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Interactive comment on “Sediment $^{231}\text{Pa}/^{230}\text{Th}$ as a recorder of the rate of the Atlantic meridional overturning circulation: insights from a 2-D model” by Y. Luo et al.

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The model simulations of Luo et al. provide useful insights and constraints for using sedimentary Pa/Th ratios as a proxy for past changes in Atlantic Meridional Overturning Circulation. As such, the paper should be published. However, I recommend that the authors include a more extensive discussion of the limitations of their modeling approach in revising the paper.

Most important, the model has no representation of lateral mixing. As such, the model tends to overestimate lateral concentration gradients that are otherwise reduced by lateral mixing. For example, Chase et al. (2003; cited by Luo et al) showed that there is

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no detectable meridional gradient in the concentration of ^{231}Pa or of ^{230}Th across the “opal belt” of the Southern Ocean when data are compared along isopycnals, indicating that lateral mixing smoothes out any concentration minima associated with enhanced scavenging under the region of high diatom production. Similarly, I pointed out at the GEOTRACES model-data synergy workshop, attended by Luo, that the dissolved Pa/Th ratio in deep water exhibits no detectable change along the flow path of the “deep conveyor”, from the North Atlantic to the North Pacific Ocean. This, too, must reflect a strong influence of lateral mixing on deep-sea dissolved Th and Pa distributions.

My strongest recommendation for changes to the manuscript of Luo et al. prior to publication is to add text discussing how the model results would change if lateral mixing were included.

DETAILED COMMENTS:

1) p. 2757, lines 15-16: Clarify here that the statement about sedimentary Pa/Th ratios being about half the production ratio (0.093) refers to the average for the North Atlantic Ocean. Sedimentary Pa/Th ratios at individual N Atlantic sites vary from approximately 0.03 to 0.14.

2) p. 2761, eqn. 4, and elsewhere: Clarify that the representation of the fractionation factor (F) expressed here is numerically equivalent to the original definition by Anderson et al., (1983; EPSL V62, pp. 7-23; EPSL V66, pp. 73-90), although the arrangement of the terms is different.

3) p. 2761, line 27: Doesn’t the expression for $[\text{X}]p/[\text{X}]d$ require a term for the concentration of particles?

4) p. 2765, lines 3-4: See comment 2 above in referring to the original definition of F as well as to document the original measurements of F .

5) p. 2768, line 16: The modeled fraction of Pa associated with particles, described here, seems a little high for two reasons. First, although they are not yet published,

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results from the GEOTRACES intercalibration exercise for a depth of 2000 m at the Bermuda/BATS site suggest that particulate 231Pa represents about 1% of the total, not 4 to 5% as indicated here. Second, if about 20% of the 230Th is associated with particles and F (fractionation factor) is about 10 then one expects about 2% of the 231Pa to be associated with particles. It may not be necessary for Luo et al. to make any changes to their manuscript; I just wanted to make sure that they are aware of these points.

6) p. 2768, line 21, and Figure 11: Note that in the caption of Figure 11, “western” should be changed to “eastern” when referring to Scholten’s data.

7) p. 2770, lines 10-15 & 24-27: Important points!

8) p. 2771, line 6: change “that” to “than”

9) p. 2771, line 13 and Figure 13: The units in Figure 13B are illegible in my copy. Please ensure that all graphics are legible.

10) p. 2772, lines 3-8: Very important point, here!

11) p. 2772, lines 15-17: I think the statement that the residence time increases linearly with depth is incorrect, because the definition of residence time is incorrect. Residence time (t) should be defined as $[\text{concentration}] / (\text{total rate of supply})$. Here, the authors define residence time as $t = [\text{concentration}] / (\text{production by U decay})$. However, desorption from sinking particles contributes to the overall source too, so residence time should be expressed as: $t = [\text{concentration}] / ([\text{production}] + [\text{desorption}])$. If that formulation is used, then the residence time remains constant with depth rather than increasing with depth.

12) p. 2772, lines 20-21: Here the authors infer that dissolved Pa/Th ratios decrease with increasing water depth due to the lateral advection of ventilated deep water from the high-latitude source in the North Atlantic. However, dissolved Pa/Th ratios also decrease with depth in the North Pacific Ocean, where there is no comparable lateral

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advection of ventilated deep water. While lateral advection of ventilated deep water may contribute to the trend of decreasing dissolved Pa/Th ratios with increasing water depth, results from the N Pacific indicate that other factors may be involved as well, and this should be acknowledged.

- 13) p. 2773, line 11: change “a” to “an”
- 14) p. 2774, lines 5-9: Very important point!
- 15) p. 2775, all of Section 7.1.5: Would these conclusions be changed if one considers lateral mixing? See general comments at the beginning of this review.
- 16) p. 2777, line 1: “opposite effect” on what? The meaning of the comparison here is unclear.

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