Reply on RC 1:

General comments

This paper reports sampling and analytical protocols for conducting high precision $\delta^{234}U$ analyses (c. ±0.4 ‰) on tropical, shallow water corals. The authors then investigate variations in $\delta^{234}U$ in modern and near-modern corals to determine their utility as environmental and hydrological archives.

Coeval samples of twelve species of coexisting corals are found to faithfully record analytically indistinguishable values of seawater $\delta^{234}U$. Small but resolvable variations in $\delta^{234}U$ (up to c. 1‰) are observed in growth bands of corals sampled at sub-annual scales. Larger variations in $\delta^{234}U$ (up to several ‰) were observed in decadal-scale time series of coral samples from an area of known submarine groundwater discharge (SGD), with distinct values of $\delta^{234}U$ recorded in neighboring coral colonies. The authors conclude that corals provide reliable archives of $\delta^{234}U$ for detecting subtle climatic and hydrological signals. Much of this is unsurprising but nonetheless it will be useful to those working with coral archives to incorporate these carefully measured results into their thinking.

Line-by-line comments follow, with specific comments followed by technical corrections.

We thank the reviewer for the careful and constructive assessment of our manuscript. We agree that our results are expected and not surprising, but such a careful assessment has so far not been done and we hope that others working with coral archives incorporate our findings in their thinking. We address all comments in the following and we will revise the manuscript accordingly. Below, we respond point-by-point to the specific comments and technical corrections.

Specific comments

Line 24. On glacial-interglacial timescales, variations in seawater 238U/234U are expected (as the authors are aware) and such variation should be mentioned here.

We agree and will revise the text to acknowledge variations in seawater 234U/238U on glacial–interglacial timescales.

Now reads: “Variations in the coral skeletons and thus seawater are likely indicative of freshwater contributions from submerged groundwater discharge and river runoff, reflecting coral diagenesis, or, on glacial–interglacial timescales, variations in the seawater 234U/238U composition itself”.

Line 52. Secular variation in the past 234U/238U ratio of seawater on the multi-ka timescale is now well documented (e.g., Chutcharavan et al., 2018) so not all pristine corals are expected to yield initial 234U/238U activity ratios of ~1.45. The authors are clearly aware of this given later sentences, but the statement starting on line 52 needs to be corrected.

We thank the reviewer for this structural improvement and will place this statement to clarify that the initial 234U/238U activity ratio recorded by pristine corals varies in seawater on multi-millennial timescales.

"Contemporary studies have shown that δ234U values in pristine coral skeletons reflect the δ234U composition of ambient seawater (δ234Usw) at the time of coral growth (Gallup et al., 1994; Henderson, 2002; Esat & Yokoyama, 2006, 2010; Wang et al., 2017; Kipp et al., 2022; Li et al., 2023) although freshwater discharge from rivers and submarine groundwater may locally modify marine 234U/238U activity ratio. Additionally, glacial to interglacial variability in regional seawater U isotope composition is today well admitted (Henderson, 2002; Esat & Yokoyama, 2006, 2010)".

Line 55. The phrase "U-series open system behavior…in well-preserved corals…" is self-contradictory; please rewrite.

We thank the reviewer for pointing out this obvious contradiction and will revise this sentence as follows:

"Tropical coral α- recoil displacement of 234U (234Th) and 230Th, as well as skeleton diagenesis cause coupled and time dependent variance of reconstructed initial δ234U ratios of corals even in absence of mineralogical alterations and diagenesis (Thompson et al., 2003; Villemant & Feuillet, 2003; Scholz et al., 2004; Frank et al., 2006). In this context, δ234U has been used as a screening tool for U-series dating, with values deviating significantly from the expected seawater composition at the time of coral growth indicating potential U-series open-system behaviour and unreliable age determinations (Henderson et al., 1993; Gallup et al., 1994; Thompson et al., 2003; Scholz et al., 2004; Frank et al., 2006; Chutcharavan et al., 2018). In summary, any significant deviation of a tropical corals initial δ234U with respect to present or past seawater composition must be related to (i) influences of freshwater or (2) coral diagenesis. (Robinson et al., 2004a; Esat & Yokoyama, 2006, 2010; Chutcharavan et al., 2018)".

