Reply to the reviewers of "Long-term Ocean-atmosphere-Sediment CArbon cycle Reservoir Model " by R. E. Zeebe (gmd-2011-32)

The two reviewers recommend publication after revisions. Hence I have revised the ms following the suggestions of the reviewers, which has improved the ms. I thank the reviewers for their efforts. A point-by-point reply to the reviewers' comments is included below.

Richard E. Zeebe

Reply to Reviewer #1 (Gary Shaffer)

>... the intermediate and deep box volumes should be included in Table 1.

Done.

>It is not clear how the Tethys Ocean is connected to the rest of the ocean in the PETM configuration. …
>Anything missing should be included in Table 2 and I think that the Tethys Ocean should be included in >Figure 2 for clarity.

Done.

>One of the tracers considered in the model is d13C but important details are missing on how the model treats this tracer.

Relevant equations and details on d13C have now been included regarding gas-exchange (Sec. 3.2.1), the biological pump (Sec. 3.2.2), weathering (Sec. 4.1), and the atmosphere (Sec. 5).

>In a PETM application paper with LOSCAR (Zeebe et. al, 2009), some of the simulations were based on >a modified circulation with a contribution of North Pacific Deep Water (NPDW) formation ... include the >assumed NPDW and SO transports for these simulations...

Done. Text has been added to Sec. 9.2.

>In Figure 5 and 6 the line definitions in the insets in each of the figures are too small to be read.

The font size of the legends and axes labels of individual subplots in Figs 5 and 6 have been increased.

> For future work, it may be a good idea to reconsider LOSCAR model architecture and to use modelled and observed 14C in the tuning process.

This is a useful suggestion and will be considered in future versions of LOSCAR, when multiple high-latitude surface boxes have been included. As the reviewer points out, a meaningful C-14 model-data comparison generally requires multiple high-latitude surface boxes.

Reply to Reviewer #2 (Guy Munhoven)

Note: Some of Guy's comments were difficult to translate directly into action items for the revision of the manuscript. I have hence focused on those comments which prompted a reply and/or changes to the manuscript.

>However, there are not only "a few studies that have considered sediments" (p. 1436, l. 25)

The original wording was inaccurate and has been changed to "less studies have coupled a genuine sediment model to the ocean box model". This excludes parameterizations (e.g. Toggweiler, 2008). Additional relevant references have been included in Sec. 1.

>The omission of details regarding d13C is especially surprising

Relevant equations and details on d13C have now been included regarding gas-exchange (Sec. 3.2.1), the biological pump (Sec. 3.2.2), weathering (Sec. 4.1), and the atmosphere (Sec. 5). See reply to reviewer #1.

>It is also not entirely clear how the dissolution of CaCO3 in the water column is implemented.

The fraction representing CaCO3 water column dissolution is added to the corresponding deep boxes, hence increasing TCO2 and TA in these boxes (no depth dependence). Text has been added to Sec. 3.2.2.

>Sigman et al. (1998) fit an expression of the same form to results from the more complete 1D diagenesis
>model of Martin and Sayles (1996) that also considers the effect of organic matter respiration on
>carbonate dissolution in the surface sediment, not considered here.

Sigman et al. (1998) provide different dissolution rate constants for parameterizations with and ***without*** respiratory dissolution. Because respiratory dissolution is not considered in the present LOSCAR version, the latter rate constant was adopted (20.36×10^{10} mol/m2/y).

>The effect of organic matter respiration in promoting carbonate dissolution (Emerson and Bender, 1981)
>is neglected.

Respiratory dissolution could be important, for instance, for the steady-state lysocline. However, respiratory dissolution is unlikely to have any significant effect on the evolution of sediment %CaCO3 during massive dissolution events caused by large carbon inputs from fossil-fuel burning or during the PETM. Because these events were the modeling targets so far for our LOSCAR applications, respiratory dissolution has not been included. Future versions of LOSCAR should consider this feature when processes are modeled for which respiratory dissolution is critical.

>The author himself (Zeebe, 2007) has shown that it is critical to consider the effect of a diffusive
>boundary layer at the top sediment interface.

Zeebe (GCA, 2007) showed that inclusion of a diffusive boundary layer can be critical for certain types of sediment models that calculate carbonate dissolution fluxes based on explicit modeling of porewater CO3= profiles. However, this type of sediment model is not employed in LOSCAR, and so the argument does not apply here.

>How is chemical erosion implemented?

As described in the original ms, chemical erosion is included based on Eq. (28) on p. 1450 of the original ms. Sub-surface sediment properties are stored based on the initial steady-state configuration of the sediment model. For model applications that require multiple dissolution cycles with varying conditions during accumulation, the model should be restarted with appropriate initial conditions. Text has been added to Secs. 6.1 and 6.3.

>Parameters of the weathering feedback

Different weathering parameterizations used in the literature were summarized in Fig. 1 of Uchikawa & Zeebe (2008). The default values of ncc = 0.4 and nsi = 0.2 adopted in LOSCAR represent conservative values (default feedback is weak). The user is welcome to change and vary those parameters as has been done in Uchikawa & Zeebe (2008) and Komar and Zeebe (2010). Text has been added to Sec. 4.1.

>Throughout: for clarity, summation indexes should be given with summation symbols

Done.

>It would furthermore be helpful to have an exact definition of the CCD adopted in this work

In the default LOSCAR setup, the CCD is taken as the depth at which the CaCO3 sediment content is reduced to 10 wt.% (Ridgwell & Zeebe, EPSL 2005). Text has been added to Sec. 8.

>p. 1440, eq. (3): please specify the summation index with the summation symbols to increase readability.

Done.