

We thank this reviewer for the many very constructive and helpful comments. Below we outline how we plan to improve the revised text in response to these comments.

Review of *'Isotopic constraints on the pre-industrial oceanic nitrogen budget'* by C. J. Somes et al. (MS No. bg-2013-6, in *Biogeosciences Discuss.*, 10, 3121-3175, 2013, doi:10.5194/bgd-10-3121-2013)

General Comments

This article is excellent in its scientific significance, scientific quality, and presentation. Somes et al. clearly and elegantly describe a dual-model (MOBI and 1- box model, '0D') analysis of the preindustrial global oceanic nitrogen budget. This analysis presents the first (to my knowledge) global ocean model N-isotope results. These results, combined with the suite of sensitivity analyses performed, provide a high level of mechanistic insight into the relative importance of modeled N-isotope fractionation processes occurring during N₂ fixation, and denitrification in the water column and within sediments. The authors identify both nitrate utilization in suboxic zones and the net benthic denitrification fractionation factor as having particularly large impacts. The model-data comparison employs a new benthic sediment d¹⁵N dataset, which serves as a useful model target. Using the model simulation that best reproduces the observational dataset, Somes et al. provide new estimates of preindustrial N₂ fixation, water column denitrification and benthic denitrification. The level of background information throughout this well-written article achieves the ideal balance of informing those unfamiliar with oceanic nitrogen cycling, while asking and addressing the cutting-edge scientific questions motivating this research.

Specific Comments

1. As this study presents a new approach to estimating N₂ fixation, it could be useful to include a brief review here of the "historical" non-model-based methods that have been used to measure N₂ fixation (and have been found to produce underestimates). (P 3123 L 17)

Response: This is briefly done later in the introduction (P 3124 L17-24). The revised text will expand on the results of Großkopf et al. (2012), *Nature Geoscience*, which suggest that previous methodological estimates of N₂ fixation are likely too low by a factor of 2.

2. In the text, diazotrophs' growth rate is described to be no longer set to zero below 15C (P 3129 L 8-11), but Appendix B contradicts this (P 3151 L

17). Please update Appendix B.

Response: We thank the reviewer for identifying this error. Our phrase in the text was incorrect and will be deleted in the revised text. Equation B4 is correct.

3. There is an inconsistency between the original range of global water column denitrification estimates given at P 3124 L 26 (50-150 Tg N yr⁻¹), and what is given in the water column denitrification model experiments section at P 3132 L 20 (70-150 Tg N yr⁻¹).

Response: The recent studies that suggest this new low-end estimate for water column denitrification of ~50 Tg N yr⁻¹ were published just before our discussion paper was submitted (Eugster and Gruber, 2012) or during the review phase (DeVries et al., 2013) so we were unable to explicitly test this new low-end estimate. This will be mentioned in the revised text.

4. Can you briefly clarify in the text (P 3135 L 21-26) that model seawater d15N is not being simultaneously adjusted when the d15N of PON reaching the seafloor is enriched by 0.9‰ km⁻¹ to account for diagenesis. It would be good to make clear that the adjustment of sediment d15N does not affect isotope conservation and is done expressly for model-data comparison.

Response: Thanks for this excellent suggestion of how to clarify the text. The revised text will clearly state that this diagenesis adjustment is only used for model-data comparison and does not affect isotope mass conservation in the model.

5. Given the range of recently reported high ϵ_{BD} values (=4-8‰), I wondered why the authors chose to not perform an additional sensitivity experiment well within this range (for example, $\epsilon_{BD} = 6‰$). This is indirectly addressed in the discussion section (P 3142 L 16-29), and at that point it is clear that the 0D model was run using $\epsilon_{BD} = 6‰$. Unfortunately, these results are not shown. Please address this choice in the text.

Response: A model experiment with $\epsilon_{BD}=6‰$ was attempted with the 3D model, but it was not possible to attain a balanced global nitrogen budget because the required rates of benthic denitrification were too high to be balanced by N₂ fixation in the 3D model. The

revised text will note this attempt with the 3D model and refer to the 0D model results that also require very high benthic denitrification rates when $\epsilon_{BD} > 4\%$ (Figure 6).

