

Proposing a mechanistic understanding of changes in atmospheric CO₂ 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

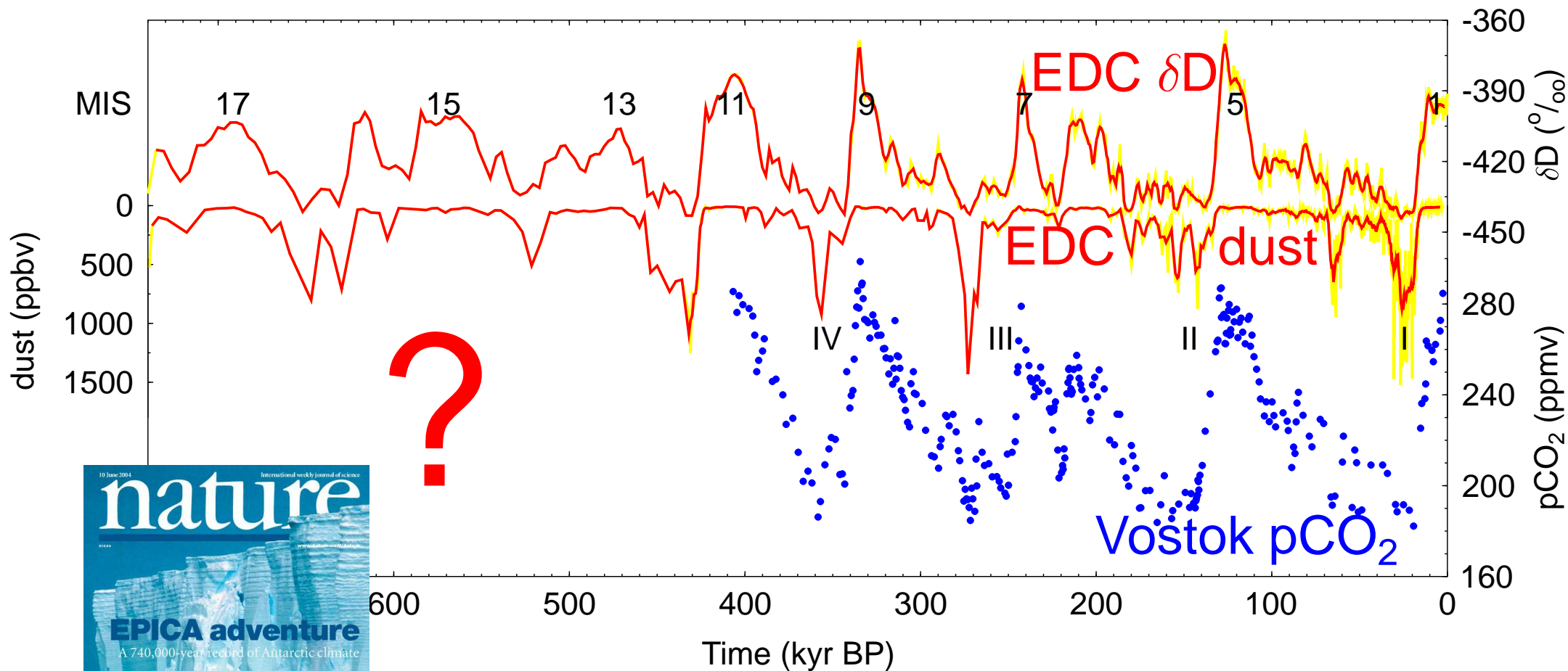
BICYCLE - a box model of the isotopic carbon cycle

Termination I (20 – 10 kyr BP)

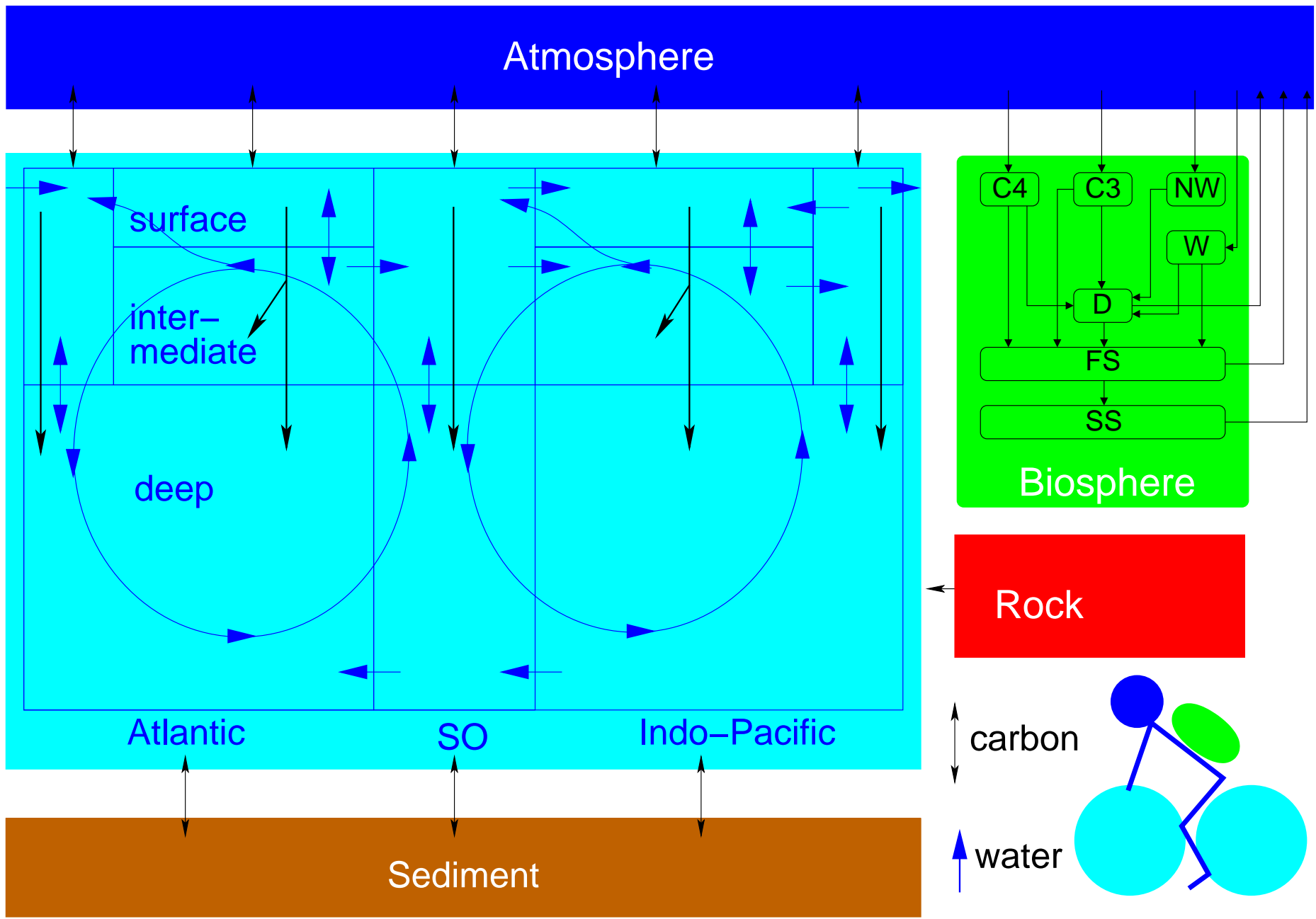
Our contribution to the EPICA challenge — riding the bike for 740 kyr

