Daisy World Activity
GEO201: Earth Systems Processes
Due 1/17/2024
[20 points]

Background Information
Daisyworld is an artificial world having a very simple biota which is specifically designed to display the characteristics in which we are interested - namely, close coupling of the biota and the global environment (McGuffie and Henderson-Sellers,1997). In simple terms, this means that living things are affected by, but also affect, the environment. This simple computer model is designed to illustrate Lovelock's Gaia Hypothesis, which views the Earth as a living, self-regulating entity. While evolving, life forms on earth modulate their environment (temperature, etc.).

This model describes an imaginary planet called Daisyworld, a very simple planet that has only two species of life on its surface – white and black daisies. The planet is assumed to be well-watered, with all rain falling at night so that the days are cloudless. The atmospheric water vapor and CO_2 are assumed to remain constant, so that the greenhouse of the planet does not change. The key aspect of Daisyworld is that the two types of daisies have different colors and thus different albedos. In this way, the daisies can alter the temperature of the surface where they are growing.

Navigate to the NetLogoWeb website:
https://www.netlogoweb.org/launch#https://www.netlogoweb.org/assets/modelslib/Sample%20Models/Biology/Daisyworld.nlogo

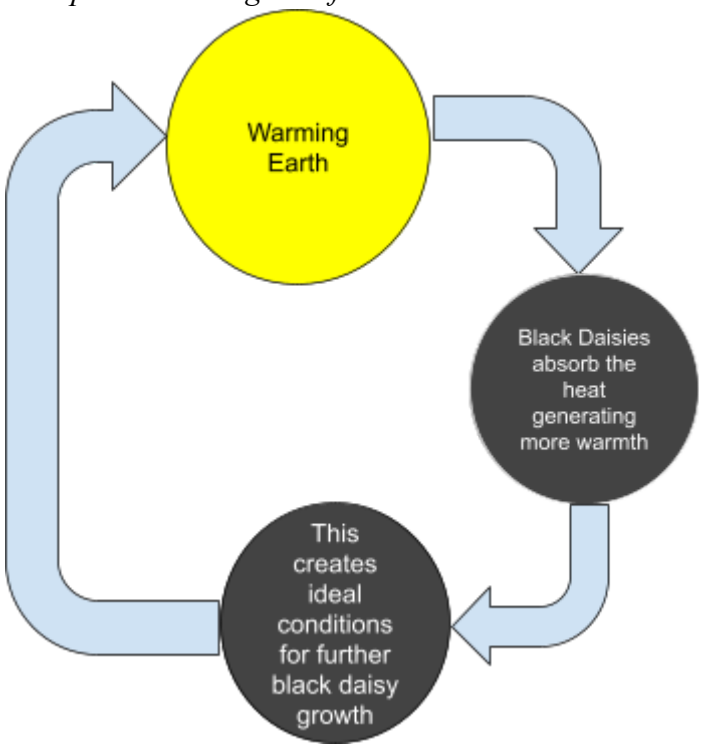
Be sure to select the "Sample Model/Biology/Daisyworld" library.

Set solar luminosity to 1.000 and albedo of the surface to 0.50, using the scenario "maintain current luminosity". Set the population of daisies to 20% white, 20% black and albedo of white daisies to 0.75 and black daisies to 0.25.

- *Describe what happens to the populations of black and white daisies.*
    - The population of the black and white daisies balance each other out. Because black daisies have low albedo, at the start of the simulation, they grow rapidly (up to just above 500 on the y-axis). This results in a drastic increase in global temperature. However, this warming creates the ideal conditions for white daisies to grow, while causing black daisies to begin dying (to about 350 on the y-axis), resulting in a shift in population favoring white daisies. The white daisies have high albedo resulting in cooling, dropping global temperatures, creating the ideal conditions for black daisies again, thus creating a constant cycle.
- *What happens to the temperature of the Earth?*
    - As described in the previous question, the balanced population and luminosity of the sun allows both daisies to thrive equally, balancing each other out. This is reflected in the global temperature as it fluctuates between growing warmer when there are more black daisies, and becoming cooler as there as more white daisies appear.

Draw a feedback loop that can occur within Daisyworld.

- *Label it as a positive or negative feedback.*



  - This is a **positive feedback** loop as it promotes the growth of black daisies. One thing to keep in mind however is that this loop is temporary as eventually it warms the earth enough where black daisies cannot thrive causing the population to drop.

Why do the populations of both daisies remain stable when both are present?

- The populations of both daisies remain stable when both are present because the growth of one supports the other. The black daisies warm the earth enough for white daisies to thrive, which counter-balances the warming effect of the black daisies enough for black daisies to also thrive.

Gradually decrease solar luminosity to 0.800.

- *Describe what happens to the populations of black and white daisies.*
  - The population of white daisies slowly fades out leaving only black daisies remaining. This is a slow process as the luminosity goes down incrementally, with white daisies eventually fading out at around 0.8.
- *What happens to the temperature of the Earth? Why?*
  - The temperature of the Earth increases. This is because while the luminosity has gone down, the slow decline in white daisies allow for black daisies to grow, generating a feedback loop in which further black daisy growth warms the Earth more. Ultimately, as white daisies are eliminated, the temperature stabilizes around the 40's range (in the y-axis) as black daisies dying and regrowing stabilizes the temperature.

Repopulate the world with 20% each of white and black daisies. Set the solar luminosity to 1.000 and run the simulation until temperatures stabilize. Then slowly increase solar luminosity to 1.400.

