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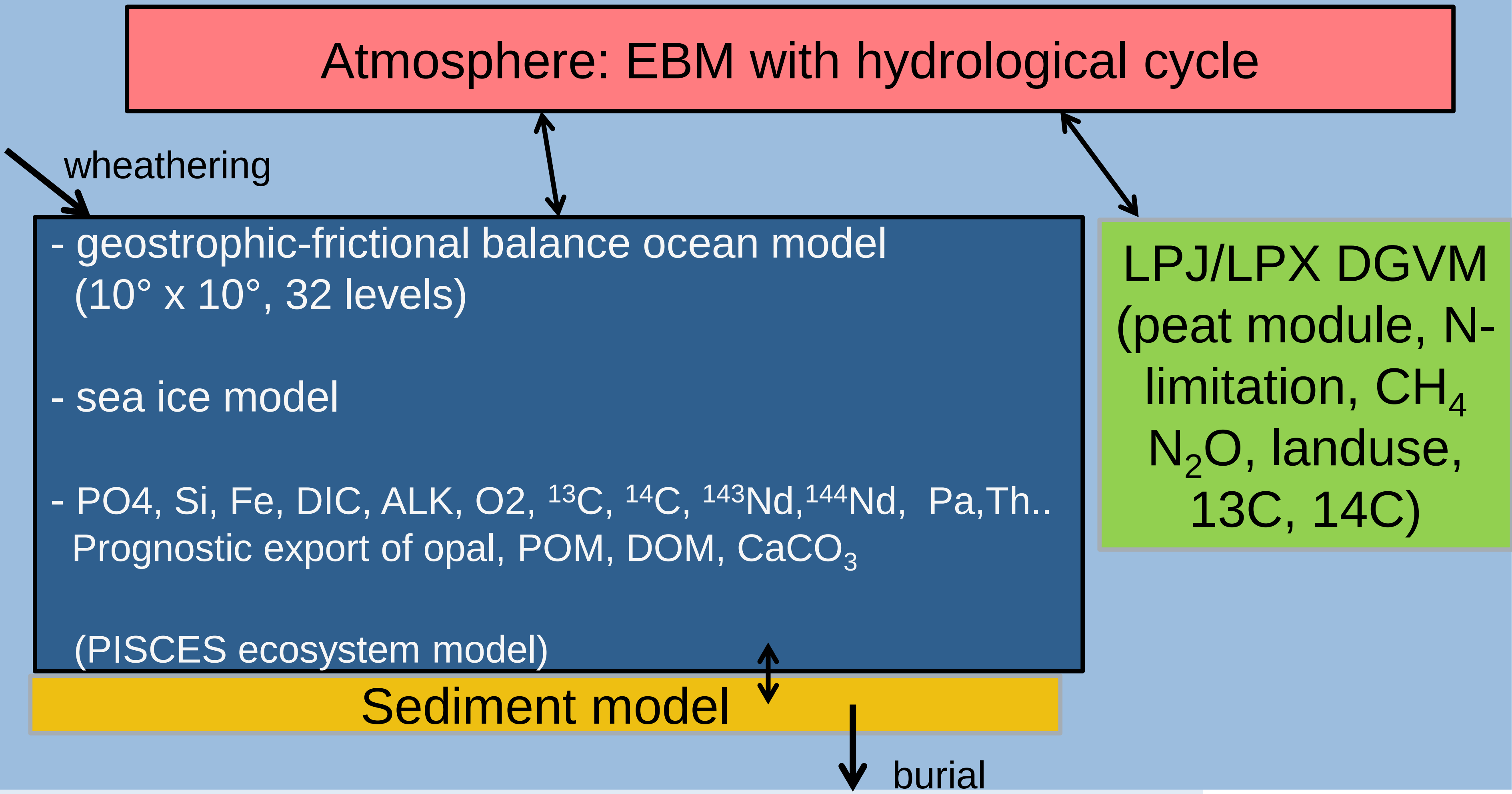
OESCHGER CENTRE CLIMATE CHANGE RESEARCH

Carbon and Nd Isotopes and paleo-applications in a low resolution model

Fortunat Joos, Laurie Menviel, Johannes Rempfer, Anil Bozbiyik and many others

Climate and Environmental Physics and
Oeschger Centre for Climate Change Research
University of Bern

The Bern3D Model



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Example 1:

Transient simulations over the last 125 ka to investigate variations in CO2 and $\delta^{13}C$

Menviel, Joos, Ritz., submitted

The last glacial cycle in EPICA Dome C

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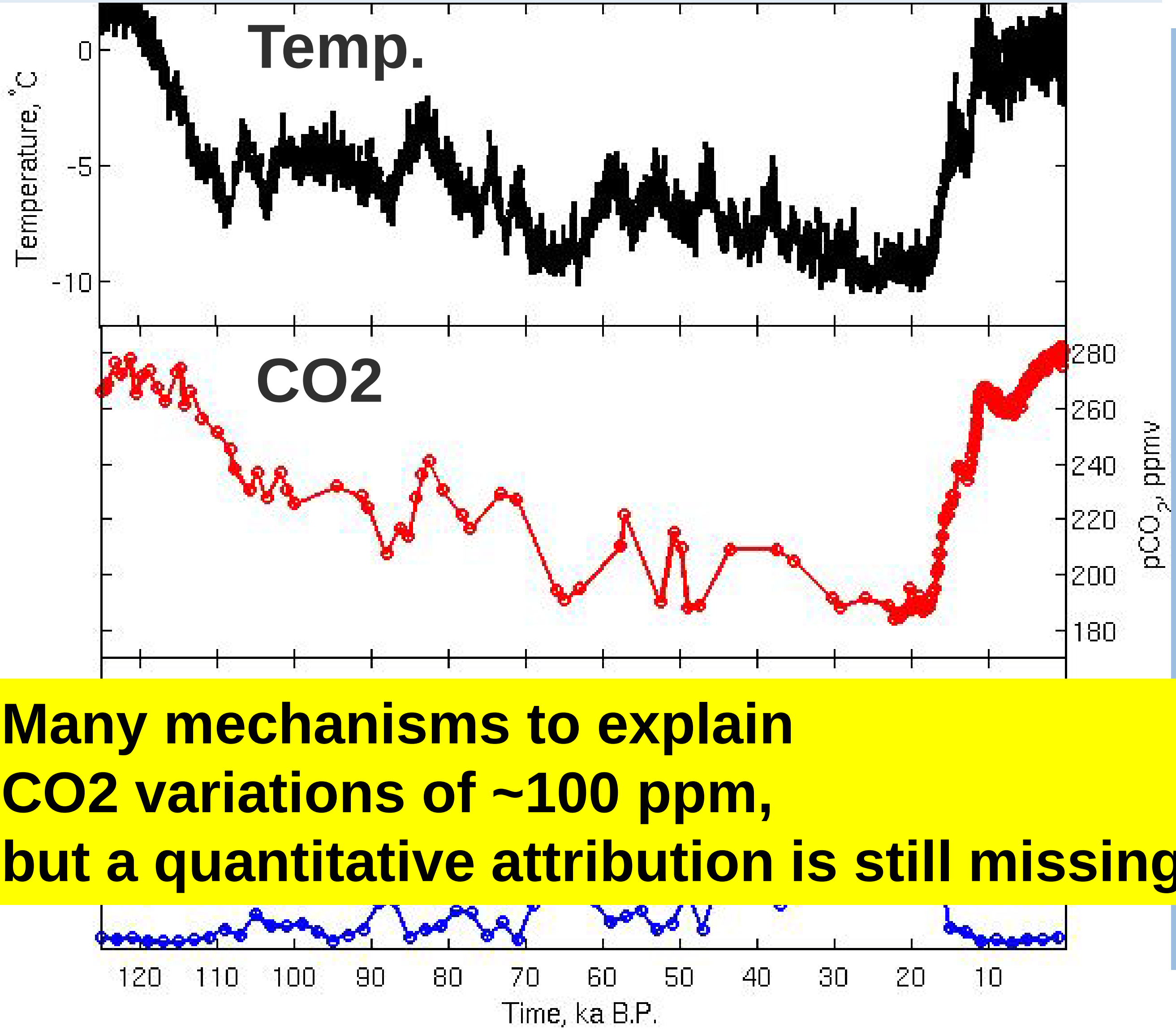

Many mechanisms to explain CO_2 variations of ~100 ppm, but a quantitative attribution is still missing

Transient simulations of the last 125 kyrs

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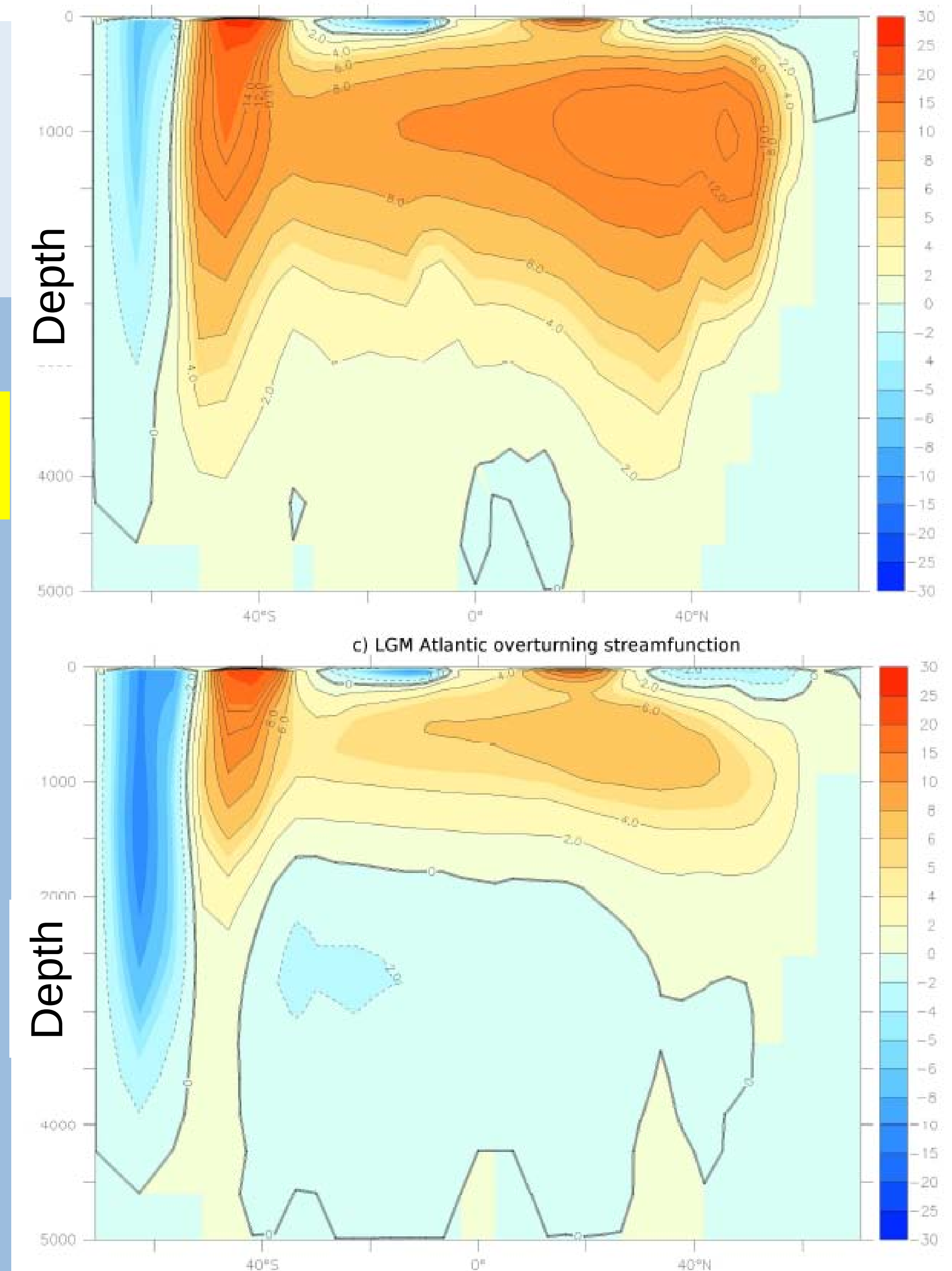
Prescribed Physical Forcing

