Atmospheric CO_2 during the last glaciation and its implications for changes in the carbon cycle

Bernhard Bereiter*[1], Dieter Lüthi[1], Michael Siegrist[1], Simon Schüpbach[1], Thomas F. Stocker[1] and Hubertus Fischer[1]

[1]Climate and Environmental Physics, Physics Institute and
Oeschger Centre for Climate Change Research, University of Bern, Switzerland.

*bereiter@climate.unibe.ch

Climate and Environmental Physics

UNIVERSITÄT BERN
OESCHGER CENTRE CLIMATE CHANGE RESEARCH

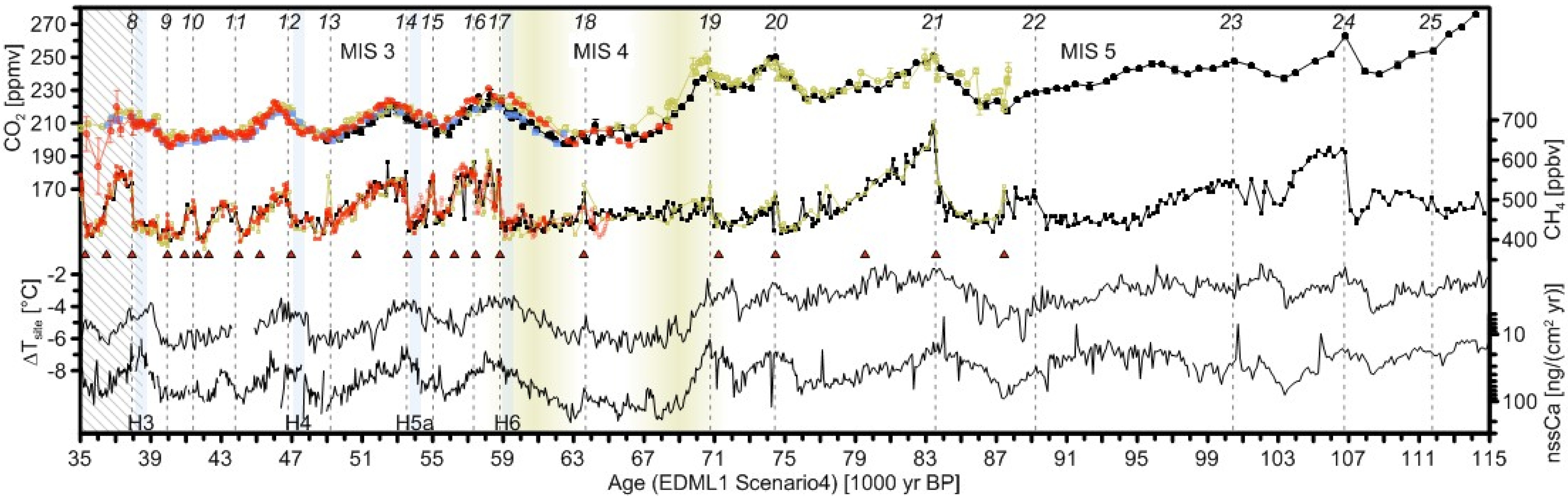

Fig. 1: A: Atmospheric CO_2 concentrations from different Antarctic ice cores (red: Talos Dome and black: EDML[1] (most from this study); blue: Taylor Dome[2]; green: Byrd[3]. B: CH_4 concentrations[4] (same color code as above. open red circles: Talos Dome (this study)). Red triangles show tie points for age scale synchronization. C: ΔT record relative to modern temperature from EDML ice core[5]. D: non sea salt (nss) Ca flux measured at the EDML ice core[6]. All data are plotted on EDML1 Scenario 4 age scale. Dashed lines indicate CH_4 jumps associated with DO-events (numbered at the top). The green shaded areas indicate the transitions from MIS 5 to MIS 4 and MIS 4 to MIS 3, respectively. The blue bars represent the Heinrich-events (named at the bottom, timing uncertain) and the dashed area marks strongly fractionated Talos Dome CO_2 data which are not used for interpretation.

Introduction

Atmospheric CO_2 is strongly linked to Antarctic temperature changes during the last glacial period and hence, to variations of the bipolar seesaw. Two new overlapping atmospheric CO_2 records with sub-millennial resolution from two different Antarctic ice cores (Talos Dome (TALDICE) and EPICA Dronning Maud Land (EDML)) covering the time period from 38,000 to 115,000 years BP are used to investigate the interplay of CO_2 and the bipolar seesaw. The availability of highly resolved CH_4 data from both cores allows us to synchronize the two records and identify Dansgaard-Oeschger-Events (DO-Events, proxy for changes of the bipolar seesaw) with a minimum of temporal uncertainty.

