Two-way interaction between biota and climate

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The apparent stability and habitability of the Earth's surface environment on timescales of billions of years stimulated the controversial Gaia hypothesis, in which living organisms and the global environment are thought to be arranged in a negative feedback loop, stabilizing the system.

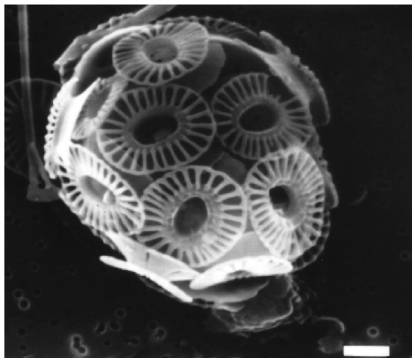

Fig. 1 *Phytoplankton, like the Emiliania huxleyi in this photo, might seem so small as to be insignificant (scale bar = 1 micron). However, they are so abundant that by taking an active part in the carbon and sulfur cycles, they may significantly affect the Earth's climate. Image courtesy of Patrick Holligan (from the Ehux website http://www.soc.soton.ac.uk/SOES/STAFF/tt/ehux.html).*

Indeed, there is a coupling between ocean and terrestrial biota and their physical and chemical environment on a wide range of spatial and temporal scales. Oceanic biota is influence by ocean circulation and mixing processes that regulate the availability of nutrients and light for photosynthesis. In turn, ocean biota can affect the physical environment. Phytoplankton (Figure 1) modulate the penetration of solar radiation in the upper ocean controlling, to some extent, the buoyancy distribution and local stratification of the surface ocean. In addition, oceanic biological activity acts to sequester carbon in the ocean and away from the atmosphere and also affects the number of sulphate particles and of cloud condensation nuclei (CCN- particles which provide a seed on which cloud droplets may form) in marine clouds by producing dimethyl sulphide (DMS); both influencing the radiative balance of the atmosphere (Figure 2). The terrestrial biosphere affects the Earth's albedo, the hydrological cycle, and the gas composition of the atmosphere. The lightning-biota climatic feedback is an example of negative feedback loop between climate and the terrestrial biosphere (Figure 3). Hence there is a capacity for two-way interactions, or feedback loops, between the biosphere and climate.

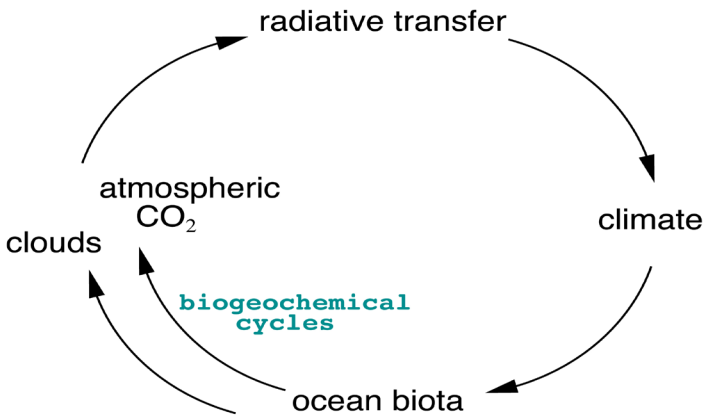

Fig. 2 *A schematic representation of the connections between ocean biota and climate indicating the potential for feedback loops, or two-way interactions. The state of the Earth's climate may influence oceanic biological activity through modulation of ocean circulation and the transport of essential nutrients. Oceanic biological activity influences the atmospheric partial pressure of carbon dioxide and possibly cloud properties. These, in turn, affect the radiative balance in the atmosphere and the climate system.*

As suggested by proxy records extracted from ice and ocean cores, by recent measurements, and by numerical models, such two-way interactions were likely major players in past climate variability, and may act to amplify or moderate an anthropogenically induced climate change in the near future. At present, our lack of understanding of these interactions hampers our ability to anticipate the consequences of possible anthropogenic climate change. Understanding the interactions between the ocean biota and climate is a difficult yet important challenge for the geosciences in the 21st century. Many questions regarding these feedbacks are open, and this challenge can be overcome only by a multidisciplinary approach and by combining field observations and modeling.

Selected publications

Gildor, H. and M. Follows (2002) Two-way interaction between ocean biota and climate mediated by biogeochemical cycles, Israel Journal of Chemistry, 42, 15-27, (special issue on Environmental Chemistry).

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(Eds.), The ocean carbon cycle and climate, 317-352, Kluwer Academic Publishers.

Shepon, A. and H. Gildor (2008), The Lightning-Biota Climatic Feedback, Global Change Biology, 14, 440–450, doi: 10.1111/j.1365-2486.2007.01501.x.

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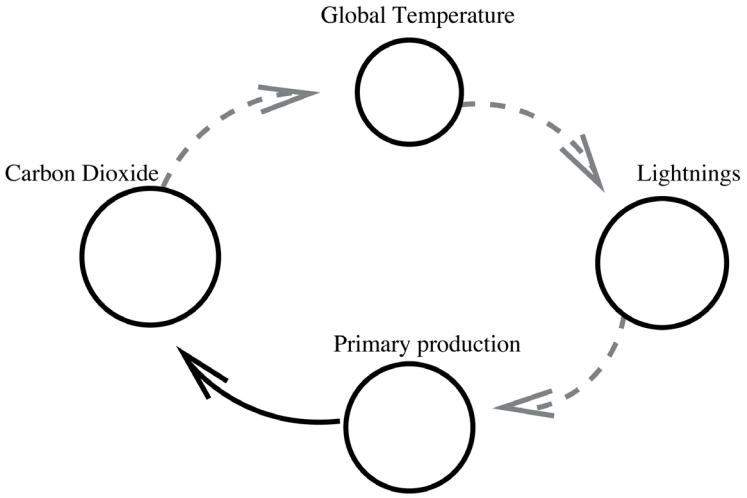

Fig. 3 *The lightning-biota climatic feedback: As the temperature increases more lightnings are produced, creating more bio-available nitrogen compounds. These compounds are limiting nutrients to the primary production of the biota over wide areas. Therefore, as more of these available nitrogen compounds are inputted into ecosystems, more primary production takes place, and thus more carbon dioxide is ultimately being uptaken from the atmosphere through photosynthesis. Consequently, global temperature decreases and a negative feedback loop is formed. The black solid arrows indicate a negative correlation (i.e., as one variable increases/decreases the other one decreases/increases) while the dashed gray arrows indicate a positive correlation (as one variable increases/decreases the other one increases/decreases).*