- Orbital parameters (Berger et al. 1978)
- Ice-sheet extent: albedo and freshwater induced changes (Lisiecki and Raymo, 2005)
- Radiative forcing by CO2 & CH4 (Luthi et al. 2008, Loulergue et al. 2008)

Atlantic Overturning

modern

LGM



30 Sv

0 Sv

-30 Sv

Menviel et al., submitted

South North

Simulated versus reconstructed $\delta^{13}C$ anomalies in the Atlantic (LGM-modern)

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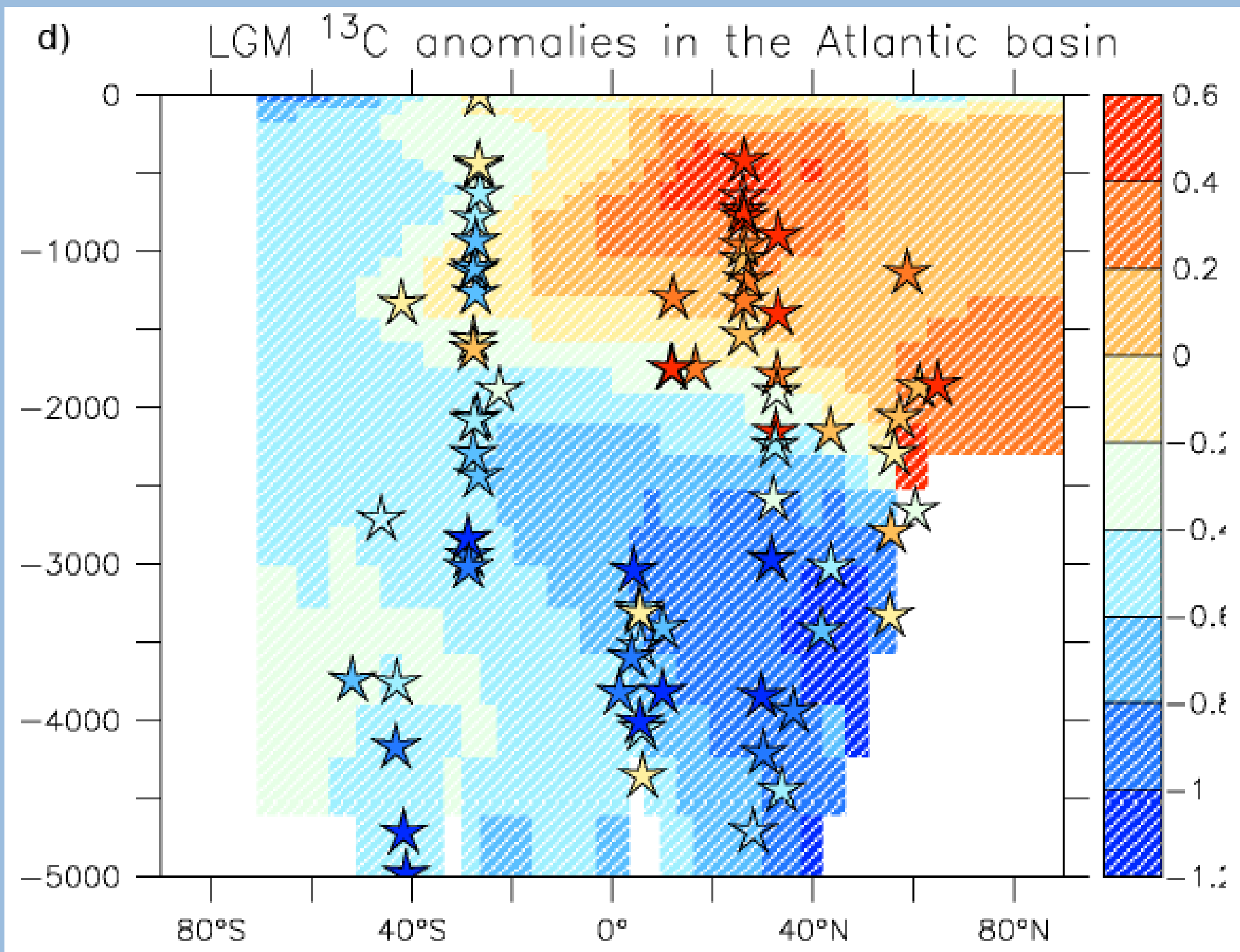

$\delta^{13}C$ data suggest that the LGM water mass distribution is simulated well

Menviel and Joos, in press

Transient simulations of the last 125 kyrs

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Prescribed Physical Forcing

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Biogeochemical mechanisms driving CO2 variations

- solubility (T,S),
- circulation
- iron input (Wolff et al. 2006)

Somewhat speculative:

- *terrestrial carbon changes*
- *remineralisation depth of POM increases by 7% (scaled to EPICA Temp.)*

Simulated CO_2 and $\delta^{13}C$

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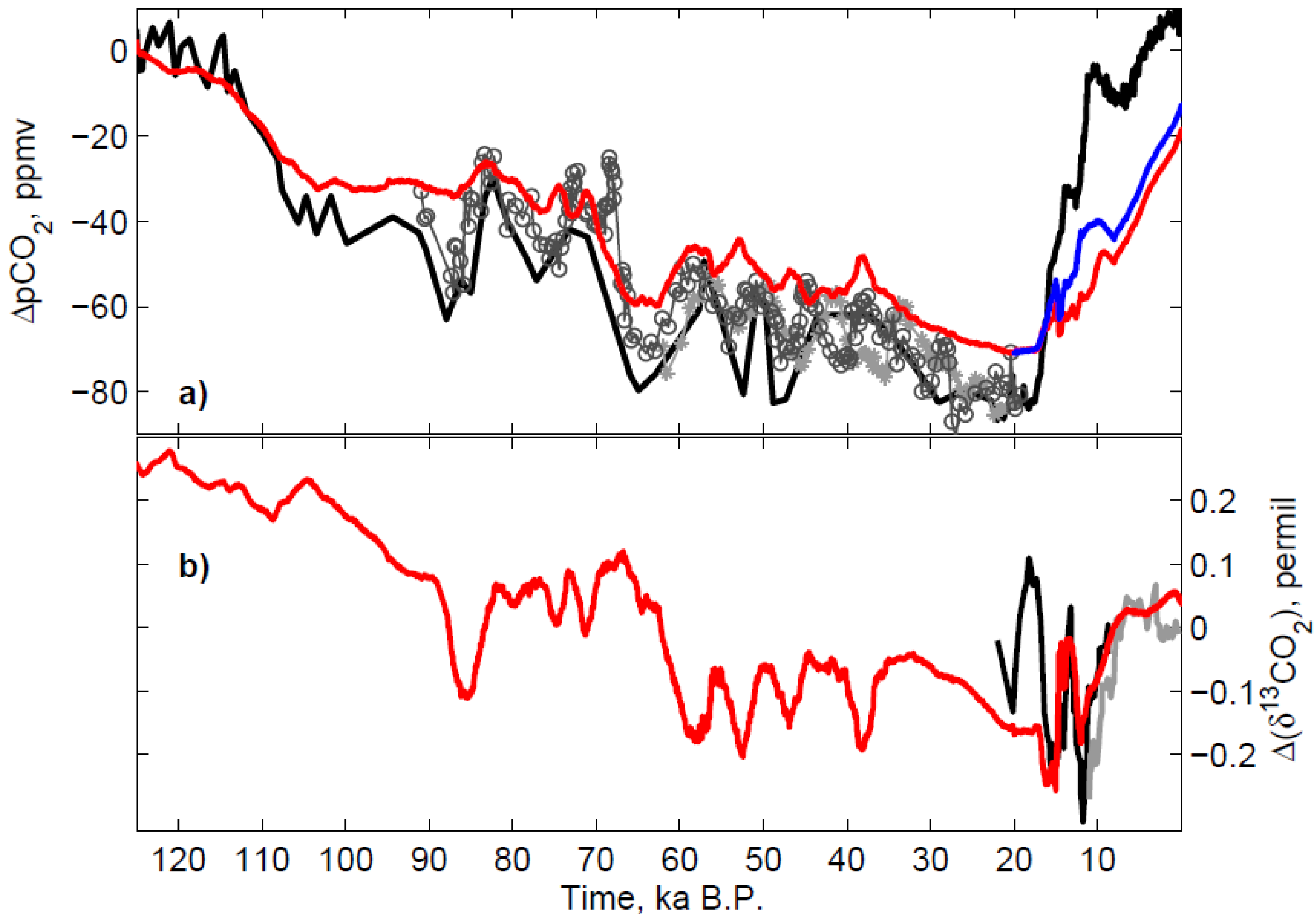

Menviel et al., submitted

Attribution of simulated pCO2 changes from 125 ka to 20 ka BP (factorial runs)

