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Biogeosciences Discussions

Interactive comment on "Regional differences in modelled net production and shallow remineralization in the North Atlantic subtropical Gyre" *by* B. Fernández-Castro et al.

B. Fernández-Castro et al.

bieito.fernandez@uvigo.es

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General comments

This paper estimates biogeochemical rates of net photosynthesis and respiration at two subtropical North Atlantic time series locations using a mass balance approach applied to climatological annual cycles of dissolved oxygen, dissolved inorganic carbon, and nitrate. It builds on a similar approach applied to one of the sites in an earlier study (Ono et al. 2001). The authors make useful improvements by including a variable (in time) vertical diffusivity, more robust error estimates, and, most importantly, extension to another a second location that has an intriguing difference in export production. The

paper is well done and I recommend publication.

Specific comments

I do take issue with the following claims made in the abstract: "Lateral advection, which was more significant at ESTOC, was responsible for the differences in estimated oxygen remineralization rates between both stations. Due to the relevance of the horizontal transport at ESTOC, we cannot assert that the differences in shallow remineralization rates computed for both stations can explain the observed discrepancies in the flux of sinking organic matter." It does not make sense to me that lateral advection is responsible for remineralization, even "estimated remineralization." The only way this would be true is if organic matter was advected into the region; however, there is no evidence for this.

Lateral advection through the manuscript refers to lateral advection of the tracers (oxygen in this case). We have modified the abstract and the text in order to clarify this point:

-P. 12479, Lines 10-18 (abstract):

"Shallow remineralization rates between 110 and 250 m computed at ESTOC (-3.9 ± 1.0 mol O_2 m^{-2}, 1.53 ± 0.43 mol C m^{-2} and 38 ± 155 mmol N m^{-2}) were statistically higher for oxygen compared to BATS (-1.81 ± 0.37 mol O_2 m^{-2}, 1.52 ± 0.30 mol C m^{-2} and 147 ± 43 mmol N m^{-2}). Lateral advection, which was more significant at ESTOC, was responsible for the differences in estimated oxygen remineralization rates between both stations. Due to the relevance of the horizontal transport at ESTOC, we cannot assert that the discrepancies in shallow remineralization rates computed for both stations can explain the observed discrepancies in the flux of sinking organic matter."

modified to:

"Shallow remineralization rates between 110 and 250 m computed at ESTOC ($-3.9 \pm$

1.0 mol O_2 m^{-2}, 1.53 ± 0.43 mol C m^{-2} and 38 ± 155 mmol N m^{-2}) were statistically higher for oxygen compared to BATS (-1.81 ± 0.37 mol O_2 m^{-2}, 1.52 ± 0.30 mol C m^{-2} and 147 ± 43 mmol N m^{-2}). The divergence in the lateral transport of tracers, which was more significant at ESTOC, was responsible for the differences in estimated oxygen remineralization rates between both stations. According to these results, the differences in net production and shallow remineralization are not consistent with the differences in the flux of sinking organic matter observed between both stations, suggesting a convergence in the horizontal advection of slowly sinking, suspended or dissolved organic matter at ESTOC."

-P. 12496 lines 26-28 and P. 12497 lines 1-2:

"The lateral transport at ESTOC could explain the differences in the remineralization rates computed for both stations, as the 1D model without geostrophic advection resulted in oxygen consumption rates reduced by 56% at ESTOC (-1.73 ± 0.30 mol O_2 m^{-2}) and only by 16% at BATS (-1.18 ± 0.10 mol O_2 m^{-2})."

modified to: (*)

