Svet krasuljaka

25. 01. 2013.

Da li grešimo kada nastanjivost posmatramo pasivno?

- Fizički, hemijski, itd. preduslovi nastanjivosti… – sve je **abiotičko**!
- Da li sam život pomera (prostorne i/ili vremenske) granice CNZ?
- Ključna razlika između praznih i nastanjenih habitata!
- Povratna sprega / samo-interakcija

Džejms Lavlok (1919-)

* Ekolog, filozof, ...
* „Gaja hipoteza“
  * Slaba verzija: celina kompleksnosti
  * Jaka verzija: Gaja je super-organizam!
* Podrška Lin Margulis
* Inspirisao rad na CFC i ozonu (Crutzen, Molina, Rowland inspirisani njegovim radom).
* „Do 2050. Sahara će se protezati na sever do Pariza. Ni gram hrane neće se moći uzgajati u Evropi.“ (Lovelock, 2006)
* „Samo nuklearna energija može sprečiti dalje globalno zagrevanje.“ (Lovelock 2004)

Bellis perennis

- Lovelock & Watson (1983)
- Istorijat publikacija zanimljiv... Retko izvinjenje Džona Medoksa.
- Zamislimo planetu identičnu Zemlji...
- Bela rada, tratinčica,
- (detalji irelevantni, kao u svakom misaonom eksperimentu!)
- Jedna od prvih kvantitativnih analiza globalne ekologije…

„parabola“

Tellus (1983), *35B*, 284–289

Biological homeostasis of the global environment: the parable of Daisyworld

By ANDREW J. WATSON, *Marine Biological Association, The Laboratory, Citadel Hill, Plymouth PL1 2PB, England and* JAMES E. LOVELOCK, *Coombe Mill, St. Giles on the Heath, Launceston, Cornwall PL15 9RY, England*

(Manuscript received October 20, 1982; in final form February 14, 1983)

ABSTRACT

The biota have effected profound changes on the environment of the surface of the earth. At the same time, that environment has imposed constraints on the biota, so that life and the environment may be considered as two parts of a coupled system. Unfortunately, the system is too complex and too little known for us to model it adequately. To investigate the properties which this close-coupling might confer on the system, we chose to develop a model of an imaginary planet having a very simple biosphere. It consisted of just two species of daisy of different colours and was first described by Lovelock (1982). The growth rate of the daisies depends on only one environmental variable, temperature, which the daisies in turn modify because they absorb different amounts of radiation. Regardless of the details of the interaction, the effect of the daisies is to stabilize the temperature. The result arises because of the peaked shape of the growth-temperature curve and is independent of the mechanics by which the biota are assumed to modify the temperature. We sketch out the elements of a biological feedback system which might help regulate the temperature of the earth.

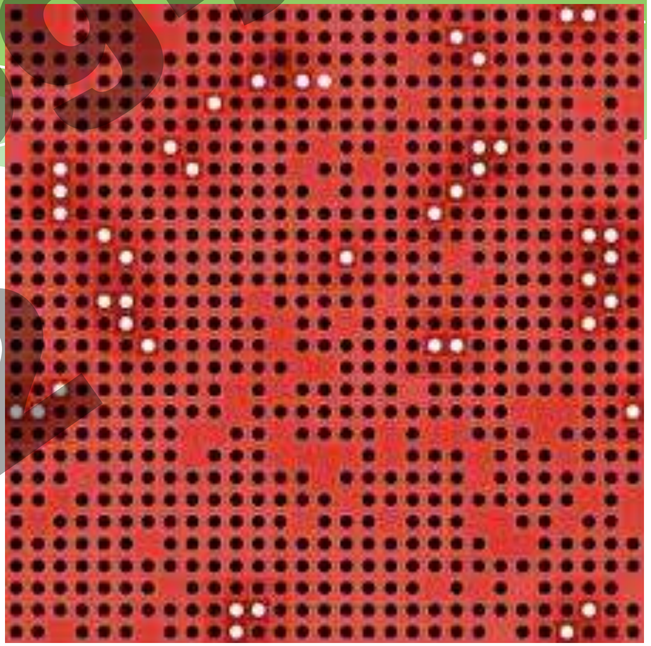
1. Introduction

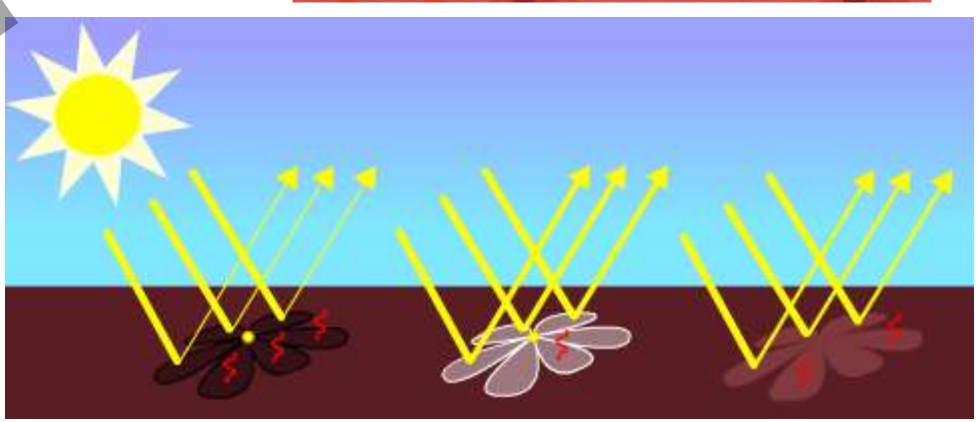
On earth, modification of the environment by living things is apparent on any scale that one cares to look at, up to and including the global scale. In

have chosen to study an artificial world, having a very simple biota which is specifically designed to display the characteristic in which we are interested—namely, close-coupling of the biota and the global environment. By simplifying our bio-

