Reviewer 2 (anonymous)

Major comments

Comment: 1. Overall, I agree with reviewer 1 that the model is not well enough explained. I can live with a brief description of the pelagic model ("as they reproduce the biogeochemical characteristics from of its region", p6, line 24), but how denitrification is described should be clear before the model results are discussed. Now I had to glue bits and pieces of descriptions that can be found in the "conclusions" (section 4). My impression is that there is no real sediment model but rather a reflective boundary ("instantaneous" remineralisation, line 26, p 6). Reviewer 1 has the impression it is a "vertically integrated model", which is not quite the same, so what is it?. Even more important: how is the denitrification imposed upon this remineralisation?

Response: The sediment model is indeed formulated as a reflective boundary, which we have emphasized in page 4, line 125 (new text in italics below):
"(instantaneous remineralization of particulate organic matter reaching the seafloor, *i.e. a reflective boundary*)".

A more detailed description of how benthic denitrification is now included in Section 2, after equation 2 (page 5, lines 136-155):

> "From the oxidation of 1 mol of organic matter within the sediments (i.e., 16 mol-N, 106-mol-C), only a fraction ψ is released as NH_4 back to the water column, while a fraction 1- ψ is lost as N_2. The release of NH_4 from (and oxygen demand by) the sediments is based on an empirical relationship between coupled nitrification-denitrification and oxygen consumption in the sediments (Seitzinger and Giblin, 1996). A larger compilation of measurements gave essentially the same fit as Seitzinger and Giblin, indicating that bottom-water concentrations of NO_3^- or O_2 are not effective predictors of sediment denitrification in oxic environments (Fennel et al., 2009). Combining the Seitzinger and Giblin relationship and the assumption that organic matter reaching the sediments can only be remineralized aerobically or denitrified, Fennel et al. (2006) calculated that in the MAB model 86% of the oxidation of organic matter is aerobic and 14% occurs through coupled nitrification-denitrification. Further calculations led to a value of ψ=4/16 (see their Appendix A). Since the VIS model uses photosynthetic quotients (PQ, Laws, 1991) rather than Redfield's O_2:C ratio (PQ=1.1 vs. O_2:C = 106:106 =1), the above calculations led to 85% aerobic remineralization, 15% denitrification, and ψ=3/16 in that model (Bianucci et al., 2011). The partition of benthic oxidation between aerobic and anaerobic pathways resulted in a different O_2:N ratio within the sediments compared with the water column. In the latter, O_2:N ratios are 106:16 in the MAB and 117:16 on the VIS. In the sediments, oxygen is consumed following a O_2:N ratio of 115:16 in the MAB and 125:16 on the VIS (Bianucci et al., 2011)."

Moreover, we included more information on the models set-up and initialization as suggested by Reviewer 1 (please refer to the answer to his question 7 for details).

Comment: 2. For me how the oxygen budget is affected by the denitrification is difficult to grasp without seeing the concomitant nitrogen budget. Now this is described in very vague terms, e.g the 'importance of external sources" on the VIS. To fully appreciate the effects of the sediments on water-column processes more background information is needed for the two areas, also on nutrient levels – see next point.

Response: The DIN budget was added. Please refer to the next answer.

Comment: 3. The fact that there is no "direct" denitrification in the model is the weak point in the modeling exercise. I assume (but I do not have this information) that nitrate concentrations are much higher in the VIS than in the MAB, so I would expect significant "direct" denitrification here, in a way that the sediments are a sink of nitrogen rather than a source. Now, sediments can only be a source of nitrogen, as there is only coupled nitrification-denitrification. "direct consumption" of bottom water nitrate of course would have much larger effect on the nitrogen content of the water column in VIS, maybe to the extent that it *does* affect primary production (the more because sediment mineralization seems to be very important in this region – see fig. 4). This would in turn have a larger effect on the oxygen budget. The authors need to be more convincing than simply saying "given the external sources of new nutrients on the VIS,. . . not likely to affect significantly ".

Response: Nitrate concentrations were not found to be an effective predictor of sediment denitrification by Fennel et al. (2009). We added text in the manuscript to address this issue (please refer to the new text shown in Question 1).

We do recognize that direct denitrification would provide a stronger feedback between sediment denitrification and oxygen concentrations in bottom waters and have emphasized that in the manuscript (please see the response to Question 3 from Reviewer 1). We have added the dissolved inorganic nitrogen budget to support our statement about the role of external sources of nutrients on the VIS (page 10, line 321; new text emphasized in italics below):

> "…*advection of nitrogen nutrients to the whole VIS region is comparable with biological sources of DIN (Fig. 6). Therefore,* given the external sources of new nutrients to the VIS *(i.e., from wind-driven upwelling and the* NO_3*-rich VICC)*, direct denitrification is unlikely to *strongly* affect primary production and oxygen concentrations."

