

Land ice distribution suggests an irregular pattern of interglacials across most of the Quaternary

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GRAND CHALLENGES

There is no 100-kyr cycle ... only multitudes of 41-kyr \Rightarrow **obliquity-driven system**
(Land ice sheets are mainly influenced by obliquity (41 kyr).)

Tzedakis et al 2017 (T17), doi: 10.1038/nature21364:

A simple rule to determine which insolation cycles lead to interglacials

We propose that the appearance of larger ice sheets over the past million years was a consequence of an increase in the deglaciation threshold and in the number of skipped insolation peaks.

Past Interglacials Working Group (PIGS) of PAGES 2016, doi: 10.1002/2015RG000482:
Review on **Interglacials of the last 800,000 years**

Chosen definition:

Interglacials are characterized by absence of NH ice outside Greenland; different interglacials must be separated by lowering of sea level below a set threshold.

In practise:

LR04 benthic $\delta^{18}\text{O}$ is taken (PIGS 2016, T17), \Rightarrow differs from NH ice outside Greenland.

Here: ice sheet model @ Utrecht deconvolves LR04 benthic $\delta^{18}\text{O}$ into:

$\Delta T_{\text{deep o}}$, ΔT_{atm} (40–80°N), **ice sheets distribution**, sea level

\Rightarrow **Instead of LR04 $\delta^{18}\text{O}$ we can indeed investigate interglacials as defined.**

red points: onset of new IG following our land ice analysis

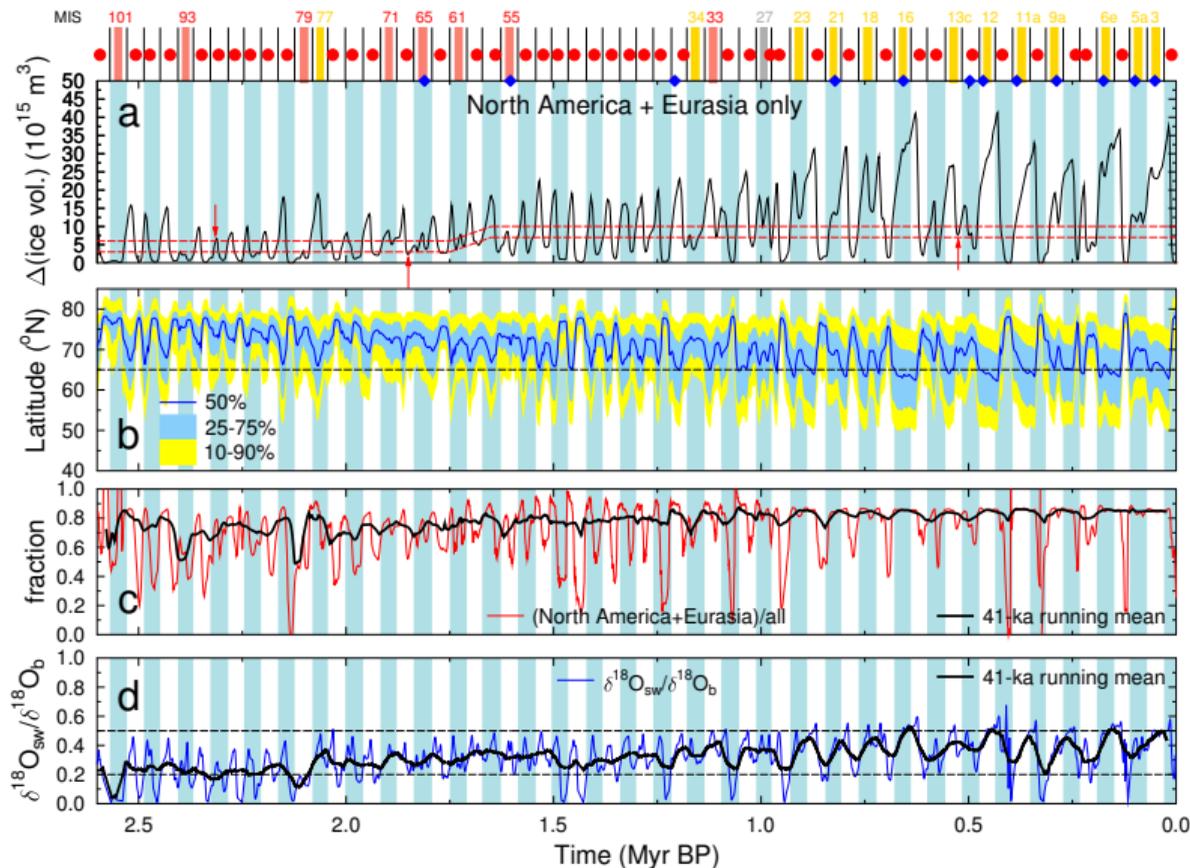
Coloured bars:

