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Title: (IWG6-Invited) Atmosphere-Biosphere Interactions and Maximum Entropy Production in the Earth System

Abstract:

The biota affect Earth system processes and thereby the rate of entropy production. For instance, photosynthetic life modulates the global carbon cycle, and thereby the concentration of greenhouse gases in the atmosphere. On land, terrestrial vegetation influences the energy- and water partitioning at the Earth's surface. The work that the biota perform by growth and reproduction, and which leads to the biotic effects on the Earth system, is derived from photosynthesis and produces entropy. Here I apply the MEP principle to understand the nature of atmosphere-biosphere interactions. The MEP principle states that processes in thermodynamic non-equilibrium systems with sufficient degrees of freedom maintain macroscopic steady states at which entropy production is maximized. A macroscopic MEP state of the biosphere implies macroscopic reproducibility: Given a certain climate, one can for instance predict whether the dominant vegetation type of a region is likely to be a rainforest or a grassland, that is, the macroscopic state of terrestrial vegetation. MEP also implies a macroscopic state of maximum productivity: This can, for instance, be understood by the contrasting effects of stomatal conductance on productivity and convective cloud cover. Higher conductance allows for more supply of atmospheric carbon dioxide to the leaves, increasing the potential to do photosynthesis. But simultaneously, it also leads to higher rates of transpiration and a moister boundary layer, which is likely to be more cloudy, thereby reducing the amount of solar radiation at the surface. This line of reasoning is confirmed by sensitivity simulations with a coupled dynamic vegetation - climate model, and the climatic implications are being discussed. This line of reasoning is extended to the global-scale biotic effects on carbon cycling and the long-term evolution of the climate system. It is shown with a conceptual model that the maintenance of a biotic MEP state can lead to environmental homeostasis, with global mean temperature being insensitive to the long-term increase in solar luminosity. I close with a discussion on the potential applicability of MEP and its limits as well as its potential use in describing an adaptive biosphere under global climatic change.

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