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Interactive comment on "Diatoms and their influence on the biologically mediated uptake of atmospheric CO_2 in the Arabian Sea upwelling system" *by* T. Rixen et al.

T. Rixen et al.

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Please find enclosed a point-by-point response to the issues raised by the referee #1:

1. Schiebel et al. presented data on diatoms, coccolithophorids and numbers of foraminifera obtained during the German JGOFS cruises M32/5 and SO119. The cruise M 32/5 was undertaken at the same time as the US JGOFS cruise ttn49. The cruise SO119 was two years later and diatoms have been counted only at one site. During the cruise M32/5 seven stations were located close to the US JGOFS transect but only at one of these sites foraminifera were counted which seem to be the main carbonate exporters in the Arabian Sea. (Coccolithophorids contribute only ˜15% to the particulate inorganic carbon flux as indicated by sediment trap results (Zeltner, 2000)). The data published by Schiebel et al. have been integrated in the revised version of the manuscript (see Figure 9). It turned out that at least to our opinion the diatom

counts presented by Schiebel et al. are extremely helpful for the discussion of factors, including iron, influencing the development of large diatom blooms in the Arabian Sea during the onset of the upwelling season. Please see chapter 4 in the revised version of the manuscript for more detailed information.

2. In contrast to the North Atlantic iron instead of silicate is assumed to limit the diatom growth in parts of the Southern Ocean and the Pacific Ocean (see comment no. 3). In the Arabian Sea silicate in contrast to inorganic nitrogen hardly approaches concentrations close to zero. Plankton counts during the cruises M32/5 and ttn50 show that the number of diatoms and the contribution of diatoms to the plankton community, respectively, decrease although silicate is not depleted in the surface water. This shows that in the Arabian Sea the relationship between silicate and diatoms is not straightforward as one would assume. Results obtained from the Norwegian mesocosms (and here Egge and Aksnes are cited) reveal that diatoms lose their ecological advantage over other organisms when the silicate concentration falls below 2 μmol/l. This implies that in addition to nutrient concentrations ecological aspects also have to be considered in order to explain declining diatom blooms in the Arabian Sea which we tried to do better this time in the revised version manuscript.

3. Considering the comment concerning iron stimulating diatoms bloom in HNLC region we submit that in different regions different factors can limit the diatom growth and these factors have to be identified also in the Arabian Sea. The data published by Schiebel et al. (2004) and results obtained from other studies cited in revised version of the manuscript have been very helpful for improving our discussion on this topic. Please see chapter 4 in the revised version of the manuscript.

4. Refield et al. 1963 is cited because of the Redfiled ratio and not because of the calcification effect on the atm CO2. 'The efficiency of the biological pump can be enhanced by raising the uptake ratio of carbon to nutrients (C/N/P Redfield ratio) during the production of organic matter and by a reduction of the calcium carbonate precipitation, because the latter process increases the pCO2 in sea water (Redfield et al., 1963;

Berger and Keir, 1984; Heinze et al., 1991)'.

5. In our study only the ratio between POC and PIC of the exported matter at 100 m water-depth or at the base of the mixed layer is regarded as rain ratio.

6. The impact of increasing CO2 concentration in the atmosphere on the precipitation of carbonate in the ocean is very interesting topic. The reference (Heinze, 2004) has been included in the revised version of the manuscript. Harrison and Conley indeed consider effects of varying silicate inputs and Matsumoto and Sarmiento investigated iron triggered reorganisation of the marine silicon cycle that could fertilize diatom blooms in the ocean at lower latitudes where silicate is assumed to limit the diatom growth. In all these studies the diatom-coccolithophorid balance plays an important role. Our study at lower latitudes focuses on the total carbonate export as coccolithophirds are not the main carbonate exporters in the Arabian Sea (Zeltner, 2000) and probably in the global ocean (Schiebel, 2002). Our results seem to be in line with the opinion of the referee as they reveal relatively low changes of the rain ratios on seasonal time scale probably due to the declining large diatom bloom in an iron- and silicon- enriched environment during the onset of the upwelling season. 7. The Findlater Jet is an atmospheric jet and the most pronounced feature of the SW monsoon: ' The SW winds (SW monsoon) from a low level jet (Findlater Jet) extending almost parallel to the Arabian coast' and lead to upwelling off the Arabian coast. Upwelling is associated with net water mass advection away from the coast in a SE wards direction and this is assumed to be the main feature in the western Arabian Sea (Smith, 2001; Fischer et al., 2002). Filaments are cold water structures caused by an accelerated transport of upwelled water and different advection velocities of upwelled water are considered in our analysis. Upwelled water replaces the warm oligotrophic Arabian Sea surface water that was formed during the intermonsoon season. As we are not aware of another defined water mass occurring at this time in the upwelled region off Oman we performed only a two end-member analysis. S13 has been selected as the oligotrophic end-member because there are hardly any discernible salinity changes

between S13, 14, 15. (Since the data obtained at these sites are so similar there are only minor changes in the results if one uses S14 and S15 as end-member). Within the revised version of the manuscript we have changed the first paragraph of chapter 3 in order to discuss in more detail the latest JGOFS's results implying that advection of coastally upwelled water is the main feature in the western Arabian Sea during the upwelling season (Smith, 2001; Fischer et al., 2002). This result justifies the application of a two-end-member mixing analysis. Furthermore, we tried to point out more clearly in the revised version of the manuscript that the two-end-member mixing analysis leads to realistic Redfield and rain ratios and new production rates and to us this is most reassuring. To us it seems to be problematic to include approximations and assumptions leading to unrealistic results into the error estimate because the error range obviously increases as the assumptions become more unrealistic.

8. Yes, DIC concentrations decrease because of CO2 emission, POC and PIC export (and mixing, of course).

9. Our approach provided an idea about the Si/N uptake ratios in a natural environment and the results are within the range of Si/N uptake ratios reported from other environments. The trend seen in our Si/N uptake ratios fits into our overall concept as pointed out in the old version of the manuscript. Nevertheless, we agree with the referee that the approach is problematic and for that reason we have not used the Si/N uptake ratios to support our conclusions in the revised version of the manuscript.

10. Please see our response to comment no. 9.

11. That is right, there are large uncertainties regarding the CO2 emission. We used the mean CO2 emission as described in the text as it leads to Redfield and rain ratios which are acceptable and to new production rates which are in line with published data on primary and export production measured at the same time.

12. Quigg et al., 2003 performed laboratory experiments and the main purpose of our work is to study the stoichiometry of organic matter in a natural environment where

stress exerted by environmental factors influences the formation of transparent exopolymeres which are enriched in carbon and enhance the C/P ratios of the formed material (Engel et al., 2002). However, since the changes of the C/N ratio derived from sediment trap data are relatively low we followed the advice of the referee in the revised version of the manuscript.

13. Vertical mixing and open ocean upwelling have been suggested to act as nutrient source in the open western Arabian Sea. However, the latest JGOFS's results imply that advection of coastally upwelled water is the main feature in the western Arabian Sea during the upwelling season (Smith, 2001; Fischer et al., 2002) and this is supported by our mixing analysis which provides qualitatively and quantitatively reliable results (see comment no 7).

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