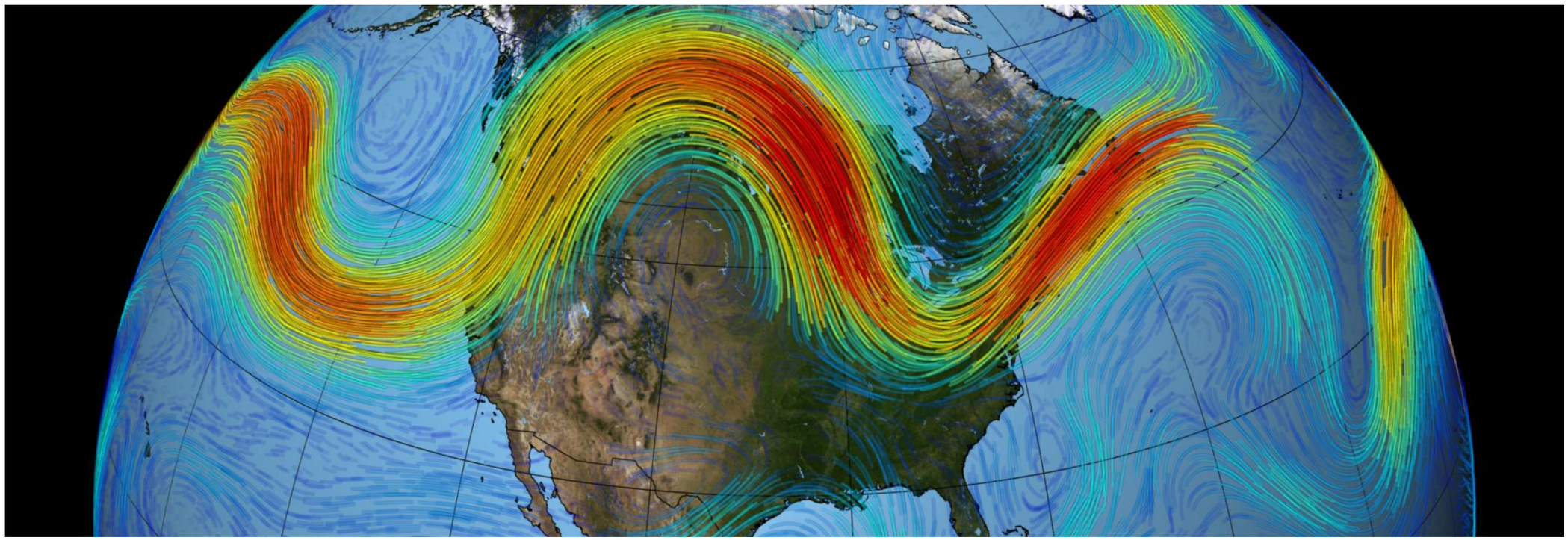
Climate Dynamics
Lecture 11



Fall 2025

J Noronha-Hostler

https://jnoronhahostler.github.io/IntroductionToComputationalPhysics/intro.html

Announcements

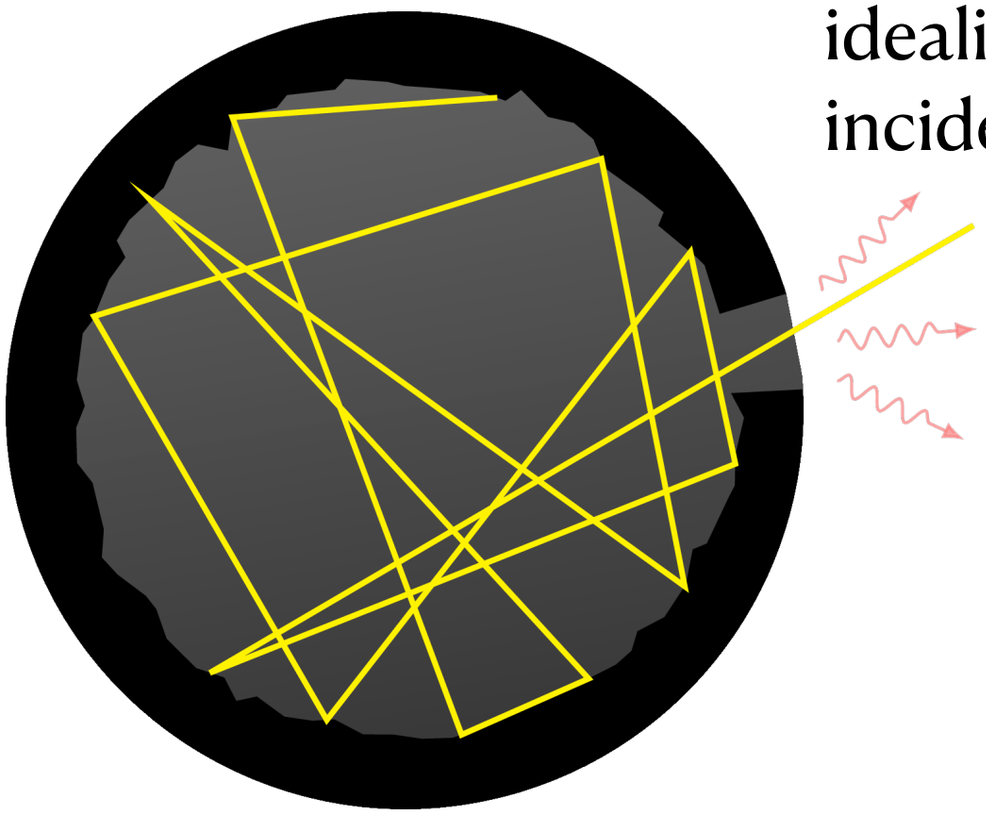
- I’ll need to leave early this week and will be traveling next week.
-