Also, since young corals have d234U ≈ 450 versus the d234U of CRM-122A ≈ -38.5, it's important to test that the normalization based on CRM-122A is appropriate for the coral analyses. The authors have done so using their seawater standard, although their results are not mentioned until line 228. It would be helpful to expand line 194-195 to include words to the affect that "The reproducibility was also assessed with repeated measurement of an in-house seawater standard, which yields a mean δ234U value of 145.7‰ with a standard deviation of ±0.3‰, thus comparable in precision to NBS-CRM-112A", with appropriate repositioning of call outs for Figs. 2 and 3.

We thank the reviewer for pointing this out. We will move the results for the in-house seawater standard to the section describing analytical reproducibility and now explicitly state that repeated measurements yielded a mean δ234U value of 145.7‰ with a standard deviation of ±0.3‰.

Line 189. The authors state that "all isotope measurements were normalized to the NBS-CRM-112A standard". The authors should briefly describe how this was done and how large the normalization factors were.

We thank the reviewer for pointing out that our normalization procedure was not described in sufficient detail. We have clarified the procedure and now distinguish between the instrumental normalization using HU-1 and the subsequent normalization to NBS-CRM-112A.

We will expand the description as follows:

"Measurements were performed using the standard bracketing method with HU-1 to monitor measurement stability and correct for instrumental drift. For data reduction, the measured $^{234}U/^{238}U$ ratio of HU-1 was assigned a constant reference value ($\delta^{234}U = 0‰$). This step serves as an instrumental normalization and does not imply that HU-1 is assumed to be in secular equilibrium. Following this correction, all measurements were normalized to NBS-CRM-112A using its reference $\delta^{234}U$ value of −38.5‰.

The 66 measurements of CRM-112A yielded a mean value of −38.5‰ with an external reproducibility of ±0.4‰ (2 SD). As CRM-112A was used to define the final normalization, these measurements demonstrate the external reproducibility of the method but do not provide an independent assessment of its absolute accuracy."

Line 206. Please specify the signal levels (in amps or volts with respect to a 10E11 ohm amplifier) typically obtained for 238U in Fig. 1 or state your typical sensitivity in volts/ppb. Such signal levels are more useful than concentrations for assessing mass spectrometer performance and analytical uncertainties. Also please give the approximate amount of 238U consumed during typical analyses.

We thank for this helpful comment and we will add the following details: "Under our analytical conditions, the instrument sensitivity was approximately 1.6–2 V per ppb 238U, with an optimal 238U signal of approximately 100 V. The Aridus II was operated at 238U concentrations of up to approximately 50 ppb because higher concentrations resulted in unstable 238U. Typical sample consumption during an analysis was approximately 1 mL at a rate of 50µL/min.

Line 217. (a) The certified value of CRM-112A should be added to Fig. 2 to illustrate this statement.

done

Lines 217-219. (b) The authors state that "The methodology applied here allows theoretically for ε-level precision for δ234U measurements …"However, this statement is not supported by the data presented since the scatter observed for replicates of CRM-112A is too high to support ε-level precision. It would be appropriate to omit this statement unless it can be supported by measurements.

We thank the reviewer for highlighting this distinction. We agree that the standard deviation of the individual CRM-112A measurements does not demonstrate ε-level precision for individual measurements. Although the mean of the 66 CRM-112A measurements agrees with the assigned reference value within approximately 0.3‰, this agreement does not independently establish the absolute accuracy of our normalization procedure. The uncertainty of the mean ($2\sigma M = \pm 0.06‰$) reflects the reproducibility of the mean and should not be interpreted as the precision of an individual measurement.

As demonstrated in previous studies (e.g., Anderson et al., 2004), repeated measurements can yield ε-level precision in the mean even when individual measurements do not achieve this level of precision. More recently, tests using our current detector and amplifier setup and the APEX Omega introduction system have demonstrated that increasing the 238U signal intensity to approximately 400 V substantially improves the signal-to-noise ratio at mass 234. Under these conditions, an internal precision of approximately 0.1‰ was achieved without changing the integration time or baseline correction procedure, and the precision improved further with additional scans. These results, which will be presented in a subsequent

