Late Pleistocene interglacials: Defining them and getting hold of their CO_2

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PMIP Workshop on IG @ Bremerhaven, 09 Jan 2025

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HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

Layout

Interglacials defined by:
(absence of NH) land ice (outside of Greenland)

CO_2

MIS 11c and 31

Layout

Interglacials defined by:

(absence of NH) land ice (outside of Greenland)

Defining Interglacials

(Past Interglacials Working Group of PAGES 2016)

AGU PUBLICATIONS

Reviews of Geophysics

REVIEW ARTICLE
10.1002/2015RG000482

Interglacials of the last 800,000 years

Past Interglacials Working Group of PAGES[1]

— Conceptual change of state
— "As warm or warmer than the Holocene"
— Fixed threshold
— Varying threshold
— Interglacial defined as the interval following a glacial termination
— Interglacial defined as the most prominent peak(s) within each odd-numbered marine isotopic complex
— Interglacials are characterized by absence of NH ice outside Greenland; different interglacials must be separated by lowering of sea level below a set threshold.

Defining Interglacials

(Past Interglacials Working Group of PAGES 2016; Tzedakis et al. 2017)

Choosing an insolation metrics

Defining interglacials

Deriving a simple scheme

Chosen definition for Interglacials (IG):

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:

(detrended) LR04 δ^{18}O taken,

but this is NOT NH ice outside Greenland

ARTICLE

doi:10.1038/nature21364

A simple rule to determine which insolation cycles lead to interglacials

P. C. Tzedakis[1], M. Crucifix[2], T. Mitsui[2] & E. W. Wolff[3]

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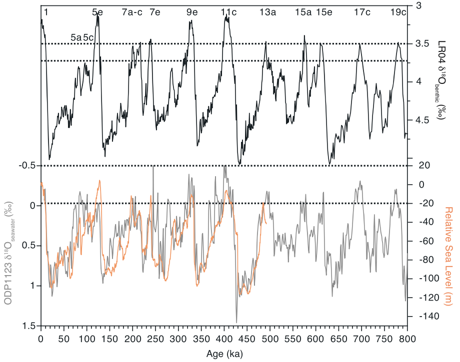
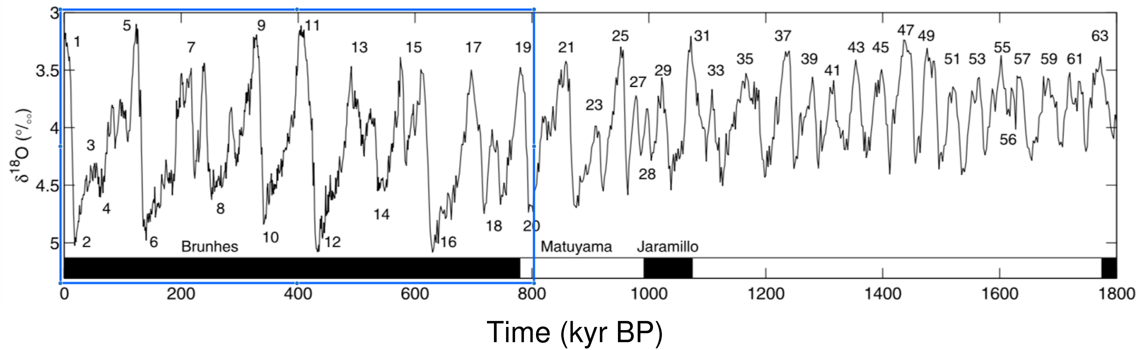


Time running this way

From benthic δ^{18}O to land ice, $\Delta R_{[LI]}$ & ΔT_g (Lisiecki & Raymo, 2005)



Input	Method	Output
reconstructed deep ocean δ^{18}O	3D ice sheet model δ^{18}O → sea level & ΔT	land ice distribution definition of IG (no NH ice out of Greenl.)
(Lisiecki & Raymo, 2005)	(de Boer et al., 2014)	(Köhler & van de Wal 2020)

1500 kyr Ice Volume Change

(Köhler and van de Wal, 2020)

benthic $\delta^{18}O$

land ice=f($\delta^{18}O$, model)
(de Boer et al 2014)