The EPICA challenge

Predicting pCO₂ 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

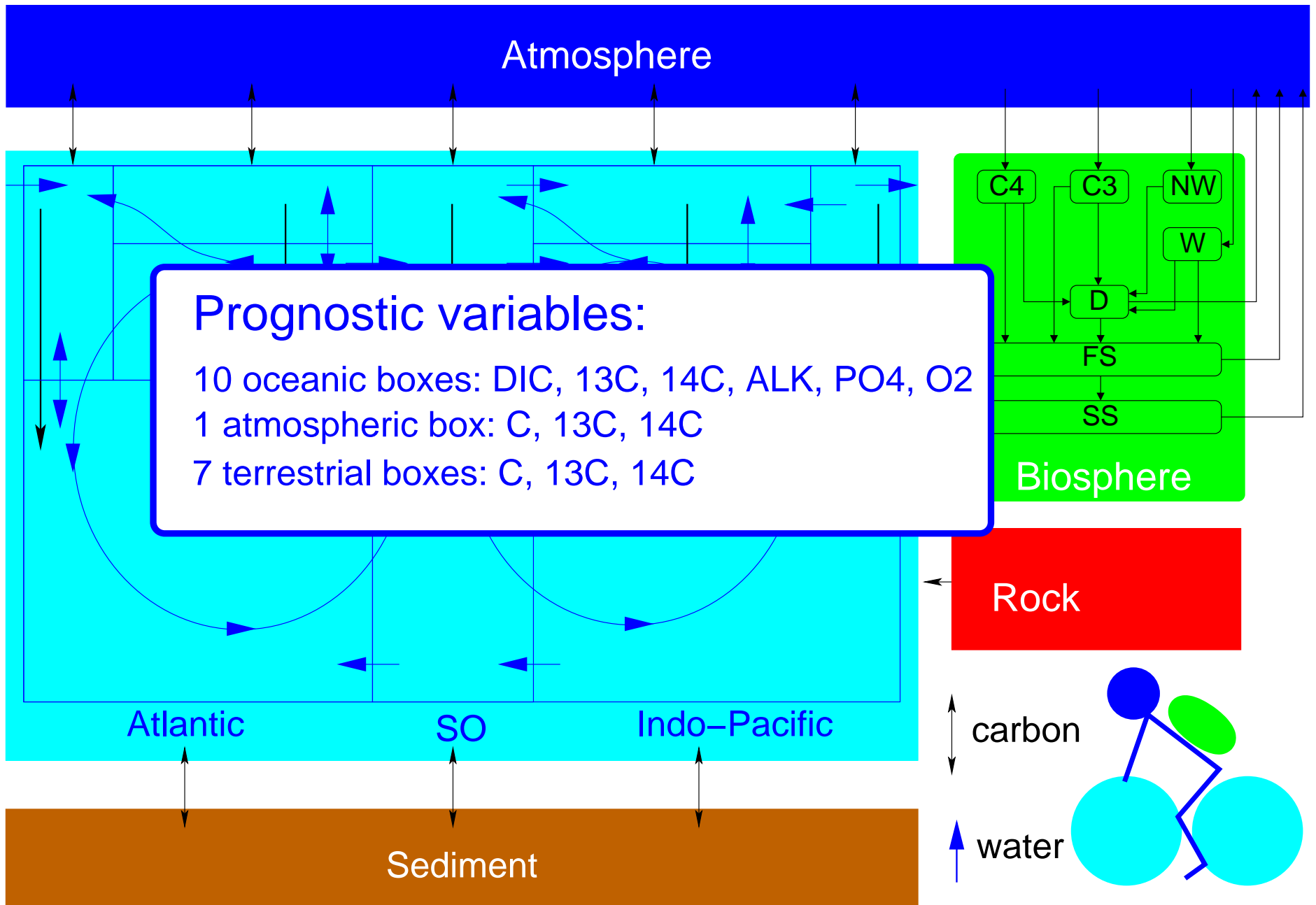


(EPICA community members, 2004; Petit et al., 1999)



Box model of the Isotopic Carbon cYCLE

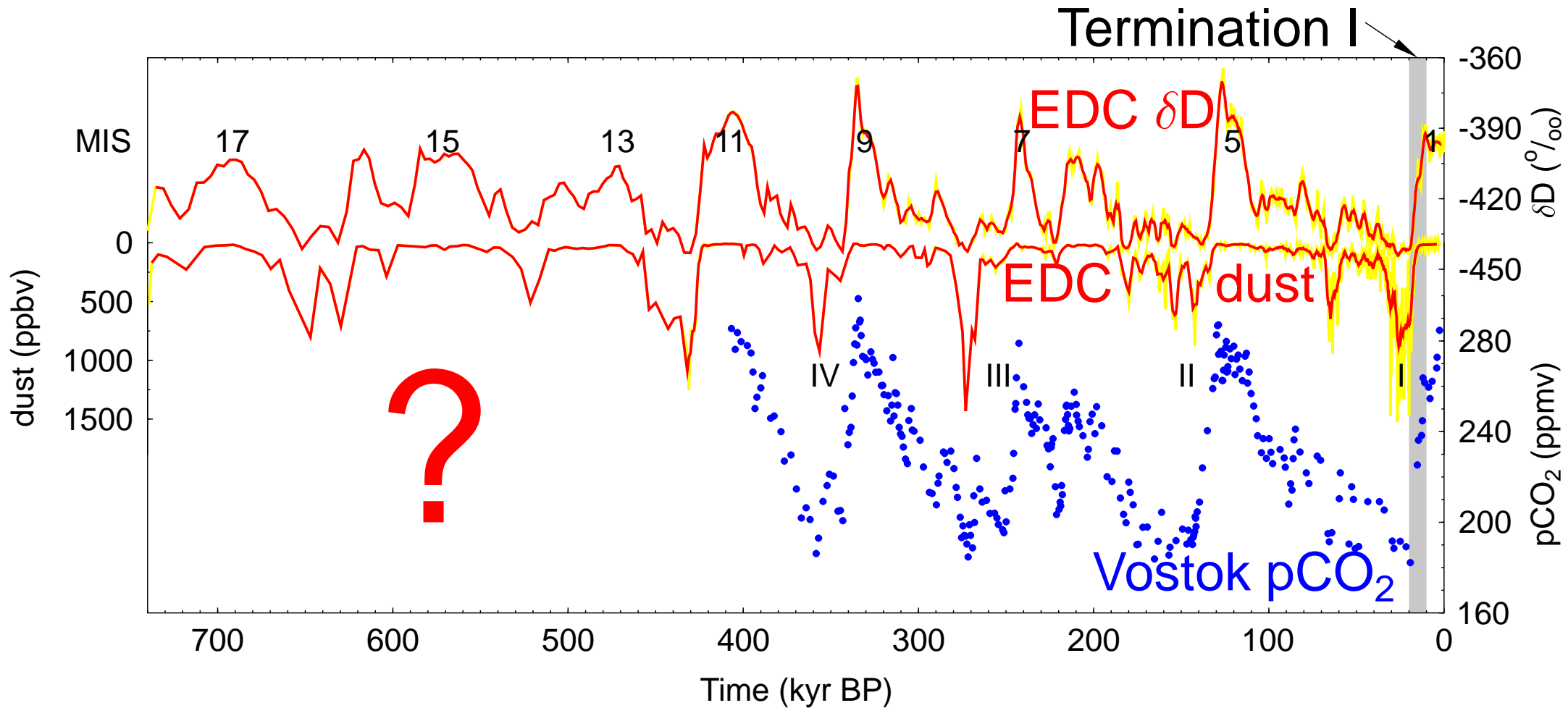
BICYCLE



Box model of the Isotopic Carbon cYCLE

The EPICA challenge

Carbon cycle model simulations based on understanding of Termination I.

