

World Atlas of late Quaternary Foraminiferal Oxygen and Carbon Isotope Ratios – response and changes to manuscript

Reviewer comment 1 (Ralf Schiebel): The foraminifer isotope atlas of Stefan Mulitza and coauthors is much appreciated as a contribution to paleoceanography and paleoclimate, and should be published as soon as possible. In general, the manuscript is well written, and I would suggest only minor changes. I provide an annotated pdf file, which may allow for quick finding of some typos, and explains some suggestions.

Author's response: We thank Ralf Schiebel for his helpful comments and improvements on the manuscript.

Changes to manuscript: We have incorporated all additional changes suggested in the annotated pdf copy of the manuscript (mostly typos and minor wording changes) into the revised manuscript.

Reviewer comment 2 (Ralf Schiebel): To account for the ecology of planktic and benthic foraminifers, I would suggest to define the depths habitats in a bit more explicit way. The terms "shallow" and "deep" dwelling may be misleading. I would suggest to use the term "surface mixed layer" and "subthermocline" dwelling. For example, *Neogloboquadrina pachyderma* may live as deep as 200 m water depth, but which is still in the surface mixed layer of the deep mixed polar ocean. In contrast, *Globorotalia truncatulinoides* may usually dwell at 200 m water depth in the tropical to temperate ocean, but which is well below the thermocline, at sub-surface water depth. When specifying the habitats more clearly, the isotope ranges of the different taxa may be better explained. This would still not account for the largely latitudinal and seasonal distribution of many taxa.

Author's response: We agree that our categorization into "deep dwelling" and "shallow dwelling" is somewhat misleading and subject to interpretation and likely even dependent on the local environmental conditions. Since a detailed discussion of foraminiferal ecology is beyond the scope of this manuscript, we abandoned any classification into specific depth habitats.

Changes to manuscript: We exchanged the terms "deep dwelling" and "shallow dwelling" with the actual species names for the most commonly used species and summarize less commonly used species under "other". We now consistently follow this categorization for all figures except for fig. 6 where the isotope ranges are broken down to the species level wherever possible. The categorization of the species names has been updated in the supplement. As also requested by Reviewer #2 (see comment #4 from Reviewer #2), we now state the wide geographic distribution and the mixed layer habitat as potential reasons for the common use of *G. ruber*, *T. sacculifer*, *G. bulloides*, *N. pachyderma* and added the following sentence to section 3.2:

"These species have a relatively broad geographical coverage and are considered as mixed-layer species in their respective environments (Schiebel and Hemleben, 2017)."

Reviewer comment 3 (Ralf Schiebel): The benthic foraminifer genera *Cibicides* and *Cibicidoides* are not generally epi-faunal. Only two species, *Cibicidoides wuellerstorfi* and *C. lobatulus* are epifaunal, and most of the many species of the genus are shallow infaunal. Some are even deep infaunal. Please refer to the books of Murray (e.g., 2008) and Schiebel and Hemleben (2017), in which the ecology of benthic and planktic foraminifers are explained, respectively.

Author's response: We agree.

Changes to manuscript: Complementary to the changed categorization of planktic foraminifera (see response to comment #2 from Reviewer #1), we now distinguish the most commonly used *Cibicides/Cibicidoides* and *Uvigerina* genera, summarize the less commonly used species/genera under “other”, and abandon any classification of benthic foraminifera as epi- or infaunal.

Reviewer comment 4 (Ralf Schiebel): The term Foraminifera is a systematic term (not foraminifers, foraminiferal), which starts in upper case. By convention, only genus and species names are given in italic style; any addition to the name, such as spp. and sinistral, is not given in italic style, but in normal style.

Author’s response: We agree.

Changes to manuscript: We changed “Foraminifera” to upper case and removed the italic style from the additions to the species names.

Reviewer comment 5 (Ralf Schiebel): The genus name of the species *sacculifer* has changed from *Globigerinoides* to *Trilobatus* some time ago, and which may be mentioned at some place in the text, where *T. sacculifer* is discussed (e.g., on page 5, line 10).

Author’s response: We agree.

Changes to manuscript: We exchanged “*Globigerinoides sacculifer*” with “*Trilobatus sacculifer*”. All names summarized under this species are listed in the supplement.

Reviewer comment 6 (Ralf Schiebel): *Creseis* (spp. and *acicula*) is a pteropod, i.e., a pelagic snail, and not a foraminifer. This may be discussed in the text. However, given the very different nature (aragonite, not calcite) and ecology (fast swimmer over great water depths, not passive plankton), it may be easier not to present the pteropod in the atlas on Foraminifera.

