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Climate of the Past Discussions

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

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Summary of Marcus Regenberg's review

Feldmeijer and co-workers present paired single-specimen LA-ICP MS Mg/Ca and $\delta^{18}O$ analyses on three planktonic foraminiferal species over Interstadial 8 and Heinrich Stadial 4 from a western and a northern Arabian Sea sediment core. The aim of the manuscript is to reconstruct the seasonal range in temperatures and the vertical stratification of the water column during these intervals. The presented data set is sound and provides details of hydrographic conditions unavailable from wet geochemical analyses of bulk foraminiferal samples integrating multiple specimens.

The reasoning of the manuscript is based on the modern seasonal and vertical distribu-

tion 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.

N. dutertrei reflects "year-round thermocline temperatures" (page 3852 line 25–26).

G. bulloides reflects "the cold, summer" SST at more southern site 905, whereas *G. bulloides* at the more northern site 478 reflects "SST's form both monsoon seasons, with relative contributions depending on productivity in each season" (page 3853 line 9–10).

Unfortunately data analyses and interpretation lacks the promised investigation of "mismatches between Mg/Ca- and $\delta^{18}O$-derived temperatures reflect[ing] changes in salinity caused by regional variability in the hydrological cycle" (page 3848 line 13–15) because $\delta^{18}O$ was not used to calculate the local $\delta^{18}O_{sw}$ from combining paired Mg/Ca and $\delta^{18}O$. The missing local $\delta^{18}O_{sw}$-data calculation, however, is crucial to a successful interpretation of Arabian Sea upper-ocean hydrology and linking of paleoceanographic conditions with monsoon intensities. After major revision of the manuscript including integration of $\delta^{18}O_{sw}$ data and their thorough interpretation in concert with the Mg/Ca temperatures I would encourage the authors to resubmit the manuscript.

Major issues

Paired measurements of Mg/Ca and $\delta^{18}O$ are usually used to calculate the local $\delta^{18}O_{sw}$. Yet Feldmeijer and coauthors decided to calculate and discuss paleotemperatures from ice-volume corrected $\delta^{18}O$ despite the fact that temperature estimates from Mg/Ca and $\delta^{18}O$ 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 $\delta^{18}O_{sw}$ 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 $\delta^{18}O_{sw}$ and discuss the outcome with respect to environmental conditions during IS8 and HE4.

Detailed comments

4. Results Although separated into subsections 4.1 Mg/Ca and 4.2 Oxygen isotopes, results of $\delta^{18}O$ 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.

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

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.

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.

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.

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.

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 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.

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

Page 3859 line 3–8: Given the great potential of paired Mg/Ca and $\delta^{18}O$, the superficial

remark that "δ^{18}O 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.

5.3 Comparing Mg/Ca and δ^{18}O mentions possible biases on Mg/Ca and δ^{18}O 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 $\delta^{18}O_{sw}$ signal is not extracted from the paired Mg/Ca and δ^{18}O measurements.

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?

Page 3859 line 15: The primary literature of Spero et al. (1997) should be used to refer to δ^{18}O vs. [CO_3^{2-}] relationships.

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

Fig. 6: What is the relevance of this cross plot? Since Mg/Ca as well as δ^{18}O are related to temperature covariation of both proxies is not surprising. Clear dependency of δ^{18}O 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.

References other than in the manuscript

Anand et al. (2003) Calibration of Mg/Ca thermometry in planktonic foraminifera from sediment trap time series, Paleoceanography 18.

Brock et al. (1992) Southwest Monsoon Circulation and Environments of Recent Planktonic Foraminifera in the Northwestern Arabian Sea, Paleoceanography 7.

Lea et al. (2000) Climate impact of late quaternary equatorial Pacific sea surface temperature variations, Science 289.

Regenberg et al. (2009) Calibrating Mg/Ca ratios of multiple planktonic foraminiferal species with δ^{18}O-calcification temperatures: Paleothermometry for the upper water column, Earth and Planetary Science Letters 278.

Regenberg et al. (2014) Global dissolution effects on planktonic foraminiferal Mg/Ca ratios controlled by the calcite-saturation state of bottom waters, Paleoceanography 29.

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