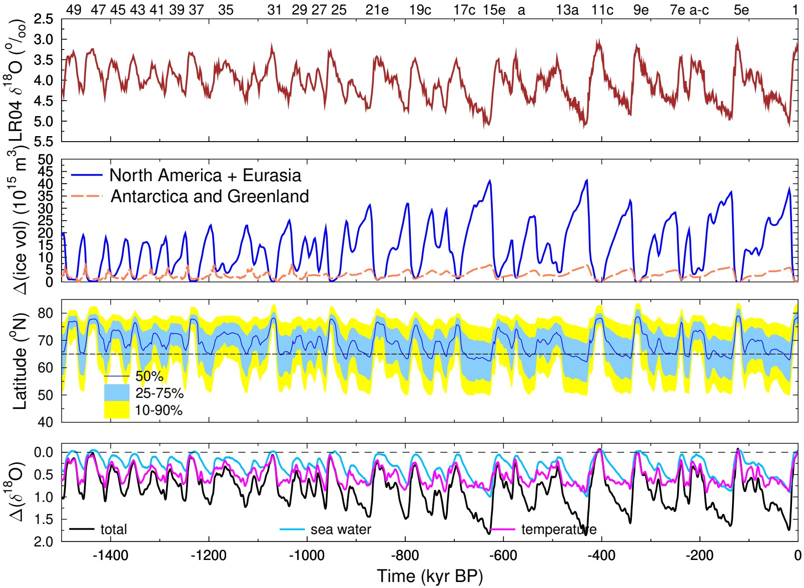
Findings for IG:

IG defined by lack of NH land ice outside of Greenland

$\delta^{18}O_{sw}$ vs $\delta^{18}O_T$

ANT+GIS>PRE

Residual NAM+EUR



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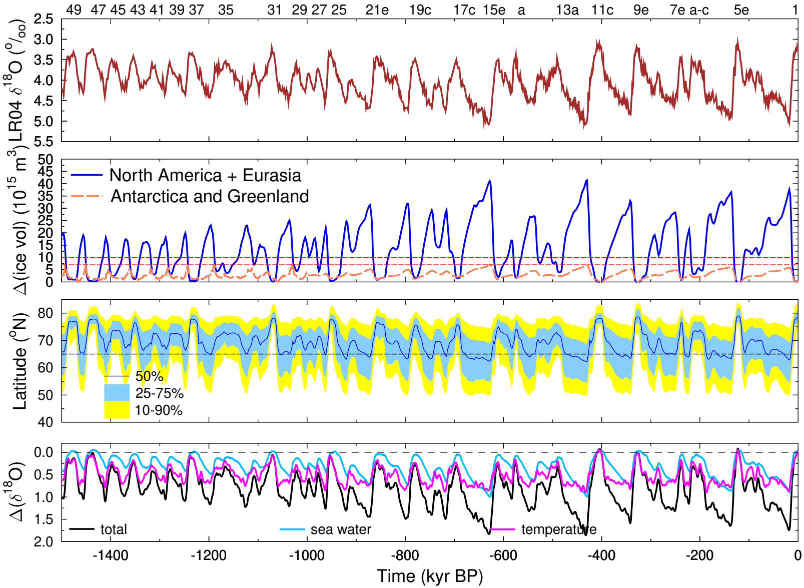

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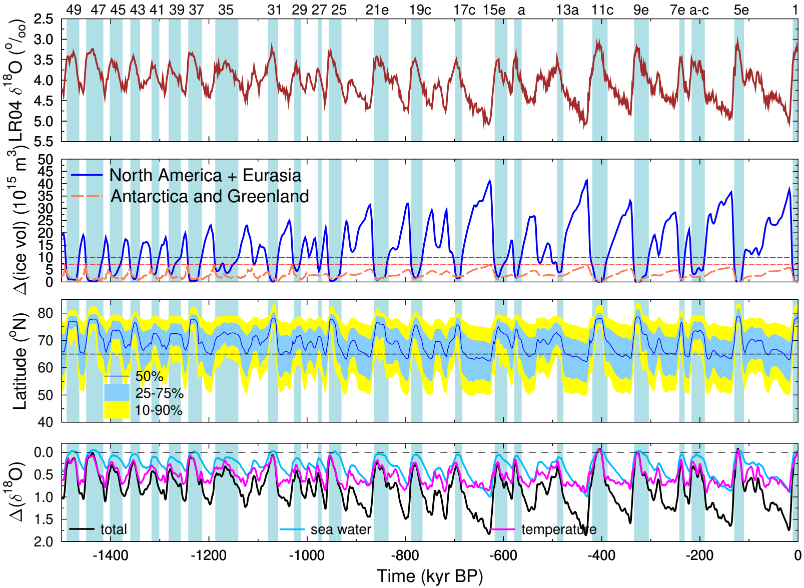

