

**Interactive comment on “Global database of oceanic particulate organic carbon to <sup>234</sup>Th ratios: Improving estimates of the biological carbon pump” by Viena Puigcorbé et al.**

***Response to reviewers***

We greatly appreciate the comments of the Reviewers as they both consider the value of this paper for future use and modeling. Their constructive comments have helped us to improve the manuscript. We have expanded the dataset to include 2 studies that have been published between mid 2019 and March 2020 and an additional unpublished work from the authors, adding a total of 208 extra data points. We have edited the text to avoid repetitions and to simplify its reading and we have also modified some of the figures based on the reviewers' suggestions. Please find below the detailed responses to the reviewers' comments.

***RC1 Erin Black (Referee)***

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Introduction and Methods: Good introduction and justification for this study. The data will be very useful for future modeling. Sufficient detail given in the methods and database setup section.

Line 70+: ‘While uranium is conservative and proportional to salinity in well oxygenated seawater (Chen et al., 1986; Ku et al., 1977; Owens et al., 2011), thorium is not soluble in seawater it is scavenged by particles as they form and/or sink along the water column.’ Should there be a comma after ‘in seawater, it is scavenged’?

R: Thanks, we have changed it accordingly.

Lines 89-95: ‘The determination. . .oligotrophic regions’. This sentence is rather long and might be easier to read if broken up.

R: We have split the sentence in two. It now reads as: (L88-94) “*The determination of the POC/Th ratio has been historically attained by assuming that sinking carbon is driven by large particles, generally >50 μm in size (researchers also use 51, 53 or 70 μm, depending on the mesh supplier) whereas organic carbon within small particles is assumed to remain suspended and therefore not contribute to the export flux (Bishop et al., 1977; Fowler and Knauer, 1986). However, recent studies have shown that small particles can be significant players in the particle export and should not be disregarded (Alonso-González et al., 2010; Durkin et al., 2015; Le Gland et al., 2019; Puigcorbé et al., 2015; Richardson, 2019), particularly in oligotrophic regions.*”

Lines 194-197: ‘These high ratios. . .’. Should there be a comma before the ‘but’ in this sentence?

R: We have added a comma as suggested.

Lines 200-204: Another rather long sentence. I would suggest breaking it up for clarity, but this is only personal preference and the authors should do what they think is best.

R: We have left this sentence as it was: (L200-204) *“High POC/Th ratios are usually associated to the presence of large phytoplankton groups, such as diatoms, which are dominant in high latitude areas with no nutrient limitations, or where zooplankton populations are large and there is a significant input of fecal pellets, which should have also high POC/Th ratios.”*

Lines 206-207, Lines 216-217: Suggested comma before ‘but’.

R: We have added a comma as suggested.

Lines 214-215: This sentence needs an ending. ‘compared it to three different satellite-derived export’ . . .export what? Models? Estimates?

R: Thanks. We have added the missing word, “models”.

Lines 220-221: Is the citation format ok here? I would think it should be ‘as done by Henson et al (2011)’.

R: Indeed. We have corrected it.

Section 3.4: Remove period from after recommendations since there isn’t a period after other section titles.

R: Done.

Line 231: Either use ‘we recommend that’ or say something like ‘it would be beneficial for future efforts to obtain data. . .’. Saying ‘it would be recommended’ is a bit awkwardly phrased.

R: We have edited the sentence as suggested and now it reads as: (L230) *“It would be beneficial for future efforts to obtain data....”*

Figure 1: where you say ‘see main text for details’ please put the Section number where you mention these definitions.

R: We have added “section 3.1 Data classification” in the caption of Figure 1.

Figure 2: It’s a bit hard to see the variability in A-C. Since this is a database presentation, the readers can plot the data themselves and don’t need additional figures in the manuscript. However, I wish some of these figures were log scale and/or bigger.

R: We concur and we have modified Figure 2 to have a maximum ratio of 100  $\mu\text{m}/\text{dpm}$  so that the variability can be clearly seen. The modified Figure 2 is this one:

