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Simulating low frequency changes in atmospheric CO_2 during the last 740 000 years

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Abstract. Atmospheric CO_2 measured in Antarctic ice cores shows a natural variability of 80 to 100 ppmv during the last four glacial cycles and variations of approximately 60 ppmv in the two cycles between 410 and 650 kyr BP. We here use various paleo-climatic records from the EPICA Dome C Antarctic ice core and from oceanic sediment cores covering the last 740 kyr to force the ocean/atmosphere/biosphere box model of the global carbon cycle BICYCLE in a forward mode over this time in order to interpret the natural variability of CO_2. Our approach is based on the previous interpretation of carbon cycle variations during Termination I (Köhler et al., 2005a). In the absense of a process-based sediment module one main simplification of BICYCLE is that carbonate compensation is approximated by the temporally delayed restoration of deep ocean $[CO_3^{2-}]$. Our results match the low frequency changes in CO_2 measured in the Vostok and the EPICA Dome C ice core for the last 650 kyr BP ($r^2 \approx 0.75$). During these transient simulations the carbon cycle reaches never a steady state due to the ongoing variability of the overall carbon budget caused by the time delayed response of the carbonate compensation to other processes. The average contributions of different processes to the rise in CO_2 during Terminations I to V and during earlier terminations are: the rise in Southern Ocean vertical mixing: 36/22 ppmv, the rise in ocean temperature: 26/11 ppmv, iron limitation of the marine biota in the Southern Ocean: 20/14 ppmv, carbonate compensation: 15/7 ppmv, the rise in North Atlantic deep water formation: 13/0 ppmv, the rise in gas exchange due to a decreasing sea ice cover: −8/−7 ppmv, sea level rise: −12/−4 ppmv, and rising terrestrial carbon storage: −13/−6 ppmv. According to our model the smaller interglacial CO_2 values in the pre-Vostok period prior to Termination V are mainly caused by smaller interglacial Southern Ocean SST and an Atlantic THC which stayed before MIS 11 (before 420 kyr BP) in its weaker glacial circulation mode.

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