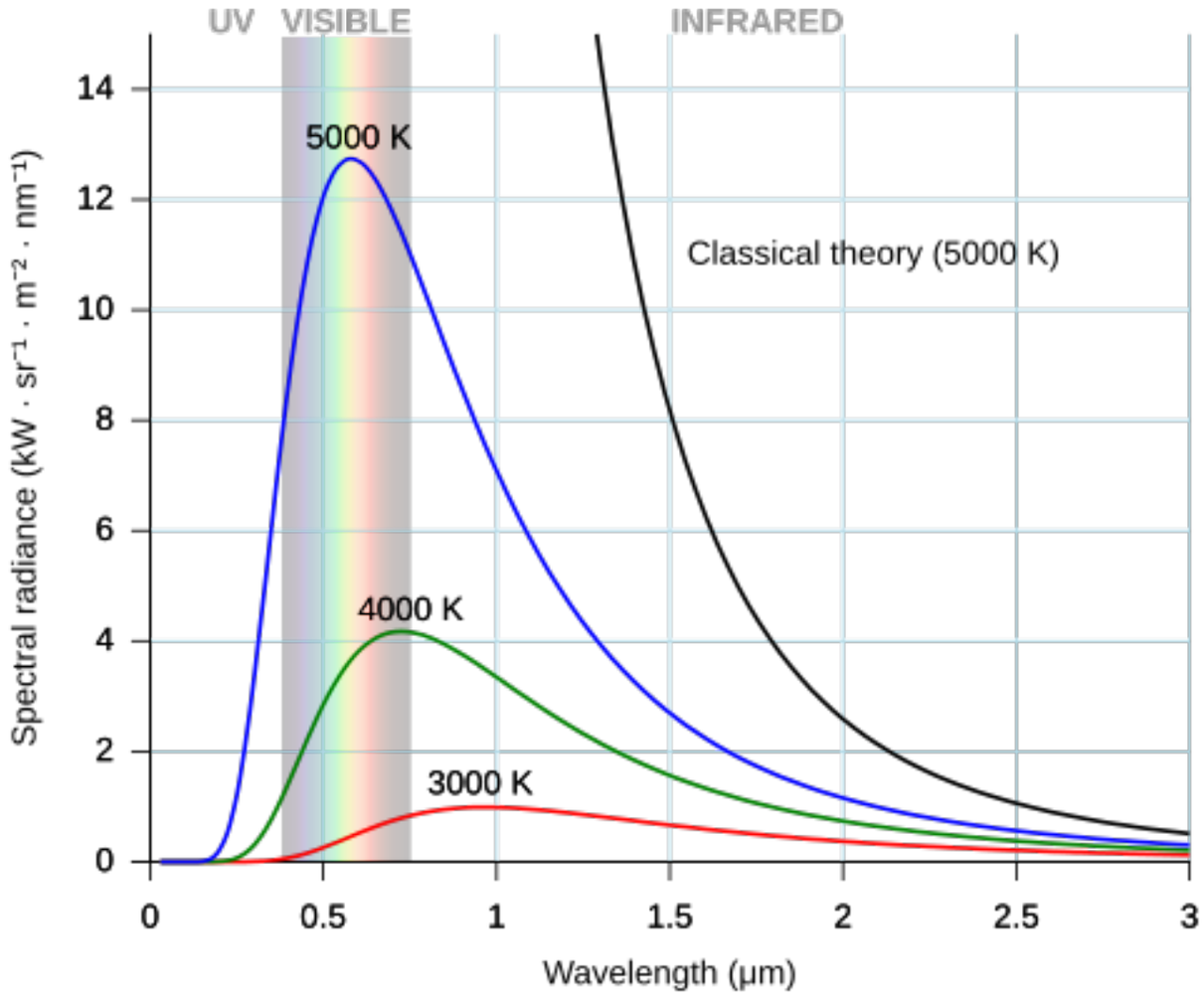
Final Guidance

- Teams up to 4 people
- Small coding project
- Presentations ~5 minutes
- Graded on:
    - Presentation skills: Intro, methodology, results, conclusions
    - Working code
    - Shared work responsibilities
- Date/Time: Wednesday 17 December at 1:30 PM
- Location: **32 psychology**

Black Body Radiation

