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 3: Ed Hathorne (Referee)

This paper describes the results of a model of the marine Nd cycle implemented in the ocean part of the fast climate model derived from the Hadley center GCM. The use of such a model for simulating the Nd isotopes of seawater is a useful development as the fast run times allow more experiments to be conducted, although care must be taken that the ocean circulation is resolved correctly as this is what we hope to trace with Nd isotopes. From the standpoint of a geochemical oceanographer this paper is very interesting because it directly tests the hypothesis that the distribution of Nd isotopes in seawater is mostly controlled by a flux from marine sediments, sometimes known as the "bottom flux hypothesis". Along with other models of the marine Nd isotope cycle published very recently, this work affords many insights into the processes that are likely, and unlikely, to control the distribution of Nd isotopes in seawater. The discussions paper is rather long but with some editing, clarification in places and discussion of the other very recently published works, I would gladly recommend this for publication.

We thank the reviewer for his positive comments. His and other reviewers' specific comments have been valuable for making the presentation of this work even stronger in the revised manuscript.

This could be an important contribution as the authors have the most up to date data compilation available, but this should be utilised throughout. For example, in Figure 9 the global marine Nd inventory of 4.2 x10^12 g from Tachikawa et al. (2003) is used to assess which reversable scavenging scenarios are realistic. Although this ground breaking study is clearly still relevant, many samples have been taken and measured in the intervening decades as shown in Figure 8. Would it not make sense to estimate the marine Nd inventory with all the available data? Perhaps it will make little difference but in 2003 there were very few data available for the entire Southern Ocean and North Pacific (Table 1 in Tachikawa et al., 2003).

This is an interesting point, and we fully support the suggestion to calculate a new marine Nd inventory with all the available data, updating the estimate made by Tachikawa et al. in

2003. However, to do this robustly is a big piece of work that goes beyond the data compilation and model results presented here. This is because it requires precise characterization of water mass Nd with a sophisticated interpolation between discrete point measurements that accurately distinguishes (in 3D space) the different water masses of the global ocean (and some oceanic regions remain sparsely measured). A potentially useful way to undertake this activity would be within the framework of a multi-model intercomparison, using the output from multiple models all running the same careful experiment design in combination with the observations to characterise global ocean Nd. This could even be achieved without activating an Nd isotope scheme, for example, using the ensemble of CMIP6 historical simulations to identify distinct water mases and their mixing, and combining this ocean structure with our presented catalogue of seawater measurements. Such a substantial undertaking would be a very useful piece of research, but it is beyond the scope of our study.

In light of this, we will continue to use the estimate by Tachikawa et al. (2003) as the best available 'target' [Nd] inventory for evaluating our global budget. However, we can also report an independent estimate of the global Nd inventory, which we derive from our best performing simulation for [Nd], EXPT_SED2, based on it returning the lowest MAE and RMSE with respect to our newly compiled [Nd] database. Furthermore, we can provide a basin-by-basin breakdown of that budget, noting that the total [Nd] from this best performing simulation is likely an underestimate because of missing marginal seas in our model. Whilst subject to the model's limitations, this estimate does have the advantage of having used FAMOUS to undertake the complex task of producing a globally continuous marine Nd field, and it does make use of the updated catalogue of observations, since this is what has been used to evaluate the model's performance and identify the 'best' simulation.

We have edited the text (Section 3.2, lines 1375-1386) and added Table 4 (shown below) to the main text to include this new result.

Ocean Region	Nd inventory (Tg)
Global	3.89
Arctic Ocean	0.05
North Atlantic	0.33
South Atlantic	0.45
North Pacific	0.96
South Pacific	0.76
Indian Ocean	0.63
Southern Ocean	0.28

Using these realistic reversable scavenging values (can it please be clarified if this is also 100% released like in Tachikawa et al., 2003?) a very simple universal sediment flux is tested.

In the scheme, biogenic particles follow dissolution profiles, when the particles dissolve 100% of the Nd associated with the particles is released back to seawater.

Although it is very interesting that this fails to simulate the tails of the observed data, both radiogenic in the Pacific and unradiogenic in the N Atlantic, this is not proof that the bottom flux hypothesis is wrong. Assuming a constant flux over the entire ocean bottom is clearly unrealistic and this point should be clearly stated. With rare earth element concentrations >2 times that of shale, the red clay sediments covering large parts of the abyssal Pacific (e.g. Kato et al., 2011, Nature Geoscience 4) are most likely a sink for Nd. Here and also in areas influenced by hydrothermal particles (German et al., 1990, Nature 345, 516-518) the bottom flux is likely to be negative. The fact that Pasquier et al. (2022) use a parameterisation which increases the sediment flux at both radiogenic and unradiogenic extremes of sediment composition should be mentioned in the context of a constant bottom flux not simulating the highest and lowest seawater values.

Done: we have modified the text to clarify our discussion, pointing to the literature and other modelling studies to explore the need for more precise constraints on the benthic source, highlighting the diverse sedimentary regions/environmental conditions that may drive enhanced benthic fluxes or act as effective sinks. See lines 1555-1559 for a discussion on the benthic processes in Pacific red clays.

Detailed comments and suggestions are provided in an annotated PDF. I still hope publishers will provide a tool for extracting comments from PDFs. Please also note the supplement to this comment:
https://egusphere.copernicus.org/preprints/2022/egusphere-2022-606/egusphere-2022-6 06-RC4-supplement.pdf

Thank you! We have used the annotations to improve the text throughout.