Statistical physics approach in tipping point analysis

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There exist various methodologies of studying critical phenomena in climate system, ranging from bifurcation theory to machine learning applications. We demonstrate that applying statistical physics (Fokker-Planck equation) and stochastic modelling allows one to obtain early warning signals of tipping events, detect critical transitions, and forecast evolution of a dynamical system, such as the climate system, based on its trajectories (time series or data flows). These techniques follow evolution of critical transitions and constitute tipping point analysis. As a part of it, system potential analysis allows one to analyse system dynamics and detect the changes of the system states (bifurcations), which then can be extrapolated using the dynamically varying system potential. Potential dynamics can be visualised in a multiscale potential plot, where the changing number of potential states is monitored at different scales, similarly to wavelet analysis.

An interesting raising topic in tipping point analysis is the limit of control under uncertainty of early warning signals, which is directly related to climate adaptation. Can we, upon issuing an early warning signal, response in timely manner and prevent critical transitions with adaptation measures? How fast should be the mitigation response with respect to the system dynamics? What are the requirements on observational data and how can statistical physics help prevent critical transitions? We will discuss the ongoing work in this area, including controlled laboratory experiments in international collaborations.

Applications include several paleo and modern climate datasets, artificial data simulations and sensor data from environmentally affected installations, in which we apply techniques for uncertainty quantification of early warning signals and for detection of statistically significant transitions. We will discuss them in the context of known climatic phenomena, as well as data-driven discovery of climate anomalies.

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