Reply to reviewers' comments: egusphere-2022-606

S Robinson *et al*.

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Title: Simulating marine neodymium isotope distributions using ND v1.0 coupled to the ocean component of the FAMOUS-MOSES1 climate model: sensitivities to reversible scavenging efficiency and benthic source distributions

Summary of Changes

Blue text below is our response to the reviewer's comments (reproduced in black). Line numbers refer to the tracked-changes version of the manuscript.

Response to reviewer 4: Torben Stichel (Referee)

This discussion paper by Robinson et al. discusses the incorporation of Nd (isotopes and elemental concentration) into FAMOUS GCM's ocean component to better understand the GLOBAL marine Nd cycle. I really like the paper and it addresses the current debate on the direction of control in Nd (and REE) distribution. Acknowledging the paper has set its focus on the sensitivity of the scavenging efficiency and benthic fluxes, it leans towards comparing itself with previous modelling studies (Rempfer et al., Siddall et al., Pöppelmeier et al). The overall reality test is done by comparing their results with a global data base. They conclude that reversible scavenging is important for the Atlantic-Pacific gradient in eNd, but again the modelled Pacific Ocean does not match the observed data there. They admit that a global constant sediment flux in the model runs could be the issue here as the Pacific Ocean supposedly provides more reactive material (young, mafic rocks) than the Atlantic, which would support different sediment fluxes within these basins. As a non-modeller, I would like to avoid evaluating the technical parts of this paper, but I would like to highlight some important aspects on the biogeochemical cycles of Nd. Overall, I found the paper very well written, a bit wordy though.

We thank the reviewer for his positive and constructive comments, which have helped us to revise the manuscript. We have also shortened the text.

I do admit, I am bit surprised that recent particle studies (e.g. Lagarde et al. 2020, Paffrath et al., Stichel et al. 2020) were very marginally used in this paper. From those studies, we now have information on eNd in particles, different mineral fractions, different kDs etc. from the same locations as the dissolved fraction. We also know that pNd/dNd unfortunately is not uniform in the ocean. Also, in the last paragraph of the discussion (lines 927 ff.), where the authors compared their model outcome with observations in the North Atlantic – the area where the aforementioned papers have their study area – the composition of particles would help to assess the NADW composition (e.g. fig.6 in Stichel et al. 2020). In the search for end member composition, the authors might want to consider the very dynamic particle composition in that area (pointing towards different sources) and not necessarily from bulk sediments. If I am not mistaken, in those papers the observational

pNd/dNd are often one order of magnitude higher in the North Atlantic, compared to the global average assumed in the modelling studies (0.001 to 0.006). Or do I miss something here? Of course, it is reasonable to assume that Pacific pNd are very much lower than in the North Atlantic and therefore the pNd/dNd is very much skewed towards lower values. This discrepancy should at least be mentioned and justified.

Done: we have included these key studies and discussion points within the manuscript (e.g., lines 1008-1010), including highlighting and discussing the simplified assumption of a globally uniform $[Nd]_p/[Nd]_d$, which is mainly a pragmatic choice in the model development.
We have also updated the discussion on the North Atlantic to include information on the provenance of particles: lines 1008-1015.

The suggested studies are important, reporting measured Kd values for Nd, alongside measuring $[Nd]_p/[Nd]_d$ in the ocean. The reported $[Nd]_p/[Nd]_d$ values in the suggested studies are a magnitude higher compared to the global average reported in modelling studies. Unfortunately, a direct comparison between the modelled and measured $[Nd]_p/[Nd]_d$ is difficult to make, here we explain why. In the observed values reported, it appears that all particulate matter is totally digested, which includes detrital particles. Thus, the measured particulate Nd concentrations cannot be compared to simulated particulate concentrations directly, because we define these in our scheme (as do other similar schemes) as the adsorbed/authigenic fraction only. This difference is most clearly visible in the bottom most stations that sampled benthic nepheloid layers. The nepheloid layers can have very high detrital particle concentrations, which explain the [Nd]p/[Nd]d ratios in these samples. "True" (or adsorbed only particulate fraction) [Nd]p/[Nd]d ratios of Nd would therefore be lower. For comparison, the particulate to dissolved ratio of Th, which is much better studied and has a greater particle affinity to particles should be between 1 and 5%.

I would like to point out another rather minor issue, which is the database used. I acknowledge that with the now very impressive global Nd data sets available, it is very convenient to cite the GEOTRACES IDP. However, the authors want to double-check whether data actually IS in the data product. For instance, large parts of the eNd from GA03 (or US-GEOTRACES North Atlantic Zonal Section) are not included in the IDP 2021 but was used a citation here. For those data sets you can find the correct citations here: http://data.bco-dmo.org/jg/info/BCO/GEOTRACES/NorthAtlanticTransect/Nd_GT10%7Bdir =data.bco-dmo.org/jg/dir/BCO/GEOTRACES/NorthAtlanticTransect/,data=data.bco-dmo.org:80/jg/serv/BCO/GEOTRACES/NorthAtlanticTransect/Nd_GT10_v8_joined.html0%7D?. I apologise for this rather shameless self-advertisement…

We think there is a misunderstanding here: the data sources highlighted by the reviewer are all included in the previous compilations referenced in our manuscript (Osborne et al., 2017, 2015; GEOTRACES Intermediate Data Product), as described in line 706-710: '*The observational data used in this assessment are from the seawater REE compilation used by Osborne et al. (2017, 2015), augmented with more recent measurements including data in the GEOTRACES Intermediate Data Product 2021 (GEOTRACES Intermediate Data Product Group, 2021) from GEOTRACES cruises (GA02, GA08, GP12, GN02, GN03 and GIPY05).*' and lines 715-718: '*The location and spatial distribution of all observational records used in this study are shown in Fig. 8, and full details of the*

seawater compilation including a full list of all the references for the data sources are provided in Supplementary Information: Table S3.'

We realise that citing the full list of original data sources and methods papers would be preferable, but such a list comprises too many references (141 in Table S4) to all be included here. Hence in the main text we cite the published compilations that include the original studies – Osborne et al., (2017, 2015), which includes the ε_{Nd} from GA03 (e.g. Stichel et al., 2015*), plus the additional cruises in the GEOTRACES Intermediate Data Product 2021 (which adds in ε_{Nd} from cruises GA02, GA08, GP12, GN02, GN03 and GIPY05) – and in Table S3 we have attempted to adequately reference the original work. It would be better if journals had a way of indexing original data sources when a data compilation is cited in order to correctly attribute the credit (e.g. if we could link the citations in our Table S4), and we would certainly welcome any innovation to implement this.

*Stichel, T., Hartman, A., Duggan, B., Goldstein, S.L., Scher, H. and Pahnke, K. (2015). Separating biogeochemical cycling of neodymium from water mass mixing in the Eastern North Atlantic. Earth and Planetary Science Letters, 412:245-260.
The other two citations included at the referenced web page (Hartman et al. and Duggan et al.) are listed as 'in prep', and we have been unable to find them elsewhere (e.g. with a Google scholar title or author search)

I fully support the publication of this paper eventually. It is an important work and will be key for a better understanding of the Nd cycle as it is one of (if not) the most complete modelling papers for marine Nd isotopes and concentrations. The supplement's profound eNd/YREE data set is also great! Thanks for providing this with your publication.

Thank you very much for the positive comments, a lot of work has gone into this, and it is gratifying to see it so well received.