Low frequency changes in the carbon cycle during the last 120 kyr and its implications for the reconstruction of atmospheric $\Delta^{14}$C and the $^{14}$C production rates estimates — a simulation study

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We use the ocean/stratosphere/biosphere box model of the global carbon cycle BICYCLE (Köhler et al. 2005) to reproduce low frequency changes in atmospheric $^{14}$CO$_2$ as seen in Antarctic ice cores during the last glacial cycle (~120,000 years) (Köhler et al. 2006). We force the model forward in time by various paleo-climatic records derived from ice and sediment cores. The simulation results of our proposed scenario match a compiled CO$_2$ record from various ice cores with high accuracy ($r^2 = 0.83$). The processes that contribute most to the glacial/interglacial changes in CO$_2$ are variations in the sedimentation and dissolution rates of CaCO$_3$, ocean circulation, ocean temperature and glacial ice fertilization of the marine biota in the Southern Ocean. The BICYCLE model includes also calculations for the carbon isotope $^{13}$C and $^{14}$C and we assess what changes in atmospheric $\Delta^{14}$C might be based on variations in the carbon cycle. Our results suggest that during the last glacial cycle in general less than 120% of the increased atmospheric $\Delta^{14}$C are based on variations in the carbon cycle, while the largest parts of the variations have to be explained by changing $^{14}$C production rates. Processes acting on the glacial carbon cycle that increase glacial $\Delta^{14}$C are restricted glacial gas exchange between the atmosphere and the surface ocean through sea ice coverage, a reduced glacial ocean circulation, and the enrichment of DIC with $^{14}$C in the surface waters through isotopic fractionation during higher glacial marine export production caused by iron fertilization. From the available $^{14}$C data covering the last 50,000 years and our carbon cycle-based simulation results we can infer changes in the $^{14}$C production rates, which are then compared with two other estimates based on $^{10}$Be and geomagnetic field reconstruction. The agreements and discrepancies between these three independent approaches to estimate the $^{14}$C production rates are discussed and highlight the limitations and possible uncertainties in all three approaches.

Keywords: carbon cycle, $^{14}$C cycle, $^{14}$C production rates, glacial/interglacial, modeling, box model, radionuclides

References:


Variable $^{14}$C production rate

Comparing three approaches to estimate $^{14}$C production rates

Carbon cycle-based reconstruction of $^{14}$C production rate based on different $\Delta^{14}$C data sets.
Literatur


