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 2: Catherine Jeandel (Referee)

The manuscript egusphere#2022-606 proposes the implementation of the oceanic cycles of the Nd isotopes (143 and 144) in the FAMOUS-MOSES1 climate model. There are interesting novelties in this work as 1) the use of the detailed epsNd map established by the author and comprising the bottom sediment signatures (Robinson et al, 2021); 2) exhaustive sensitivity test of two main parameters driving Nd and epsNd cycles: the reversible scavenging and the external flux, mostly the sediment one here. Actually, this represents a tremendous work; the manuscript is well written (although sometimes a bit wordy) and illustrated. It certainly deserves publication in *egusphere*. Nevertheless, I have some comments that I submit here to the authors.

We thank the reviewer for her kind comments recognising the effort of the work presented.

- Sediment flux vs Boundary Exchange (BE) processes

I think there is a misunderstanding or a confusion between these two terms that needs tobe clarified.

At several places in the manuscript, it is written that sedimentary flux is encompassing Boundary Exchange (e.g lines 250-255, around 345 but also 998-1000 and at other places highlighted in the manuscript) while to me, it's the opposite (ie BE is encompassing sedimentary flux, down to 3000 m -which is already deep!) in our preceding works

"Seafloor sedimentary fluxes, an umbrella term that refers to a multitude of processes encompassing boundary exchange (Lacan and Jeandel, 2005), submarine groundwater discharge (Johannesson and Burdige, 2007), and a benthic flux released from pore waters (Abbott et al., 2015a), are simulated via a combination of a sedimentary source applied across sediment-water interfaces together with a separate sink occurring via particle scavenging"

I suggest to write this paragraph differently (as well the other places where it's a bit confusing, identified in my direct comments in the pdf). Indeed, when we proposed the "BE Concept" with F. Lacan (EPSL, 2005), we did not pretend to describe any specific processes that occur at the land-ocean interface and more specifically along the margins because we could not differentiate them. Later, I listed the potential processes that could explain the "BE (Jeandel, 2016). In other words, "BE" broadly comprises all the processes that could release Nd from the solid to the liquid but also those which would scavenge it, more or less at the same time and in the same area (note that this comprises reversible scavenging too!). More recently, one of the conclusions of the PAGES-GEOTRACES workshop (2018) pushed by Martin Franck was to "kill the BE", in other words to disentangle these processes, among them the seafloor sedimentary fluxes (either through early diagenesis or dissolution of resuspended sediments), low temperature hydrothermalism, SGD, benthic fluxes etc...

The point here is that the authors removed the depth limitation of 3 km which was forcing the model to consider sedimentary fluxes along the margins only. But the sedimentary flux they consider are occurring everywhere including along the slopes. This does not mean that the Sed Flux (a specific mechanism) encompasses the BE (a broader concept).This just means that this flux is extended to the whole ocean in the proposed work.

Done: we have updated the definition of the boundary exchange in the introduction, and throughout the text to:

'The term 'boundary exchange' was then coined to describe significant modification of Nd isotopic composition by the co-occurrence of Nd release from sediment and boundary scavenging, without substantially changing [Nd] (Lacan and Jeandel, 2005).' (e.g. line 91-93).

- 'Top down' vs. 'bottom-up' processes (issue linked to what is discussed by Reviewer 1)

I'd cautiously use this opposition which was never clear to me (and I had long debates with B. Haley on this issue). By the way, the earliest Nd budgets proposed 2 sources: dissolved rivers and hydrothermal (see the historical works of Goldstein, O'Nions etc…). To my knowledge, hydrothermal is not "top down". Consider now the most recent budgets: most of them invoke "Boundary exchange" which includes processes that occur in the deep waters, down to 3000 m depth (see above), in other words they include "bottom processes". Thus, although I agree with what is written line 103 and after (reported below), it seems to me that this was not "new" because the *benthic* flux is occurring at any place where there is a contact between sediment and water, in other words everywhere from the beach to the deepest parts of the ocean. Again, there is a confusion between the processes and the location. Thus, I strongly suggest to the authors to be cautious here. What was "new" is that it could concern sediments below 3 km depth.

