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Interactive comment on "^{231}Pa and ^{230}Th in the ocean model of the Community Earth System Model (CESM1.3)" *by* Sifan Gu and Zhengyu Liu

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We thank the reviewer for his/her time for constructing the comments.

In the following, we have addressed all comments, with the original review text underlined in italics and red.

"The paper 231Pa and 230Th in the ocean model of the community Earth system model (CESM1.3)" by S. Gu and Z. Liu is presenting the implementation of 231Pa and 230Th in their general circulation model. It is mainly following the procedure defined by previous work Siddall et al (2005) and Dutay et al (2009). The implementation of the tracers in the model is described and results are compared to observations. However some severe weaknesses are found in the manuscript. The comparison with

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Discussion paper

observation is insufficient, it is strictly following the analysis performed by Siddall et al in 2009, while It now exists , thanks to the GEOTRACES project, new data set. Moreover, the paper do not only show the implementation of the tracer in the model and its validation, which is the scope of the GMD journal, It also propose the response to hosing experiments that is paleoclimate studies that are application that are not devoted to this journal, Climate of the past would be a more appropriate journal if this study was more correctly analysed. For all these reasons I propose to reject this paper from publication in GMD."

Thanks for pointing out the new data set provide by GEOTRACES. In our revised manuscript, we include this new data set. A recent study by Rempfer et al., (2017) shows 231Pa and 230Th in Bern3D model. We also compare our results with theirs. The results in the hosing experiment is an example to show the advantages of our model. The interpretation of sediment 231Pa/230Th as a paleo proxy for reconstructing AMOC has been questioned because it will also be influenced by particle flux change. Our model includes two versions of 231Pa and 230Th, which can help to detangle these two effects. The hosing experiment is an example to show that with these two versions of 231Pa and 230Th, our model is able to help the interpretation of paleo 231Pa/230Th reconstructions. GMD encourage submissions with "tangible and potentially useful advance related to model development" (Editorial 1.1, Introduction) and we think the content in the hosing experiment fits this scope.

"Specific comments: Page 4 section 2.2. The authors show particle flux surface horizontal distribution without concrete comparison with observation. This diagnostic is interesting but it is not sufficient for the proposed study. The model uses particle concentrations and results are strongly dependent to the quality of these fields. It now exist observations to validate the particle fields (Lam et al, 2015) that were not available for Siddall et al (2005) and Dutay et al (2009). A more detailed analysis of the vertical particle concentration distribution at large scale is required."

The particle fields used in this study is generated from the ecosystem module of the

CESM, which has been validated extensively in previous studies (e.g. Doney et al., 2009; Long et al., 2013; Moore et al., 2002, 2004; Moore and Braucher, 2008). The export production is similar to satellite observations in both pattern and magnitude (Sarmiento and Gruber 2006). Global average POC concentration is 2.6*10-6 kgC/m3; CaCO3 is 1.1*10-6 kgC/m3 and opal is 3.9*10-6 kgSi/m3, consistent with Rempfer et al., (2011). Therefore, the particle fields in CESM is more or less right, although regional discrepancies from observation may exist. We appreciate the reviewer's suggestion to validate the performance of the ecosystem module of the CESM with new data. But our focus of study is the Pa/Th in the model.

Also, we show the distribution of particle fields to help the discussion of sediment 231Pa/230Th, which is influenced largely by particle distribution. Compare with Siddall et al., 2005, Dutay et al., 2009, and Rempfer et al., 2017, all models use particle fields generate from different models (but the general patterns are the same) but yields similar 231Pa and 230Th results.

"Page 5 section 2.3 Abiotic and Biotic name for simulations are not appropriate. These names suggest that the tracers are subject to different processes while it is not the case. The two approaches are the same except that the particles fields are fixed in the Abiotic run. None biogeochemical process affects the tracer except adsorption and desorption onto particles, so the appellation Biotic run seems exaggerated. Line 162: No validation of particle fields is preformed while it affect strongly the model results. Observations are now available (see for instance lam et al 2015)"

Thanks for pointing out this inappropriate usage. We have renamed the version which is coupled to the ecosystem model as "p-coupled" and the version which uses prescribed particle fields as "p-fixed".

"Pages 7 and 8 section 4, results Definition and way of estimation of the residence time given for the tracers should be explained."

The residence time is calculated as the ratio of global average total isotope activity and the radioactive ingrowth of the isotope. The way of calculated is used in Rempfer et al., (2017) and Yu et al., (1996). We add this in the revised manuscript (line 248-249).

"Comparison of Atlantic zonal averaged model results with observations is no more adequate. It is strictly following analysis performed by Siddall et al (2005) and Dutay et al (2009) a decade ago, but now many new observations are available in the different basins thanks to the GEOTRACES program. This validation is not appropriate any more. Discussion concerning the ratio 231Pa/230Th is very poor. More detailed analysis must be given. For instance what causes low ratio in the north atlantics south of Grennland: convection?"

With the new GEOTRACES data, we update the model data comparison with two GEOTRACES transects in the Atlantic (Fig.2 and 3). This is a more appropriate comparison than Atlantic zonal mean figure.

The large-scale feature of sediment 231Pa/230Th is small value in North Atlantic and large value in the Southern Ocean discussed in line 282-293. Regionally, the distribution of sediment 231Pa/230Th is controlled by particle distribution (especially opal) due to the particle flux effect (line 56-58). The low values south of Greenland at about 50N is because of this particle flux effect (line 293-296). Opal production is larger in both south and north of this region. Therefore, the particle flux effect will transport 231Pa out of this region, resulting lower sediment 231Pa/230Th in this region and higher sediment 231Pa/230Th north and south of this region.

"Page10 and 11. This part is already an attempt to use the model development for scientific question. It is not the purpose of GMD papers. This part should be more deeply analysed and submitted to another more appropriate journal (eg climate of the past)"

The purpose of implementing 231Pa and 230Th in CESM is to provide a tool to better interpret sediment 231Pa/230Th reconstructions. The advance of our modelling study compared with previous studies is that we have two version of 231Pa and 230Th to separate the circulation effect and particle effect, both of which will change in response to freshwater forcing. Section 4.3 is to examine this model feature and show that although circulation effect dominates sediment 231Pa/230Th over low productivity regions in the North Atlantic and on long time scale, particle effect can be important over high productivity region and on short time scale. This part is an example to show the model advantage to detangle these two effects and therefore we think it is important to include this part to demonstrate our model advantage.

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