Changes in ocean circulation

Ocean proxies show a change in NADW distribution and carbon stocks in the deep ocean at the transition from MIS 5 to MIS 4 (Fig. 3). It has been shown that the deep water flow speed declined exceptionally in the North-Eastern Atlantic at the same transition[7]. Taking these facts together, we conclude that during the MIS 5 to 4 transition deep ocean circulation changes globally leading to an uptake of carbon of the deep ocean.

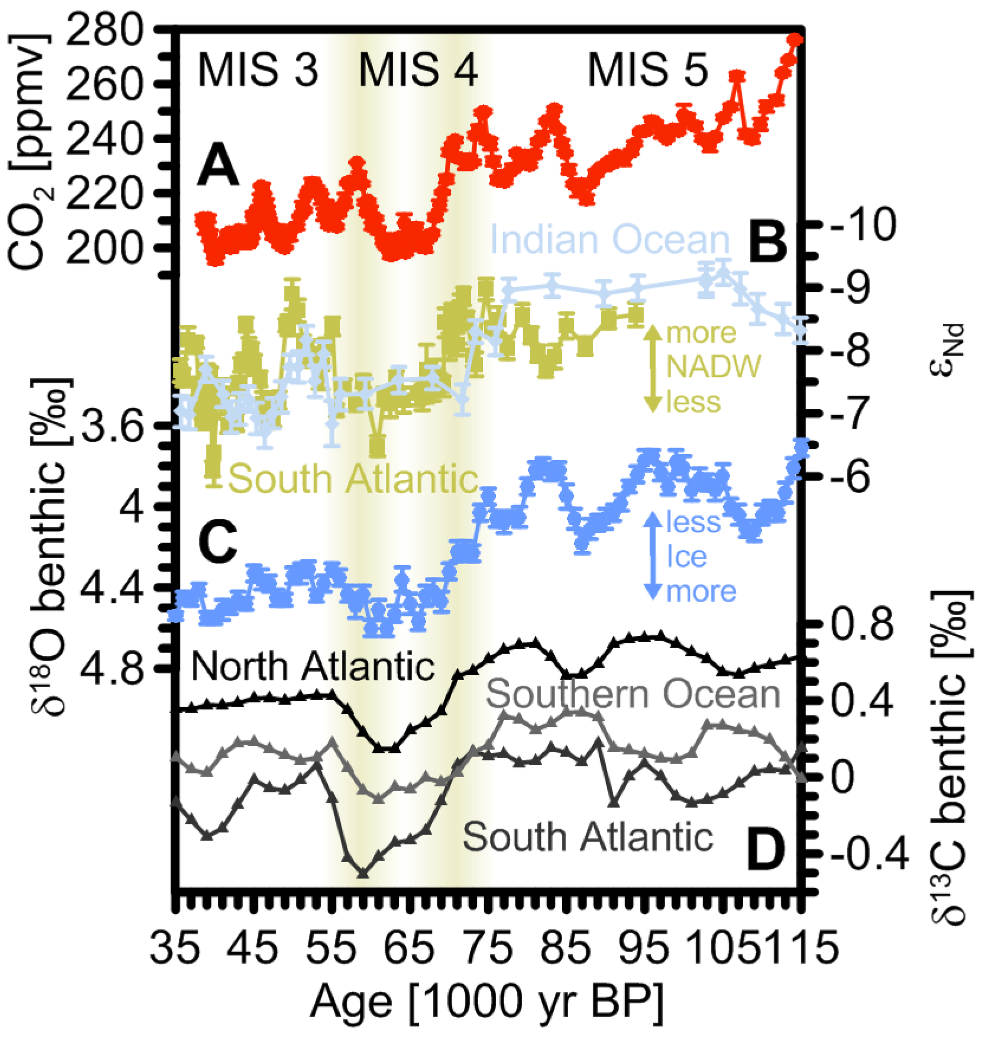

Fig. 3: A: CO_2 composite from EDML and TALDICE. B: Nd-isotopes from two sediment cores[8,9], representing NADW portion of local water mass. C: global benthic $\delta^{18}O$ signal[10], indicating the evolution of global ice mass. D: benthic $\delta^{13}C$ values averaged over ocean basins[11], being a proxy for carbon stock of water masses.

Changing phasing of CO_2 and DO-Events

The onset of DO-Events coincides with a sharp increase of atmospheric CH_4 concentrations. The high-resolution CO_2 and CH_4 data from the same ice cores allows us to investigate the phasing between DO-Events and CO_2 with very little temporal uncertainty. Figure 2 shows that the phasing is different between MIS 5 and MIS 3. Furthermore, the CO_2 baseline is about 30 ppm higher during MIS 5 than during MIS 3. This change occurs at the transition from MIS 5 to MIS 4 (Fig. 1).

