Comment on essd-2021-259
Anonymous Referee #2

Referee comment on "Revisiting five decades of $^{234}$Th data: a comprehensive global oceanic compilation" by Elena Ceballos-Romero et al., Earth Syst. Sci. Data Discuss., https://doi.org/10.5194/essd-2021-259-RC2, 2021

Review of “Revisiting five decades of $^{234}$Th data: a comprehensive global oceanic compilation” by Ceballos-Romero et al.

General comments

This paper provides a global dataset on $^{234}$Th data in the ocean, accompanied by additional parameters used in the application of the $^{234}$Th approach to derive export fluxes, mainly particulate carbon export fluxes. This effort comes after the compilation of $^{234}$Th fluxes by Le Moigne et al. (2013) and the recent compilation of POC:$^{234}$Th ratios by Puigcorbé et al. (2020), both published in ESSD, therefore I believe it is well suited within the scope of ESSD. This compilation will be very useful, as the authors mention, to better constrain the contemporary ocean carbon uptake by providing easy access to all the $^{234}$Th data collected over the last 50 years.

This is a major effort that has brought together a large number of datasets. The information provided regarding the global dataset, what parameters are included, how they are organized and how to access them is clear for the reader. Additionally, the authors have added a detailed history of $^{234}$Th and its use as particle tracer from its beginnings until today, and even looking into future programs.

I did enjoy reading the entire manuscript, but I also believe it should be streamlined because there is a bit of repetition between sections and within the same section. As a general comment, there were several typos and formatting errors along the manuscript, repeated words and sometimes sentences appeared out of the blue or were unfinished/misplaced. I had the feeling that the manuscript needed an additional proof reading by the authors prior to submission, but I tried to provide detailed comments when...
I spotted some of these issues.

Particular to Section 5, this section does not always discuss the gaps in the dataset, but it expands on issues that, although very important, most reader will be aware of them and they are not real gaps of the dataset, at least not in the way they are presented. To be honest, this section feels like it is a section to "advertise" the work of the first author (7 citations out of 8 in page 24 are Ceballos-Romero et al.), which it is actually really good, but I don't think it belongs to the "gaps of the dataset" section. Maybe move it to the overview of the dataset or to the discussion. If the authors decide to keep it in Section 5, as mentioned in my detailed comments, those particular paragraphs should be more to the point.

The $^{234}$Th timeline part (4. Discussion) would largely benefit from a figure showing a timeline and the key dates/milestones listed in the text. I think the readers and future researchers interested in $^{234}$Th would appreciate having Section 4 summarized in a nice timeline figure.

Also related to Section 4, I have provided specific comments below, but I believe that, even though this manuscript has a whole section of "storytelling", without providing additional data (which I enjoyed reading), the division by era's should provide some useful information for scientific purposes (e.g., period of years that the era lasted, using the name of the main program of the era, or stating what was done during such era). Although it is quite "artistic" to have named them by well-known novels linked to the ocean, those titles don't serve a clear purpose (they don't clearly describe the actual era) and changing their names might be more adequate when publishing a research paper. Moreover, in that line, I think the manuscript, since it is a research publication, should provide some actual data, not just referring to the number of publications and number of datapoint, but actual data on $^{234}$Th, similar to what was done in the two previous compilations related to $^{234}$Th (see Fig. 1, 3, 7 and Table 2 from Le Moigne et al. (2013) or Fig. 2, 3 and 5 from Puigcorbé et al. (2002)). This manuscript does not provide data on $^{234}$Th, just on the number of studies/cruises/stations/parameters. The authors could include a table with $^{234}$Th concentrations (tot/part/diss) similar to Table 2 from Le Moigne et al. (2013) or in a figure similar to Fig. 4 from Puigcorbé et al (2020) or something completely different, but they should report actual $^{234}$Th data/values, not just data points. A description of the number of datasets, studies and locations is already provided in the abstract of the dataset in the PANGAEA repository. In this manuscript, the authors should provide something additional to it, that goes beyond explaining the structure of the dataset, the percentage of studies that do one thing or another, or the history of $^{234}$Th.

