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Proposing a mechanistic understanding of changes in atmospheric CO_2 during the late Pleistocene — a contribution to the EPICA challenge

Peter Köhler and Hubertus Fischer

7th International Carbon Dioxide Conference — Broomfield, Colorado, USA, 09/2005

The EPICA challenge

BICYCLE - a box model of the isotopic carbon cycle

Termination I (20 – 10 kyr BP)

Our contribution to the EPICA challenge — riding the bike for 740 kyr

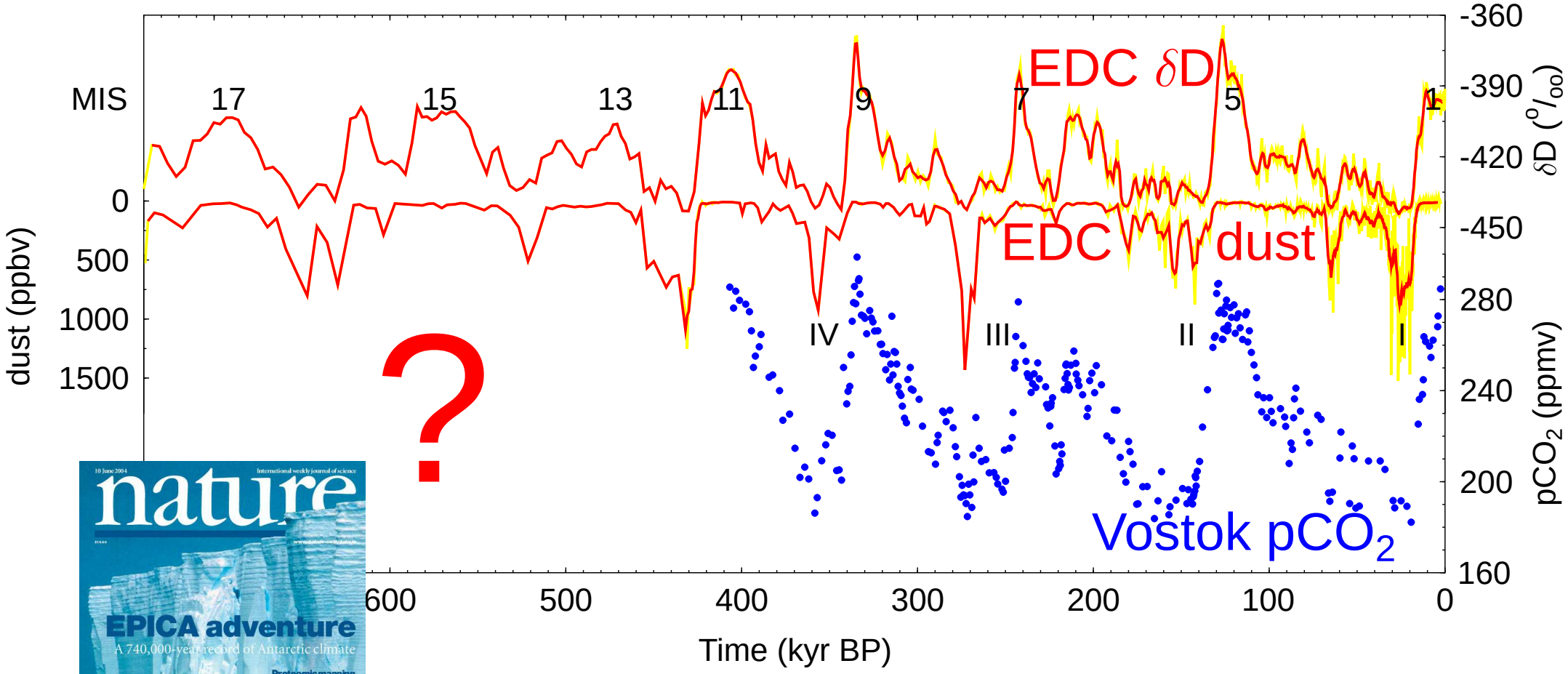
— Slides differ from talk as no new EPICA pCO_2 data in here! —

The EPICA challenge

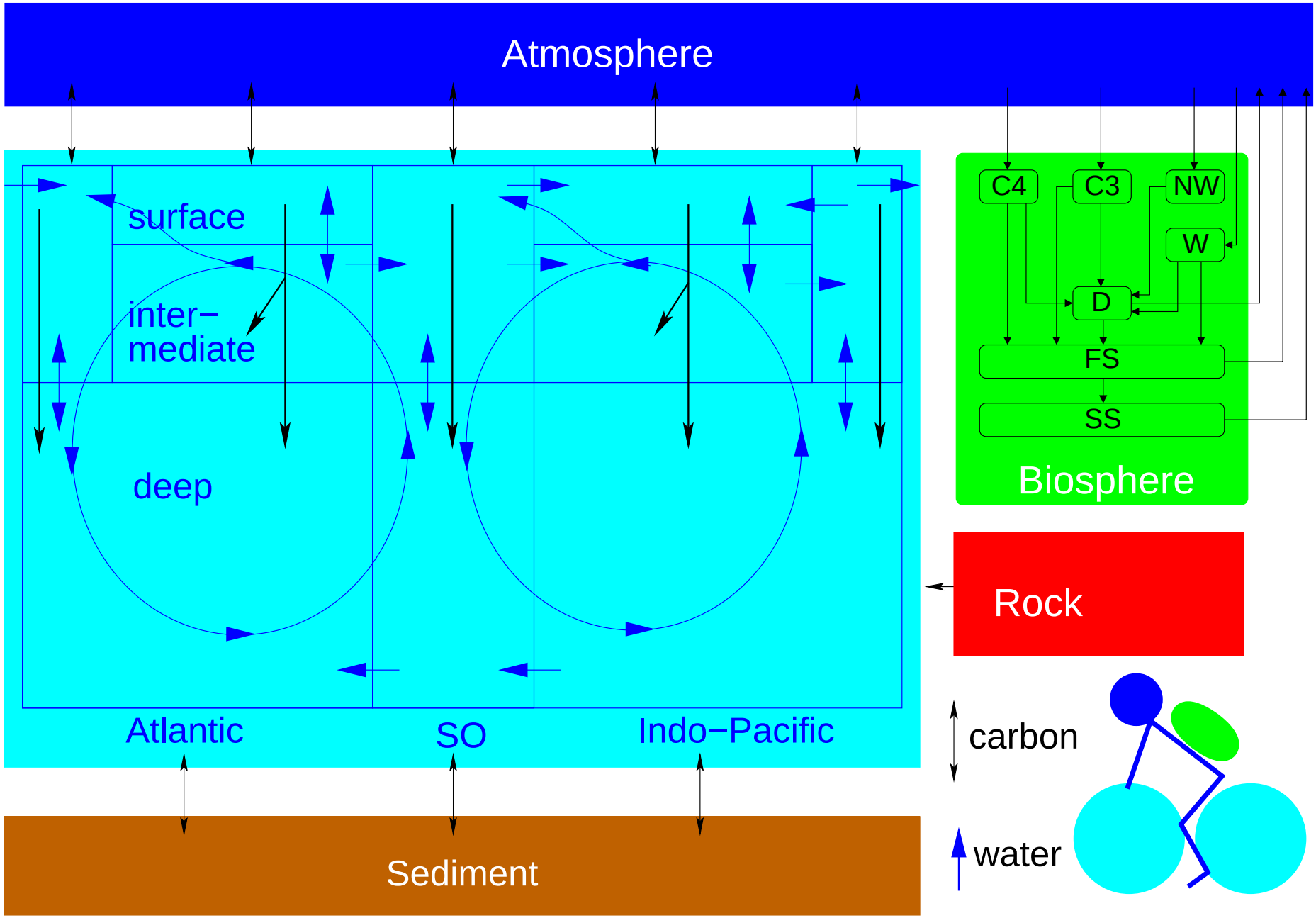
Predicting pCO_2 prior to Vostok (Wolff et al., 2004, 2005, EOS)