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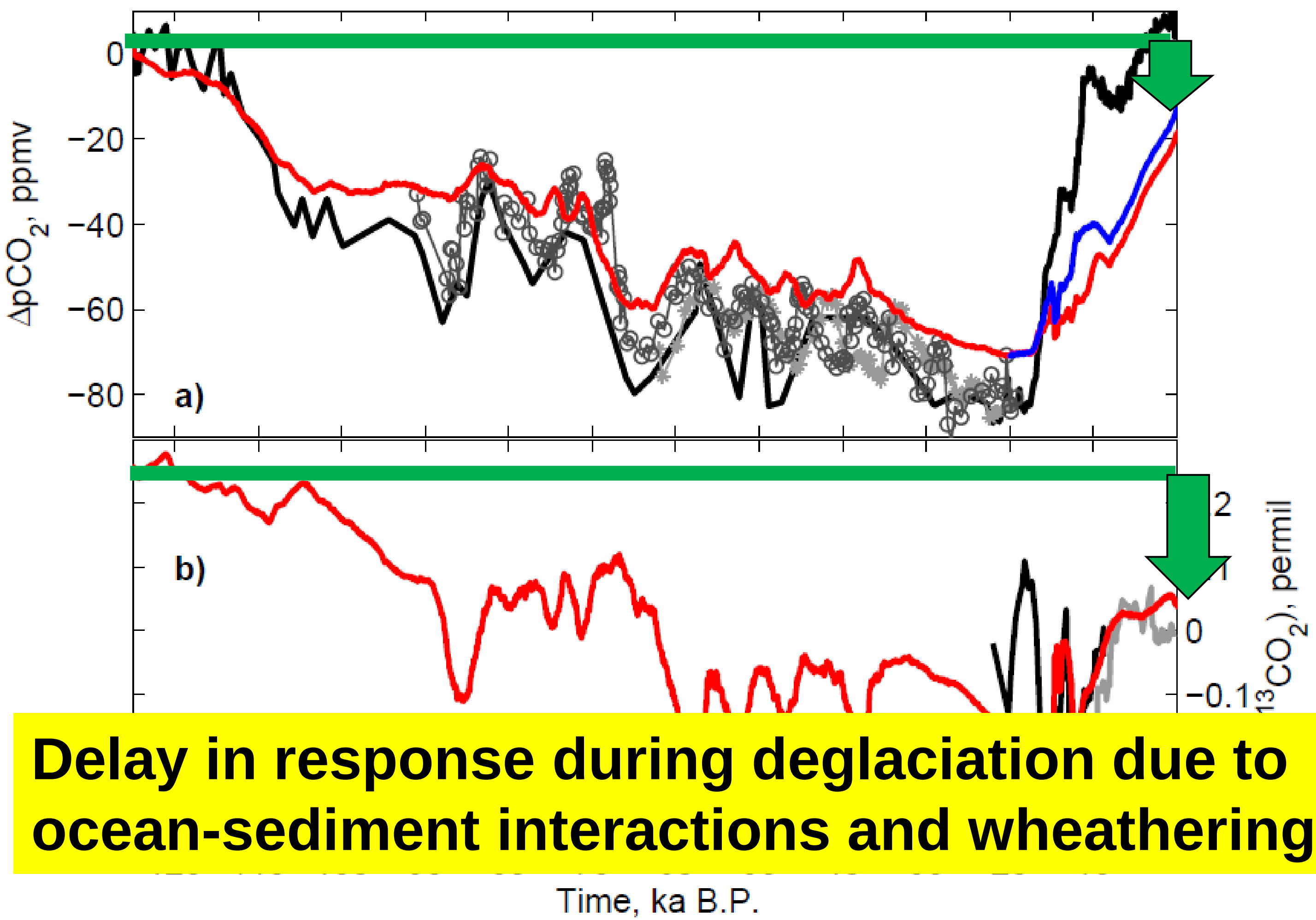
Relatively well known:	
Physical processes:	- 31 ppm
Fe fertilization	- 11 ppm
More speculative	
deeper POM (and DOM) remineralisation	- 41 ppm
Terrestrial carbon	+14 ppm
Total	- 72 ppm

Sediment amplification is essential for response
(amplification by factor three for remineralisation mechanism)

Change is smaller from 20 ka to 0 ka than from 125 ka to LGM



Delay in response during deglaciation due to ocean-sediment interactions and wheathering cycle!

Menviel et al., submitted

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Simulated versus Lisiecki et al, 2008
$\delta^{13}C$ of DIC in the deep Atlantic and Pacific

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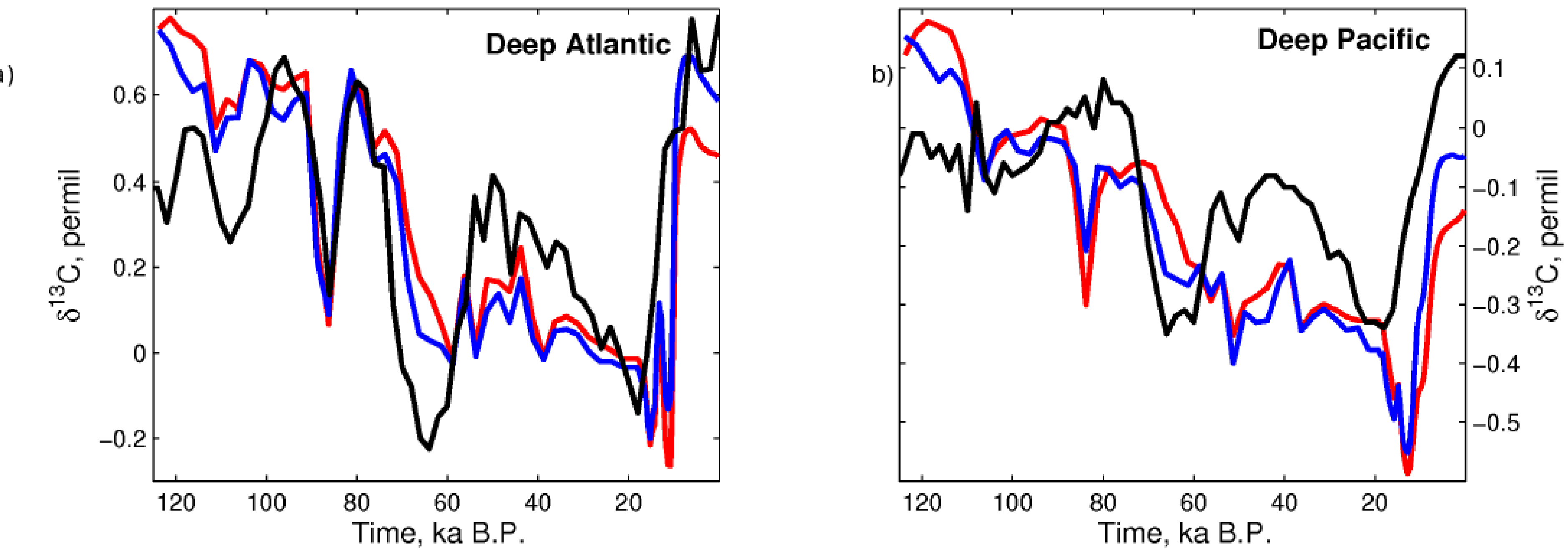

Spatio-temporal evolution of $\delta^{13}C$ data provide additional constraints.

Menviel et al., submitted

Simulated deep ocean $\delta^{13}C$ of DIC at the LGM versus proxy reconstructions

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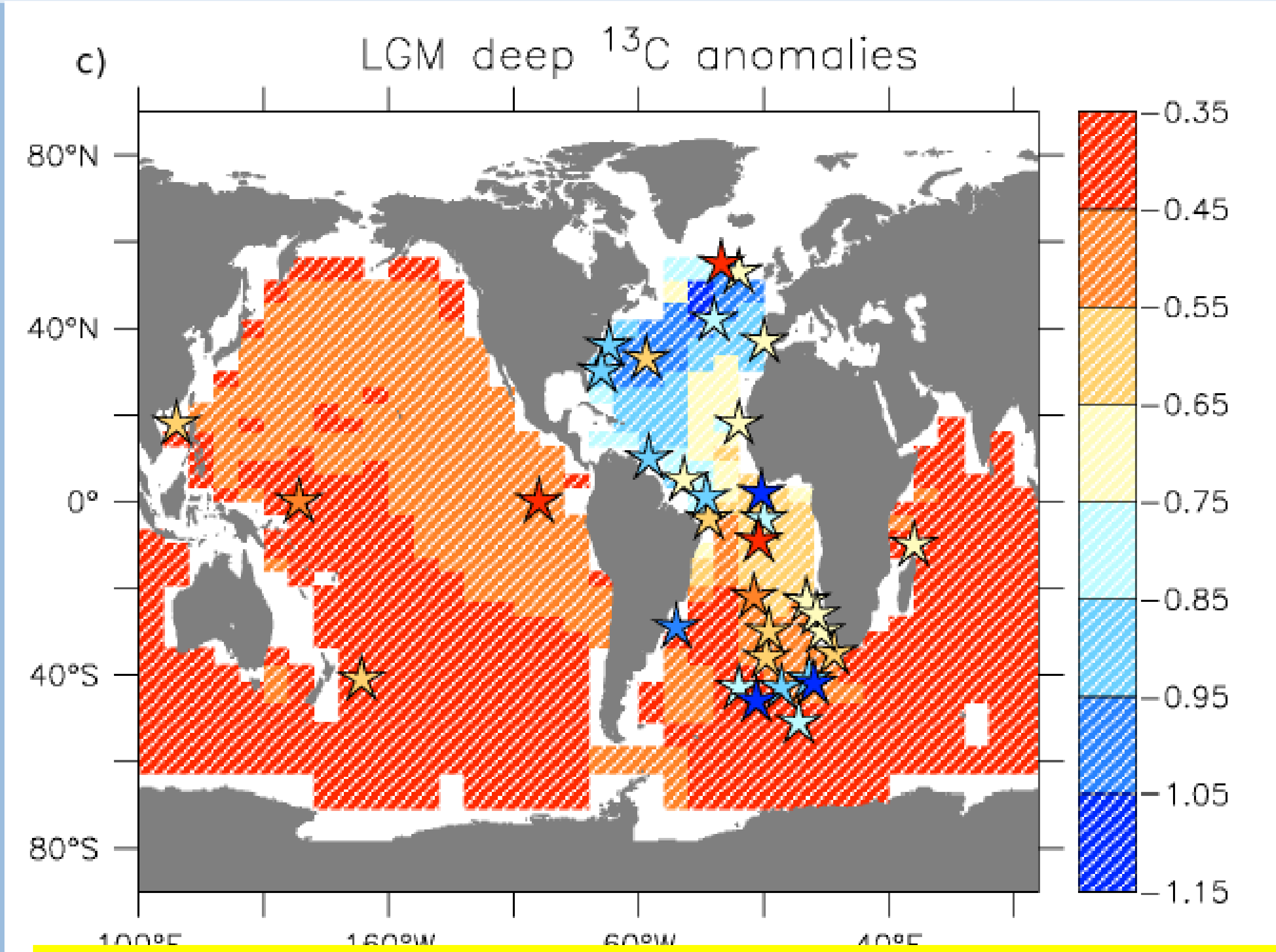