idealized physical body that absorbs all incident electromagnetic radiation





Stefan-Boltzmann law:

$$\frac{P}{A} = \sigma T^4$$

σ Stefan-Boltzmann constant

P/A total energy per unit of time per unit of surface area

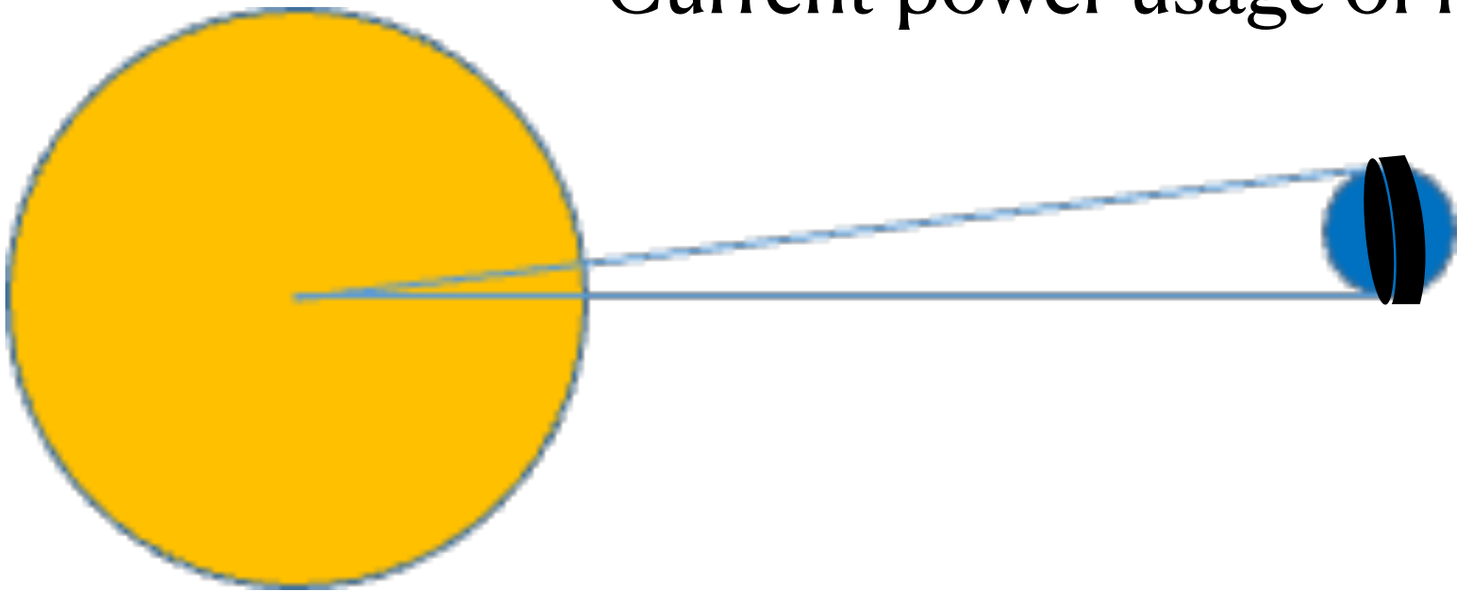
Earth-Sun thermodynamic system

Sun as a blackbody $P_{sun} = \sigma_{SB} T_s^4 A_{sun} = 3.6 \times 10^{26}\text{W}$

