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Interactive comment on "Late Pleistocene Glacial–Interglacial related shell size isotope variability in planktonic foraminifera as a function of local hydrology" *by* B. Metcalfe et al.

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Anonymous Referee 2

We thank you for the careful consideration of our manuscript. Please find outlined below our response to your reviewer comments and corrections of the manuscript, " Late Pleistocene Glacial-Interglacial related shell size isotope variability in planktonic foraminifera as a function of local hydrology.", submitted to Biogeosciences.

Specific comments on the text and figures.

First a comment on terminology. The authors consistently use the terms 'enriched'

and ‘depleted’ to describe both isotopic ratios and the amount of each isotope. This is at times very confusing. Can I please request that when referring to enrichment or depletion of a specific isotope that it is noted which one is being discussed. Further, isotope ratios themselves are not strictly speaking enriched/depleted they are, e.g., higher/lower. A little thing but separating the terms out this manner would help to simply matters considerably.

Isotope ratios are indeed strictly speaking higher or lower (as they are ratios), but when referring to a change in the relative abundance between one isotope and another isotope of a given element then the terms enriched and depleted can be used. Of course we will endeavor in the correction to mention which specific isotope it is that we are referring to.

P136 L13 - do you mean that size-isotope trends within each species are not constant through time and thus, comparison of isotopic data from same sized-individuals in different species are also not constant through time? Can you please be more explicit about which of these options you’re referring to or if both.

Our results show that the offset between different size fractions is not constant, whether this means that using the same size fraction for all species makes the species not comparable is dependent on your use for the information. Most researchers pick different species with the intent to get a different signal (i.e. thermocline, deep water etc.), so being more explicit would serve no purpose.

P136 L20 – implying that these taxa calcify in a similar water depth throughout their life cycle – worth being explicit here as for the globorotalids?

Unfortunately this is not as simple, and thus the reason for vague or lack of explicit definition of whether different sized individuals calcified in different or similar water depths. Calcification during the winter mixing/start of the spring bloom gives the same isotopic equilibrium value for the upper 200 m (the defined water depth of this species) which means that distinguishing the water depth for this species is particularly difficult

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(see fig 11), therefore we felt it was prudent to leave it at similar isotope values.

P138 L13 – are planktic foraminifera really limited in their ability to track favorable conditions? If plankton can be anywhere (see Norris, 2000) then they can maintain populations wherever suitable conditions pop up.

The sentence does mention that when favourable conditions a population can be maintained, however the recent work of van Sebille et al. [2015; Nature Communications] highlights just how fast oceanic dispersal occurs. As an individual, a foraminifer does not have the ability to actively seek favorable conditions (it does not have a flagellum or biological mechanism in which active swimming can occur). Both Weyl's [1978; Science] oceanic carousel and Cifelli and Smith's (1970) statement that "Owing to the environments mobility, planktonic organisms are constant involuntary travelers that during their lifetimes, may find themselves in places they do not care to be" is what we are referring to here.

P140 L17-20– specify planktonic. Also a bit more detail needed here. Specify if dry residue weighed within each narrow sieve size fraction or total dry bulk weight? Why 200 particles? Abundance counts usually on >300 specimens to obtain representative numbers. Also please note if sample splitter used to obtain aliquots or if they are representative splits.

Each size fraction was split into an aliquot of roughly 200 particles and counted, normal abundance counts of 300 particles are performed on the 150-250um and >250um or just the >250um size fraction(s) which can underestimate small-larger and/or rare species. We have changed the text to highlight this.

P145 L12 onwards – mention in brackets with table that samples for which null hypothesis is rejected highlighted in grey

We agree that it would be better to indicate which samples had the null hypothesis rejected, however for G. inflata this is 20 out of 26 samples and G. truncatulinoides has

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25 out of 26, which would make it impractical. Therefore we feel that is better to leave it as it is.

P145 L2 – also mention that these offsets are not constant through time and refer to insets here?

Whilst this does show that the offsets are not constant through time, it would be better in our opinion to wait to the section in which we discuss the t-test results to mention this.