Despite agreeing on the fact that this dataset is very necessary, and it will be very useful, I have two (relatively major) issues with it:

- Not all the studies reported analyzed POC, some analyzed PIC+POC. There is no reference made regarding this "problem". Either in the manuscript or in the dataset (or both), a comment should be made to indicate if the data reported is truly POC, or if it is
The authors have compiled additional data, when available, on water temperature, salinity, $^{238}$U, and particulate nitrogen, and if they can, they also report the bloom stage. However, the authors have omitted a critical parameter for the application of the $^{234}$Th method. This is particularly surprising since one of the authors has recently (2020) published a PNAS paper entitled "Metrics that matter for assessing the ocean biological carbon pump". It has been shown that the integration depth has an impact on the magnitude of the fluxes (the strength of the biological carbon pump) and therefore, we should be using reference depths related to the euphotic zone (or primary production zone (PPZ); Owens et al. (2015)). I understand that not all the studies, particularly in earlier days, provided this information, but recently, the integration depth is no longer fixed and authors explain what kind of reference depth they use to integrate the fluxes. I believe fluorescence and/or PAR data to define the euphotic zone or the PPZ (or providing those depths directly) should be added in the dataset, the same way that temperature and salinity are. With that addition, in the manuscript it should also discuss the importance of the integration depth and cite the Buesseler et al. (2020b) paper in a more appropriate line than where it is currently cited (L778). If this dataset is expected to be "alive" and authors want to be contacted to update it by adding new data, having this kind of input is crucial for future applications of the $^{234}$Th method.

Finally, regarding the datasets available in PANGAEA, I found that https://doi.pangaea.de/10.1594/PANGAEA.918125 provides the metadata information and there is a table with parameters shown in that file. However, https://doi.pangaea.de/10.1594/PANGAEA.937414 contains the actual data but there is no table of parameters there. Please consider including such table for clarity (even if it is a long one), since not all the "parameters" might be clear to the reader/user, e.g., "integrated_depth_real_particle (m)". Notice my comment below for Table 1, where the starting and end date for the sampling period have been reversed in some cases. The dates are also incorrect in the dataset. I noticed some from Table 1 but please double check them all again in the dataset as well.

**Detailed comments:**

L11-16: “However, it was... the biological pump.” This is a very long sentence. I don’t think that level of detail is necessary for the abstract. The information detailed here is already discussed in detail in the manuscript. Please, simplify it.

L 20-21: “...that include two size classes;...". By reading the rest of the paper more pores (e.g., <70 μm) are mentioned and reported. Maybe just finish that sentence after "filtration method" in the abstract.

L23: “...included, including...”. Try to find another word to avoid repetition.
I understand where that is coming from but production rates of anthropogenic radionuclides might not always be that well characterized or can vary over time.

I would even say more than just years (paleo tracers).

“use” instead of “used”

Delete “a” from “a $^{234}$Th”

“when high scavenging by particles”. Correct, there is something missing.

Instead of citing that many papers without a clear reason behind their selection, maybe cite Le Moigne et al. 2013, which provides a compilation of studies using the $^{234}$Th approach to derive estimates of POC export.

PIC and BSi abbreviations are not needed. PIC is only used one more time, in L 474, where it is also defined, and BSi is not used anywhere else in the manuscript.

“...is in part...” seems to imply that there is another part, but it is never mentioned.

Not sure how necessary is to provide the editors’ names for the special issue.

Maybe delete the “only”

Missing Th after $^{234}$

“..and useful metadata to be used“. Change words to avoid repetition of “use...”

Add the GEOTRACES website
L124: “…spanning all oceanic regions” maybe add “across”: “spanning across all oceanic regions”

L129: Do you mean when reported by the original authors? There could be issues on the way the different authors, over the different years, have decided if the conditions were non-bloom, pre-bloom, bloom or post-bloom. Please discuss it a bit more.

L145: 210 should be a superscript. Same for L435, L537, L610, L665 and L666

L158-159: “…the authors were directly contacted for data is indicated in the localization.” Please rephrase for clarity.

L169: It should be μmol instead of μm. Same for L178

L169-170: “…and include… in which we included”. Try to find synonyms to avoid repetition of words

L174: Correct “The particles’ sampling…”

L180: “Measurement uncertainties in the data points as provided by the data measurer…”. Please rephrase for clarity.

L200-203: Delete or move to the section “General overview”, rephrase or delete “here” since you refer to “here” for the entire manuscript, for a particular section that you are discussing and for a particular section that you are about to discuss, which makes it confusing.