8 contributions: from regression analysis to full carbon cycle model

AGU Fall Meeting December 2004 San Francisco

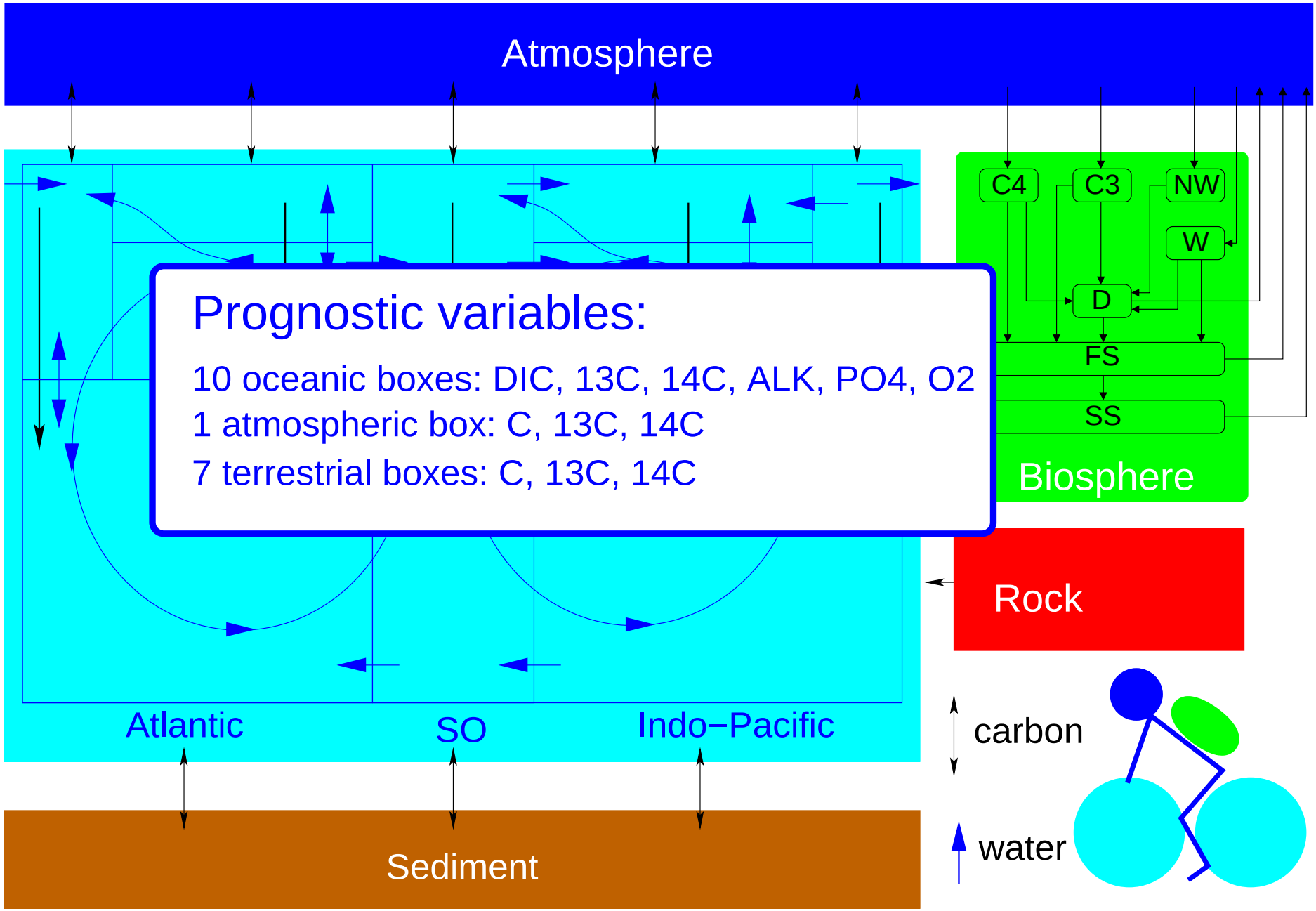


(EPICA community members, 2004; Petit et al., 1999)