P145 L19 – Is this not also implied by the largest offset from the 1:1 line in terms of the gradient compared to other taxa?

We agree it could, but the 1:1 only uses the smallest and largest size fractions, which could be called into question (by selecting only the "end-members"). Therefore, we felt that it is better to use all the available data.

P145 L23 – a little bit of text streamlining in this section, e.g., ditch "thus for this species" and "whereas all size fractions show a statistical difference and thus"

It is our opinion that re-iterating what we mean by the null hypothesis saves the reader having to search for it in the methods section, and therefore it is better to keep this section of text.

P151 L22 – not necessarily the zone of optimal conditions for bulloides may be much broader than in the modern ocean if bulloides prefers cooler and more eutrophic water masses. Feels like a lot of discussion in size change across the G-IG given no size change is apparent in the dataset to the naked eye at least. Does the Schmidt data show any significant changes across G-IG cycles in this taxa at a similar latitude? Removing unnecessary words and just giving the key information relevant to the story ultimately could significantly shorten this section that no decrease in size, implying optimal conditions at site and influenced but increased productivity in this region.

This discussion is pertinent to our results, we state on page 150 that "in the modern

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ocean G. bulloides has its largest size at 50°N, if one is to consider that a compression or elimination of certain transitional water masses occurs during glacial periods then this maximum size should be centered at or to the south of the location of the studied core, i.e. a size decrease should be observable at our core location.". Our results do not tie into what is known in the literature and therefore we felt that this mismatch should be discussed.

P159 – 160 – Lots of discussion of controls on d13C but not well linked back to original data. For instance no conclusion is reached on the main mechanisms controlling the datasets presented here and only for gametogenic calcite is it mentioned whether or not the hypothesis is consistent with the new data,

One of the major reasons we have not been explicit in the main mechanism is the lack of consistency, shell-size isotope relationships are not consistent through time which means that finding a mechanism that explains all of our data is difficult.

P160 L12 – it might be worth mentioning earlier in the text that the deeper dwellers particularly G. truncatulinoides may actually have a longer life span than 2-4 weeks like bulloides and ruber perhaps more like a year, which may help to explain calcification in different seasons.

It is true that it is considered to have a life cycle that extends to a year, but no paper has concretely proven this. Many papers, using sediment traps have seen a single flux event and considered that this is proof of a year long life cycle, however in order for a single foraminifera to calcify in different seasons it would have to somehow negate both sinking and the movement of oceanic currents staying static at a given spot in the ocean. Therefore, whilst it could explain the data, we have refrained from pursing that line of reasoning.

P160 L26 – on what basis is 300-355 um best? Can you add a comment about why? Most consistent offsets?

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We state that: “Our results would suggest that 300-355 μm would serve this purpose given the offsets between the species, however we would caution against using a ‘one-size fits all’ approach given the seasonal structure of the water column and seasonal succession of species at this core location”.

P160 L23 “and that previously published” Also rephrase next sentence consider deleting “between studies” so reads “lack of a resolution in the existing literature as to the recommended size fraction : : :.” –

Changed.

doesn’t birch make a decision about the best size fraction based on correlation of foram d13C to d13C of DIC? 250-300 um?

With respect to Birch et al., they do make a decision, but other authors suggest other size fractions. So therefore the issue is not resolved. What we’re attempting to say is that different authors from different ocean basins give different size fractions, but our results show that this can easily be misinterpreted (through no fault of the previous authors).

P160 – the authors use differences between size fractions – I wonder whether it would be better to discuss size-isotope trends to avoid confusion with differences between the same size but different species? It might be worth checking out the new paper in Paleoceanography by Ezard et al. 2015, which compiled and modeled the size-isotopic relationships for all modern taxa and includes a large discussion of potential biases on isotope-size trends.

We use differences between size fractions as this wording does not imply any link between the size fractions. Trend would suggest that there is a progression in isotopic values or connection between different sizes which we have not tested. This wordage (‘trend’) suggests that the different sizes are linked i.e. by age. Although we do admit it that ‘trend’ can also be used to show a general tendency.