L203: “on in” correct it

L208: “larger” instead of “lager”

L209: “During these 50 years of study, we have….”. Maybe rephrase so it doesn’t sound like you took 50 year to write this manuscript. Something like “During these 50 years of $^{234}$Th data” similar to the title.
L209 and L211: “14 major ocean programs” vs “as part of one of these 13 programs”

L211: “as reported by the authors”. I’m not sure which authors are you referring to, the ones of that major program? Yourselves? If it is yourselves there is no need to have that sentence. If it is referring to the authors of those datasets, I don't think it is correct, because they could not tell that their dataset represented 30% of the total datasets.

L212: “reported” instead of “compiled”

L214: delete the - after TSS

L218: “time-series stations” should be TSS as defined in L214.

L222: “least” instead of “last”

L222-223: “re-occupied” should be “reoccupied”, as in L223

L225-231: Missing the degree (°) symbol for the coordinates of all the time series stations

L237: POC(PON) to $^{234}$Th ratios have been defined previously (e.g., 144) as POC(PON):$^{234}$Th.

L247: Correct “datasets”

L253: Correct “expeditions to the”

L258: “is not significant of the number”. Rephrase for clarity.

L263: Correct “experiments”
L264: Delete “started in 1969” or add “which”

L271: it should be “of” instead of “on”

L276: Delete #

L288: Same as previous comment from L237

L301: it should be “sample” instead of “sampled”

L304: “yet maximize...” add “the number of locations sampled”

L305: “were” instead of “was”

L308: Correct for consistency “POC(PON):\textsuperscript{\textsuperscript{234}Th}”

L317: “...in situ pumps, bottles and...” remove the “and” and change for a comma.


L337: “...in an oceanographic expedition...”, delete “field” is redundant.

L340: I would recommend changing the names of the eras in order to actually provide some information about each era. Naming era 1 "The Old Man and the Sea" doesn’t say much about what happened during this era. I would provide the periods of each era and, if possible, something more such "JGOFS", "GEOTRACES" or something related to the main advances of each era, e.g., “the beginning of \textsuperscript{234}Th as tracer of POC export” or in that line.

L344: Bhat had co-authors in that first \textsuperscript{234}Th publication.
L345-347: “Bhat et al. (1969)... part of the total $^{234}\text{Th}$.” What’s the purpose of this sentence? It is interesting but it appears out of the blue and it is not discussed any further in a way that it is linked to the following sentences. Maybe rephrase between L345 and L354 to facilitate the flow.

L353: It sounds strange to say that you use "this radionuclide" (referring to $^{234}\text{Th}$) to study the scavenging of thorium. All the thorium isotopes are particle-reactive.

L358: Rephrase “realizing the relevance to the downward $^{234}\text{Th}$ flux” for clarity.

L367: Correct “increase” instead of “increased”

L371: Correct “prolong” instead of “prologue”

L376: It should be “MnO$_2$” (the 2 should be a subscript)

L380: Linked to my comment from L340, here the authors refer to JGOFS era. Avoid confusions.

L382-385: Missing the degree (°) symbol for the coordinates of all the time series stations

L388-389: Avoid repeating “introduced”

L391: “...a precipitate that serves for removing Th...”. Change to “...a precipitate that removes Th...”

L393: Maybe refer to it as “For the MnO$_2$ cartridges technique”, since MnO$_2$ is the method being used currently, although mainly without the cartridges.

L394: Same comment as L376

L394: Delete “(MnA and MnB)”. There is no graph and, therefore, there is no need to
specify the name of the cartridges (which could also be “named” Mn-I and Mn-II or Mn-1 and Mn-2 or many other ways).

L394: Did you mean “and gamma count them”? Not sure it is needed here since gamma counting is mentioned in L398.

L397: Why the differentiation between MnO$_2$ and Mn cartridges? We have only been talking about cartridges with fibers impregnated with MnO$_2$.

L398: Refer to it as MnO$_2$ cartridges for consistency. Otherwise, modify the text above and refer to Mn cartridges the whole time, after specifying that those are cartridges with fibers impregnated with MnO$_2$.

L403: The reference to the volumes sampled doesn’t seem to have a purposed. It is not discussed or linked in any way to the rest of the paragraph. It provides information but I don’t think it is relevant as it is presented right now, plus the sample volume reference is not done for the studies cited between L404-410.

