Reply to O. Marchal's comments

Major comments:

1) Our approach is clearly different from earlier modeling studies investigating the distribution of 231Pa and 230Th in the ocean. As suggested by the reviewer, we have removed the word "circulation" from the description of our model in the abstract, introduction and caption of Fig. 1. Clearly, ours is not a "circulation" model and this specifically distinguishes our approach from earlier modeling studies.

The goals of our study are very simple. They are (1) to establish the patterns of $^{231}Pa/^{230}Th$ distribution in the water column and sediment that can be generated by a simple overturning circulation, (2) propose possible explanations for some of the existing field observations in the water column and sediments, (3) provide a baseline for further evaluating the influence of the other factors that affect the distribution of $^{231}Pa/^{230}Th$ in the real ocean, and (4) develop a sampling strategy to maximize the information on paleocirculation that could be obtained form a very limited sediment database. While investigating the distribution of Pa and Th in circulation models based on dynamical principles is important, such an approach would not serve our purpose. The only constraint that we need to pay attention to regarding our circulation schemes is volume conservation. Whether they are dynamically feasible is beyond the scope of our study. All we want to document is the Pa/Th patterns they would generate if they were occurring.

We have more clearly defined our objectives in the introduction.

The velocity field that we chose is based on the meridional overturning transports for the North Atlantic reported by Talley (2003). We have reworded our section 2.2. to make this clearer.

2) Statistical analysis: Our 2-D model is not going to reproduce data from a 3-D ocean precisely and it is not clear to us what useful information would a RMSE statistical analysis provide. Again, our purpose is not to develop a model that constrains ocean circulation based on Pa/Th data but to establish qualitative Pa/Th trends generated by our prescribed circulation scheme.

3) Our approach is not suitable to provide sampling guidelines for the GEOTRACES program. Such purpose would be better served by developing a full 3-D model based on more realistic circulation dynamics.

4) Missing references have been added at the end of the introduction and in the text.

Minor comments:

1. We have defined Δ to be the upwind flux. We introduce a new notation to make the finite differencing in the vertical clear.

2 Done

3 Added “essentially constant”

4 It is not obvious how a nepheloid layer would increase scavenging in bottom water if the sediment that are deposited on the seafloor are already in equilibrium with bottom water. That seems only possible for radioisotopes with short half life (e.g. ^{234}Th, ^{210}Pb) which would rapidly decay upon burial. For the longer lived ^{230}Th and ^{231}Pa, enhanced scavenging in bottom water could only happen if the resuspended sediment is tens of thousand of years old (thereby allowing for decay of a substantial fraction of the radioisotopes initially adsorbed by the settling particles).

5 δ^{13}C (or Cd/Ca) is not exactly a water mass tracer. Only preformed d13C is. In the Atlantic, because preformed nutrient concentrations dominate over regenerated nutrient concentration, δ^{13}C is essentially a water mass tracer. On the other hand, if regenerated nutrient concentrations were the dominant component and if the rate of nutrient regeneration was well established, then δ^{13}C would become a kinematic tracer. The same applies for sediment Pa/Th. Here, however, “preformed Pa/Th” is less important in dictating the Pa/Th of seawater. Instead, changes in Pa/Th are generated along the path of the AMOC and are dictated by the rate of the AMOC, following fairly well established principles based on the reversible scavenging model. It is therefore a kinematic tracer.

6 Done

7 Deep Western Boundary Current added. Enhanced particle scavenging in the nepheloid layer cannot account for the lower 231Pa concentration in the western South Atlantic (see reply to comment 4)

8 This explanation is provided in section 5.6: “We can calculate sediment ^{231}Pa/^{230}Th at equilibrium with bottom waters using $[X]_p/[X]_d = K_1^X/K_{-1}^X$ for ^{230}Th and ^{231}Pa (Fig. 9i)”

Table 3: “Equilibrium” Fractionation Factors used in the model (derived from the adsorption and desorption rate constants listed in Table 1).

Fig. 14&15 & 17: units are 10^5 m/y and correct. Red symbols represent the depth of maximum lateral velocity (a), minimum Pa/Th (b) and latitude of minimal Pa/Th (c). This has now been added to the figure captions.