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Dansgaard–Oeschger events: bifurcations in the climate system

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The largest variability in temperature of the last sixty thousand years is connected with Dansgaard–Oeschger events. These are fast warming episodes (in the North Atlantic region, $5 - 10°C$ in a few decades), followed by a cooling period that lasts from hundreds to thousands of years, with a final small jump to initial conditions. They occur with a periodicity of approximately 1500 years. The connection between Dansgaard–Oeschger events and large changes in the Atlantic meridional overturning circulation is today generally accepted. Various prototype models from different authors have been able to qualitatively reproduce the climatic signal, but no observational constraint has been forwarded to choose between different theories.

We use high–resolution ice core isotope data to investigate the multimodality of the system and the statistical properties of fluctuations in the period before the onset of the abrupt change. Through a phase space reconstruction based on Takens' theorem, we show that the time series has a robust bimodal behaviour. We show that techniques previously suggested for detecting early warning signals of abrupt transitions can provide important constraints to climate models. In particular, it is found that the statistical properties of fluctuations are fully compatible with a model that connects Dansgaard–Oeschger events with the crossing by the climate system of fold bifurcation points, in response to an external forcing. This view implies hysteresis and switches between two equilibria of a component of the climate, most likely the Atlantic meridional overturning circulation. Other hypotheses, that explain Dansgaard–Oeschger oscillations as noise–induced transitions or motion along an homoclinic orbit, can be rejected.

These results demonstrate that abrupt transitions in the climate system can happen in response to a forcing that crosses a critical threshold. Dansgaard–Oeschger events are an example of this behaviour.