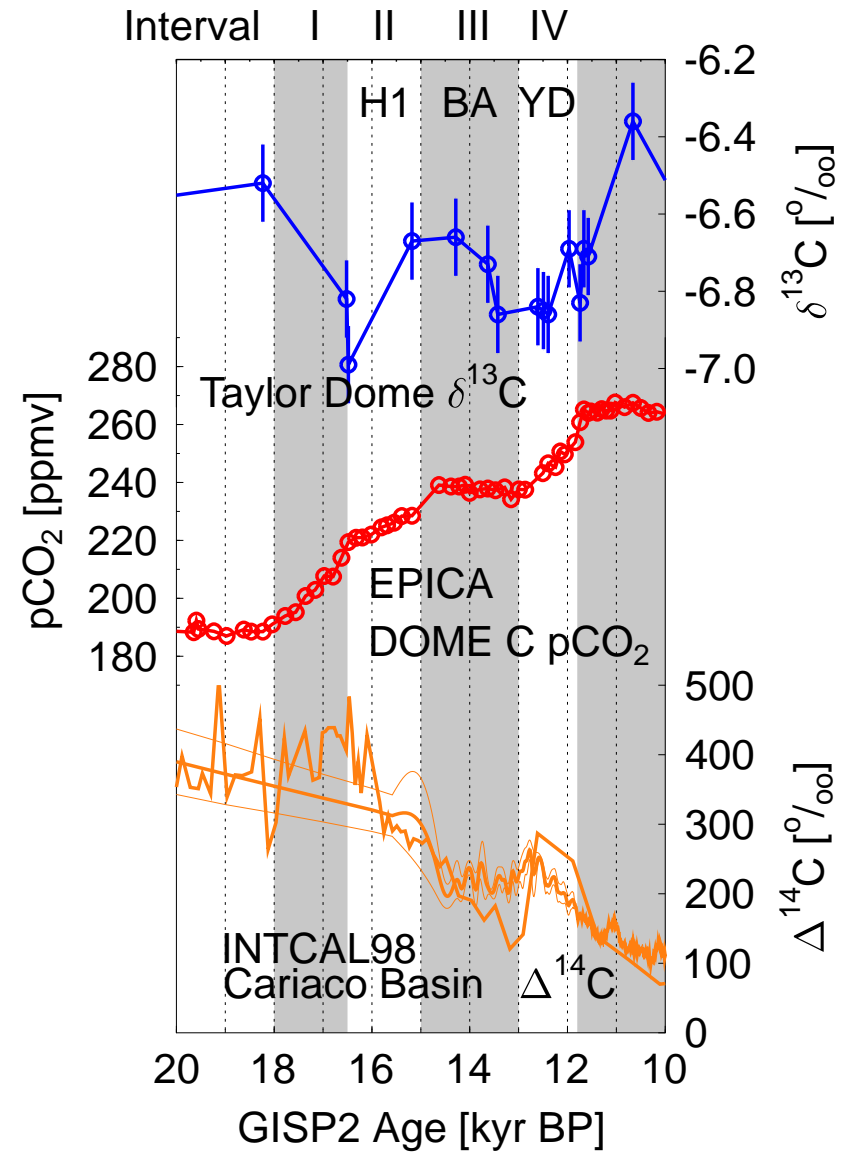


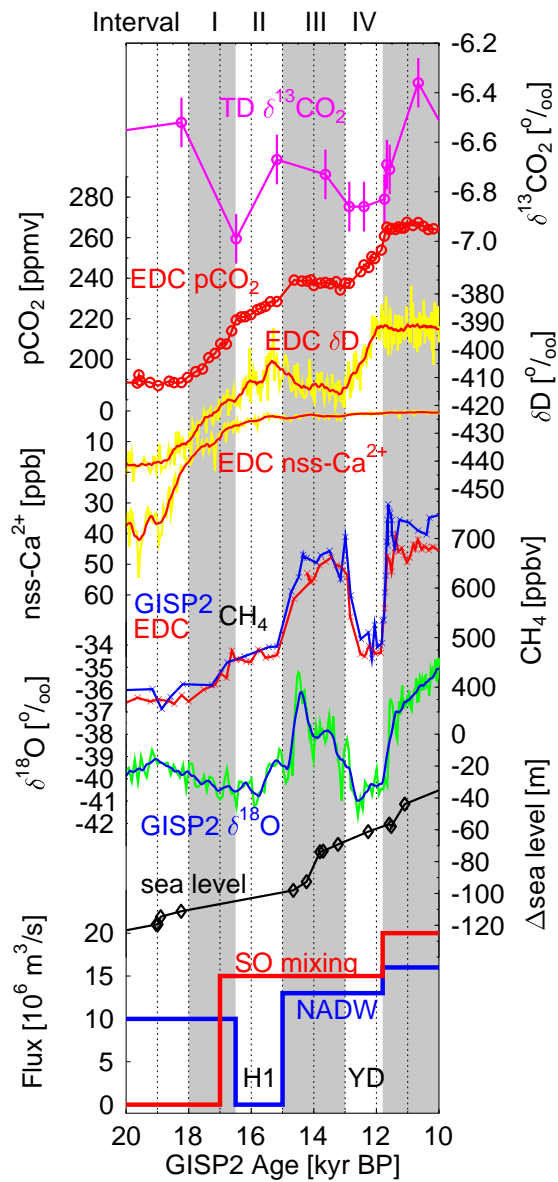
(EPICA community members, 2004; Petit et al., 1999)

Atmospheric carbon during Termination I

Explain the temporal evolution of atmospheric $p\text{CO}_2$, $\delta^{13}\text{C}$, $\Delta^{14}\text{C}$ records by carbon cycle simulations.

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

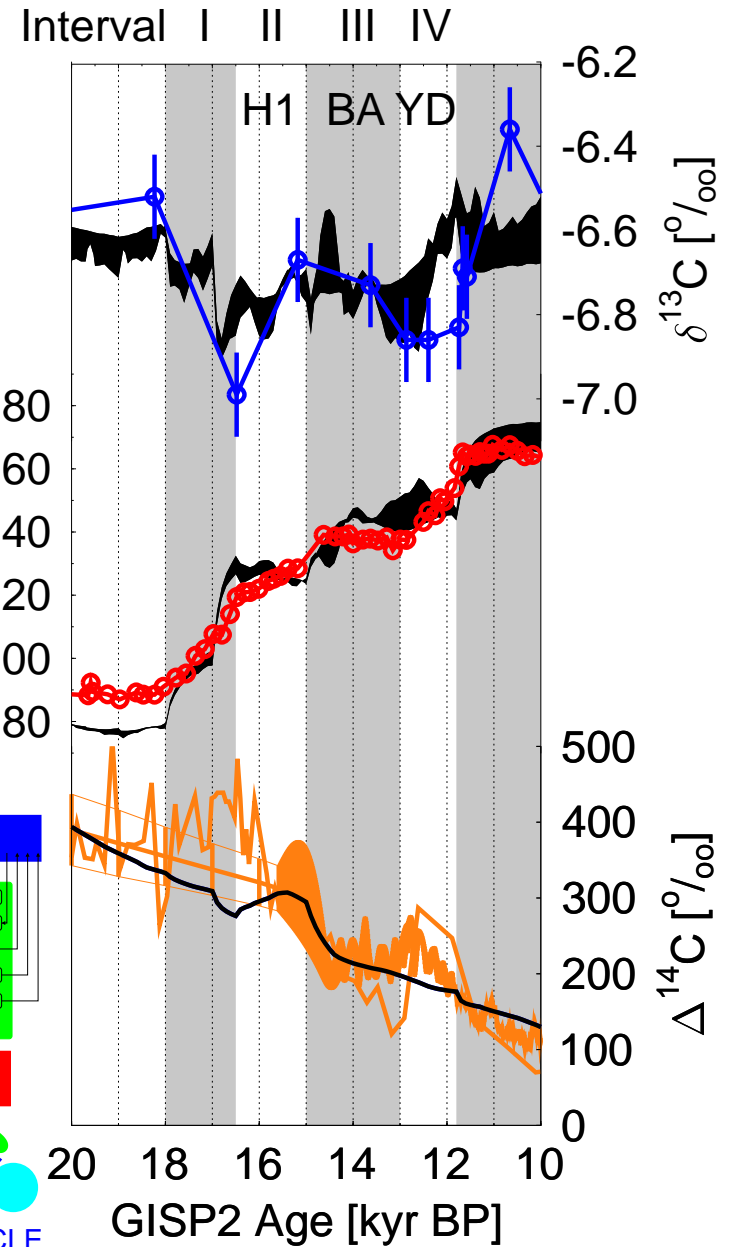
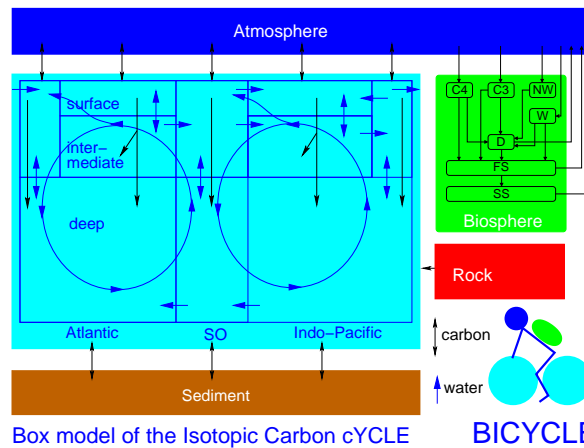