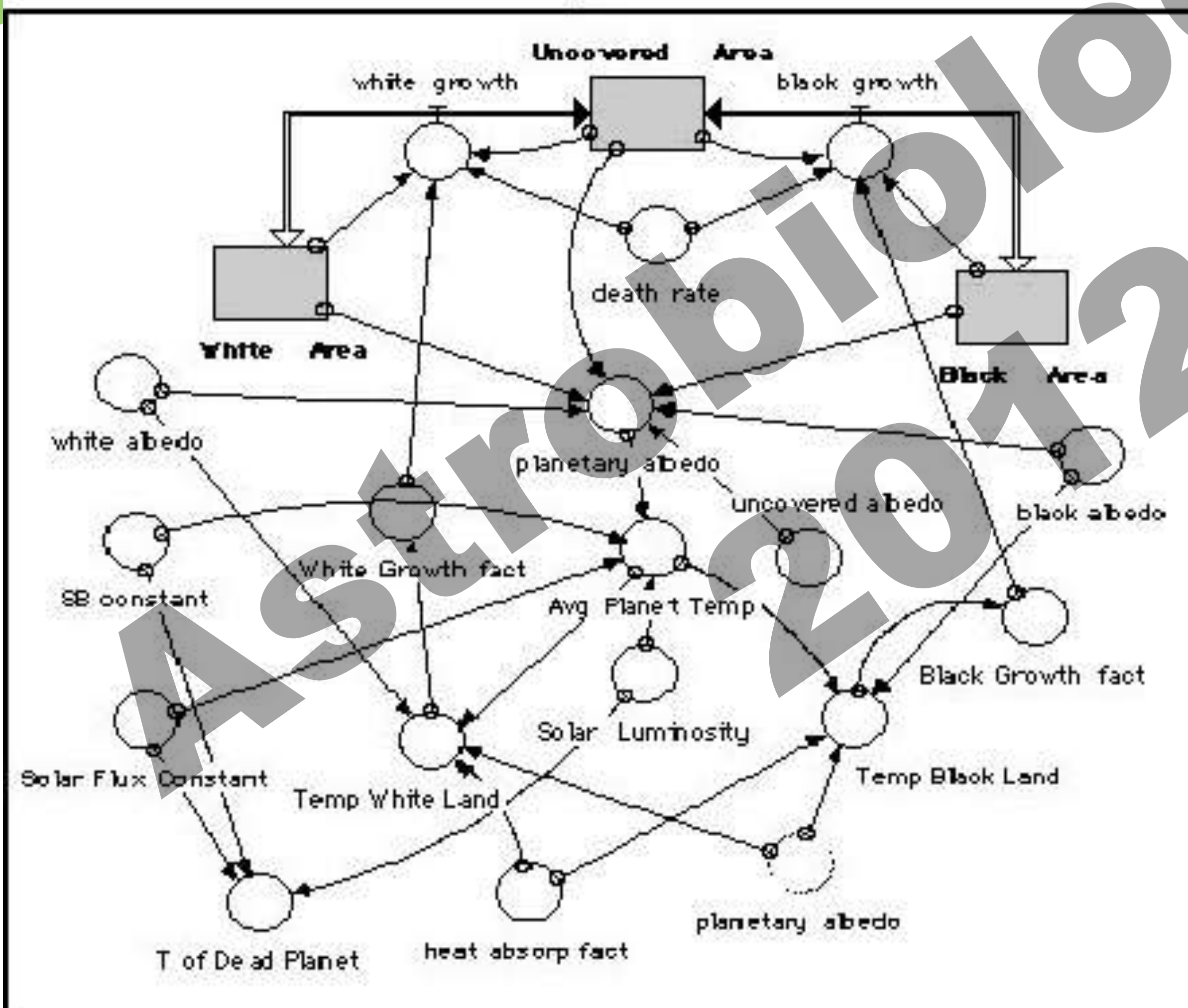
Aproksimacije, aproksimacije...

* Pretpostavljamo da je planeta **ravna** ili bar cilindrična!
* Zanemarujemo atmosferu i njen efekat staklene bašte.
* Zanemarujemo kretanje kontinenata i posledične **abiotičke** promene albeda.
* Zanemarujemo ostatak flore i faune!
* Koristimo jednostavan model rasta.

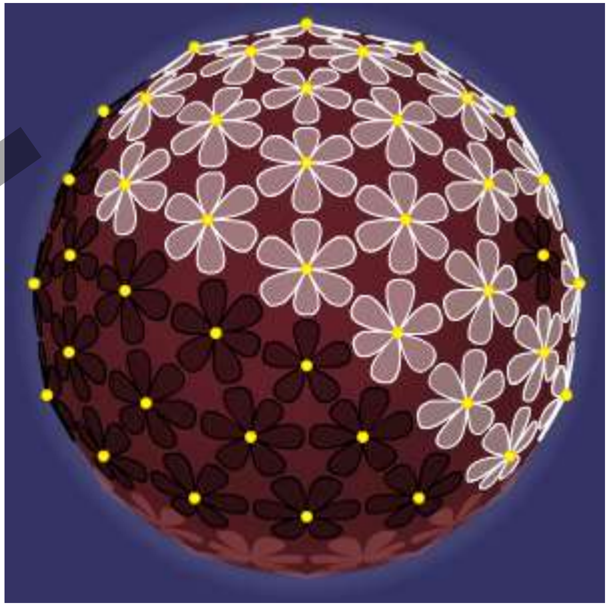




Daisyworld



Uncovered Area
white growth
black growth
death rate
White Area
Black Area
white albedo
planetary albedo
uncovered albedo
black albedo
SB constant
White Growth fact
Avg Planet Temp
Black Growth fact
Solar Luminosity
Solar Flux Constant
Temp White Land
Temp Black Land
T of Dead Planet
heat absorp fact
planetary albedo



Osnovni parametri modela

- α_w = površina pod belim krasuljcima
- α_b = površina pod crnim krasuljcima
- x = „prazna“ površina
- β = stopa rađanja (lokalna, krasuljaka cm^{-2} s^{-1})
- γ = stopa smrtnosti (globalna, krasuljaka s^{-1})
- T_{eff} = efektivna temperatura (globalna)
- T_{lok} = lokalna temperatura na nekom delu površine
- T_{opt} = optimalna temperatura za jednu ili drugu vrstu krasuljaka
- q = parametar koji opisuje prenos toplote

