Daisy World Assignment

Learning Objectives:

- Explore homeostasis on Daisy World, i.e. how it self regulates it global temperature;
- Understand the faint-young sun paradox; Make graphs and discuss their meaning;
- Understand that small changes in external forcing can sometime lead to large changes in climate state;
- Learn how positive and negative feedback processes can control system behavior.

1. Description of Daisy World

Acknowledgement: Much of the text in sections 1 through 3 is taken from http://stress.swan.ac.uk/~mbarnsle/teaching/envmod/pdf/em-chapter14.pdf

The following description of Daisy World is taken from Hardisty *et al.* (1993): Daisy World is an imaginary planet, with a transparent atmosphere, free from clouds and greenhouse gases. The planet is flat, resulting in similar changes in temperature with changing solar luminosity (energy from the sun) and albedo being experienced simultaneously over its surface, and does not experience any seasonality in climate. The composition of the planet's biota is similarly lacking in complexity: two species of daisies occur as discrete populations; one dark (black), the other light (white) in color. In addition a species of herbivores grazes the daisies in a non-selective manner (*i.e.,* they show no preference for black or white daisies) and is responsible for recycling of any organic material. The herbivores do not, however, exert any other measurable effect on the system and are thus are not further considered here. Conditions on Daisy World are suitable for the growth of daisies over the entire surface of the planet.

2. Assumptions of the Model

The model makes a number of fundamental assumptions about the functioning of the system, namely:
1. The rate of population change for both species of daisy depends on the death rate and the potential birth rate for that species, and the amount of fertile land available for growth.

2. The birth rate for both species of daisy depends on the local temperature near each daisy type.

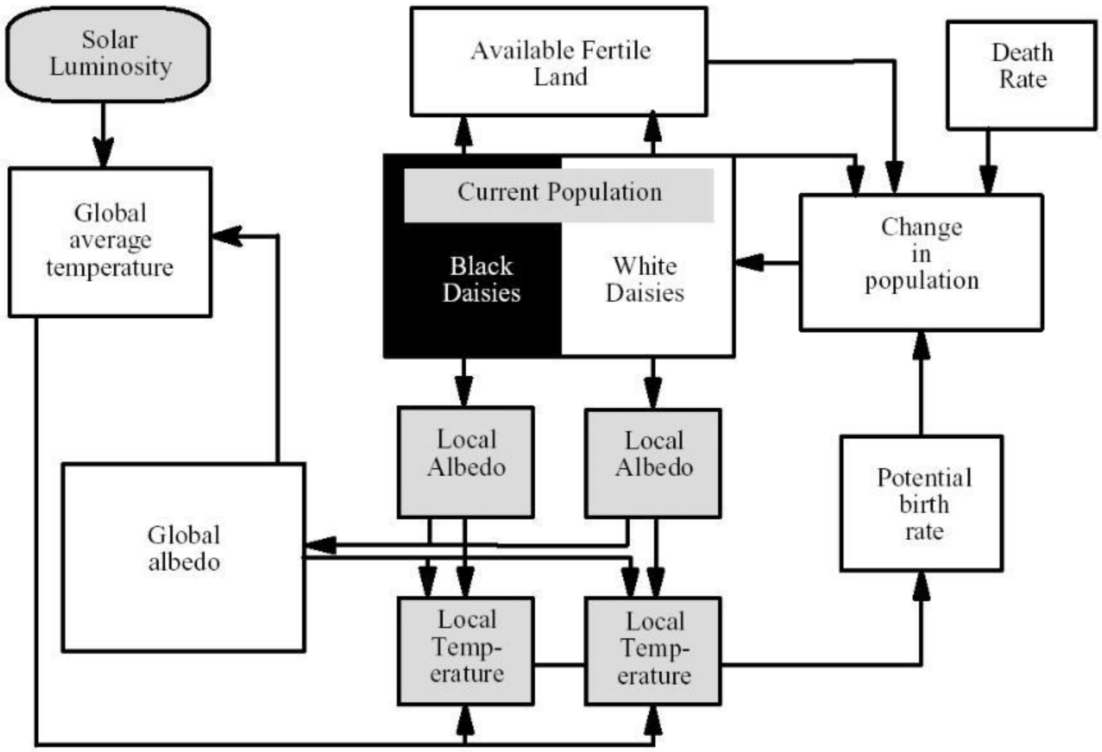
3. The local temperature depends on the difference between the global and local albedo, and on the global temperature. If the local albedo is large then the local temperature is less than the global temperature.

