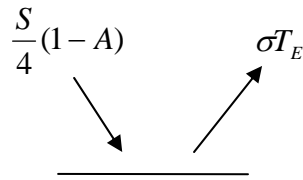


Homework 1: System Fundamentals and Daisyworld

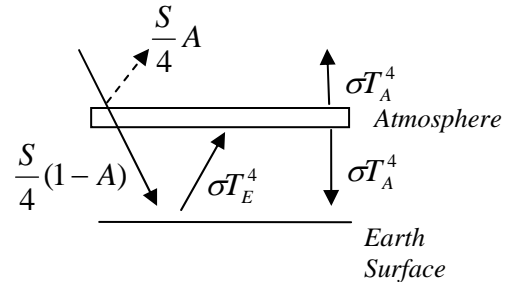
General Questions

- 1) First, a quick review of converting between the three commonly used temperature scales: Celsius versus Fahrenheit versus Kelvin. In this class we usually use Celsius.
- Write the formula for converting from Fahrenheit to Celsius
 - Write the formula for converting from Kelvin to Celsius
 - For each temperature, provide its counterpart in Celsius or Fahrenheit. Note: there is a typo in the textbook for the conversion from Celsius to Fahrenheit. The correct formula is $T_F = (9/5 * T_C) + 32$
 - 71.6°F (the average July temperature in Madison for 1971-2000)
 - 17.3°F (the average January temperature in Madison for 1971-2000)
 - 98.6°F (typical healthy body temperature)
 - 25°C (room temperature)
 - a 1.4°C *difference* between two temperatures, i.e. $T_1 - T_2$ (IPCC2001's low-end projection for increases in 21st-century global mean temperatures)
 - a 5.8°C *difference* between two temperatures (IPCC2001's high-end projection for 21st-century temperature increases)
- 2) Describe and sketch a systems diagram for two systems – not from book or lecture -- one with a positive feedback and the other with a negative feedback. Your examples do not have to be limited to the earth system. Include in your description a clear statement of the *state variables* in the system and the mechanisms represented by each coupling.
- 3) **Extra Credit.** In class we calculated that the earth's surface temperature at radiative equilibrium was $T_E = 255\text{K}$ (below left diagram). This calculated temperature, however, is lower than the actual surface temperature (288K) because it ignores the ability of the atmosphere to trap outgoing radiant heat (i.e. the Greenhouse Effect). A more realistic model (below right) includes a 1-layer atmosphere that partially reflects sunlight back into space (cooling the earth) but also absorbs and reradiates outgoing longwave radiation (warming the earth). Construct two energetic balances ($I=O$), one for the surface and one for the atmosphere, and use these to calculate T_A and T_E . $S=1370 \text{ W/m}^2$. $A=0.3$.

In this model, the atmosphere does not absorb any sunlight, but does reflect some sunlight back to space (so that $S/4(1-A)$ passes through to the surface and $S/4(A)$ is reflected to space. The atmosphere has both a downward and upwards flux, each equal to σT^4 . (Note your calculated T_E will be $>288\text{K}$. This is because our simple model incorrectly assumes that the atmosphere absorbs all outgoing radiation from the earth.) General Circulation Models typically have ~20 atmospheric layers and much more realistic physics!



Energy Balance Model,
No Atmosphere



Energy Balance Model,
1-layer atmosphere

Daisyworld

Introduction

The parable of Daisyworld, introduced by James Lovelock in the 1980's, is highly useful for showing how internal feedbacks within a system can strongly modulate the response of the system. The story: Daisyworld orbits a sun that, like our own, is slowly increasing in luminosity, i.e. the amount of energy it emits. (When the earth first formed, ca. 4.5 billion years ago, the luminosity of our sun was about 70% of its present value.)

Daisyworld has only one species, a white daisy, that grows on an otherwise barren dull gray soil. Daisies grow best at 22.5°C but can tolerate temperatures between 5°C and 40°C. Daisyworld has a neighboring planet, Barrenworld, with no daisies or other life. As you'll see, Daisyworld and Barrenworld surface temperatures respond very differently to changes in solar luminosity.

Exercise

- 1) Go to: <http://gingerbooth.com/courseware/daisy>
- 2) Click on 'Discussion' for more background information.
- 3) Run the Daisyworld model: Click on 'Scenario' then 'White Daisies'. Observe closely the two plots – the top plot shows the changes in daisy area as solar luminosity increases; the bottom plot shows the changes in temperature as daisy area increases

Questions

- 1) Sketch a curve showing the response of Barrenworld temperatures to the long-term changes in solar luminosity. Explain the processes causing the observed Barrenworld response.
- 2) Sketch a curve representing the growth response of daisies to temperature. Label axes. (hint: see Details).
- 3) What key property of daisies allows them to (unintentionally) co-regulate surface temperatures?
- 4) Sketch two system diagrams representing the Daisyworld feedback loop. This feedback loop should include the following state variables: planetary albedo, daisy

extent, and surface temperature. The first diagram should represent the growth response of daisies to increases in temperature at temperatures *below* 22.5°C; the second diagram should represent the growth response of daisies to increases in temperature *above* 22.5°C.

- 5) As Daisyworld output shows, the %area covered by daisies shows a steady increase, followed by a rapid crash. Explain this phenomenon.
- 6) Based on your answers to question 1-5 what happens to Daisyworld temperatures when solar luminosity increases? Why is the Daisyworld temperature response different from Barrenworld?

Further Exploring (*Optional – not part of handed-in assignment*)

- 1) Try the 'Black and White' scenario, then move to scenarios with more and more daisies. What changes?
- 2) Pursue the suggestions in the Questions section.

Truly Hard Core (*Optional*)

Work through the Details section, making sure you understand the basic equations underlying the Daisyworld model. Use a graphical calculator or Excel to plot out some of the key formulas.