Author’s response: We thank Ralf Schiebel for finding this important error.

Changes to manuscript: We excluded the two *Creseis* records from the data set and deployed the corrected collection on PANGAEA. All figures, statistics and numbers in the manuscript have been updated accordingly.

Reviewer comment 7 (Reviewer #2): Mulitza et al., present a global “living” repository of sediment cores with oxygen and carbon isotope data which include new and previously published data. They outline their data sources, organization, coverage, distribution, and potential future applications of this database. The authors explain the merit of the global atlas, how to download and navigate the data, invite others in to contribute data, and recommend uses for the atlas (e.g., education, expedition planning, etc.). I commend their effort to organize for the first time such decentralized and complicated data from many sources. I suggest that the paper be published after some minor revisions which would clarify information flow and provide context for the findings.

Author’s response: We thank Reviewer #2 for the constructive comments and very helpful suggestions for our manuscript.

Changes to manuscript: None

Reviewer comment 8 (Reviewer #2): Missing data: A database not cited here may have relevant information for the atlas. The authors should compare their atlas to the database at <https://doi.org/10.1594/PANGAEA.875998> and accompanying paper (<https://doi.org/10.5194/essd-9-739-2017>). Borreggine et al., 2017 assessed sediment core collection in the North Pacific, Sea of Japan, Bering Sea, and Sea of Okhotsk. They document meta data and isotope data among other characteristics. It would be beneficial to cross-check your atlas to this database to ensure no cores/records are missing and update numbers (i.e., # of cores, # of records, percentages, distribution data, figures, etc.) if necessary. The accompanying paper may also include analysis that could provide further context to this article.

Author's response: The amount of foraminiferal isotope data generated over the last 50 years is enormous and new data are constantly produced and published. The task to assemble newly published and historical data in a single homogenous data product can only be approached iteratively. As ESSD encourages the generation of “living” data products, we are indeed committed to continuously update the atlas in the future both with newly published and historical data. The meta study by Borreggine et al. (2017, <https://doi.org/10.5194/essd-9-739-2017>) is a great source of information to recover and rescue older data and we will use it for a future update of the isotope atlas. However, as Borreggine et al. (2017) do not provide the actual isotope data or links to the data (which was not the purpose of that particular paper), the search for the isotope data listed therein with the necessary quality control and formatting would require too much time to be completed within this revision. Furthermore, our data set is already very comprehensive (including many of the data listed in Borreggine et al., 2017) and the documentation of the sources in the appendix has already reached a considerable size. We therefore suggest to follow a more practical iterative approach and propose to include and document the available data listed in Borreggine et al. (2017) into the next update of the atlas.

Changes to manuscript: To emphasize the need to rescue historical isotope data, we added two sentences to section 6 explicitly stating our plans to frequently update the atlas with newly published and historical data citing Borreggine et al. (2017) as an example for historical data to be included:

“As new foraminiferal isotope measurements become frequently available, we plan to update the atlas in reasonable intervals. Also, more historical isotope data may become available and need to be rescued (i.e., Borreggine et al., 2017).”

Reviewer comment 9 (Reviewer #2): In Section 3, the authors assess data distribution and offer some brief explanations. Section 3.1 does a good job of explaining core distribution across ocean area and water column depth but does not offer an explanation as to why most cores are found in tropical regions, why isotope records are predominantly found in the Atlantic, or why the Mediterranean has the highest core density.

Author's response: We agree.

Changes to manuscript: We added the following two sentences with possible explanations to section 3:

“This pattern is likely the result of the year-round accessibility of low latitudes compared to high latitudes where, due to sea ice cover or harsh weather conditions in the cold season, expeditions are often constrained to the warm season.”

“The Pacific and Indian Oceans are currently only covered by 2 and 2.1 cores/million km², respectively, which is likely a result of relatively low accumulation rates and poor carbonate

preservation over large areas. In addition, the retrieval of sediment cores in the remote and deep central areas requires more ship time compared to the Atlantic and Mediterranean Sea.”

Reviewer comment 10 (Reviewer #2): Additionally, Section 3.2 may benefit from a brief analysis on why certain species are the most commonly used.

Author’s response: We agree.

Changes to manuscript: We added the following sentence as a possible explanation to section 3.2:

“These species have a relatively broad geographical coverage and are considered as mixed-layer species in their respective environments (Schiebel and Hemleben, 2017).”

