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Biogeosciences Discussions

Interactive comment on "Shelf erosion and submarine river canyons: implications for deep-sea oxygenation and ocean productivity during glaciation" *by* I. Tsandev et al.

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The Late Pleistocene glacial-interglacial cycles are very well documented through a wide variety of records, which included ice-cores, marine, lacustrian and continental sediments, and speleothems. Many fundamental questions remain, however, unanswered, and especially the mechanisms implied in the lowering of atmospheric CO2 levels during glacials are not yet fully elucidated. A plethora of proposals has been forwarded, which encompasses changes in ocean circulation, the oceanic carbon cycle and storage of carbonate and organic carbon, continental vegetation and soil, biogeochemical weathering rates, and so on. In particular, the role of oceanic productivity

and changes therein has been examined in detail, and a complex pattern has emerged, where certain basins were indeed more fertile, whereas others less. In relation to this, spatial and temporal trends in nutrient delivery to the ocean have been investigated and modeled, which may explain the postulated changes in productivity and carbon storage. With the evolving degree of observations, the interpretations and models become increasingly detailed and complex. Tsandev et al. add another dimension of complexity to the existing explanatory models, in postulating an important role for glaciation-related sea-level fall, progressive exposure of continental shelves and sediment reworking, and focused river output directly into the deep oceanic basins via canyons. They build upon an existing numerical model (Slomp and Van Cappellen, 2007; Tsandev et al., 2008), to which they added the possible effects of increased organic carbon and nutrient input directly into the deep basins by these mechanisms. As a result, they find a tendency towards increased oxygen utilization and improved organic carbon burial, whereas phosphorus burial rates are less affected because of higher redox-dependent phosphate recycling. The authors provide an innovative and valuable model, with which they are able to reconcile apparently incongruent observations, such as the widespread decrease in deep-water oxygen levels during glacials, in spite of disparate pattern in oceanic primary productivity and negligible changes in phosphorus burial rates across glaciations (Tamburini and Föllmi, 2009). The manuscript is important with regards to our understanding of the interactions between sea-level change, changes in the oceanic carbon and phosphorus cycles, and climate change during the Late Pleistocene. As always, in providing new answers, the findings exposed in this manuscript also provoke further questions:

1. Do we have direct evidence for the importance of erosional processes on freshly emerged shelves during late stages of glaciations? One would expect that the regions higher than 50° N and S latitudes developed widespread permafrost, which may have immobilized sediments. Also, sea-level fall and canyon formation may have focused sediment transport by rivers, thereby decreasing general erosion pattern in coastal areas? 2. Do we have evidence for increased burial rates of refractory organic car-

bon of continental origin in deep-water sediments during glaciations as is postulated by the authors (page 891, line 20 onwards)? 3. Which portion of the total amount of particulate organic matter transferred into the deep sea is assumed to have been remineralized in the model? This is important with regards to our understanding of the dynamics of oxygen consumption, etc. This is not very clearly stated in the manuscript and some contradiction seems present: the authors assume that "particulate material is assumed to mineralize (into dissolved nutrients) or get buried as proximal sediment" (page 884, line 18), without specifying the ratio between the two processes. In the first part of the manuscript, one may get the impression that most particulate material is mineralized: "allows the deep-sea nutrient supply to increase significantly" (page 889, line 11); "The net effect of all the mechanisms is some ocean fertilization. Dissolved reactive P (SRP) increases in the deep-sea and correspondingly so does primary production" (page 890-891). Later on, the authors state, however that "The variable most affected by river canyons and the particulate load from the continents and shelves is organic carbon burial in the deep-sea which increases twice as much as the dissolved phosphate reservoir. Therefore, most of the carbon arriving from the continent is buried in ocean sediments, which helps explain why ocean productivity can remain relatively low despite high loads of labile organic material" (page 891, line 20 onwards). This apparent contradiction reflects the somewhat difficult situation the authors are confronted with: on one hand they need important remineralization rates in order to explain the changes in oxygen consumption in the deep oceans and the increase in redox-dependent phosphorus recycling rates, and on the other hand, they need subdued remineralization rates in order to prevent productivity rates to rise. 4. The authors assume that ocean productivity rates were generally lower during glacials, thereby using the results of an earlier model (Tsandev et al., 2008). In this paper, the authors relate this to changes in ocean circulation and increased retention of phosphorus in the deep ocean. This assumption is important to this paper and the authors may devote a paragraph or two in discussing why they keep overall glacial ocean productivity rates on the same low level as was identified in the 2008 publication, in spite of the

increased importation of nutrients directly into the open ocean? 5. In their model, the authors restrict their findings and assumptions to the oceans and changes in continental weathering and corresponding changes in nutrient fluxes from the continent to the ocean are not considered. How may such changes influence the output of their model? For example, during the early stages of deglaciation phases, phosphorus mobilization and output rates may have considerably increased because of ice melting (liberating precipitation-derived phosphorus contained therein) and the biogeochemical weathering of freshly produced glacial sediments (Anderson, 2005; Föllmi et al., 2009).

In the following, I listed a few minor spelling mistakes:

Page 884, line 27: "antigenic": authigenic? Page 887, line 22: "@" ??? Page 887, lines 26-27: "oragnic": organic Page 892, line 7: "to the deep": to the deep ocean? Page 892, line 10: "the open ocean need not be": the open ocean needs not be

References Anderson S. P.: Glaciers show direct linkage between erosion rate and chemical weathering fluxes. Geomorphology 67, 147-157, 2005. Föllmi, K. B., Hosein, R., Arn, K. and Steinmann, P.: Weathering and the mobility of phosphorus in the catchments and forefields of the Rhône and Oberaar glaciers, central Switzerland: implications for the global phosphorus cycle on glacial-interglacial timescales. Geochimica et Cosmochimica Acta 73, 2252-2282, 2009 Slomp, C. P. and Van Cappellen, P.: The global marine phosphorus cycle: sensitivity to oceanic circulation. Biogeosciences 4, 155-171, 2007 Tamburini, F. and Föllmi, K.B.: Phosphorus burial in the ocean over glacial-interglacial time scales. Biogeosciences 5, 5133-5162, 2008. Tsandev, I., Slomp, C.P. and Van Cappellen, P.: Glacial-interglacial variations in marine phosphorus cycling: implications for ocean productivity. Global Biogeochemical Cycles 22, GB4004, 2008.

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