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Cascading tipping points in dynamical systems and paleoclimate

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In the framework of cascading tipping points, networks of dynamical systems exhibit cascades where a critical transition in one sub-system triggers a critical transition in one or more other sub-systems. The individual transitions may arise via noise- or rate-induced switching in between attractors, or via slow passage through a bifurcation. This yields a variety of different cascading scenarios.

Real-world analogues might exist in the climate, where several sub-systems could undergo chains of critical transitions under future anthropogenic climate change. Recent studies indicate a role of cascading effects leading up to past climate changes. Paleoclimate data and models suggest that so-called Dansgaard-Oeschger events arise from sequential shifts in the atmospheric circulation, sea ice cover and ocean circulation.

We hypothesize a tipping cascade as underlying mechanism, and construct a conceptual model with sea ice and ocean components, which both show a double fold bifurcation structure. Changing atmospheric conditions are modeled by a slow parameter drift or additive noise. The ocean component permits rate-induced tipping, yielding a rich array of tipping cascades.

With this system we explore mathematical signatures of tipping cascades and implications for paleoclimate changes. We assess the statistical significance of early warning signals related to critical slowing down and changes in cross-correlation, as well as the transient behavior of the probability density.