

Interactive comment on “Nitrate assimilation and regeneration in the Barents Sea: insights from nitrogen isotopes” by Robyn E. Tuerena et al.

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Authors response to review 2

We thank the reviewer for their constructive review of our manuscript. They have contributed some very useful points to help improve the manuscript. Please find all responses following on from each reviewer comment:

In the manuscript Nitrate assimilation and regeneration in the Barents Sea: insights from nitrogen isotopes, Tuerena and colleagues present a timely study on nitrate supply and dynamics in the Barents Sea. To date the majority of work in the Arctic utilizing the isotopes of nitrate and particulate N has focused on the western Arctic Ocean, so the spatial coverage and seasonal aspects of this study will be well received by the

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community. Overall the manuscript is well written (and clarification is just needed in some instances), but the data seems underutilized in places and there are a number of figure panels that are never discussed, for example Figure 4f, D(15,18), I think this could help elevate the discussion of nitrification in this system. I have expanded on these points in detail below.

Line 20: please clarify what season you are referring to here with the phrase ‘through the season’.

-Sentence changed to say: The ammonification of organic matter in shallow sediments resupplies N to the water column and replenishes the nitrate inventory available for the following season.

Line 24 to 25 / 396 to 398: the foundations of this conclusion are not clear to me and hence it seems a little speculative as currently presented, please rephrase / elaborate.

-These conclusions relate to that fact that our study finds uptake and recycling processes do not significantly change $\delta^{15}\text{N}$ in nitrate through the Barents Sea. Therefore, nitrate assimilation and recycling is efficient in this shelf region and sedimentary denitrification does not decrease the N inventory. This implies that the main process which could alter the nutrients supplied to Barents Sea Water and to the central Arctic basin halocline is a change in the nutrient supply within AW.

Lines 24-25, changed to read: Our results suggest that as nutrients are efficiently recycled in the Barents Sea and there is no significant loss of N through sedimentary denitrification, the changing productivity in the Barents Sea is unlikely to alter N availability on shelf or, the magnitude of N advected to the central Arctic basin. However, we suggest that the AW nutrient source ultimately determines Barents Sea productivity and changes to this supply may alter Barents Sea primary production and subsequent nutrient supply to the central Arctic Ocean.

Lines 396-398, changed to read: Given the Barents Shelf is not currently a locale that

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hosts significant sedimentary denitrification and NPP here is limited by N, the future changes are likely to be different from those envisioned for other Arctic shelves. We suggest that N supply through the Barents Sea to the Arctic is likely to be determined by variability in AW inflow. Future changes in this inflow could impact the nutrient inventory transported through the Arctic Intermediate Water, impacting productivity in the central Arctic Basins where AWs are transported.

Line 90: im not sure efficiently is the correct word here, I think you mean the reaction goes to completion and hence no fractionation is expressed. It would also be nice to see some of the more recent literature here that has looked at the cellular and apparent fractionation factors associated with sedimentary denitrification e.g. the work of Moritz Lehmann, Kirstin Dähnke and colleagues.

-Changed to read: In sediments, denitrification does not usually impart a signature on nitrate isotopes as the reaction normally goes to completion and thus the isotope effect is not expressed (Sigman et al., 2003, Lehmann et al., 2007).

Line 140: the wrong delta has been used here. -changed

Line 141 / 142: 48mm filters? Is this correct, or should it be 47mm? -Changed to 47mm

Line 170 to 171: The correction used here needs to be clarified, what is the basis for the -24 ‰ from Kemeny et al, 2016, looking at that paper I think this value is -24 +/- 38 ‰ is this correct? Why have you only corrected the 15N values here and not the 18O, could you not assume that the 18O-NO₂- would have fully exchanged with the water and use that value in a correction? I think it would also be beneficial if you could mention the nitrite concentrations observed in your samples (just the range maybe), either here or in the results (around line 191).

-d18O data are also corrected. Paragraph has been restructured to provide more information. The concentration range has also been added:

Nitrite concentrations in our study region ranged from 0-0.66µM, the highest concen-

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tration contributing 6% of the N+N pool. Our isotopic measurements are compared to studies where the nitrite in a sample has been removed using sulphamic acid (Granger and Sigman, 2009), to account for this, where nitrite was >2.5% of nitrate+nitrite, samples were re-run with sulphamic acid removal. For all other samples, we correct our d18O-NO₃ data for the ~25 ‰ lower d18O of N₂O produced from nitrite (Kemeny et al., 2016). d15N-NO₃+NO₂ samples were also corrected assuming a d15N-NO₂ of -24‰ (Kemeny et al., 2016, Henley et al., 2017).

