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Dynamic bifurcations for predictability of climate tipping events

Elena Surovyatkina (1,2,3) and Juergen Kurths (3,4,5)

(1) Space Research Institute of Russian Academy of Sciences, Space Dynamics and Data Analysis Department, Moscow, Russia (selena@iki.rssi.ru), (2) Kamchatka State Technical University, Petropavlovsk-Kamchatsky, Russia, (3) Research Domain IV – Transdisciplinary Concepts&Methods, Potsdam Institute for Climate Impact Research, Potsdam, Germany, (4) Department of Physics, Humboldt University, Berlin, Germany, (5) Institute for Complex Systems and Mathematical Biology, University of Aberdeen, Aberdeen AB243UE, UK

Despite recent advances in understanding of the nonlinear processes responsible for changes in the climate system predicting the future abrupt climate changes remains an outstanding scientific challenge of special importance for the society. Better understanding of nonlinear mechanisms of tipping points is a major goal in treating this problem. Existed approaches to examine climatic tipping points allow identifying the climate-tipping events in the past but very limited to predict them in advance. Our recent theoretical findings suggest that for predicting tipping points it is crucial to distinguish which scenario of a bifurcation transition dominates: dynamic (predictable) or stochastic (unpredictable).

In order to illustrate suggested approach we compare the features of dynamic and stochastic bifurcations in most common scenario of abrupt transition between two climate states. This scenario is associated with a saddle-node and a transcritical bifurcations. Such scenario has been used, in particularly, in the analysis of stability of the thermohaline circulation against freshwater flux, Indian summer monsoon against global change. We demonstrate the effect of the rate of change of the bifurcation parameter at dynamic bifurcation and noise effect at stochastic bifurcation transitions by theoretical estimates.

We analyse pre-bifurcation noise-dependent and rate-dependent phenomena, and distinguish its roles as “precursors” of impending bifurcations for dynamic and stochastic transitions. We show that appropriate choice of “precursors” might lead to improving predictability of climate tipping points. Additionally, the evaluation of the role of dynamic and stochastic factors might be also useful for the assessment of the vulnerability of tipping elements to noise-induced changes. Finally, our preliminary investigations suggest that a hitherto neglected dynamic effect induced by such small parameter as rate of change of the bifurcation parameter may have had important influence on abrupt climate changes on the scale of the geological history of the Earth.