Earth as a blackbody $P_{\text{earth}} = \sigma_{SB} T_e^4 4\pi R_e^2 = 2 \times 10^{17}\text{W}$

$$\frac{P_{\text{incident}}}{A_{\text{earth}}} = P_{\text{sun}} \frac{\pi R_e^2}{4\pi d_e^2} = 1.6 \times 10^{17}\text{W}$$

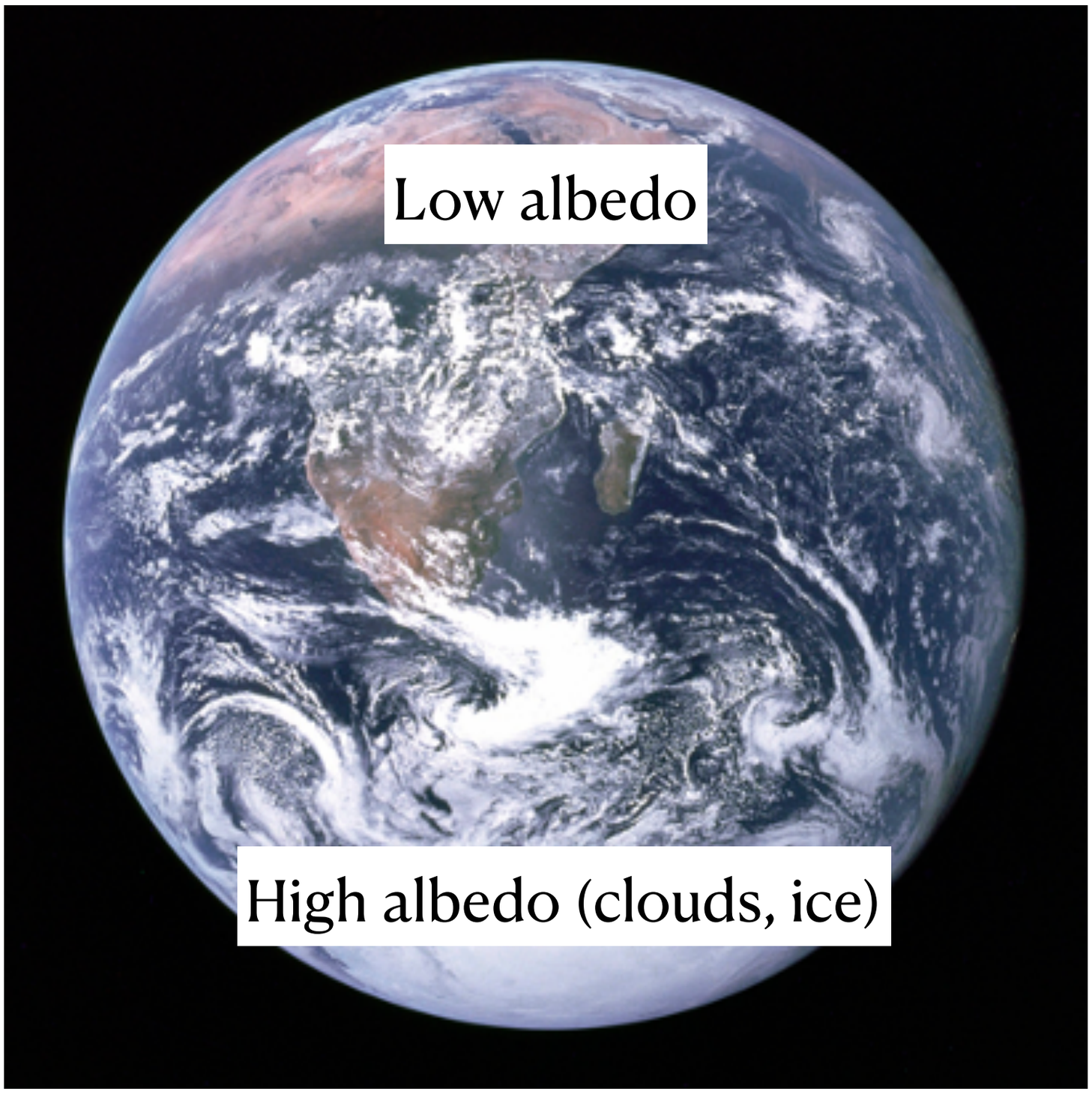
Current power usage of humanity: $1.7 \times 10^{13}\text{W}$