Box model of the Isotopic Carbon cYCLE

BICYCLE

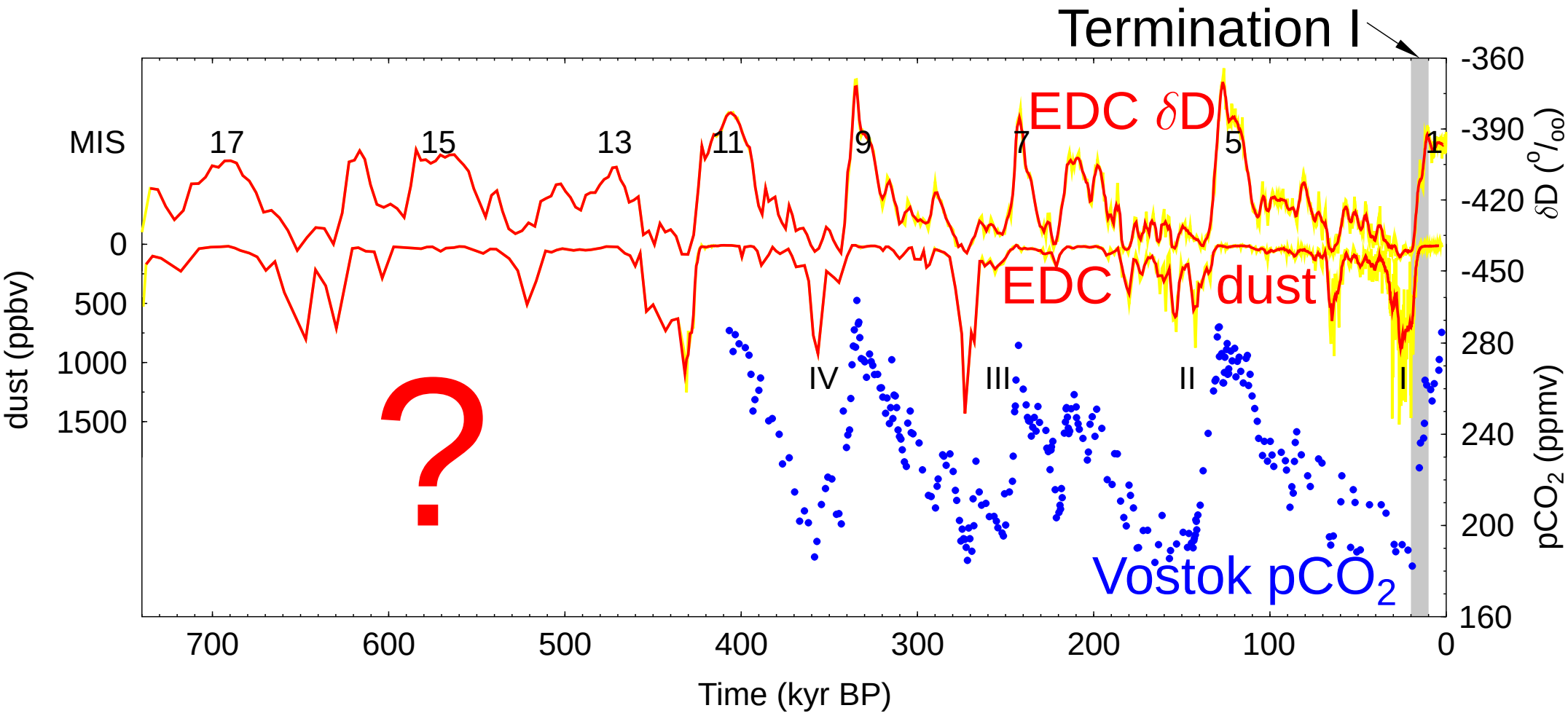


Box model of the Isotopic Carbon cYCLE

BICYCLE

The EPICA challenge

Carbon cycle model simulations based on understanding of Termination I.

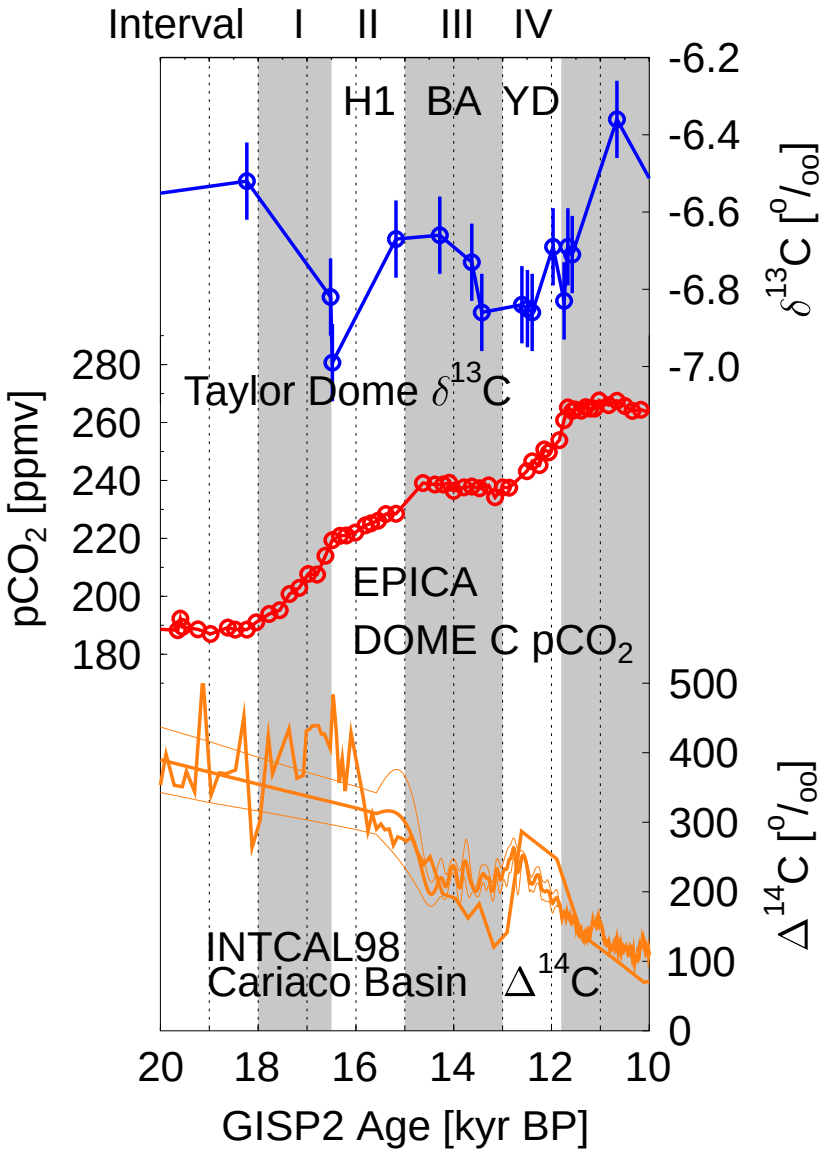


(EPICA community members, 2004; Petit et al., 1999)

Atmospheric carbon during Termination I

Explain the temporal evolution of atmospheric pCO_2, $\delta^{13}C$, $\Delta^{14}C$ records by carbon cycle simulations.

(Smith et al., 1999; Monnin et al., 2001, Stuiver et al., 1998; Hughen et al., 2004)



