

Paleoclimatic tipping points and abrupt transitions: An application of advanced time series analysis methods

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Motivation

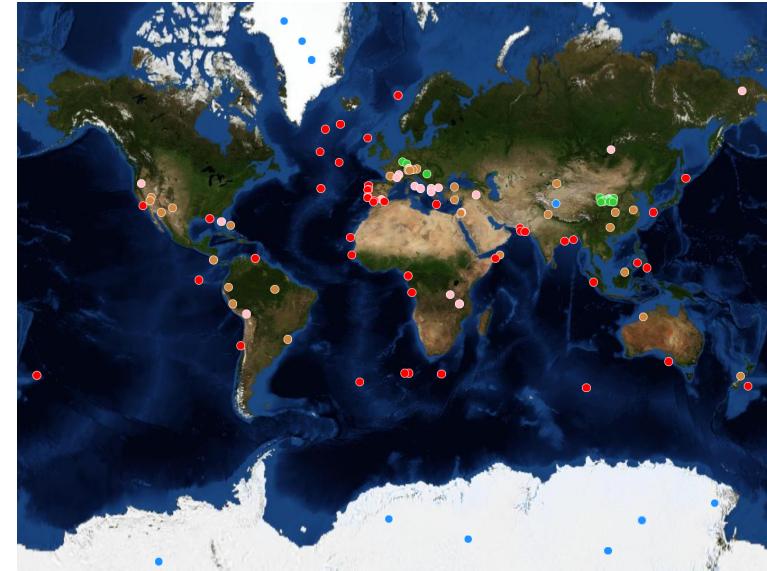
Records of past climate exhibit abrupt transitions, which may represent tipping points (TPs) in the Earth system's past.

Paleoclimate proxy records provide information for identifying TPs in current and future climate evolution.

Identifying TPs in paleoclimate records is complicated as the records vary in their resolution, time spans, and periodicities.

An objective, automated methodology is crucial for identifying and comparing TPs.

PaleoJump database: <https://paleojump.github.io>



123 sites:

- 49 marine sediment cores
- 29 speleothems
- 18 lake sediment cores
- 16 loess records
- 11 ice cores