Termination I

Combining all assumptions on changes in

- A Physics
- B Ocean circulation
- C Biogeochemistry



Forcing



Model

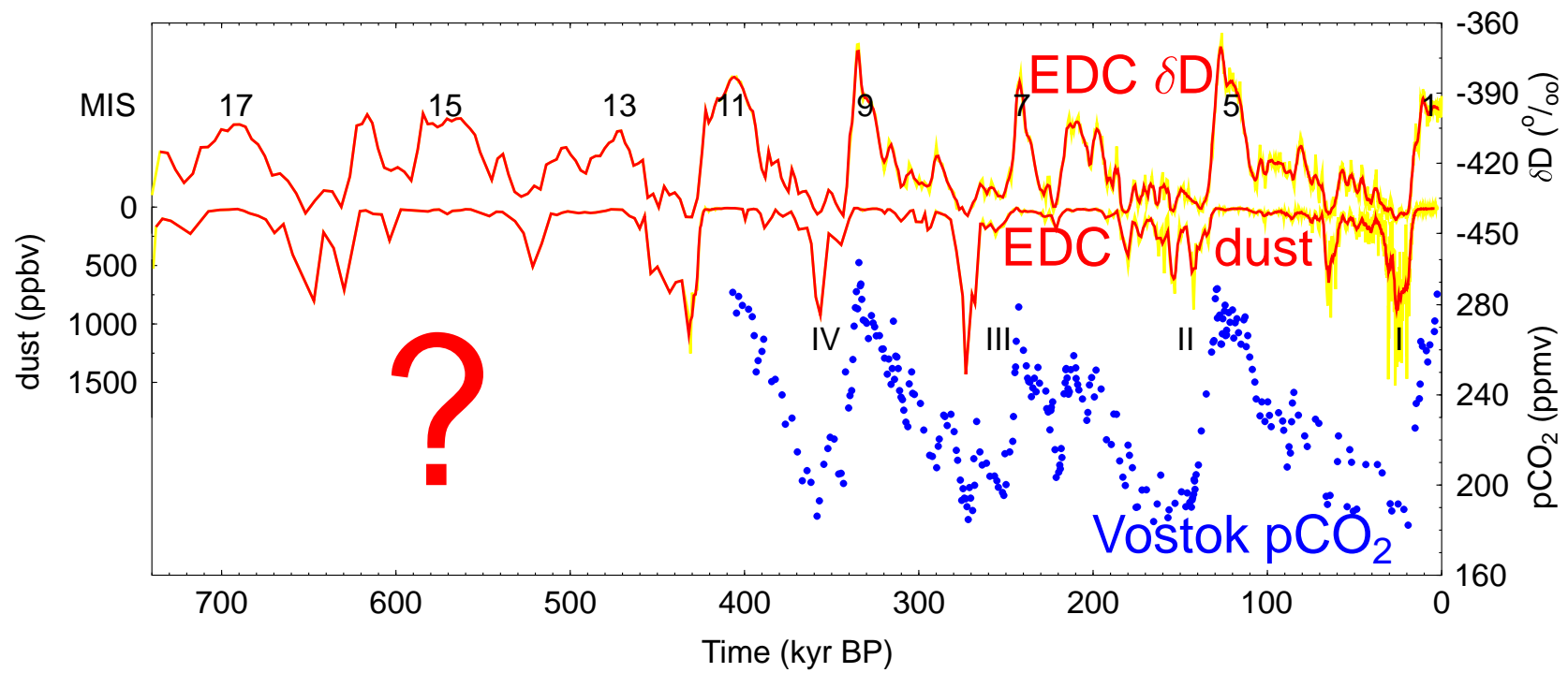


Results

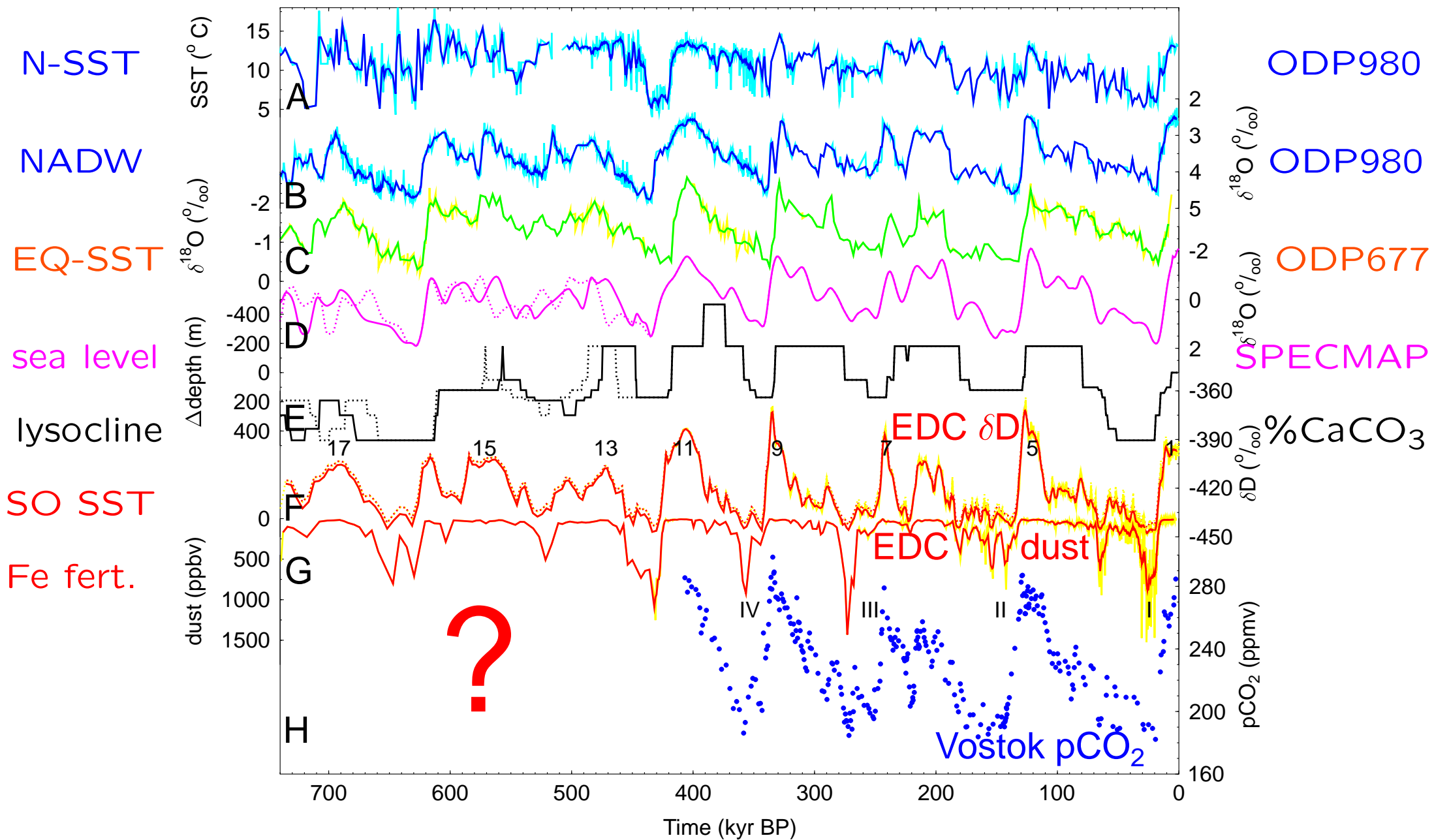
Processes & contribution to pCO₂ rise during Termination I