Line 175: Please provide information on the standards used and the reproducibility (standard deviation) of these measurements.

-Sentence added: L-glutamic acid standards USGS 40 and USGS 41A were used as calibration standards during each analysis run. d15N values obtained for USGS 40 were -4.52 ± 0.08 ‰ n = 28 and for USGS 41A were 47.56 ± 0.18 ‰ n = 21.

Line 199 to 203: here you note that there is no significant difference in 15N-NO₃- or N* between AW and ArW, but note in the opening line that nitrate concentrations are lower, are nitrate concentrations significantly lower? Looking at the errors presented it doesn't look like it, please clarify and adjust language where needed (and check throughout).

-The nitrate concentrations are not significantly different, the text has now been altered to address this: The cooler ArW in the north of the Barents Sea had slightly lower (although not significantly different) nitrate concentrations of 10 ± 1.1 µM (Table 1).

Line 217: here you refer the reader to Table 1, but the values don't match and I assume that is because of the depth cut-off, please clarify and delete the references to Table 1 if needed.

-Thank you for this, the error value has now been edited and the text edited to describe samples from below the mixed layer.

Line 220 to 242: throughout this section I am a little unclear what is your contribution and what has come from the literature.

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-Our results find the same conclusions of Peng et al/Van Oostende et al, - that d18O is elevated over d15N, which is attributed to partial nitrate assimilation and nitrification. Our contribution shows that this signal is well mixed and transported onto the Barents Sea shelf, as the signature shown throughout the AW.

We have made edits to this section to make it clearer. For example: 'Our results suggest that seasonal mixing in the subpolar North Atlantic leaves an enrichment in d18O-NO₃ to depths of >200m, a signal which is then transported onto the Barents Sea shelf.'

Line 228: a reference is needed here. -Added: Buchwald et al., 2012, Sigman et al., 2009b

Line 254: why are you only discussing the 15N fractionation here, and not the 18O as well? In the introduction you take the time to introduce the idea of 1:1 relationship, so it seems surprising here that you don't take the time to talk about the 18O values shown in Figure 5b. This section would also benefit from a comparison to literature values.

-This is a valid comment and we have added further discussion of the d18O fractionation from uptake: Increases in d18O-NO₃ demonstrate an uptake fractionation of ~6‰ slightly higher than estimated for d15N-NO₃ (Figure 5a & 5b). In general, d15N-NO₃ and d18O-NO₃ increase to a similar degree at individual stations, with muted values of ϵ in the Arctic Waters and higher values in the AWs (Figure 5). Seasonal fractionation in d18O-NO₃ is also slightly higher ($\epsilon=5.3\%$ compared to d15N-NO₃ ($\epsilon=4.2\%$ (Figure 5d). Our estimates of AW uptake fractionation of ~4-8‰ for both d15N-NO₃ and d18O-NO₃ fall into the expected range for algal uptake (Tuerena et al., 2015, Sigman et al., 2009). The higher fractionation of d18O-NO₃ may suggest some degree of simultaneous assimilation and nitrification co-occurring in the euphotic zone (Difiore et al., 2010).

Line 270: how you determined the concentrations of PON needs to be mentioned in the methods and where can the reader see this data?

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-The following sentences have been added to the methods section: A 10-point calibration using standard USGS 40 was measured to provide the linear regression equation (peak area vs expected N concentration) which was used to derive PN concentrations from the measured peak areas. $\mu\text{g/L}$ concentrations were then calculated using concentration obtained from the whole filter and volume of seawater filtered. The detection limit for PN was 10 μg .

Line 278: why are you not using the isotope effect that you determined in this study (I know a value of 5 is close, but it would still be nice to see you using your own value, unless there is a reason not to)?

-Figure has now been changed to use an isotope effect of 4.8 per mil

Line 283: I think this should be Figure 6d.

-Thank you, yes this has now been changed

Line 308 to 309: for clarity I suggest you add in an 18O to this sentence, so 'range in nitrified 18O-nitrate values'. The work of Carly Buchwald on this was not only from co-cultures but also field measurements, making this work / values even more valuable.

-Sentence changed to now read: This decline is consistent with N recycling and nitrification. A range in nitrified d18O nitrate values of -1.5 to 1.3‰ have been reported from nitrifier cocultures and field experiments (Buchwald et al., 2012).

