Geosci. Model Dev. Discuss.,
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Geoscientific Model Development Discussions

GMDD

Interactive comment

Interactive comment on "A global scavenging and circulation ocean model of thorium-230 and protactinium-231 with realistic particle dynamics (NEMO–ProThorP 0.1)" *by* Marco van Hulten et al.

Anonymous Referee #3

Received and published: 7 January 2018

Scientific Significance

The authors present a model for scavenging of thorium-230 and protactinium-231 that adds more realistic particle dynamics. In particular, they have added two size classes for most particles and have added lithogenic particles. Sedimentary records of thorium-230 to protactinium-231 ratios hold the promise of determination of past Meridional Overturning Circulation speed, not just extent. Understanding and quantifying the process of scavenging and sedimentation of these isotopes will enhance our ability to interpret this unique record. Thus, the paper potentially represents a substantial contribution to modelling science. Potentially because one critical assumption is not sufficiently well justified in the current manuscript (or perhaps, cannot be made).

Scientific Quality

1. I do not believe that one of the central assumptions is justified. You assume that the absorption and desorption rates are much faster than the settling of the absorbed phases. This is marginally true for small particles sinking at 2 m day^{-1} but is not at all true for particles sinking at 50 m day^{-1}. Considering just Thorium, desorption rates are on order of 1 yr^{-1} (e.g. Bacon and Anderson, 1982). Considering the full depth 5000 m deep ocean, the time scale for sinking for big particles is 100 days.

   To determine if this actually matters, I considered the case of a single particle type and no mixing or advection, just sinking and scavenging. This allows an analytic solution:

$$A_{i,B} = \beta_i \frac{z}{w_B}$$

$$A_{i,D} = \frac{k_d}{k_a} A_{i,B} + \frac{\beta_i}{k_a}$$

   where k_a, k_d are the absorption and desorption strengths, respectively.

   If we assume instant equilibrium, the ratio of $A_{i,D}/A_{i_B}$ is k_d/k_a. However including the sinking there is a second term so

$$\frac{A_{i,D}}{A_{i,B}} = \frac{k_d}{k_a}\left(1 + \frac{w_B}{k_d z}\right)$$

   If I plot the last term in the brackets using a sinking rates of 2 and 50 m day^{-1} and a desorption rate of 1 yr^{-1} I get the results plotted in my attached figure. For the slower sinking rate, the ratio is always greater than 1, the equilibrium value, and for all depths below 1000 m is smaller than 2; potentially acceptable given all the other assumptions. However, for the larger sinking rate the ratio is always greater than 4 and reaches 10 at 2000 m depth.

The authors must either justify in detail why the assumption is valid (and thus explain why my analysis is in error) or include the absorption/desorption process.

2. Why did you chose 20% small and 80% large for your lithogenic particles?

3. pg 16, last line : "These discrepancies .... arise from the different speeds for each type of particle" But don't all big particles sink at the same rate? I think you could make this more clear but adding columns to Table 4: small Litho, big Litho, total Litho etc.

4. pg 22 Lines 10-20: also consider including Luo et al (2010) in this discussion as their simple model allows one to see the impact more easily

Scientific Reproducibility

The authors explain most of the methods well but there are some questions I could not find answers to.

1. How long was the NEMO-OPA model run? Was a single year of forcing used repeatedly? If so, what year? If not, what years of forcing were used?

2. Was an ice model included?

3. Please include the fourth order equation for $CaCO_3$ dissolution.

4. I don't think you actually code equation (5). If I'm correct, please give the equations you actually code.

5. Under Simulations, first sentence “The model” please specify that this is the PISCES+tracer model.
6. Please include a run table, showing your physical run, your spin-up and your two analyzed runs.
7. Link biogenic silica and opal, in case your readers don’t understand you are using them interchangeably.
8. Where does one get the new scavenging model?

Presentation Quality

The manuscript wording is generally clear (though see 11 and 13 below). However, a bit more work on the writing would improve this manuscript. I have listed some points below but this is not an exhaustive list.

1. pg 1, l 19 “and the carbon”
2. Fig 1 “triple”
3. pg 5, l 7 “corresponding to”
4. pg 5, l 14 “(e.g. Van Hulten et al, 2013)”
5. pg 9, l 22 “a large number of measurements”
6. pg 9, l 23 “on this transect”
7. Table 3: over run on second last line.
8. pg 11, l 5 drop “thereof”

9. pg 11, l 11 “water sinks down”
10. pg 11, l 12 “Antarctic”
11. pg 12, l 10 “whereas we only have small particle data for the Atlantic Ocean"
12. pg 14, l 6 drop “as well”
13. pg 15, l 14 “Globally in the model,”
14. pg 16, l 12 “discrepancies”
15. pg 19, l3 or 18 depending how you count! “POC accounts for only”

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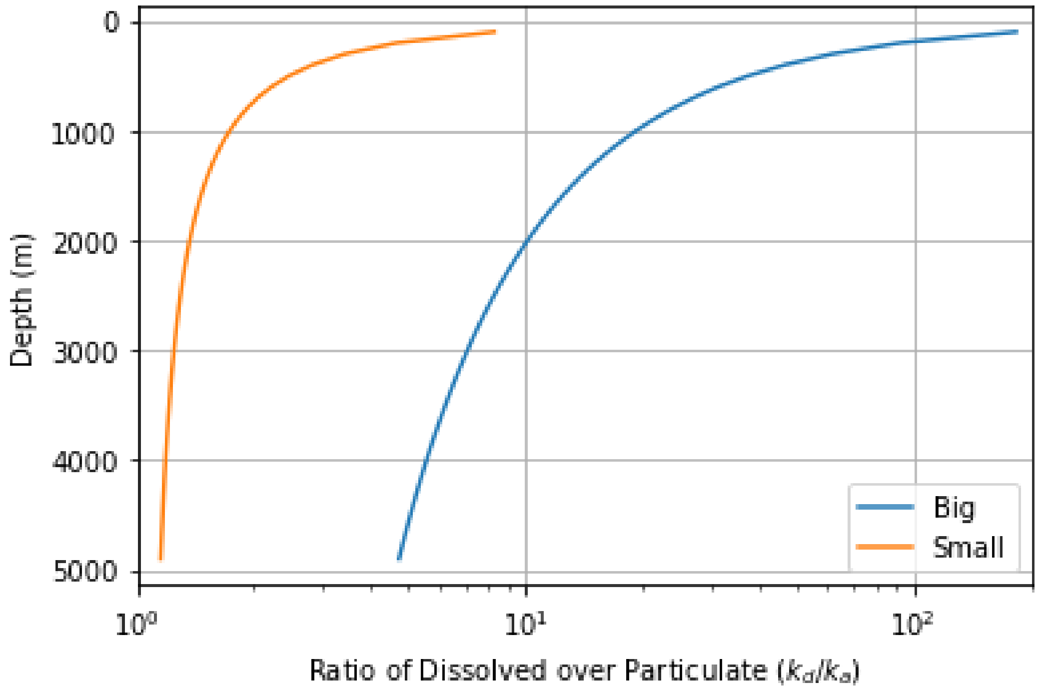

Fig. 1. Ratio of Dissolved to Particulate Isotope

Interactive comment

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Discussion paper