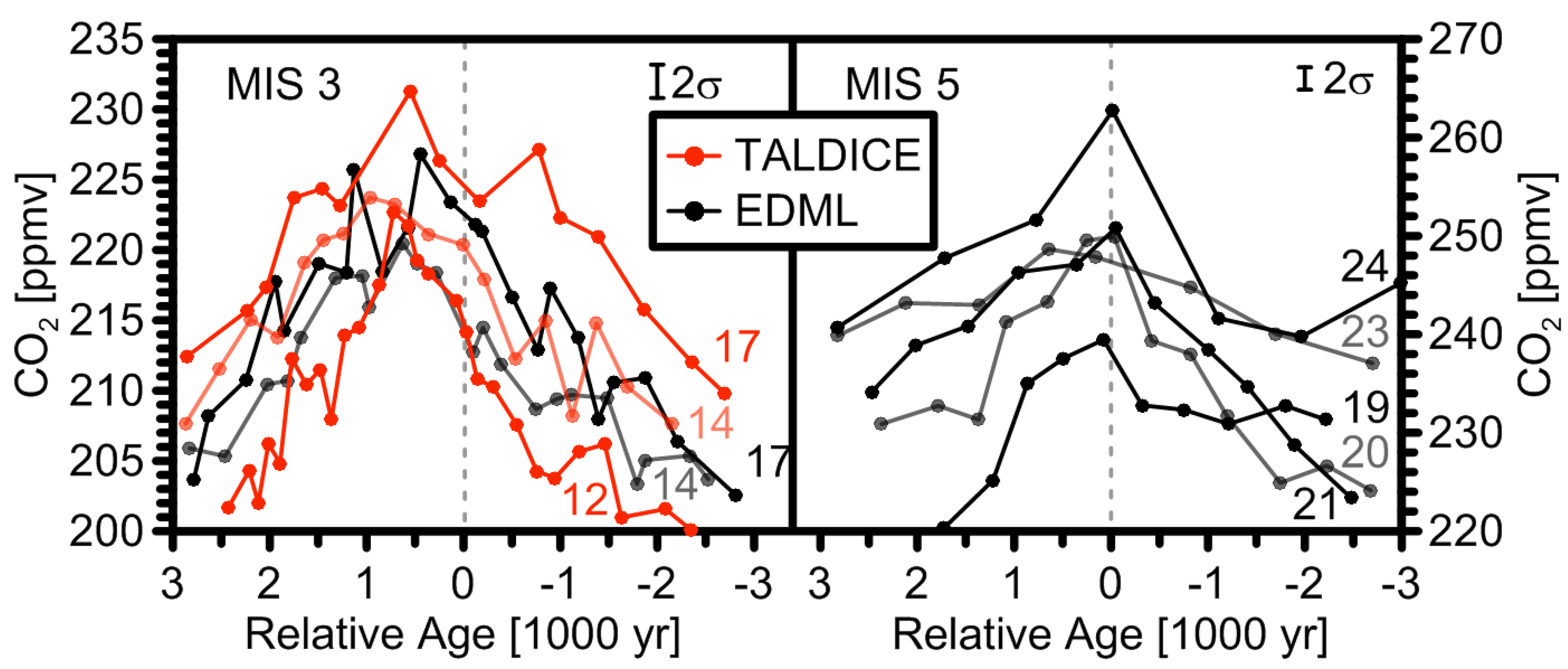

Fig. 2: Left: CO_2 variations during MIS 3. Time zero corresponds to the onset of the corresponding DO-Event and CH_4 jumps, respectively (DO-Number at the right). Right: As left but with data during MIS 5. The error bars indicate the average uncertainty.

Conclusion

In general, our new data confirm the strong link of DO-Events and atmospheric CO_2. They show that even during less pronounced DO-Events (in particular during DO-Number 9, 10 and 11) CO_2 varies correspondingly. But our data also show that in contrast to MIS 5, CO_2 maxima during MIS 3 are delayed for 500-1000 years with respect to the onset of their corresponding DO-Events. Ocean proxies indicate that deep ocean circulation changes significantly at the transition from MIS 5 to MIS 4 associated with an increasing carbon stock in the deep ocean likely leading to the CO_2 decrease meanwhile. Therefore, we conclude that the delayed CO_2 maxima are caused by these changes and hypothesize further that the increased deep ocean carbon stock during MIS 3 gets flushed during DO-Events causing the delayed CO_2 maxima.

References
[1]Lüthi et al. 2010, EPSL; [2]Indermühle et al., 2000, GRL; [3]Ahn et al., 2009, Science; [4]Schilt et al., 2010, EPSL and references in there; [5]Stenni et al., 2010, QSR; [6]Fischer et al., 2007, EPSL; [7]Guihou, et al., 2010, EPSL; [8]Piotrowski et al., 2009, EPSL; [9]Piotrowski et al., 2005, Science; [10]Lisieki et al., 2005, PO; [11]Oliver et al., 2010, CP.