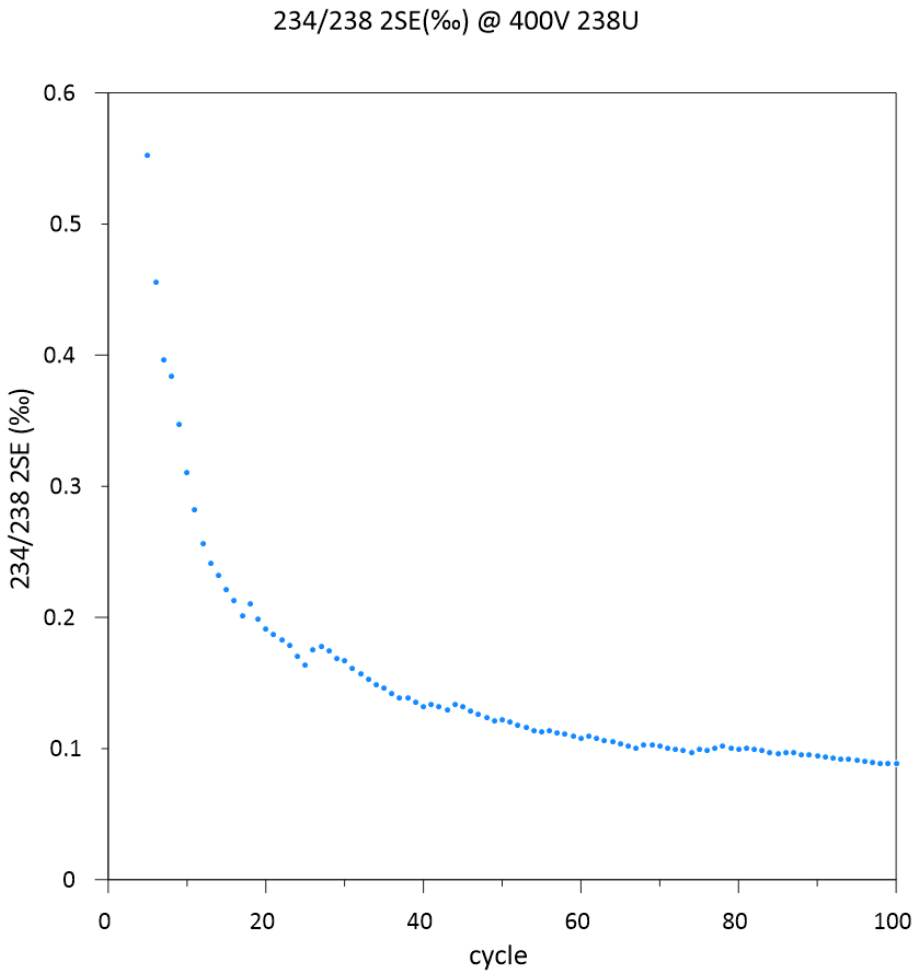
publication, indicate that ε-level precision for individual measurements is achievable under optimized signal conditions, but do not independently validate the accuracy of the tailing correction or normalization used in the present study.

We will revise the manuscript to distinguish between the reproducibility achieved for repeated measurements, the precision of individual analyses, and the accuracy of the δ234U values. For the coral records investigated here, the environmental variability of interest is generally substantially larger than the external analytical reproducibility achieved in this study. ε-level precision may nevertheless be important for future applications targeting smaller-amplitude variations, such as subtle temporal changes in seawater δ234U recorded by cold-water corals.

The authors go on to state that although the instruments used in this study and that of Hu et al. (2025) are similar, runs of impractical length (c. 3 hours) would be required to achieve ε-level precision with the author's protocol. But there are some salient differences in the measurement and data reduction protocols in the two studies. For example, Hu et al apparently use much higher intensity 238U beams — ~400 volts versus mostly ~80 volts or less in the current study (judging by Fig. 1). Other things equal, the large beams used by Hu et al provide a 5X improvement in signal/noise ratios on Faradays. This may help explain why excessively long runs would be necessary to attain ε-level precision with the author's protocol. Another notable difference in the two studies is how corrections for peak-tailing on 234U are made, with measurements at distinct e/m positions and different curve-fitting approaches being used. It's possible that larger samples are not the sole reason, or even the main one, for the higher precision reported by Hu et al. for CRM-112A and other materials.

In any case, as the authors point out, an external precision of ~ ±0.3–0.4‰, which they demonstrate for CRM-112A, their in-house sea water standard, and replicate coral analyses is adequate to assess variable 234U/238U in corals at the c. 1‰ level, which is the topic of this paper.

