Summary

An eleven-box model of the ocean-atmosphere subsystem of the global carbon cycle is developed to study the potential contribution of continental rock weathering and of oceanic sedimentation to variations of atmospheric CO_2 pressure over glacial-interglacial time scales. The model is capable of reproducing the present-day distributions of total dissolved inorganic carbon, total alkalinity, phosphate, $\delta^{13}C$, and $\Delta^{14}C$ between the various ocean basins, as well as the partial pressure of atmospheric CO_2. A simple sedimentation scheme drives carbonate deposition and dissolution at the sea-floor as a function of the depths of carbonate and aragonite lysoclines in each ocean basin considered (Atlantic, Antarctic and Indo-Pacific). Carbonate accumulation on the shelf is also taken into account

Three different methods are used to calculate histories for the evolution of CO_2 consumption by continental rock weathering processes, with special emphasis on silicate weathering. The first method relies on the marine $^{87}Sr/^{86}Sr$ isotopic record. We find that this record does not represent a very strong constraint, due to the large spread of the $^{87}Sr/^{86}Sr$ ratios of waters draining silicate terrains. It is possible to construct a silicate weathering history that reproduces both the strontium isotopic record and the glacial-interglacial CO_2 signal. This weathering history implies that CO_2 consumption by silicate rock weathering was about 120% higher during glacial than during interglacial time.

The second approach is based upon the marine Ge/Si record. Taking the major uncertainties in the knowledge of the Ge and Si cycles into account, several histories for the evolution of the riverine dissolved silica fluxes are calculated from this record. The investigation of the systematics between riverine dissolved silica and bicarbonate fluxes under different weathering regimes leads us to the tentative conclusion that, although there is no correlation between dissolved silica and total bicarbonate concentrations in the major rivers, there may exist a negative correlation between weathering intensity and the ratio of bicarbonate derived from silicate weathering alone to dissolved silica. With this correlation as a working hypothesis, it is possible to interpret the dissolved silica fluxes in terms of equivalent CO_2 consumption rates. The calculated histories indicate that glacial rates of CO_2 consumption by chemical silicate rock weathering could have been twice, and possibly up to three times and a half, as high as they are today. When used to force the carbon cycle model, they are responsible for glacial-interglacial p_{CO_2} variations in the atmosphere of typically 50–60 ppm and up to 95–110 ppm. These variations are superimposed to a basic oscillation of 60 ppm generated by the model, mainly in response to coral reef buildup and erosion processes. The total p_{CO_2} signal has an amplitude of about 80–90 ppm and up to 125–135 ppm. Although these large amplitudes indicate that silicate weathering processes should be taken into account when studying glacial-interglacial changes of CO_2 in the atmosphere, it also raises new problems, such as too high CO_2 levels during the period from 110–70 kyr B.P.

In the third approach, the glacial-interglacial histories for the consumption of CO_2 and the resulting transfer of bicarbonate to the ocean are calculated from the erosion model GEM-CO_2. The required variations of the continental runoff are derived from four different GCM climatologies. We find that the CO_2 consumption and river bicarbonate fluxes were about 20% higher at the last glacial maximum than at present. The exposed shelf accounts for a large fraction of the calculated LGM flux, overcompensating the 20% decrease of the two fluxes over the continent. The constructed weathering scenarios still produce p_{CO_2} variations of about 60 ppm between glacial and interglacial times, but the contribution from variable silicate weathering to this signal is now reduced to only 12 ± 5 ppm.