**DaisyWorld**

**Introduction**

The Daisy World is an imaginary planet with a transparent atmosphere. This planet has neither greenhouse gases nor any clouds. Strangely, this planet is also flat and this results in homogenous changes in temperature with varying solar luminosity and albedo being experienced simultaneously across its entire surface. There is no seasonality in the climate.

The only life forms on Daisy World are 2 species of Daisy and a herbivore:

- White daisies
- Black daisies
- Herbivore which grazes non-selectively on either black or white daisies

Conditions for daisy growth are favourable across the entire planet surface - however because of differences in albedo the local temperature is greater above black daisies (reflecting less radiation) than over white daisies. Growth of the daisies occurs equally for both species between 5°C and 40°C. Because of the difference in albedo and thus temperature, black daisies grow more rapidly than white daisies at lower globally averaged temperatures whilst at higher globally averaged temperatures the reverse is true.

The rate of expansion of an area covered by both species is dependent upon:

- Local temperature
- Amount of fertile land available
- Death rate

In the Daisy World model the death rate is a constant, but local temperatures and fertile land available are variables and are both indirectly dependent upon the level of incoming solar radiation which steadily increases with time.
The model employs a number of formulae:

1. First we must determine the amount of fertile land available for growth:

\[ x = [P - (a_b + a_w)] \]

Where:
- \( x \) = amount of available land
- \( P \) = proportion of land available for growth = 1.0
- \( a_b \) = area of black daisies = 0.2 (initially) and
- \( a_w \) = area of white daisies = 0.2 (initially)

2. Next we must determine the total (overall) albedo of the planet:

\[ A = x(A_g) + a_b(A_b) + a_w(A_w) \]

Where:
- \( A \) = albedo of the planet
- \( A_g \) = albedo of bare ground = 0.5
- \( A_b \) = albedo of black daisies = 0.25 and
- \( A_w \) = albedo of white daisies = 0.75

3. Now we must determine the globally averaged temperature of the planet:

\[ T_e = \left( \frac{SL(1 - A)}{s} \right)^{0.25} - 273 \]

Where:
- \( T_e \) = globally averaged temperature
- \( S \) = a solar constant (energy from the Sun) = 1000
- \( L \) = Luminosity (proportion of present day value) = 0.7 initially, but increasing in steps of 0.025 and
- \( s \) = Stefan's constant = 5.67 x 10^{-8}
4. Now we must work out the local temperatures for populations of white and black daisies (as these control the growth rate):

\[ T_{b,w} = (q(A - A_{b,w}) + Te) \]

Where:
- \( T_b \) = local temperature of black daisies
- \( T_w \) = local temperature of white daisies
- \( q \) = a constant used to calculate local temperature as a function of albedo = 20

5. The growth rate of the populations of black and white daisies is calculated thus:

\[ B_{b,w} = \{1 - [0.003265((22.5 - T_{b,w})^2)]\} \]

Where:
- \( B_b \) = growth rate for black daisies
- \( B_w \) = growth rate for white daisies
- values of 1, 0.003265 and 22.5 are all constants ensuring that growth occurs between 5 and 40ºC and peaks at 22.5ºC

6. The change in area of black and white daisies is:

\[ \Delta a_{b,w} / \Delta t = \{a_{b,w}[(xB_{b,w}) - y]\} \]

Where:
- \( \Delta a_b \) = change in area of black daisies
- \( \Delta a_w \) = change in area of white daisies
- \( y \) = death rate = 0.2 and
- \( t \) = time

7. The new area of black and white daisies is:

\[ Na_{b,w} = (\Delta a_{b,w} / \Delta t + a_{b,w}) \]

Where:
- \( Na_b \) = new area of black daisies
- \( Na_w \) = new area of white daisies
**Practical Tasks**

There are THREE separate tasks - together forming your DaisyWorld Practical Report:

**Workflow/MindMap Diagram**

Using the formulæ provided as well as the background information and additional resources, draw up a detailed model flow diagram based on the systems approach. This model diagram should show how each of the variables within Daisy World are related and should show the Daisy World as a complete system. If you prefer, the diagram can be shown in the form of a 'mindmap' or 'spider' diagram.

**Annotated Graphs**

Carefully examine the implementation of the Daisy World model in a spreadsheet environment (Excel spreadsheet file). Remember that Luminosity changes (increases) by 0.025 for each time step. You should produce graphs of:

- Temperature changing over time
- Proportion of the planet surface changing through time (black and white proportions)
- Changes in Albedo changing in time

These graphs should be fully annotated with a written commentary of what you believe they are showing and why.

**Sensitivity Analysis**

Finally, you should provide evidence that you understand the effects of sensitivity analysis - i.e. changing values of variables by a set percentage (5% above, then 10% etc) to see which components of the Daisy World are most sensitive. Provide a written commentary of your sensitivity analysis and relate this to implications for climate forecasting.

Allow ONE A4 page for each of the three practical tasks - then hand in your 3-page practical report during the lecture session one week later (i.e you have a week to complete this practical)

**Supporting Resources For This Assignment**

For the main part of this assignment you will need to use the DaisyWorld spreadsheet file:

http://www.ukscience.org/_Media/daisyworld.xls

(accessible from the EG6517 unit page on ukscience.org - in the 'Support Documents' section)
In addition, you may also refer to the following useful online resources:

- http://zool33.uni-graz.at/schmickl/Self-organization/Climate_control/Daisyworld/daisyworld.html

**Science Direct Starter References**


**Reading List**
Henderson Sellers A and Robinson PJ. (1986). Contemporary Climatology. Published by Longman


