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Simulation of glacial-interglacial atmospheric CO2 variations using a comprehensive Earth system model of intermediate complexity

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The mechanisms of strong glacial-interglacial variations in the atmospheric CO2 concentration and the role of CO2 in driving glacial cycles still remain debatable. Here using the model of intermediate complexity CLIMBER-2 which includes all major components of the Earth system – atmosphere, ocean, land surface, ice sheets, terrestrial biota and weathering, aeolian dust and marine biogeochemistry – we performed simulation of the last glacial cycle using variations in the Earth's orbital parameters as the only prescribed climatic forcing. The model simulates rather realistically temporal and spatial dynamics of the Northern Hemisphere glaciation and temporal dynamics of the atmospheric CO2 concentration. During the glacial inception, the model is able to simulate a decrease in the atmospheric CO2, despite of release of terrestrial biosphere carbon. The drop in CO2 concentration during the first part of the glacial cycle is between 20 and 40 ppmv. It is related primarily to the physical mechanisms – increase of the ocean solubility and relative volume and the age of the Antarctic bottom water masses. The latter is related to increased sea ice formation in the Southern Ocean and lowering of the surface salinity in the northern North Atlantic. During the second part of the glacial cycle, the atmospheric CO2 concentration decreases towards the level of 200 ppmv. A part of this drop is due an increase of biological productivity in the Southern Ocean which is directly related in the CLIMBER-2 model to increase of aeolian dust supply into the Southern Hemisphere via the iron fertilization mechanism. Significant part of the decreasing CO2 trend is also explained by increased weathering on land, especially on the exposed tropical shelves. A decrease in shallow water carbonate sedimentation and shift of CaCO3 sedimentation towards the deep ocean also plays important role in CO2 decrease. With the onset of the glacial termination, initial rise in the atmospheric CO2 concentration is explained by a weakening of the Atlantic thermohaline circulation due to increased freshwater input into the northern North Atlantic. The model is able to simulate the return of CO2 concentration to its interglacial value after termination of the glacial cycle but simulated CO2 concentration still lags considerably behind the ice core reconstructions.