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Predicting past tipping points: The Dansgaard-Oeschger events of the last glacial period

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The Dansgaard-Oeschger (DO) events of the last glacial period provide a unique example of large-scale climate change on centennial time scales. Despite significant progress in modeling DO-like transitions with realistic climate models, it is still unknown what ultimately drives these changes. It is an outstanding problem whether they are driven by a self-sustained oscillation of the earth system, or by stochastic perturbations in terms of freshwater discharges into the North Atlantic or extremes in atmospheric dynamics.

This work addresses the question of whether DO events fall into the realm of tipping points in the mathematical sense, either driven by an underlying bifurcation, noise or a rate-dependent instability, or whether they are a true and possibly chaotic oscillation. To do this, different ice core proxy data and empirical predictability can be used as a discriminator.

The complex temporal pattern of DO events has been investigated previously to suggest that the transitions in between cold (stadial) and warm (interstadial) phases are purely noise-induced and thus unpredictable. In contrast, evidence is presented that trends in proxy records of Greenland ice cores within the stadial and interstadial phases pre-determine the impending abrupt transitions and allow their prediction. As a result, they cannot be purely noise-induced.

The observed proxy trends manifest consistent reorganizations of the climate system at specific time scales, and can give some hints on the physical processes being involved. Nevertheless, the complex temporal pattern, i.e., what sets the highly variable and largely uncorrelated time scales of individual DO excursions remains to be explained.