Osnovne jednačine

$$d\alpha_b/dt = \alpha_b(\alpha_g\beta(T_b) - \gamma)$$

$$d\alpha_w/dt=\alpha_w(\alpha_g\beta(T_w) - \gamma)$$

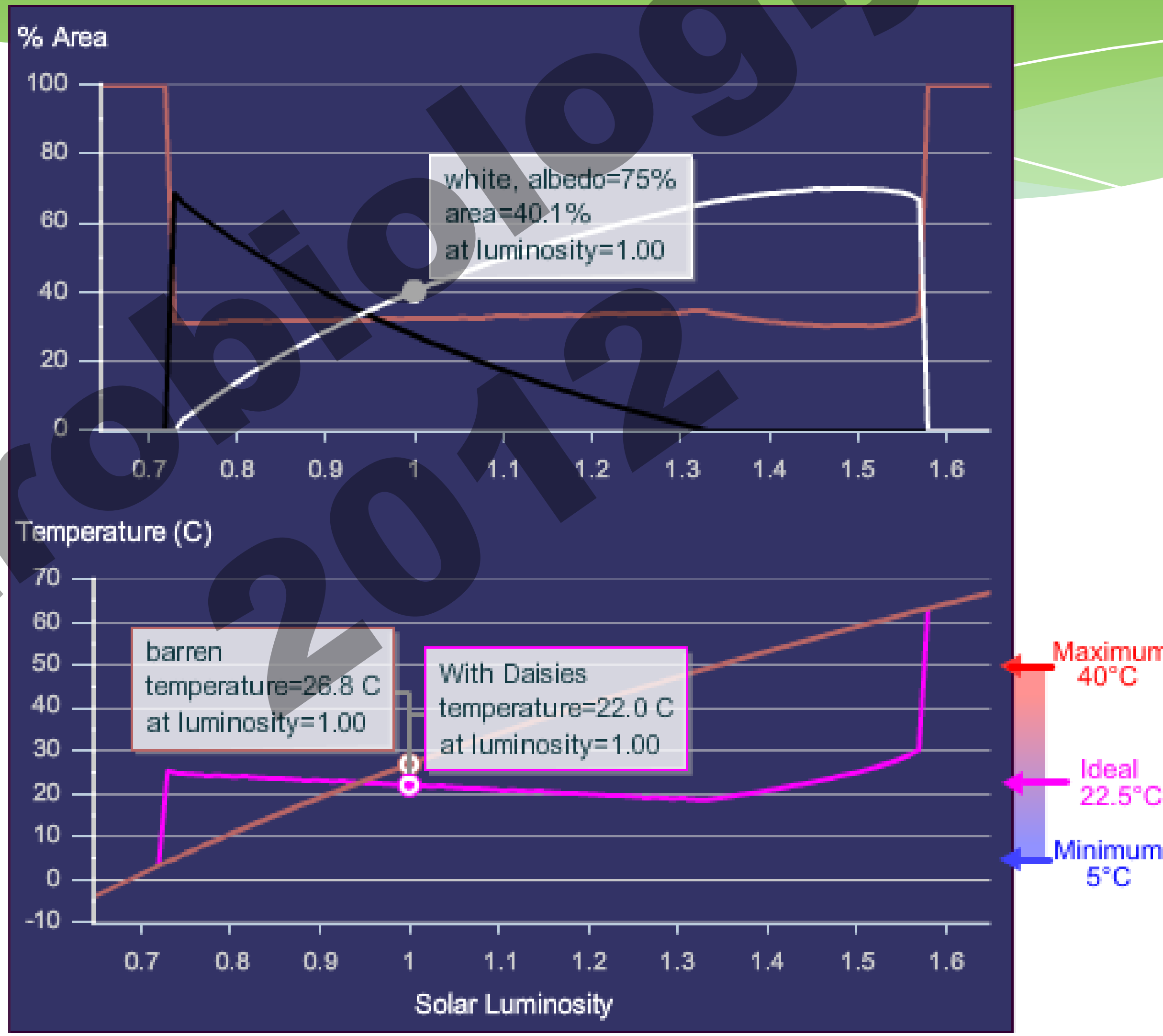
$$\sigma(T+273)^4 = SL(1-A)$$

$$A = \alpha_g A_g + \alpha_b A_b + \alpha_w A_w$$

$$T_b^4 = T^4 + q(A-A_b) \qquad T_w^4 = T^4 + q(A-A_w)$$

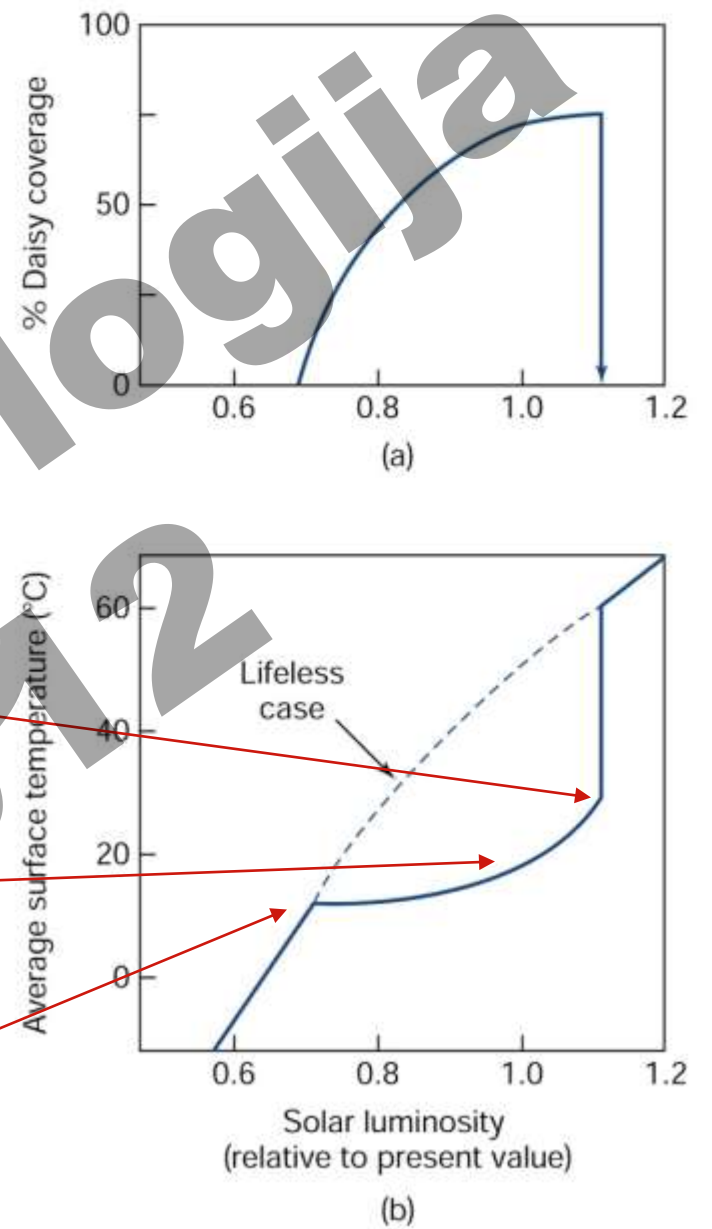
Od Sun Cua do Lanchestera…

Najjednostavniji slučaj



Ukupni klimatski odgovor