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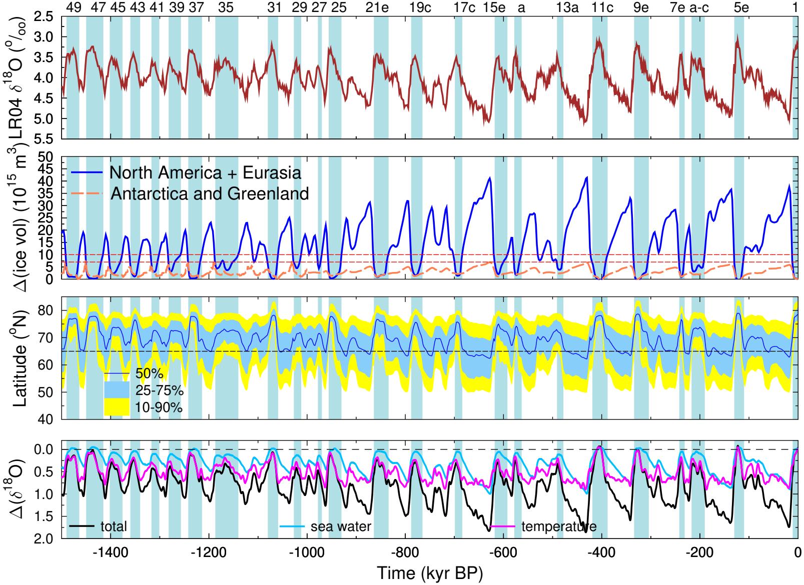

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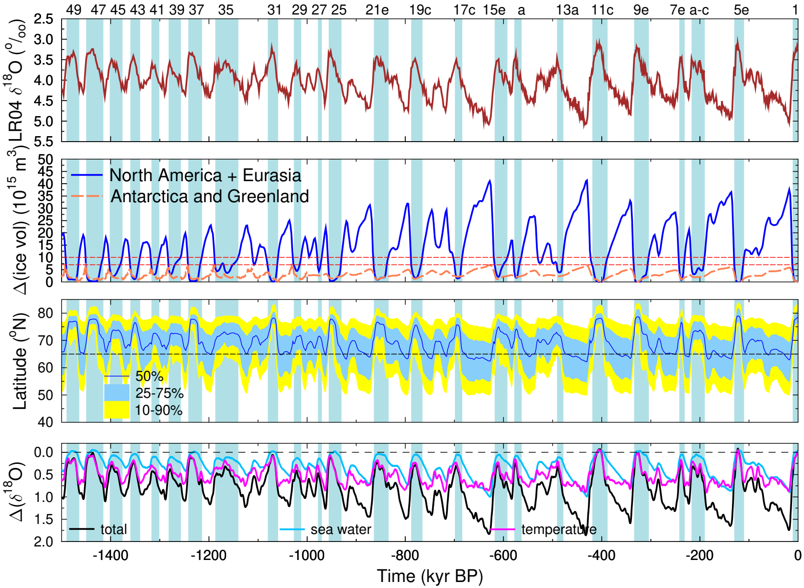

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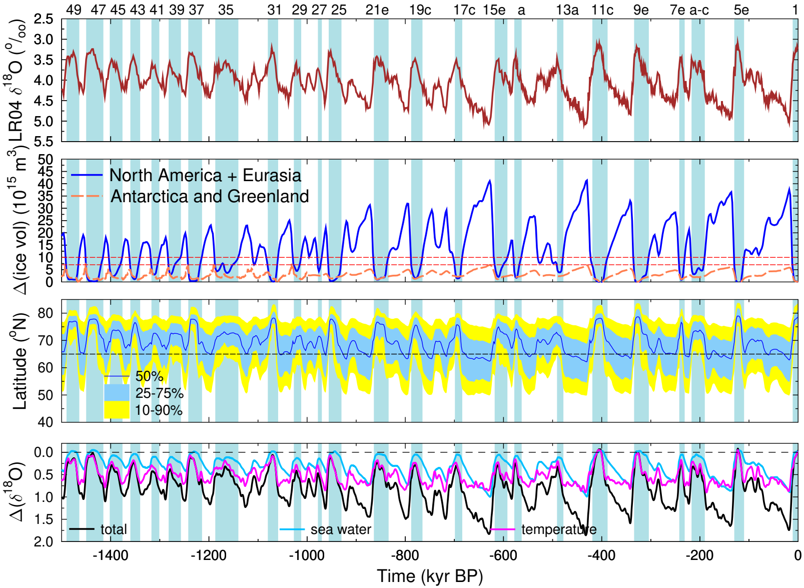
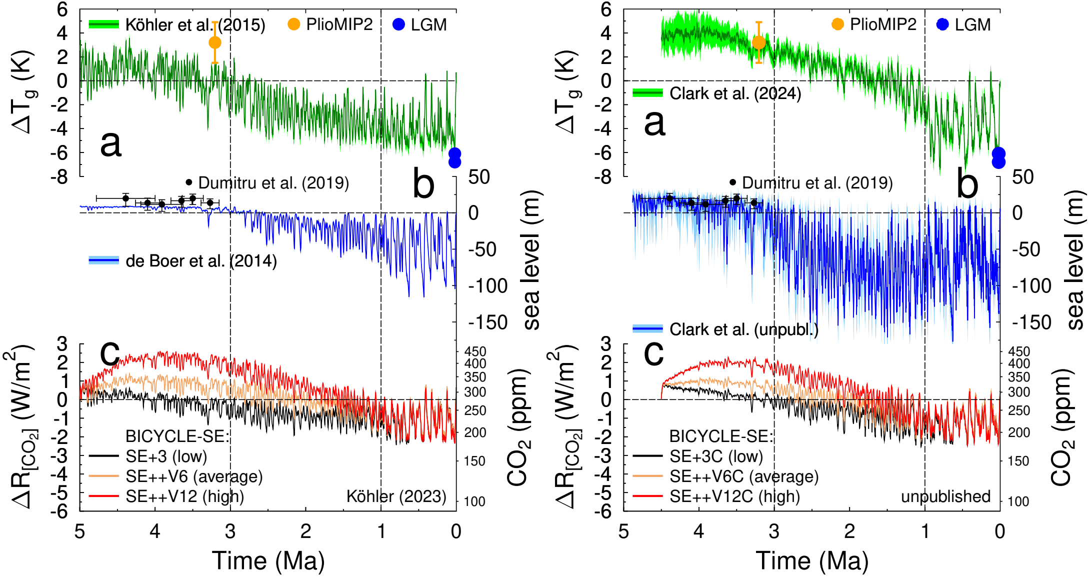