Spatio-temporal evolution of $\delta^{13}C$ of DIC appears reasonable

Menviel et al., submitted

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Example 2:

Neodymium isotopes as water mass tracer

Rempfer et al, GCA, 2011

Modern distribution of neodymium isotopes: model versus observations

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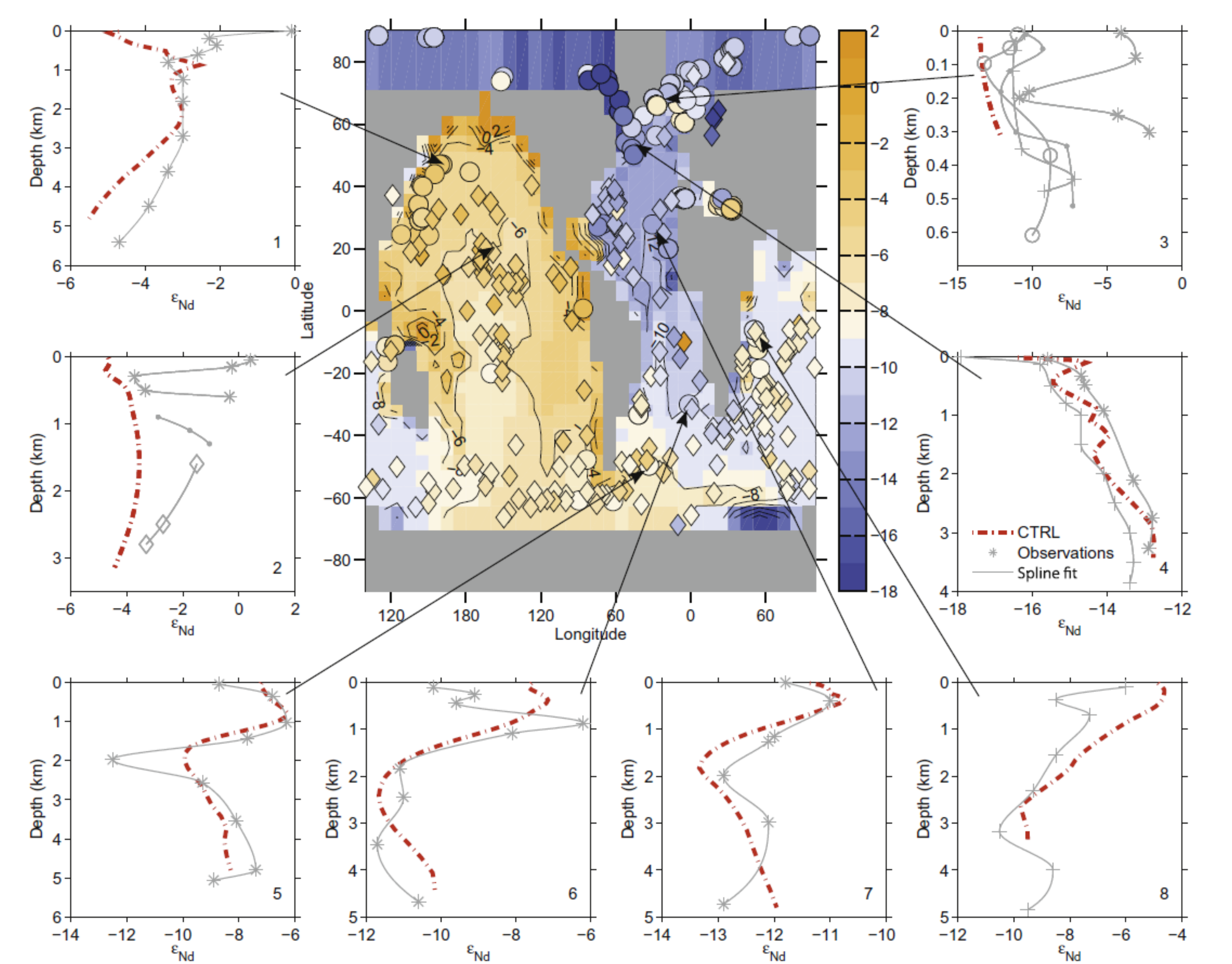

Rempfer et al, GCA, 2011

Transient response over the past 125 ka

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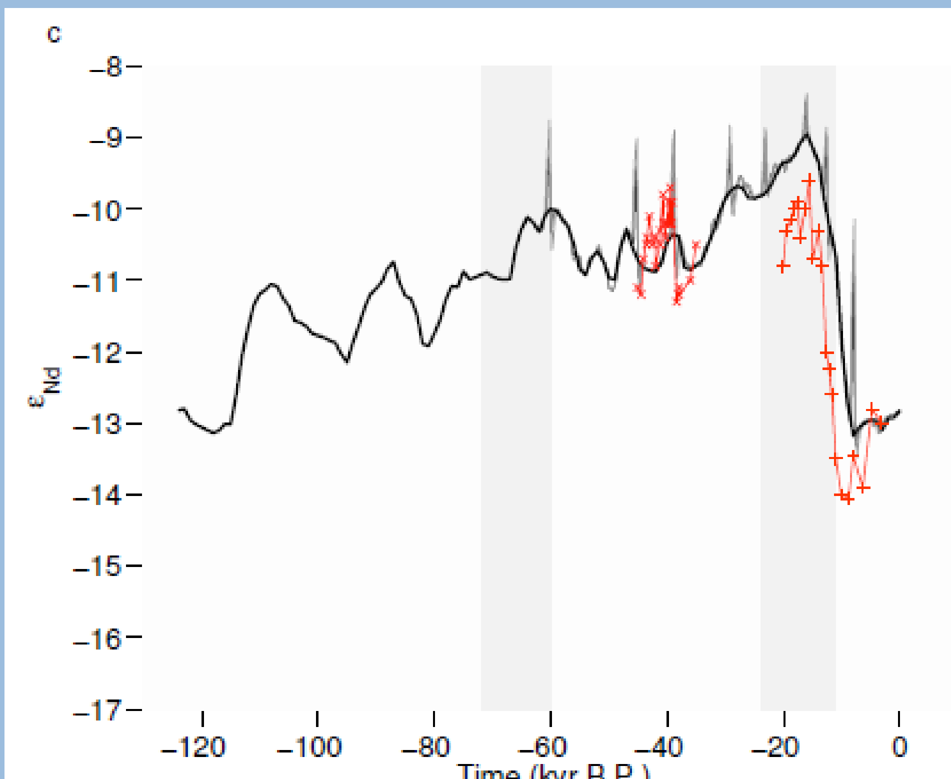
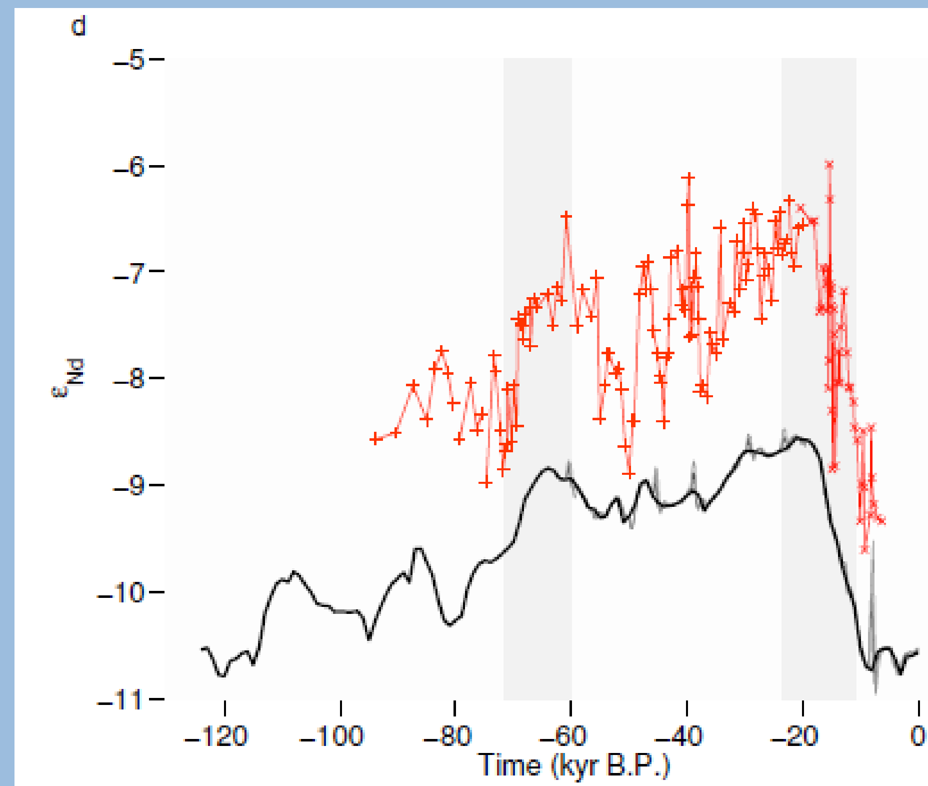
Northwest Atlantic



South Atlantic



Rempfer et al., in prep.

Example 3: water use efficiency changes over industrial period (iTree project)

Work in progress: implementation of $\delta^{13}C$ in the CLM4.0.32

Anil Bozbiyik.