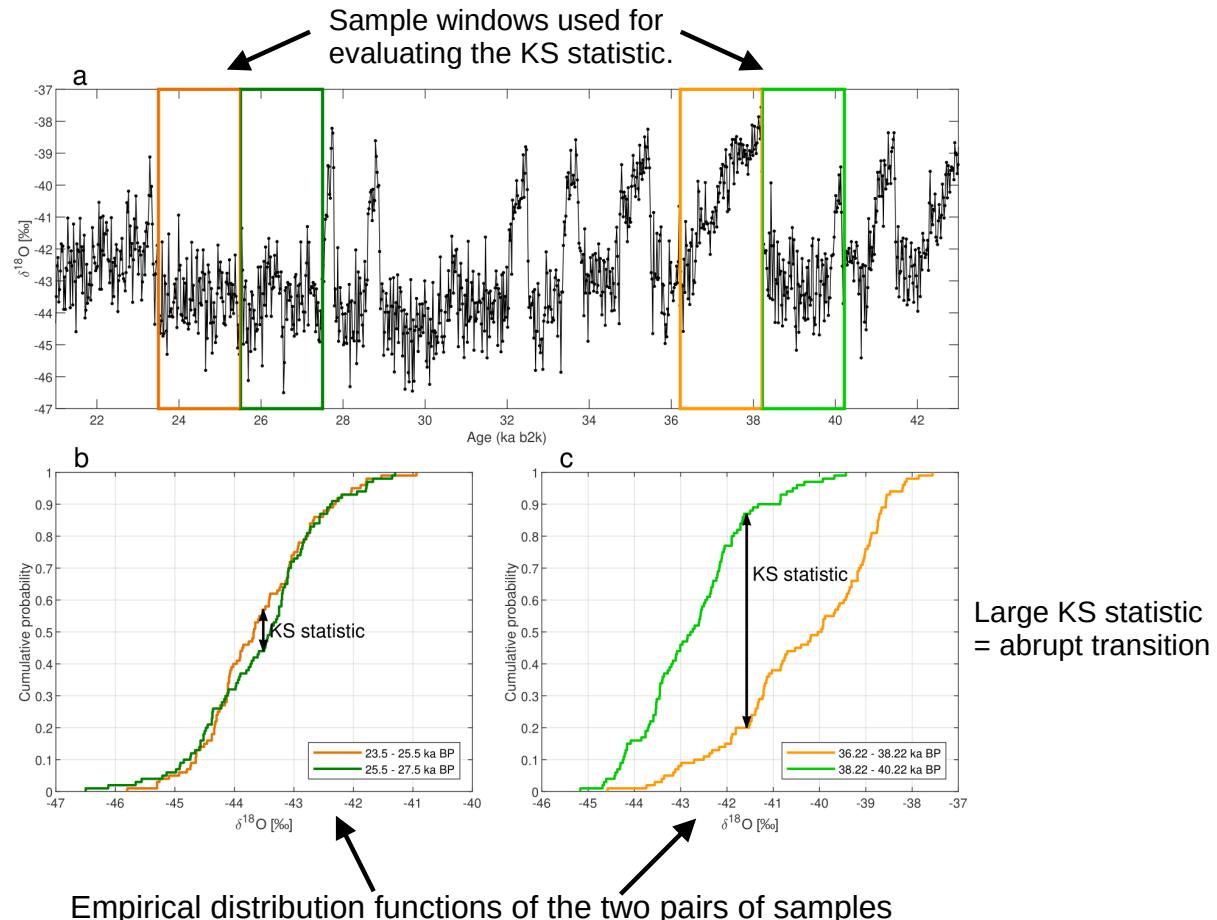
The database contains high-quality paleoclimate proxy records that exhibit abrupt transitions.

Main focus on the Last Climate Cycle, with some records extending further back in time.

Information provided for each site: location, elevation, temporal range, resolution, available proxies, links to the original data and the associated publications.

Abrupt transitions in the records identified using a modified Kolmogorov-Smirnov test and Recurrence Quantification Analysis.

