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The Rain Ratio Hypothesis: Can it be Rescued?

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The Rain Ratio Hypothesis (Archer and Maier-Reimer, 1994, Nature 367, 260–263) ascribes an important part of the observed glacial-interglacial variations of CO_2 in the atmosphere to reduced sea-floor rain ratio (i.e., carbonate-C/organic-C in the biogenic particle flux at the sea-floor) during glacial times. With a lower sea-floor rain ratio the influence of organic carbon respiration on carbonate dissolution is stronger. The deep-sea carbonate ion concentration required for global ocean carbonate compensation will then be higher, which in turn contributes to lower atmospheric pCO_2.

Munhoven (2007, Deep-Sea Research II, 722–746) showed that the suggested rain ratio reductions lead to unrealistic sedimentary records for $\%CaCO_3$: the transition zone changes in the model sedimentary record were too large and opposite in phase to available observational data. The rain ratio reduction applied by Munhoven (2007) was uniform over the ocean and the author hypothesised that a non-uniform reduction could change the complete picture. If the rain ratio variations had primarily taken place in open ocean areas of great depth—essentially in regions where the sea floor was deeper than the saturation horizon or the CCD—then the transition zone boundaries could possibly have moved less.

Here, we test this hypothesis and analyse the effect of depth dependent variations. It is shown that concentrating rain ratio changes over areas of greatest water depth completely alters the sedimentary imprint: the phase relationship of the signal reverts (compared to the uniform case) and the amplitude of the change decreases, bringing it into better agreement with the observations. However, the pCO_2 response is also reduced. The global average rain ratio reduction of 40% that yielded a 40 ppm reduction of atmospheric pCO_2 in the uniform case only leads to 25 ppm in this non-uniform case. Results for other depth-dependent reductions will also be discussed.