Methods: Sites with tree ring data
(ring width, late wood density, O and C isotopes)

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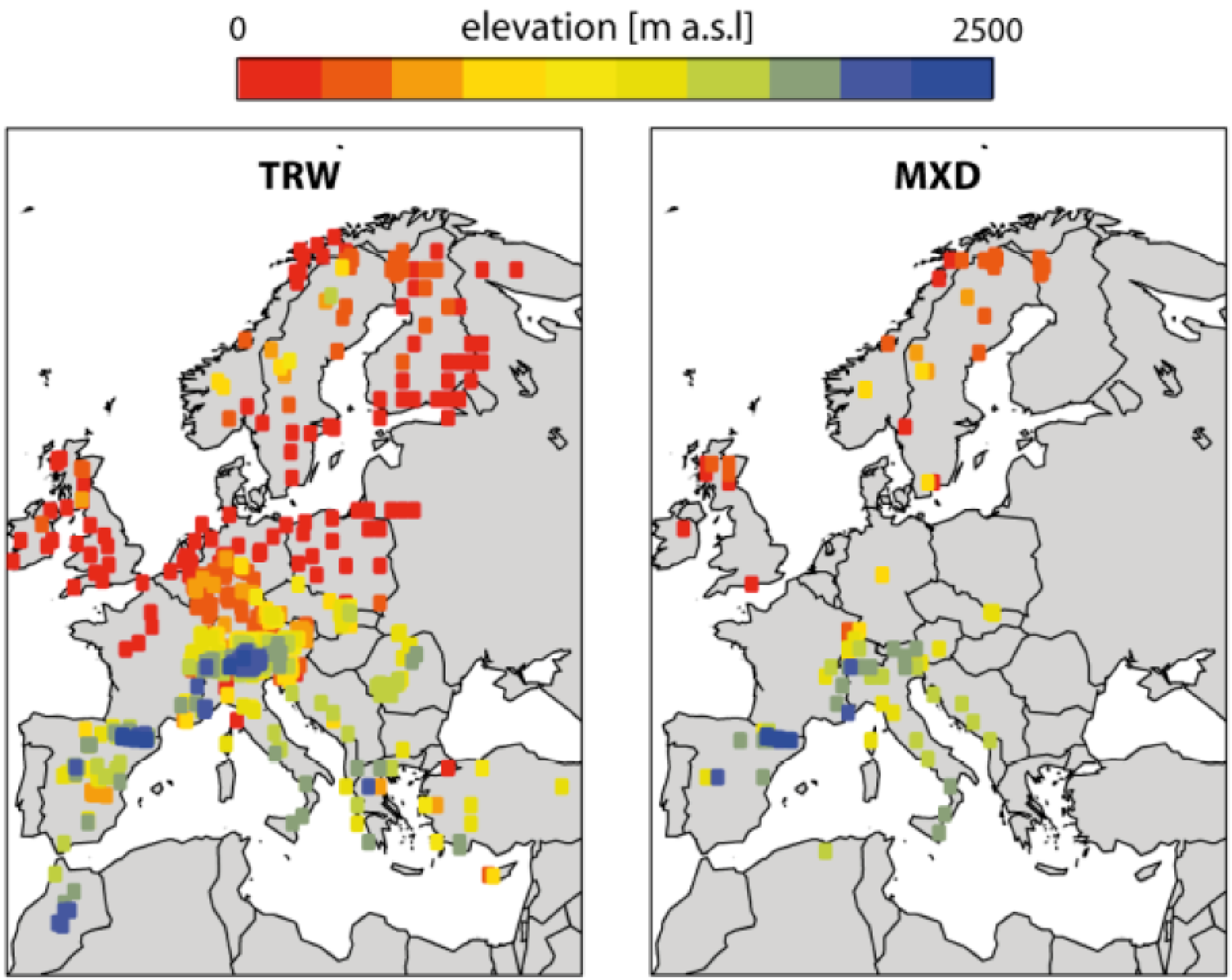
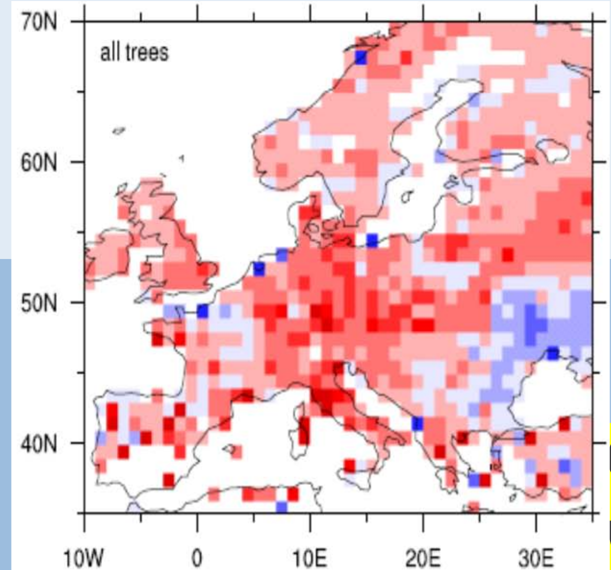


LPX model

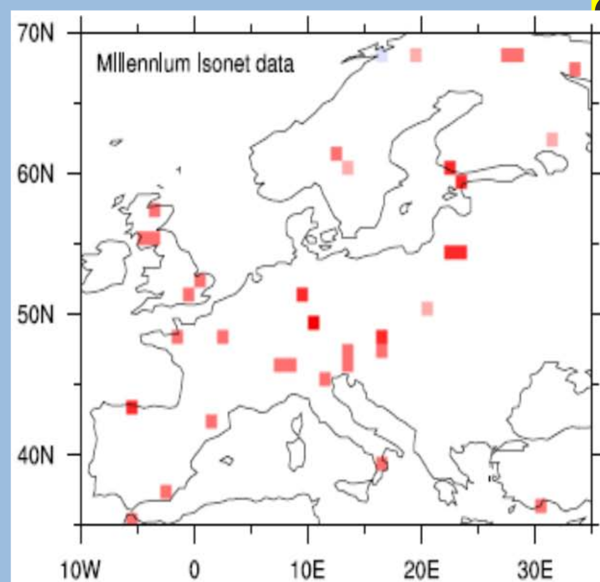
model

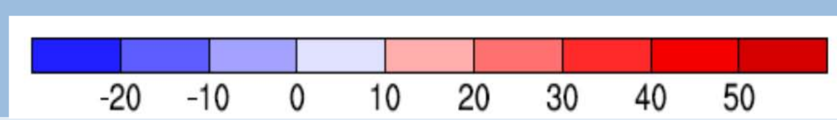


Change (%) in intrinsic water use efficiency over the 20th century

δ13C tree ring data

data





Saurer et al., in prep

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δ[13]C in the CLM4. 0.32: signature of GPP

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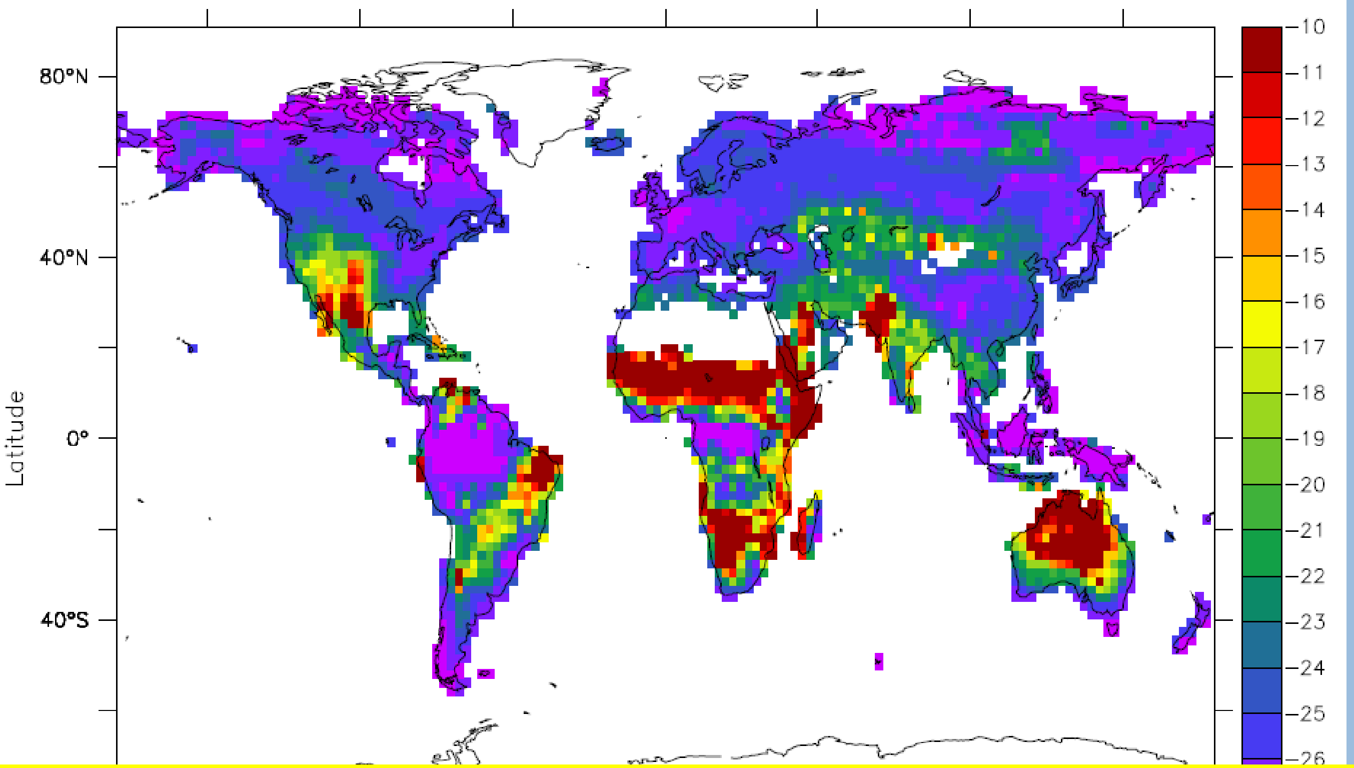

Anil Bozbiyik.