Evolving Revised Understanding

(Clark et al., 2024, submitted)



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Findings for IG:

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$\delta^{18}O_{sw}$ vs $\delta^{18}O_{T}$

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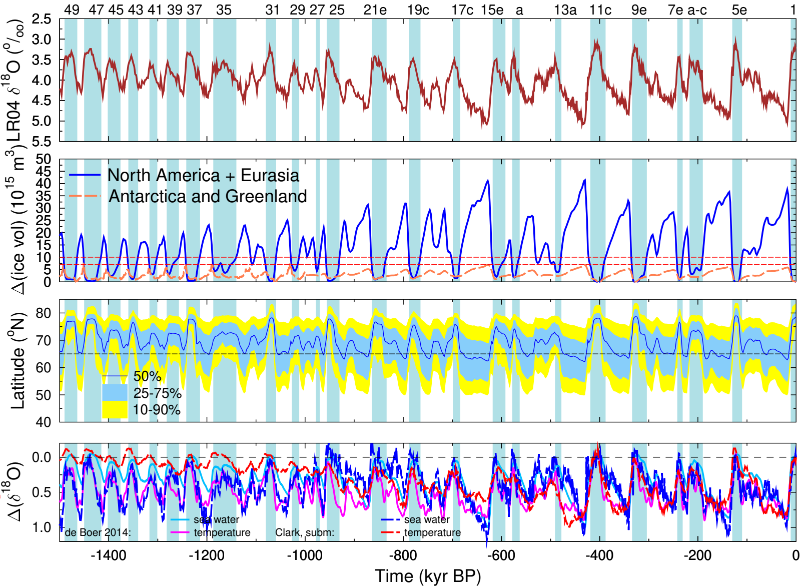
Residual NAM+EUR

Alternative $\delta^{18}O_{sw}$ + $\delta^{18}O_{T}$

Temperature data-based

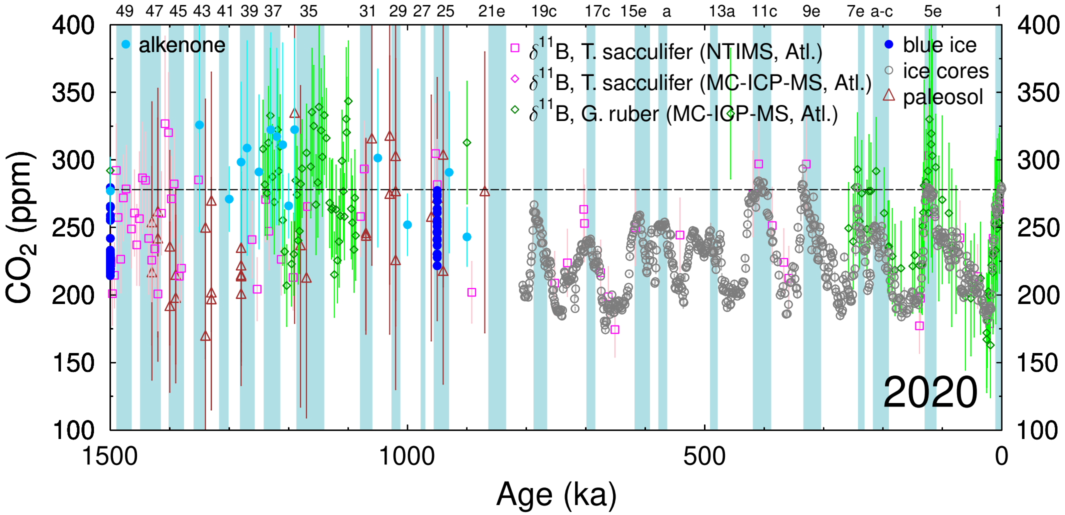
(Clark et al., 2024, subm.)



