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Interactive comment on "High resolution ^{14}C bomb-peak dating and climate response analyses of subseasonal stable isotope signals in wood of the African baobab – A case study from Oman" *by* Franziska Slotta et al.

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Dear Dr. Mazumdar, dear referees,

We gratefully acknowledge the efforts of Dr. Santos and Dr. Chakraborty for their comprehensive reviews of our manuscript. Their questions, criticism and thoughtful comments are very appreciated. In this response – prior to the editor's decision - we provide additional input and perspective that make some of the referees' concerns less pressing and may dispel others altogether. In the revised MS minor comments will

thoroughly be considered, grammar and spelling mistakes corrected.

The most critical comments of the referees can be summarized three key points: 1) our paper does not discuss in sufficient detail all potential causes of the observed F14C values of tree-ring cellulose being significantly lower than in the corresponding atmospheric CO2 for the period around the bomb peak. Referees question our arguments for significant tree-physiological causes and particularly criticize the lack of discussion of external reasons. 2) our methodological and analytical description is lacking detail, unclear, ambiguous or not up to the mark. 3) The stable isotope data, our analysis of climate-proxy relationships and the climatological interpretation has raised no particular interest of the referees. If given the opportunity by the editor to revise our MS we will particularly focus on addressing these three issues. We will consider and incorporate the literature suggested by the referees. In view of this we will carefully re-write our methods section exemplifying that sample preparation and mass spectrometric analyses (IRMS and AMS) were performed in compliance with international standards and good scientific practice. In the discussion we will be taking into special consideration the potential external causes of 14C change during the period of the bomb peak (e.g. fossil fuel burning, atmospheric circulation etc. as put forward by the referees). In the following, we outline the key changes we intend to incorporate into the revised manuscript to consider the individual key points raised by the referees. Comments to Referee #2:

General remarks Radiocarbon analysis of the annual rings of trees has been carried out by several in- vestigators to study a variety of natural processes. Such kinds of records, especially in the extra-tropical region of the northern hemisphere are widely available. The trop- ical region, however, is not well represented. To fill this gap Slotta et al. attempted to reconstruct atmospheric 14C records from southern Oman based on the radiocarbon analysis of tree rings. The atmospheric radiocarbon activity showed anomalous enrichment during the early to mid-1960s, which is well documented in various atmospheric measurements as well as observed in several tree ring-based proxy records. The authors have made a high-frequency sampling of a baobab tree during the bomb peak interval in order to study the nature of the 14C variability and the underlying mechanism that caused the observed variability. One of the main observations of their analysis is that the 14C variability in this region is characterized by a significantly low value (ca 9%) compared to the expected value across the similar latitudinal belt. The authors opine that the internal cause, such as plant physiological processes are primarily responsible for this depletion.

Apparently, they ignore the external factors, such as the fossil fuel dilution of atmospheric 14C variability, which may also produce such kind of anomalous signal. I would suggest the authors discuss this aspect as well to systematically rule out this possibility before coming to a definitive conclusion. Response: Thank you very much for this identifying this significant weakness of our MS. Changes to MS: If given the opportunity by the editor, in the revised MS we will address the issue of external factors diluting bomb-induced 14C variabilty in the atmosphere and give more details on the aspects raised by the referee below.

Section 4.1 The authors observed 14C activity in their tree ring that was noticeably lower than the NH3 and SH3 around the bomb peak (1964-1967). The authors explain that the anomalously low values were driven by plant physiological activities, the carbohydrate turn over time. But this hypothesis suffers from some limitations because such kind of low tree ring 14C activities has been reported by some investigators in the Asian region without invoking the tree physiological process. For example, Kikata et al. observed a bomb peak around D14C = 692‰ in Vietnam. Hua et al. (2000) found 694‰ in northern Thailand. Chakraborty et al. (1994) found 630‰ in an urban area in west India. Murphy et al. observed a slightly higher value of 705‰ in central India, which was also supported by Chakraborty et al (2008)'s observation of 708‰ in another site in central India. Response: Thank you very much. We were unaware of the details of papers you mention. Changes to MS: We will incorporate the results to our MS, carefully change our discussion and cite the above mentioned literature

accordingly.

Some of these authors have attributed the lower value of atmospheric 14C activity in a specific region in terms of fossil fuel dilution. For example, Chakraborty et al. (1994) analyzed a teak sample from a western Indian urban area and found a somewhat low value of 630‰ but the same species of another teak sample obtained from a central Indian but forested environment showed a bomb peak of 708%. The lowering of bomb peak (approx. 11%) in the urban area was attributed to fossil fuel dilution of atmospheric 14C. Response: Thank you very much for this information. Changes to MS: We will evaluate our data with respect to potential effects of fossil fuel dilution of atmospheric 14C.