- **Added additional dimension for isotopes to all carbon-related variables (~300 variables)**
- **40 CLM modules modified**
- **Further work is ongoing to resolve remaining problems**

Concluding remarks

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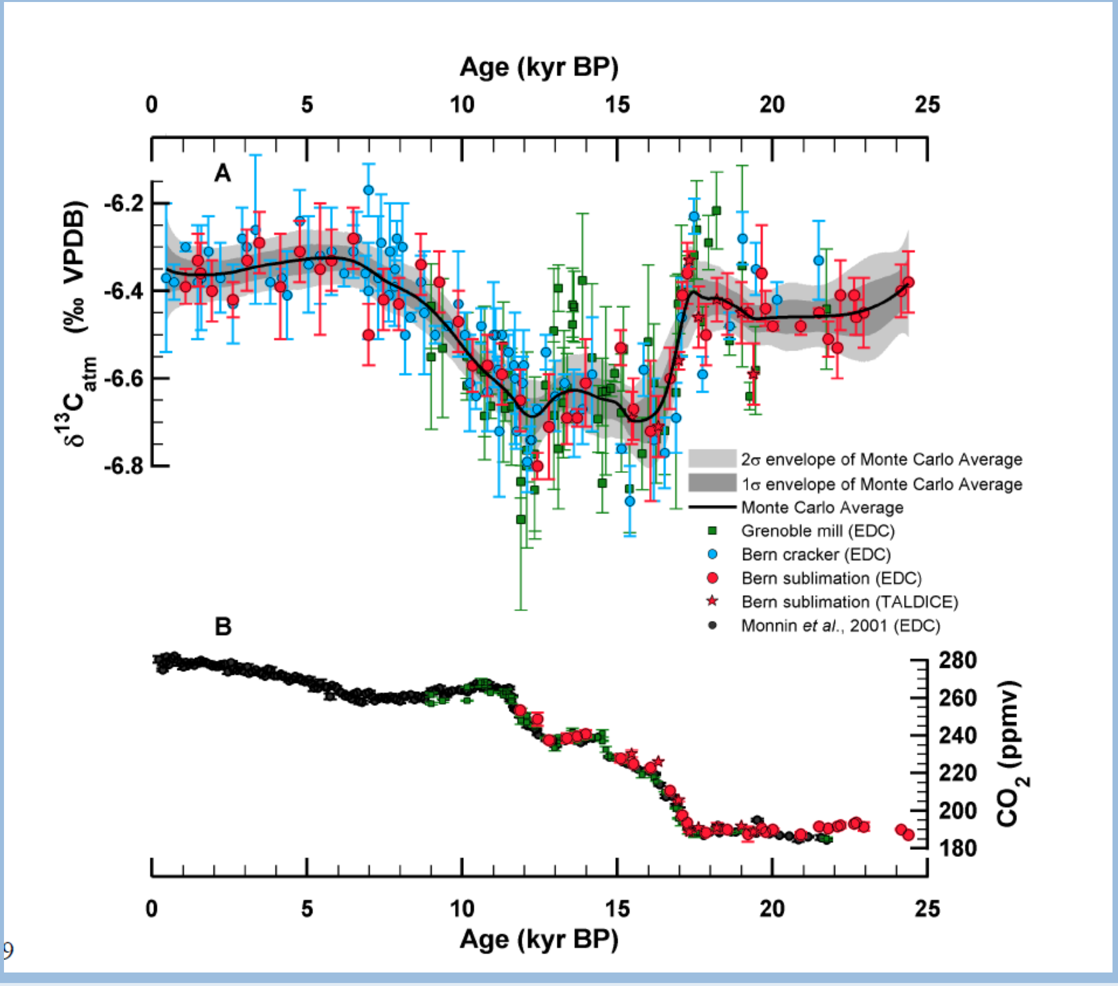
- Carbon and neodymium isotopes provide additional constraints on past climate conditions
- Long response time scales of interactions with ocean sediments and the weathering/burial cylce.
  This may hamper interpretation of time slice simulations
- Carbon and water isotopes: provide information on water use efficiency changes of plants, e.g. related to CO2 changes
- New, high precision ice core 13C data covering the last two terminations and warm periods as well as isotope stage 3 are becoming available
  (Schmitt et al., Science, in revisions, Schneider et al, in prep.

Thank you for your attention



Schmitt et al., Science
In revision

Radiocarbon production by cosmic rays over the Holocene as deconvolved from the Intcal09 14C data

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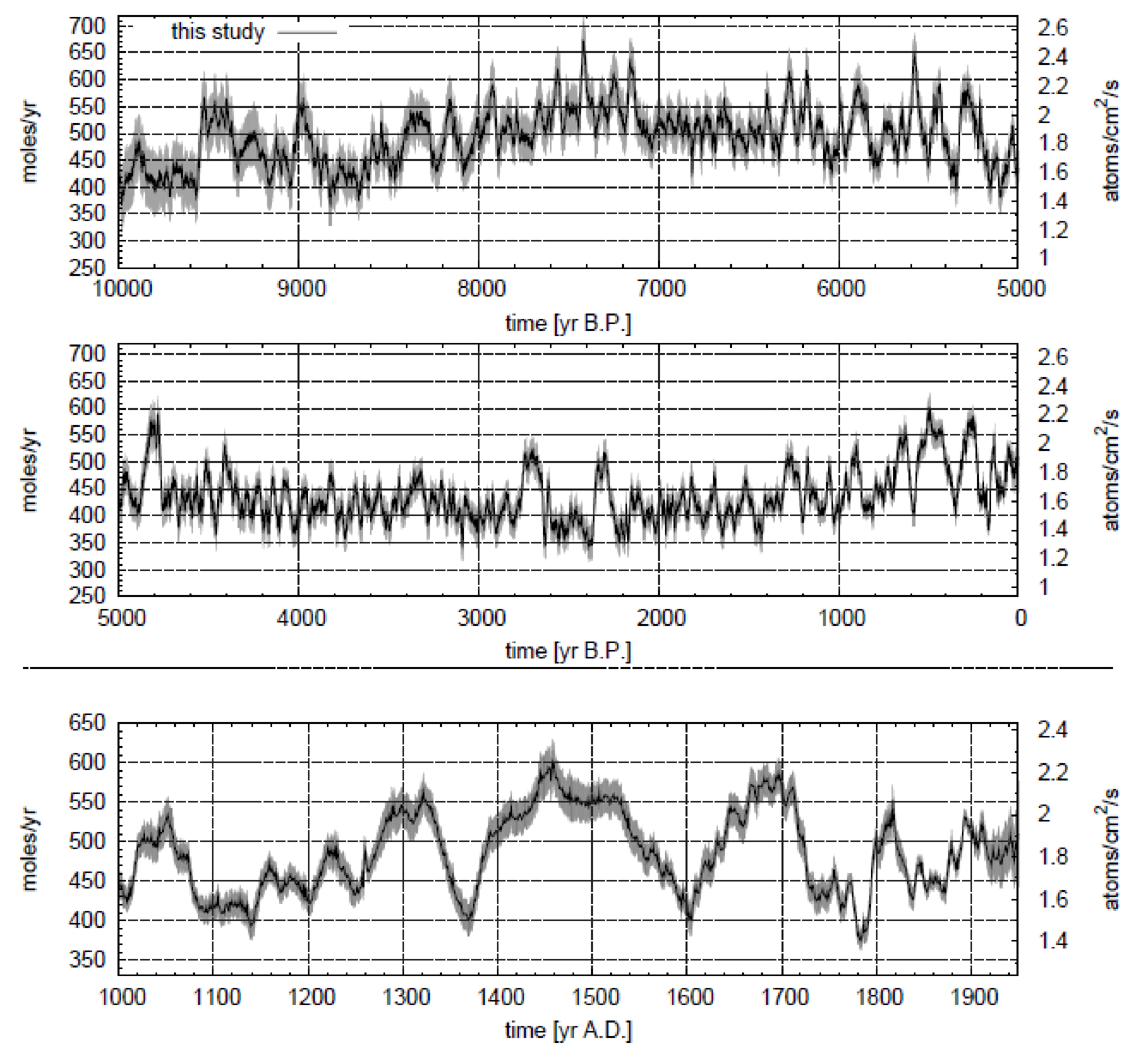
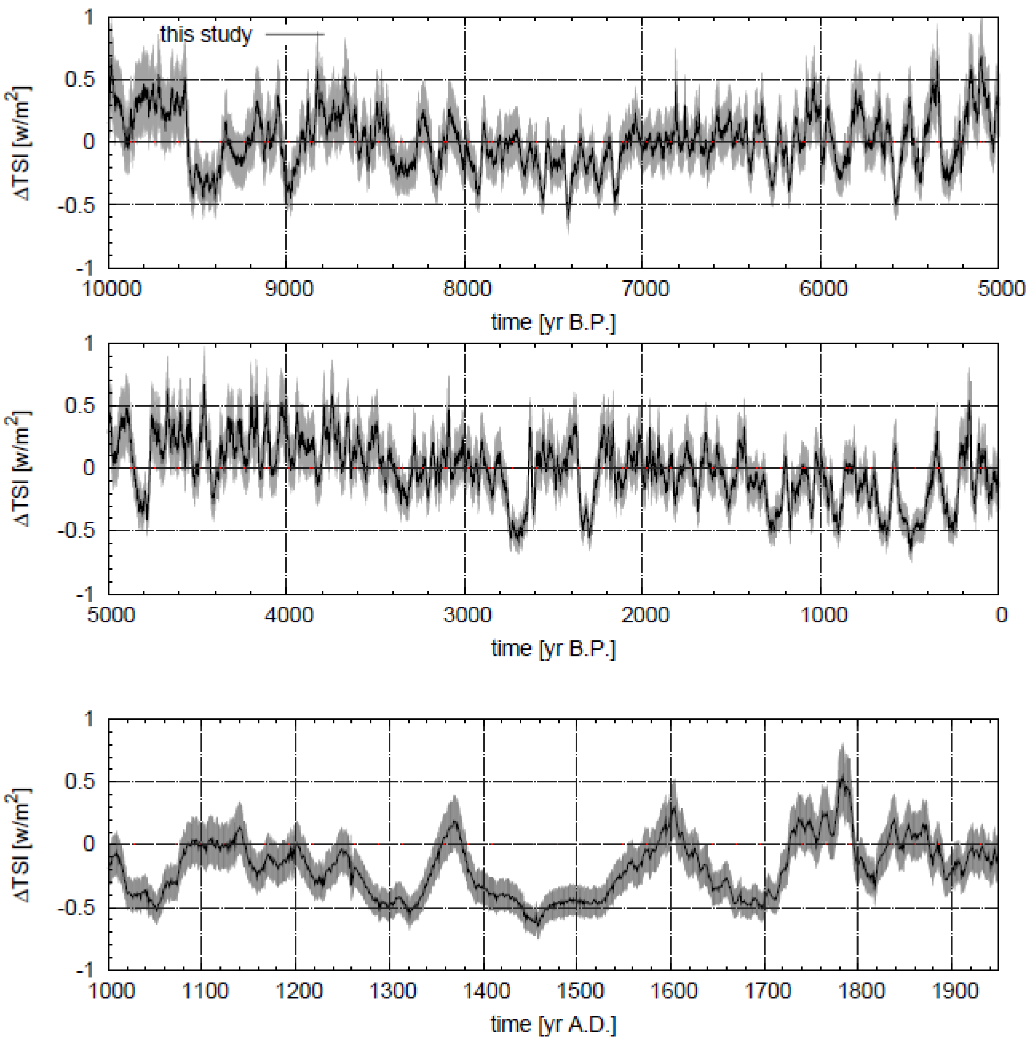