4. The global temperature depends on the luminosity of the Sun and the planetary albedo.

5. The planetary albedo is the sum of the local albedo components (*i.e.*, the albedo of the black and white daisies and of the bare ground). Albedo of White Daisies is 0.75 , Black 0.25, and bare ground 0.50.

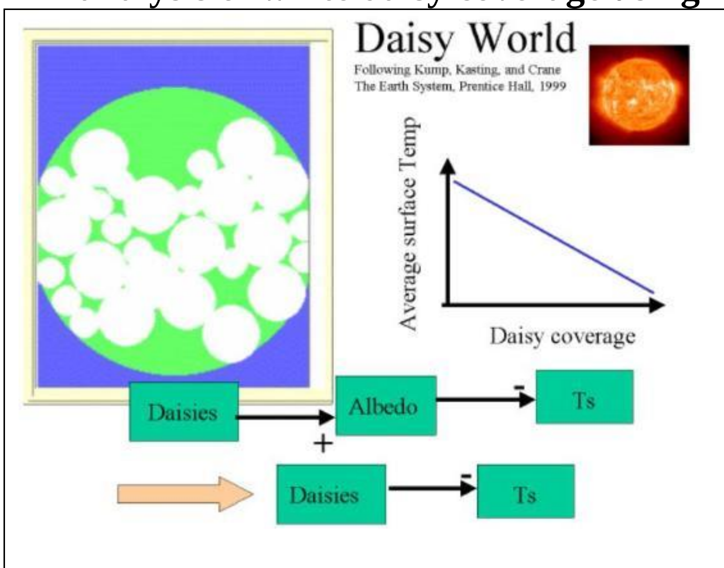
6. The amount of fertile land available for further growth of the black and white daisies depends on the total amount of fertile land (fixed) and the total coverage the two species of daisy.

3. Graphical Representation of the Daisy World Model.



4. An analysis Daisy World using feedback loops.

An analysis of white daisy coverage using feedback loops. (Figure 1 of 3)



White daisies reflect more sunlight than bare ground, so as white daisies grow the planetary albedo increases and the planetary temperature decreases.

The reverse is also true.

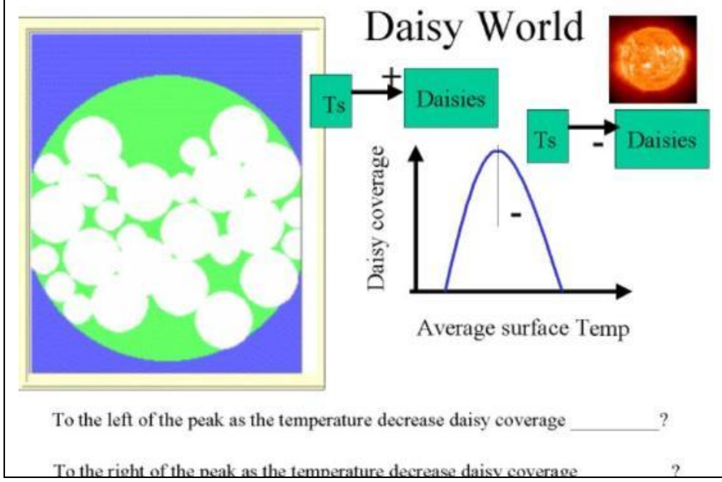
As white daisies die the planetary albedo decreases and the planetary temperature increases.

