We would like to thank the reviewers for their time and suggestions which helped improve the manuscript. Main results have not changed. Major modifications are:

- We have updated the statistical analysis. In the first version, plankton tow samples where integrated in the dataset for statistical analysis. It has been removed. Now, only the corrected I/Ca from core-tops samples is used.
- In order to confirm the Mediterranean trend, MD04-2722 core-top has been added. The sample has been dated to 3.6 ka BP (Cornuault et al. 2018).
- We have added iodine speciation dataset from the Indian ocean in Fig. 3 (Chance et al. 2020; Farrenkopf et Luther 2002).
- We have added clarifications about the use of the p25 compared to minimum oxygen value, and about the presented calibration of the proxy that must not be used to quantitatively reconstruct past oxygen concentration.

The lines pointed here corresponds to the revised manuscript with tracked changes.

Reviewer 1: Dalton Hardisty

This is a much-needed examination of the controls on the foraminiferal I/Ca proxy. The new data are of high quality and so is the global I/Ca compilation and associated statistical analyses.

We are deeply grateful of this review by Dalton Hardisty and his careful reading. These comments were very helpful to improve the manuscript.

A few important considerations before publication:

1. Since 2026, 2 papers were published (Wang et al., 2026 and He et al., 2026) that are highly relevant to this topic. These papers should be integrated into the discussion and analyses of the paper at hand. In particular, this includes the impacts of oxycline depth and latitude on I/Ca.

We agree that these two papers must be cited in the manuscript, and considered for statistical analysis and discussion. We have added the oxycline depth and oxycline oxygen value to the statistical analysis.

2. The authors need to clarify under what circumstances they suggest the proxy is quantitative, if at all. My general reading of the authors text as well as my own impression from this paper and others in the field is that there are large limitations on the degree to which I/Ca can be used predict O2, but I don't think those limitations are clearly outlined. For example, several other papers identified I/Ca ranges linked to O2 ranges, but not explicit O2 values. It should be explained how this approach does or does not differ from these past more conservative approaches and provide a more prescriptive breakdown of when, where, and why I/Ca can or can't be used quantitatively for O2, if at all. For example, Line 242: "The objective of this representation is not to find the best fit, but rather to determine whether the relationship between iodate proportion and dissolved oxygen content could explain the variation in foraminiferal I/Ca-based oxygen reconstruction." Here the authors express that the I/Ca vs O2 equations are intended solely to explore potential relationships. However, I feel that this apparent intention is lost in the Discussion since it is not mentioned again although multiple equations are presented. I find this confusing and fear that readers will over extrapolate such equations to define O2 from I/Ca. Regardless of whether I correctly understand the authors intentions, clarifications should be presented appropriately in the discussion as a caution to readers for when and when not to apply I/Ca as quantitative for O2 reconstructions.

We agree that our message of the limitations of the quantitative use of the proxy may not be clear enough, leading to potential misuse of the proxy. Our statistical analysis of a larger dataset confirmed the major role of dissolved oxygen on foraminiferal I/Ca values. However, it is very difficult to determine precisely when, where, and why I/Ca can or cannot be used quantitatively for O2.

The main difference in our approach compared to the previous studies is our use of p25[O2], which has a more robust statistical definition. As a result, the data points are more evenly spread along the x-axis (new Fig. S8). To evaluate the limitations of using foraminiferal I/Ca as a quantitative proxy, we examined the influence of the scattered relationship between the proportion of iodate and the concentration of dissolved oxygen (Fig. 3a and 3b), as well as the effect of seawater temperature on iodate incorporation, assuming the relationships obtained for abiotic calcite (referred "modelled" below) are valid for foraminiferal calcite. A comparison of the data and modelled values shows that most of the field data are within the expected range, even though some data are above or below the modelled I/Ca ratio (Fig. S8). The data below the 95% prediction interval are found within or at the boundary of OMZs but this geographical trend is not systematic, regardless of whether p25[O2] or [O2]min is used (Fig. S8b and S8d). Using min[O2], 29 sites present I/Ca values outside of predicted area, and 46 are outside using p25[O2]. Data with a positive anomaly are observed in the Atlantic Ocean, but it is unclear whether this observation is real or biased by spatially heterogeneous sampling. Further multi regression analysis did not allow us to identify additional factors affecting foraminiferal I/Ca ratios (Fig. S6), making it very difficult to quantify the limits of using I/Ca as a quantitative proxy.

In light of these observations, we emphasise the use of foraminiferal I/Ca as a semi-quantitative proxy for changes in ocean oxygenation. The proxy primarily responds to oxygen and oxygen-related parameters (Table 2, Fig. S5, Table S1 and Fig. S6). The dispersion of the relationship between inorganic iodine speciation and p25[O2] partly accounts for mixing and differences in inorganic iodine redox kinetics. For these reasons together with potential non-investigated parameters, foraminiferal I/Ca alone cannot be interpreted as a quantitative proxy. Combining it with other proxies and/or a modelling approach is highly recommended.

We have added this precision in the last discussion section and in the conclusion to summarise our position on the proxy: a semi-quantitative proxy to highlight oxygenation change at subsurface. Lines 695 to 711 and 739 to 742.

3. How would mixing impact the I/Ca proxy relationship with local O2? The IO3 vs O2 relationship has a major mixing component and so I/Ca is expected to as well in addition to vital effects, diagenesis, etc. See Cheng et al., 2024, which demonstrates the challenges of modeling iodate in the ocean with reduction and oxidation dependent on solely O2. See also the Wang et al., 2026 paper referenced above which shows mixing signals and oxycline depth. Mixing is not discussed as an impact on iodate in ODZs. See Moriyasu et al., 2020; Hardisty et al., 2021; Evans et al., 2020, which together make a case for mixing impacts on iodate in the Tropical North Pacific ODZ. This is also summarized in Cheng et al., 2024. This is because iodide oxidizes slowly, so low iodate signals can be mixed and integrated over large areas of ODZs without a clear local O2 dependency.

It is true that mixing has a major impact on inorganic iodine speciation in the ocean, partially because of the difference in oxidoreduction timing. This could produce low iodate concentration in highly oxygenated water, which results in low I/Ca. However, the mixing solely cannot explain the observed dispersion. For example, despite of the low foraminiferal I/Ca in the Mediterranean Sea, no evidence of oxygen deficient water has been observed. The lowest reported oxygen value in the Alboran Sea is about 170 µmol/kg (Packard et al., 1988). Considering the challenge of modelling inorganic iodine

speciation depending on oxygen, we have used direct measures in the 0–500 m layer. This approach is expected to partly account for the mixing, which could be responsible for an important part of the scattering, together with primary productivity iodate uptake.