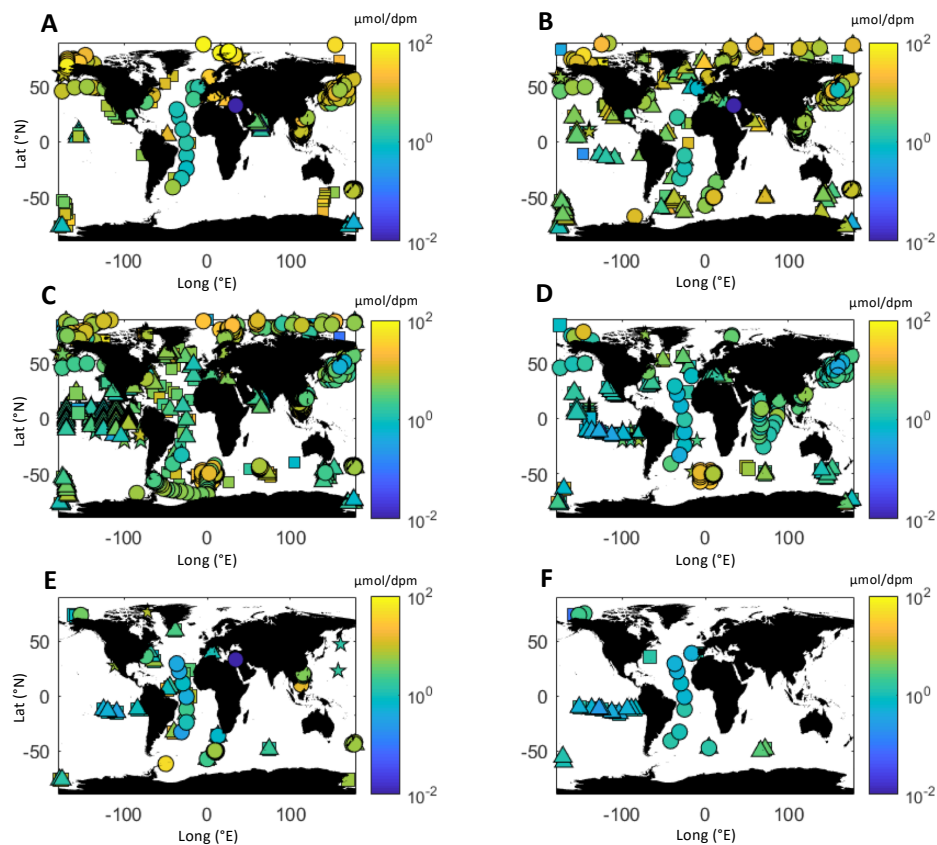


Figure 5: Does log-scale look any different or provide more information to the reader? Only a thought, not a suggestion.

R: No, not really. The aim of this figure is to show the magnitude of the ratios along the latitudinal range where they were collected. We believe Fig. 5 shows what is meant to show and the log-scale does not provide more information to the reader.

Database use comments: Locating the files was easy. Generally, the data is presented in a usable format. I would recommend that the authors note when actual dates and lat/long were not available for each location (and midpoints were used as noted in the text). It would be helpful for the data users to know which dates and locations are exact and which are not. If this was already done and indicated, I didn't see it and the authors should point clearly to this identifier in the text.

R: We agree that is important to know which dates and locations are exact and which ones are midpoint. In order to simplify the initial dataset we were recommended to have the data in one spreadsheet and the comments related to that dataset in another. Therefore two additional datasets are found in the main page for the dataset in <https://doi.pangaea.de/10.1594/PANGAEA.911424>, one with the actual data and the other with the comments (see screenshot below):

#### Datasets listed in this publication series

1. **Puigcorbé, V (2019):** Global database of oceanic particulate organic carbon to particulate  $^{234}\text{Th}$  ratios: Comments. <https://doi.pangaea.de/10.1594/PANGAEA.902103>
2. **Puigcorbé, V (2019):** Global database of oceanic particulate organic carbon to particulate  $^{234}\text{Th}$  ratios: Data. <https://doi.pangaea.de/10.1594/PANGAEA.911423>

In order to clarify this aspect, we have added the link to the “comments” of the dataset in the main text (see [L148-149](#)): “(see details in the comments related to the dataset; <https://doi.pangaea.de/10.1594/PANGAEA.902103>; Puigcorb , 2019).”

The data may not be intended for use in Microsoft excel, however, I opened the file in a tab-delimited format and some odd symbols showed up. For instance, ‘POC/234Th [ $\hat{\text{A}}\mu\text{mol}/\text{dpm}$ ] (C/Th ST)’ has an odd A in the heading. The actual data (numbers) are not impacted, so this issue is extremely minor. I can clearly understand and use the data as is. It may only be possible to post the data in a few formats and it seems like the website indicates which formats these are.