Reconstructed solar irradiance



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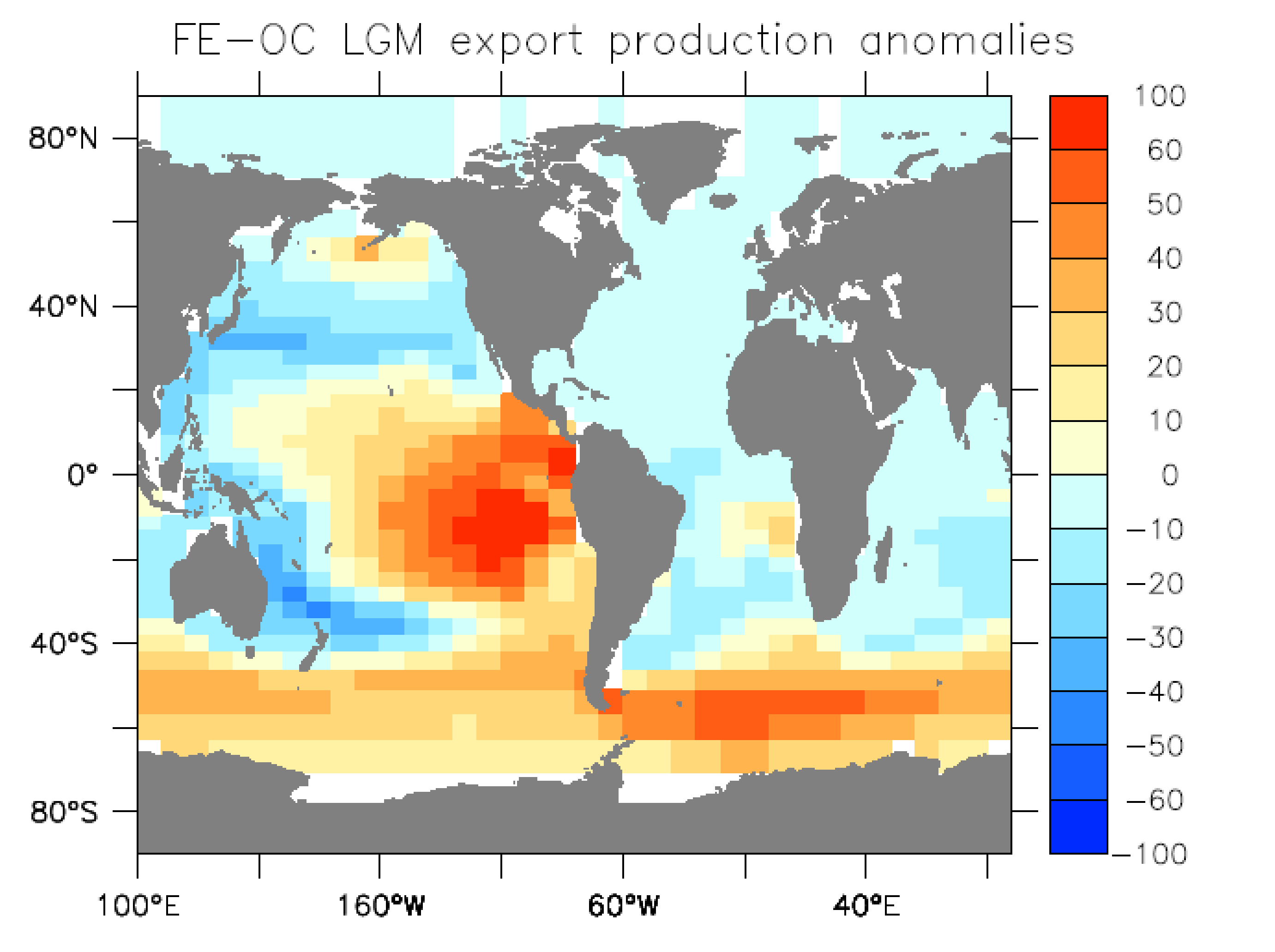
Export Production change due to iron fertilization (LGM-modern)



LGM carbonate ion and export

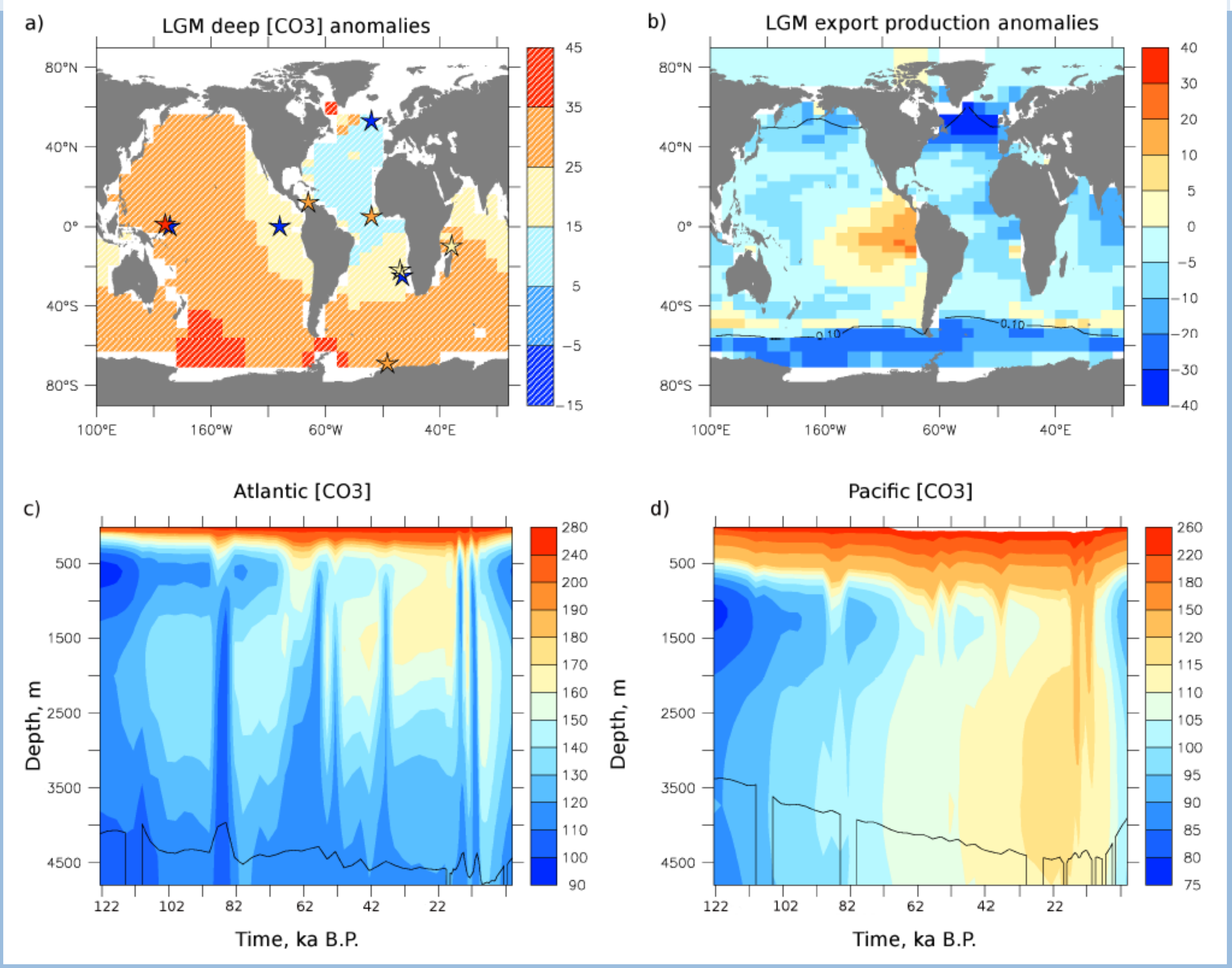


Table 2: Attribution of pCO_2 (ppmv), $\delta^{13}CO_2$ (permil) and $\delta^{13}C_{DIC}$ (permil) changes to processes for the period 125 to 20 ka B.P. and 20 to 0 ka B.P. $\delta^{13}C_{DIC}$ reflects the whole ocean change in $\delta^{13}C$ of DIC.

	125 to 20 ka B.P.			20 to 0 ka B.P.		
Processes	ΔCO_2	$\Delta(\delta^{13}CO_2)$	$\Delta(\delta^{13}C_{DIC})$	ΔCO_2	$\Delta(\delta^{13}CO_2)$	$\Delta(\delta^{13}C_{DIC})$
Physical processes (OC)	-31	-0.22	-0.24	+20	+0.18	+0.16
Fe fertilization (FE–OC)	-10.5	+0.12	-0.002	+10	-0.14	-0.014
Remineralization rate (RE3–FE)	-41.5	-0.12	-0.04	+26	-0.075	-0.14
Terrestrial carbon (VG–FE)	+14	-0.12	-0.1	-19	+0.2	+0.19
Shallow-water $CaCO_3$ deposition	–	–	–	+12	+0.026	+0.013
Total (ALL)	-72	-0.4	-0.45	+53	+0.2	+0.22