We have added explanations about mixing and primary productivity and how it is thought to be partially accounted for in the inorganic iodine speciation model. Lines 296–301 and lines 695–711.

Detailed comments:

Figure S2: Wang et al., 2026 was published recently. It demonstrates a relationship between iodate and oxycline depth. Is the same relationship observed in the data here? I recognize that the Wang 2026 paper was published after the manuscript in hand was submitted, but that paper is highly relevant to this one, so should be incorporated into the discussion. https://doi.org/10.1016/j.gloplacha.2026.105412

We agree with this suggestion. To better discuss the influence of oxycline, we have added oxycline depth and oxygen value at oxycline to the tested parameters influencing foraminiferal I/Ca. The results indicate an important influence of mean oxygen at oxycline (p-value < 0.01). However, oxycline depth is not significantly correlated to foraminiferal I/Ca (p-value = 0.06 for Spearman and 0.17 for Kendall). After removing the influence of p25[O2], oxygen concentration at oxycline still has a significant correlation with the I/Ca residuals (p-value < 0.01). Oxycline depth is not correlated to residuals (p-value = 0.82 for Spearman and 0.99 for Kendall). It does not mean that oxycline depth and oxygen concentration at the oxycline depth are not important for I/Ca, but rather that their influence may already be integrated in p25[O2] or that it can have a secondary influence, or be responsible for some scatter. Lines 213–217, 504.

Figure S2: He et al., 2026 also demonstrate a relationship between I/Ca and latitude that mimics the same relationship seen for IO3 and latitude. Does the dataset assembled here also reveal that pattern? https://doi.org/10.1038/s41561-025-01896-w

We have also found a pattern between foraminiferal I/Ca and oxygen (Figure S5). However, it is possible that this pattern is related to the spatial distribution of data points. Most OMZs investigated with I/Ca are found at low latitudes, and oxygen depletion would trigger iodate reduction. Similar pattern is also found in p25[O2] as a function of latitude (Figure S2). Moreover, a temperature effect has been shown in iodine incorporation in abiotic calcite (Zhou et al., 2014). Thus, it is difficult to correlate directly the influence of latitude to I/Ca, as other parameters co-vary with it. Lines 338–340.

Line 351: “This mismatch between oxygen and iodate concentration may at least partly explain the apparent presence of iodate in waters here defined as oxygen-depleted.” Is it not the other way around: i.e., that the presence of iodate in low O2 waters explains the mismatch between O2 and IO3?

We agree that we meant a potential presence of iodide was possible in oxygenated water. This sentence has been corrected. Lines 462–464.

Figure 4: Why are data from samples younger than 8kyr used here? Elsewhere 2kyr is used. It seems difficult to expect a comparison between I/Ca from samples from last 8kyr and contemporary water column O2.

We agree that foraminiferal I/Ca ratios dated at 8 kyr do not reflect the current oxygen concentration. This selection is to examine the spatial coverage of the data at this stage. Figure 4 highlights the new data from the Mediterranean Sea and the Arabian Sea that are dated at around 6 ka BP. We think it is important to show this sample as high I/Ca exists in the Mediterranean Sea.

Figure 1: Do the color of the symbols on the map in part A marking locations correspond to I/Ca legend? Their colors overlap but the values all seem very low and thus inconsistent with the subsequent graphs of I/Ca. I'm wondering if the maximum values on the color scale are too large thus giving the impression of uniformly low I/Ca? If this is the case, adjust the color scale range so the spread in I/Ca is more clearly visualized.

The colour of the symbols in Figure 1a and 1b correspond to the I/Ca colour scale in the legend. We choose a linear colour scale maxed at 10 µmol/mol because all core-tops I/Ca are found in this range (0–10 µmol/mol). We have added ticks to the colour bar to clearly present a linear scale.

We are now using corrected I/Ca to take into account reductively cleaned samples (30% as suggested by reviewer#2).

Line 395 and Figure 6: Zhou et al., 2014 also demonstrated a temperature dependency between I/Ca and iodate in medium (see their supplement). It looks like this was utilized but a uniform temp of 19 deg was used, though the color bar shows a large range of temperatures. It would be helpful to use the iodate concentrations and temperature from each site at the depth of p25(O2) to plot the synthetic calcite predicted I/Ca value using the temperature dependent I/Ca equations from Zhou et al., 2014 and plot these against the actual measured I/Ca values. This could be done for each site and demonstrate the relationships, if any. This could aide in interpreting deviations from "ideal".

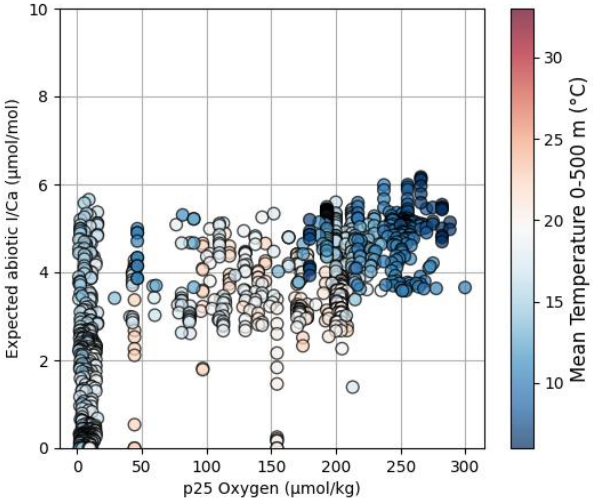
Due to scarce inorganic iodine speciation, it is not possible to define a concentration in iodate at foraminiferal I/Ca sites. This is why we choose to represent foraminiferal I/Ca data and a prediction model of abiotic calcite based on iodate speciation in different oxygen contexts, inorganic iodine distribution, and the equation of I/Ca depending on iodate concentration at given temperature from Zhou et al. (2014). The colour scale of foraminiferal I/Ca data is the mean temperature in the upper 500 m 0.25°x0.25° around sampling site. The objective was to see if a pattern in temperature was visible with more/less iodine incorporated when temperature is low/high. But no pattern is visible.

As you mentioned, it is possible to compare in another way, by modelling expected abiotic I/Ca at given iodate concentration and temperature. In order to achieve this, we need make a few assumptions. Zhou et al. (2014) have presented 3 curves for 6, 19 and 33 °C. A linear interpolation for temperatures within this range is needed. However, we think that extrapolation of equation for temperatures below/above 6/33 °C may be too uncertain. The range 6–33 °C offers the ability to compare a lot of points in various oceanographic contexts.