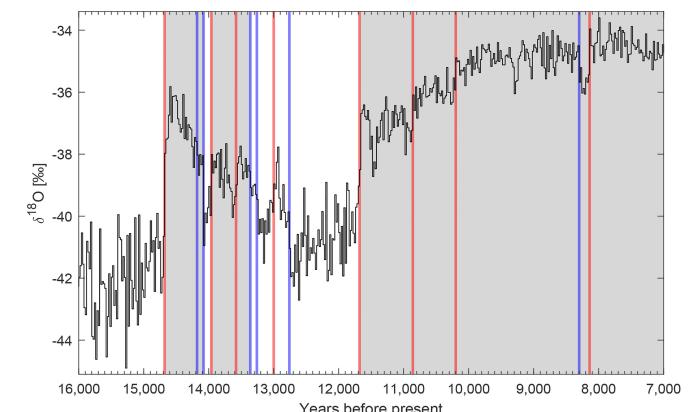
Kolmogorov-Smirnov test



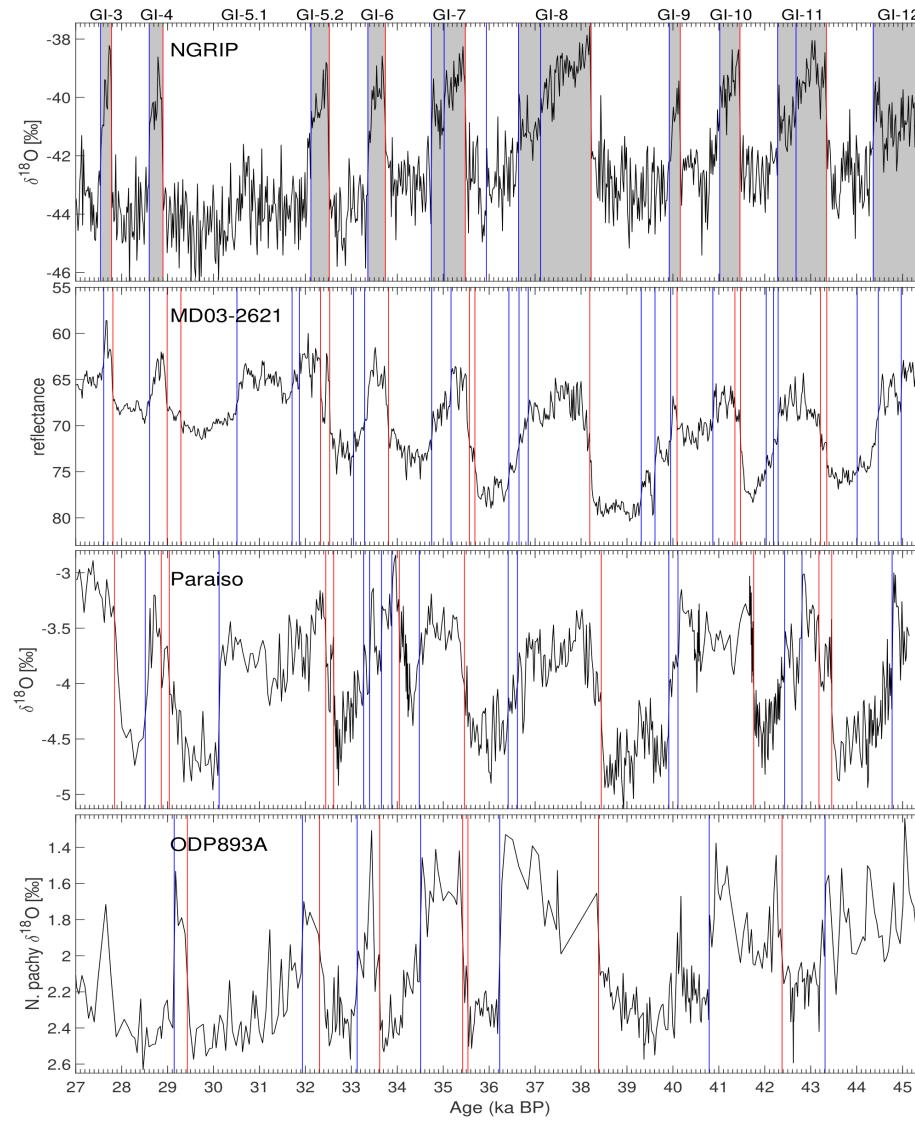
We apply an augmented KS test (Bagniewski et al., 2021) to identify abrupt transitions in the records included in the PaleoJump database.

Other key components of the methodology:

- varying window size
- minimum rate-of-change threshold
- long term trends in maxima and minima



Transition detection: 4 records (45.5 – 27 ka BP)