Comment: 4. The supposed scheme how denitrification can affect the oxygen budget seems to be unnecessarily complex (page 4). The importance of the three "processes" are not subsequently discussed as process 1, 2 and 3, so there is no need for this separation. If this paragraph is retained in this form in the paper, then I would advise to make a scheme of this. Also what is the use of contrasting between coupled nitrification-denitrification and "direct" denitrification if the model only considers the first (I think).

Response: We added the suggested scheme as the new figure 1 (the processes are discussed on page 8 in Section 3). The contrast between coupled nitrification-denitrification and direct denitrification early on helps to introduce the discussion regarding the effects of assuming only coupled nitrification-denitrification in Section 4. We extended the discussion of those effects in Section 4 (please see Question 3 from Reviewer 1).

Comment: 5. The manuscript is structured in a strange way. From line 26p5 -line10p 6, is the "conclusion" of the paper, yet it is in the introduction section. The conclusion section contains the description of the model and the discussion.

Response: We rearranged the text in the following way:

1) Removed from the Introduction (Section 1) the last paragraph starting in line 26, page 5 of the old manuscript.

2) Named Section 4 as "Discussion and Conclusions"
3) The models are now better described in previous sections, so the reader does not need to wait until the last section to understand model details. We leave the brief descriptions in Section 4, since they are part of the discussion of model effects (e.g., how differences between models could affect our results).

Comment: 6. From this paper, I get the impression that there is no other modeling study that deals with the effect of sediment processes on the oxygen budget / hypoxia? In fact, there do exist modeling studies that have a better representation of the benthic nitrogen cycle and that also look at the effects of this on water column hypoxia.

Response: We added text referring to previous studies (page 2, lines 44-45):

> "Previous studies have shown the important role of sedimentary pathways in bottom-water oxygen dynamics (e.g., Middelburg and Soetaert, 2005; Soetaert and Middelburg, 2009; Reed et al., 2011)."

Details

Page 2 - line 8. We use "a " coupled .. model – misleading as they are two different physical model setups and two different pelagic models

Changed to read (changes in italics):

> "We used *two* coupled physical-biological *models* based on the Regional Ocean Modeling System (ROMS)"

page 2 - Line 15. "denitrification efficiently decreases the pool of N , since recycled nitrogen supports most of the primary production". What does this mean. Only after reading the entire manuscript can this be understood.

We re-wrote this sentence to make it clearer (changed text in italics):

> "Denitrification represents a loss of bioavailable nitrogen through the production of dinitrogen gas, with the potential to affect biogeochemical cycles. In our MAB model, *this loss of regenerated nutrients through* denitrification within the sediments *significantly affects primary production,* since recycled nitrogen supports most of the primary production in that region."

Page 2 - Line 24 "this process" -> denitrification

We amended the text to say "sediment denitrification" instead of "this process"

Page 7. Nitrate is written HNO3 for the denitrification, NO3- for the nitrification. Same for ammonium/ammonia. Be consistent.

New equation for denitrification written in terms of NO_3^- and NH_4^+:
$C_{106}H_{263}O_{110}N_{16}P + 97.8H^+ + 84.8NO_3^- \Rightarrow 106CO_2 + 42.4N_2 + 16NH_4^+ + PO_4^{3-} + 148.4H_2O$

P 7 - line 9 The term "bottom oxygen" is very vague – is it the oxygen in the sediment / layer 1 m above the sediment - Is the term defined on line 19?.

The term was intended to represent the "oxygen concentration in the bottom waters" (not in the sediment). In page 6, line 177 we changed "bottom" to "bottom-water" to make explicit that we do not mean oxygen in the sediments, and rewrote the sentence right before equation 3 (new text emphasized in italics below):

> "The change in near-bottom oxygen due to the presence of denitrification within the sediments was calculated as the relative difference between experiments of the oxygen fields in the *near-*bottom layer *(i.e., deepest vertical level in the water column)*"

Page 9 . I do not understand why the sediment mineralization is so much more important compared to pelagic mineralization in VIS. Based on the "presence of DOM in the VIS model (p6, line 20) I would have expected the reverse.

Oxygen consumption is linked to the carbon cycle in the VIS model. The remineralization rate for semilabile DOC (rDOC) is 0.005 day^{-1} in this model, leading to a turnover timescale of 200 days for DOC (Bianucci et al, JGR, 2011). However, since the turnover of sediments is instantaneous in the experiments presented here, O2 is consumed as soon as organic matter reaches the seafloor. This leads to a predominant role of the sediments as a sink of O2 compared with pelagic remineralization. Even with a different sediment boundary (one that accumulates organic matter and remineralizes carbon at a rate = 0.035 day^{-1}), sedimentary O2 consumption is still larger than that due to water column remineralization, although not as large as with the reflective boundary (Bianucci et al, JGR, 2011).

P 10 -Line 13. "Diminshed "

Text amended.

Figure 4: Strange units for budget terms in figure 4. It says mmol O2 /m2, but it should include also time, as it is a budget. Is this over the 75 days, one hour?

Units should have been mmol O2/m2/d (we fixed the figure). In the figure caption, we added that the budget terms are "averaged over the 75 days of the analysis period".