Response to referee #2

The paper presents an analysis of the nutrient supply mechanisms in the Atlantic cold tongue (upwelling system) based on a combination of a regional biogeochemical model and observations from cruised conducted over about a decade, a mooring and satellite remote sensing (chlorophyll). After showing that observations and model results agree to a good extend the authors make use of the model (output) to disentangle the role of horizontal and vertical advection and diffusion, respectively to support the observed seasonality of chlorophyll with a strong maximum in August and September and a more moderate maximum in November-December. Vertical advection and vertical diffusion are found to be is the major source terms of nitrate to the euphotic zone in the cold tongue in summer, while meridional advection redistributes nitrate (in the ml) away from the upwelling center. The difference between the stronger summer nitrate supply (and bloom) and the smaller November-December upwelling (and bloom) are found to be associated with differences of the vertical locations of EUC core.

The paper is very well written and the descriptions are usually very clear. The study is carefully conducted and presents a important piece of science.

We thank the referee for his/her remarks. We hope that our responses will clarify the different points. Changes in the manuscript are also indicated.

I have only a few minor, technical, comments:

a) *The terminus 'cold tongue' is never defined, characterized or regionally narrowed down. After using this term in title and abstract, I would have expected something like a definition in the introduction. Instead you use the 'synonym' equatorial upwelling system there and only in line 79 use that terminus again. The first implicit definition that I see is in l 125ff. Perhaps it could help a wider audience if you better introduce/integrate the two terms 'cold tongue' and 'upwelling' in the introduction already.*

We agree that we should define the cold tongue at the beginning of the text. We added "Variations of the equatorial upwelling in the Atlantic Ocean are essentially seasonal. The so-called cold tongue spreads east of about 20° W to the African coast and is centered slightly south of the equator (Carton and Zhou, 1997; Caniaux et al., 2011). The maximum cooling is reached in July-August and a secondary cooling occurs in November-December (Okumura and Xie, 2006). The cold tongue is a region …" at the beginning of the introduction.

b) *l 134, Fig. 2a,b,c: please give (in the caption) explicitly which time periods you selected for no-upwelling vs. upwelling*

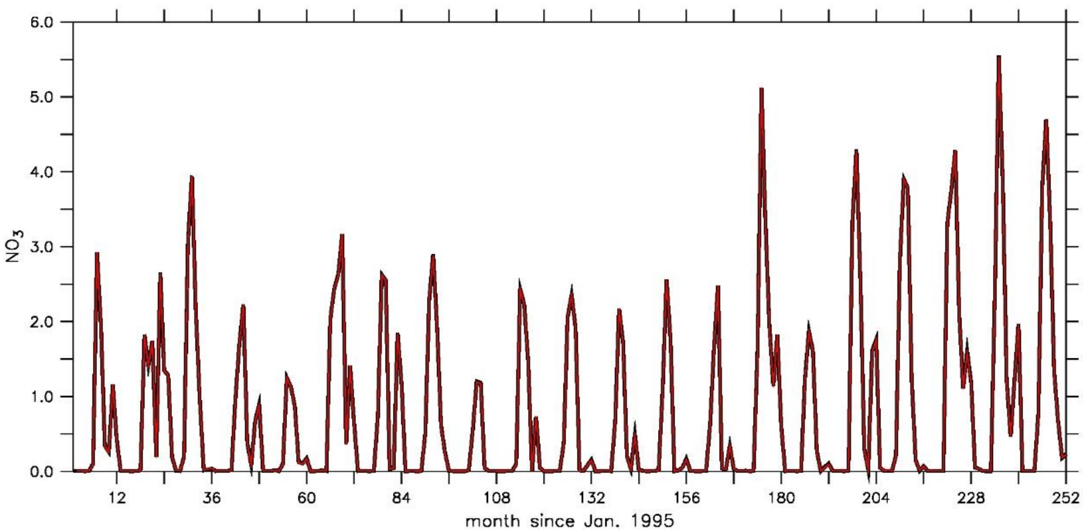
Now, we explicitly indicate in table 1 which cruises are used for each period. We also reworded lines 133-134 as “Vertical sections of nitrate, chlorophyll, and zonal current along 10° W measured during the PIRATA cruises and averaged separately in no-upwelling/low productivity and upwelling/high productivity seasons (table 1) are shown in Fig. 2a-c.”

