Nonlinear Dynamics Lab (110231)

Daisyworld: Biological homeostasis in an idealized world

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9-10 May, 2016

Introduction

Daisyworld is a simple model of a hypothetical planet with only two types of organisms, black and white daisies, which compete for empty space. Black daisies absorb more light than white daisies and, thus, become warmer. Since the growth rate of both types is temperature dependent peaking at an optimum temperature, black daisies have a competitive advantage over white daisies at low irradiances and vice versa. However, daisies do not only regulate their own local temperatures, but also affect the climate by alterating the planetary albedo. This is determined by the weighted albedos of bare ground and the areas populated by black and white daisies. By this mechanism, daisies stabilize the climate of their planet over a wide range of astronomical forcing.

Report submission and grading policy

All exercises in this module count equally for the final grade. Submit the source code required to solve the exercises and write a short report with figures explaining your solution. The grade for each exercise will be based on the quality of the source code (30%), the quality of the comments explaining the source code (30%), and the quality of the report (40%). Please submit all parts as one zip archive to a.merico@jacobs-university.de.

Exercise 1

Code the daisyworld model given in the article by Watson & Lovelock (1983) and Lenton & Lovelock (2001) and plot the time evolution of the different types of daisies and the global temperature T_e. Use the parameters given in Table 1 and in the articles.

What characterizes the dynamics of the system, regardless of the parameter set used ? Why do daisies not colonize the entire planet ? Which parameter controls the fraction of empty land in the model ?

Exercise 2

Perform a sensitivity analysis of the daisyworld model with respect to luminosity L and plot the area coverd by the daisies and empty ground as a function of luminosity. Also show how the global temperature changes as a function of luminosity with and without daisies. How can you influence the level at which the global temperature is stabilizing in the model ?

Exercise 3

Extend the model coded for exercise 1 to a multi-species system, in which species differ only by the albedo. Is co-existence of all species possible or do only few species dominate the system ?

Consider a periodic, an increasing, and a decreasing luminosity forcing. How does the system respond to these different forcing? Show that the system is capable of generating ecological relevant phenomena, e.g. tipping points, succession, co-existence, and competitive exclusion.

Table 1: Variables and parameters of the daisyworld model.

symbol	**name**	**value**
α_w, α_b	area of daisies	–
β_w,β_b	growth rate of daisies	–
t	time	–
T_w, T_b	local temperatures	–
T_e	global temperature	–
A_p	albedo of the planet	–
x	empty ground	–
A_x, A_w, A_b	albedos	[0.25, 0.5, 0.75]
T_{opt}	optimal temperature	22.5 °C
L	luminosity	[0.6 . . . 1.4]
γ	death rate of daisies	0.3 t^{-1}
σ	Stefan-Boltzmann constant	5.67×10^{-8} W m^{-2} K^{-4}
S	solar constant	1368 W m^{-2}
q	constant	2.064×10^{9} K^{4}

References

Watson, A.J. & Lovelock, J.E. (1983) Biological homeostasis of the global environment: the parable of Daisyworld. *Tellus*, 35B:284–289.

Lenton, T.M. & Lovelock, J.E. (2001) Daisyworld revisited: quantifying biological effects on planetary self-regulation. *Tellus*, 53B:288–305.