Reply RC1: 'Comment on gchron-2023-7', Paula Reimer, 13 May 2023

All reviewer text is in red. Author replies in black.

Marine radiocarbon calibration requires an estimate of the reservoir offset from the marine calibration curve (ΔR). These estimates can be based on ^{14}C measurements of pre-nuclear weapons testing, known age shells, independently dated coral, or contemporaneous marine and terrestrial samples. Until now the ΔR values for coastal Greenland have been sparse. The authors have significantly enlarged the dataset of known age shell measurements from coastal Greenland and neighboring regions of the Arctic. They have carefully selected samples from museum specimens to ensure the mollusks were collected alive. The effects of sea ice cover, water depth and mollusk feeding habits were investigated and discussed. Regional averages were calculated for zones based on "prevailing currents and water masses" although most of the zones have overlapping values. The authors also compared ΔR values for a limited number of samples stored in ethanol to dry samples.

Specific comments/questions:

Wet vs dry sample comparison: This comparison is based on only 6 dry samples and 4 wet samples from one region (Suppl. Fig 2). This is a rather small dataset to reach the conclusion that dry samples are not reliably collected alive. It is difficult to tell which dry samples were used in the comparison but, of the 5 dry samples from Kaiser Frans Joseph Fjord, 4 were species with unknown feeding habits or deposit feeders. It is well known, and also shown in this manuscript, that deposit feeders may incorporate older carbon from their environment. This comparison apparently forms the basis for one of the stated criteria for sample selection (line 412-413): 'Museum sample storage: As the exact age of samples from "dry" collections is possibly unknown, only samples with soft tissue present, stored in "wet" collections, should be used for ΔR evaluation'. Samples stored in ethanol may be ideal to ensure live collection but this criterion would exclude many of the existing values in the literature. In some cases, the museum documentation is unambiguous about live collection but there are also other indications of whether "dry" bivalves in collections were most likely collected live or shortly after death. These include fragile mollusks that would have been abraded if transported to a beach as well as those with residual ligament, muscle or periostracum (O'Connor et al. 2010). In addition, some species have colours that are light sensitive so would be bleached if not collected alive and stored in the dark (Angulo et al. 2007).

This is a good point, and we will make changes in the text to tone down this strict criterium for selecting museum samples. Where possible, "wet" samples are preferred, but we will acknowledge that useful information can definitely be obtained from “dry” samples.

The study also makes use samples from water depths that would not be considered surface ocean in general. The low ΔR values for these samples provide a very interesting and useful observation for these locations which are ‘characterized by convection and formation of North Atlantic Deep Water and Labrador Sea Water’. The authors advise that: ‘When calibrating benthic dates from deeper sites one could therefore consider excluding extreme values obtained from surface ocean samples when making the choice of which reservoir correction to apply’. This seems like valid advice for these regions however it should be noted that surface ocean ΔR values are not generally applicable for benthic dates in other regions where deep water can be very depleted in ^{14}C. Ideally one would have ΔR values from deep water samples to use for radiocarbon calibration of benthic samples but these are scarce in the literature.

Thank you for these nice comments. It is true that these deep “young” samples are probably more the exception than the rule, because of their location in areas of deep water formation. We will make changes to the text to make sure that this advice should not be applied in other areas where the ΔR of deeper waters is not known, or not showing this pattern of younger ages.

Also is there an explanation for the low ΔR values for relatively deep samples in NW Greenland zone 5? Is the West Greenland Current fed by Labrador Sea water?

This is an interesting observation. Indeed, in Figure 3 it is clear to see that multiple deeper sites (>500m) on the NW Greenland shelf have low ΔR values. We attribute this to the presence of young Atlantic Water at depth in the WGC, originating from the East Greenland Current mostly, but indeed Labrador Sea water can play a role here also. We will include this observation and discussion to the manuscript.

Technical comments:

If no reply is listed, we agree with all the below suggestions, and will make adjustments to the manuscript accordingly.

Line 18: ” Marine20, the most recent radiocarbon calibration curve” Insert “marine” ahead of radiocarbon.