Layout

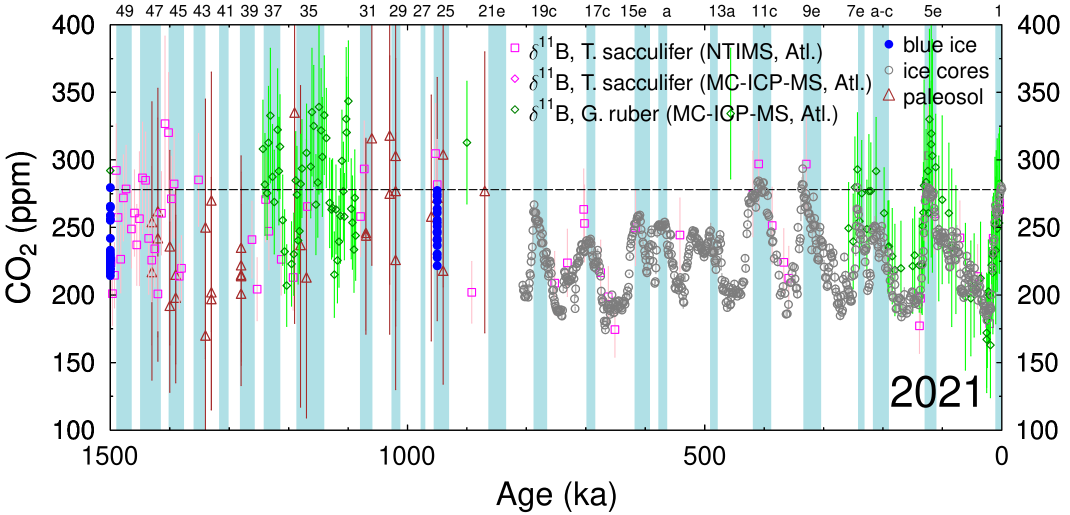
CO_2

CO_2 ... as evolved over recent years



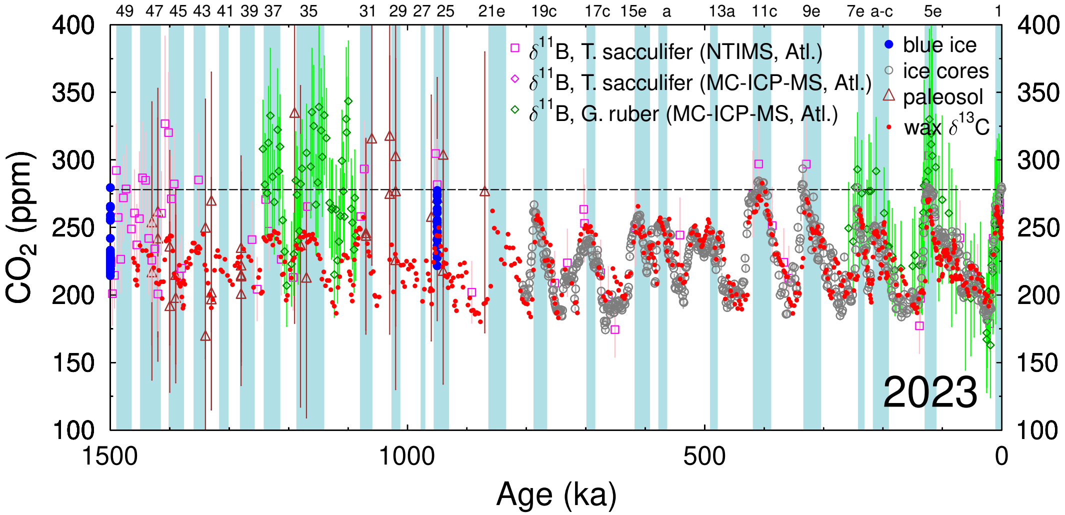
δ^{11}B-isotopes, alkenones, paleosol, blue ice, ice cores

