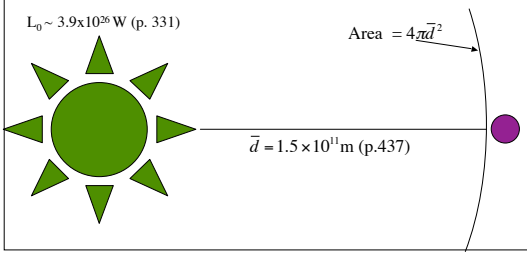
Simplified Climate Model

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



Solar Constant

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



Simplified Climate Model

- At thermal equilibrium (why?)

$$F_S = F_L$$
$$0.25*S_0(1-\alpha_p) = \sigma T_e^4$$
$$T_e = [0.25*S_0(1-\alpha_p)/\sigma]^{0.25}$$
$$T_e \sim 255K$$

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

Sensitivity to Albedo

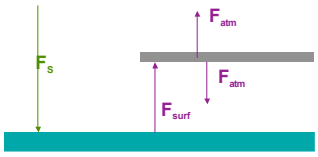
- What if albedo changes?

$$T_e = [0.25*S_0(1-\alpha_p)/\sigma]^{0.25}$$
$$\alpha_p=0.31,\ T_e \sim 255K$$
$$\alpha_p=0.30,\ T_e \sim ?$$

- 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



TOA: $F_s = F_{atm}$

$0.25*S_0(1-\alpha_p) = \sigma T_{atm}^4$

$T_{atm} = 255K$

Atmos: $F_{surf} = 2F_{atm}$

$\sigma T_{surf}^4 = 2\sigma T_{atm}^4$

$T_{surf} = 303K$

What's 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
  - Not perfectly opaque to infrared
  - Not in pure radiative equilibrium with surface

- Three assumptions were wrong!

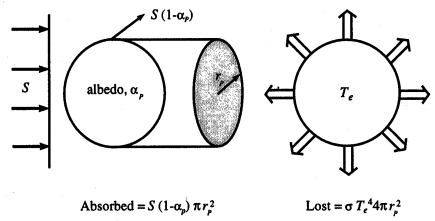
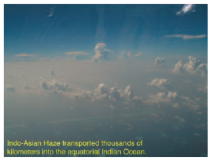
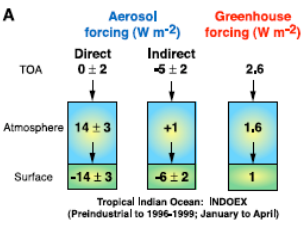


Figure 12.1 Radiative energy balance of the Earth. The Earth absorbs energy from the sun and loses energy through longwave emission.

Current Research: Radiation

- Large surface cooling: -20 W m^{-2}
  - Reduces evaporation, short-circuiting precipitation

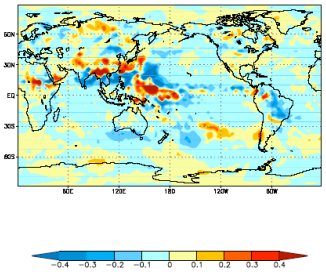




Ramanathan et al., 2001

Current Research: Global Models

- Aerosol impacts on rain are not local



Change in JJA mean precipitation (mm day-1) between the 6-year perturbation and the 12-year control.

Erlick, Ramaswamy, and Russell, 2005

Vol 435|30 June 2005|doi:10.1038/nature03671 nature

PROGRESS

Strong present-day aerosol cooling implies a hot future

Meinrat O. Andreae[1], Chris D. Jones[2] & Peter M. Cox[3]

"…aerosols counteract warming by an uncertain, but potentially large, amount…Strong aerosol cooling would imply that future global warming may proceed at *or even above* the upper extreme of the range projected by the IPCC."