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

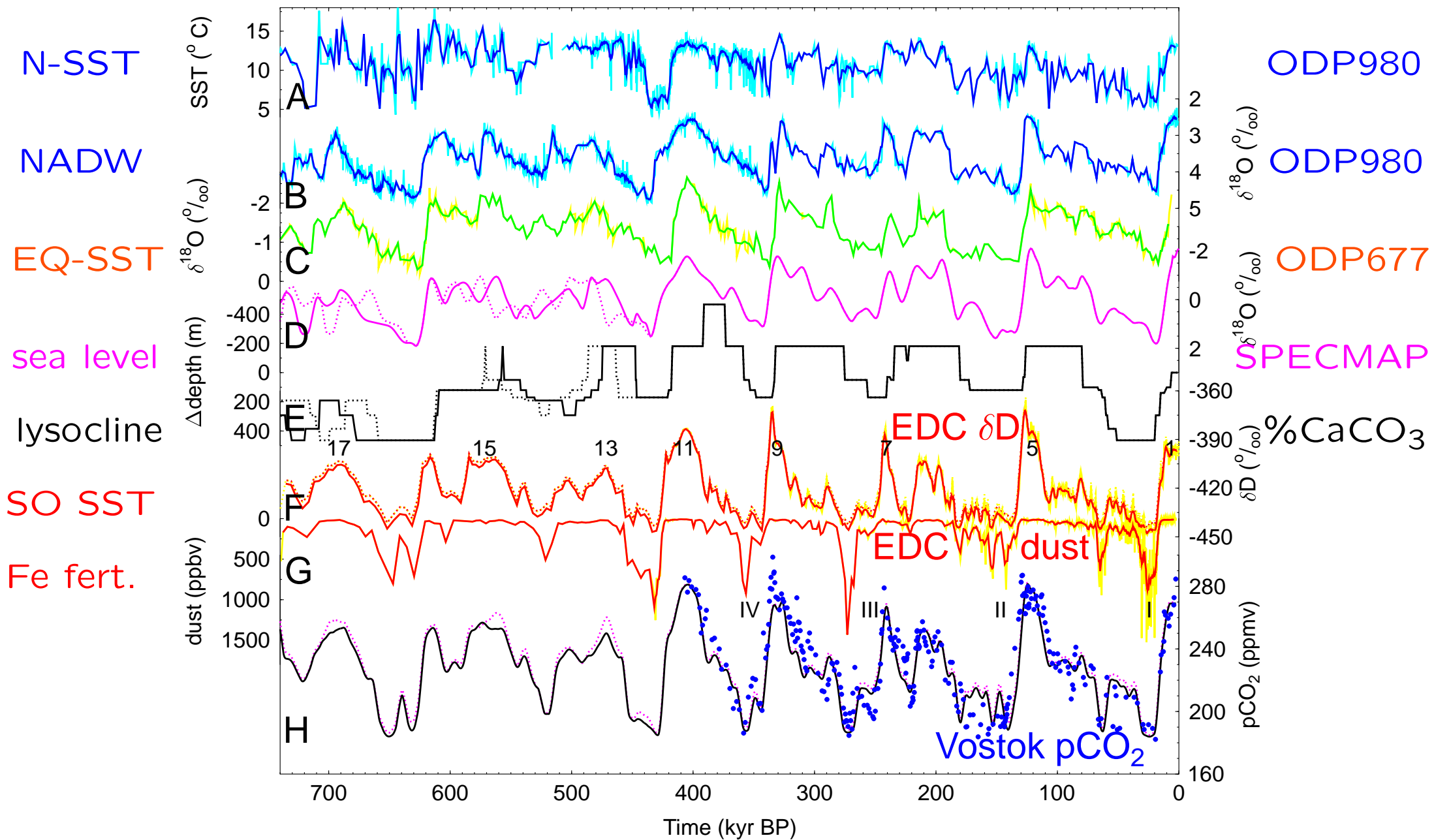
The EPICA challenge



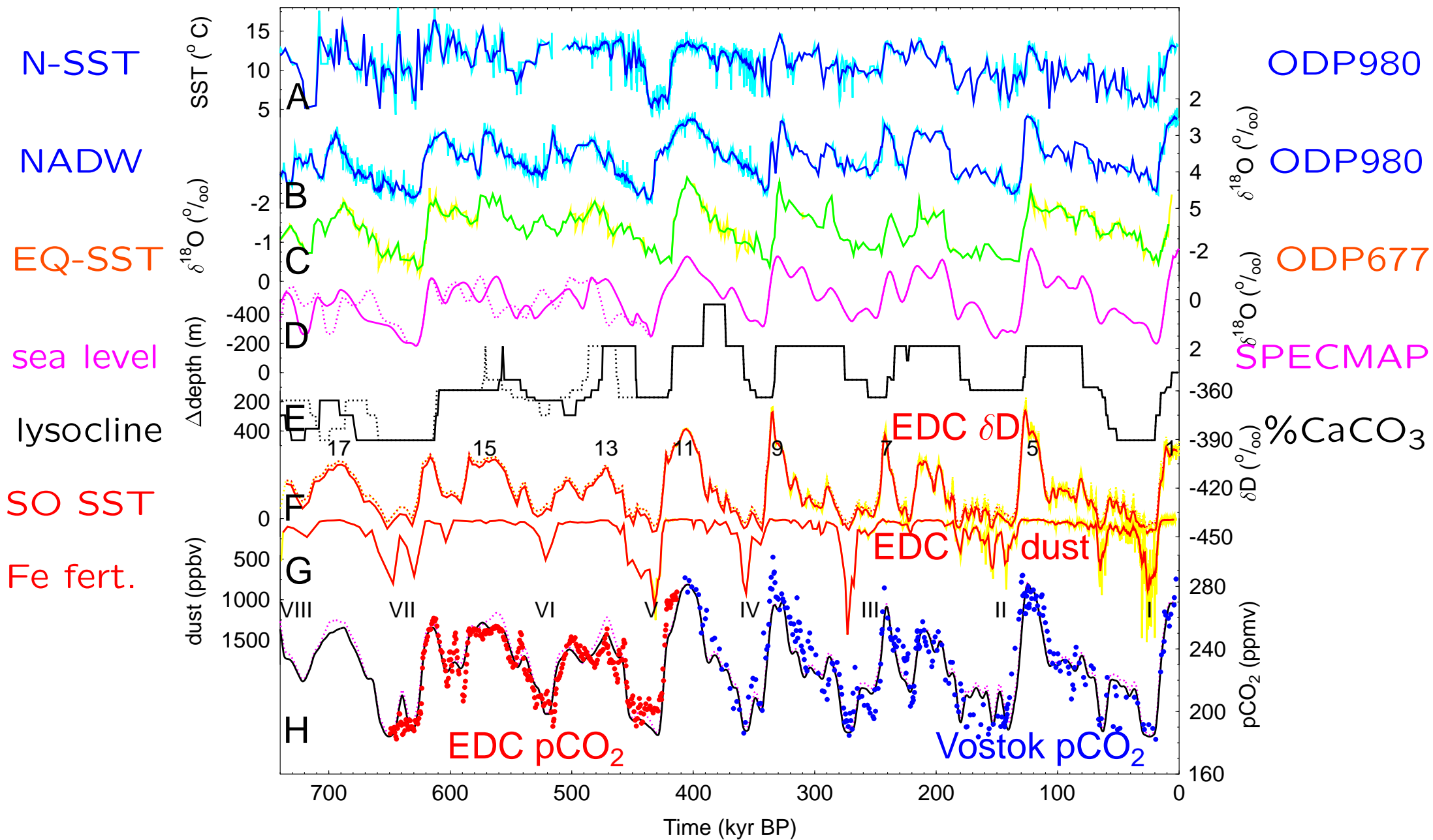
The EPICA challenge



The EPICA challenge

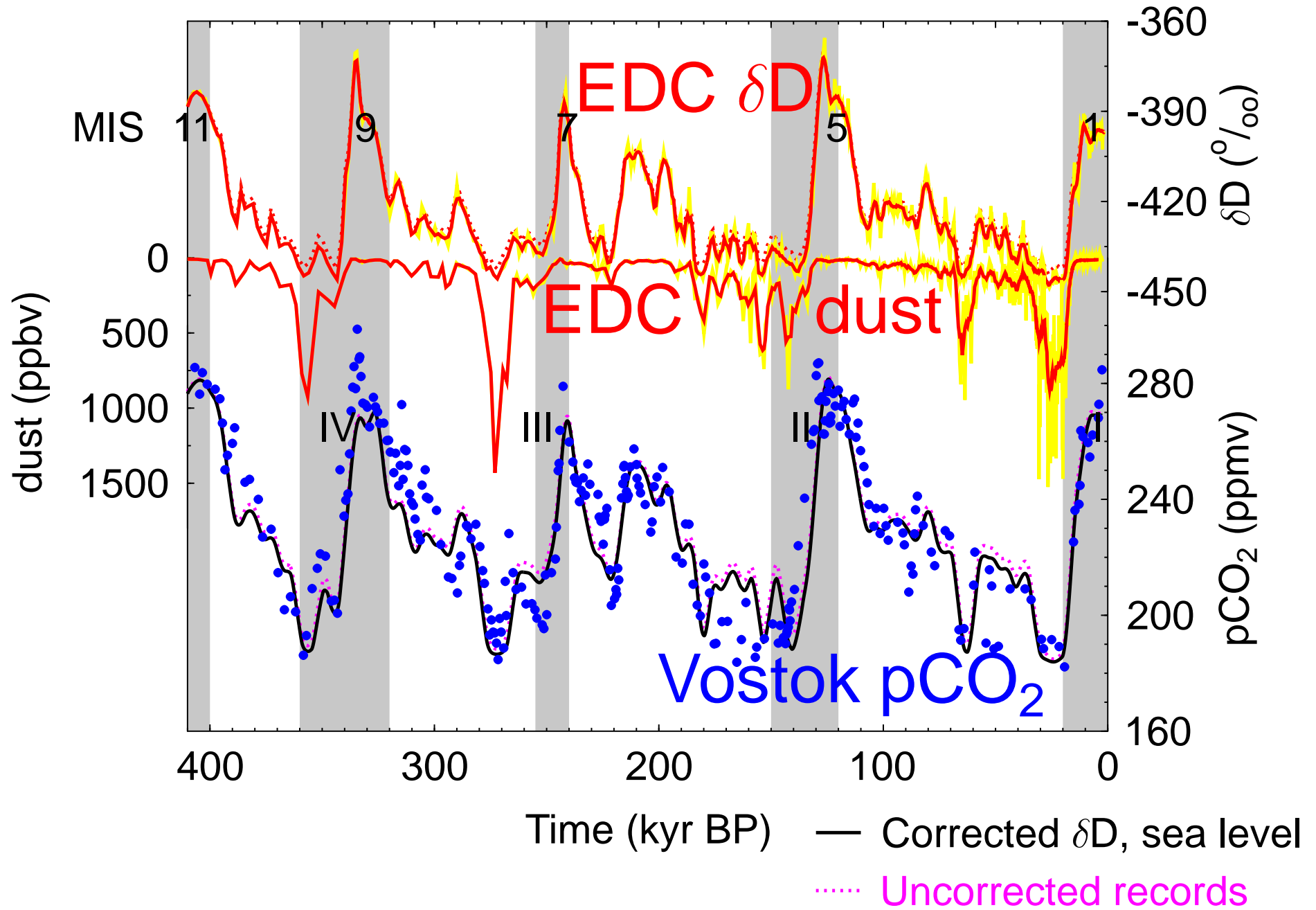


The EPICA challenge



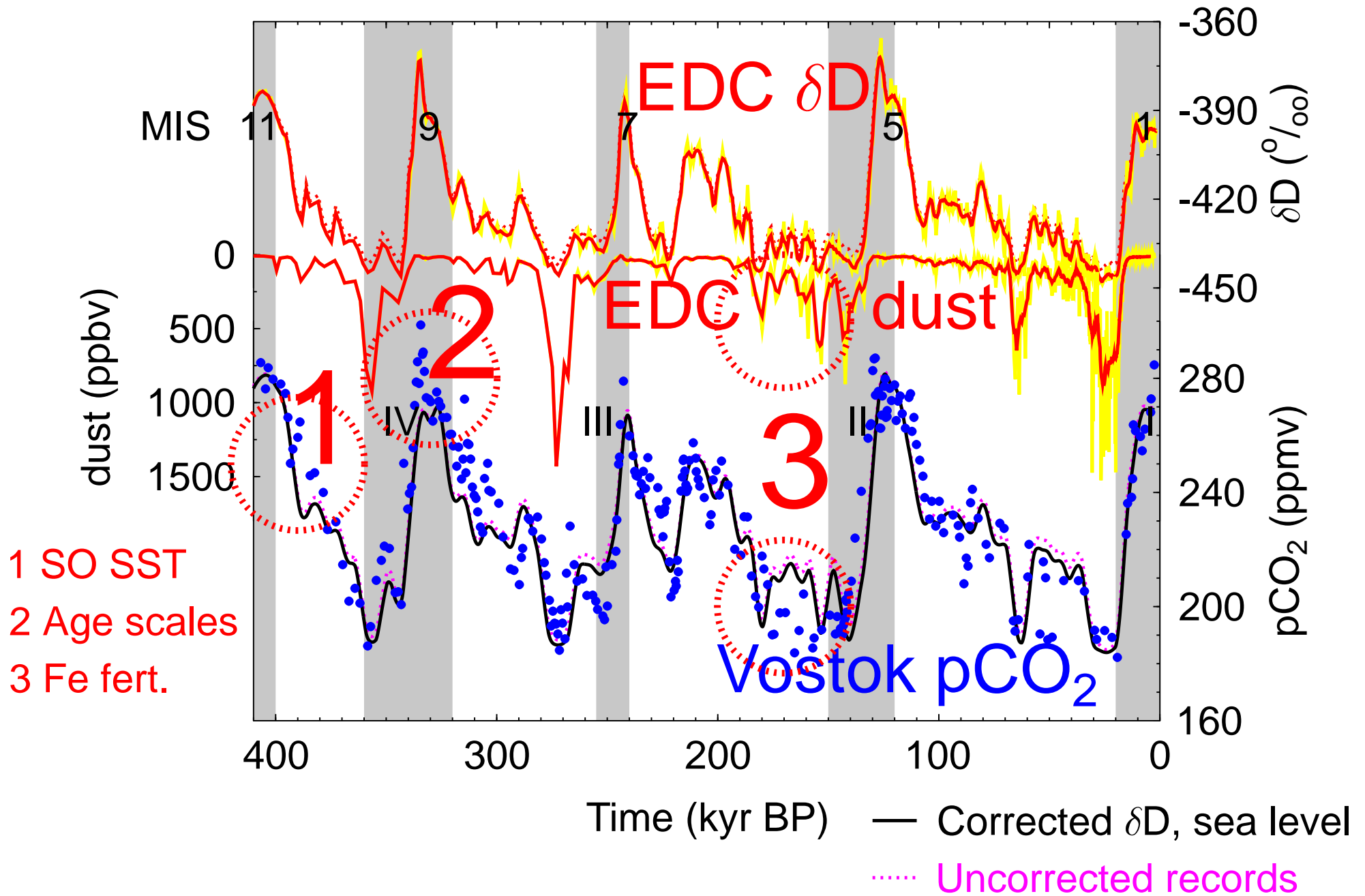
Vostok period

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



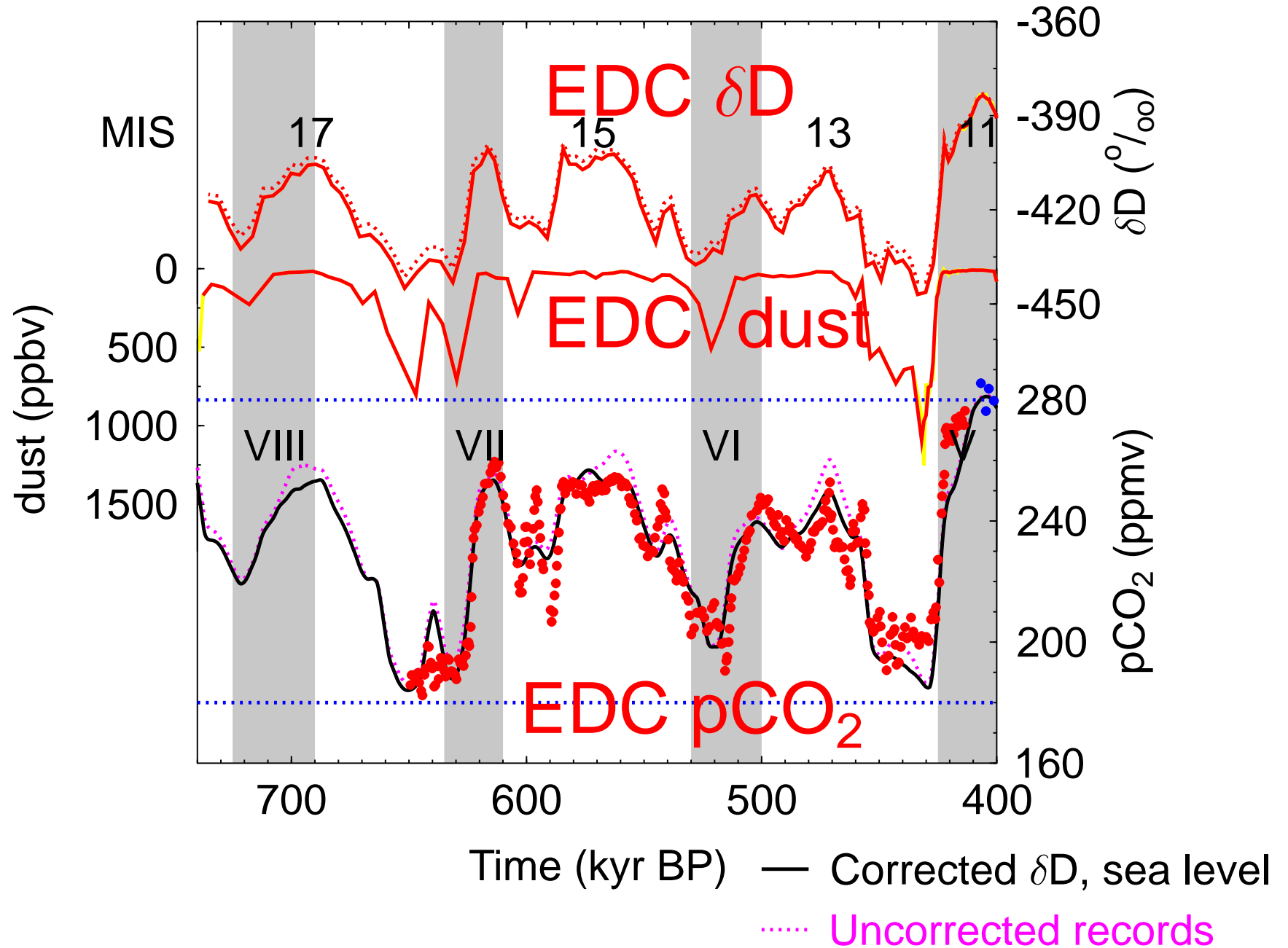
Vostok period

Main caveats can be explained with model limitations



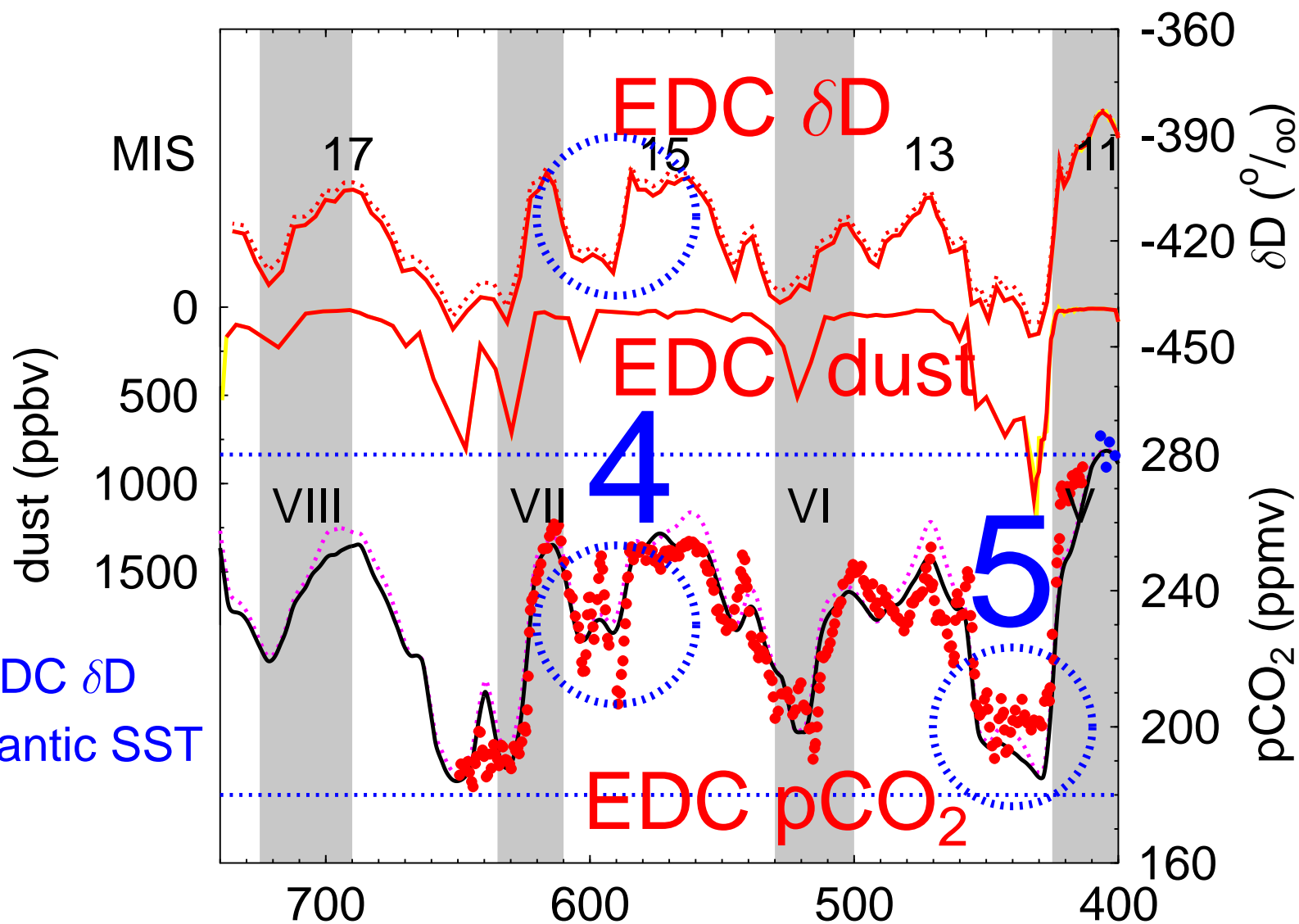
Pre-Vostok period

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



