Biogeosciences Discuss., 5, S2198–S2202, 2008
www.biogeosciences-discuss.net/5/S2198/2008/

Biogeosciences
Discussions

Interactive comment on "Sinking rates of particles in biogenic silica- and carbonate-dominated production systems of the Atlantic Ocean: implications for the organic carbon fluxes to the deep ocean" *by* G. Fischer and G. Karakas

G. Fischer and G. Karakas

Received and published: 5 November 2008

Interactive comment on the review of referee #1

In our ms we did not want to give the impression that fecal pellets generally sink more rapidly than aggregates and that there is no debate on this subject. The reviewer is right in saying that care should be taken about the complexity of sinking mechanisms. We believe to have provided a broad overview on this topic (e.g. at page 2551: lines 4-9 in the results/discussion section: diatom-aggregates sink with 288 m per day). We also mentioned examples, where coccolithophorids sink rather slowly (65 m per day) as mats in the Panama Basin (page 2551 starting with line 12) which does not coincide with our general picture of a tendency of higher sinking rates in carbonate dominated production systems. To stress this still ongoing debate on ballast minerals and sinking rates of pellets and aggregates, we will provide more information on this in the introduction, not only in the result/discussion section. We will also cite some publications showing a retention of fecal pellets within the surface ocean layer.

Although we have choosen the results from Francois et al. as a starting point for our ms, we are aware that it is also debated in the literature. In fact, we also discussed some of the weaknesses of this study in the introduction (page 2543 line 25...; page 2545, line 12.....) but also later (page 2552, line 25....). The referee is right in saying that we should stress that we want to understand the regional and temporal variations in the efficiency of the biological pump. That is exactly what we wanted to do with this study. We therefore looked more into the regional variability within the Atlantic but also focussed on the seasonal changes of particle sinking rates which has not been done yet in this way (except partly in Berelson, 2002; but he studied not the seasonal changes). Our conclusion of higher sinking rates in carbonate dominated systems are not drawn only from Figure 4d, but are derived from multiple evidence (seasonal data off Cape Blanc (Fig. 6), regional data from literature from Berelson, 2002). Alkenone and flux studies from the Cape Blanc region also point to high carbon transfer combined with high particle sinking rates, when coccolithophorids dominated mass flux (page 2554, lines 11-22). Densely packed appendicularian fecal pellets preserved in sediment trap samples off Cape Blanc had settling rates of 732 m per day, measured with a vertical flow system (Ploug et al., 2008b, L&O 53, 5) Furthermore, experimental/laboratory studies highlight our field observations. M. Iversen and H. Ploug from the MPI in Bremen found higher sinking rates in experimental aggregates containing coccolithophorids compared to those containing diatoms. We will stress these points in our new version and will draw our conclusions more carefully when discussing Fig. 4d. We already mentioned in the ms, that a statistical relationship between particle sinking rates and carbonate flux cannot be observed from Fig. 4d (page 2551 line 22....). We also provided an explanation for this (page 2551, line

24.....). We feel that albeit not statistically proven, the tendency to higher sinking rates in carbonate (coccolithophorid) production systems (when considering all presented data) is of great interest for the study of aggregate remineralisation processes and carbon. It should also stimulate the discussion on the ballast theory using field data.

It has not been found out yet what role dust plays in ballasting (page 2552, line 3....). In the view of Francois et al., the role on a global scale is unimportant. However, at certain locations and during certain seasons, this may be completely different and more detailed studies are necessary. As particle sinking rates off NW Africa appear to be exceptionally high, dust particles might be one potential reason; this has to be proven in the field and lab. We plan to contribute to this by making aggregation experiments with natural dust samples.

In principle the referee is right, as long as the remineralisation length scale, which is defined by the ratio of sinking velocity to remineralisation rate constant, is preserved, the seasonal flux variation might have also been modelled by changing remineralisation rates and keeping the sinking velocity constant. However, our modelling study is based on the observations of sinking velocities in the water column. The main question was whether observed variation in sinking velocities can reproduce deep water fluxes when they are incorporated into the model. The variation of remineralisation, although a very interesting topic to investigate, was not within the scope of this study. However, in the revised paper we will draw attention to the importance of remineralisation as a further area of investigation.