Chakraborty et al. (2008) did not invoke the idea of tree physiological process in this case, though the possibility, in principle, may not be ruled out. But, the occurrence of two different 14C values in the same tree species at two different places seem to be driven by an external factor(s) rather than the tree physiological processes. Response: We understand, that the teak tree species invested by Chakraborty et al. 2008 is much different in wood anatomy and tree ecophysiology than the baobabs studied in our MS. Wood anatomy and wood cell types and proportions of fibre vs. parenchyma tissue is closer to those of angiosperms from temperate zones. Although the proportion of parenchyma tissue of teak is higher than those of angiosperm tree species of temperate zones, which might partly (besides dilution by fossil fuel burining and others)e xplain why lower 14C ratios were found as well in teak. Changes to MS: We will evaluate our data with respect to potential effects of fossil fuel dilution of atmospheric 14C and compare and discuss our data with those of the above suggested publications.

There may be other reasons to doubt the tree physiological process affecting the tree ring 14C activity. The mechanism explained by the authors involves the incorporation of previous year's carbon that significantly affects the average age of the current year wood. If that be the case, then a similar effect should have been observed by other investigators. Response: No, we disagree! No other tree species invested for 14C during the bomb peak period has such high proportion of long-living parenchyma. As mentioned by the referee #2 above also authors have found lower values of atmospheric 14C activity as expected.

Hua et al. (2003) analyzed a Pinus Radiata tree sample collected at Armidale in New South Wells, Australia and found excellent agreement with the atmospheric observation for the period of 1952 to 1967. But these authors observed higher 14C values in their Armidale tree ring samples for the period of 1968-1975. Obviously, an increase in radiocarbon activity cannot be explained by tree physiological processes. So either an increase or a decrease in 14C activity is likely to be driven by external factors. Response: We admit that observed variability of 14C values in tree rings cannot be explained by tree physiological processes alone, however, and in return we cannot follow the argument that only external factors cause 14C variability. Tress are living organisms, they react to changes of their environment in many ways. For example, they modify the stomatal aperture of their leaves/needle in response to moisture availability or CO2 concentration of the atmosphere. Related to this isotopic fractionation occurs that can lead to very individual or site specific 13C and 14C contents in tree organic matter. Changes to MS: We will stress the importance of external factors and will detail them in the revised MS. However, we do not see striking arguments why our suggestion to consider tree physiological effects to some extent should be discarded.

Using a numerical exercise and autocorrelation analysis of d13C data Slotta et al. estimate that approx 85% of fast cycling carbon pools and 15% of slow-cycling carbon pools are contributing to the lower values of the bomb peak. If this explanation is true, then this effect should have been manifested in the entire record the authors have reported, which is not apparent from their results. Rather, the authors admit that the baobab F14C values for 1945, 1952-1954, 1956 and 1957 are indeed higher than the calculated range. This observation casts doubt in their explanation of the old carbon turn over mechanism in explaining the negative excursion of 14C activity during the bomb peak period. Response: As mentioned in response to referee#1 above, the un-

expected significant mismatch between the baobab F14C values and the post-bomb atmospheric curve NH3 prompted for some reasonable interpretation. Hence, we suggested and still suggest that it is from a mixed carbon pool in conjunction with the extraordinary high content and longevity of parenchyma tissue relative to short lived fibre tissue that constitute the tree rings of baobabs. With the simple model considerations presented here we do not intend to precisely describe or capture temporal changes of carbohydrate pools in baobab trees. We can show, however, that the F14C values of baobab tree-ring cellulose can better be explained when assuming a mixing of pools of carbohydrate precursors of cellulose instead of assuming direct transfer to atmospheric carbon into organic matter of tree rings. Changes in the manuscript: We will rewrite ithe MS to stress the uncertainties involved with our interpretation.

There may be another explanation of lower 14C activity in this region. Cember (1989) analyzed coral 14C from across the Red Sea to estimate the gas exchange rate. Cember observed a very high air-sea exchange process over the Red Sea region. If this process is also operative in this region which is not very far from the Red Sea, then a viable explanation of anomalous 14C activity in the atmosphere may be provided. Response: Thank you very much for this comment. Changes in the manuscript: We will pick this up and incorporate the potential air-sea exchange processes into our interpretation and discussion.

2.4 Radiocarbon dating The analytical description provided by the authors is not up to the mark. For example, radiocarbon dating requires 13C correction and age correction; there is no mention of whether such kind of corrections has been done. The reporting of 14C activity, especially in the case of sequential samples (tree ring, corals) is typically done in cap delta notation (D14C), but the authors have preferred normalized activity. Response: By utilizing F14C we follow the suggestion of Reimer, P. J., Brown, T. A. and Reimer, R. W. (2004). "Discussion: Reporting and calibration of post-bomb C-14 data." Radiocarbon 46(3): 1299-1304. In this paper the advantages of using F14C in studies of the bomb peak period are well described.