Kad saberemo bele i crne krasuljke…



Suviše vruće za bilo koje krasuljke

Rast temperature usporen promenom albeda

Krasuljci počinju da rastu

Dve ili više vrsta krasuljaka...

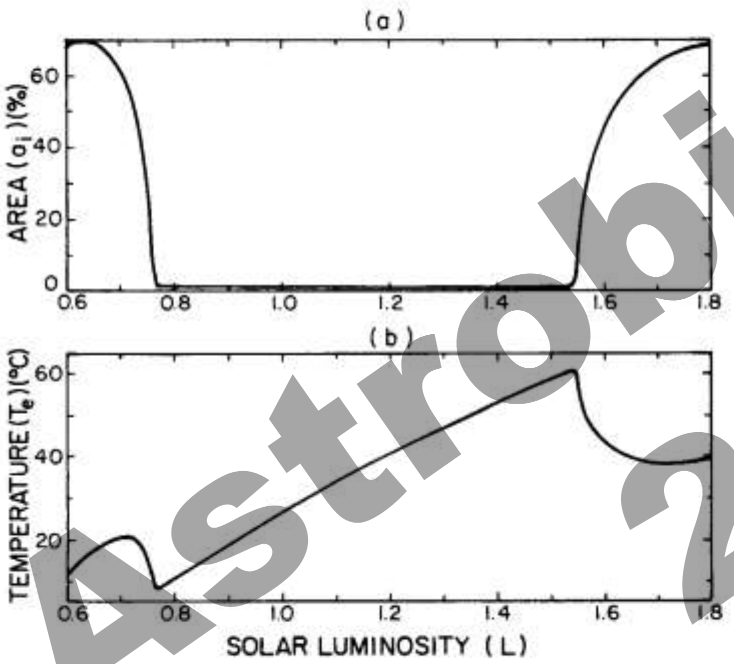


Fig. 2. Steady state responses of daisyworld with eq. (8). (a) Areas of black and white daisies; (b) Effective temperature T_e.

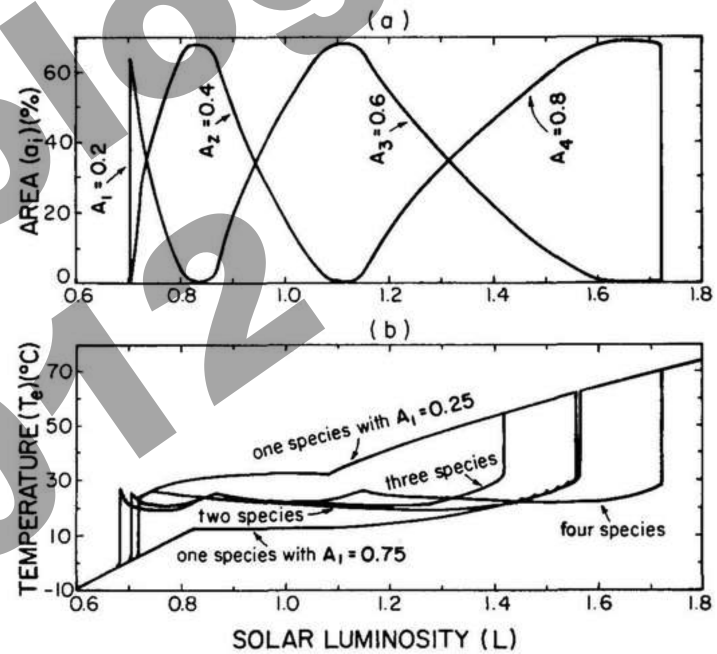
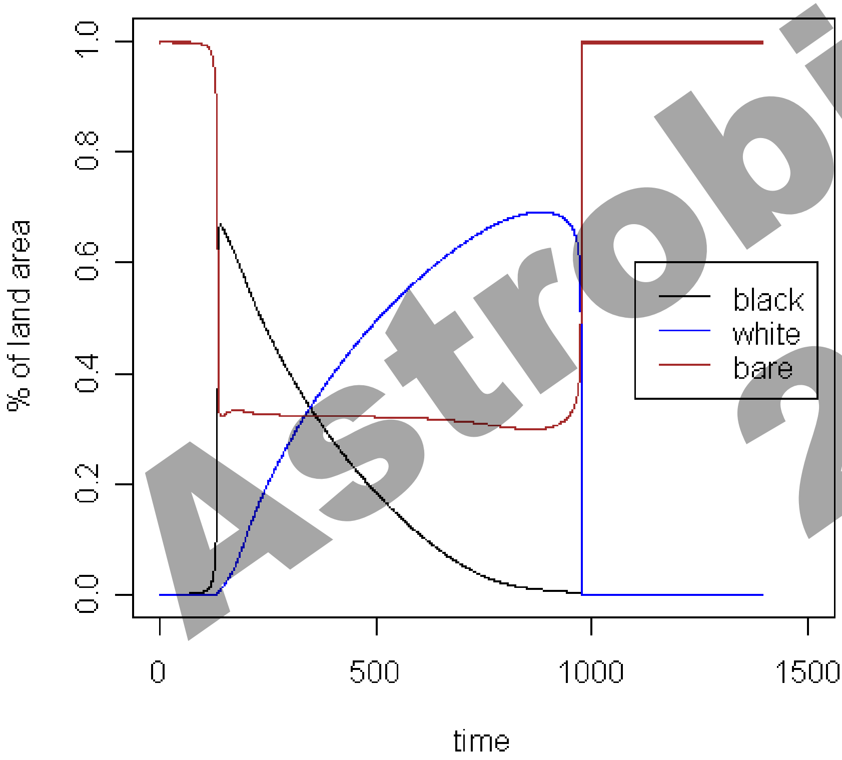


