Transient Changes in the Global Carbon Cycle During the Last Glacial/Interglacial Transition

Peter Köhler & Hubertus Fischer

Alfred Wegener Institute for Polar and Marine Research, P.O. Box 12 01 61, D-27515 Bremerhaven, Germany,
email: pkoehler@awi-bremerhaven.de, hufischer@awi-bremerhaven.de

Alfred Wegener Institute for Polar and Marine Research

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Abstract

The global carbon cycle plays a significant role in glacial/interglacial transitions. On one hand because carbon reservoirs and exchange rates are subject to external climate conditions, on the other because changes in pCO_2 lead to amplification and mediation of regional climate variations. Time slice experiments were so far unable to unambiguously explain the driving forces of the glacial/interglacial pCO_2 change of about 80 ppmv. Additional information can be derived from the temporal evolution of the carbon cycle using transient model runs and from the carbon isotopic composition of CO_2. Here, we use a coupled atmosphere/biosphere/ocean Box model of the Isotopic Carbon cYCLE (BICYCLE) to quantify changes in pCO_2 and ^{13}C in Antarctic ice cores. To this end the model is transiently driven by various proxy records over the last 26,000 years. The result shows that a breakdown in Southern Ocean (SO) stratification triggered by SO warming might explain the initial drop in atmospheric ^{13}C by 0.5‰. In addition, a significant role of the terrestrial biosphere on changes in ^{13}C during the second half of the transition is supported. Carbonate compensation has to be considered as additional process to explain the observed increase in pCO_2.

Keywords: 1827 Glaciology (1863), 4267 Paleoceanography, 4805 Biogeochemical Cycles (1615), 4806 Carbon Cycling

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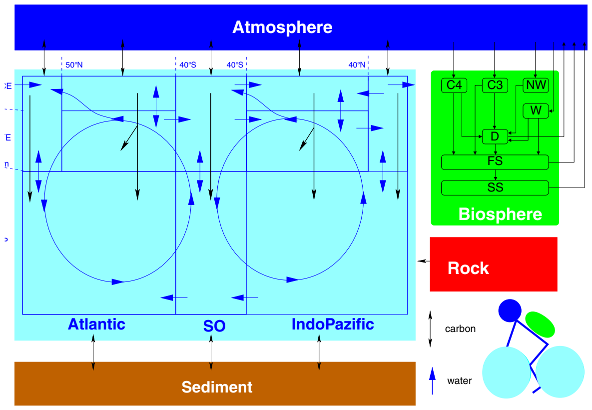
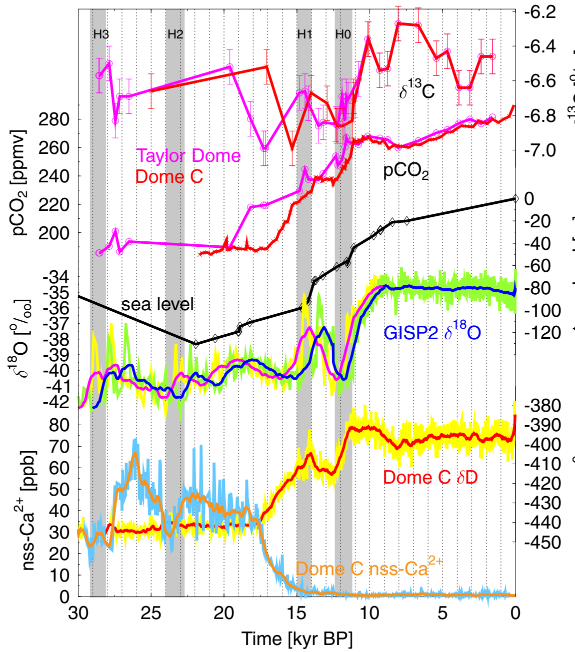