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Specifically you should consider the potential role of changes in preservation (particularly disso-lution) on your datasets given the large associated changes in carbonate chemistry.

Unpublished work, using single specimen isotopes for G. bulloides and G. inflata along a depth transect close to the core location, but deeper then it between 2700 and 4500 m, put the d18O change (using the average) between shallow and deep core tops at 0.34 and -0.14 ‰Ṫhe d13C change (using the average) between shallow and deep is larger at 1.16 and -0.04 ‰Ȧs these results are deeper we would suggest that the dissolution effect is minimal for the core location.

These authors also nicely highlight that in sediment cores, body size doesn't necessarily equate to foram 'age' something alluded to here and that it may instead relate to maximum adult size a function of growing conditions so consider tying this into the discussion.

In actuality we discuss this on page 149 lines 18-24, albeit rather shortly: "Consider that the transition from juvenile-neanic to adult stages occurs between 100 and 200 μm (Brummer et al., 1987), then all specimens above 200 μm are adult. The shape of the size frequency distribution of the pre-adult population is exponential whereas in comparison the adult population has a distinct Gaussian shape (Brummer et al. 1986, 1987; Peeters et al., 1999), which suggests that adult specimens that are larger than the mean should be considered giants and on the contrary smaller specimens as dwarfs (Berger, 1971)".

Detailed comments: Title – ditch the "related"

'Related' removed

P136-L5 – delete "the" so text reads "from equilibrium"

Changed

P136-L12 – please clarify what you mean by "dynamic" – this could refer to using

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difference sieve size fractions in different samples for example. I think you mean, ": : : utilizing measurements from multiple narrow sieve size fractions spanning a large range of total body sizes"

Replaced with your wording

P136 L15 – define small in um

212-250 um added to text

P136 L23 - ": : :may be used to reconstruct past..."

Changed

P137 L3 – "physical proxies determine"

Changed

P137 L5 – specify here d13C and d18O

Changed

P137 L10 - This sentence doesn't make too much sense at the moment needs reorganizing, e.g., "Vital effects are isotopic offsets from equilibrium values reflecting.."

Changed

P137 L13 – specify reduce effects on palaeonvironmental reconstructions?

Added

P138 L15 – need to add "that growth occurs"

Changed

P138 L17 – 25 – very long sentences consider breaking up for increased clarity.

Changed

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P138 L26 – delete “sized”

Deleted

P139 L4 –The first sentence is a little unclear so some suggestions below to increase clarity. “Here we test”, specify planktonic foraminiferal tests

Changed

and “: : :to large-scale environmental perturbation across a glacial-interglacial transition (TIII). We utilize data from Feld... and present new data that expands upon shell-size isotope relationships between species and through time”

Changed

P139 L8 – a little expansion on the methods please – e.g., Individual foraminifera were picked from narrow sieve size fractions from JGOFS: : :. Please specify your sieve size fractions.

Changed

P139 L12 – specify dextrally and sinistrally coiled?

Changed

P139 L15 – perhaps “multiple specimens” would be better?

Changed

P139 L15 – Specify multi-specimen analyses were repeated and delete “seen” as unnecessary. Add reference for this statement as has been demonstrated elsewhere and very specific in L18.

Changed

P139-L19 – Specify ”In other words by combining multiple specimens for each analysis, : : :..” for clarity.

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Changed

P140 L 1 – typo “recrystallization”

Changed

P140 L5-14 – necessary? Seems nicer to finish mentioning that single specimens give us a discrete snapshot of ocean conditions at time of calcification? Can you include some of this info at the beginning of the section when you say why MIS7-8?

We have altered the structure so that the MIS7 follows our introduction of T-III and then finish as you suggested when we mention that single specimens give a discrete snapshot of the ocean.

P140 L24 – “the absolute number of individuals by the split: : :” and “size frequency distribution (SFD) was approximated”

Changed

P141 L1 – careful here bulk measurements could be confused with bulk sediment analyses (i.e., total carbonate) so best to be specific that typically 8-40 : : :. , use same number of decimal places on weights here.

