Energy balance model

Building models

- What is the actual problem?
- How much complexity?
  (i.e., define scope)
- What are the state variables?
  (i.e., define system)
- Are there conservation laws?
- Are there rules for changes in state variables?
  (i.e., what is the mathematical model)
- How should this be implemented in a computer?
  (i.e., discrimination, numerical methods)
- What are useful diagnostics?
  (i.e., output that is needed to answer science objective)
- How do you test the model is correct?
- How do you double check the model is correct?

Global energy balance model

- i.e., radiative equilibrium

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

Allows us to predict global mean temperature if we know the albedo, emissivity and the solar constant

Time stepping

- Can write change as: change in state over some time
- That is, a ***finite difference***

$$\frac{dT}{dt} \approx \frac{T_{future} - T_{now}}{\text{time difference}} = \frac{T_{future} - T_{now}}{\Delta t}$$

- As such, we can make a prediction for one (small) time step (Δt)
- The advance in time (future becomes now) by one time step

$$T_{future} = T_{now} + \Delta t \frac{dT}{dt}$$

- and start again…

This is an integration of the differential equation in time.

Today's objectives

1. How to log onto atoc
2. How to write and compile a Fortran program
3. How to write and compiler a useful Fortran program

4. Think about some experiments with your shiny new EBM

Remember use class web site and our wiki as a first source of help.

Experiments/discussion

- What is the radiative equilibrium temperature of Earth?
- Does this depend on the choice of the time step?
- Change the heat capacity so as to model the upper 70 meters of the ocean rather than the atmosphere (Cp = 2.95x108 J/K). Does the equilibrium temperature change?
- Is the mean temperature the same if there is a diurnal cycle? Annual cycle? "Glacial" cycle?
- 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?
- How can the e-folding time be found analytically from (1)?
- What are some limitations of this model, and what are their consequences?
- How would you construct a coupled atmosphere-ocean model with this level of complexity?

For next Tuesday's class