Complex dynamics, regime shifts, catastrophes and long-term transients in a model of plankton-oxygen dynamics under the climate change

Sergei Petrovskii

Department of Mathematics, University of Leicester

Leicester, LE1 7RH, UK

Email: sp237@le.ac.uk, http://www.math.le.ac.uk/PEOPLE/sp237

Ocean dynamics is known to have a strong effect on the global climate and on the composition of the atmosphere. In particular, it is estimated that more than one half of the total atmospheric oxygen is produced in the oceans due to the photosynthetic activity of phytoplankton. Any significant decrease in the net oxygen production by phytoplankton is therefore likely to eventually result in the depletion of atmospheric oxygen and in a mass mortality of animals and humans. However, the rate of oxygen production depends on water temperature and hence can be affected by the global warming. We address this issue theoretically by considering a novel model of a coupled plankton-oxygen dynamics where the rate of oxygen production changes with time to account for the ocean warming. We first prove that our model, albeit being simple or "conceptual", provides an upper bound for a class of complex realistic models of ocean (bio)dynamics. We then show that, when the temperature rises sufficiently high, a regime shift happens: the sustainable oxygen production becomes impossible and the system's dynamics leads to plankton extinction and oxygen depletion. We also consider a scenario when, after a certain period of increase, the temperature is set on a new higher yet apparently safe value, i.e. before the oxygen depletion disaster happens. We show that in this case the system dynamics may exhibit a long-term quasi-sustainable dynamics that can still result in an ecological disaster (oxygen depletion and mass extinctions) but only after a considerable period of time. Finally, we discuss the early warning signals of the approaching regime shift resulting in the disaster.