- *Describe what happens to the populations of black and white daisies.*
    - The population of black daisies slowly dies out while white daisies dominate. This is most likely because as the luminosity increases, black daisies are unable to handle the increasing light while white daisies are able to reflect more of it.
- *What happens to the temperature of the Earth? Why?*
    - The temperature decreases slowly. This is because as black daisies die out and white daisies dominate. The increased presence of white daisies creates a cooling effect stabilizing the temperature at minimum point for white daisies to thrive. In this case, it is around 6 to 7 (on the y-axis)

Populate Daisyworld with all white daisies and set the solar luminosity to 0.900.

- *Describe what happens.*
    - All the white daisies die out almost immediately. This is most likely because the initial lower luminosity creates non-ideal conditions for white daisies causing some to die out. As some die out, the global temperature increases due to having less of the cooling effect, causing more of the white daisies to die out until they are all gone.

Populate Daisyworld with mostly white daisies and 1 black daisy (use the Paint tool to insert only 1 black daisy) and set solar luminosity to 0.900.

- *Describe what happens.*
    - We see a substantial growth of black daisies, which, in effect, manages to stabilize the environment/temperature enough such that the white daisies are “rescued”. The temperature as well as the white and black daisy populations then stabilize where black daisies dominate with a smaller population of white daisies.
- *Why are there different results? Relate to the Gaia hypothesis.*
    - The results are different because as the Gaia hypothesis dictates, by including even one counter-balancing force, the Earth will “self-stabilize” such that ultimately both existing populations balance out. In this case, by introducing a black daisy, the conditions that cause the white daisy to die out, are the same conditions that allow black daisies to thrive, which in term, allows them to generate the heat required for white daisies to also survive.

Crank up the heat by changing the solar luminosity to 2.000. Remove all of the daisies. Paint on a few white daisies while the simulation is running.

- *What happens to the daisies and why?*
    - All the white daisies die out almost immediately and global temperatures increase. This is because there are not enough white daisies to counter the increased heat generated by the luminosity.

Stop the simulation and add a big patch of daisies (at least a third of the world).

- *How is the result different from the previous simulation? Why?*
    - Here, the white daisies thrive and global temperatures stabilized around 30 (y-axis). This is because there are enough white daisies this time to counter-balance the increased luminosity. With enough white daisies, the increased luminosity is actually a net benefit, allowing the white daisies to reflect light, cooling down the earth enough for white daisies to thrive.

Stop the simulation. Set up Daisyworld with 20% each white and black daisies and run the "ramp-up-ramp-down" (found under scenario) luminosity simulation a few times through. (try it 3 or 4 times by resetting in between simulations). Speed up the simulation so this doesn't take an hour.

- *There are three different ways this simulation can end. Name two of them. What biological event(s) determine the destiny of the planet?*
    - White Daisies Dominate: In this scenario, the initial luminosity is just below 1. Similar to the scenario below, this kills off a great majority of the white daisies. Unlike the scenario below, some white daisies survive. As the luminosity ramps up, like before, the remaining black daisies die off while the white daisies are suddenly given the opportunity to thrive. The sudden die off of black daisies and rise of white daisies results in major fluctuations in global temperature that ultimately stabilize around a good temperature for white daisies to thrive.
    - Everything Dies: In this scenario, the initial luminosity is just below 1, which effectively kills off the white daisies. The remaining black daisies cause the overall global temperature to increase. During this time period, luminosity also increases to around 1.6-7, which, in turn, kills off the remaining black daisies as well.
- *What might you be able to do (what are some planetary conditions you can adjust) to save any surviving white daisies at the end of the simulation? How do your changes indirectly affect the environment?*
    - The main planetary condition I could adjust (assuming luminosity is a solar condition and we can't change the albedo of the daisies) is the surface albedo. In such an instance, if we turn the surface albedo down to near 0, the white daisies are capable of thriving, albeit somewhat in an unstable state. This is because by decreasing the surface albedo, it allows for more chances to warm the earth (when there is no daisies in a spot of land), thus creating a better environment and a better chance for daisies to thrive (warmer environment).

Imagine the Earth was covered in daisies, just like Daisyworld. Yes, these daises can grow on glaciers, and bare rock and even oceans. They are space-daisies from another planet, after all.

- *Predict which daisies would dominate at high latitudes and low latitudes. Justify your answer.*
    - Based on the simulations previous run, the high latitudes would be largely dominated by black daisies while the low latitudes would be largely white. In the most extreme locations of each, there would be an absence of either. We would see a more balanced distribution in the mid-latitude ranges between the high and low latitudes. This is because high latitude areas tend to be colder and receive less

sunlight, creating conditions for black daisies to begin growing. This would promote further growth of black daisies as the area warms. In low latitude areas, the opposite is true. Because it is warmer and receives more sunlight, we would see a large growth of white daisies as they thrive in warmer, more luminous settings. The areas between high and low latitudes would be the most reflective of the Gaia hypothesis in which both would types of daisies would equal out.

- *What would happen to the temperature difference between the equator and the poles? Why?*
    - Interestingly enough, as the daisies spread, we would see temperatures begin to invert. As white daisies dominate the equator, we would see the temperatures around those areas drop while in the poles, where black daisies dominate, we might see the temperatures increase. This would essentially flip the most suitable conditions for each of the daisies, thus creating a sort of equilibrium as the temperatures fluctuate (in a balanced manner) based on which daisy is populating where.

- *Given your answer above, would you expect average wind speeds on Earth to increase, decrease, or stay constant? What might cause the change?*
    - Average wind speeds would increase as the dramatic changes in temperature between latitudes and poles would generate greater gradients in temperature, leading to greater wind speeds.