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Last glacial termination preceded by change in time-reversibility structure of paleoclimate dynamics

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The time-reversibility structure of climate time series provides important information on the nature of the underlying processes. A novel statistical test for time-reversibility is employed that is based on the study of time-directed properties of visibility graphs constructed from time series and is particularly suitable for the study of irregularly sampled paleoclimate proxy records. Several oxygen isotope records of Greenland paleoclimate during the late Pleistocene and Holocene are investigated. We find that the records' time-reversibility structure changes from irreversible to reversible several 10 ky before the glacial termination. This finding suggests that strongly nonlinear (irreversible) climate dynamics (probably related to the asymmetric saw-tooth-like profile of strong Dansgaard-Oeschger and Heinrich events) during the coldest stage were followed by reversible more Holocene-like dynamics appearing well before the actual beginning of the Holocene. Hence, changes in time-reversibility structure may provide a nonlinear early warning signal for climate tipping points, complimenting features such as critical slowing down or increasing auto-correlation.