"The divergence of the lateral transport of oxygen caused the differences in the remineralization rates computed for both stations, as the 1D model without geostrophic advection resulted in oxygen consumption rates reduced by 61% at ESTOC (-1.51 ± 0.29 mol O_2 m^{-2}) and only by 27% at BATS (-1.31 ± 0.80 mol O_2 m^{-2}). The input of nitrate through lateral advection was also responsible for the low remineralization rate and the large error computed for nitrate at ESTOC, as the 1D model computed a higher rate and lower associated error (135 ± 23 mmol N m^{-2}). The fact that differences in remineralization rates between both stations were only statistically significant for oxygen could be related to the different temporal resolution of the databases used to compute the lateral gradients of the tracers. Oxygen and nitrate horizontal gradients were calculated from the World Ocean Atlas 2009 monthly climatology, whereas DIC gradients were obtained from the Global Distribution of Total Inorganic Carbon and Total Alkalinity

Below the Deepest Winter Mixed Later Depths climatology, which includes lower temporal resolution tri-monthly averaged data (see section **??**). Model results show that inconsistency in remineralization rates differences between the tracers decreased if oxygen and nitrate variability was reduced through smoothing (data not shown). Large errors associated to nitrate remineralization were probably due to the lower number of observations used to compute the nitrate, compared to oxygen, climatology."

-P. 12498 line 25 to P.12499 line 2:

"Due to the relevance of the allochthonous sources of organic matter at ESTOC, we cannot assert that the differences in shallow remineralization computed for both stations could explain a significant fraction of the observed discrepancy in carbon export rates. Alonso-González et al. (2009) indicated that this difference could be, at least partially, explained by low sedimentation rates of the particulate organic matter in the eastern part, as slow-sinking or suspendend POC does not accumulate in the sediment traps and can be laterally advected (Arístegui et al., 2009)."

modified to:

"Alonso-González et al. (2009) indicated that the reported differences in the carbon export rates between both stations could be, at least partially, explained by lower sedimentation rates of the particulate organic matter in the eastern part of the gyre, as slow-sinking or suspended POC does not accumulate in the sediment traps and can be laterally advected (Arístegui et al., 2009). Although organic matter was not explicitly taken into account in our model, our results support this hypothesis as they show stronger lateral transport and higher remineralization rates based on oxygen consumption at ESTOC, which can not be sustained by the flux of sinking organic matter."

-P.12500 line 9 to 15:

"Our results are consistent with enhanced respiration processes at ESTOC. However, the importance of horizontal processes in the seasonal cycles at ESTOC indicates that

oxygen consumption at this station could be also supported by allochthonous inputs of organic matter. The comparison of our estimates with vertical fluxes of POC shows that whereas a significant fraction of the shallow remineralization is sustained by sinking organic matter at BATS (25%), this fraction is much lower at ESTOC (5%)."

modified to:

"The comparison of our estimates with vertical fluxes of POC shows that whereas a significant fraction (25%) of the shallow remineralization is sustained by sinking organic matter at BATS, this fraction is much lower at ESTOC (5%). The importance of horizontal processes in the seasonal cycles at ESTOC indicates that oxygen consumption at this station could be also supported by allochthonous inputs of organic matter. "

Figure 5 Caption:

"(a) Observed and (b) simulated temperature rate of change, (c) errors in the simulated temperature seasonal cycle, and (d) contribution of geostrophic horizontal advection to the temperature rate of change at BATS and ESTOC. The black discontinuous line represents the mixed layer depth and the black thick line represents the zero rate of change isoline."

modified to:

"(a) Observed and (b) simulated temperature rate of change, (c) errors in the simulated temperature seasonal cycle, and (d) geostrophic horizontal advection flux divergence at BATS and ESTOC. The black discontinuous line represents the mixed layer depth and the black thick line represents the zero rate of change isoline."

-P. line 7 to 8 (conclusions)

"As our approach misses part of the winter-spring bloom period, we can not discard that it underestimates the differences in net production between the two stations."

modified to

"As our approach does not estimate mixed-layer net production, particularly during the winter-spring bloom period, we can not discard that it underestimates the differences in net production between the two stations."

What is really puzzling is that there is a difference in remineralization estimated from oxygen vs. DIC and nitrate. That difference needs to be discussed more in the paper. Along the same lines, I don't think the authors can state (Page 12500, Lines 9-10) that their results are consistent with enhanced respiration until they can reconcile the inconsistent differences between oxygen and the other two tracers (DIC and nitrate).