*The positive connection between daisies and albedo indicates that as white daisies increase albedo increases and as white daisies decrease albedo decreases.

*The negative connection between albedo and temperature indicates that as albedo increase temperature decreases and as albedo decrease temperature increases.

***Notice (+)(- = (-)**

An analysis of white daisy coverage using feedback loops. (Figure 2 of 3)

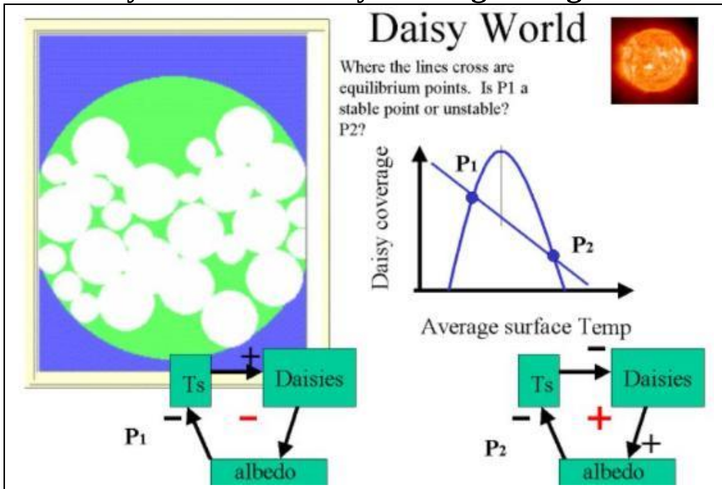


There is an optimum temperature for daisy growth.
* To the left of the graph's peak increasing local average temperature causes increase in daisy coverage. (it ***was*** too cold)

* To the right of the graph's peak increasing local average surface temperature causes decrease in daisy coverage (it ***becomes*** too hot)

This figure also applies to black daisies in regard to the local average surface temperature near them.

An analysis of white daisy coverage using feedback loops. (Figure 3 of 3)



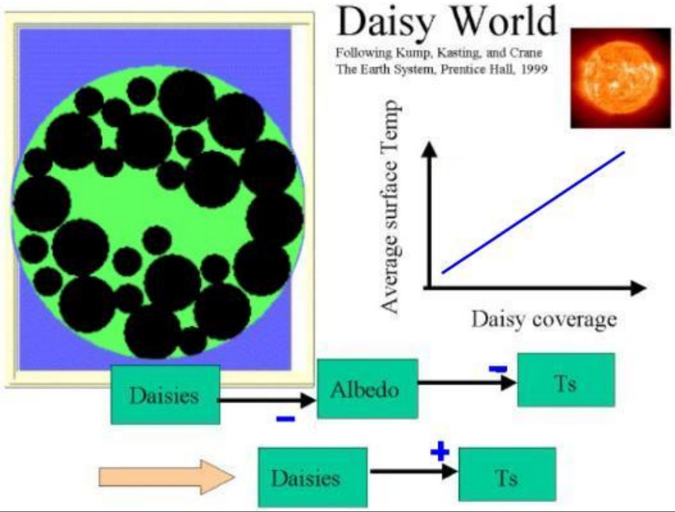
Combining the ideas from the last two figures.

To left of graph's peak: An increase in temperature causes more white daisy growth, an albedo increase, and a temperature drop towards its original value. **OR** A decrease in temperature causes reduced white daisy coverage, an albedo decrease, and a temperature increase towards its original value. (negative loop is stable)

To right of graph's peak: An increase in temperature causes reduced white daisy coverage, an albedo decrease, and a temperature increase further away from its original value. **OR** A decrease in temperature causes more white daisy coverage, an albedo increase, and a temperature decrease further away from its original value. (positive loop: unstable)

5. **Assignment: Part 1.** Whenever missing, fill in the appropriate statement, draw sketches, graphs, connections, and loop diagrams similar to those for white daisies above except for black daisies.