Pre-Vostok period

Caveats in the pre-Vostok period

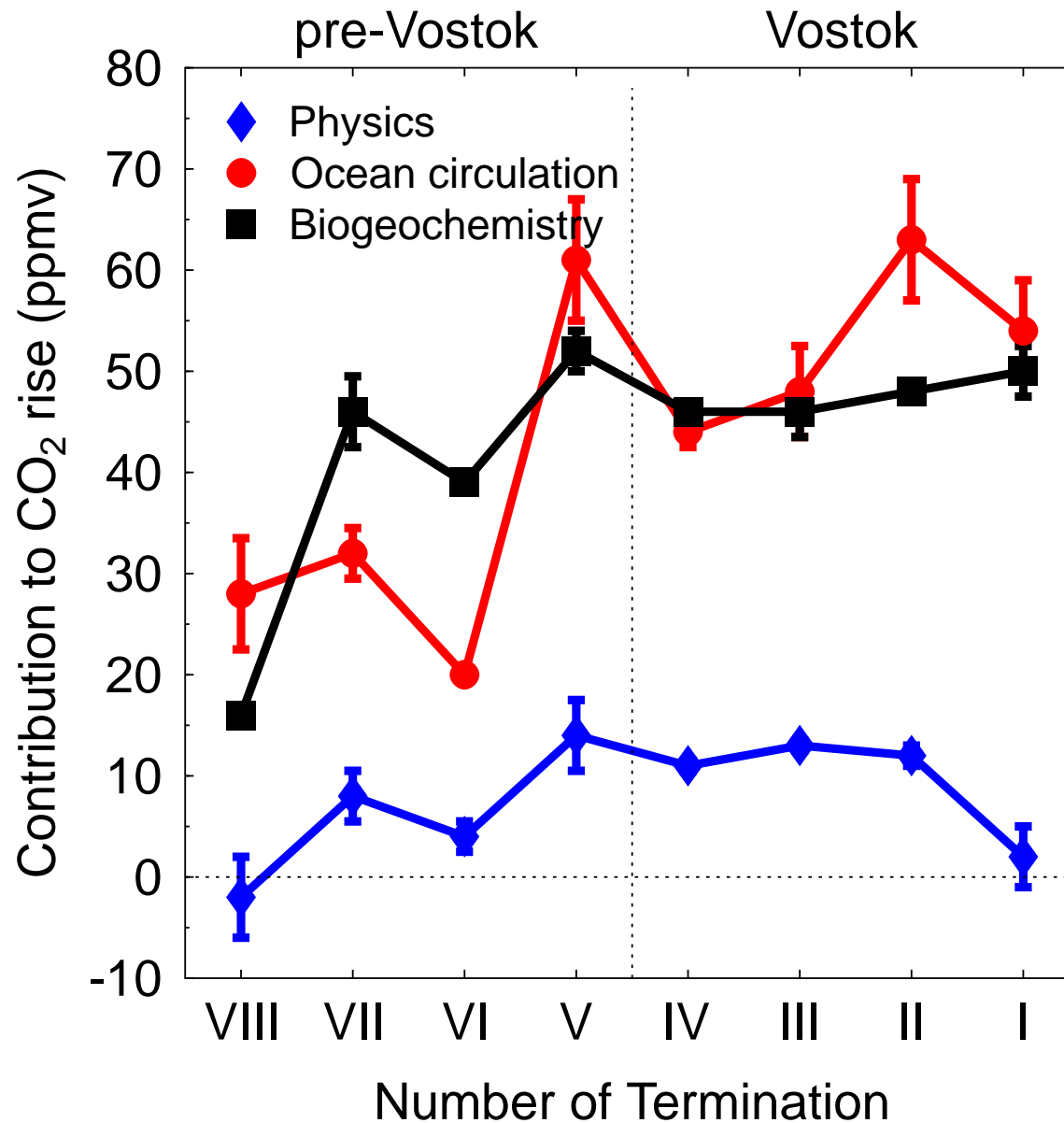


4 coarse EDC δD
5 North Atlantic SST

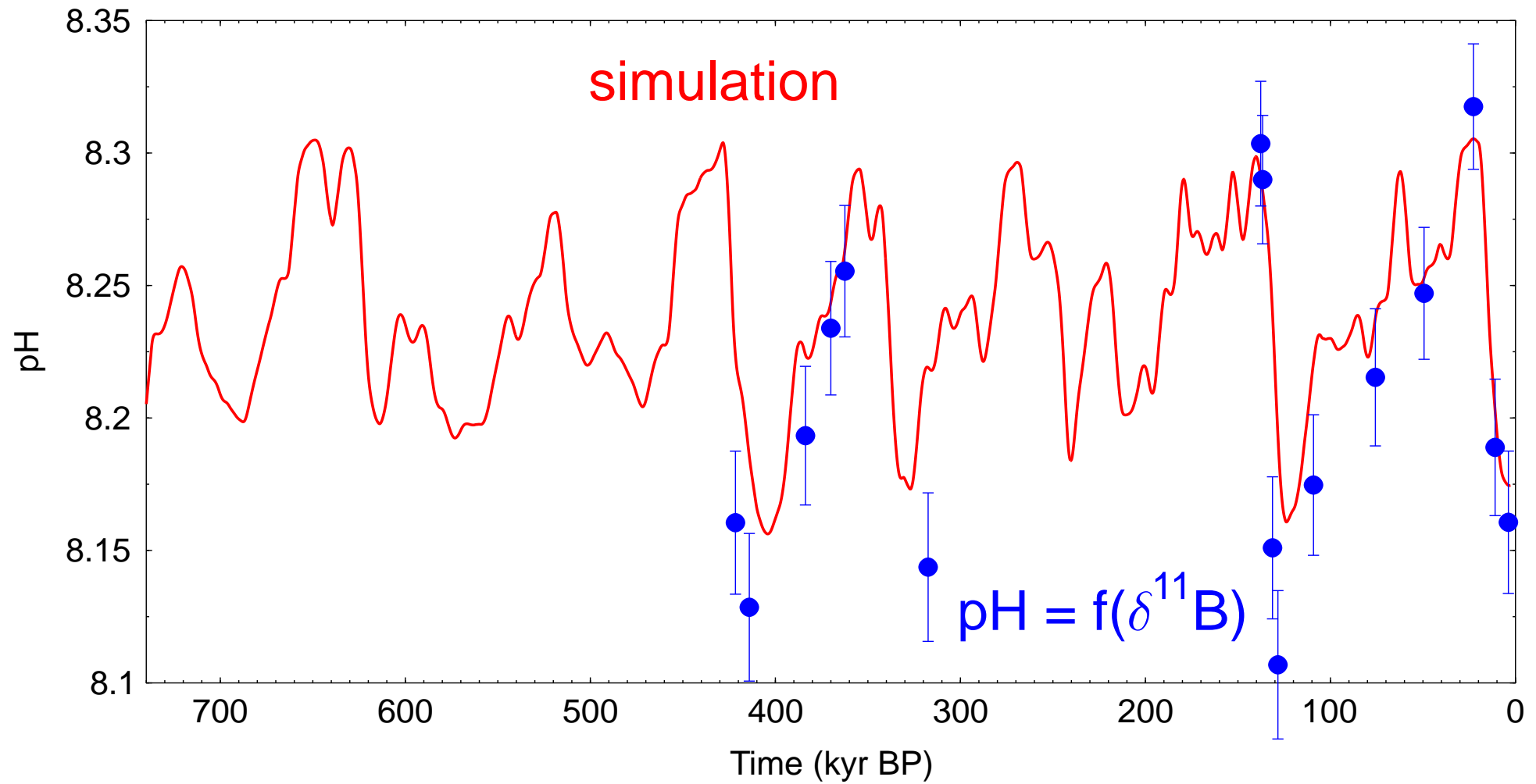
Time (kyr BP) — Corrected δD , sea level

..... Uncorrected records

Processes during Terminations I-VIII



Oceanic evidence from pH reconstructions



Hönisch & Hemming 2005, EPSL, 236, 305–314
pH from $\delta^{11}\text{B}$ in surface waters of equatorial Atlantic

Conclusions

Conclusions

1. Model-based reconstruction of pCO₂ in Vostok and EPICA Dome C data ($r^2 = 0.8$). Main offsets can be explained with model limitations.

Conclusions

1. Model-based reconstruction of $p\text{CO}_2$ 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 $p\text{CO}_2$ prior to Termination V were caused by smaller interglacial $p\text{CO}_2$, caused by smaller interglacial SO SST and reduced interglacial ocean circulation.

Conclusions

1. Model-based reconstruction of $p\text{CO}_2$ 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 $p\text{CO}_2$ prior to Termination V were caused by smaller interglacial $p\text{CO}_2$, 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.

Conclusions

1. Model-based reconstruction of $p\text{CO}_2$ 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 $p\text{CO}_2$ prior to Termination V were caused by smaller interglacial $p\text{CO}_2$, 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 $p\text{CO}_2$ 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 $p\text{CO}_2$ data were measured by Urs Siegenthaler (Thomas Stocker) at the Department of Climate and Environmental Physics, University of Bern, Switzerland.



Paleoclimate Research
German Climate Research Programme

SPONSORED BY THE



Individual processes during last 8 glacial/interglacial cycles

