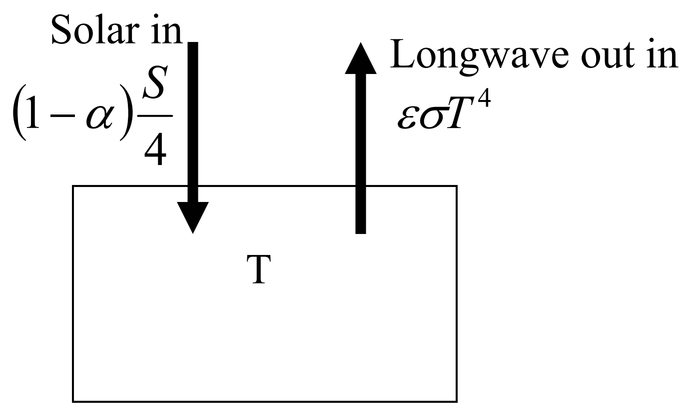
ATOC 7500: The Art of Climate and Environmental Modeling

Week 1 Lab Assignment
Energy Balance Model

Construct an energy balance model (EBM) for the Earth. The energy balance should take into account shortwave radiation coming in from the Sun, and longwave radiation going out. This is most simply described as a single "box" for which temperature is the only variable.



The change in temperature is thus given from the 1st Law of Thermodynamics by:

$$C_p \frac{dT}{dt} = (1-\alpha)\frac{S}{4} - \varepsilon\sigma T^4 \qquad (1)$$

Where C_p is the heat capacity (which is specific heat capacity times mass, p_s/g), S is the solar constant σ is the Stefan-Boltzman constant (5.67×10^{-8} W/m^2/K^4), ε is the emissivity, and α is the planetary albedo.

Construct a numerical scheme to solve the time evolution of the temperature, by approximating the derivative with a finite difference in time.

Question for discussion and experiments:

1) What is the radiative equilibrium temperature of Earth?
2) How does this depend on the choice of the time step?
3) Change the heat capacity so as to model the upper 70 meters of the ocean rather than the atmosphere ($C_p = 2.95\times10^8$ J/K). Does the equilibrium temperature change?
4) Is the mean temperature the same if there is a diurnal cycle? Annual cycle? "Glacial" cycle?
5) If the sun should stop, how long does it take for the temperature to become a factor of e^{-1} its equilibrium value (i.e., what is the e-folding time), for both the atmosphere and upper ocean?
6) How can the e-folding time be found analytically from (1)?
7) What are some limitations of this model, and what are their consequences?
8) How would you construct a coupled atmosphere-ocean model with this level of complexity?