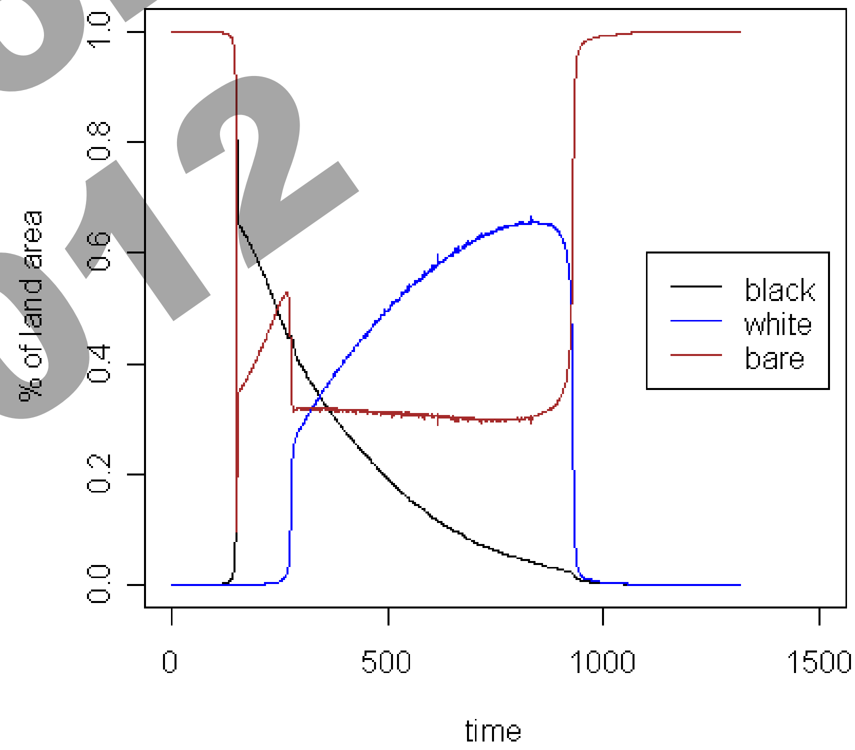
Fig. 1. Steady-state behavior of daisyworld. (a) Areas of four species, where A_1, A_2, A_3, and A_4 are 0.2, 0.4, 0.6, and 0.8; (b) Effective temperatures for one to four species: for four species, albedos are as given above; for three species, A_1, A_2, and A_3 are 0.1, 0.4, and 0.7; for two species, $A_1 = 0.75$ and $A_2 = 0.25$; for one species, $A_1 = 0.25$ or $A_1 = 0.75$.

Korišćenje novih metoda: ćelijski automati

Površina pod krasuljcima



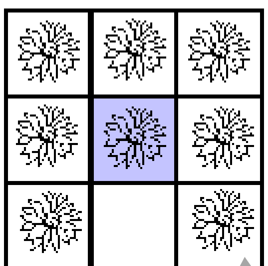
(diferencijalne jednačine)



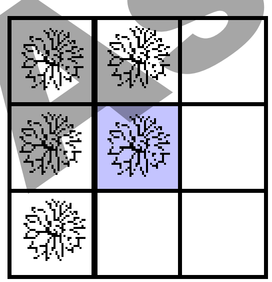
(2D ćelijski automat)

