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Interactive Comment

Interactive comment on "Past and present of sediment and carbon biogeochemical cycling models" *by* F. T. Mackenzie et al.

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The manuscript offers a wealth of ideas and gives a fascinating historic overview on the growing understanding of the global carbon cycle. The article follows the classical approach of geochemistry in applying box models for establishing biogeochemical budgets. I would like to address 3 issues which I find interesting:

1. What significance have the geologic processes affecting the global carbon cycle in view of potential large scale deliberate deep ocean storage of anthropogenic CO_2 ?

2. Is there any way of placing error bars to the estimates of carbon net fluxes between shallow seas and the atmosphere ?

3. The need for process based simulation models.

To 1.: On page 41 of their paper, Mackenzie et al. point out that the atmosphere could be depleted from CO_2 in a few thousand years, if the burial flux of organic carbon into the sediment would not be balanced by another process which supplies CO_2 to the

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atmosphere. Of course, we know that as long as there will be life on earth, always a significant amount of organic material will be produced and degrade afterward so that the burial flux is balanced or at least not strongly perturbed. The processes occurring at the water sediment interface and at the base of the sediment mixed layer, however, may undergo significant changes if indeed large amounts of man made CO_2 would deliberately be stored in the deep ocean through direct injection methods. I think it is worthwhile to investigate the early diagenetic processes that may occur under a CO_2 lake or in a deep ocean water column with considerably lower pH than at present. Could this bring an imbalance to the organic carbon burial flux relative to CO_2 supply from other sources ? What would happen if bioturbation within the sediment mixed layer stops in a low pH environment ?

To 2.: The most important statement of the paper in my opinion is found on page 59: "Based on the current data available in the literature, it is not possible to conclude unequivocally whether or not the global shallow-water ocean environment acts as a sink or source of atmospheric CO_2..." This shows the difficulty that we are faced with in establishing large-scale carbon budgets of the shallow seas. Due to the complexity of the boundary conditions in shallow seas and the complex processes governing local carbon redistributions, I have severe doubts whether simplified kinematic box models can give a really useful quantification for the earth's shallow water carbon budgets. Walsh (1991) presented three "archetypes" of carbon transport in shallow seas. Already a splitting of the shallow ocean into domains representing these three "archetypes" would bring box model computations to the limit of their capabilities, not to speak of correct representations of tidal motion etc. Nevertheless, kinematic box models could be used for studies of the sensitivity of the budgets to the assumptions made. A consideration of the errors associated with the budget estimates by introducing perturbations in the model systems may help in pinpointing the quantitatively crucial mechanisms and domains in the shallow water systems.

To 3.: The difficulty in quantifying the shallow water carbon budgets is an extreme

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example that underlines the need for simulation models. We are still far away from a global shallow-water coupled physical-biogeochemical ocean general circulation model as a module for a global earth system modeling approach. The difficulties in establishing such a model is the need for a high spatial resolution in conjunction with reasonably long integration times. The development of such models will be one of the major challenges for the coming decades of ocean research. However, for the open deep ocean, already encouraging simulation model studies are available, which include the interaction between atmosphere, ocean and sediment (Maier-Reimer, 1993; Archer and Maier-Reimer, 1994; Heinze et al., 1999, 2003). The methodology for creating a model derived sedimentary record in order to "drill" into the simulated model sediment is available (Heinze, 2001), that will help to calibrate biogeochemical ocean models with paleoceanographic observations and to validate respective model simulations. Mackenzie et al. consider in their study kinematic box models which are based on mass conservation and the mass action law as "first principle". However, there is a need for exploiting further first principles such as Newton's second law in the form of the Navier Stokes equations as carried out in dynamical ocean circulation models which deliver the physical input fields to simulation models of the ocean carbon cycle. A major challenge is the formulation of life processes within these models, as within ecosystem models so far no basic natural laws governing life processes were formulated and possibly never will be. An interdisciplinary dialog including classical geochemists and developers of state-of-the-art earth system models will provide us with exiting material to be explored.

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