The fact that differences in remineralization rates between both stations were only statistically significant for oxygen could be related to the different temporal resolution of the databases used to compute the lateral gradients of the tracers. Oxygen and nitrate horizontal gradients were calculated from the World Ocean Atlas 2009 monthly climatology, whereas DIC gradients were obtained from the Global Distribution of Total Inorganic Carbon and Total Alkalinity Below the Deepest Winter Mixed Later Depths climatology, which includes lower temporal resolution tri-monthly averaged data (see section 3.2.1). Model results show that inconsistency in remineralization rates differences between the tracers decreased if oxygen and nitrate variability was reduced through smoothing (data not shown). Large errors associated to nitrate remineralization rates were probably due to the lower number of observations used to compute the nitrate, compared to oxygen, climatology.(See above)

Technical comments Page 12479, Line 24: replace "in" with "on"

Done

Page 12481, Lines 3-5: please give the depths of the traps, which are key for understanding at what depths remineralization difference may help to account for particle flux differences.

Page 12481, Lines 3-5:

"Although both stations are characterized by similar phytoplankton biomass and primary production rates, annual mean carbon export measured by using sediment traps is significantly lower at ESTOC, 5 by a factor of 3–5, than at BATS."

Modified to:

"Although both stations are characterized by similar phytoplankton biomass and primary production rates, annual mean carbon export measured by using sediment traps at 150, 200 and 300 m is significantly lower at ESTOC, by a factor of $3 - 5$, than at BATS."

Page 12482, Line 19: replace “seasonal” with “mean annual”

Done

Page 12483, Line 15: remove “Maxima”

This sentence reports maxima mixed layer, instead of averaged mixed layer, depths computed for both stations for the considered period.

Page 12484, Line 21: replace “extend” with “extent”

Done

Page 12484, Line 25: remove “to”

Done

Page 12485, Equation 2: You should state that K is assumed to be constant with depth but variable in time. I would even take K out of the derivative to make this clearer.

K was taken out of the derivative and K was replaced by $K(t)$ in the text

*P*age 12491, Line 5: replace “consistently” with “consistent”

Done

*P*age 12492, Line 28: replace “with” with “to”

Done

Page 12493, Line 18: replace “for a season scale” with something like “for the depths (mixed layer base to 110 m) and time period (April-December) we considered”

Done

*L*ast sentence of paper: “At the light of this . . . ” does not translate well

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Replaced by "In the light of this" following the suggestion by the other reviewer.

Tables 1 and 2 are not needed because almost everything in them is in Figures 8 and 9, which are better ways to present the budget. Having said that, the small font size and some of the box shading makes these two figures very difficult to read, so they need to be made more legible.

Tables 1 and 3 were removed. The geostrophic lateral advection term was also included in figures 8 and 9.

Figure 6 has a typo. The title of the second panel in the top row should say “O2” not “DIC”

The typo has been corrected

SEE MODIFIED MANUSCRIPT IN THE SUPPLEMENTARY MATERIAL

References

Alonso-González, I. J., Arístegui, J., Vilas, J. C., and Hernández-Guerra, A.: Lateral POC transport and consumption in surface and deep waters of the Canary Current region: A box model study, Global Biogeochem. Cy., 23, GB2007, doi:10.1029/2008GB003185, 2009.

Arístegui, J., Gasol, J. M., Duarte, C. M., and Herndl, G. J.: Microbial oceanography of the dark ocean's pelagic realm, Limnol. Oceanogr., 54, 1501–1529, doi:10.4319/lo.2009.54.5.1501, 2009.

Please also note the supplement to this comment:
http://www.biogeosciences-discuss.net/8/C6387/2012/bgd-8-C6387-2012-supplement.pdf

Interactive comment on Biogeosciences Discuss., 8, 12477, 2011.