Technical corrections:

1.P 3123 L 19-20: the word “to” missing from “estimated to be”

Response: This change will be included in the revised text.

2.P 3124 L 10: ETSP has not been defined – change to Eastern Tropical South Pacific (ETSP)

Response: This change will be included in the revised text.

3.P 3124 L 17-19: the sentence starting “Estimates for N₂ fixation...” is awkward – at minimum change “predicting” to “predict”

Response: This sentence will be clearly rephrased in the revised text.

4.P 3124 L 21 – change to “found to underestimate”

Response: This change will be included in the revised text.

5.P 3127 L 17 – ‘...implicit in the model simulations that perform superior with respect to observed...’ should be replaced with ‘...implicit in the model results that most closely simulate observed...’

Response: This change will be included in the revised text.

6.P 3127, L 20 – remove ‘used’

Response: This change will be included in the revised text.

7.P 3129 L 24 - change 'to' to 'by'

Response: This change will be included in the revised text.

8.P 3130 L 22 - change 'hits' to 'reaches' or 'arrives at'

Response: This will be changed to 'reaches' in the revised text.

9.P 3130 L 26 - here the word 'parameter' is used twice - after the O₂* equation, remove 'parameter of oxygen and nitrate concentrations'

Response: This change will be included in the revised text.

10. P 3132 L 10 - insert equal signs before '~5‰' and '~30.8 μM'

Response: This change will be included in the revised text.

11. P 3132 L13 - insert 'section(s),' before 'annual mean results'

Response: This change will be included in the revised text.

12. P 3132 L 18 - remove 'given' before 'nitrate thresholds'

Response: This change will be included in the revised text.

13. P 3135 L 22 - change 'hitting' to 'reaching' or 'arriving at'

Response: This will be changed to 'reaching' in the revised text.

- 14. P 3137 L 4 – at ‘with greater’, change ‘with’ to ‘of**

Response: This change will be included in the revised text.

- 15. P 3153 L19 – First, why introduce here the labile carbon flux term F_c if it's not used in the following equation, and second, please define the RRPOC term (as in Bohlen et al. (2012): “rain rate of POC to the sea floor”). You could additionally introduce RRPOC on P 3130 L 19 after “organic carbon rain rate”.**

Response: The “labile carbon flux” term will be referred to as “rain rate of POC to the seafloor” in the revised text for consistency.

- 16. P 3140 L 18 – in ‘nitrification-denitrification loop’, denitrification is misspelled**

Response: This change will be included in the revised text.

- 17. P 3142 L 1 – remove ‘both’ (a double instance)**

Response: This change will be included in the revised text.

- 18. P 3143 L 27 – suggested rewrite: “The fact that MOBI is directly comparable to $d_{15}N$ observations in regions where denitrification occurs in the water column and sediments allows better validation of the various isotope effects.”**

Response: This change will be included in the revised text.

- 19. P 3144 L 4 – first usage of ETNP – spell out or define acronym earlier**

Response: This change will be included in the revised text.

20. P 3144 L 10 – change ‘levels’ to ‘level’

Response: This change will be included in the revised text.

21. P 3145 L 17 – change ‘is likely’ to ‘are likely’

Response: This change will be included in the revised text.

Technical corrections – Tables and Figures:

1. Table 3 – The percent symbols should be changed to per mille symbols for categories ‘Sinking PON full mean (%)’. Also, please add to the caption that observational estimates, where available, are given in parentheses (as in Table 2).

Response: These changes will be included in the revised text.

2. Figure 1 – the caption should include definitions of terms used in the schematic, as well as the Somes et al. (2010b) reference.

Response: These changes will be included in the revised text.

3. Figure 4 – add units to the y-axis (‰)

Response: This change will be included in the revised text.

4. Figure B1 – revise the x-axis label from ‘threshold value’ to ‘NO₃⁻ threshold value (μM)’

Response: This change will be included in the revised text.

