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Modelling the interactions between climate and biosphere over geological timescales

Peter N. Nielsen, Peter D. Ditlevsen

The Niels Bohr Institute, University of Copenhagen, Juliane Maries Vej 30, DK-2100 Copenhagen O, Denmark (penoni@fys.ku.dk)

The observation that the climate of the geologically young Earth was generally warm, in spite of a considerably less luminous Sun, is explained by an intensified greenhouse atmosphere due to enhanced concentrations of CO_2 and/or CH_4. Evidence of geologically shorter extreme glacations in Earth's history, perhaps of global extent, is taken as results of temporary collapses of this greenhouse atmosphere. Many aspects of this climatic evolution of the Earth are thought to be related to the evolution of the biosphere, due to the biospheric influence on the atmospheric content of greenhouse gasses, and potentially also on the planetary albedo.

We present here a conceptually simple model that includes interactions between the climate and the biosphere over geological timescales. The model is set up by coupling a global energy balance model to a logistic growth model of the biosphere. The biospheric influence on climate is related to the dependence of the atmospheric content of greenhouse gasses and, to a lesser extent, also of the planetary albedo, upon the size and nature of the biosphere. The climatic influence on the biosphere is related to the dependence of the environmental hospitality upon the climatic state. These interactions, along with the abiotic ice-albedo feedback mechanism and the dependence of weathering upon temperature, comprise the web of feedback mechanisms that control the dynamics of the system. The model is analysed within the context of a nonlinear dynamical system, with special focus on the role of the varying solar luminosity. It clearly signifies the potentially profound climatic consequences of the biospheric evolution.