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Interactive Comment

## *Interactive comment on* "Organic nutrients and excess nitrogen in the North Atlantic subtropical gyre" by A. Landolfi et al.

A. Landolfi et al.

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Reply to comments by Referee #2:

We would like to thank referee #2 for reviewing the manuscript and for the very constructive suggestions that have substantially improved the quality of the manuscript.

1. We agree with this comment as the individual data points appear to be relatively scattered. However general trends can bee seen and new figures with different scales have been provided to improve the visibility of these trends. In fact it if for this very reason that we progressively used more complicated models to estimate the development of TNxs. In the text we clarified the justification of the three methods. Despite the large uncertainties that remain also with the more sophisticated models the message





we want to give is that the error we commit by ignoring the contribution of the organic fraction to TNxs development is larger then the uncertainties of the single methods. Specifically: Figure 5 has been split into two subplots where DINxs, TONxs and TNxs have been interpolated both on depth and density layers. A better description of the method provides some explanations as to why W-E gradients are not expected to occur in Figure 8. As the average vertical profiles suggest (Fig. 6) the accumulation of DINxs, TONxs and TNxs changes with depth. Figure 8 represents the water column integral of TNxs accumulation rate with respect to the preformed TNxs at each station (stations closer to the western boundary have higher TNxs but also higher age). Thus it is expected that the spatial variability of the rate of TNxs accumulation is not the consequence of ageing water masses (which occurs along the respective isopycnals layers) but rather influenced by the spatial variability of biogeochemical processes (atmospheric deposition/ $N_2$  fixation). When looking at the development of TNxs on specific isopycnal layers the reviewer is right to expect gradients along the isopycnals with increasing age. Therefore Fig. 10 has been modified with different scaling for the two parameters DINxs and TNxs. Fitted lines have been added to the plots and information on statistics are included in the text. Similar considerations apply for Fig.11. The poor statistic of the still relatively small data sets is a general problem of isopycnal analyses (Gruber and Sarmineto, 1997, Hansell et al., 2004, Hansell et al., 2007). This has in fact motivated the use of a two end-member mixing model, as the assumption of negligible mixing along the isopycnal (one end-member mixing model) might be violated.

2. Detailed information of preformed values has been included in table 1

3. The TOP concentrations at 350m has been traced back to an analytical problem and has now been eliminated from the dataset. It turned out that this data point had not influenced our analysis as it can be observed from Fig. 8, 10, 11.

4. A list of station locations and depths of samples has been included as supplementary material. The interpolation of DINxs TONxs and TNxs along constant densities

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has been carried out and new figures have been included. This analysis did not significantly change our results. This is because the first method uses a vertical integration of the upper 1000m where TNxs deviations are observed; The 2nd method is based on the selection of data on specific isopycnals and the subsequent estimate of the TNxs areal rates is carried out by summing the contribution of all isopycnals. The 3rd method is based on actual data (and not interpolated values).

5. We do agree that preformed values are of fundamental importance and more details are provided regarding the number of data-points and their range, station location, depth range and time of sampling. Extrapolations on certain isopycnals were necessary as TON and TOP data in the region and at the depths and on the isopycnal of interest are very scarce.

We have inserted all the technical comments in the revised version of the manuscript, except for the few points noted below:

Pg 688, lines 9-10: The process that we were referring to is preferential remineralization of phosphate at the surface (likely linked to preferential phosphate uptake). This can lead to positive DINxs anomalies in the intermediate layers because the organic material falling in these layers would carry an excess N which could be then remineralised to nitrate creating positive DINxs. It is for this reason that it is important to consider the deviations of the total N and P pools along all the depths layers where these anomalies occur (corresponding in the North Atlantic to the top 1000m). This has been further clarified in the text.

Pg 692, line 3: The depth of the isopycnal surfaces appear clearer in the new figures provided.

Pg 692, lines 4-5: The TONxs anomalies appear clearer in the new figures provided.

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Pg 693, line 13: In the list of possible processes leading to the accumulation of DINxs, TONxs and TNxs the contribution of atmospheric deposition has been evaluated in terms of the organic and inorganic N and P deposition. The effect of the possible fate or preferential remineralization of the deposited products has not been evaluated.

Pg 693: The causes of possible negative TONxs and TNxs anomalies have been added to the list.

Pg 695, lines 9-15. Given the large  $\Delta TNx$  s values and the short ventilation timescales of the shallow isopycnals, leaving out the contribution of isopycnals < 26 would omit a large part of the contribution of the organic fraction to TNxs accumulation. Some notion of the importance of these surface isopycnals is obtained by comparing the twoend member mixing model (which excludes the shallow isopycnals) with the other two methods. This argument is now discussed in more detail in the manuscript.

Pg 697, lines 6-9: To estimate the annual accumulation of TNxs across the gyre we need to take the difference of TNxs at time  $t_{final} - t_0$ . This time difference corresponds to the spatial gradient west - east (the end of the gyre circulation pattern and the begging of the circulation pattern respectively). Given that TNxs general trend is to increase over time along the path from east to west (fig. 9) the oldest waters that are found at the end of the circulations pattern (west) are expected to have the highest TNxs. This is why to compute  $TNxs_{tfinal} - TNxs_{t0}$  it is reasonable to use: TNxs<sub>tfinal</sub> =  $TNxs_{maximum}$ .

Pg 699, lines 17-20: The winter MLD is  $\sim 70m$  (WOA temperature MLD climatology using the criterion = + or - 0.2°C). The average CFC12 age is 11 years, so we assume this is the time of isolation from the surface, which is much longer than a year and so should be situated well below the winter MLD.

Pg 699, lines 24-26: We term short time scale processes all those processes that have time scale shorter than the gyre circulation pattern. It should be kept in mind that the increase of our tracer TNxs on isopycnals is expected to occur on gyre-scale

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timescales. Overimposed on this mean behavior are short time scale processes eg: sporadic deposition events,  $N_2$  fixers blooms (sinking of organic matter occurs at fast rates). These events provide noise to the mean large/long term behavior.

Pg 702, lines 20-25: What we suggest is that for mass conservation the new diazotroph derived N will enter the TN pool. This new N comprises also the HMW DON pool described by Meador et al. 2007 but it is not limited to it. It must be said that the diazotroph released HMW DON pool is obviously a small quantity compared to the bulk TON pool. It is however, the rate of production and the fate of this pool that needs to be considered to understand how this pool might contribute to the build up of the TNxs pool. Although N<sub>2</sub> fixers DON-release rates are hard to extrapolate, given the difficulty of choosing the right spatial and temporal scales, some measurements seem to indicate that these rates can be significant ( $\sim 100 \text{ pmol N colony}^{-1}h^{-1}$ , Capone et al. 1994).

Reference:

Capone, D. G., Ferrier, M. D., and Carpenter, E. J.: Amino-acid cycling in colonies of the planktonic marine cyanobacterium Trichodesmium-Thiebautii, Appl. Environ. Microb., 60, 39898211;3995, 1994.

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