gold (13): obliquity cycle without new IG following T17, CONFIRMED here

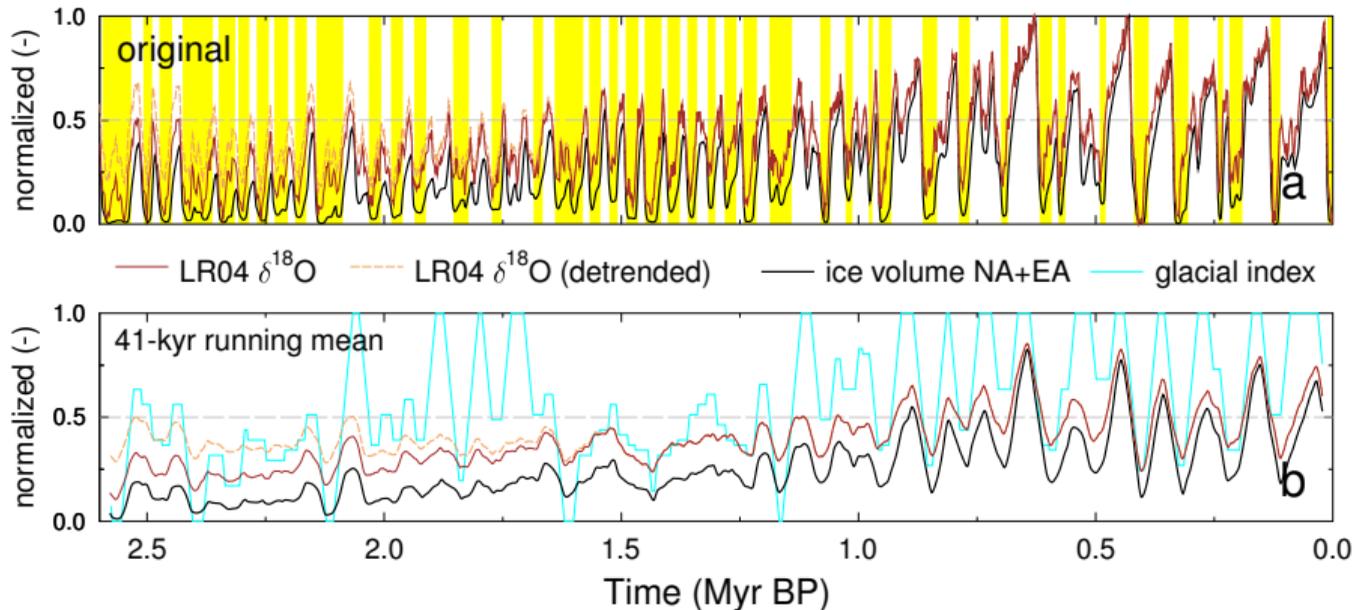
grey (1): obliquity cycle without new IG following T17, NOT CONFIRMED

red (8): new obliquity cycle without new IG ACCORDING TO THIS STUDY

lightblue bars: every 2nd obliquity cycle



- Prior to the MPT the relatively large anomalies in the LR04 benthic $\delta^{18}\text{O}$ (from which a regular pattern of interglacials has been detected in T17) transform in rather small anomalies in the NH ice volume changes outside of Greenland, making 7 obliquity cycles (2–3 questionable, 4–5 robust) in our definition to periods without the onset of a new interglacial .
- From our revised definition based on NH land ice volume outside of Greenland (the original definition) interglacials seemed to appear irregularly both prior and after to the MPT.
- The definition of interglacials restricts the climate spectrum to a binary pattern (glacial or interglacial). However, all definitions are due to the chosen (partly subjective) definitions of thresholds prone to errors or arbitrariness.



Indices of Quaternary climate. (a) Original data including in yellow bars the identified interglacial periods (this study); (b) 41-kyr running means. Normalized time series of ice volume change in North America (NA) and Eurasia (EA) used to define interglacials (this study) and of the LR04 benthic $\delta^{18}\text{O}$ stack and its detrended version used in T17. In (b) the glacial index (the inverse to the yellow interglacial periods contained in (a)) is shown due to its in-phase dynamics to the other time series. This index is built, when the ice volume in North America and Eurasia is reduced to a binary pattern (glacial = 1; interglacial = 0).