So, by considering iodate concentration and temperature, we can model the predicted abiotic I/Ca independently of foraminiferal I/Ca dataset. Then, we can plot the expected abiotic I/Ca as a function of p25[O2].

The result (see the figure below) is similar to the reconstructed range in Figure 6, with I/Ca values between 0 and 6 µmol/mol. However, this approach allows for high I/Ca at low p25[O2], which is not seen with foraminiferal I/Ca. Also, low I/Ca values (< 2 µmol/mol) in more than 50 µmol/kg of oxygen are scarce with iodate dataset.

As the conclusions do not differ and the results are very close to the modelled abiotic I/Ca from Figure 5, we don't think the addition of this figure is necessary.



Line 408: The highly elevated values of I/Ca > 6 µmol/mol are not necessarily specific to foraminiferal calcite. It is noteworthy that similarly elevated values are observed for core-top aragonite (see Hardisty et al., 2017 data from Great Bahamas Bank), which may reflect partition coefficient differences for aragonite or other environmental influences. Also see Lu et al., 2022 for a similar discussion from benthic forams.

https://doi.org/10.1016/j.gca.2022.06.001 and https://doi.org/10.1016/j.epsl.2017.01.032

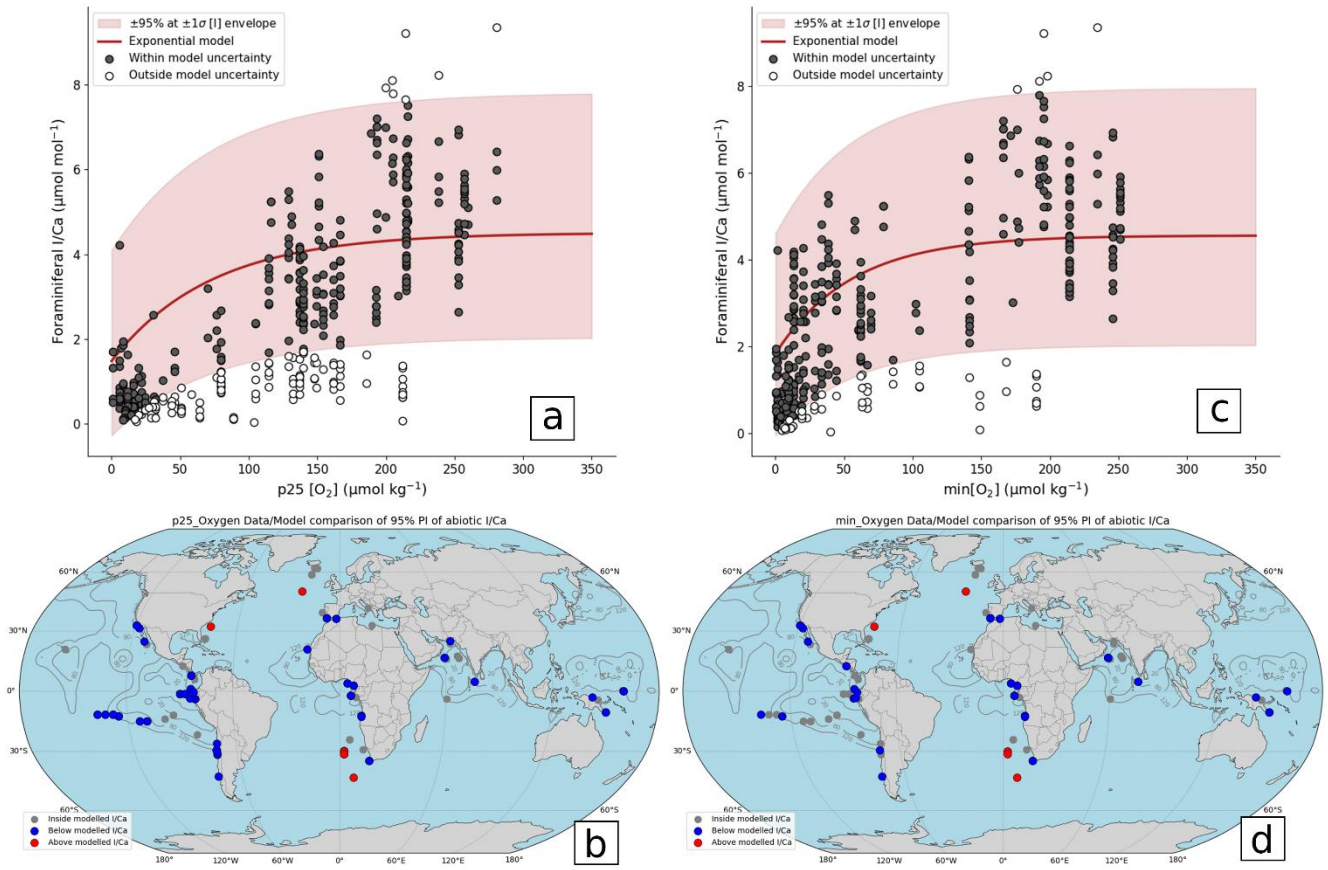
We agree that aragonite-rich sediment may have a higher I/Ca. In the new data presented, the highest ratio is found in SL95 core (6.86 µmol/mol). SL95 is located in the Gulf of Sirte, area with high aragonite concentration due to the presence of *Halimeda* (Reitz et De Lange 2006). Remaining grains of aragonite after cleaning may result in higher I/Ca. To investigate the influence of the presence of aragonite, we are using a binary mixing between aragonite and foraminifera. Sr/Ca of SL95 core top is 1.35 mmol/mol. Typical foraminiferal value is 1–2 mmol/mol (Rosenthal et al. 2004), and aragonite value is 8–10 mmol/mol (Bolden et al. 2023). The highest contribution of aragonite possible would be 5% considering a binary mixing. We consider an I/Ca of 10 µmol/mol in aragonite, similar as the ratio measured in scleractinian corals (Sun et al. 2023). With a 5% contribution of aragonite and an expected I/Ca of 4 µmol/mol, the foraminiferal I/Ca would be 4.30 µmol/mol. Aragonite contribution would need to be around 40% to account for an I/Ca between 6 and 7 µmol/mol. The aragonite proportion needed can be reduced to 30% if an I/Ca of 13 µmol/mol (maximum value measured in aragonite). Sr/Ca of these mix would be 4.8 and 3.9 mmol/mol, respectively. As the Sr/Ca from SL95 core-top is 1.345 mmol/mol, the mix does not correspond to the observed value. The contribution of aragonite alone cannot explain the measured value. Another possible source for iodine in the calcium carbonate would require the presence of iodate at the water–sediment interface during secondary calcite precipitation, thereby increasing the I/Ca value. However, 20% secondary calcite precipitation would require an I/Ca

ratio of 18 µmol/mol. An I/Ca this high has never been measured in natural and recent sample, and a 20% contribution of secondary calcite would have been excluded during foraminifera picking due to visible encrusting. We have pointed this in the discussion lines 550 to 562.