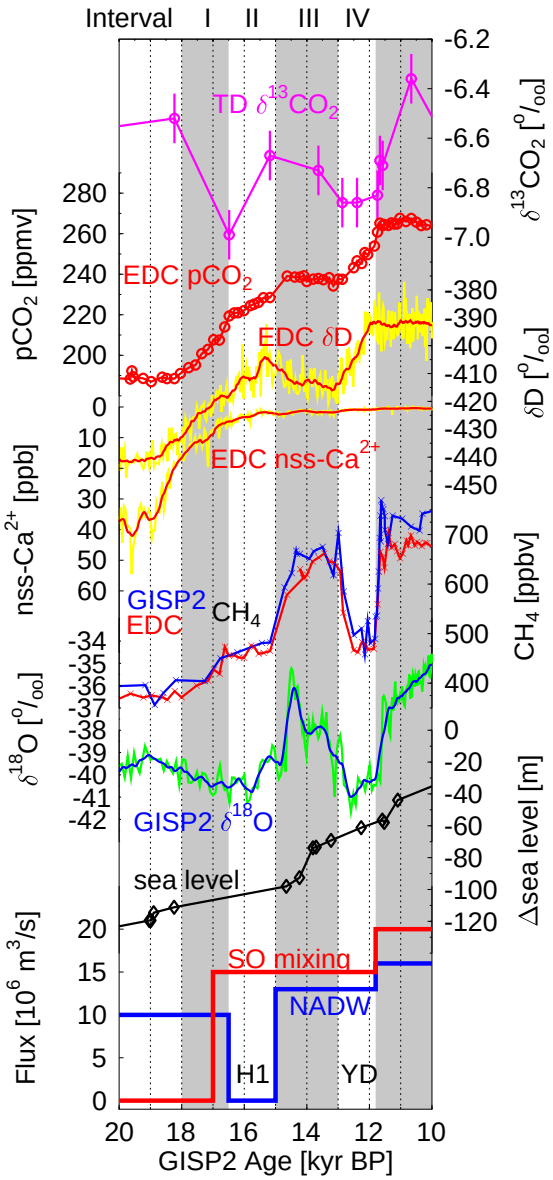
Termination I

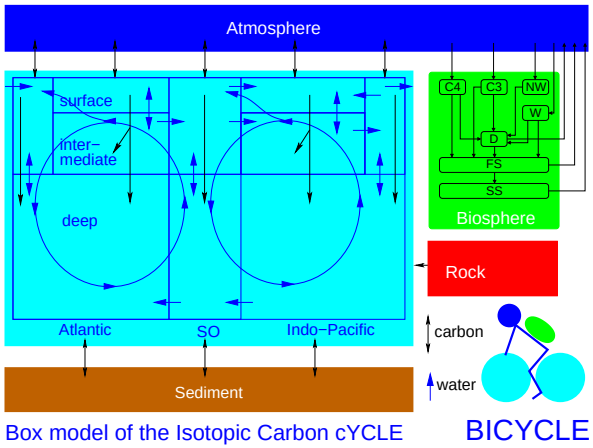
Combining all assumptions on changes in

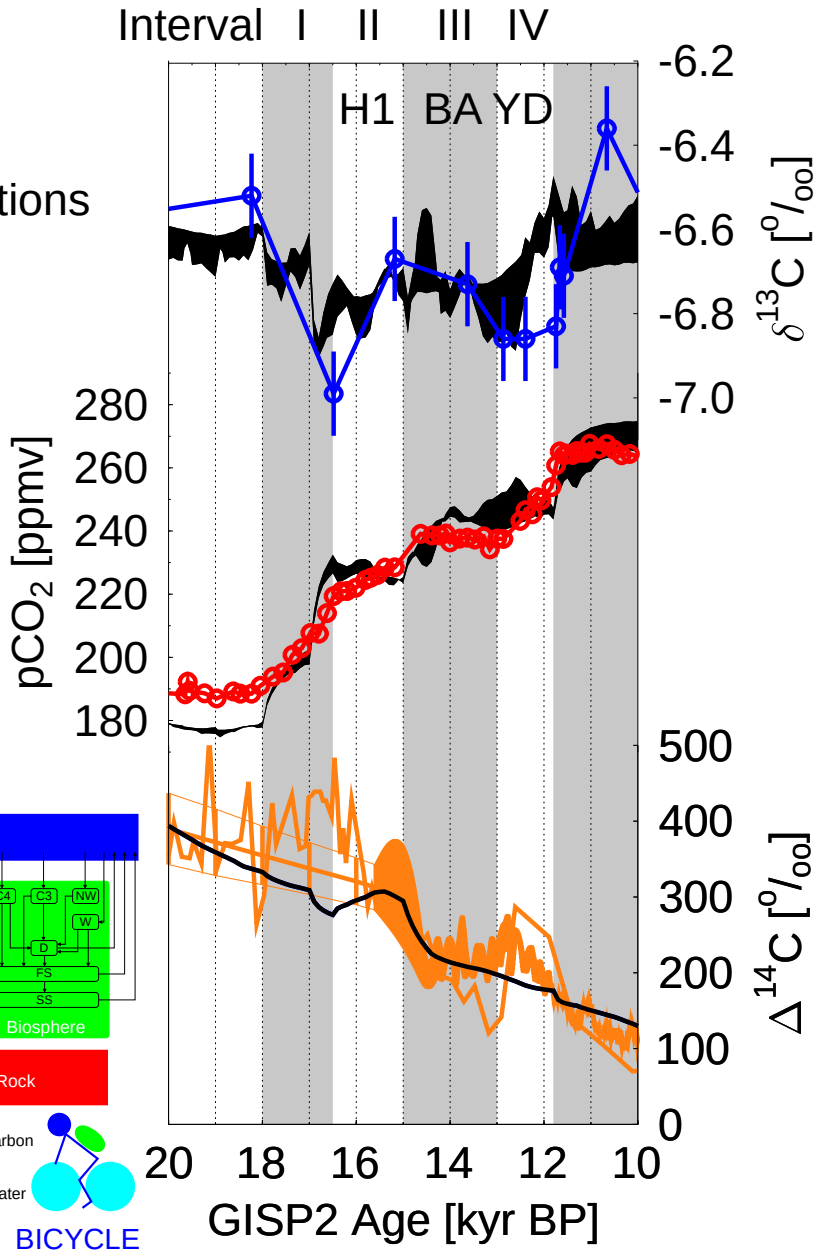
A Physics

B Ocean circulation

C Biogeochemistry







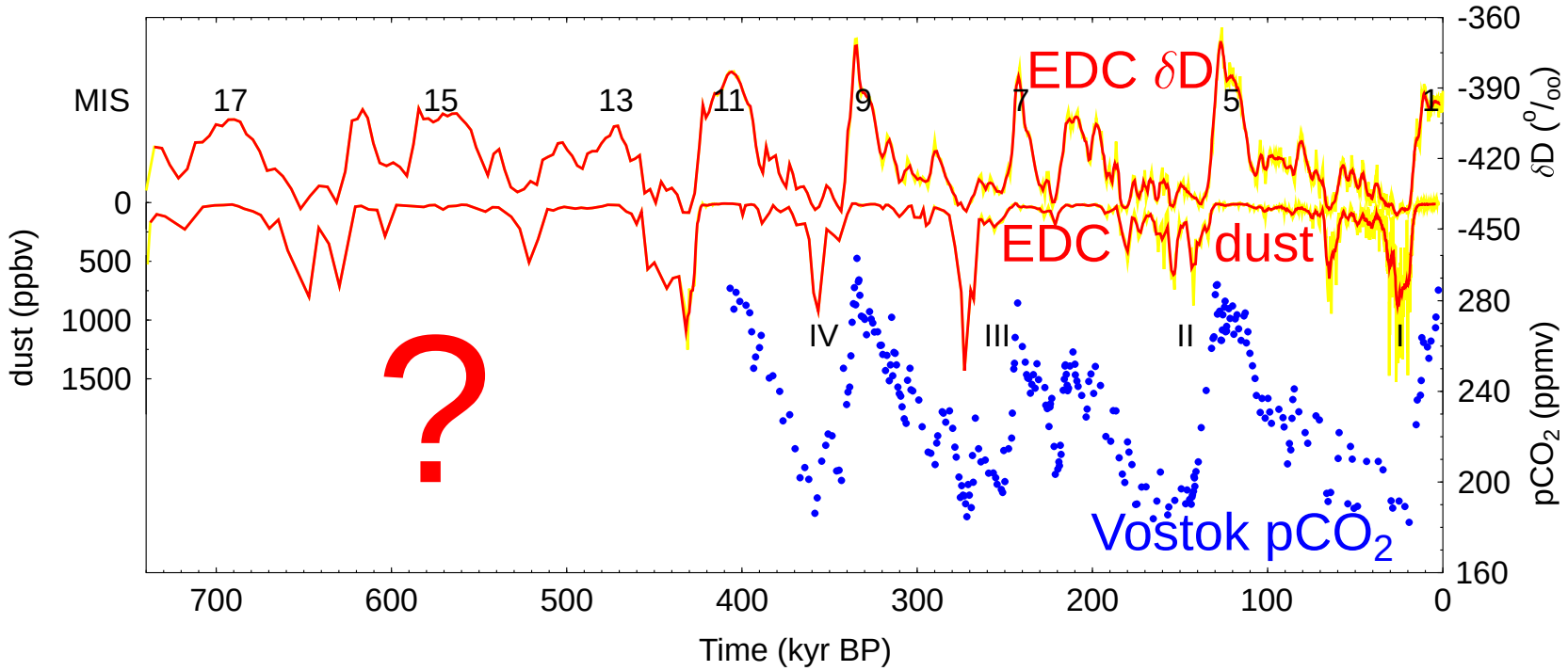
Forcing ⇒ Model ⇒ Results

Köhler et al., GBC, in press, preprint for download at my homepage

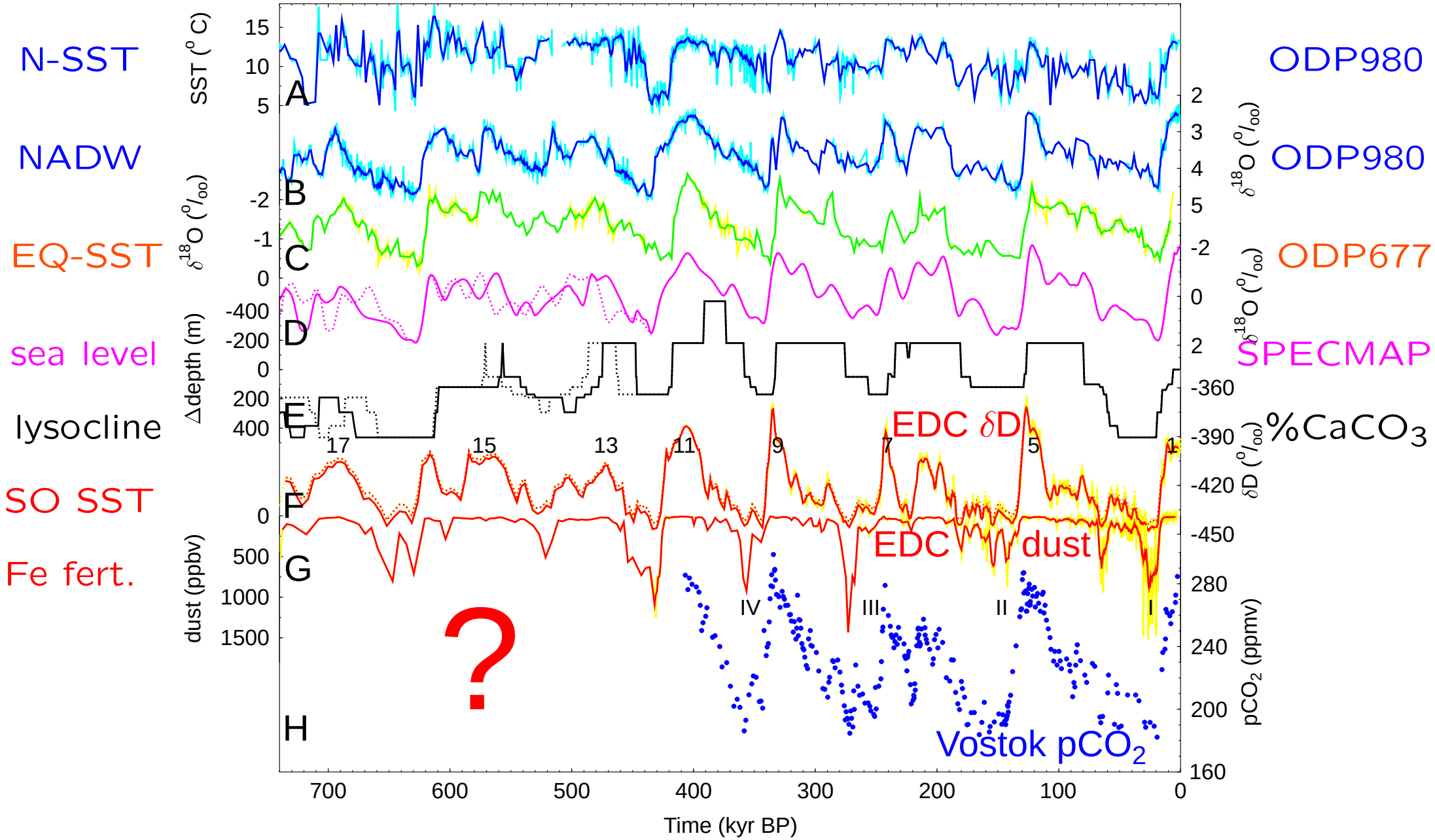
Processes & contribution to pCO_2 rise during Termination I

Process	Change over Termination I	G/IG impact on pCO_2 (ppmv)	Rank
Physics			
Ocean temperatures	+(3–5)°C	$+31 \pm 7$	+++
Salinity / sea level	+120 m	-14 ± 3	-
Gas exchange rates / sea ice	× 0.5	-13 ± 3	-
dominated by North (sink), not South (source)			
Ocean circulation			
NADW formation	10 Sv to 16 Sv	$+15 \pm 2$	+
SO vertical mixing	9 Sv to 29 Sv	$+35 \pm 4$	++++
Biogeochemistry			
Fe fertilisation in SO	export prod. −10%	$+24 \pm 4$	++
Terrestrial biosphere	+1000 PgC	-20 ± 5	—
$CaCO_3$ chemistry	lysocline dynamics	+44	+++++
(Terrestrial weathering		$\sim +5$	∘)
(Coral reef growth	sea level > −70 mbp	$\sim +10$	∘)