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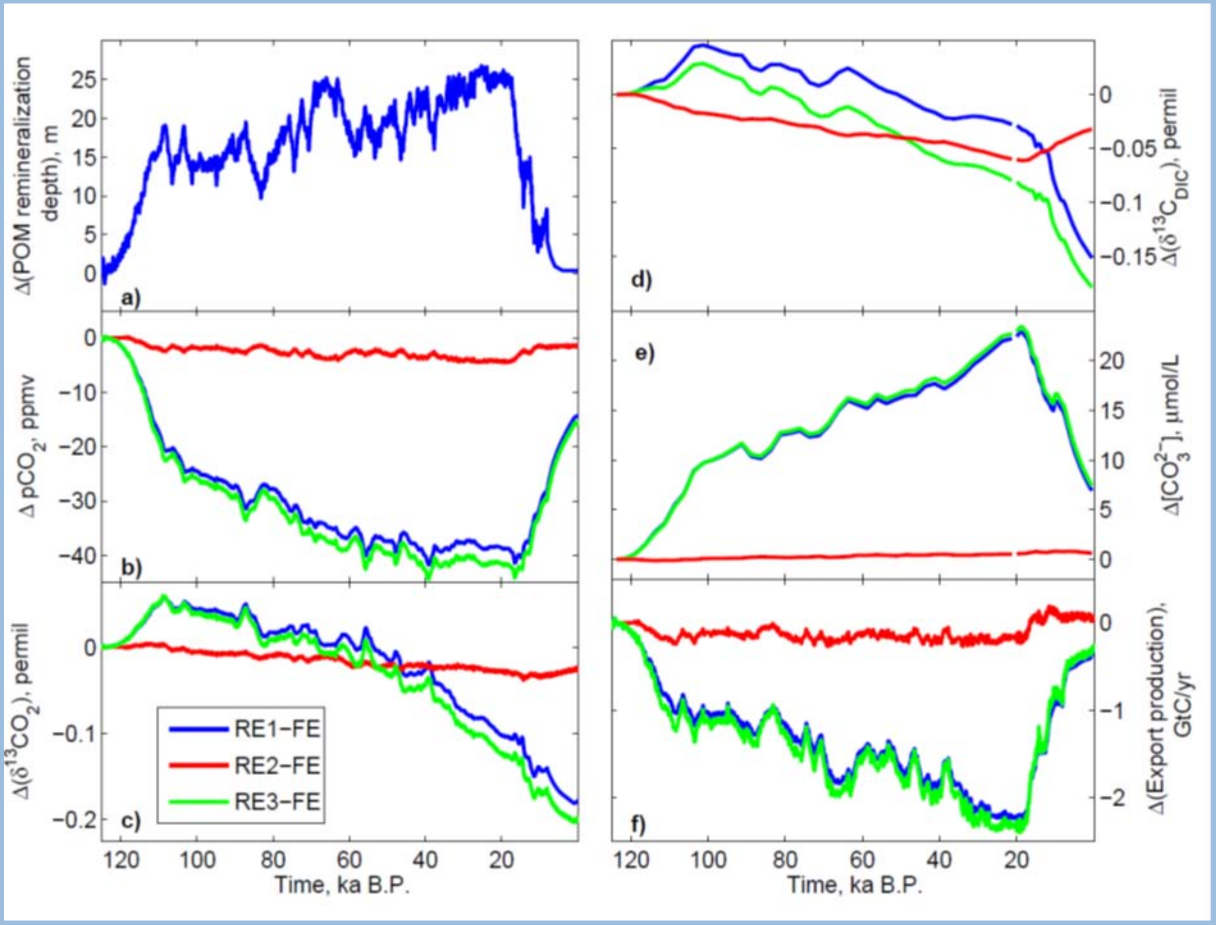

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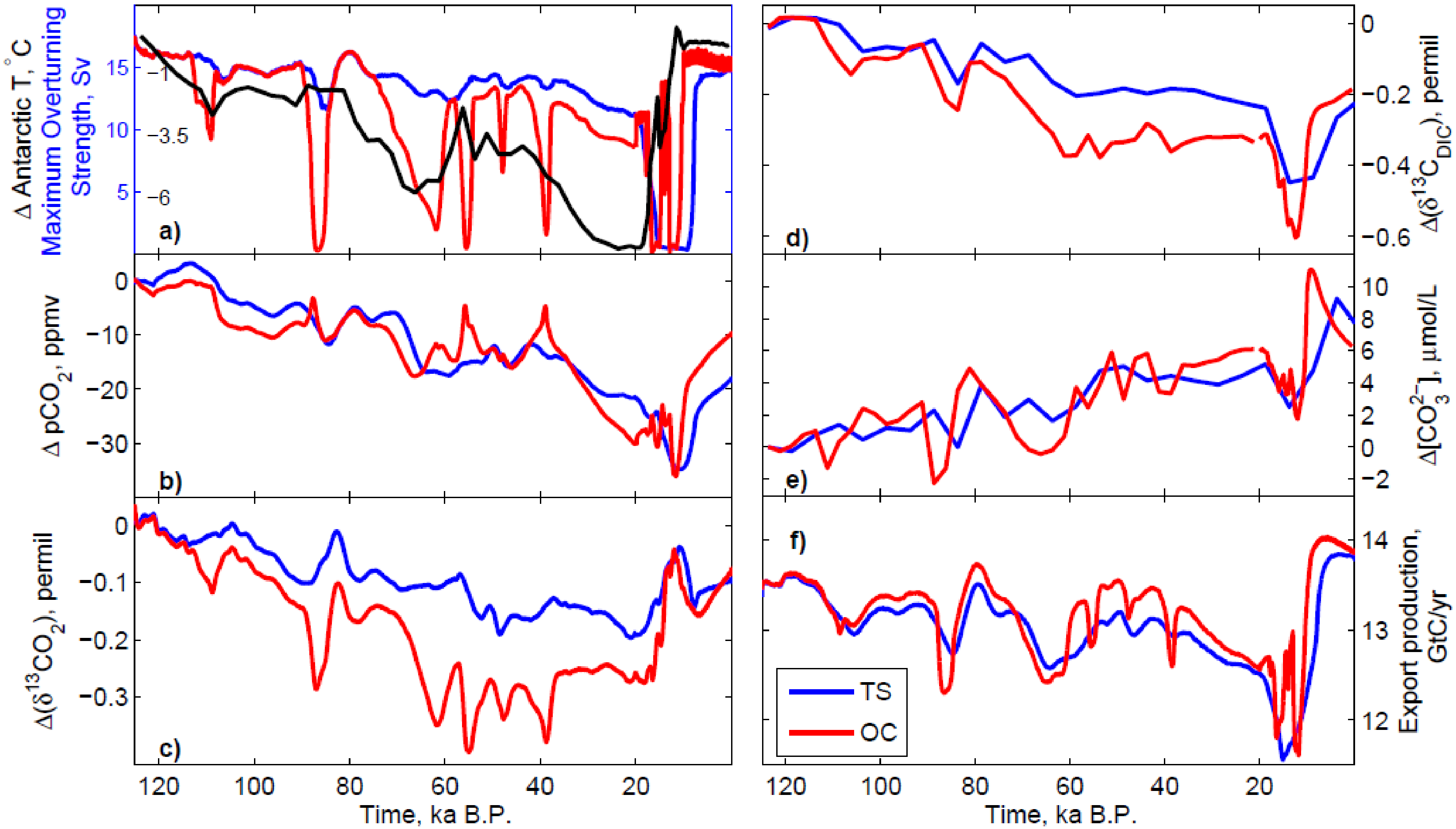

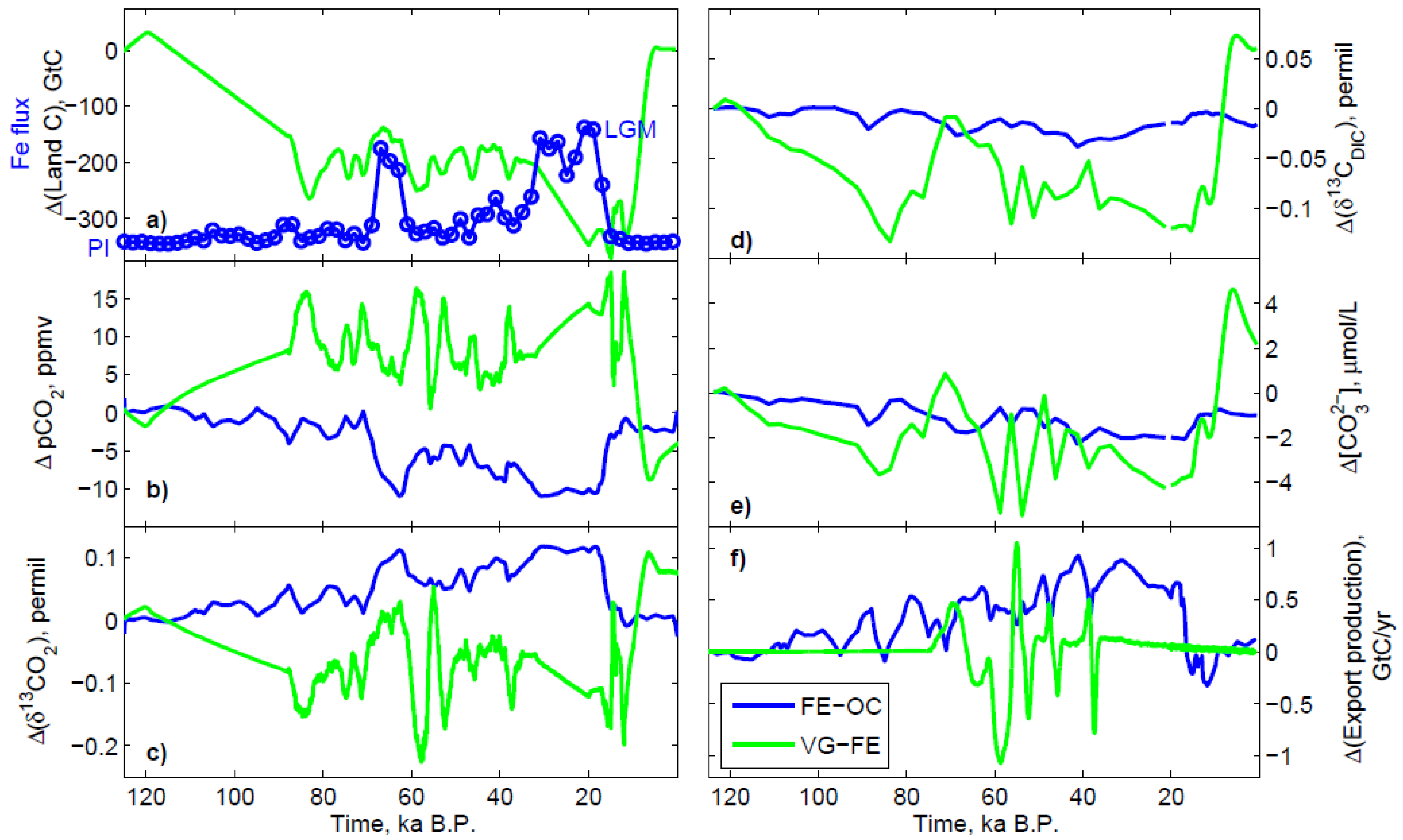

Fe flux
Δ(Land C), GtC
LGM
PI
a)
b)
c)
d)
e)
f)
Δ pCO2, ppmv
Δ(δ13CO2), permil
Δ(δ13C DIC), permil
Δ[CO3 2−], μmol/L
Δ(Export production), GtC/yr
FE−OC
VG−FE
Time, ka B.P.
Time, ka B.P.