R: We have experienced that same issue and discussed it with the PANGAEA Data Archiving & Publication team. The issue is related to the way the file it is opened. Their response was:

*“When you download the file from PANGAEA, you can select encoding. For us standard is UTF-8. If I want to get both issues right (names and ranges not in date format), I open a new sheet first, then go to tab Data and select Import from Text. Then I find the Tab file stored on the computer (need to specify "all" formats, .tab doesn't show automatically in my version). Then comes:*

- 1. a dialog, in which you can choose how to import the data, so first select "separated" and encoding UTF-8*
- 2. tab as delimiter,*
- 3. and the difficult part in the next step, finding the column that should not be date and change the format to Text. This is not trivial in such a complicated table, off course.*

*This is really an unpleasant way if you want to get the table into excel, but then some people do not use excel and this .tab format which we use as an export format for the tabular data in the database is machine readable and also better suited for starting to work with it in R or Python. For better visualization adding another version in Excel like you did is probably a good compromise between human and machine readability.”*

To avoid this problem for Excel users we provided the dataset in an Excel file that can be downloaded directly and it should not have the problem with the odd symbols. The Excel file can be found just after the list of references under “Other version” section (see screenshot below).

	<b>Zhou, Kuanbo; Nodder, Scott D; Dai, Minhan; Hall, Julie A (2012):</b> Insignificant enhancement of export flux in the highly productive subtropical front, east of New Zealand: a high resolution study of particle export fluxes based on 234Th:238U disequilibria. <i>Biogeosciences</i> , <b>9(3)</b> , 973-992, <a href="https://doi.org/10.5194/bg-9-973-2012">https://doi.org/10.5194/bg-9-973-2012</a>
Other version:	Global database of oceanic particulate organic carbon to particulate <sup>234</sup> Th ratios (link to xlsx file)
Coverage:	Median Latitude: 30.166816 * Median Longitude: 179.801383 * South-bound Latitude: -77.990000 * West-bound Longitude: 0.000000 * North-bound Latitude: 90.000000 * East-bound Longitude: -5.053086 Date/Time Start: 1989-04-29T00:00:00 * Date/Time End: 2016-05-08T00:00:00

## *RC2 Anonymous Referee #2*

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Global database of oceanic particulate organic carbon to  $^{234}\text{Th}$  ratios: Improving estimates of the biological carbon pump by Viena Puigcorb , Pere Masqu , Fr d ric A. C. Le Moigne

### General comments

Overall, this data description paper is straightforward and generally well-written. The data compilation has the potential to further the reuse of the extensive dataset and be useful for future interpretations and models. However, as it should contain all data available, it would be necessary and reasonable to extend the dataset to 2018 (at least). In addition, some sections are redundant and the conclusion section is too similar to the abstract.

R: The dataset submitted covered studies published until mid 2019. The sampling for those studies took place between 1989 and 2016. Since mid 2019 until March 2020 we have found 2 more publications reporting POC/Th ratios, which have now been included, increasing the dataset with 129 additional data points. The overall message of the manuscript does not change with the addition of these two new studies.

We have rephrased the introduction and conclusion sections to avoid similarities with the abstract and tried to shorten and simplify the text to minimize long sentences and redundancies.

### Specific comments

Lines 29-32: However, quantifying the magnitude of the biological carbon pump at both the regional and global scales is challenging and current assessments vary widely, with estimates ranging from 5 to 20 GtC y<sup>-1</sup> being exported below the euphotic zone or the mixed layer depth (Guidi et al., 2015; Henson et al., 2011; Laws et al., 2011).

Are the wide ranges of estimates due to the challenges of quantifying the magnitude of the biological carbon pump, or do they simply accurately reflect the actual spatial and temporal variations? Please clarify the statement.

R: We believe this range largely reflects the paucity of estimates and methods used. Variability at spatial scale is large, and of course also seasonally. In some case, even if estimates are reported as annual values, the calculations are made assuming a number of considerations, hence significant uncertainty applies. And models, no matter how sophisticated, are known not to be perfect.

Lines 85-87: The sinking particles from which the ratio is measured should, ideally, be collected at the depth where the export has been estimated and represent the pool of particles that is driving the export of organic carbon.

It would be informative to highlight these ‘ideal’ datasets in the table; future users may want to focus on these data only. It would also be interesting to verify if the same trends reported here would be observed when using these data only.

R: That depth will change depending on the study. Traditionally a 100-150 m depth is been used (see compilation by Le Moigne et al. (2013), Global database of surface ocean particulate organic carbon export fluxes diagnosed from the  $^{234}\text{Th}$  technique, ESSD). Recent studies have

highlighted the importance of using different depths based on depth of the euphotic zone, or more recently, the depth of the primary production zone (e.g., Owens et al. 2015, Puigcorbé et al. 2017) or the equilibrium depth (e.g., Thomalla et al. 2006, Puigcorbé et al. 2017). We do not have this information available for many of the studies compiled in this dataset and it goes beyond its scope, but modelling efforts could use records of mixed layer depth or euphotic zone depths to assess what that ideal depth would be in each case.