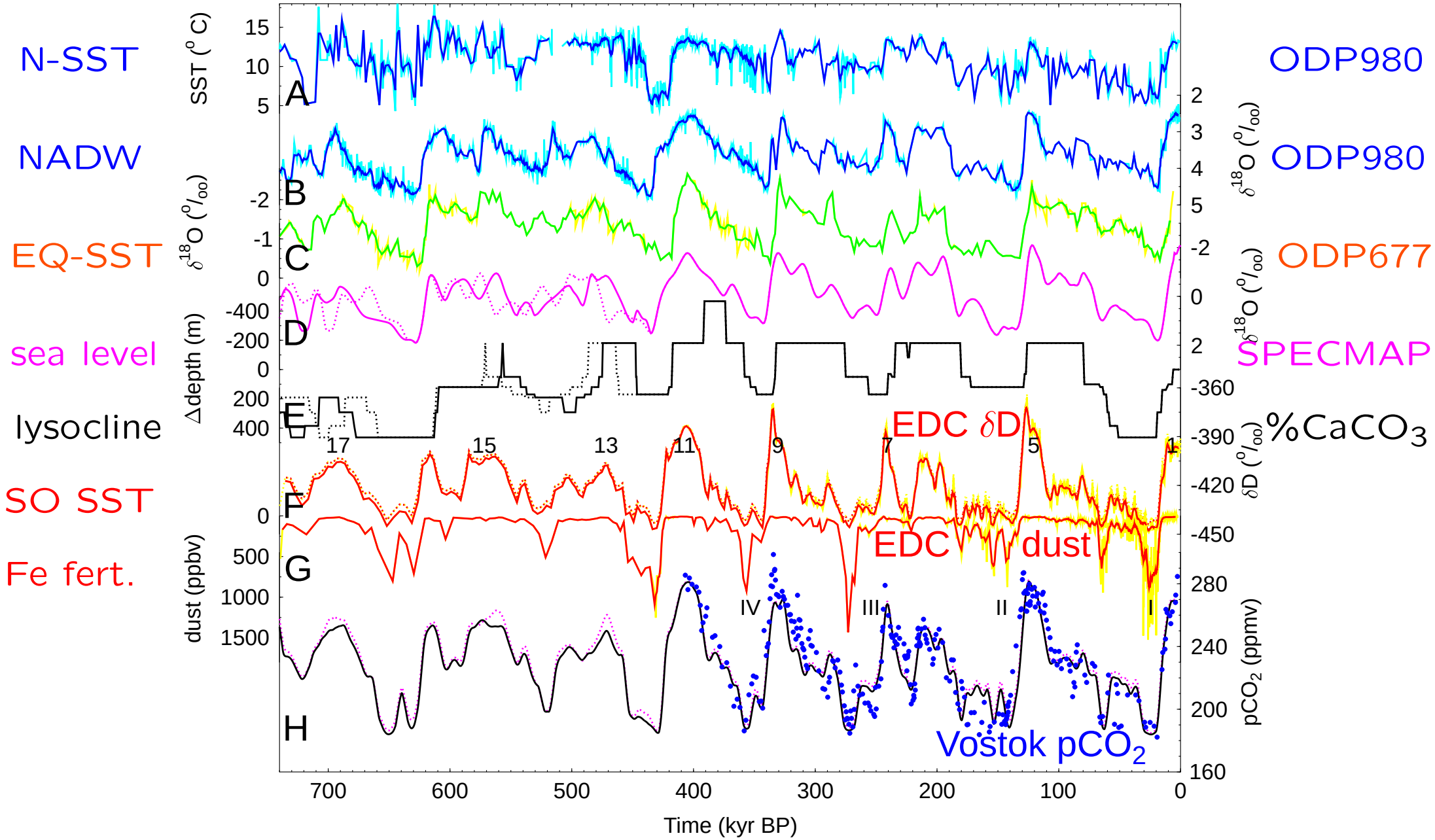
The EPICA challenge



The EPICA challenge

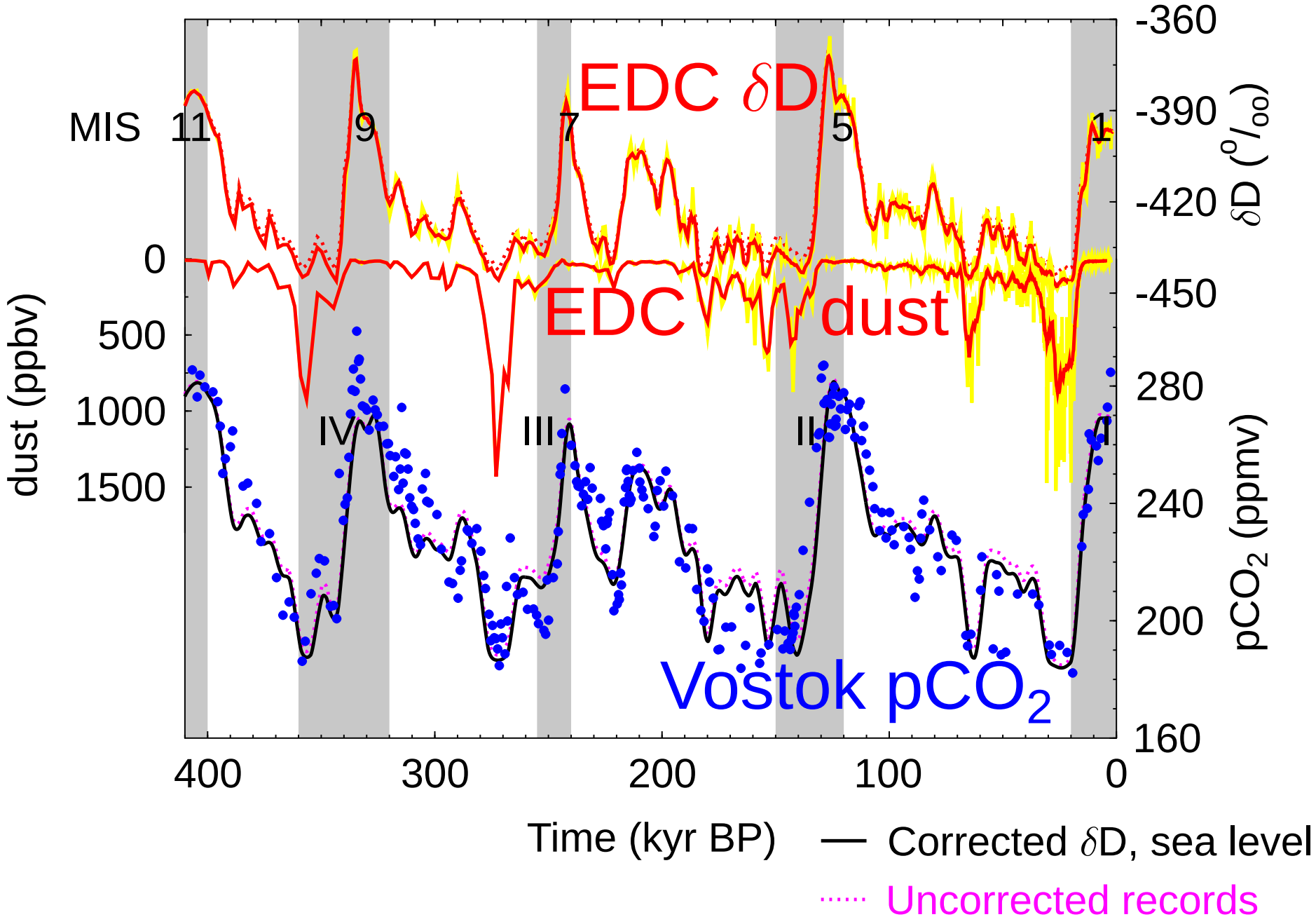


The EPICA challenge



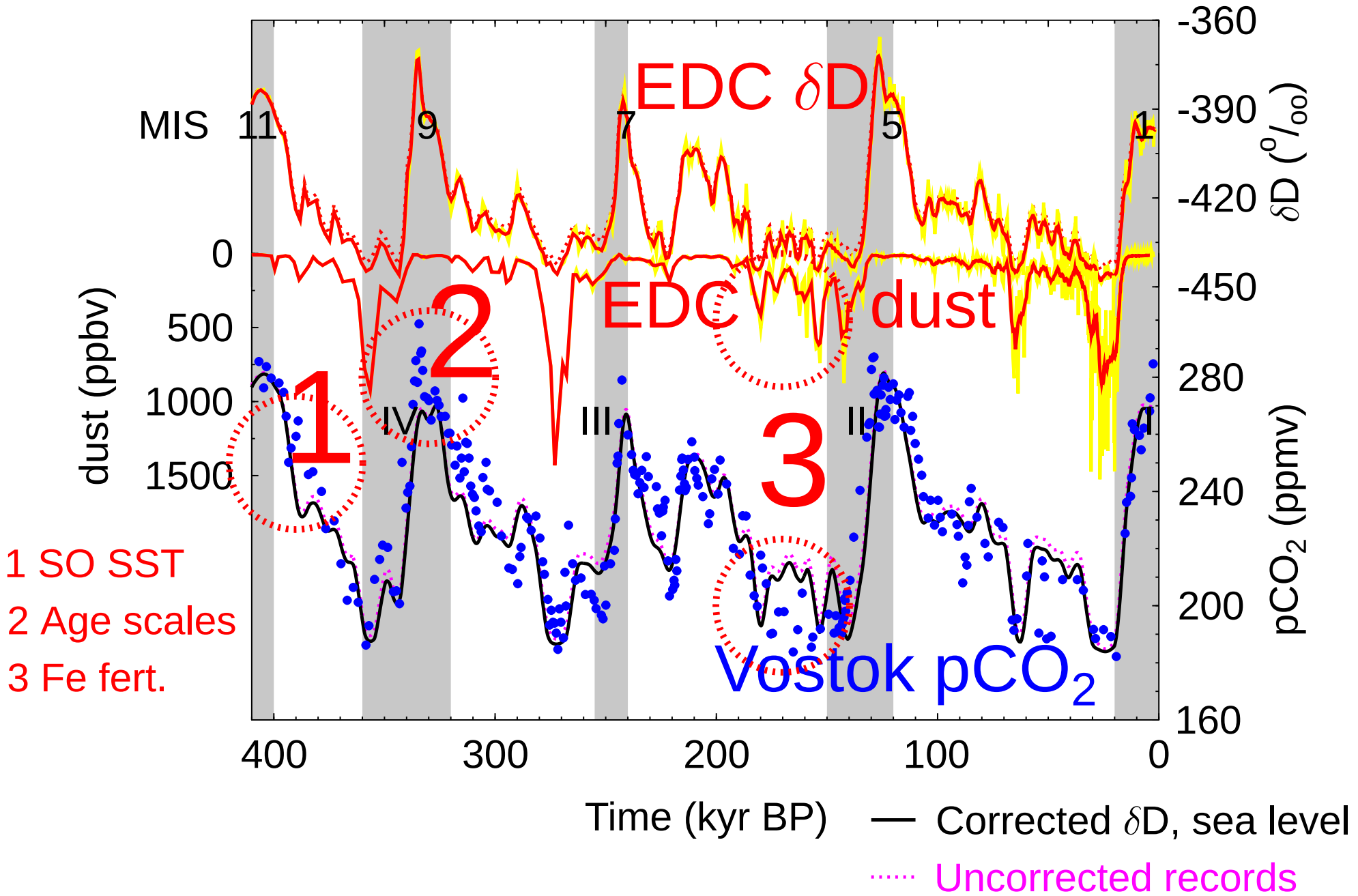
Vostok period

Match to Vostok data remarkable ($r^2 = 0.79$).



