±10% change from preindustrial times to present found in most global 3-D simulations [Wang and Jacob, 1998]. One factor not considered in the other global 3-D studies is the decrease of stratospheric O_3 concentrations since the late 1970s, which, Krol *et al*. [1998] estimated, contributes to a 2% increase of the global mean OH concentration. They suggested that increasing water vapor concentrations in the tropics and a decoupling of NO_x and CO emissions (with increasing NO_x but decreasing CO emissions) by about 10% each could explain the rest of the OH increase. A shift in the global mean OH concentration by this magnitude would therefore signify substantial changes taking place in anthropogenic emissions or global climate. Resolving the difference between the two studies and obtaining additional independent estimates are critical.

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Perspectives on the Earth System

Recent issues of the NewsLetter have carried various articles on the nature of the Earth System, the effects of human activities on the System (e.g., 'The Anthropocene', see NL 41), and the scientific challenges to studying the Earth System. We invite continued contributions on this theme. Please be as speculative, provocative or controversial as you like! Reactions to these articles are invited in the new Correspondence section of the NewsLetter.

This issue's contribution comes from Victor Gorshkov and Anastasia Makarieva, who explore the fundamental role of life in the stability of the Earth System.

Environmental safety, climate stability and the non-perturbed biota

by V.G. Gorshkov and A.M. Makarieva

Humanity is currently faced with the prospect of further development of civilisation. On the one hand, the inherent human claim for improving living standards urges further acceleration of economic growth and exploitation of biospheric resources. On the other hand, it becomes evident that uncontrolled spontaneous development of modern civilisation in the direction determined by catering for immediate human demands goes hand-in-hand with global environmental devastation. This, in turn, inevitably impairs quality of life and undermines the security of human existence.

In searching for a compromise between the two trends, hopes for sustainable development are most often associated with creation of technologies capable of imposing a stabilising impact upon the global environment (e.g. struggling with anthropogenic pollution). This necessitates further enhancement of civilisation power, growth of human population and inevitable cultivation of the remaining natural biota and other biospheric resources. However, the very possibility of a technological solution to the global environmental stability problem remains entirely unproved.

A different path of development compatible with long-term environmental safety lies in conservation and restoration of a substantial part of the Earth's biosphere in its natural non-perturbed state, bearing in mind the stabilising potential of the natural biota of Earth with respect to the global environment. Restoration of the stabilising biotic potential would mean relaxation of anthropogenic pressure on perturbed territories and complete abandonment of further cultivation of the remaining natural biota. This strategy sets a ceiling to exploitation of biospheric resources, economic growth and global human population number.

The global stabilising environmental impact of the natural biota of Earth becomes especially clear from the analysis of the problem of climate stability. There are two physically stable states of the Earth's climate, that of complete ice coverage with global mean surface temperature close to $T \sim -100$ °C, Fig. 1 (**1**), and that of total evaporation of the Earth's hydrosphere with temperature close to $T \sim +400$ °C, Figure. 1 (**3**) (Gorshkov *et al*., 2000). In both stable states life is impossible. The modern climate of Earth, Figure. 1 (**2**), where the predominant part of the hydrosphere exists in the liquid state, proves to be physically unstable. The observed stability of the suitable-for-life global mean surface temperature over geological timescales can be only explained if one allows for appearance of biotically controlled singularities in temperature-dependent behaviour of the greenhouse effect and albedo within the life-compatible temperature interval from 5 °C to 25 °C.

Biotic processes aimed at maintenance of climate stability should be necessarily characterised by strictly defined succession, direction and duration, i.e., fluxes and stores of information. Such information is contained in the genetic programme of biological species combined into ecological communities of the global biota. Anthropogenic disturbance of natural ecological communities results in violation of the natural population density distribution of species and of genetic programs of natural species due to creating artificial sorts of plants and breeds of animals. This leads to degradation of the stabilising environmental potential of the biota, which may ultimately cause rapid spontaneous transition of the Earth's climate to either of the two life-incompatible physically stable states.