Lines 149-150: The database consists of 9110 measurements of POC/Th ratios in the ocean. Particles were collected using in situ pumps (ISP), water collection bottles (CB) and sediment traps (ST).

Could you provide the amount of measurements for each method in the text?

R: Table 1 contains the number of measurements classified as “small particles”, “large particles”, “bulk particles” and “sediment traps”. We refer to that table in [L162](#) at the end of that paragraph.

Other points to discuss:

1- POC flux composition

Lines 201-206: High POC/Th ratios are usually associated to the presence of large phytoplankton groups, such as diatoms, which are dominant in high latitude areas with no nutrient limitations, or where zooplankton populations are large and there is a significant input of fecal pellets, which should have also high POC/Th ratios. Low ratios, on the other hand, are commonly observed in warm oligotrophic areas where productivity is limited and the main phytoplanktonic groups are picoplankton (see Buesseler et al., 2006 and references therein).

While the influence of the composition of the POC flux is mentioned, it is possible that this is the main factor influencing POC/Th ratios. Seasonal, regional and depth variations may actually simply reflect variations in the composition of the fluxes. Could the authors further discuss this important aspect? Determining the composition of the POC flux is critical to better understand variations in POC/Th ratios and in the magnitude of the POC flux and this should be emphasized.

R: We concur. Unfortunately, not all the studies included in this dataset have a detailed POC flux composition description so we cannot provide additional information in that sense. However, the final goal of compiling this dataset is to use it in combination with other major datasets and satellite-derived tools in order to contribute to decipher this type of questions and be able to model the variability of the POC/Th in the global ocean.

2-Timescale

What about the difficulty of comparing POC/Th ratios (timescale of weeks) to global patterns of surface productivity, phytoplankton composition, zooplankton abundance, mixed layer depth, dust inputs to the surface ocean, and ice cover; all measurements with shorter timescales? Please address this issue.

R: The POC/Th ratio at a certain location and at a certain time is not integrating over weeks (the  $^{234}\text{Th}$  export flux is). We can then put that information (POC/Th ratio) together with other data, such as the one mentioned, obtained at the same time and location, without necessarily using different time scales. If needed, surface productivity can be integrated over different time scales from satellite-products, and similarly it can be done with some of other of the parameters mentioned where data is available from time-series studies. No action taken.

### 3-Lateral advection

Could the export of small particles reflect lateral advection instead of downward export?

R: Each study has its particularities based on the location and the currents in the area. Advection is not commonly assessed in  $^{234}\text{Th}$ -derived POC export studies and it tends to be considered negligible. This is likely a valid approach in the open ocean. Small particles that might sink slow are potentially more affected by lateral movements than particles that sink fast. Still, small does not necessary imply slow sinking and therefore, lateral advection may or may not have an impact on small particles. However, this discussion is beyond the scope of this paper, which is primarily intended for publishing a dataset, and could be addressed in a more specific study by assessing the hydrography of the study area and the sinking velocities of the particles. We do not have this information for the dataset provided here.

### Technical corrections

-The first sentences of the introduction are the exact same sentences than the abstract - Please modify.

R: That sentence has been modified and now it reads as: “The vertical export of photosynthetically produced particulate organic carbon, from the surface waters to the deep ocean (i.e. biological carbon pump; Eppley and Peterson, 1979), has a strong impact in the global carbon cycle.”

-While Lepore and Moran (2007) is listed in Pangaea, it is not listed in the reference list and in the table. Was it included in the analysis? - Please revise the reference list.

R: Thanks for noticing it. Lepore and Moran (2007) should not be listed in PANGAEA, Lepore et al. (2007) Seasonal and interannual changes in particulate organic carbon export and deposition in the Chukchi Sea, should be the reference used instead. It is correctly cited in the manuscript but not in the online repository. The mistake has been corrected.

-Some sentences are much too long - Please revise throughout the text.

R: We have revised the text and shortened those sentences that were unnecessarily long.

-Please do not use language such as: . . .is presented in Figure 4; Figure 3 shows. . . ; . . .are shown in Figure 4. Simply refer to the figure at the end of the sentence.

R: We do not find that change necessary and we have not modified the text in that sense.

-Figure 2: Could you adjust the color scales (log?) so that it is possible to see a gradient? It appears all or nothing as it is.

R: We concur and we have modified the figure to show the colour scale in log format. See new Fig 2 in response to comments from reviewer #1 above.

-Figure 4 would benefit from larger fonts.

R: We have increased the size of the fonts as much as space permits.