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Synchronous signatures of time-irreversibility in Northern and Southern Hemisphere records of last glacial climate and the Holocene

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The time-reversibility structure of climate time series provides relevant 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 ice core, speleothem and lacustrine records of paleoclimate during the late Pleistocene and Holocene from both Northern and Southern hemispheres are investigated. We find a consistent and robust signature of time-irreversibility and, hence, nonlinear processes driving climate dynamics, in the time-interval between approx. 40 and 60 kyr BP (before present). This signature is most pronounced in ice core records from Greenland and Antarctica, but also partially apparent in selected speleothem and lacustrine records from the mid-latitudes and tropics. In contrast, time-reversible climatic dynamics is detected consistently during the following last glacial maximum period and the Holocene. These findings suggest that strongly nonlinear (irreversible) climate dynamics (probably related to the asymmetric saw-tooth-like profile of particularly pronounced Dansgaard-Oeschger and Heinrich events) between 40–60 kyr BP were followed by reversible more Holocene-like dynamics appearing well before the actual beginning of the Holocene. These globally detectable changes in time-reversibility structure may provide novel insights into climatic dynamics, particularly considering the mechanisms underlying Dansgaard-Oeschger events during the last glacial and Bond events during the Holocene, as well as those behind the switch between glacial and interglacial conditions.