For comparison purposes with the published records, the authors are suggested to report the 14C activity in cap delta notation. Finally, the error in 14C measurement should be mentioned in terms of cap delta as well as the corresponding temporal value. Changes in the manuscript: We are inclined not to make changes to our nomenclature (cf. above). However, if requested by the editor we can provide del14C values for the most prominent excursions of our baobab record in the revised MS. As indicated in the figure captions, errors are smaller than the symbols of the figures. However, we will specify the numbers in the methods section of the revised MS.

Minor issues: Line 92: The rainfall amount and its isotopes usually show a weak inverse correlation. Pls, provide reference for evidence of “strong” correlation. Line 141: very heavy rainfall in a single day producing high negative d18O “due to amount effect” is not technically right. Many studies (Lawrence and Gedzelman, 1996; Gedzelman et al., 2003; Lawrence et al. 1998; Chakraborty et al., 2016; Xu et al., 2019), showed that extreme precipitation events such as cyclonic activities produced very low values of precipitation d18O. Response: Thank you very much for this comment. Changes in the manuscript: We will correct this in the revised MS and will be technically more specific.

Line 181: pls provide a zoomed figure for the 1962-63 record of bomb 14C. Line 199: What are the reference materials used? Response: Thank you very much for this comment. Changes in the manuscript: We will be more specific in the revised MS.

Line 202: Please provide the permil sign after 0.15 and 0.25. Line 217: ‘weakening’ should be “weaken”. Response: Thank you very much for this comment. Changes in the manuscript: We will correct these mistakes in the revised MS.

Line 251-252: How the interpretation of the F14C data was confirmed by visual and sta- tistical comparison of the TRW chronology with precipitation data should be explained in detail. Response: Thank you very much for this comment. Changes in the manuscript: We will be more specific in the revised MS.

Line 255: ’shallow’ should be replaced by "gentle". Changes in the manuscript: We will do in the revised MS.

Line 268: ’radiocarbon’ should be followed by "analysis". Line 275: ‘considerably declining’ meaning is not clear. Changes in the manuscript: We will be more specific in the revised MS.

Line 280: What is the physical basis of getting a strong correlation between d18O and RWI? Also mentioned in Line 334. Please provide the value of correlation and state the sample number. Response: Thank you very much for this comment. Changes in the manuscript: We will be more specific and provide correlation coefficients in the revised MS.

Line 309: the lag between cyclonic events and the corresponding d18Omin should be provided on a monthly time scale. Line 355: ’extend’ should be replaced by "extent". Changes in the manuscript: Thanks, we will correct this in the revised MS.

Line 494: "evaporative enrichment in 18O...".Please provide supportive evidence of enhanced soil evaporation, say by means of observed or reanalysis data in support of this speculation. Changes in the manuscript: Thanks, corresponding papers will be cited in the revised MS.

Line 505: "Vapor pressure deficit ...18O enrichment in leaf water", and "lower stomatal conductance...13C discrimination to decline" require supporting literature. Changes in the manuscript: Thanks, corresponding papers will be cited in the revised MS. For instance: Barbour MM (2007) Stable oxygen isotope composition of plant tissue: a review. Funct Plant Biol 34 (2):83-94. doi:https://doi.org/10.1071/fp06228

Line 514: the authors argue that the decline in d18O...might be due to the previous year’s October precipitation. If so, then d18O is also expected to be auto-correlated. Response: This is correct, thank you very much for this comment. Changes in the manuscript: We will delete this speculation in the revised MS.

Line 524: likely in 'would have likely..." should be deleted. Changes in the manuscript: Thanks, we will correct this in the revised MS.

References: Cember 1989 Bom radiocarbon in the Red Sea: a medium scales gas exchange ex- periment. JGR Ocean 94:2111-2123. Lawrence, J. L. & Gedzelman, S. D. Low stable isotope ratios of tropical cyclone rains. Geophys. Res. Lett. 23, 527–530 (1996). Gedzelman, S., Lawrence, J., Gamache, J., Black, M., Hindman, E., Black, R., Dunion, J., Willoughby, H., Zhang, X., 2003. Probing hurricanes with stable isotopes of rain and water vapor. Mon. Weather. Rev. 131 (6), 1112–1127. Hua, Q., Barbetti, M., Zoppi, U., Chapman, D. M., and Thomson, B. 2003 Bomb Radiocarbon in Tree Rings from Northern New South Wales, Australia: Implications for Dendrochronology, Atmospheric Transport, and Air-Sea Exchange of CO2, Radiocarbon, 45, 431-447. Xu et al. 2019 Stable isotope ratios of typhoon rains in Fuzhou, Southeast China, during 2013–2017. Kikata Y, Yonenobu H, Morishita F, Hattori Y. 1992. 14C concentrations in tree stems. Bulletin of the Nagoya University Furukawa Museum 8:41–6. In Japanese. Changes in the manuscript: Thanks, corresponding papers will be cited in the revised MS.

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