Primer prostorne konsolidacije

* Kritični prag za širenje = 6

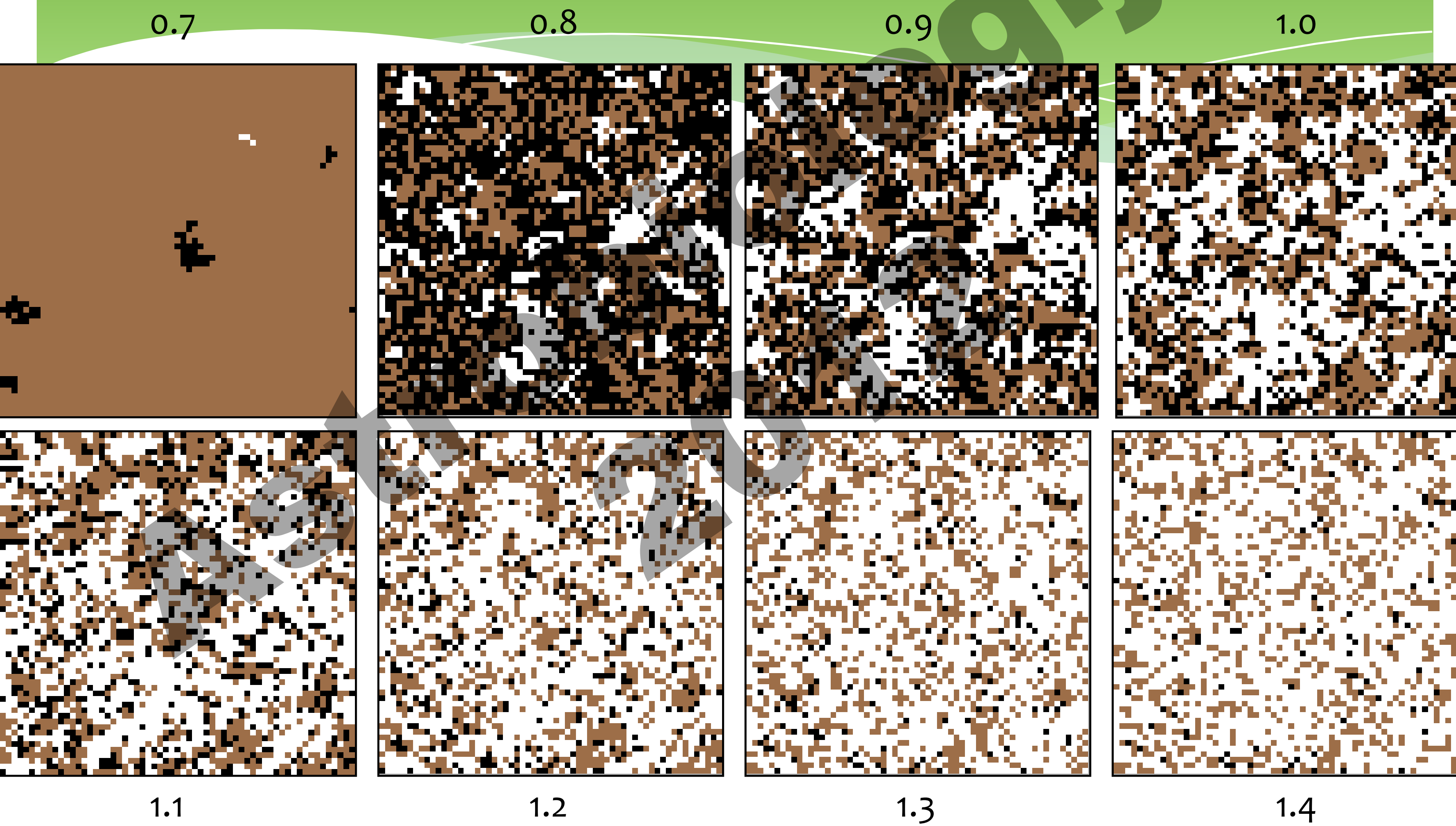


=> Počinje nova oblast krasuljaka



=> Nova oblast ne počinje

Evolucija ćelijskog automata sa luminoznošću



* Dodavanje vrsta poboljšava regulaciju temperature!
* Kompleksniji sistemi imaju efikasniju povratnu spregu $\Rightarrow$ značaj **biodiverziteta**, prvi numerički argument!
* Ovo se odnosi i na dodavanje faune (biljojeda)

Svet krasuljaka…

* …demonstrira moć misaonog eksperimenta u astrobiologiji.
* …pokazuje da se misaoni eksperimenti uspešno mogu nadograditi numeričkim!
* …pokazuje da postoje **globalni (ekološki) mehanizmi evolucije** različiti od lokalne prirodne selekcije.

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Consequences of inter-specific competition among multiple adaptive species in Daisyworld

T. Pujol[1], **J. Fort**[1], and **V. Méndez**[2]

With 5 Figures

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Summary

We investigate the consequences of Darwinian selection in a daisymodel with uniform temperature, inter-specific competition and multiple daisies. The assumption of a higher competition between species than within them allows for the coexistence of more than two species in equilibrium. Thus, it is the first time that a high biodiversity with equal environment-altering traits at the same trophic level in a daisymodel is reported under stationary conditions. Adaptation in the biota occurs through mutations, leading to changes in the optimum temperature in order to achieve the maximum growth rate at the individual level. We study the planetary sensitivity (i.e. the variation of the global mean temperature due to a 1% change in solar radiation) as a function of the strength of the inter-specific competition and of the number of different species that grow in the model. We find the following: 1) by fixing the parameter that defines the strength of the inter-specific competition, the planetary sensitivity increases as biodiversity increases; 2) by keeping constant the number of different species in the planet, the planetary sensitivity also increases as competition between species increases. In any case, however, the planetary sensitivity associated with adaptive daisies is much greater than that obtained from non-adaptive species. However, the range of mean solar radiation where biota grows in the planet is substantially larger for adaptive species than for non-adaptive ones. This result suggests that adaptation of multiple species with the same environmental-altering traits may not imply a strong regulation of the mean planetary temperature, which differs with recent studies that analyse adaptation of single species. Similar results are obtained by using a constrained adaptation and non-uniform temperatures.

1. Introduction

The Gaia theory asserts that feedback mechanisms between the physical environment and the biosphere keep the planet in habitable conditions (e.g. Lovelock, 1989; Lenton, 1998). Several 'Gaian' processes have been proposed for the Earth system, such as the amplification of rock weathering by living organisms (e.g. Schwartzman and Volk, 1989) and the variation of cloud cover linked to the release of dimethyl sulfide by marine plankton (e.g. Bates et al., 1987). The regulatory ability of the Earth system has been also investigated by means of conceptual models that include simplified coupling mechanisms between life and the environment (e.g. Watson and Lovelock, 1983; Svirezhev and von Bloh, 1996; Lenton, 1998). Special attention has been devoted to the model Daisyworld since, in its original version, it showed a very robust stabilisation of the planetary temperature due to the effects of the biota (Watson and Lovelock, 1983), thereby providing a lucid illustration of the propositions stated by the Gaia theory.

Catastrophes on Daisyworld

David M. Wilkinson

Biological and Earth Sciences, Liverpool John Moores University, Byrom Street, Liverpool L3 3AF, UK

For 20 years, a research tradition based on 'Daisyworld' models, which have strong coupling between life and the abiotic environment, has developed largely independently of mainstream theoretical ecology. A new paper in this tradition shows how small changes in external forcing can lead to catastrophic environmental change on this virtual planet. This has potential implications for the way that we view the Earth system, both in respect to the effects of human actions and for testing Lovelock's Gaia hypothesis.

Tellus (2005), 57B, 175–188
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TELLUS

"Wet/dry Daisyworld": a conceptual tool for quantifying the spatial scaling of heterogeneous landscapes and its impact on the subgrid variability of energy fluxes

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(Manuscript received 26 October 2004; in final form 4 February 2005)

ABSTRACT

We modified the "Daisyworld" model of Watson and Lovelock to consider the energy balance of vegetation with differing potential to evaporate water vapour across a 2-D landscape. High resolution spatial fields of surface temperature, latent heat exchange and net radiation are computed using cellular automata (CA). The CA algorithm considers competition between actively transpiring "wet daisies" and "dry daisies" for bare ground through temperature-dependent birth and death probabilities.

This paper examines how differences in biophysical properties (e.g. surface albedo and surface conductance) affect the composition and heterogeneity of the landscape and its energy exchange. And with high resolution and gridded spatial information we evaluate bias errors and scaling rules associated with the subgrid averaging of the nonlinear functions used to compute surface energy balance.