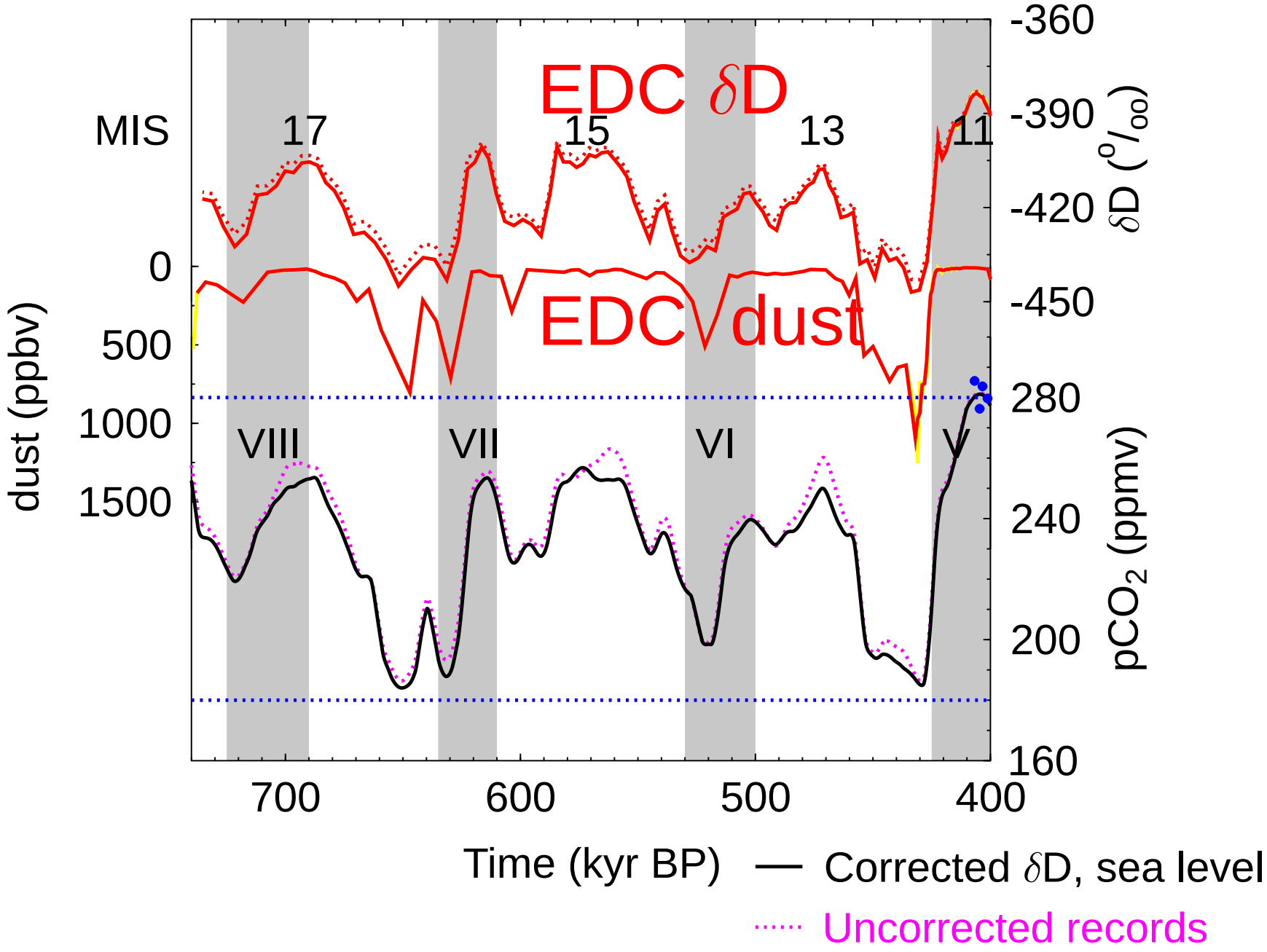
Vostok period

Main caveats can be explained with model limitations

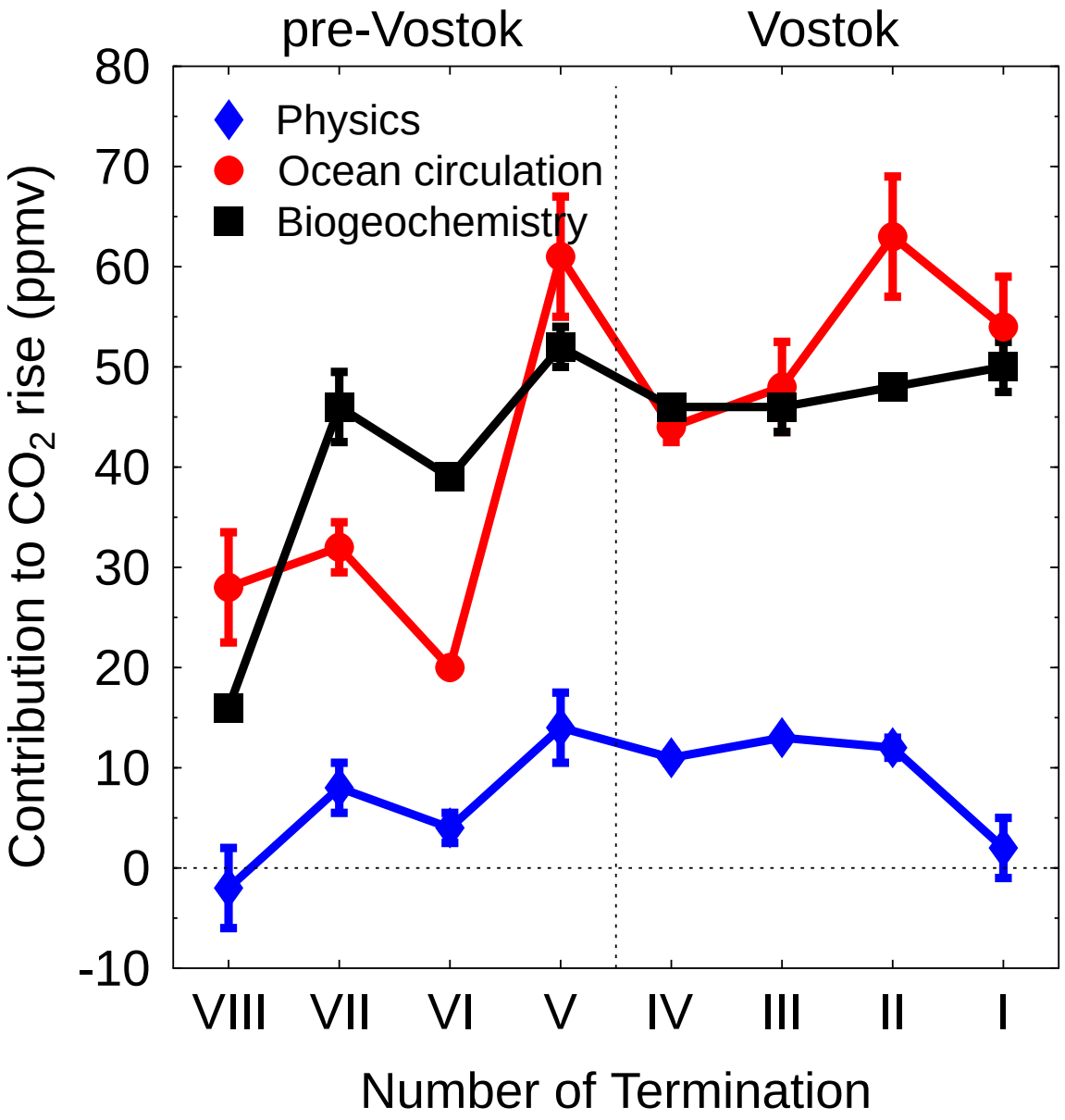


Pre-Vostok period

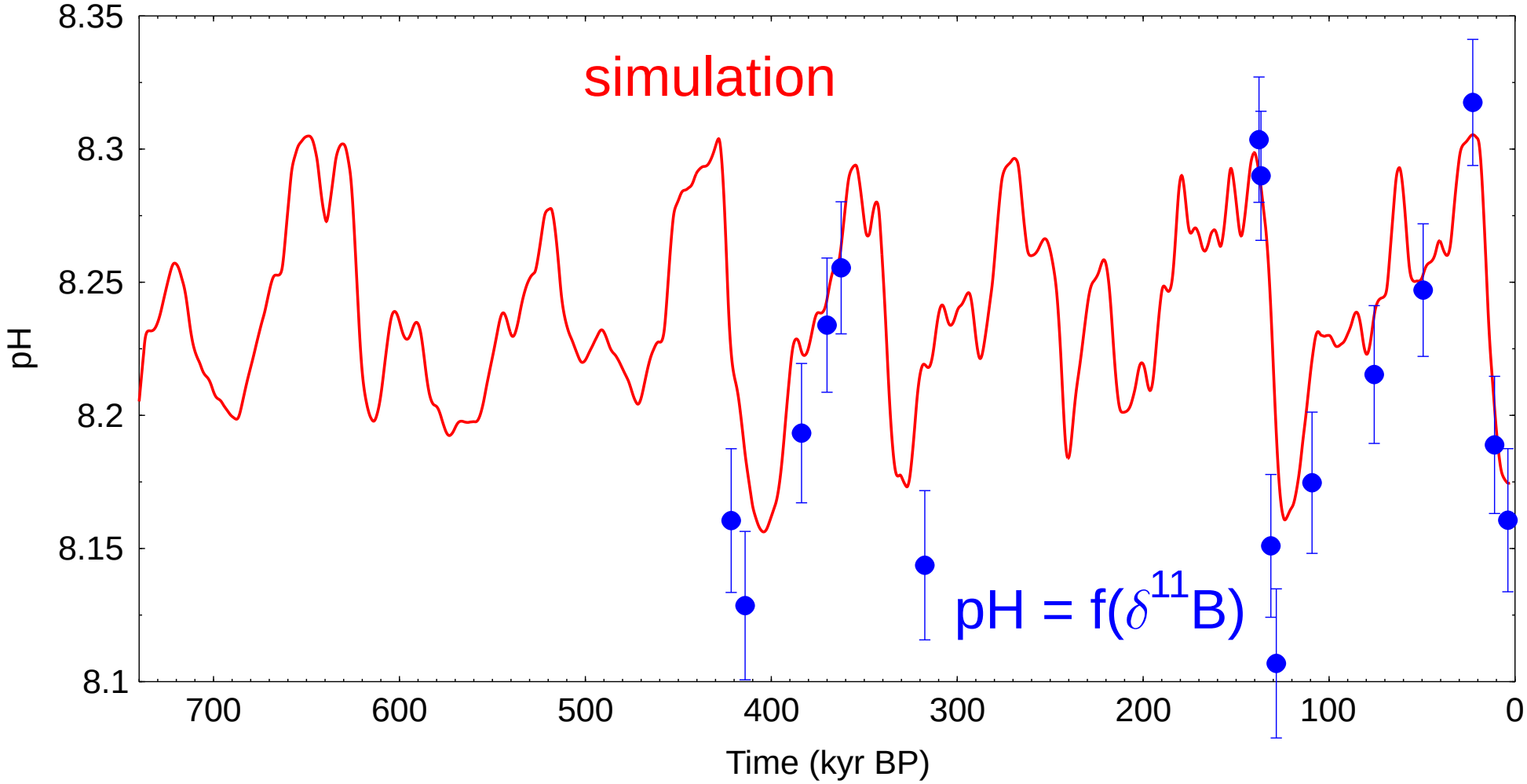
Match to EDC data: $r^2 = 0.81$; smaller glacial/interglacial amplitudes



Processes during Terminations I-VIII



Oceanic evidence from pH reconstructions



Hönisch & Hemming 2005, EPSL, 236, 305–314

pH from δ^{11}B in surface waters of equatorial Atlantic

Conclusions

1. Model-based reconstruction of pCO_2 in Vostok and EPICA Dome C data ($r^2 = 0.8$). Main offsets can be explained with model limitations.

2. Smaller G/IG amplitudes in pCO_2 prior to Termination V were caused by smaller interglacial pCO_2, caused by smaller interglacial SO SST and reduced interglacial ocean circulation.

3. Due to data and model uncertainties we can not exclude alternative scenarios. The amplitudes of the individual processes are to a certain extend model dependent.

4. However, as our main understanding was based on Termination I, the fact that we can reconstruct not only the regular Vostok pCO_2 cycle but also smaller G/IG amplitudes prior to Termination V gives us confidence in our results.

THANK YOU FOR YOUR ATTENTION

Acknowledgments:
The new EPICA Dome C pCO_2 data were measured by Urs Siegenthaler (Thomas Stocker) at the Department of Climate and Environmental Physics, University of Bern, Switzerland.

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