BIO-CONTROLLED THERMOSTASIS INVOLVING THE SULFUR CYCLE

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Abstract. The Gaia hypothesis proposed by Lovelock and Margulis presumes the existence of an unspecified biological means of ameliorating climate that has operated since the emergence of life 3500 Myr ago. Recently it was suggested that the mechanism of thermostasis may involve biospheric cycling of atmospheric carbon dioxide.

We suggest an alternative hypothesis of biotthermostat operating through the sulfur cycle, rather than the carbon cycle. The mechanism would operate by altering planetary albedo through the selective creation of biospheric organic sulfide gases which go on to metamorphize into submicron particles and introduce cooling. In contrast to the carbon-cycle mechanism, sulfur-based cooling would have the ability to ameliorate climate well into the future, in principle over stellar Main Sequence time intervals. The main feature of interest is that the S cycle represents a particularly favorable thermodynamic pathway, involving three to four orders of magnitude less mass of active material cycled through the biospheric-atmospheric system (in response to a given temperature-imposed stress) than would be the case for a greenhouse gas hypothesis.

There is no evidence that the suggested biospheric controlled particle-albedo change mechanism is actually operating, but we speculate that the probability of its rising importance and perhaps eventual dominance will improve when the partial pressure of atmospheric CO₂ drops low enough to impose stress on metabolic processes. The intriguing thing about the process is its extremely high efficiency.

1. Introduction

Lovelock and Margulis (1974) introduced an interesting paradigm (the Gaia hypothesis) to account for the remarkable thermal stability of the terrestrial climatic system over time intervals of billions of years. They surmise the existence of an unspecified biological mechanism of thermostasis which has provided an equable climate for the biospheric system in spite of the fact that the sun's radiant energy output has increased by about 25% since life emerged 3500 Myr ago. The rising solar luminosity is a feature common to all Main Sequence stars, a consequence of continual depletion of hydrogen in the sun's core as it burns in the nuclear fusion process.

In an attempt to specify a mechanism through which Gaia might operate, Lovelock and Whitfield (1982) suggested that the climate stabilization feedback loop might involve bio-control of the abundance of atmospheric CO₂. Such a mechanism would lead to systematic depletion of the 'greenhouse gas' and therefore, to a limited life span of the biosphere in comparison to the time interval the sun spends on the Main Sequence.

The present communication raises the idea of an alternative biocontrol mechanism,
which would seem to be thermodynamically more suitable by several orders of magnitude than a biofeedback linkage involving CO₂; it involves the sulfur cycle, rather than the carbon cycle, and would operate by altering planetary albedo and introducing cooling through the introduction of light-scattering sulfate aerosols. Rationale for introducing this admittedly quite speculative hypothesis is that its operation would involve very small quantities of material cycling through the biosphere to ameliorate climatically-imposed stress. So far we have no compelling evidence indicating that the proposed mechanism has actually operated but it seems worthwhile to put the ideas forward as they may be useful to deparochialize ourselves in thinking about the evolution of life and climatic systems elsewhere. The purpose of the present communication, in short, is to stimulate areas of thought into ways which biospheres might adapt planetary-scale strategies to cope with planetary-scale alterations of climate.

2. Evidence of Biogenic Participation in the Sulfur Cycle

There is considerable evidence favoring the bacteriogenic cycling of large quantities of sulfur (Sze and Ko, 1979) through the ocean-atmosphere system. Once they are injected into the atmosphere, sulfur-bearing gases convert to submicron sulfate aerosols through successive oxidation to SO₂ and by homogeneous nucleation. Aerosols can alter planetary albedo and, moreover, they are particularly effective at doing so.

Organically-produced dimethyl sulfide, DMS, (CH₃-S-CH₃) seems to be one of the most important components in the S cycle (Lovelock et al., 1972): it is a major emission from bacteria, fresh water blue and blue-green algae and red, green and brown seaweed (Rasmussen, 1974). Oceanic produced DMS may, in fact, be responsible for cycling up to 30% of the amount of S required to balance the S budget (Nguyen et al., 1978).

COS and carbon disulfide (CS₂), both quite stable gaseous species, are also significant biogenic contributors to the land-ocean-atmosphere S budget (Sandalls and Penkett, 1979; Hanst et al., 1975). Logan et al. (1979), estimate that oxidation of CS₂ and COS by reaction with the hydroxyl radical provides ~ 10¹³ g S yr⁻¹, which would make these gases significant contributors to the tropospheric sulfate aerosol system. A review of DMS, COS, CS₂, and H₂S and their consolidation into a chemical-meteorological model (Sze and Ko, 1979) concludes, along with Logan et al. (1979) and Graedel (1979), that DMS and H₂S are biogenic products confined mainly to the lower troposphere, but that COS is likely to be a major source of atmospheric S throughout the troposphere. Sulfate aerosol, mainly in the form of hydrated H₂SO₄ and NH₄ (SO₄)₂ (Bigg, 1980; Shaw, 1982) are ubiquitous throughout the troposphere (Cunningham and Zoller, 1981; Delmas and Boutron, 1980; Winchester et al., 1981) and they seem to be derived daughter products (arising by nucleation) from parent biogenically-produced SO₄, which in turn arise through the slow oxidation of COS, DMS, etc. Biogenic participation in the atmospheric sulfur aerosol system thus is in actuality an ongoing process and it would seem to have a reasonable potentiality as a feedback climatic adjusting linkage.