Among our key findings we observe that there are critical conditions, associated with albedo and surface resistance, when wet or dry/dark or bright "daisies" dominate the landscape. Second, we find that the heterogeneity of the spatial distribution of "daisies" depends on initial conditions (e.g. a bare field versus a random assemblage of surface classes). And third, the spatial coefficient of variation of land class, latent heat exchange, net radiation and surface temperature scale with the exponential power of the size of the averaging window.

Though conceptual in nature, the 2-D "wet/dry Daisyworld" model produces a virtual landscape whose power-law scaling exponent resembles the one derived for the spatial scaling of a normalized difference vegetation index for a heterogeneous savanna ecosystem. This observation is conditional and occurs if the initial landscape is bare with two small colonies of "wet" and "dry" daisies.

Bias errors associated with the nonlinear averaging of the surface energy balance equation increase as the coefficient of variation of the surface properties increases. Ignoring the subgrid variability of latent heat exchange produces especially large bias errors (up to 300%) for heterogeneous landscapes. We also find that spatial variations in latent heat exchange, surface temperature and net radiation, derived from our "Daisyworld" model, scale with the spatial variation in surface properties. These results suggest that we may be able to infer spatial patterns of surface energy fluxes from remote sensing data of surface features. "Wet/dry Daisyworld", therefore, has the potential to provide a link between observations of landscape heterogeneity, deduced from satellites, and their interpretation into spatial fields of latent and sensible heat exchange and surface temperature.

1. Introduction

Numerical models and remote sensing instruments borne on satellites are among the tools employed by biogeoscientists to assess weather, climate and atmospheric chemistry. Numerical models calculate the time rate of change of meteorological scalars by quantifying both the fluxes of mass and energy into and out of the atmosphere and the advection across lateral and vertical boundaries (McGuffie and Henderson-Sellers, 1997; Sellers et al., 1997). These calculations hinge upon information on the composition, structure and functional capacity (e.g. minimal stomatal resistance and maximal photosynthesis rates) of the Earth's terrestrial biosphere. Today, some information on surface structural and functional properties and flux boundary

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Tellus (1990), 42B, 309–318

Chaos in daisyworld

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(Manuscript received 18 May 1989; in final form 8 November 1989)

ABSTRACT

Lovelock proposed a concept, referred to as Gaia, in which feedbacks from the biosphere minimize fluctuation in climatic conditions. A simple model, referred to as daisyworld, was later developed to illustrate the Gaia concept. Daisyworld is defined on a cloudless flat or cylindrical planet with negligible atmospheric greenhouse gases in which bare soil and daisies of different colors interact so as to maintain stable climatic conditions. In the current paper, this daisyworld model is used to study the interaction between biota and their environment in more detail. It is found that periodic, and even chaotic, states can exist when the parameter controlling the feedback between biota and environmental temperature is changed. The existence of periodic and chaotic solutions is verified by their power spectra, fractal dimensions, and Lyapunov exponents. These results show that stable climatic conditions are not always maintained in daisyworld, despite the presence of daisies which supply the required feedback. While daisyworld is a simple model, the mathematical analysis of this model raises questions about the validity of the Gaia hypothesis.

1. Introduction

It is now widely accepted that the Earth is a single system which consists of the biota and their environment. These two elements of the system are closely coupled: the biota regulate the environment (e.g., climate on a planetary scale) and, in turn, the environment restricts the evolution of the biota and dictates what type of life can exist as a consequence of Darwinian natural selection. Changes in one part will influence the other, being opposed by negative feedback or enhanced by positive feedback, and this may lead to oscillation or chaos in the system. Therefore, in order for climate models to predict the consequences of changes caused by human activities (e.g., the increase of greenhouse gases), the biota should be included in the model. On the other hand, the biota and the environment of the Earth are so complex that this system, or even a single aspect of feedback in it, can not yet be adequately described by simple mathematical equations.

In the past few years, a model, daisyworld, which is an active system where the biota and the environment are tightly coupled, was first described by Lovelock (1982) and used to study the interaction between daisies of one or two species and the temperature of the environment (Watson and Lovelock, 1983). These authors found that the inclusion of feedback from the environment, regardless of its direction, stabilized daisyworld, and this was consistent with the earlier Gaia hypothesis that the climate and the chemical composition on the Earth have been and are maintained at a steady state by the presence of life itself (Lovelock and Margulis, 1974).

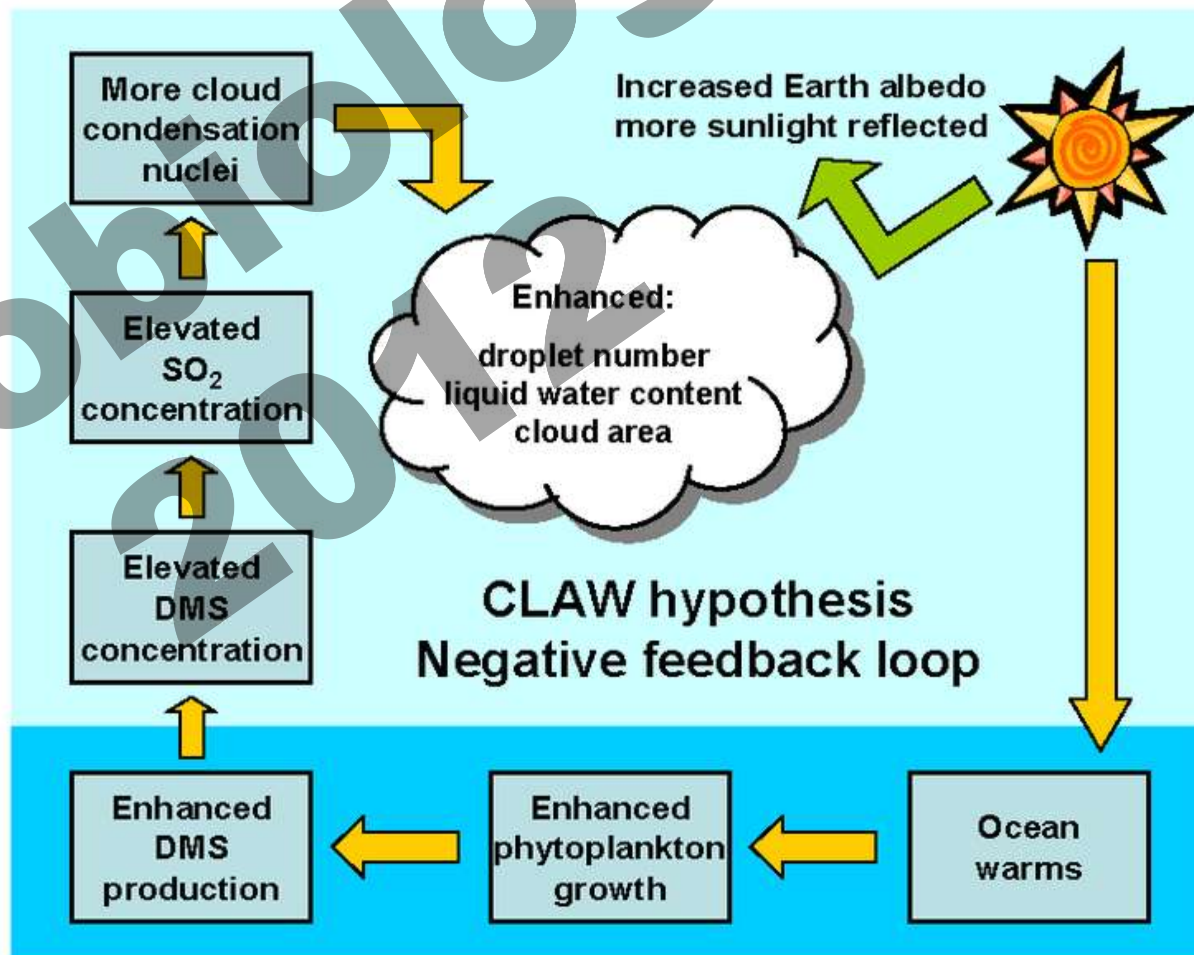
Though the feedback in daisyworld is much simpler than that on the Earth, research on such an imaginary planet may provide insight into the properties of the Earth's climate. Therefore, further studies are needed. The purpose of this paper is to study the fictional world in more detail, and, especially, to evaluate the chaotic properties of this model. Both qualitative and quantitative methods from modern chaos theory

