Biogeosciences Discuss., 4, S1744–S1748, 2007
www.biogeosciences-discuss.net/4/S1744/2007/

Biogeosciences Discussions

Interactive comment on "On the treatment of particulate organic matter sinking in large-scale models of marine biogeochemical cycles" *by* I. Kriest and A. Oschlies

I. Kriest and A. Oschlies

Received and published: 29 October 2007

We appreciate the critical review and the helpful suggestions by referee # 2.

We would like to follow the referee's suggestions as follows:

1. We choose two different descriptions of POM fluxes - namely the Martin curve and constant particle sinking speed - because they are often applied especially in three-dimensional, large scale models (see introduction). The third parameterization, the incomplete gamma function, was developed from the assumptions laid out in section 2.3 and 2.4. By doing so, we wanted to show how a priori assumptions about particle properties translate into flux parameterizations, and vice versa.

One result of our study is that a constant sinking speed of detritus combined with a constant remineralisation rate cannot reproduce observed fluxes at a variety of locations (depths) simultaneously. Our theoretical analysis of mechanistic principles and the model-data comparison both suggest, that average POM sinking speed increases with depth (analogously: remineralisation rate decreases with depth). This is accounted for by both the power law or gamma-function flux curves. From the comparison of these two parameterisations with observations, so far we cannot decide for any of the two functions. This will be subject of a further analysis, which makes use of different particle flux models coupled to a more detailed physical model, and compares the results to observations. However, the gamma-function model provides a mechanistic explanation for the increase of POM sinking speed with depth.

We further find that the regional variation of remineralisation length scales suggested by previous authors could be explained by variations in the surface particle size spectra. While the gamma-function provides a consistent and mechanistic link between upper ocean biogeochemistry and the deep ocean, to our knowledge such a link has not been established for the Martin curve (although via the relation $b = z_0\, r / w_0$ a model with regionally or temporal variation in upper ocean sinking speed could result in regionally varying remineralisation length scales). Summarising, we suggest one of the two functions (Martin or gamma function) for the coupling between surface and deep ocean, preferably with a regional variation of remineralisation length scales.

We would try to emphasize these things and the “take home message” more clearly in a revised version of this paper.

2. The exponent of particle size spectra, after conversion to the distribution defined in equation (A1) of the manuscript, in the ocean range from $\approx$ 2.2 (Maranon et al.,

BGD

4, S1744–S1748, 2007

Interactive Comment

EGU

2004) to $\approx$ 5.2 (Cavender-Bares et al., 2001), but many observations suggest that size-spectra are more or less "flat", i.e., mass is distributed evenly among logarithmically increasing size classes. In our case, assuming that the exponent that relates particle mass to its diameter (ζ) is set to 2.28 (Mullin et al., 1966) a "flat" mass distribution would be characterised by $\epsilon_0 = 3.28$, whereas a "flat" volume distribution would yield $\epsilon_0 = 4$. For our analysis, we have chosen $\epsilon_0 = \zeta + \eta + 1.01 \pm 0.5 = 4.46 \pm 0.5$, where η is the exponent that relates a particle's sinking speed to its diameter, and is set to 1.17 (Smayda, 1970). The value of the standard run (4.46) was chosen because it allows the direct evaluation of the incomplete gamma function (i.e., $a_F > 0$, see eq. A17), while still being in the range of observed spectral exponents; the experiments (4.46 ± 0.5) explore the sensitivity of the function to alterations of the exponent. If the exponent approaches a "flat" distribution, the curve shown in Figure 3 would become even more straight (i.e., less dependent on depth). However, the exploration of the full range of possible exponents, as well as fitting the model to observed fluxes (i.e., changing several parameters such as the remineralisation rate, minimum sinking speed etc.) will be subject of a different paper.

We would explain the choice of parameters in more detail in the revised version of this paper.

3. We agree: it is difficult to untangle the effect of remineralisation rate and sinking speed.

With respect to the power law function a decrease in remineralisation would be analogous to an increase either in POM sinking speed at z_0 via the relation $b = z_0\, r/w_0$ (see also equation 4 and p. 3011). In this paper, we interpret the imposed change in b as a change in the surface boundary conditions (ϵ_0 or w_0; see text for further explanation); it can however, also be interpreted as a change in remineralisation rate r under fixed ϵ_0, in particular $r = 0.056$ for $b = 1.6$ and $r = 0.012$ for $b = 0.364$. Thus, the experiment with different b also describes the sensitivity of the Martin function to a changed remineralisation rate (see Figure 3, right panels of the article).

Things are slightly different for the gamma function model, as here r is not directly related to the initial sinking speed, or the upper ocean size distribution (see Eq. A17, and definitions for a_F, x and X given above). Roughly speaking, under a fixed $\epsilon_0 = 4.46$ (w_0) an increase (decrease) in r to the values mentioned for the power law (0.056 and 0.012, respectively) will decrease (increase) the flux ratio especially at greater depths, whereas a change in ϵ_0 will change the flux ratio especially at shallower depths (see Figure 3, middle panels of the article).

Finally, the gamma function model will also depend on other parameters, such as the size range considered, etc. Theoretically, we think it is possible to disentangle the effects e.g., of ϵ_0 and the POM scaling parameters (e.g., ζ or η of the mass vs. diameter or sinking speed vs. diameter relationship). The success of such an approach will, however, strongly depend on the data set used to constrain the parameters. We would prefer to present this in future work, together with a more detailed model-data comparison.

In a revised version of the paper we would add some details on this. If desired, we can also add a figure displaying the sensitivity of the flux profile of the size spectral model to changes in r.

4. We agree, and would follow the referee's suggestion to edit the appendix and include in the main part of the paper.

5. See response to referee 1, point 2, for more details on processes that can affect the particle size distribution and properties especially in the ocean interior. In a revised version of this paper we would add a more detailed discussion of the processes.

6. Yes, we agree: the approach used by Maier-Reimer is indeed very appropriate

BGD

4, S1744–S1748, 2007

Interactive Comment

for use in global models, whose focus is on longer time and larger space scales. We just wanted to emphasize that the approach (which is also used by the models presented here) cannot be used to resolve the short-term (daily to seasonal) changes in sedimentation. Also, as referee #1 noted, the neglect of the temporal resolution might not be appropriate in areas of high eddy activity and/or high vertical mixing.

References:

Cavender-Bares, K.K., A. Rinaldo and S.W. Chisholm (2001). Microbial size spectra from natural and enriched ecosystems. Limonol. Oceanogr., 46, 778-789

Marañón, E., P. Cermeño, E. Fernández, J. Rodríguez, E. Fernández and L. Zabala (2004). Significance and mechanisms of photosynthetic production of dissolved organic carbon in a coastal eutrophic ecosystem. Limnol. Oceanogr., 49, 1652–1666

Mullin, M.M., P.R. Sloan and R. W. Eppley (1966). Relationship between carbon content, cell volume, and area in phytoplankton. Limnol. Ocanogr., 11, 307–311

Smayda, T.J. (1970). The suspension and sinking of phytoplankton in the sea. Oceanogr. Mar. Biol., 8, 353-414

Interactive comment on Biogeosciences Discuss., 4, 3005, 2007.

BGD

4, S1744–S1748, 2007

Interactive Comment