Figures: If the authors intend to present I/Ca as quantitative for O2 under any circumstance, it would be useful to make another map like Figure 1A showing marine O2 (showing p25O2 in this case) but with the fill of the circles marking sites shaded with the predicted O2 based on the I/Ca measured at this site. This would provide a global visualization not apparent in the other figures for which regions follow the predicted trend line and which do not.

We do not intend to present foraminiferal I/Ca as a quantitative proxy for oxygen as explained above. New Figure S8 is added for the visualisation of global trend.

We have added the information in the discussion lines 588 to 591.



Reviewer 2: Anonymous

I agree with Dalton that this review of the factors affecting I/Ca is a needed contribution for the development of this proxy. The factors the authors have chosen are extensive and appropriate. I appreciate the effort the authors have put into compiling a database with core-top I/Ca values and these factors, which will be very helpful moving forward, as well as their statistical approach. Though they are a relatively small part of the manuscript, I particularly appreciate the look at the effects of photosymbionts and authigenic overgrowths.

At first, we are deeply grateful to the anonymous reviewer for the numerous insightful comments and careful reading. These comments were very helpful to improve the manuscript.

The following is a list of my concerns and suggestions.

Correction for reductive cleaning: The Barker et al. (2003) protocol (line 125) uses a reductive cleaning step, which Zhou, Hess et al. (2022) showed causes a ~30% lowering of I/Ca. Can the authors confirm whether they included that step? If so, a correction is needed to make measured values comparable to other core-top data used in the analyses, without which the statistical analyses and calibration can't be accurate.

We agree that the correction method was not explicitly mentioned when it should have. In the previous version of the manuscript, the correction was not applied for the data where oxidative and reductive cleaning was realised. The new samples from this study followed the short cleaning protocol from Barker et al. (2003), which does not contain a reductive cleaning. This is now mentioned in the manuscript lines 145-146.

Correction is now applied for the I/Ca with Reductive + Oxidative cleaning, a column in the dataset now summarises the cleaning method used for the sample. A correction of I/Ca of +30% has been added for the reductively cleaned samples. However, the use of the corrected value for 197 samples out of 568. This update doesn't change the main message of the manuscript but slightly changes the equations. We have updated all the figures, equations, and statistical analysis.

Factors affecting I/Ca aside from oxygenation: As Dalton noted in his review, it's important to acknowledge that oxygen is not the only factor determining iodine speciation. While I agree that the spread in iodate concentrations at a given oxygen value likely leads to a lot of the spread in the I/Ca measurements (paragraph beginning line 353), other factors aside from oxygen concentrations of that water parcel also affect iodate concentrations (e.g., productivity, different rates of oxidation vs reduction, mixing). This concept is key to the manuscript and needs to be better explained/supported (see lines 86-87, 147-149, 347-352).

We agree with the reviewer. Factors other than oxygen do influence inorganic iodine speciation. And, if partially accounted for in the inorganic iodine speciation model, it should be mentioned in the text. Our model may not fully cover the range of possible inorganic iodine speciation in different oceanic contexts. This is now mentioned lines 296-301.

Proposed p25 calibration: The calibration of I/Ca to p25 instead of [O2]min is a major deviation from previous calibrations, and therefore needs to be explained in detail and well supported. The authors compare and contrast the relationship between iodate and these two oxygen parameters (Fig. 3), but the comparisons are not always apples-to-apples and the logical step from the iodate-O2 comparison to I/Ca could use more explanation. More specifically,…

We have proposed p25 calibration considering the difficulty to define minimum oxygen concentration (Lu et al. 2020). The definition of minimum oxygen concentration can be influenced by the dataset used. This, in turn, is affected by sampling seasons, potential measurement issues, and database management. During our database creation, we encountered several inaccurate oxygen values. We aim at creating I/Ca dataset with the oxygen dataset as reliable as possible to eliminate outliers. To capture the local dynamic of oxygen, we consider the full 500 m in depth and time in the limits of the dataset. Moreover, the goal of the p25 calibration is not to propose a quantitative interpretation of the proxy. Iodine concentration and speciation dynamics, not fully captured oxygen variability may still be responsible for the important dispersion observed. With p25, the oxygen parameter with the best fit, it is possible to de-trend the oxygen influence and try to obtain clues of secondary parameters influencing I/Ca. We have added these explanations to the revised manuscript lines 258-263 and 266-267.

Conceptually, the use of [iodate]/[total iodine] rather than simply [iodate] needs more explanation/justification. If foraminifera incorporate iodate but not iodide, and iodine=iodate+iodide, how does the total iodine affect I/Ca? Importantly, Figure 2a and 2b use different y-axis parameters, making it impossible to compare the relationship between iodate and the two oxygenation parameters. What would 2a look like with [iodate] on the y-axis or 2b look like with [iodate]/[total iodine]?

Inorganic iodine (iodate + iodide) concentration is not constant in the ocean. So, a higher total inorganic iodine concentration may lead to higher iodate concentration, and so, to a higher I/Ca in oxygenated water. This effect is considered by using ± 1σ range for the total inorganic iodine concentration as shown in Figure 3c.

Figure 2 only presents oxygen distributions for 3 different sites, showing 3 different oxygen dynamics identified in our dataset.

Figure 3 presents 2 different concepts to understand inorganic iodine in the ocean based on oxygen. Fig. 3b present iodate concentration as a function of min[O_2]. This is the behaviour and relationship commonly imagined. Fig. 3a is our proposition, the biggest change being the y-axis. [Iodate]/[Iodate+Iodide] as a function of min[O_2] would look similar to Fig. 3a as p25[O_2] is not a big deviation from the minimum value. Both parameters are related to local oxygen dynamic, and the aim of p25 is to have a statistically defined oxygen depletion value.

As the main message of the figure is to present a different concept to remove the influence of total inorganic iodine concentration and not a comparison between min[O_2] and p25[O_2], we think it is not necessary to modify the figure. However, a sentence was added lines 298–299 to make sure reader does not see Fig. 3 as a comparison of p25 and min[O_2].