An analysis of Black daisy coverage using feedback loops. (Figure 1 of 3)



Black daisies absorb more sunlight than the bare ground so as the black daisies grow the planetary

albedo _____________ and the planetary

temperature__________________.

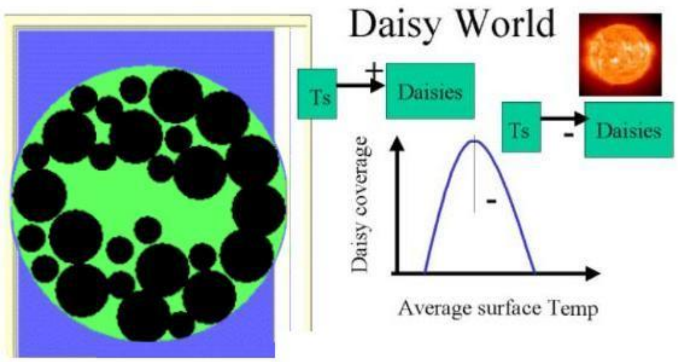
The reverse is also true.

As black daisies die the planetary albedo

___________________ and the planetary

temperature _________________.

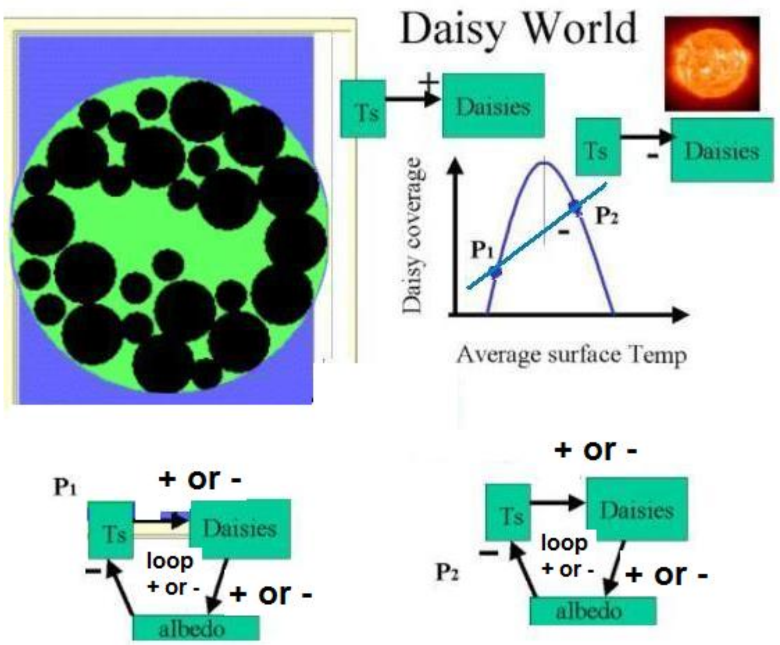
An analysis of Black daisy coverage using feedback loops. (Figure 2 of 3)



There is an optimum temperature for black daisy growth.
* To the left of the graph's peak increasing local average temperature causes increase in daisy coverage. (it was too cold)

* To the right of the graph's peak increasing local average surface temperature causes decrease in daisy coverage (it becomes too hot)

An analysis of black daisy coverage using feedback loops. (Figure 3 of 3) Complete all missing parts of the text to the right for black daisies. Your answers should be as detailed as those in Fugure 3 of 3 above for white daisies.

	Combining the ideas from the last two figures. To left of graph's peak: An increase in temperature causes ___________ black daisy growth, an albedo _____________, and a temperature _______________ its original value. **OR** A decrease in temperature causes ___________ black daisy coverage, an albedo _____________, and a temperature ___________________ its original value. (__________ loop is ____________) To right of graph's peak: An increase in temperature causes ___________ black daisy growth, an albedo _____________, and a temperature _______________ its original value. **OR** A decrease in temperature causes ___________ black daisy coverage, an albedo _____________, and a temperature ___________________ its original value. (__________ loop is ____________)

Part 2. To complete the table below watch the youtube video **Daisy1** .