Changed

P141 L7 – “: : :on the analytical methodology: : :”

Changed

P141 L10 – replace “about” with “up to”

Changed

P141 L15 – A little more specificity here please particularly for test 2 – so test 1 = to test for any statistical differences between size fractions with each species in each sample and test 2 = to test whether any differences between body size and isotope values are constant within each species downcore? And/or to assess whether the

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differencebetween same size fractions in each species varied downcore? P141 L26 – I'd argue that this depends on what you're trying to determine!

Changed

P142 L30 – delete "are different"

Changed

P144 L9 – specify that figures in brackets are relative abundances ": : :have higher abundances during MIS7e and lower abundances: : :".

Changed

P144 L18 – "during which time the abundance of the species is low"

Changed

P145 L3 – specify d18O values

Unsure of what this comment refers to, as pg 145, L3 is an introductory sentence to figure 6

P146 – "with larger insolation differences : : :"

Changed

P146 – Not really necessary to give all this detail about d13C values is it? Sometimes a little too wordy which reduces clarity. I'd suggest just go straight for the key points (1) D13C is typically lower in G. trunc and G. inflate small than large specimens but not clear distinction between small fractions continuously throughout record. May be larger = higher d13C. (2) bulloides more difficult to discern differences. Even better can younot integrate the descriptive observations of your graphs with the stats to cut the text and make this snappier?

Changed

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P146 L23 – “deviate” typo

Changed

P147 – L10 – in reference to what are they statistically significant = new paragraph here so you need to be explicit.

Changed

P148 –L15-20 – references needed here. Also carbonate ion effect (Spero et al 1997) impacts values

References added

P148 L22 “significant variation of size with d18O values..”

Not changed

P148 L23 – should better employ Figure 10 here to mention that overall patterns are consistent with previous studies.

We’d prefer to leave it til later in the text to employ this figure.

P148 L26 “with increasing: : :”

Changed

P148 L26 – I’m not convinced that the discussion of these curves in the context of Berger, 1978 really adds much as effectively repeats findings from sentences above.

It relates our work to one of the original workers of the subject and therefore we consider it relevant to discuss it here.

P149 L7 – these physical parameters are presumably a function of depth habitat though with smaller individuals calcifying at shallower depths and thus the same as (iii)?

Not really, (i) can refer to not only depth habitat (i.e. the same as (iii)) but also to spatial variation in physical parameters. Whereas (iii) is specifically depth habitat.

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P149 – need to be specific that it's isotopic disequilibrium that you're referring to

Unsure as to what you are referring to here, page 149 is discussing the isotopic composition of foraminifer.

P149 L7 – doesn't really explain why these factors might create the 'normal' trend.

We provide a short summary of Berger's (1978) ideas for what may cause a 'normal' trend, with links to papers that highlight such scenarios, but for a detailed explanation any reader should read the original paper for a more refined explanation.

P150 – the change in size during the interglacial is only really visible in truncatulinoides so be explicit in this opening sentence. I'd actually restructure this sentence to be clear that you're talking only about bulloides right up front at the beginning otherwise this is potentially confusing. Don't need the bit about concurrent in size or magnitude as already said see a minor change in abundance/size? So key point is that there is no isotopic variation between size fractions.

Unchanged, it is clear that we are referring to G. bulloides in this sentence

P151 L12 – be explicit that your talking about your site

Changed

P151 L15 -replace "occur' with "extend"?

Changed

P151 L19 - delete "occurring" as unnecessary

Changed

P151 L23 – sentence overly long

Unchanged

P151 L3 typos "development" and "with a .."

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Changed

P152 L12 - delete “for example occurring” as unnecessary

Changed

P152 L11 – be specific “species abundance counts in plankton tows” also isotopic analysis of foraminifera tests not sedimentary material – this implies bulk carbonate currently which is not what you mean

Changed

P152 L21 – be explicit that differences in the depth of the DCM relates to seasonality and water column structure

Changed

P152 L24 – Ok so seasonality controls the DCM by impacting stratification but did the Ottens paper say anything about whether the deeper habitat in april also corresponded to an increase in the deep of the DCM? If so, please say so.

