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Combined response of atmospheric CO_2 and sedimentary carbonate to rain ratio variations on glacial-interglacial time scales

G. Munhoven

LPAP – Institut d'Astrophysique et de Géophysique, Université de Liège, B–4000 Liège (Guy.Munhoven@ulg.ac.be)

A reduction of the carbonate-carbon to organic-carbon export rain ratio during glacial times is commonly advanced to explain parts of the observed glacial-interglacial atmospheric CO_2 variation. This hypothesis was tested and side-effects on the evolution of carbonate preservation/dissolution in the surface sediment explored with a multi-box model (MBM) of the ocean carbon cycle, fully coupled to the new early diagenesis model MEDUSA. MEDUSA is a transient advection-diffusion-reaction model representing early diagenesis processes of carbonate minerals in the surface sediment. It explicitly considers the role of organic matter remineralisation in the sediment column to enhance carbonate dissolution. It is fully bi-directional and takes chemical erosion into account in times when carbonate dissolution makes the sediment mixed-layer collapse faster than the sediment supply to the surface is able to counterbalance. Coupled model experiments were run for 240,000 years, forced by variable sea-level, temperature and salinity histories, and variable continental weathering inputs. Various rain ratio variation scenarios were tested.

A peak reduction of the rain ratio by 40% at the Last Glacial Maximum (LGM) was found to produce a net atmospheric pCO_2 reduction of about 30 ppm, on top of a 60 ppm reduction due to changing continental shelf carbonate accumulation and changing continental weathering inputs. The overall 90 ppm oscillation compares well with the observed data. However, the effect on the model sediments is clearly at odds with actual sediment records. Changes related to continental shelf processes and variable weathering flux depress the calcite saturation horizon by about 1 km at the LGM; rain ratio variations depress it by another km.