It seems that the reason p25 gives the best fit with I/Ca is driven very strongly by the new data from sites ODP977 and MD99-2341; in Figure S1's p5 plot (the closest presented to the [O2]min which would be p0), it looks like those are 2 of the 3 sites with data that fall below the main data cloud at ~200

umol/kg O2. This is especially problematic if the 30% correction for reductive cleaning has not yet been applied. Aside from that, is there anything unusual about these sites?

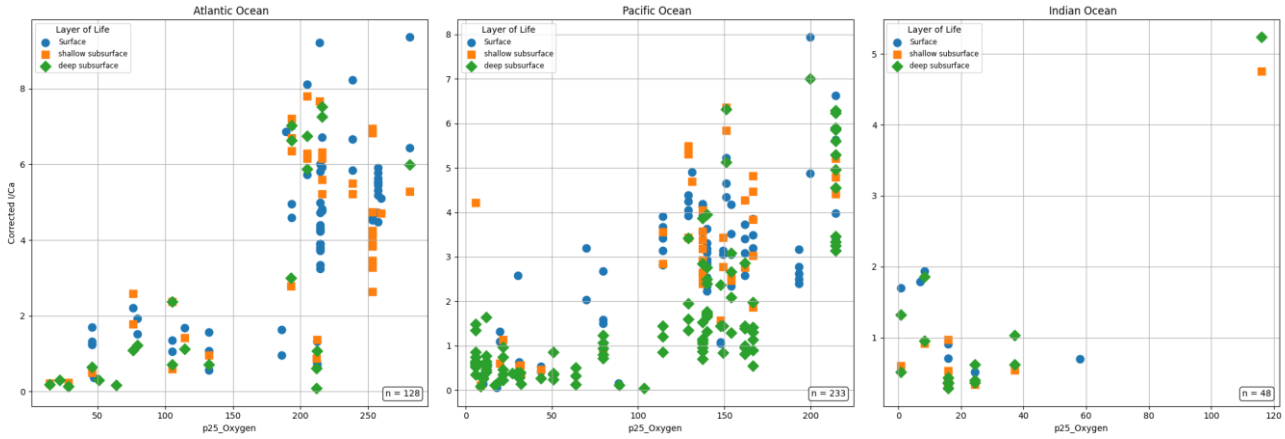
To answer this question, Figure S1 is made using the corrected I/Ca (+ 30 % for 197 reductively cleaned samples, no change for oxidatively cleaned samples) but without our Mediterranean and Gulf of Cadix data. p25 still gives the best fit, with data from V14-70 site in Southern Benguela (Lu et al., 2020a) ending up in the same domain as low Mediterranean I/Ca. This could potentially indicate important oxygen variability patterns (as it was shown by Lu et al., 2020) or local iodine speciation such as iodate depletion due to time for iodide oxidation. Regarding Gulf of Cadix, no mention of oxygen depletion nor low oxygen values could be found. For the Alboran Sea, Packard et al. (1988) is the only mention of an oxygen depletion in the area. But the lowest oxygen values reported are 3.85 mL/L, around 170 µmol/kg.

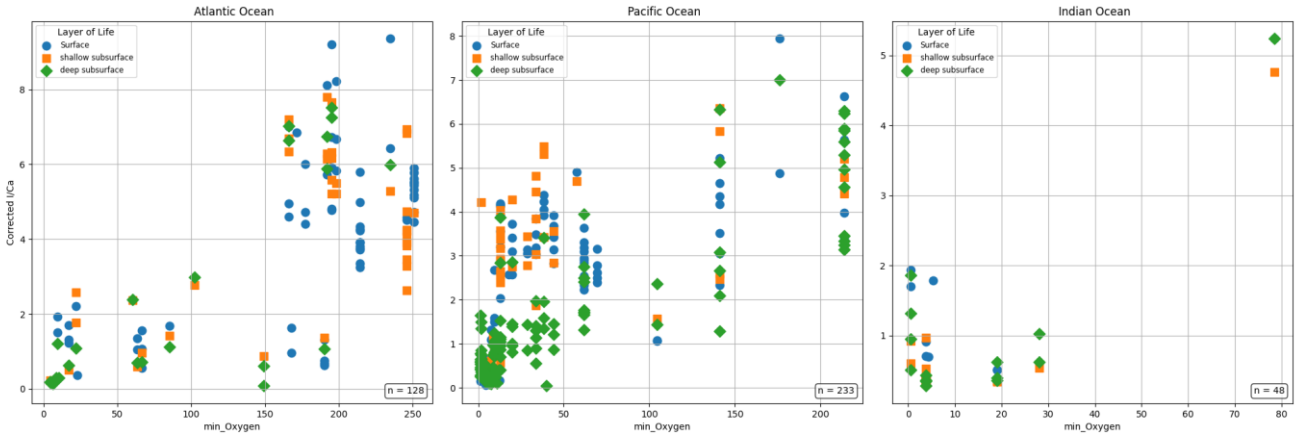
Hess et al. (2025) showed that I/Ca of different species varies with depth, with different patterns in OMZs and the open ocean: deeper dwellers have lower I/Ca values than shallow dwellers in areas with an OMZ (driven by iodate reduction below the forams in the OMZ), and the opposite in areas without an OMZ (driven by productivity iodate reduction in the surface). In Figure S4 and lines 330-331, we lose that pattern, which makes me think [O2]min makes more conceptual sense than p25.

Depth dwelling of different species is an important assumption in paleo-studies. We agree that for OMZs areas, deep dwellers show lower I/Ca than surface dweller, especially in the Pacific Ocean (Fig. S4). This pattern was less visible at very low oxygen levels when using p25. The following figures show our examination of the dataset by ocean, presenting Atlantic, Pacific and Indian oceans as a function of both p25 and min[O_2] to evaluate the influence of the definition of dissolved oxygen (p25 [O2] or min[O2]). We only present core-top values dated at younger than 2 ka to be coherent with the other figures.

The pattern of foraminiferal I/Ca with calcification depths is visible at moderately oxygenated sites (100 < p25 < 180 µmol/kg) in the Pacific Ocean. With min[O2], this pattern is not clearly observed at this oxygen range because of the differences with p25[O2]. The pattern is visible at low oxygen concentrations (0 < min[O2] < 50 µmol/kg).