"Recent pore fluid concentration profiles measured on the Oregon margin in the Pacific Ocean indicate that there may be a *benthic* flux of Nd from sedimentary pore fluids, presenting a new, potentially major seafloor-wide source of Nd to seawater (Abbott et al., 2015b, a)."

Done: we have removed the 'top down' vs 'bottom up' statements from the manuscript and replaced with more detail on the processes under each statement. For example, line 1604-1607: '*This could be interpreted as evidence against a globally widespread benthic flux driven model of the marine Nd cycle with a spatially constant flux across diverse sedimentary environments in favour of the more distinct* $[Nd]_d$ *distributions that may be achieved under a model of marine Nd cycling with larger and more heterogenous surface and near surface Nd sources, and a greater dominance of reversible scavenging*'

We have updated the sentence mentioned to be clear that recent benthic flux measurements have led to the suggestion that the sedimentary fluxes are no longer limited to the continental margins, lines 142-144: '*Recent pore fluid concentration profiles measured on the Oregon margin in the Pacific Ocean indicate that there may be a benthic flux of Nd from sedimentary pore fluids, presenting a potential major seafloor-wide (i.e., no longer limited to the continental margins) source of Nd to seawater (Abbott et al., 2015b, a).*'

- The choice of the Ndp/Ndd ratio to conduct the Fsed sensitivity test.

I did not understand why the authors did not kept the value of 0.004 instead of that of 0.003 to do these sensitivity tests. Indeed, as underlined in Table 5, the value of 0.003 leas to residence times larger than 1000 y, leading to more moderate range of 40 years difference in the *f*sed simulations Nd

I did not see a clear justification of this choice in section 3.1 and would be keen to see the same sensitivity tests but with the Ndp/Ndd ratio of 0.004, which was the most consistent with the data.

Done: we have added further clarification to our explanation of this in lines 827-834. To paraphrase: due to the computational demands, all simulations were run in parallel, and hence we had to decide the $[Nd]_p/[Nd]_d$ value before we had the results from the $[Nd]_p/[Nd]_d$ sensitivity experiment. Our choice of 0.003 is in the middle of the range (0.001-0.006) identified by previous modelling studies (Rempfer et al., 2011; Arsouze et al., 2009; Gu et al., 2019) and direct observations (Jeandel et al., 1995; Stichel et al., 2020; Zhang et al., 2008; Lagarde et al., 2020; Paffrath et al., 2021). Now that we have the results from the $[Nd]_p/[Nd]_d$ sensitivity experiment, we can see that 0.004 would have been a better choice, and propose that future work to refine model performance begins with this.

- **The discussion on the reasons leading to epsNd modelled profiles that do not fit the data** is often too shy and not clear enough. Perhaps the sedimentary flux is too strong? Or the choice to attribute a constant flux for the deepest (bottom) and shallowest sediment (margin) is not appropriate? This is well exemplified by Figure 17 and the discussion lines 930-950. What would happen if the Fsed would allow differentiating the strength of the SedFlux deposited on the margin (fresh deposits fromrivers, easy to remobilize) vs that of the bottom (too strong, "counterproductive" as it is written line 942)?

Done: also to address a similar comment from Reviewer 1, we have updated the discussion to include additional arguments to explain model-data offsets, including suggestions that the too low [Nd] in the surface may be a result of too weak surface sources (dust, rivers and continental margins), and too high [Nd] at depth may be due to too strong sediment source

(especially due to the globally uniform Nd source escaping all sediment-water interfaces).

- **Minor comments:** they are highlighted in the attached pdf. I also identified some unit issues and rare typos but they are already listed by B. Pasquier (who I thank for the exhaustive list!).

  Done: many thanks – we have addressed these.

As a whole, I'd also suggest to the authors to shorten the manuscript by 10%-15% if possible.

Done: we have shortened the main text in the revised version by 10 % (cut >1,200 words) following revisions to focus the presented points.

Please also note the supplement to this comment:
https://egusphere.copernicus.org/preprints/2022/egusphere-2022-606/egusphere-2022-6

Thank you - we have used these annotations to correct and revise the manuscript.