We thank the reviewer for highlighting the differences in 238U signal intensity and peak-tailing correction between the two analytical approaches. We agree that these differences, in addition to sample size and measurement duration, can contribute to the different levels of precision reported by the two studies. Our study had never the objective to achieve a precision far beyond the natural variability observed in closely situated corals or individual specimens, neither did we want to affirm any reference value such as the seawater 234U/238U ratio, hence the focus was on the variability of 234U/238U in corals and not the highest possible precision, which has been demonstrated by our work in Kerber et al., 2023. Since we achieve identical results as Hu et al. 2025 when using identical samples, but our setup at a similar signal to noise ratio, it became clear that the key methodological difference is a very high and very stable 238U signal of 400 V and thus a stable signal of 20.3 mV on mass 234 (see above).



Line 226. It's hard to reconcile a "a total measurement duration of 4 minutes" with an "integration time of 4 s and 60 scans", which to me implies an on-peak measurement time of 240 s. Please clarify.

We thank the reviewer for pointing out this ambiguity. We will clarify the description of the measurement duration and integration time in the Methods section as follows: "The 4 s integration time over 60 scans correspond to 240 s of on-peak integration time; the stated total measurement duration additionally included the time required for uptake, wash, rinse and blank measurement which sums up to 16 minutes per single run."

Lines 235-238. How do the authors interpret the larger deviations observed for three samples out of 20?

We will expand the discussion of these three samples. We interpret the larger deviations primarily as reflecting local sampling and/or skeletal variability rather than systematic analytical offsets. Given the limited number of replicate measurements and the magnitude of the observed differences, we cannot distinguish unequivocally between small-scale natural heterogeneity and sampling-related variability. We will revise the text to make this limitation explicit.

Lines 240-242. Do the authors think they have detected true intra-band variability in the TM2020 coral?

We will revise the discussion (chapter 4.2) to be more cautious regarding the interpretation of the paired intra-band measurements from TM2020. The observed differences of approximately 0.3–1.2‰ are consistent with small-scale intra-skeletal variability, but the available paired measurements do not allow us to distinguish unequivocally between true micro-scale heterogeneity and analytical or sampling variability. We therefore no longer interpret these observations as definitive evidence of true intra-band variability.

Lines 356-375. This section could be reduced by 50% or more. The main point — that SGD, already a known feature of the region, provides a plausible explanation for the differences in the d234U time series of the two corals — can be stated more succinctly.

We agree and will substantially shorten this section. The revised text will focus on the main interpretation that the differences between the two coral records are consistent with the influence of submarine groundwater discharge in the region, while reducing the additional discussion of possible mechanisms and background information.

Technical Corrections

We thank the reviewer for the careful technical corrections. We will address these throughout the revised manuscript

Line 22. Can delete “geochemical”

done

Line 27. Add “characterize”; i.e., characterize intra-skeletal variability.

done

Line 28. Specify confidence level of quoted reproducibility.

done

Line 34. “Elemental and isotopic compositions…” instead of “Geochemical element and isotope composition…”.

done

Line 35 “Coral-based”, not “Coral based”. Delete “over”.

done

Line 42. “freshwater discharge from rivers and submarine groundwater may locally modify marine 234U/238U ratios.”

done

Comment: chose either 234/238 or 238/234 and then be consistent. Since d234U is defined in terms of the 234/238 ratio, that is probably the better choice.

done

Line 44. Delete “today”.

done

Line 47. Sentence beginning with “Lastly…” is vague. Can you be more specific or omit?

done

Line 49. Should read “absence of, or accurate correction for, initial 230Th.

done

Line 61. Suggest starting a new paragraph here, where you switch to discussing methods.

done

Line 86. Are the “skeletal structure replicates” sampled from the same growth band at different positions on the colony? If so, please so state.

done

Line 89. Delete “and” in “and past seawater…”

done

Line 169. “interspersed” rather than “interspaced”

done

Line 170, 171. Ohm is not capitalized when used a unit of measurement. Also, it seems a word is missing after electronic; e.g., electronic source…

done

Line 262. That these samples are coeval should be stated right away; i.e., Eleven coeval samples…

done

Line 304. Minor or subtle, not both.

done

Line 320. “high resolution uranium isotope…”

done

Line 380. No capital needed for uranium.

done