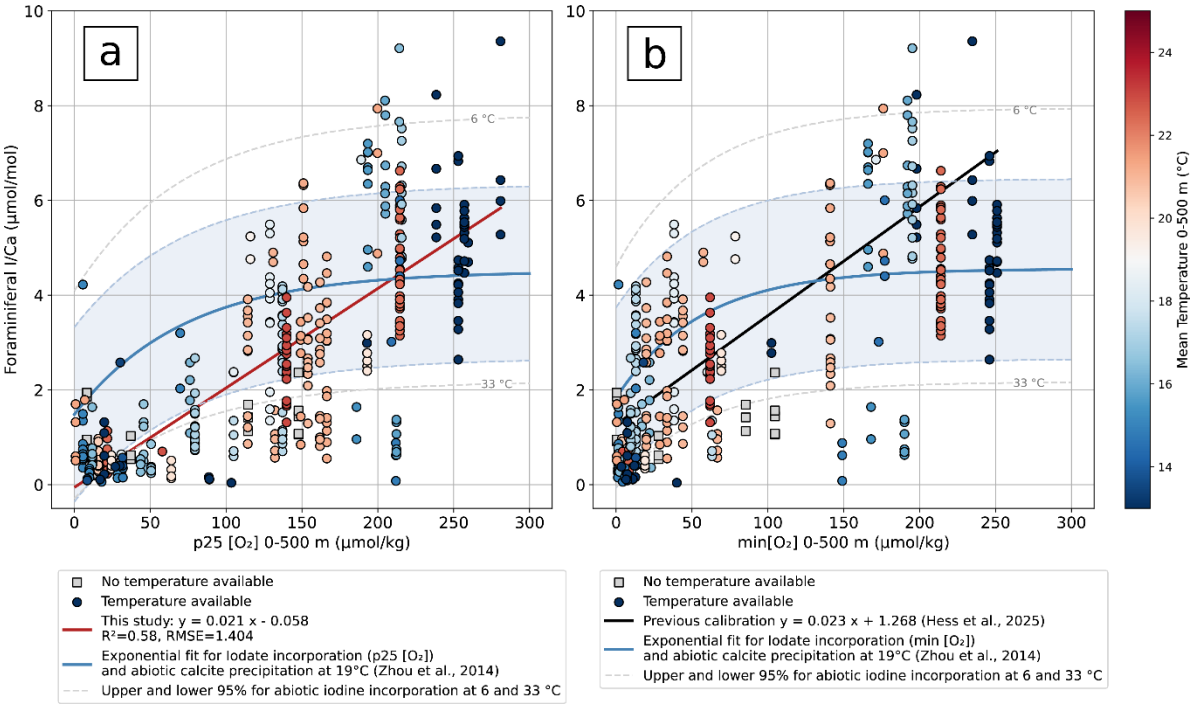
We propose to use the following figure presenting ocean sub-datasets as a function of p25 instead of the global Figure S4 presented in the first version of the manuscript. We have updated the text lines 430–432 accordingly.





Figures 3 and 5 make a nice comparison between p25 and [O2]min. It would strengthen the story substantially to continue that comparison through to Figure 6 by adding a version using [O2]min.

We agree that the comparison is interesting. While we think the comparison is important but should not be in the main manuscript as it could lead to the misinterpretation that low I/Ca in high oxygen concentration are isolated, which is not the case. As this is a dataset issue, we propose to add the following figure in the supplementary. We have added the comparison with min[O_2] Fig. S7 and fixed the text accordingly lines 547–549. Previous figure S7 is now S8.



Importantly, with the proposed p25 calibration, I/Ca cannot be used to determine that an OMZ existed in the past, arguably the main utility of the proxy, because I/Ca values <1 umol/mol can occur at almost any p25 value. This would be an unfortunate development for the proxy, and I find I'm not yet convinced by the arguments for using p25.

We think the proxy may still be used to determine the presence of an OMZ in the past. However, we argue that low I/Ca may occur in oxygenated place, and the absolute I/Ca value alone cannot be interpreted. The trend of the I/Ca, however, may be used at a site to capture the change in oxygenation

dynamic in the past. The use of p25 is only to consider for the variability of the oxygen concentration in space, depth, and time as much as we can at the moment. We think of the p25 as "1/4 of the oxygen data are bellow this value, so the oxygen depletion in the area is/isn't important, whether it is in intensity, thickness, or time". Moreover, large dispersion between foraminiferal I/Ca and [O_2] exists with different [O_2] definitions. Considering this dispersion, the robust interpretation of the proxy would be released by combining with other proxies and/or modelling approach.

Line-specific comments:

Lines 15-17: Grammar check, it looks like there's a shift from plural to singular

Fixed line 16.

Lines 81-83: This sentence should also reference Lu et al. (2020), who first suggested this for Atlantic sites. Have the sites that Lu et al. (2020) and Hess et al. (2025) excluded from their calibration plots also been excluded from the plots herein?

To our understanding, Lu et al., (2020) did not exclude data. In their work, they showed that using oxygen values from a 0.25°x0.25° area around sampling position helped to account for local oxygen variability (instead of using the closest oxygen profile). Hess et al. (2025) explicitly mentioned excluded values. They argued that shallow water sites (<~500 m water depth) near the southern tip of Africa from Lu et al., (2020a) are prone to important local oxygen variability. They also excluded Site RR1313 2MC (545 m water depth) for the same reason. We choose not to exclude any samples as these sites with oxygen concentration variability over small spatial scales can be useful to identify similar behaviour in certain areas, especially in Gulf of Cadix and in Alboran Sea. These two areas' foraminiferal I/Ca falls in the same domain as site V14-70 (Southern Benguela) when using p25. This deviation highlights a potential similitude in oxygen or inorganic iodine speciation behaviour at these sites. However, water depth is not thought to be the main factor, but rather the coastal influence, a parameter still not well constrained. We have added Lu et al., 2020 in the cited papers line 94.

Line 120: "of the two core-top studied" has a grammar problem. Possibly "core-tops studied"?

Fixed line 140.

Lines 157-158: Can the authors expand on what that iodine speciation data looks like, i.e., spatial resolution? In my experience, this type of data is typically geographically sparse and also has low vertical resolution, with possibly only a few points in the upper 500m. Can the authors explain whether they encountered these problems and, if so, how they addressed them?