Detailed comments:

Page 2542: the reviewer is right, it might be confusing giving pCO2 ranges in the light of the uncertainties in the anthropocene. pCO2 numbers will be omitted.

Page 2543: range of e-ratios will be changed (2-50%).

Page 2543: similar ranges of sinking rates for marine snow will be given.

BGD

5, S2198–S2202, 2008

Interactive Comment

Page 2546: we will provide more information concerning degradation in the sampling cups in the method section.

Page 2546: the reviewer is right, some of our cups sampled above 1000 m which might cause some undersampling in this depth range. Even if this occurred, a change in the absolute flux numbers should not necessarilly change particle sinking rates.

Page 2548: In fact our aim has been more modest. In the modelling part of our study, we wanted to show the applicability of a simple biogeochemical model in reproducing deep water fluxes, rather than investigating the role of diatoms and coccolithophorids in the biological pump. We do that by prescribing a seasonal sinking velocity for the large detritus compartment of the model to mimic the sedimentation of different species in different seasons. Page 2548: As we explained in our response to the Referee #3, the remineralisation rates were chosen to maintain similar remineralisation length scales with the original model, while implementing estimated, realistic particle sinking velocites. The ratio of remineralisation between small and large particles is 3 in the original model, which is left unchanged in our configuration too. We will explain this and the reference provided by the referee (Moriceau et al., 2007), which points to a similar ratio of silica dissolution rates between aggregated and freely suspended diatoms will also be cited in the revised manuscript. Comparable remineralisation rates for marine snow are found by Ploug and Grossart (2000) and Ploug et al. (2008) as we used in our study.

Page 2550- (section 3.1): we will formulate this more carefully as mentioned above. We will say that there is a tendency to higher sinking rates in carbonate and dust-dominated production systems when considering all data presented in this study. The referee is right, the role of dust remains unclear (see comment above) and deserves further, more detailed research in the lab and in the field. We will reorganize the section 3.1. by first describing the results more clearly, then discuss some literature values and finish with some conclusive remarks.

BGD

5, S2198–S2202, 2008

Interactive Comment

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

Page 2558: Developing an empirical relationship between sinking rates and an environmental variable as the referee puts it, and subsequent analysis by modelling work would be very interesting and certainly valuable indeed. And we should also point to the significance of such an investigation. But, as the reviewer stressed himself, it is not so simple and straightforward and global relationships between some environmental variable and particle sinking rates are not available yet and may not be obtainable in the future (because parameters may be strongly site-specific). However, we hope that our study may stimulate such a discussion and we wanted to emphasize the important role of particle sinking rates for mass fluxes and thus, ocean biogeochemistry. Certainly, this is not the only parameter which is relevant, remineralization is another one. The scope of our study is limited to the testing of observed sinking velocity to match the deep water fluxes. Most biogeochemical models limit particle sinking to 10-20 m per day, which is far less than observed values. Our objective was if we can reproduce fluxes with a 2-particle class simple biogeochemical model without using more costly aggregation models, which take into account particle characteristics, porosity, density etc. This study shows possibilities and limitations of such a simplification. Although good estimations of deep water fluxes are possible, they are site- and depth specific. In this sense we confirm findings of Kriest and Oschlies (2008) who state that 'a model with constant sinking speed of particles may be biased towards observations and/or biogeochemical settings at a specific location or depth'. In the revised manuscript we will try to describe our modelling objectives and conclusions more clearly.

Another important finding of our study - which has implications for carbon fluxes, remineralization and ocean biochemistry - is the increase of particle sinking rates with depth, derived from sediment trap studies shown in Figure 5.

We thank the reviewer for the constructive comments and suggestions.

Interactive comment on Biogeosciences Discuss., 5, 2541, 2008.

BGD

5, S2198–S2202, 2008

Interactive Comment