Main NGRIP DO events also observed in the other 3 records

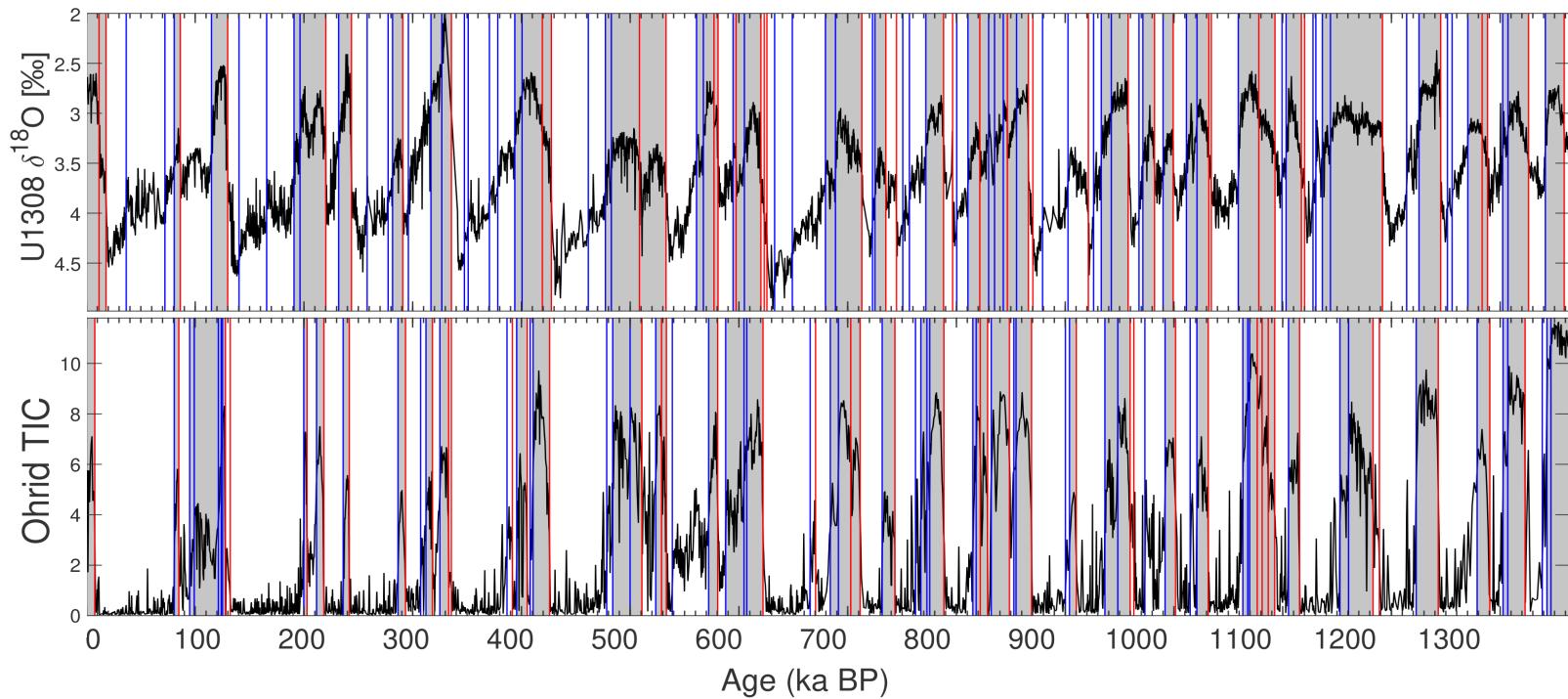
In addition to the classical Greenland transitions, several additional jumps are identified

Some transitions only found for South American records: regional events?

Some DO events appear combined: Tipping Point not crossed?

Potential for using the KS method to improve fine-tuning the chronology of paleo records

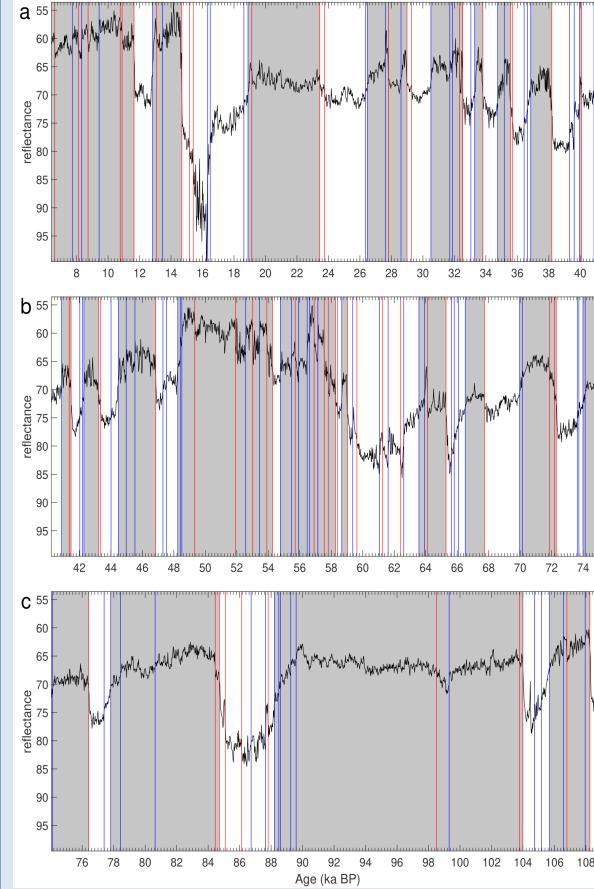
Transition detection: 2 records (1.4 – 0 Ma BP)