L407: Correct “where” instead of “with” or say, “with a predominant particulate size class cut-off of 0.45 μm”. If it is just for one study, can you say it is the predominant size class? Were there others in that same study?

L408-410: “Note that... McKee et al., 1986).” This sentence seems not to match the size class cut-off of 0.45 μm mentioned just before. Is this operational distinction applying to the previous studies cited between L403 and L405? If that’s the case, move it there. If not, remove or integrate better to the paragraph.

L435: Same comment as L145: 210 should be a superscript

L436: Same comment as L340

L437: The authors keep referring to the JGOFS era: “…what we are calling the “JGOFS era” (1989-2003)” but this is not an actual era in their manuscript, not by period of time nor by name. Please avoid confusion by naming the eras appropriately to refer to something that has a meaning linked to the history of $^{234}$Th.
L443-444: It is odd to cite a reference from 2008 in the 2nd era (1992-2001). Moreover, the following sentence starts with “Accordingly, ...”. Please cite the first paper discussing this topic, not one from 2008.

L446 or 447-448: Adapt the format of equation 1 to match the format of the different parameters in the description (e.g, add 234 as a superscript, keep consistency with italics and non-italics, etc.)

L477: Add the units of the $^{234}$Th$_{\text{flux}}$ as done for the ratio.

L452: It should be “Element: $^{234}$Th” instead of “POC:element”. I don’t think the italics are needed.

L453: “its” should be “their”

L453: Delete “dependent” since it already says that they vary with both depth and particle size. Or say that they are “depth and particle size dependent”

L454-456: “…can be calculated from the disequilibrium between the $^{238}$U-$^{234}$Th resulted from particle sinking…” This has already been said a couple of times before. Simplify: “$^{234}$Th flux can be calculated by evaluating...”

L456: Why “of the dissolved $^{234}$Th”? It has been done with total $^{234}$Th (see Savoye et al. 2006-Marine Chemistry and references in there).

L458: Add “a”: “only a single $^{234}$Th profile”

L458: Remove the comma after “NSS model”

L458-460: Simplify it. Too many sentences within one sentence. “...when activity gradients can be assessed in time thanks to repeated sampling, ideally over the course of 2 to 4 weeks.”

I think the authors should refer to Resplandy et al. (2012)-DSR-I work
L473: PIC abbreviation is not required since it isn’t used anymore. Also, notice that PIC and POC fluxes are elemental fluxes of the same element, C.

L476: It should be “MnO₂” (the 2 should be a subscript)

L481: Missing the degree (°) symbol for the coordinates of the time series station

L487: “with large volumes (2500-3500 L) passing...” instead of “passed”

L498: Why “we initiated”? Delete

L489: Why “and filtered”? Delete

L492-494: There are 7 studies that sampled 2 size fractions but there are only 4 papers cited, 2 for 53 μm screens and 2 for 70 μm screens. Either cite the 3 remaining studies or add “e.g.,” when citing the other studies.

L494: How many studies used sediment traps? 7 studies did size fractionation, it would be good to mention those that used sediment traps, for consistency.

L503: Another reference to the “JGOFS era”. Maybe consider this as one of the eras then?

L505: “at” instead of “in”

L506: Based the era period described by the authors (1992-2001), the NABE study should not be included here. It’s not part of the overlap, it’s overlapping with era 1, but not with era 2.

L506-520: There is no consistency in the amount and type of information provided for each process study. For example, why the objective of the EqPac study is described but
not for the other studies, for which mainly the dates and locations are provided?

L523: “initiatives” should be singular (only OMEX included here).

L525: “carried out” instead of “made”


L535-536: 10 studies used sediment trap and also $^{210}$Pb-$^{210}$Po at the same time (same studies for both)? If not, rephrase for clarity

L536: Same comment as L145: 210 should be a superscript.

L538: Same comment as L340

L543-544 and L551-552: Same sentences. Delete one to avoid repetition or change them to say different things.

L556-557: Missing the degree (°) symbol for the coordinates of the PAP station

L557-558: Why there is so much detail provided for the PAP station and not for the others? Why it is not explained what sensors the other TSS have? Provide similar levels of detail for all.

L560-564: I’m not sure the level of detail provided here is necessary. Simplify.

L569-571: “An additional improvement... method.” This is out of place, this should be moved and discussed in the following era since it was published in 2021.