CO_2 ... as evolved over recent years



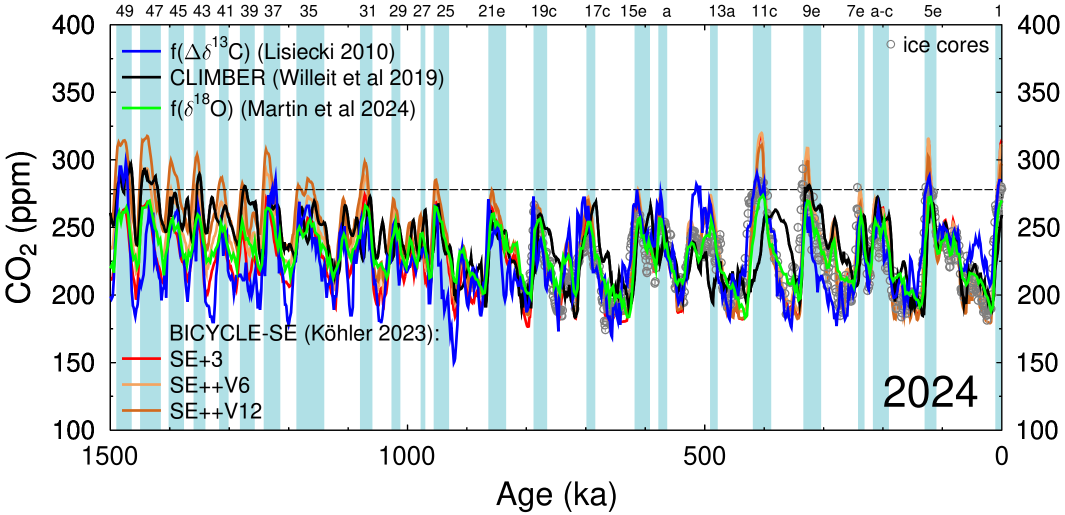
alkenones not reliable anymore (Phelps et al., 2021)

CO_2 ... as evolved over recent years



new data: leaf wax δ^{13}C (Yamamoto et al 2022)

CO_2 ... as evolved over recent years

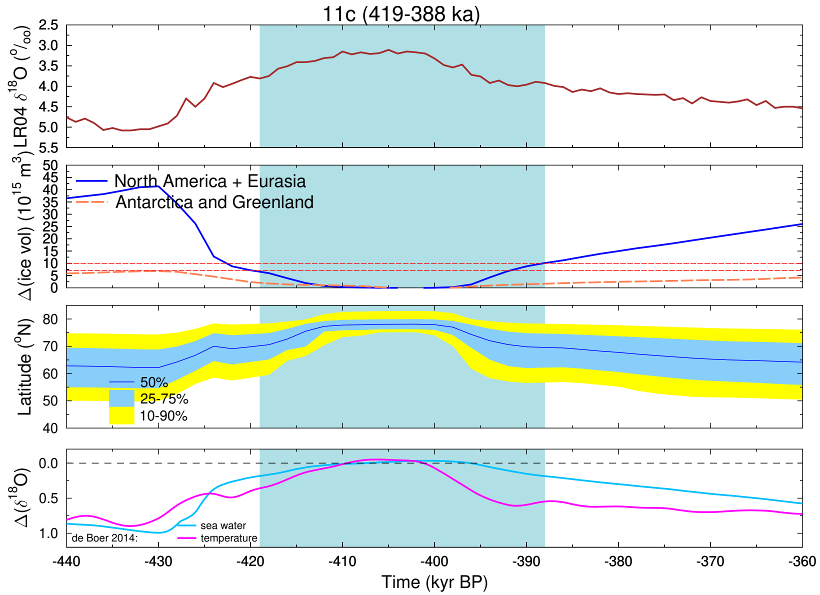


Carbon cycle simulations and transfer functions from marine data

MIS 11c and 31

MIS 11c

(Köhler and van de Wal, 2020)



