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Interactive comment on "The potential of ^{230}Th for detection of ocean acidification impacts on pelagic carbonate production" *by* Christoph Heinze et al.

Anonymous Referee #1

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This modelling study seeks to test whether the oceanic distribution of dissolved 230Th could serve as an indicator of reduced biogenic CaCO3 formation as the ocean acidifies due to anthropogenic CO2 emissions. It proposes that 230Th concentrations, particularly in the deep ocean, may be a more sensitive indicator of such change than direct observations of changing alkalinity in the surface ocean.

In some ways, the modelling work described is a rather incremental advance relative to earlier work assessing the 230Th response to change in the CaCO3:POC ratio presented in Heinze et al. 2006. The present manuscript, however, focuses specifically on testing how this ratio might be influenced by future ocean acidification, and whether

this could be detected by 230Th measurements.

The ability to detect systematic change in the production of biogenic CaCO3 in response to ocean acidification would be a useful tool, making this modelling endeavour potentially useful. The idea that 230Th may allow such detection is not intuitive, but interesting and worthy of consideration. So the general direction of this contribution is welcome. I am, however, unsure from the present manuscript that the utility of 230Th to assess CaCO3 flux has been demonstrated.

1. Threshold for detection The authors assume that detection of change in 230Th depends only on the analytical uncertainty of measurement. Measurements of 230Th in seawater shows significant spatial and temporal variation, however, which far exceed measurement uncertainty. Some of this variation reflects known processes, such as productivity or large-scale circulation, which cause consistent spatial patterns. But other variation is akin to 'noise', caused by seasonality of particle flux, eddying circulation, variability in boundary scavenging etc. To assess the possibility to detect change in the profile of 230Th due to variation in the composition of settling particles requires consideration of the natural variability of the 230Th field. One way to consider this might be to statistically compare closely spaced samples in the ever-growing observational 230Th dataset to assess small-scale natural variability. My guess is that a more realistic detection threshold is likely to be 2 to 3 times higher than the value assumed in this study. That would not prevent detection in the deep ocean (e.g. in Fig 9) but would delay the date of detectability in that setting, and would prevent detection at shallower depths. Intuitively that seems realistic given that intermediate depths typically show quite large (and presently poorly explained) temporal changes in 230Th concentrations.

2. Sensitivity to other changes To be a useful monitor for CaCO3 flux change, future 230Th concentrations must be more responsive to that process than to other possible changes. There is very little consideration in the manuscript of other likely controls on the 230Th distribution. These might include future changes in circulation driven by

changing wind fields or freshwater inputs; changing productivity of organic carbon due to circulation changes; changing remineralisation of organic carbon due to altered O2 levels; changing fluxes of silicate dust due to changing winds and continental aridity; or changing ballasting related to ecosystem change. I do not have an instinct about whether any such changes are likely to generate substantial changes in the 230Th field, but this seems a fundamental issue for a modelling study such as this one to address. Can the authors do more to assess whether CaCO3 fluxes are really the dominant control on 230Th change? Or only one of several global changes that will alter the field?

3. Accuracy of the model The 230Th model used is well established and has been thoroughly documented in the literature before, but there are some presentational issues in the present manuscript that limit the reader's ability to assess its prediction of future 230Th change:

i. Since Heinze 2006, there are significantly more 230Th observations, including long ocean sections (see http://www.egeotraces.org/?group=Dissolved%20Natural%20Radionuclides,variable=Th%2(It is now possible to directly compare modelled sections (e.g. Fig 3) with observations, and this should be done in this manuscript. Doing so reveals some quite important discrepancies, particularly in the deep ocean which is being touted here as a sensitive indicator for changing CaCO3 fluxes. These discrepancies include deviations related to scavenging at the seafloor and in MOR plumes. If these processes are not considered, the deep-ocean sensitivity of 230Th to downward particle flux may well be overestimated.

ii. Perhaps I have misunderstood, but Figures 8-10 indicate that even the control run shows a significant change in deep 230Th, despite the lack of CaCO3 change in this run. This is puzzling, and seems to suggest a problem with the long-term handling of 230Th in the model?

iii. Less significant, but it would also be good to see how the model predicts change as a profile or section, rather than as a timeseries at a single depth. As you go to greater depth in the ocean, the residence time of 230Th increases, so change might be slower, but the flux of organic carbon decreases so the influence of a CaCO3 change will be more important. Seeing how such depth-related effects compete in the model would be interesting, and help to assess how realistic it is in representing the natural cycle.

Overall, these three concerns leave me unconvinced that this study is ready for publication. The idea of using 230Th to assess CaCO3 fluxes is interesting, however, so I'd encourage the authors to seek to address these issues. A revised version of the work could then be a useful contribution.

Other comments:

P4-6: The description of the model set up could be reduced, given that this is a previously described model, and that some aspects (e.g. C isotopes) are not relevant to this study.

P7: It's good to see the GEOTRACES data used, but the source of this data is strangely attributed. Neither de Baar nor Boyle were involved in collection of 230Th data. Please cite the relevant papers directly for this data (e.g. Hayes et al., Deng et al) in addition to the Mawji et al. paper.

Are any spatial changes expected because of changing rain-ratio? High latitude waters will decrease saturation faster than mid-latitude, so changes may be more acute there. I wonder if looking at the relative change in 230Th between regions may be a more sensitive indicator of the specific response to changing carbonate saturation than the general deep-ocean response?

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