Line 19 and 74: ‘we introduce the term ΔR_{13}”. This term has been previously introduced in Heaton et al. 2023. I would suggest replacing ‘introduce’ with ‘use’

Line 51: 'to a lesser extent, injection of 14C-depleted CO2 from the burning of fossil fuels' Although this is a common perception and definitely true for reservoir ages relative to the atmosphere, for ΔR this is insignificant. ΔR is the difference between the marine radiocarbon age and the marine calibration curve which is modelled with input from the atmosphere so includes the Suess effect.

Line 54: 'tephrochronology (Pearce et al., 2017; Austin et al., 1995; Olsen et al., 2014), or paired marine/terrestrial dating' ΔR values may also be determined by U-Th dated coral (e.g. Hua et al. 2015).

Line 57: 'Several hundred different studies were made to study the local reservoir age'. Replace 'were' with 'have been'.

Line 127: 'the most commonly used value for the reservoir age correction (prior to publication of Marine20), ΔR = 0 14C years' Since ΔR without a subscribe is defined earlier as relative to Marine20 ,it would be better if this written here as 'Rxx = 0 14C were xx =04, 09 or 13.

Line 184: 'Wet samples were placed in a drying oven at 40 °C for several days' It would be worth stating that this is to remove any ethanol from the shell since contamination from the ethanol might be a concern.

Line 189: 'milliQ water' Trademark symbol needed

Line 239: 'where ΔRi and σi are the mean value and uncertainty of calculated local reservoir age offset'. Add 'of sample i' to clarify.

Line 243: 'Where the subscript w indicates that the uncertainty is calculate using the error each ΔRi' Change 'error' to 'uncertainty' and 'is calculate' to 'is calculated'

Line 368: 'no ΔR values higher than 50 years are found, and where ΔR values exceed 160 years,' ΔR values should be given as '14C yrs' rather than 'years'

Line 370: 'there is also a positive correlation between sea-ice cover and reservoir age'. Are the correlations significant?

Following your question, we have calculated the correlation and significance, and only for Zone 2 we found a significant positive correlation between sea ice concentration and ΔR. We will add this to the results description and the figure caption.

Line 429: 'these values remain only valid for the modern situation' Insert 'pre-bomb' before modern because the values would not be valid for post-bomb samples.

Fig. 1 caption: Need to define WGC, NFL, EGC.

Also. ‘Areas of deep convection in the Labrador Sea and north of Iceland are colored yellow’. These look light green on top of the blue background - perhaps 'shaded light green' would be better

Fig 2. Given the results, is there justification for separate zones for the Greenland coastal waters since ΔR values overlap?

It is correct that the values overlap, but our hypothesis was that the values would follow the different prevailing currents and water masses. We believe therefore that it is still valid to show these zones in Figure 2. In the discussion we mention that these regional averages are provided, but we encourage users to consult the full dataset before making decisions on which value to use. Other factors such as water depth can play an equally important role.

Suppl. Fig 2. Sample numbers on Suppl. Fig 2 would be helpful for comparison of species and feeding habits

This is a good idea. We will add the sample numbers to the markers on the map.

References:

Angulo, R. J., Reimer, P. J., De Souza, M. C., Scheel-Ybert, R., Tenório, M. C., Disaró, S. T. & Gaspar, M. D. 2007. A tentative determination of upwelling influence on the paleo-surficial marine water reservoir effect in southeastern Brazil. Radiocarbon, 49, 1-5.

Heaton, T. J., Bard, E., Bronk Ramsey, C., Butzin, M., Hatté, C., Hughen, K. A., Köhler, P. & Reimer, P. J. 2023. A response to community questions on the MARINE20 radiocarbon age calibration curve: marine reservoir ages and the calibration of 14c samples from the oceans. Radiocarbon, 65, 247-273.

Hua, Q., Webb, G. E., Zhao, J.-X., Nothdurft, L. D., Lybolt, M., Price, G. J. & Opdyke, B. N. 2015. Large variations in the Holocene marine radiocarbon reservoir effect reflect ocean circulation and climatic changes. Earth and Planetary Science Letters, 422, 33-44.

O'Connor, S., Ulm, S., Fallon, S. J., Barham, A. & Loch, I. 2010. Pre-bomb marine reservoir variability in the Kimberley region, Western Australia. Radiocarbon, 52, 1158-1165.