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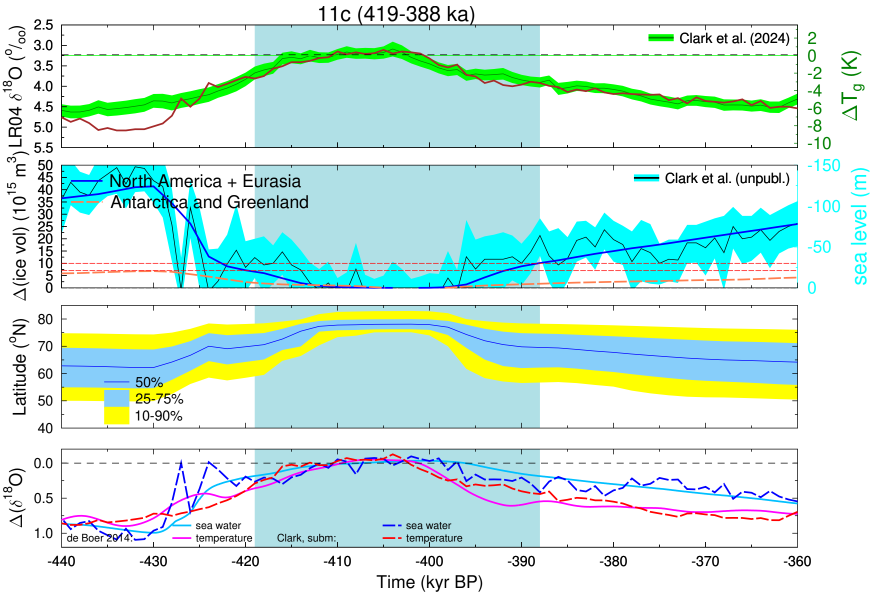
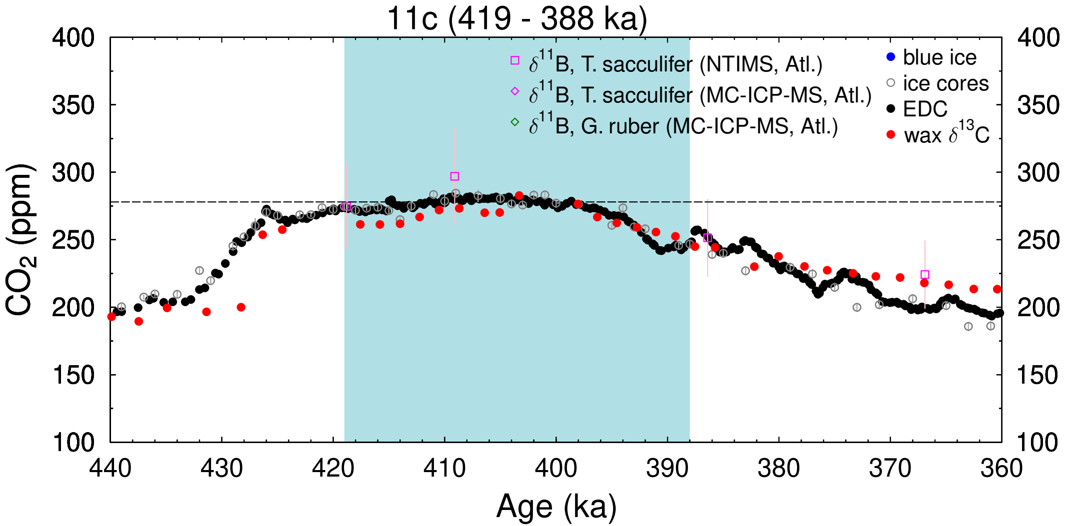


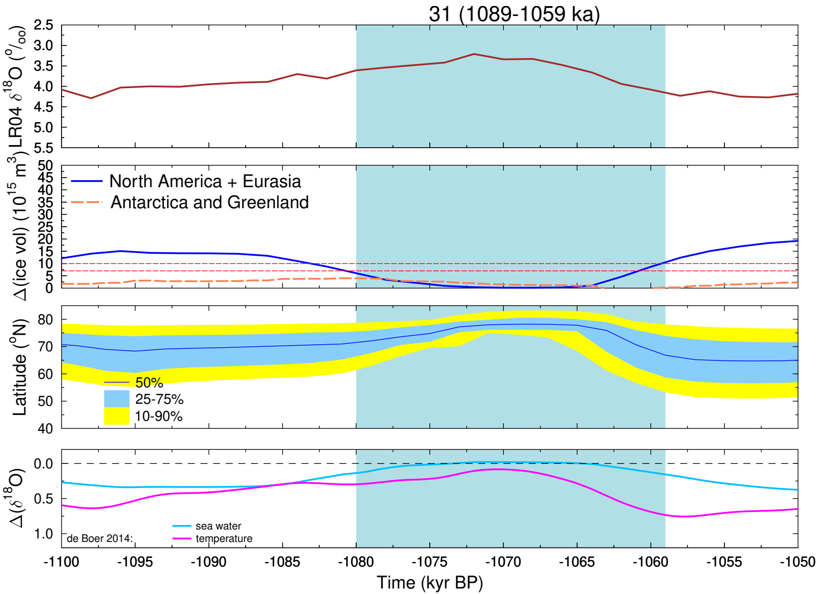
CO_2 MIS 11c



MIS 11c: high-res ice core data (Nehrbass-Ahles et al (2020) + some proxy data

MIS 31

(Köhler and van de Wal, 2020)