Sun "sees" a disk of

$A_{Earth} = 4\pi R^2$

Albedo (reflection due to clouds etc)

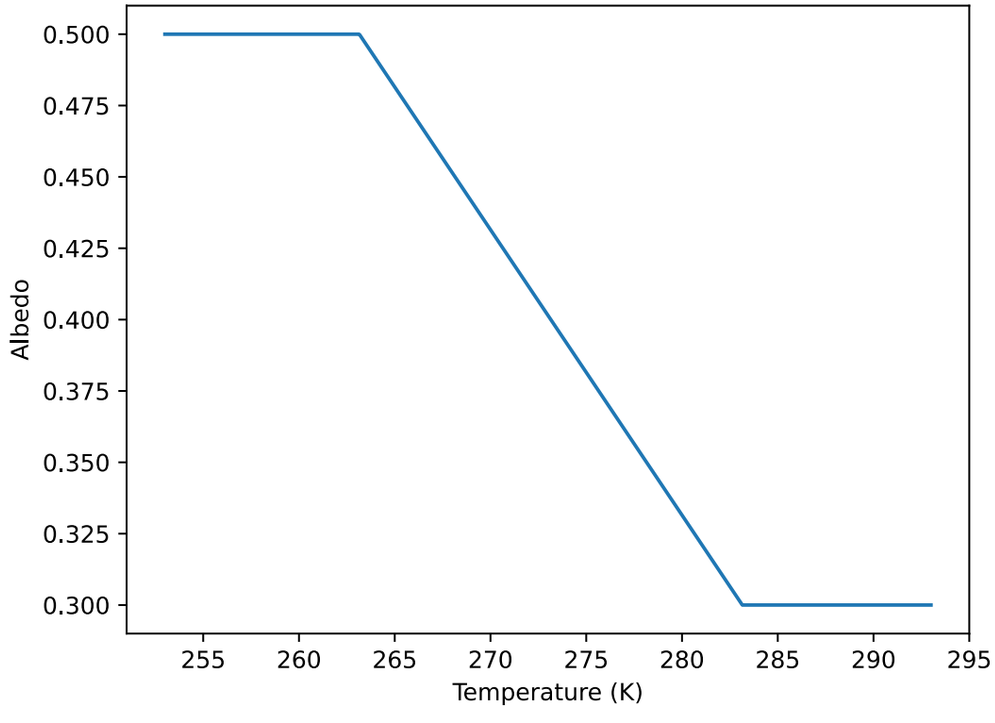


Models:

a) On average around 0.3 (30%) of the visible light incident on the Earth is reflected back out. (ex 1)

b) Slow freezing of ice (ex 2)

c) Abrupt freezing of ice (ex 3)



Greenhouse Effect

The Earth is emitting a huge amount of infrared radiation!

Some of that is blocked by the atmosphere and the heat is kept instead of radiating out to space.

Models:

a) $P_{emit}/A = \epsilon\sigma_{SB}T_e^4$ (ex 1a,b)

b) $\frac{P_{emit}}{A} = A + BT_e$ (ex 1c, 2, 3)

c) $\frac{P_{emit}}{A} = A + BT_e + r\log\left(\frac{\rho}{\rho_0}\right)$ (ex 1d)

Models

Exercise 1:

a) What if the Sun and Earth were complete blackbodies (it would be cold)

b) Add in albedo and effect of greenhouse gases

c) Modify greenhouse gases a bit

d) Incorporate changing CO_2 through 'forcing'

Exercise 2: Feedback loops

a) Time dependence of the climate

b) Effect of ice on albedo

c) Hysteresis

Exercise 3: Latitude dependence

a) Latitude dependent insolation and albedo

b) Latitude dependent temperature

c) Heat diffusion through the latitudes

Time dependence/equilibrium

$$C\frac{dT}{dt} = P_{in} - P_{out}$$

Discussion: what is equilibrium?

Snowball Earth