



Are abrupt climate changes predictable?

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It is taken for granted that the limited predictability in the initial value problem, the weather prediction, and the predictability of the statistics are two distinct problems. Lorenz (1975) dubbed this predictability of the first and the second kind respectively. Predictability of the first kind in a chaotic dynamical system is limited due to the well-known critical dependence on initial conditions. Predictability of the second kind is possible in an ergodic system, where either the dynamics is known and the phase space attractor can be characterized by simulation or the system can be observed for such long times that the statistics can be obtained from temporal averaging, assuming that the attractor does not change in time. For the climate system the distinction between predictability of the first and the second kind is fuzzy. This difficulty in distinction between predictability of the first and of the second kind is related to the lack of scale separation between fast and slow components of the climate system.

The non-linear nature of the problem furthermore opens the possibility of multiple attractors, or multiple quasi-steady states. As the ice-core records show, the climate has been jumping between different quasi-stationary climates, stadials and interstadials through the Dansgaard-Oeschger events. Such a jump happens very fast when a critical tipping point has been reached. The question is: Can such a tipping point be predicted? This is a new kind of predictability: the third kind.

If the tipping point is reached through a bifurcation, where the stability of the system is governed by some control parameter, changing in a predictable way to a critical value, the tipping is predictable. If the sudden jump occurs because internal chaotic fluctuations, noise, push the system across a barrier, the tipping is as unpredictable as the triggering noise. In order to hint at an answer to this question, a careful analysis of the high temporal resolution NGRIP isotope record is presented. The result of the analysis points to a fundamental limitation in predictability of the third kind.

Reference: P. D. Ditlevsen and S. Johnsen, "Tipping points: Early warning and wishful thinking", *Geophys. Res. Lett.*, 37, 2010