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Interactive comment on "Sensing Seasonality in the Arabian Sea: a coupled $\delta^{18}\mathrm{O}-\mathrm{Mg/Ca}$ approach" *by* W. Feldmeijer et al.

W. Feldmeijer et al.

w.feldmeijer@vu.nl

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We sincerely thank Dr. Regenberg for the careful consideration of our manuscript. Please find outlined below our responses to the comments and corrections for the resubmission of the manuscript.

The reasoning of the manuscript is based on the modern seasonal and vertical distribution of the three planktonic foraminiferal species G. ruber, N. dutertrei and G. bulloides. G. ruber abundances "are relatively constant throughout the year" page 3852, line 14–15) and is assumed to "reflect average and seasonal variability in [...] SST" (page 3852 line 17). Please expand on how a species reflects at the same time "average and seasonal variability". Is average SST reflected in the average Mg/Ca ratio, while seasonal variability is expressed in the Mg/Ca range indicated by the single measurements?

Please change "average" to annual average.

- "average" changed to "annual average"

Major issues Paired measurements of Mg/Ca and _18O are usually used to calculate the local _18Osw. Yet Feldmeijer and coauthors decided to calculate and discuss paleotemperatures from ice-volume corrected _18O despite the fact that temperature estimates from Mg/Ca and _18O are not matching, neither the absolute value nor the gradient between species and time slices. Such discrepancy is generally thought to be caused by changes in local _18Osw signatures probably linked to changes of the freshwater budget at the spot of calcification. I suggest that the authors should use their Mg/Ca temperatures to insert them in the Kim and O'Neil (1997) equation to obtain the local _18Osw and discuss the outcome with respect to environmental conditions during IS8 and HE4.

- We agree with the reviewer and have now added the suggested calculation to Table 1. We have used the average Mg/Ca temperature for the Kim and O'Neil (1997) equation and subtracted this from the ice volume corrected δ18O from the same shells which is now better described in the table caption. These discrepancies were then discussed in terms of environmental conditions.

Detailed comments 4. Results Although separated into subsections 4.1 Mg/Ca and 4.2 Oxygen isotopes, results of _18O are presented in 4.1 (page 3855 lines 7, 9–10, 12). Consequently, redundant statements are given in subsection 4.2 (e.g., page 3855 line 26). Please avoid redundancy.

- In order to avoid confusion, we have now removed the sub-headers.

5. Discussion 5.1 Mg/Ca starts with a summary of species-specific temperature gradients between cores and time slices (page 3856 line 16–22). While temperature gradients of G. bulloides and N. dutertrei are related to environmental conditions of "upwelling of deep, cold waters in summer caused by the SW monsoon" (page 3856 line

19–20) and "the decrease in thermocline temperature during HE4" (page 3856 line 22), respectively, anomalously high G. ruber northern Arabian Sea temperature during IS8 is not interpreted.

- We have now added a description for interpretation of G. ruber temperature gradients (line 239-240).

How do SST estimates agree with other proxies like UK37 mentioned on page 3858 line 18?

- The Mg/Ca- and δ18O-based SSTs compare well to those derived from UK37 on time slices from cores derived in this region (e.g. Reichart et al., 2002).

Page 3856 line 21–22: How can the authors conclude from the 3 _C difference between IS8 and HE4 to a year round abundance of N. dutertrei at both sites? However, I totally agree with the interpretation of the decreased thermocline temperature.

- We agree with the reviewer and have therefore removed this sentence from the revised version of our manuscript.

Page 3856 line 25–page 3857 line 1: Strong seasonal cooling would bias an annual average towards lower temperatures except for the case that during the remainder of the year temperatures are higher than usual. Either G. ruber experienced such a warming during the remainder of the year or G. ruber avoids the cold season and reflects an average of the non-upwelling season.

- This suggestion has been used to extend the interpretation of the G. ruber-derived temperatures (line 252-253).

Page 3857 line 10–17: This paragraph compares the natural variability found in the single measurements to literature data. Without any relation to environmental interpretation, I would suggest to place the paragraph at the beginning of the Discussion, then placing paragraph in line 22–26, and finally starting with unraveling the environmental information.

- Text adapted as reviewer suggested to clarify this section.

Page 3857 line 10–12: Relatively large ranges of e.g., 6.6–6.8 and 3.7–3.7 mmol/mol? In this context I cannot see any kind of calculated difference indicated by "(IS8-HE4)". Please add the mean Mg/Ca ratios and their variability to Tab. 1.

- We have now added these data to Table 1.