Section 4.3.1: how do your D(15,18) values fit in here (Figure 4f), it seems like a missed opportunity to not utilize this data here and also to compare it to literature values.

-A couple of sentences have been added here: Alongside nitrification, D(15-18) increases from ~2 to 3-4 ‰ from AW to ArW as d18O-NO₃ decreases (Figure 4f). These D(15-18) values are still significantly lower than values reported from western Arctic basin and Siberian Sea highlighting that different processes are occurring in these regions (Fripiat et al., 2018, Granger et al., 2018). And further discussed in the following section.

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Line 386: communicating? -Changed to interacting

Figure 2: based on how the water masses have been characterized (Table 1 and the results text) I think the labelling is wrong in Panel A, I don't think they should all be ArW.

-Thank you for this comment! Two labels have been amended to read AW.

Figure 3 caption: it should be 'proportion of regenerated nitrate' not percentage in order to match the figure. -This has been amended

Figure 4: The panels need to be labeled in this figure and it seems a shame that the depth profiles of 15N-PN are not shown.

-Labels have now been added and we have also added PN and d15NPN panels to the plot (see attached fig. 1). We have also referenced these panels in the text.

Figure 5 caption: it would be beneficial to more clearly explain what is shown in panel C. The caption has been added to read: (c) d15N-NO₃ vs lnNO₃ for all samples from JR16006. The two trend lines are calculated for samples within the Atlantic Water ($\epsilon = 4.7\text{‰}$) and Arctic Water ($\epsilon = 1.8\text{‰}$).

-Labels for AW and ArW also added to 5c

Figure 6: For panels c and d, I think it would be beneficial to include the statistics in the figure caption. In addition it could help to clearly mark the ArW points, so that the reader can clearly see the points that move between the two panels, but I understand that this might make the figure too busy, if so I suggest that the authors remind the reader in the caption that ArW is associated with the lower temperatures.

-This is a good suggestion and we have edited the figure to distinguish the ArW points with the outline of each point highlighted in white.

Where do you discuss / utilize panel b in the text?

-Figure 6b is now referenced and discussed within section 4.2

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Interactive comment on Biogeosciences Discuss., <https://doi.org/10.5194/bg-2020-293>, 2020.

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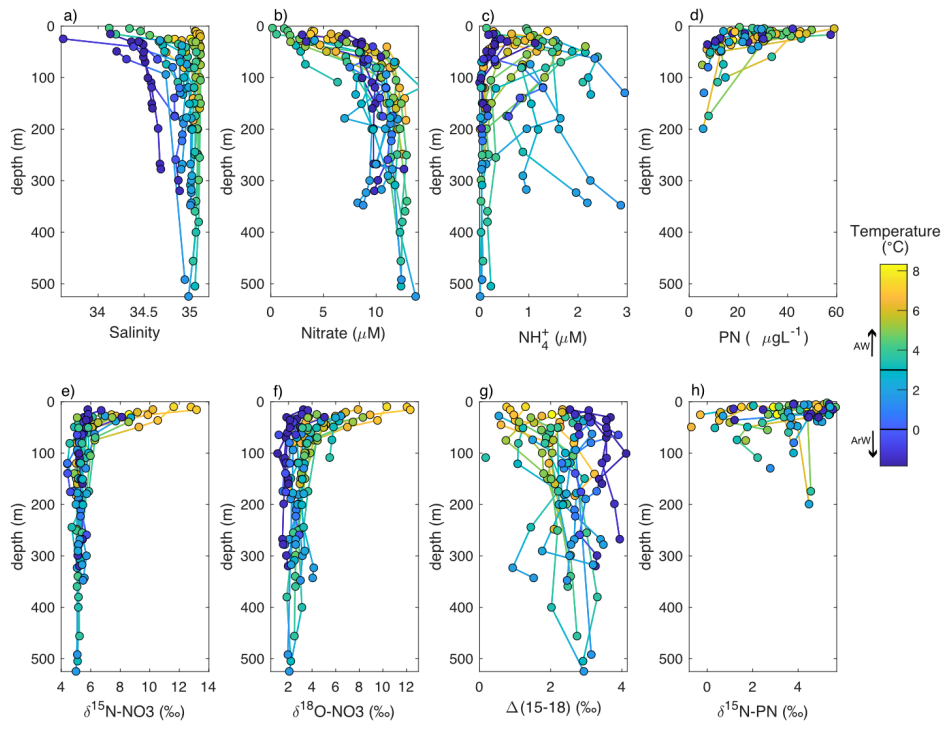


Fig. 1.