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Interactive comment on "The ^{226}Ra-Ba relationship in the North Atlantic during GEOTRACES-GA01" *by* Emilie Le Roy et al.

Anonymous Referee #1

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The authors present a study of seawater 226Ra and Ba in the North Atlantic along the GEOTRACES GA01 transect across regions that involve different water masses mixing as a crucial part of the global ocean circulation. The purpose of this paper is to improve our understanding of the relationship between 226Ra and Ba, two commonly used tracers in studying large-scale ocean circulation, and to investigate their conservative/non-conservative behaviours in the study areas. It has been a long-standing debate over the last few decades about the non-conservative behaviours of seawater 226Ra and Ba and how such behaviours restrict the use of 226Ra and Ba as conservative tracers in the large-scale ocean circulation. I think the paper has nicely approached these issues with their new dataset in the North Atlantic. The authors also use the OMP model to identify any anomalies associated with additional inputs or removals of 226Ra and

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Ba in different regions, although I think that in most of the cases the anomalies cannot be precisely quantified or qualified. Nevertheless, such information is still valuable for the community and may help to improve our understanding of 226Ra and Ba cycling in the ocean circulation. I would recommend the manuscript for publication in this special issue in Biogeosciences Discussions. However, I list a few issues below, which I think the authors should consider in their revision.

1. Do seawater 226Ra and Ba behave similarly in the ocean?

The strong correlation between seawater 226Ra and Ba has been commonly used as a result of their similar chemical behaviour. Such an argument is perhaps not as convincing as it used to be since we have seen many pieces of evidence that 226Ra and Ba have different sources and sinks, and can behave differently in different regions (as discussed in Section 4.1 in the manuscript). This is a similar argument for Ba-Si; these two elements seem to be strongly correlated, despite the fact that they have such different chemical cycles in the ocean. Any two elements can be correlated to some extent. However, without fully understanding their removal or regeneration mechanisms, such correlation could also be a coincidence. I think the authors should make that clear in the manuscript, particularly in abstract, conclusion and Section 4.1.

2. OMP analysis

One thing that concerns me a little is the uncertainty and accuracy of the OMP analysis. In Section 4.2, the authors mentioned that the OMP analysis suggests that there are 41-66% of MW present between 1000-1600m at Station1 and 21, 60% of ISOW between 2700-3000 m in Station32, and 54% of ISOW between 2100 and 3000m in Station69 and 77. Both MW and ISOW are identified with a relatively low 226Ra/Ba ratio (1.7-1.8, Table S1), compared to 2.0-2.3 in other end-members. So in theory, I would expect to see low 226Ra/Ba in these locations. However, apart from Station69, most of the stations mentioned above either show no change in 226Ra/Ba or show an even higher ratio (i.e. Station32). It would be helpful to show the OMP estimate of

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226Ra/Ba in Fig.8 as well.

I am also worried that if the estimate of OMP is correct, the absence of low 226Ra/Ba in the intermediate waters (e.g. Station21, 1000-1600m), where >50% was expected to be MW, would suggest that 226Ra/Ba is perhaps not as conservative as we thought even in the intermediate waters.

3. Removal of 226Ra and Ba

The authors suggest that phytoplankton blooms in the Labrador Sea may explain the negative anomalies of 226Ra and Ba in the areas. I think this statement requires more clarification and work. At least from the Ba point of view, we know that Ba removal (barite formation) is not a direct function of POC flux. In this case, the Labrador Sea (Station60, 64, and 69) shows nearly 10% Ba deficiency in water columns from 200 to 1500 m, according to the OMP analysis (Fig.8d). Such a huge deficiency for a relatively long-residence-time element is unlikely to be explained by seasonal phytoplankton blooms.

4. The uncertainty of estimated sediment 226Ra flux

In Section 4.4, equations (1) and (2) suggest that the uncertainty of sediment 226Ra flux comes from A (positive anomaly), T (transport rate) and S (surface area.) At the moment, a 20% error in the calculated 226Ra flux does not include the 33% error from the transport rate. I think the authors should consider the error propagation from each component in the flux calculation.

5. How much tolerance does seawater 226Ra/Ba need to be used as conservative tracers (clock) to chronometer the thermohaline circulation?

Despite that the authors suggest that 226Ra and Ba in intermediate waters are mostly conservative, the readers would not know how sensitive the seawater 226Ra/Ba is as a tracer to chronometer the thermohaline circulation. For example, based on our current understanding of the time for the global ocean circulation, how much decay of

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226Ra/Ba is expected? Considering that there might still be some non-conservative behaviour (∼30%) involved during the ocean basin scale mixing, how much tolerance does seawater 226Ra/Ba have if we want to use it for such an application? The authors could perhaps include some of this discussion in the paper.

Minor comments:

P3L33 R/V Pourquoi Pas?, the question mark seems to be a typo. P5L7-8 I understand that, in most of the cases, the particulate Ba is low (<1% of the total Ba). I think this needs to be checked for samples in nepheloid layers and hydrothermal plumes as well. P13L25-28, some references are required for this statement. P16L2, would not Ba be scavenged by Mn oxides as well? Fig.6. It would be much more clear if AABW and NEADWI are labeled on the figures to show the transformation of water properties. Fig.9. This figure shows some interesting observations. One thing worthy of notice is that the trend is not a linear relationship. I think that there are many reasons (sediment-water contact residence time, water age, and scavenging etc) to explain why sediment 226Ra flux and bottom water 226Ra concentration are not linearly correlated. This may be something interesting that the authors can point out to their readers in the discussion.

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