Inorganic iodine speciation data are sparse, as shown by Winkelbauer et al., (2023). We are using the same dataset, but with different treatment. We first select data shallower than 500 mbsl. We then only select data with iodide and iodate measures. If one of the two is missing, this would lead to a false interpretation of the total inorganic iodine, and we would not be able to account for its variability. We select total inorganic iodine in the +/- 1 sigma interval to avoid heavily iodine depleted/enriched areas. Lastly, we remove the Bermudas inshore data as they originate from a highly restricted area. After this selection, we are left with 1692 points and we were able to recover oxygen statistics for n = 1551 points. The majority of the measures are close to surface as shown by the z-axis of Figure 3a and 3b (mean depth = 113 m, median depth = 75 m). Mean oxygen of the dataset is 195 µmol/kg with standard deviation of 73 µmol/kg. p25 Oxygen mean is 152 µmol/kg with standard deviation of 95 µmol/kg.

Latitudes from the subset span from 70°S to 70°N. These statistics ensure a good coverage of different oxygenation contexts. Of course, the dataset is a first approximation of the dynamic of inorganic iodine speciation, and it may evolve as we better understand its behaviour. The main goal here is to show that the inorganic iodine speciation and oxygen relationship is complex, and the Figure 3 is a way to visualise it. We have updated the dataset and added the Indian Ocean iodine speciation measures from Chance et al. (2020; Farrenkopf et Luther III (2002).

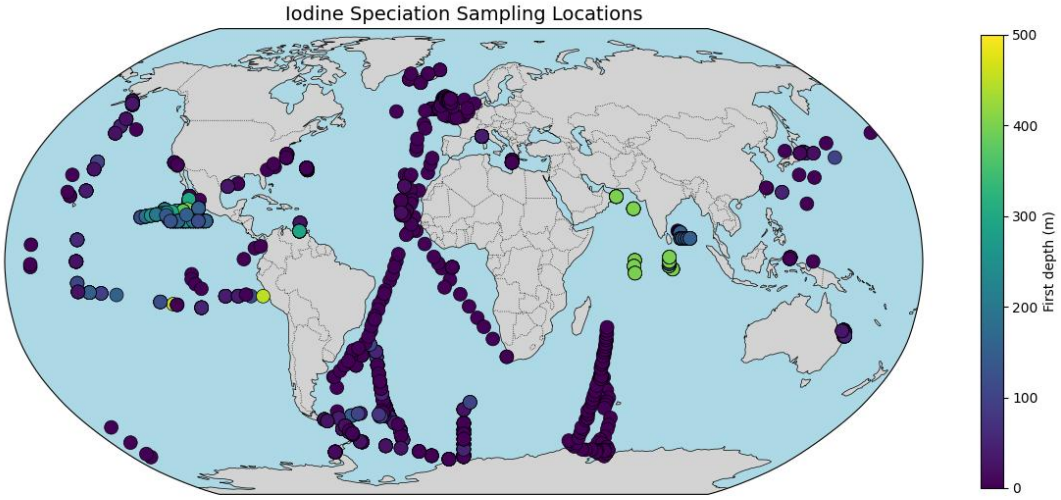


Figure 2:

There are no dotted red lines, it seems the O2min line is solid. Is the p25 line actually not shown?

We fixed the figure.

Please be more specific about which p's the gray lines represent.

Figure 2 description now indicates the percentiles represented.

Lines 125-129: most of these species are mixed-layer calcifiers, but not all. Given the importance of calcification depth on I/Ca (Hess et al., 2025), the authors should include that information

We acknowledge that not all species used in this study are mixed-layer calcifiers. Depth-dwelling layers are now specified in the manuscript lines 149–151.

Figure 3:

To make the comparisons in lines 244-246 and 248-249, the fit and prediction interval (red line and band in part a) need to also be shown for part b. However, the data in part b show a threshold, as has been widely described in the literature (most recently Wang et al., 2026), so of course they will have a poorer exponential fit. With this in mind, it doesn't seem that these plots can show whether [O2]min or p25 is a better fit for I/Ca.

We would like to clarify that the primary objective of Figure 3a and 3b is not to directly compare the statistical performance of p25 and min[O2], but rather to illustrate two different representation of inorganic iodine behaviour. Figure 3b is the commonly described threshold behaviour of iodate

reduction at low oxygen concentrations. Figure 3a is the more continuous relationship based on inorganic iodine speciation.

We agree that these two plots do not allow to compare whether there is a best fit between p25/min[O2] and inorganic iodine speciation as the Y axis are different.

The visible threshold in Figure 3b only allows iodate reduction in very low oxygen concentration (around 10-20 µmol/kg) which is highly incompatible with a linear calibration curve.

We have corrected the sentences for the comparison between Fig. 3a and 3b lines 298–301.

To help us follow the description in lines 251-255, can the Mediterranean Sea values be differentiated somehow?

We thank the reviewer for this suggestion, the figure now highlights the Mediterranean Sea values.

Line 264: missing period.

Fixed.

Line 276: What is the [O2]min at these sites?

In the Gulf of Cadix, minimum oxygen is 190 µmol/kg, and 168 µmol/kg for Alboran Sea. This is now specified lines 360 to 361.

Lines 344-345: It seems like this should reference Figure S5, is that right?

Yes, Table 2 and Figure S5 are reporting similar results, with Figure S5 being the visual representation of Table 2. We now also mention Figure S5 line 436.

Lines 358-359: I'm not following the mathematical jump from the iodate plot to the I/Ca numbers presented here. If the authors are saying that the entirety of the I/Ca variability (I think that's where the 1-5 umol/mol number comes from?) can be attributed to iodate variability, this is a very strong assertion and needs more support.

We are trying to model the foraminiferal I/Ca depending on oxygen with the assumption that the incorporation is mainly abiotic. For this, an equation to convert oxygen to iodate concentration is needed. We are using Figure 3a to determine the amount of inorganic iodine under the form of iodate at a specific oxygen value. As you mentioned, iodate concentration is not only depending on oxygen concentration, so we are also considering the prediction interval of this relationship. This 95% prediction interval is thought to account for most of the other factors influencing inorganic iodine speciation, like primary productivity, vertical mixing or the difference between oxidation and reduction time. As we are integrating in those parameters and uncertainties here, the next step of the model is the integration of the iodine in the calcite lattice. As not much work exists on this, we choose the most recent work from Zhou et al. (2014). In their work, they have synthetised calcite at different iodate concentrations. The experience was repeated at 3 temperatures, 19 °C, 33 °C and 6 °C. The incorporation of iodine in calcite was shown to be linear with the iodate concentration, with different slopes at different temperatures.

We are now left with two equations, one with the amount of inorganic iodine under the iodate form, and one with the I/Ca of synthetic calcite at different iodate concentrations. To combine the two, the percentage of iodate must be converted to a concentration. We are using the global distribution of inorganic iodine concentration (Figure 3c) to determine a mean concentration of 471 nmol/kg (Fig 3c). This value is supported by other papers (Chance et al. 2010; Luther 2023).