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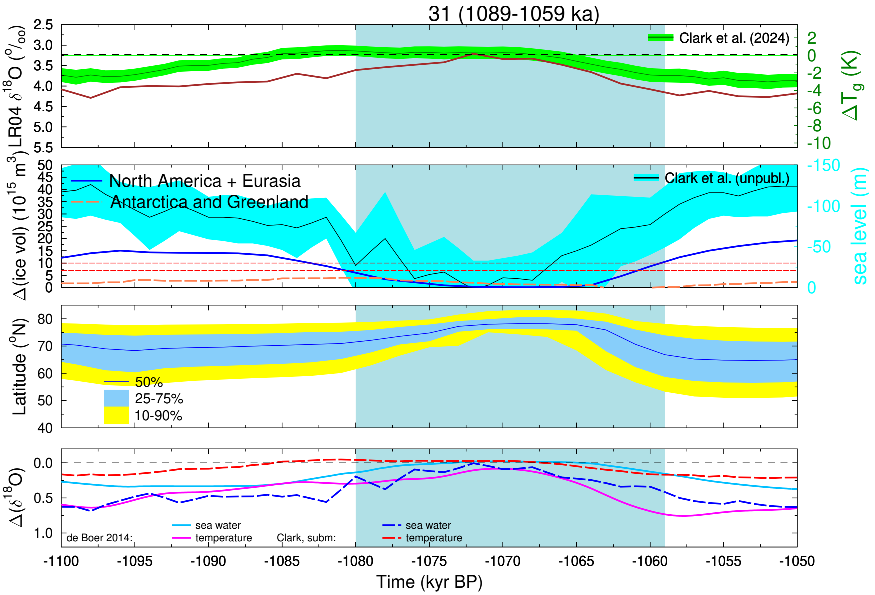
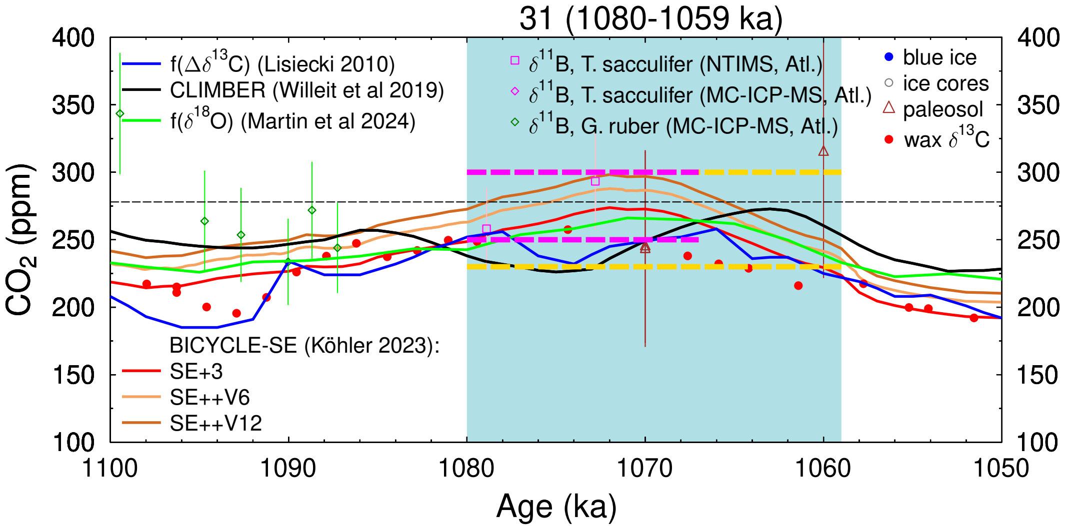


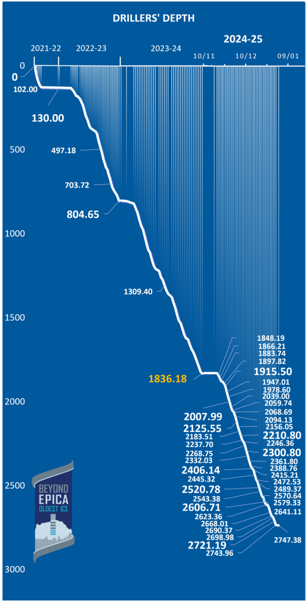
CO_2 MIS 31

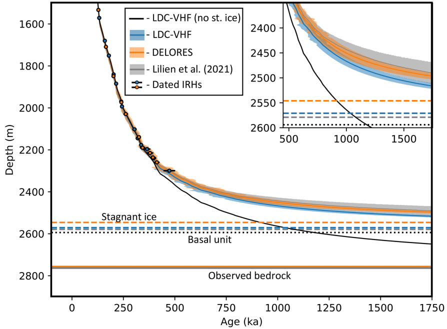


MIS 31: some proxy data and a lot of simulations

Beyond EPICA Oldest Ice Core

(Beyond EPICA, unpublished; Chung et al., 2023)





BEYOND EPICA OLDEST ICE

Recommendations

MIS 11c: CO_2 = preindustrial = 278 ppm

(but: CO_2 @ PMIP-PI run: 284 ppm!)

MIS 31: $CO_2 = \in [250, 300]$ ppm or wait for Beyond EPICA (2026)

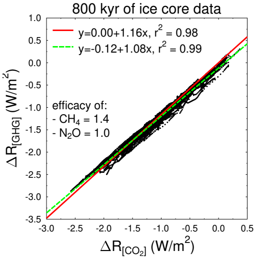
CH_4, N_2O: = preindustrial, or

CO_2 ⇒ eff. CO_2 with $\Delta R_{[GHG]} = 1.25 \cdot \Delta R_{[CO_2]}$

Non-CO_2-GHG factor of 1.25 based on Hansen et al (2023)

Older approaches have 1.16 based on different efficacies

(see Figure)



(Data used in Köhler et al., 2010 based on Hansen et al., 2008)

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