L573: I guess “contraptions” is supposed to be “concentrations”
L573: Delete “and” after “POC:234-Th”

L578: What do you mean by “surveys”? Cruises, programs? It can’t be studies because those 4 “surveys” are differentiated from the 87 studies. Please clarify

L580: Are HOT, BATS and DYFAMED considered programs? In table 2 they are referred as TSS. The program that initiated these time series was JGOFS. Maybe refer to them as TSS?

L584: Missing the degree (°) symbol for the coordinates of the K stations

L586: Correct “JGOFS”

L587: U.S. JGOFS-Japan refers to a collaborative station between US and Japan?

L587: Missing the degree (°) symbol for the coordinates of the KNOT station

L590: Rephrase: “And a pilot cruise was reported under the GEOTRACES program” or similar

L590: Correct “…discussed in the next section”

L592: “Finally, a great number of projects and experiments belong to this era (see Table S3 for a chronological summary).” Remove, starting the sentence with “finally” creates great expectations for the reader, but there nothing after that.

L593: “Sampling”

L601: “while and” is incorrect. Please choose which one to use.

L608: Change “used” for “use”
L610: 210 should be a superscript

L612: Same comment as for L340

L619: It should be “GEOSECS”

L624: “carried out two years later”. Later from which reference year? Just say the year that it took place.

L626: Correct “cruises”

L629-632: Maybe some of the studies could be cited, including Clevenger et al., (2021) cited in the previous era, or the GEOTRACES intermediate data products from 2014 and 2017 (Mawji et al., (2015) and Schlitzer et al. (2018)) or the trace metal fluxes studies (Black et al., 2018; maybe add some more studies here since you refer to a shift from POC to trace metal fluxes).

L638: “and known” should be “are known”

L643-645: The 8 cruises that sampled in the NH and the SH are included in the 27 that sampled in the SH or are considered a separate group. If so, maybe mention them apart from the NH cruises.

L646: Refer to GEOTRACES instead of “a major ocean program”.

L676: Add “and” in between “2nd 3rd”

L646-651: Why are this projects/experiments/cruises not cited in Table 2? What criteria was used to include them or not in that table?

L659: Change to “…whether a SS, a NSS or both models were used”
L660-661: Are those citations referring to what? The use of SS, NSS or both? Why so many citations? Just write “e.g.,” and cite max 3.

L665 and L666: Same comment as L145: 210 should be a superscript.

L666: Correct “compared them”

L668: Same comment as L340

L675: the abbreviation for net primary production is not needed since it is not used anymore

L677-678: “availability for phytoplankton at a key junction of the global ocean circulation”. Rephrase for clarity

L684: BCP has not been defined yet. It is defined in L697. Abbreviation probably not needed, used a few more times later on but there is a large number of abbreviations in this manuscript already.

L685-686: Why APERO and PICCOLO are no included in the previous group of projects? What is the criteria to differentiate them from COMICS, EXPORTS, CUSTARD, etc.

L689-691: Please clarify what JETZON does. “…international coordinating umbrella to serve as a focal point…” means that they organize or fund cruises, or meetings? Are any of the recent programs cited before (COMICS, EXPORTS, CUSTARD, OTZ, SOLACE, APERO, PICCOLO) included or linked to JETZON in a formal way?

L697: See my comment for L684

L697: Delete “of”

L700: “time-series site” should be TSS
L707: Use "< 1%" instead of "less than 1%" (if not add a space after "than")

L718: Correct “for the application”

L726: Change “...since most cruises do not allow repeated measurements...”

L727: Delete “i.e., neglecting changes...”. It has already been explained what a SS model implies.

L718-731: This paragraph seems repetitive with previous sections of the manuscript, when presenting SS and NSS models. This section should describe how many studies applied SS and NSS or both and in which cases the application of one model or the other had a significant impact. Maybe citing the work by Resplandy et al. (2012). http://dx.doi.org/10.1016/j.dsr.2012.05.015 can help to provide the overview on this particular gap.

L732-733: Too broad. Not all the radionuclides present deficits in the water column and not just because of their half-lives, also because of their physicochemical behavior. Please rephrase referring only to $^{234}$Th, since it is the radionuclide of interest for this manuscript.

L736: Add “e.g,” in front of the citation to Ceballos-Romero et al. (2018), there are other studies that have reported similar results.