- KS test allows precise dating for the chronology of the past glacial cycles
- Cooling transitions in Lake Ohrid often precede those in the deep ocean by several thousand years: lagging response in ice sheet growth to atmospheric cooling, or in signal propagation into the deep North Atlantic

Comparison between the KS test and Recurrence Quantification Analysis

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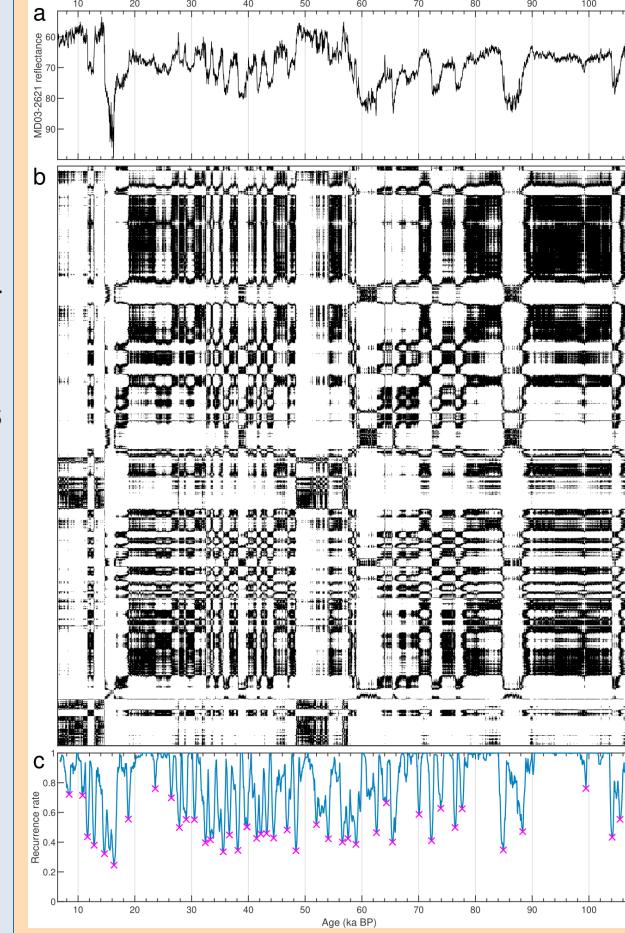


KS test

The augmented KS test is very effective in detecting abrupt transitions and allows identifying precise dates of individual transitions for different time scales

KS test reveals transitions that have not been recognized previously

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Recurrence quantification analysis (Marwan et al., 2007)

By evaluating the recurrence rate (RR) in a sliding window, we identify changes in the time series

Major transitions are identified, including regime shifts

Recognizing the transition points becomes challenging at time scales shorter than the window length

Magenta crosses: local RR minima corresponding to abrupt transitions

Conclusions

- The PaleoJump database, <https://paleojump.github.io>, is a useful, easy-to-use resource for researchers investigating tipping points in past climates.
- Its broad spatial coverage facilitates research on different potential tipping elements in the Earth's climate.
- The augmented KS test allows a robust and precise detection of previously unrecognized transitions at every investigated time scale.
- Using the KS method to compare different records may help decode the chronology of tipping events or an approximate range for a tipping threshold.
- Recurrence analysis is useful in identifying regime changes and helps establish particularly important transitions - the two methodologies complement each other.

Thank you!

References

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