I ima još dosta posla…

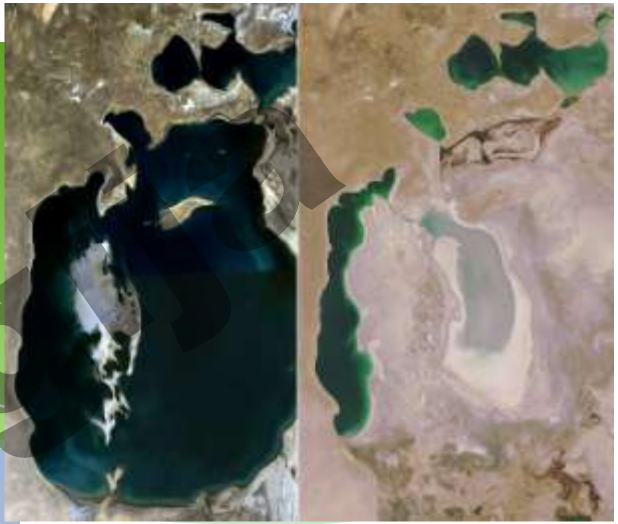
- Modeli sa faznim prelazima pokazuju veliku raznovrsnost ponašanja – ova rešenja nisu ni približno klasifikovana!
- Dalje ekstenzije
  - Efekti tektonike ploča?
  - Efekti sekularnih promena male amplitude (Milankovićevi ciklusi)?
  - Efekti velikih jednokratnih perturbacija (npr. *snowball Earth*)?
- Uspon masivne paralelizacije omogućava postizanje visoke rezolucije – novi efekti se kriju u informaciji izgubljenoj usrednjavanjem!

Druge povratne sprege: CLAW hipoteza

* Charlson, Lovelock, Andreae & Warren (1987)
* Dvostruko povećanje uloge fitoplanktona:
  * fiziološki efekat zagrevanja;
  * Pojačana fotosinteza.
* DMS = dimetil sulfid = $(CH_3)_2S$
* Sulfatni aerosoli…
* Veoma značajno za savremene debate u vezi **geoinženjeringa**!

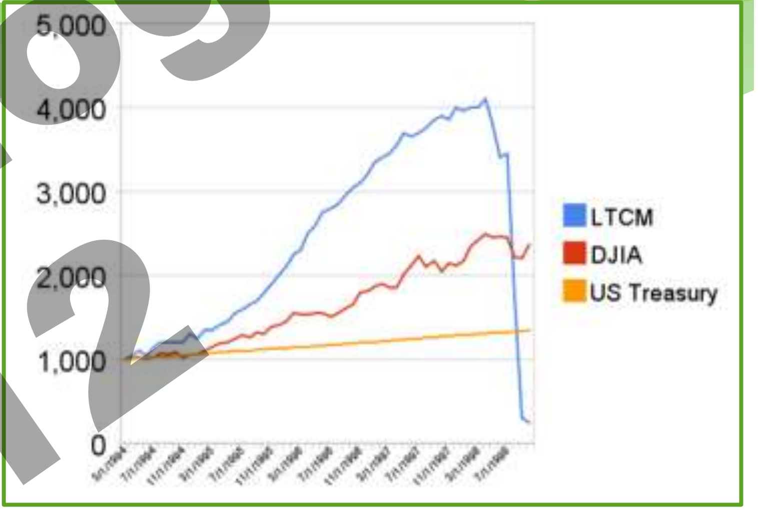


Zastrašujući primer…



Povratna sprega uzrokuje „crne labudove“...

* ...i pozitivne i negativne!
* Perturbacije generički kvazistabilnog sistema + pozitivna povratna sprega.
* Odgovor na jednu vrstu perturbacija **izaziva** drugu vrstu perturbacija.
* Eksterna prinuda = veoma bitan faktor u analizi stabilnosti.
* **Analiza sistema:** nova i dinamična oblast nelinearne dinamike.



Ukratko…

* Biotička povratna sprega igra ogromnu ulogu u nastanjivosti…
* Život menja sam koncept mogućnosti za život.
* Raznovrsnost je prijatelj nastanjivosti – a najveću raznovrsnost upravo očekujemo u astrobiološkom kontekstu!
* Tek smo na početku (eto prilika za rad mladih astrobiologa)!