L (fraction)	Avg Planet Temp (C)	Area of White Daisies (%)	Area of Black Daisies (%)	A, Planetary Albedo	Absorbed Solar [L * (1-A)]
0.60					
0.65					
0.70					
0.75					
0.80					
0.85					
0.90					
0.95					
1.00					
1.05					
1.10					
1.15					
1.20					
1.25					
1.30					

Questions Part 2.

What is the smallest value of L that initiates daisy growth?________________

For smaller values of L is the planet too hot or too cool for daisy grow? _______________

Which color of daisies first begin to grow?_______________

Is the local temperature in the Black daisy fields warmer or cooler than that in the white daisy fields?

____

What is the largest value of L before daisies stop growing?________________

For larger values of L is the planet too hot or too cool for daisy grow? _______________

As the solar luminosity increases which color of daisies are the last to stop growing?_______________

Graphs for Part 2.
Using Excel (or some other means like graphing by hand), make graphs of:
a. Average planet Temperature on the Y axis vs. Solar Luminosity L on the X- axis.
On this graph draw a horizontal line by hand from the beginning to the end of the stable climate region
Insert graph here
b. Area of Black and White daisies both on the Y axis vs. Solar Luminosity L on the X- axis.

Insert graph here
c. Planetary Albedo on the Y axis vs. Solar Luminosity L on the X- axis
Insert graph here

Part 3. The dead planet (no daisy growth)

For the dead planet we can use an energy balance to calculate the planetary temperature.
At equilibrium,

Incoming solar radiation= outgoing longwave radiation

$$\pi R^2 * (1-\alpha) So = 4\pi R^2 * \sigma T^4$$

$$T = \left[\frac{S_0(1-\alpha)}{4\sigma}\right]^{1/4} = 306.4\text{ K} = 306.4-273 = 33.4\text{ C}$$

This assumes that for Daisy World So=4000 W/m^2 and α=0.5 is the bare ground albedo.
Stefan-Boltzman's constant is σ=5.67e-8 (W/m^2)/K^4=0.0000000567 (W/m^2)/K^4. When we calculate the dead planet's Euilibrium temperature for different solar luminosities So is replace by LSo.
The Kelvin temperature for the dead daisy planet can be calculated as

$$T = \sqrt[4]{\frac{LS_o(1-\alpha)}{4\sigma}} = \sqrt[4]{\frac{L4000(1-0.5)}{4(5.67x10^{-8})}} = 100\sqrt[4]{\frac{L500}{5.67}}$$

And the Celsius temperature

$$T_C = 100\left(\frac{L500}{5.67}\right)^{.25} - (273)$$

Use this equation to calculate the Average Planet Temperature in oC and record in the folowing table. Note that the 4th root is the same mathematical operation as raising to the power of 0.25.

L (fraction)	Avg Planet Temp (C) T	A, Planetary Albedo	Absorbed Solar [L * (1-A)]
0.60		0.5	
0.65		0.5	
0.70		0.5	
0.75		0.5	
0.80		0.5	
0.85		0.5	
0.90		0.5	
0.95		0.5	
1.00		0.5	
1.05		0.5	
1.10		0.5	
1.15		0.5	
1.20		0.5	
1.25		0.5	
1.30		0.5	

Graphs for Part 3 (The Dead planet). Using Excel (or some other means), make a graph of:

a. Average planet Temperature on the Y axis vs. Solar Luminosity L on the X- axis. If you can, include this on the same axes as the graph from Part2 a.
   Insert graph here

Thought questions

- Compare the behavior of the Dead Planet to that of Daisy World
- Explain how daisy world self-regulates its planetary temperature.
- Comment on how daisy world applies to the faint young sun paradox. (see your text or do a web search to find out more about the faint young sun paradox.
- Comment on the idea that very small changes in climate forcing can result in large changes in the climate state of a planet; in this model we observed this large shift in climate state just after daisies started growing and just after they died. Is this idea relevant to today's real Earth?