The equation of iodate amount is then multiplied by the inorganic iodine concentration to obtain a model of iodate concentration at a specific oxygen value. Then, this value is integrated to the linear equation of iodate to synthetic calcite I/Ca to obtain a modelled average I/Ca at different oxygen values. By changing the last equation, we can consider for the temperature effect on iodine incorporation.

The goal of this model is not to say that all the I/Ca variability is caused by iodate variability alone. But rather that this could be a reason, or a part of the variability. However, it is impossible to confirm this without direct and comparable measures of inorganic iodine and associated speciation, together with foraminiferal I/Ca. As you mentioned, inorganic iodine speciation measures are scarce, and do not cover areas and times of foraminiferal sampling.

We have added explanations of the mathematical reasoning lines 520–532.

Figure 5:

The x-axes in parts a and b are different, and the data are plotted using those axes, but it is not possible to accurately plot both the red and blue line on both plots. The red line should be removed from part a and the blue line should be removed from part b.

We agree, the line not related to the x-axis has been removed.

Figure 6:

As with Figure 5, the line from Hess et al. (2025) can't be shown on this figure, as the x-axis is for a different measurement.

We agree, it has been removed.

Line 414: "areas"

Fixed.

Line 416-417: "we consider the linear regression is an appropriate approximation" A slight word of caution that "appropriate" is perhaps too strong here. Linear is certainly the simplest way to characterize this empirical relationship, but as we learn about the proxy, we may find another type of characterization is most appropriate. Of course, I leave this to the author's discretion.

We agree, linear regression is a reasonable way until a reason for another regression type is found. We fixed the sentence line 576.

Lines 421-423: It seems very unlikely that only the data points at moderate p25 and low I/Ca would be affected by vital effects. For this to be the case, I would expect the data to be from species only sampled in these data points, which I think is not the case? If the species from these samples have values that make sense in other parts of the curve, it seems unlikely it would be vital effects. Since many of the low I/Ca at moderate p25 points have lower [O2]min (as shown by gray lines in Fig. 5a), is another possibility that the p25 parameter is not the best way to understand the oxygenation effect on iodate concentration? To continue the compare-and-contrast that's been done between [O2]min and p25 thus far in the manuscript, I wonder what Figure 6 would look like with [O2]min and the threshold value from Fig. 3b.

In our point of view, the data points at moderate p25 and low I/Ca are not the only one affected by potential vital effects. We were thinking of vital effect as a deviation from the abiotic integration of iodine. This deviation is highlighted in this part of the figure, as the others are within the 95% prediction

interval, and we cannot differentiate vital effect (iodine incorporation) from iodate variability (water column linked process).

The problem we encountered with min[O2] is that it is not representative of what is happening in the area, it may sometimes be adequate or representative of oxygen depletion, but it is also an extreme value. This may be caused by extreme event in a specific area or by an error in the oxygen dataset. We agree that I/Ca is closely related to oxygen depletion through inorganic iodine speciation. But in order to model the I/Ca, we needed a statistically reliable variable to compare the two approaches.

Figure 7:

I suggest making the black line red to match the same line in earlier figures.

We agree that this will help follow the point. It has been fixed.

Caption describes the blue dashed lines as "grey dotted lines"

Fixed.

Interestingly, if samples were reductively cleaned and this has not yet corrected, raising the I/Ca values 30% would place most of them above the 0% line.

Yes, it is true. However, the short cleaning used didn't integrate reductive cleaning. Another parameter may be responsible for this deviation.

Line 436: Something is going on grammatically here. Perhaps "from the OMZ" or "from within OMZs"? I'm not sure which OMZ the authors are referring to in this paragraph and the next.

We fixed the sentence line 615 with "from within OMZs". We were not referring to a specific OMZ.

Line 506: "at the surface"

Fixed.

Line 509-510: I'm sorry, I'm not understanding the phrase "is hardly needed to distinguish provenance in the foraminiferal test"

We were referring to the possible contrasts of iodine concentration in the calcite lattice. Differences may exist in chambers, and so, on the development stage of the foraminifera. It could also be a reason for the deviation observed. It is now more explicit lines 716–718.

Line 528-530: Again, too much emphasis on the catchall "vital effects" and not enough information on the other factors that drive iodine speciation.

We say that remaining dispersion may result from vital effect or inorganic iodine speciation with now more details, lines 695–711.

Line 536-537: I see that the authors are saying that the Mediterranean data herein shows the proxy can be used in semi-enclosed basins, but the proxy can also be used in the open ocean. If the authors did not mean to imply it can't perhaps a slight rephrasing would help clarify. Looking at the Mediterranean data in Figure 4, with Sites ODP977 and MD99-2341 having low I/Ca despite high p25, I wonder if we actually need a caveat for enclosed basins, that I/Ca values can be low in these settings despite high oxygen, something not observed for open-ocean sites.

We agree that we did not intend to say it was only applicable in semi-enclosed basins. We meant it was also possible to use the proxy in semi-enclosed basins.

As you mentioned, low I/Ca in apparently high oxygen concentrations exists elsewhere (Lu et al., 2020a and Hess et al., 2025). The proxy apparently doesn't have a different behaviour in the Mediterranean Sea and in the open ocean. The coastal influence may play a role in some areas, but we also obtained high I/Ca in the Mediterranean Sea. It thus seems that there is currently no argument strong enough to have a region-specific calibration. The coastal areas are still very difficult to define, and the distance to coast parameter tested did not help to distinguish a threshold for a different calibration (Fig. S5 and S6). We have rephrased lines 650 to 652.

In order to confirm that the proxy's behaviour is similar in the Mediterranean Sea and in the open ocean, we have added an I/Ca measured on *G. ruber* in the Levantine Sea (Eastern Mediterranean Sea). We measured an I/Ca value of 2.84 µmol/mol for the core top sample which was dated at 3.6 ka BP (Cornuault et al. 2018).

Finally, I was curious to see which points are which in Figure 5a and tried to recreate it from the database, but after quite a while of trying I wasn't able to. Can the authors point me to the column for [O2]min 0-500m that was used to make this plot? I suggest adding a legend for the columns, with more explanation.

Figure 5a was using published oxygen values, this is the reason why it was not firstly implemented in the database you add. It is the only place where this parameter was used as it was a comparison between the two calibrations.

We agree that the provided table is not user-friendly, and that a note will help to understand all parameters. We provide it in the table, together with a description of which column is used for which figure.

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