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 $\alpha_p \approx 0.31$: 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

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

$$F_S = F_L$$

Sensitivity to Albedo

- What if albedo changes?
  - $T_e = [0.25 S_0 (1- \alpha_p)]^{1/4}$
  - $\alpha_p = 0.31$, $T_e \approx 255 K$
  - $\alpha_p = 0.30$, $T_e \approx ?$

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

\[
\text{TOA: } F_\text{atm} = F_\text{surf} \\
0.25^\circ \text{S} \{1- \alpha_p\} = \sigma T_{\text{atm}}^4 \\
T_{\text{atm}} = 255K
\]

\[
\text{Atmos: } F_{\text{atm}} = 2F_{\text{surf}} \\
\sigma T_{\text{surf}}^4 = 2\sigma T_{\text{atm}}^4 \\
T_{\text{surf}} = 303K
\]

What’s wrong?

- With no atmosphere, \( T_{\text{surf}} = 255K \)
- With "atmosphere", \( T_{\text{surf}} = 303K \)
- From observations, \( T_{\text{surf}} = 288K \)

- Real atmosphere:
  - Not perfectly transparent to incoming solar
  - Not perfectly opaque to infrared
  - Not in pure radiative equilibrium with surface
- Three assumptions were wrong!

Current Research: Radiation

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

![Radiative energy balance of the Earth](image)

Absorbed = \( S \{1- \alpha_p\} \sigma T_{\text{surf}}^3 \)
Lost = \( \sigma T_{\text{surf}}^4 \)

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.

Ramanathan et al., 2001

Current Research: Global Models

Strong present-day aerosol cooling implies a hot future

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"...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."
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