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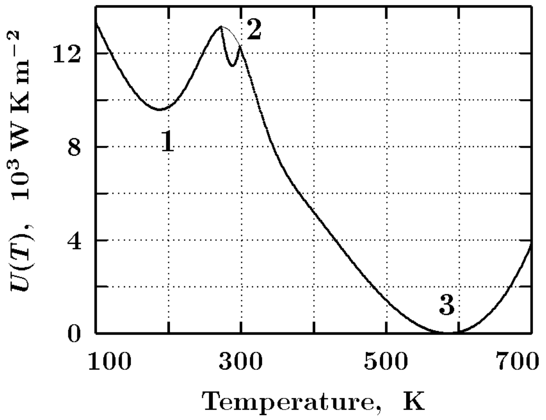

Figure 1. The potential (Liapunov) function $U(T)$ for the mean global surface temperature.

$U(T)$ is determined to the accuracy of integration constant from the equation $C\,dT/dt = -dU/dT$, where C is the average heat capacity per unit area of the Earth's surface, $C\,dT/dt$ is the rate of change of energy content per unit surface area. It is equal to the difference between the absorbed solar radiation $(I/4)\,a(T)$ and thermal radiation of the Earth's surface emitted into space, which is equal to $(sT^4)\,b(T)$. Here $I/4$ is the flux of solar radiation averaged over the whole planet's surface, I is the solar constant, $a(T)$ is the share of absorbed solar radiation ($1-a(T)$ is equal to planetary albedo), s is the Stephan-Boltzmann constant, $b(T)$ is the share of equilibrium thermal surface radiation leaving the planet ($1-b(T)$ is the normalized greenhouse effect).

Physically stable states **1** and **3** correspond to minima of the potential function $U(T)$. In these states functions a and b remain practically temperature independent over a relatively broad range of temperatures. On a lifeless Earth the physical behaviour of these functions are generally governed by the Clausius-Clapeyron equation for atmospheric water and corresponds to the central unstable maximum of $U(T)$ (**2**, thin line). To account for the observed stability of the modern climate (**2**, thick line) it is necessary to introduce non-physical singularities of functions $a(T)$ and $b(T)$ within the life-compatible temperature interval. Such singularities may only appear as the result of regulatory impact of the global natural biota.

Reference

Gorshkov, V.G., Gorshkov V.V., Makarieva, A.M., 2000. Biotic Regulation of the Environment: Key Issue of Global Change. Springer-Verlag, London.

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GLOBAL CHANGE NEWSLETTER

October 2000

The International Geosphere–Biosphere Programme (IGBP: A Study of Global Change of the International Council for Science (ICSU)

Non-Linear responses and surprises: A new Earth System Science initiative

by Pep Canadell

We live in a world where rapid and unpredicted system responses can result from even very small changes in forcing conditions or from gradual and continuous environmental change. Such nonlinear dynamics is the product of complex interactions and feedbacks and/or from simple biochemical and structural threshold-like responses that cascade throughout a system. This type of nonlinear behavior is characteristic of the way ecological systems function, yet, tremendous effort has been geared towards describing complex nonlinear responses as more readily tractable linear ones. Linear thinking is very much entrenched in the way policy-makers perceive environmental change and, consequently, ways to manage it (e.g., climate change will alter production of terrestrial ecosystems in a proportional manner).

A deeper understanding of the nonlinear nature of systems will contribute to increasing our capacity to predict future ecosystem behavior under novel combinations of resources and forcings that brought about environmental change, and to detect early in advance low-probability/high-catastrophe events, such as the terrestrial biosphere's flip from C sink to C source or the collapse of production systems.

IGBP, building upon an early initiative from GCTE (Global Change and Terrestrial Ecosystems), has initiated a new research focus to study biospheric responses to global change that involve rapid nonlinear changes and thresholds. The initiative is very much in its early stages of development but some of the emerging objectives are:

- To identify processes and resource gradients prone to generate nonlinear responses, and therefore, unexpected system behavior under future

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