L736-744: This paragraph is not referring to a gap in the dataset. This is an explanation about the importance of the bloom period and the reliability of the SS and NSS approaches (issues that the readers accessing this dataset are most probably already aware of). I don’t think it is needed, plus it seems a bit repetitive and too extensive considering that an explanation about SS and NSS already stared in L718. Please simplify from L718 to L744 in order to highlight the importance of this considerations and their implications in a much briefly way. L745-751 are great, they report the actual data and highlighting the importance of reporting bloom conditions.

L755: Correct "occurs"

L758: Delete “sampled” since it has been stated several times that all the oceans were sampled.
L760-766: Again, this is not a discussion about a gap in the dataset, it is explaining again what data is reported, how important it is to combine $^{234}$Th with other tracers or devices to quantify export, etc. This can be deleted since it has already been presented and discussed along the manuscript.

L761: Correct “provides”, since it is the "combined interpretation" that provides us with the tools.

L763-764: The "Ceballos-Romero et al. 2016" citation is not needed or add other studies, this is not the only one that has combined Th-234 with other tools.

L764-765: "For that reason....... might be missing." These two sentences are important, but they should be moved to the section describing the dataset, section 2. Data.

L777: Change “us” by “as”

L778: Please rephrase “Together with particle sinking velocities disequilibrium derived”, I do not follow it.

L781: It should be BCP

L783: all the ways to re-evaluate the $^{234}$Th-derived POC fluxes can be done using the dataset of this compilation, but it does not allow to evaluate those fluxes in relation to the particle sinking velocity or the synthesizing modelled particle remineralization, so please rephrase to clarify what can be done with it alone and what could be done if combined with other datasets.

**Table 1:**

Please check sampling periods. In several instances the dates are placed reversed i.e., first the end of the sampling followed by the starting date. See: Matsumoto, 1975; Minagawa and Tsunogai 1980; Wei and Murray, 1991; Porcelli et al. 2001 (different format used: yyyy/mm/dd); Lepore et al. 2009
This problem is also found in the dataset available in PANGAEA. Please correct it there too. I noticed these ones but please review them all again.

Also, some of the studies have only one sampling date, therefore, that term could be simplified by reporting just that date instead of reporting it twice. See: Moran and Buesseler, 1992; Buesseler et al. 2000; Cai et al 2002; Coppola et al 2002; Guo et al 2002; Hung and Gong 2007; Buesseler et al 2010 and Pabortsava, 2014

It would be good to increase the width of the “Reference” column because some of them take more than one row. No data repository is reported in that column, so the title of that column can be simplified.

Table 2:

As mentioned in my detailed comments, I would like to understand the criteria used to include programs or in this table or not, since some mentioned in the manuscript are not included. On the other hand, OSP- Station PAPA Ocean Weather Station “P” is not mentioned in the manuscript but is included in the table.

Please format the table so that the “Acronym” column as well as the “Activity” column are wide enough to have the entire name in one row. Right now, it is too big and it makes it hard to follow.

Figure 1:

Panel c) LTTS has not been used anywhere in the manuscript, the acronym used is TSS. If for some reason you prefer to use long-term, high-frequency time-series stations, do not use the acronym.

Same for L831, TTS station is the wrong acronym.
Panels a) and c) have already a lot of symbols and colours reporting data. I don’t see the necessity to provide the topography data. A scale of greys for the background might be less shocking and allow to better visualize the data reported in these panels.

**Figure 2:**

L842: vi) remove the “” from the category Others in the caption.

For panel b) the lines for 2001 and 2010 are very out of place. Please add the legend in this graph again if this panel is place right below panel a) for publication.

For panels a) and c) the dotted lines indicating the tipping points are also not centred in relation to the specific year.

**Figure 3:**

L873: Delete one of the “by the”

Same as per Figure 1, I think a grey background might allow to better visualize the datapoint reported in the different panels.

The caption does not match the symbols/colours of the map:

Panel a) ii) $^{238}$U + total $^{234}$Th the caption should be dark blue squares; iii) no $^{238}$U the caption should be magenta dots

Panels b, c and d) iii) the caption should be no total $^{234}$Th sampled (magenta dots); iv) the caption should be no POC: $^{234}$Th ratios (light blue triangles)
Notice that the legend for panels b), c) and d) the Th in the light blue triangles shouldn’t be a superscript.