c) *l 163ff&174: boundary conditions: can you briefly explain why you mix model output and observations concerning the boundary conditions; (I am not familiar are GLORYS2V2; is this only physics?)*

Yes GLORYS2V4 is only for physics. For lateral biogeochemical forcing, we mix model and observations simply because all the variables required by the model are not available as global observational climatology. We changed the text to “Interannual atmospheric fluxes of momentum, heat, and freshwater are derived from the DFS5.2 product (Dussin et al., 2016) using bulk formulae from Large and Yeager (2009). Temperature, salinity, current, and sea level from the MERCATOR global reanalysis GLORYS2V4 (Storto et al., 2018) are used to force the model at the lateral boundaries.”

d) *line 182, equ. 1 gives the explicit terms. Do the explicit terms at any time sum o fhtdNO3/dt? What about implicit terms, i.e. transports associated with, e.g., the choosen advection scheme*

* Yes, we verified that the terms on the right hand side sum to ∂NO3/∂t. We compared the variations of the monthly nitrate concentrations (black) and the nitrate time series reconstructed by integrating the right hand side over time (red) from 1995 to 2015. The following plot is an example at the surface at 15°W, 1°S. The 2 time series are superimposed and similar results are found in the thermocline.



* There is no implicit term for advection since we use a second order scheme without implicit numerical diffusion.

e) *line 201ff: a few more sentences describing the method could help here (otherwise we may need to read Vialard & Delecluse first in order to understand your quantification of entrainment; at least I did not get from that paragraph what you did)*

We add some details about the calculation of the entrainment. This part is now written as "We use the method described in Vialard and Delecluse (1998) to investigate nitrate budgets in the mixed layer and in the euphotic layer. An entrainment term appears when integrating Eq. (1) over a time-varying layer:

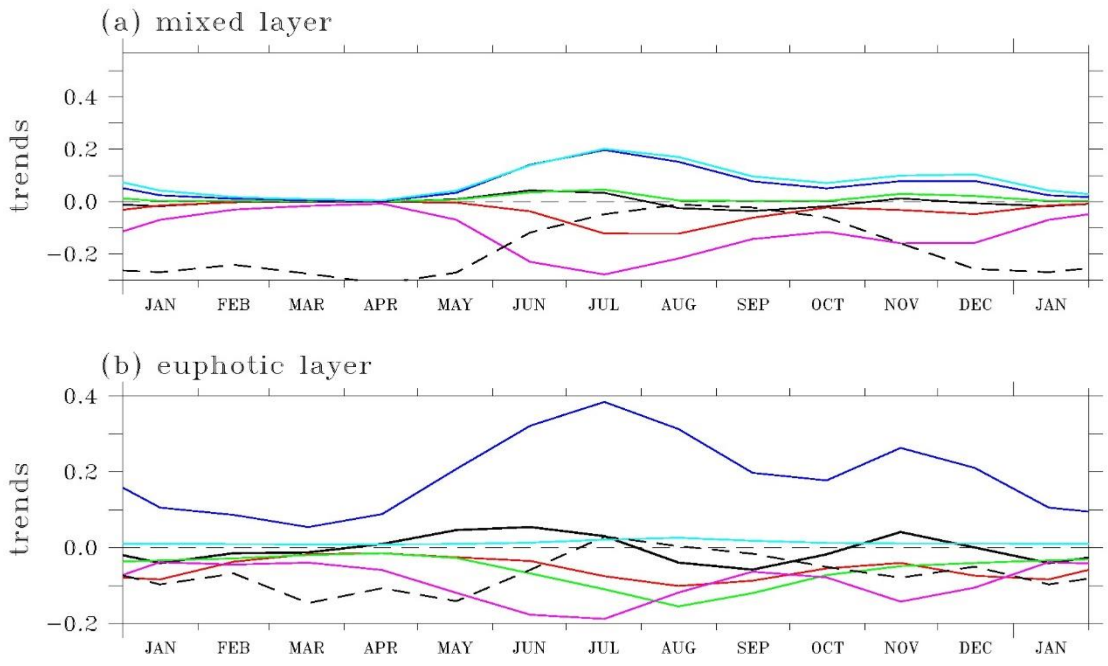
$$\frac{\partial\langle \mathrm{NO_3}\rangle}{\partial \mathrm{t}} = -\left\langle \mathrm{u}\frac{\partial \mathrm{NO_3}}{\partial \mathrm{x}}\right\rangle - \left\langle \mathrm{v}\frac{\partial \mathrm{NO_3}}{\partial \mathrm{y}}\right\rangle - \left\langle \mathrm{w}\frac{\partial \mathrm{NO_3}}{\partial \mathrm{z}}\right\rangle$$

