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Data-driven Reconstruction of Last Glacials' Climate Dynamics Suggests Monostable Greenland Temperatures and a Bistable Northern Hemisphere Atmosphere

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Multiple proxy records from Greenland ice cores exhibit a series of concomitant abrupt climatic shifts during the last glacial. These so-called Dansgaard–Oeschger (DO) events comprise, among others, warming over Greenland, a sudden retreat of North Atlantic and Nordic Seas' sea ice, and an atmospheric reorganisation of hemispheric extent. Typically DO events are followed by a phase of moderate cooling, before the climate abruptly transition back to its pre-event state. While the physics behind these dynamics are still subject to a vibrant debate, the idea that at least one of the involved climatic subsystems features bistability is widely accepted.

We assess the stability of Greenland temperatures and the Northern Hemisphere atmospheric circulation represented by $\delta^{18}O$ and dust concentration records from the NGRIP ice core, respectively. We investigate the 27-59 ky b2k period of the combined record which covers 12 major DO events at high temporal resolution. Regarding the data as the realisation of a stochastic process we reconstruct the corresponding drift and diffusion by computing the Kramers–Moyal (KM) coefficients. In contrast to previous studies, we find the drift of the $\delta^{18}O$ to be monostable, while analysis of the dust record yields a bistable drift. Furthermore, we find a non-vanishing 4^{th}-order KM coefficient for the $\delta^{18}O$, which indicates that the $\delta^{18}O$ time series cannot be considered a standard type Langevin process. In a second step, we treat the joint ($\delta^{18}O$, dust) time series as a two dimensional stochastic process and compute the corresponding coefficients of the two dimensional KM expansion. This reveals the position of the fixed point of $\delta^{18}O$ to be controlled by the value of the dust. In turn, the drift of the dust undergoes an imperfect supercritical pitchfork bifurcation when transitioning from low to high $\delta^{18}O$ values.