Box model of the Isotopic Carbon cYCLE

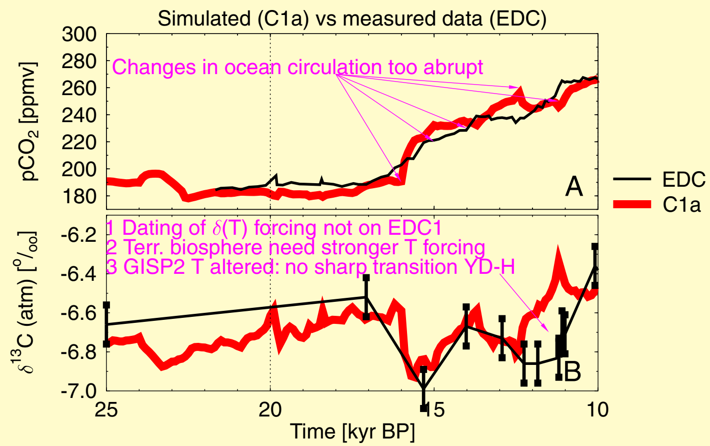
BICYCLE

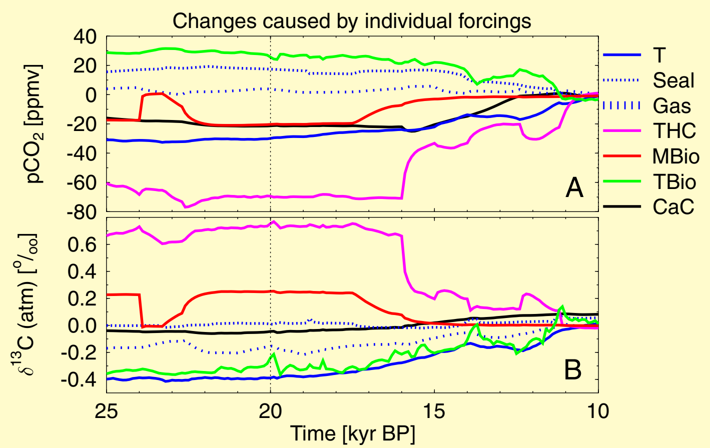


Data

Time dependent driving forces of the model:

1. pCO_2, D (temperature proxy in the SO) and non sea salt Ca^{2+} (proxy for Fe input, controlling SO marine NPP) from EPICA Dome C on the EDC1 time scale (Jouzel et al., 2001; Monnin et al., 2001; Schwander et al., 2001; Röthlisberger et al., 2002)
2. ^{13}C measured in Taylor Dome ice (Smith et al., 1999) on the EDC1 time scale via pCO_2 correlation
3. GISP2 ^{18}O (temperature proxy for the NH, Grootes and Stuiver, 1997) on the EDC1 time scale via CH_4 synchronisation
4. sea level changes derived from coral reef terraces (Fairbanks, 1990) on an independent age scale
5. Heinrich events H0-H3 indicated by grey stripes





Model

Structure of BICYCLE (Box model of the Isotopic Carbon cYCLE) adopted from Munhoven (1997) and Keshgi & Jain (2003). The internal module of the terrestrial biosphere or other model output of DGVMs can be used. Arrows indicate

Processes	pCO_2
Temperature	-29 ppmv
Sealevel	+18 ppmv
Gas exchange	+4 ppmv
Increased marine production	-20 ppmv
Ocean circulation	-69 ppmv
Terrestrial biosphere	+26 ppmv
Carbonate compensation	-18 ppmv
Sum of pCO_2 changes	-88 ppmv
Simulated pCO_2 change	-85 ppmv
Target	-80 ppmv

Conclusions

1. Glacial/interglacial changes in sea ice might induce pCO_2 changes not primarily via gas exchange (Stephens & Keeling, 2000) but via increased mixing in the SO. This can potentially explain the 0.5‰ drop in ^{13}C at the beginning of the termination.
2. Increased glacial marine export production via Fe fertilization depends on available macro-nutrients and thus oceanic transport processes.
3. SO processes as flywheel of THC kick-on (Knorr & Lohmann, 2003) are consistent with atmospheric carbon changes.
4. Dynamics in ^{13}C in the 2nd half of the transition are dominated by terrestrial biosphere growth.