Page 3857 line 18: "These ranges cannot be explained solely by temperature". Please expand on this issue - considering potential variation in season and depth habitat, how much of the Mg/Ca range cannot be explained by temperature? Given that the pre-exponential constant in Bolton et al. (2011) is high with respect to 'conventional' calibration equations (e.g., Lea et al., 2000; Anand et al., 2003; Regenberg et al., 2009), temperatures for G. ruber are possibly underestimated. The authors may think about parallel measurements of wet geochemical Mg/Ca on bulk foraminiferal samples based on multiple specimens to compare Mg/Ca averaged from laser ablation profiles with the 'conventional' average Mg/Ca ratio.

- The text of this section was extended as reviewer's suggested. Unfortunately, solution-based Mg/Ca analyses are not feasible to conduct due to a lack of sufficient material. We agree, however, that this would allow us to show how both techniques match up.

The discussion of the manuscript is largely based on species-specific and interspecies temperature gradients within and between time slices. I think that a table summarizing the temperature gradients could help the reader to better follow the discussion.

- We have added these data to Table 1.

5.2 Oxygen Isotopes expands on temperature reconstructions based on the ice-volume corrected foraminiferal _18O. Such an approach seems to be outdated facing the paired measurement of Mg/Ca ratios offering the great potential of calculating the local _18Osw. A comparison of Mg/Ca temperatures instead of _18O-derived temperatures with estimates from temperature proxy UK37 (page 3858 line 18–20) should therefore be use for further discussion.

- As the euphotic zone in the (northern) Arabian Sea is on average 40 m deep (Quasim, 1982) and the coccolithophores, from which the alkenones for UK'37 measurements are recovered, are confined to this water depth temperatures based on this signal are biased compared to those of based on foraminiferal calcite since these organisms precipitate (part of) their shells below this zone. Therefore we choose to focus on the temperature shift that took place during the transition from H4 to IS8, rather than comparison between the alkenones and foraminiferal geochemistry.

Page 3859 line 3–8: Given the great potential of paired Mg/Ca and _18O, the superficial remark that "_18O values are in line with previous suggested differences in depth habitat between the three species" shows that the presented data set should be explored in depth.

- We think the reviewer refers to a previous (major issue) and the following comment and therefore believe the suggested is covered.

5.3 Comparing Mg/Ca and _18O mentions possible biases on Mg/Ca and _18O signals. However, the results from this manuscript are not related to these possible biases. The discussed influence of salinity on the presented data set remains superficial as long as the _18Osw signal is not extracted from the paired Mg/Ca and _18O measurements.

- As we did perform this analysis the biases described in this section are based on data suggested by the reviewer.

Page 3859 line 10–13: What about dissolution of tests affecting the geochemical signature? Is deeper core 905 affected as implied by the Omani Margin study of Brock et al. (1992) indicating that even above 1400 m water depth the ratio of broken to whole tests reaches values of 86% and Fig. 7 in Regenberg et al. (2014) showing that Mg/Ca

ratios might be affected by dissolution even at water depth <1000 m?

- This might indeed be so, but does not necessarily hamper comparison between species (as Regenberg and co-workers concluded in their 2014 article: “The determined pattern is similar for each planktonic foraminiferal species”) Figure 7 from their study, moreover, suggests that potential rate of dissolution and hence bias in the Mg/Ca is similar for both core locations. Therefore, the potential offset in Mg/Ca by dissolution may be minimal and does not compromise the comparison between cores NIOP905 and NIOP478.

Page 3859 line 15: The primary literature of Spero et al. (1997) should be used to refer to _18O vs. [CO3 2ôĂĂĂ] relationships.

- We preferred to refer to the Pearson (2012) review on oxygen isotopes to encompass all factors that influence the oxygen isotope composition of planktonic foraminifera.

Fig. 1: For better comparison, please use the same scale for SST color bars.

- We agree that similar scales would facilitate comparison between subplots, however, the relatively large difference in temperatures during the SW and NE-Monsoon would reduce the detail in these plots when adopting the temperature scale. Therefore, we suggest to keep the temperature scales in Figure 1 as they were.

Fig. 6: What is the relevance of this cross plot? Since Mg/Ca as well as _18O are related to temperature covariation of both proxies is not surprising. Clear dependency of _18O on parameters other than temperature might explain the scatter. Because this figure is not needed for a better understanding of the data set and not referred to in the Discussion I suggest to leave it out.

- We agree and have removed this Figure from the revised version of our manuscript.

Interactive comment on Clim. Past Discuss., 10, 3847, 2014.