Unfortunately this is not outlined in her original text.

P152 - ditch associated with subpolar to tropical water masses in above sentence because same info given in following sentence.

Changed

P153 L3 “in the South” typo

Changed

P153 L13 – too many “its” be specific and give species name in sentence somewhere

Changed

P154 L7 – again please be specific. “Given the isotopic overlap: : :” redundant to say larger than and use > - pick one

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Changed

P158 L6 – Suggest switching/adding reference to Birch et al. (2013) or Friedrich et al (2012) instead here as these papers look at all of the same species in your study in contrast to Franco-Fragaus et al. 2011 which just looks at truncatulinoides and ruber. Also more explicitly link back to previous sentence, e.g., A positive size-d13C relationship have been explained by...."

Changed

P158 L8 - Need to be more specific because strictly speaking 13C of plankton didn't invoke photosymbiosis previous studies invoked photosymbionts etc. to explain the trend so please rephrase.

Changed

P158 L11 – sentence overly long. Split into two for clarity.

Changed

P158 L120-123 – do you mean that forams calcifying in surface waters have a higher d13C values than those calcifying at depth? a shallower depth habitat relative to what? specify "foraminiferal d13C" here

Changed – the depth habitat inferred from using the 13C and comparing it to the DIC d13C profile is different from the depth habitat inferred from 18O

P158 L123 – This sentence is another example of where it is important to be more specific as to exactly what you're referring to – enrichment of 12C in deeper dwellers? I think you need to clearly distinguish between size-isotope trends and inter-specific offsets between similar sized fractions so that the two (and most importantly the mechanisms are not confused)– separate paragraphs? Perhaps talk about the absolute offsets between taxa, i.e., some species live deeper than others with lower d13C values and then lead onto the size-specific isotope relationships?

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Our results however are not in line with the d13C profile, figure 9D highlights the complexity of the d13C. The example given that some species live deeper than others with lower d13C values is incorrect as G. bulloides (a shallow dweller) clearly has the lowest d13C values (Fig. 9D)

P159 L1 – “increases”

Changed

P159 L15 – now using test rather than shell – be consistent

Changed

P159 L18 – “raising their d13C values”

Changed

P159 29-P160L6 – sentences provide essentially the same info consider combining.

Changed

P160 L3 – clarity “whilst we find no systematic differences between the d18O of G. bulloides: : :..”

Changed

Figure 1 – Nice clear map. Just need to specify in caption that main ocean currents indicated by arrows and that these are surface? currents. Without a key for temperature need to write that red is warmest and blue coolest temperatures.

Changed

Figure 2 – specify top, middle and bottom ROWS in caption

Changed

Figure 3 – specify in caption that “Size in planktonic foraminifera across MIS7-8”. In caption use lowercase a-d but in figure capitalized – style? No need to mention oxy-

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gen isotopes explicitly on y-axis of a if also use d18O. Is this the relative abundance of each taxa from whole sample or relative to each other. I assume the former but please specify in caption. Please note what vertical dashed lines and HI5 etc.. are. To avoid confusion with how average size was calculated can you please explicitly mention average size within the text of section 2.1 – is average size = sfd?

Changed

Figure 4 – Y-axis “Single specimen” and add space between number and units on figure for sizes. Any reason why axis given to 2 dp? Might be neater to stick to 0 dp? Are Heinrich events HI4 etc. in which case please note in caption explicitly for non-specialist..

Changed

Figure 5 - Mean insolation not marked on figure – remove note in caption?

Changed

Figure 6 – Specify in caption header that isotopic differences are for each species. “: : :in d18O (top panel) and d13C (bottom panel). Careful phrasing - Equations of linear regressions not shown by coloured lines – regressions are shown and equations in table 4.

Changed

Figure 9 – Just use d13C not necessary to include description in full here. Perhapsadd the coloured species outlines behind a-c rather than grey for increased continuity.

Changed

Figure 10 - Just use d13C/d18O not necessary to include description on figure axes. “..an average size-isotope curve was : : :”

Changed

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