$$+\langle \mathrm{D_l}(\mathrm{NO_3})\rangle + \frac{1}{\mathrm{h}}\left(\mathrm{K_z}\frac{\partial \mathrm{NO_3}}{\partial \mathrm{z}}\right)_{z=-h} + \langle \mathrm{SMS}\rangle$$

$$-\frac{1}{h}\frac{\partial h}{\partial t}\left(\langle NO_3\rangle - NO_{3_{z=-h}}\right) \qquad (3)$$

where brackets indicate the vertical average over the layer depth h. The last term arises from time-variations of the integration depth h. This term is often referred to entrainment at the base of the layer (e.g. Vialard and Delecluse, 1998) and computed as a residual of the other terms of Eq. (3). Here we verified that this term is small and we chose not to show it. The mixed layer depth is…"

The following figure shows that the contribution of entrainment is several order of magnitude smaller than the contribution of other trends: nitrate change rate (black), zonal advection (red), meridional advection (green), vertical advection (dark blue), vertical diffusion (light blue), SMS (purple) in the mixed layer (a) and in the euphotic layer (b). The black dashed line is 1000 × entrainment, illustrating that entrainment is 3 order of magnitude smaller than the other trends.



f) *caption Fig. 3; for (a) it is not clear whether surface data are shown; also the language and typographic of the phrase ‘averaged in 1.5dg S-0.5deg N’ can be improved*

We changed this caption to “Figure 3: Seasonal cycle averaged in the upwelling region (a) and mean distribution in July-August (b) of simulated surface chlorophyll (mg m^{-3}). Data were averaged between 1.5° S-0.5° N in (a). The climatology is calculated over 1998-2015.”

g) *l 234: English: ‘vertical structures are too shallow’*

We changed to “vertical structures are shallower than observed”

h) *l 243: should it read: processes driving the seasonal variations of nitrate in the mixed layer are presented’ ?*

We rephrased this sentence as “Understanding variations of the surface productivity requires identifying processes below the mixed layer. So in this section, processes driving the seasonal variations of nitrate are presented in the mixed layer, but also down to the base of the euphotic layer.”

i) *Fig. 5, caption. Please add which convention you used: ‘positive eastward (c), northward (d) and upward (e,f)’, I guess?*

A nitrate tendency leads to nitrate concentration changes. Units are [concentration/time]. So, positive tendency means nitrate increase and negative tendency means nitrate decrease. It is not a nitrate transport.

j) *l 304: ‘thermocline core’ is not defined (from Fig. 7a I assume that you take the 20degC isothermal for the thermocline core, please say so explicitly*

It is defined in the preceding paragraph (line 193).

k) *discussion: discussing the literature you discuss the role of TIW and Kelvin waves; can you make this more explicit from/for your model output ? (but I am clearly not an expert here!) from the last sentence of the conclusions though, I take that you may do so in a follow up study*

The monthly frequency of outputs is too low to resolve the TIW and Kelvin waves (and higher frequency intraseasonal processes) satisfactorily. Higher frequency outputs and calculation of tendencies are required to better study impact of intraseasonal processes on nitrate distribution. We hope that changes in the last paragraph of the discussion make things clearer: “This simulation was initially designed to study the large scale processes and it does not allow concluding about the role of the different intraseasonal processes. However, our results strongly suggest that large scale processes cannot totally explain the seasonal evolution of the nitrate budget. Previous studies (e.g. Jouanno et al., 2013; Athie et al., 2009) show that this model reproduces the level of energy of the TIWs and their equatorial signature in terms of sea surface temperature. It suggests that their contribution to the nitrate budget is well resolved, but this cannot be fully demonstrated from an observational basis since the only available nitrate data in the cold tongue area are from the PIRATA cruises which do not provide high-frequency information on the nutrient distribution. A dedicated study allowing better separating the large scale and eddying signals is needed in order to identify the nature of intraseasonal processes at work and their impact on the seasonal nitrate budget in the Atlantic cold tongue area."

Very nice, thanks!