Reviewer comment 11 (Reviewer #2): The authors should provide concrete suggestions on how to apply their database beyond what is mentioned in Section 4. For example, they should expand their discussion in Section 4.3 on the merit of educating students about downcore isotope ratios and Section 5 with information on how to employ PDV.

Author’s response: We agree.

Changes to manuscript: To provide concrete suggestions how to apply the data base, we added the following sentence to section 4.3:

“Lecturers may employ the atlas together with PaleoDataView or with custom software to show examples on how isotope stages may be identified in different geological settings and on how isotope differences between species may be explained by hydrography and foraminiferal ecology. Students may also actively explore the patterns of isotope stratigraphies from different parts of the global seafloor to actively learn how global factors such as ice volume and local factors such as SST and freshwater input influence stable isotope records.”

Reviewer comment 12 (Reviewer #2): Since one of the stated goals from the authors is to contribute to the long-term maintainability and consistency of age models through this global atlas, the authors should include more detailed information about how other researchers can contribute new data in Section 6.

Author’s response: We agree.

Changes to manuscript: We added the following sentence to section 6:

“Please contact the first author if you are interested to contribute to future updates of the atlas.”

Reviewer comment 13 (Reviewer #2): The final table belongs in the supplement rather than the main text. In the attached PDF I have added these comments as well as others to the preprint for the authors to consider. The comments include technical corrections, wording suggestions, typos, and information structuring suggestions. Great work!

Author’s response: The final table is indeed very long and we understand the reasoning behind this suggestion. However, the ESSD submission guidelines state that “... citations should appear in the body of the article with a corresponding reference in the reference list”. A similar recommendation

can be found in the PAGES data guidelines (<https://pastglobalchanges.org/science/data/data-guidelines>): "... "data citations" appear in the main text alongside and in the same way as a bibliographic citation, and they are included in the reference section of the paper". A reference list/table in the supplement would probably not go into most citation data bases. We feel that it is important to give proper credit to the colleagues who generated and shared their data and thus see no alternative to an extensive table with citations in the appendix to keep the corresponding references in the main reference list of the paper.

Changes to manuscript: As suggested by reviewer #2 in the pdf copy of the manuscript we now show the latitudinal distributions of $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ (old figures 7 and 9) together in new revised figure 7. The suggested corrections of typos and wording have been incorporated.

Reviewer comment 14 (Stefano Bernasconi) This paper describes a new world atlas of foraminifera oxygen and carbon isotopes. This is a very welcome and extremely useful contribution to the paleoceanographic community and will be a very much used tool in the future. The authors have to be commended for the great effort to put this atlas together.

Author's response: We thank Stefano Bernasconi for his helpful review and encouraging comments.

Changes to manuscript: None

Reviewer comment 15 (Stefano Bernasconi): The paper is very well written and to the point. It provides the necessary information to use the database, although at present it was not possible for me to access the database. I assume the link will be activated once the paper is accepted.

Author's response: We are sorry that the access to the data was more difficult than expected. A temporary download link is available on the article page under "Assets". This link provides free access to the atlas data set on Pangaea until Feb 20, 2022 and our tests confirmed that it was indeed active during the discussion phase. We noticed, however, that the PANGAEA website still states "login required" which does not apply to the link but may restrain interested colleagues from clicking on the link under "Download dataset". All restrictions on the data set will be completely lifted upon acceptance of the paper. To make the use of the data set more convenient, we furthermore plan to distribute the data set with the PaleoDataView installer.

Changes to manuscript: We added the following corresponding statement to section 5 (data availability) of the manuscript:

"Installers for current versions of PDV for both Windows 10 and macOS including the data set are available from <https://www.marum.de/Stefan-Mulitza/PaleoDataView.html> (last access: 2 February 2022)."

Reviewer comment 16 (Stefano Bernasconi): The last chapter does not clearly describe if the database is open to additional data and if yes how they can be supplied to the authors, or if the authors plan a updated version in the future, rather than a continuous incorporation of new data as they are provided by other contributors.

Author's response: This important point was also raised by Reviewer #2 (see comment #12). We indeed plan to update the data set in the future and hope that our manuscript will stimulate the interest of the community to participate and contribute data to updated products.

Changes to manuscript: We added the following sentences to section 6:

“As new foraminiferal isotope measurements become frequently available, we plan to update the atlas in reasonable intervals.”

“Please contact the first author if you are interested to contribute to future updates of the atlas.”.