Interactive comment on **"Climatic subdivision of Heinrich Stadial 1 based on centennial-scale paleoenvironmental changes observed in the western Mediterranean area"** ***by*** **Jon Camuera et al.**

Anonymous Referee #1

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General comments

The manuscript by Jon Camuera and colleagues describes paleoenvironmental changes in southern Iberia during the last deglaciation focusing on Heinrich Stadial 1 (HS1). The authors observe a novel subdivision of HS1 in the analyzed Padul record and in other records from the Western Mediterranean and Greenland. They come to the conclusion that solar forcing accounted for an detected ~2000 and ~800 yrs climate cyclicity.

The study presents novel ideas and addresses relevant questions within the scope of the journal Climate of the Past. It is well structured, easy to follow, and concisely written. Figures are of good quality.

However, I have two main concerns. Firstly, it is not always clear whether data is new, already published, or already published but analyzed/shown in a new way. This concerns mainly the own previous studies. Nevertheless, it is important to exactly indicate the sources to avoid (self-) plagiarism (see also specific comments).

Thank you for the comment. In this new version of the manuscript we have clarified that we increased the resolution of the palynological analysis with respect to the previous study by Camuera et al. (2019). In this new study we analyzed 24 additional pollen samples between 20 and 11 kyr BP, and therefore, increased the pollen resolution from 67 samples (Camuera et al., 2019) to 91 samples (now explained in the new version of the manuscript). This permitted us to focus on the environmental and climate variability during HS1.

Secondly, the age-depth model is not as robust as stated. That does probably not affect the observed climate pattern but it may affect the cyclostratigraphic analysis. The age-depth model is based on radiocarbon dates of organic bulk sediments that might need a reservoir correction. Particularly in a wetland setting, a reservoir age of aquatic and semi-aquatic plants must be considered. The uncertainties of the age-depth model need to be taken into account and should be critically discussed when correlating records and when analyzing cyclicities.

Thank you for the comments. Firstly, we would like to apologize for the mistake we made in Table S1 (Table S2 in the previous version). The dated material of the new six samples analyzed for this study are organic vegetal residues from peat and carbonate sediments, pretreated with HCl and HF before submission to the BETA analytic laboratory for dating, and not bulk sediment as we previously stated. The organic vegetal residue should be characterized by lower reservoir effect (if any) after removing inorganic carbonates and silicates. In addition, two samples that were considered too old and were not used in the age model in the previous version of the manuscript have also been included in the new age-depth model (Fig. 2 and Table S1 in the new version) to avoid subjectivity.

With respect to the comment about dating of aquatic and semi-aquatic plants, most of the vegetation surrounding the wetland is mainly characterized by *Phragmites australis*

and *Typha domingensis* that use the atmospheric carbon as source for the photosynthesis (Brix et al., 2001; Dong et al., 2012). This information about the present-day vegetation of the Padul wetland and surrounding areas have been included in the new version of the Supplementary Information (section *Regional and local settings*). The terrestrial origin of the plant material used for radiocarbon dating is confirmed by values in $\delta^{13}C$ and C/N that are in agreement with C3 vascular land plants (Meyers, 2003; Meyers and Lallier-vergés, 1999). The $\delta^{13}C$ and C/N values have been included in new Table S1. Therefore, according to the vegetation from the Padul wetland and the $\delta^{13}C$ and C/N values recorded from samples, we can suggest that the reservoir effect of the organic carbon from the dated organic plant remains should not be high. In any case, we are aware that our radiocarbon datings could be biased by a possible reservoir effect and discussion about this possible problem has been included in the new version of the manuscript.

In order to improve the age model, in this new version of the manuscript we built a new age model based on Bayesian modelling, which accounts better for age uncertainties. This new age model for the Padul-15-05 record has been run for the last 30,000 cal yrs BP using the already published radiocarbon dates (including three specific compound radiocarbon samples) (Camuera et al., 2018) along with the six new radiocarbon samples analyzed for this study. Therefore, the new Bayesian age-depth model for the last 30 kyr BP is based on 40 radiocarbon dates (Fig. 2 and Tables S1 and S2 in the new version of the manuscript). All this changes have been included in the new version of the manuscript.

Specific comments

23/62: Please relativize the terms “robust” and “accurate”.

Thanks. We have changed and deleted these terms.

25: Please clarify which resolution is improved.

Done. We have clarified the total amount of pollen samples analyzed and how many of them were new samples analyzed for this study. We have also clarified the new pollen resolution taking into account the new pollen samples. This part has been modified from the Supplementary Information (section *Palynological analysis*) and moved to the main manuscript (section *Materials and methods*) as we think it is important information for the reader to understand the bases of this study.

34/35: Why does natural climatic variability underlie abrupt anthropogenic climate change? Please clarify or rephrase.

We have clarified the sentence.

55: Please mention the section “Regional and Local Settings” of the Supplementary Information here. In addition, please delete “new” to avoid misunderstanding.

Thank you for the suggestions. We have mentioned the “Regional and Local Settings” section and we have deleted the word “new”.

62–64: Please add reference of the radiocarbon dates.

Thank you for the comment. However, we have added the sample references in Table S1 and thus we think that it is not necessary to add the references of the radiocarbon dates in the main text. In that new table S1 we also included the $\delta^{13}C$ and C/N values

from the six new radiocarbon samples analyzed for this study as well as the information from the previously analyzed and published samples from Camuera et al. (2018).

65/66: Please add reference of the pollen data, e.g. add “based on palynological data by…” after “Precipitation Index (Ip)”. If I understood it right, the palynological data has already been published, but it is not clearly stated in the manuscript.

As we explained in your question “25: Please clarify which resolution is improved”, we have clarified the total amount of pollen samples used and how many of them are new samples specifically done for this study. We have also clarified the new pollen resolution after analyzing the new samples.

81–83: How is the start (lower boundary) of HS1 defined in your record? Could it have also started at ca. 18.7 kyr when Si, Mediterranean forest, PCI and Ip start to decline?

Yes, HS1 could have started before according to the PCI and *Ip*. However, we think that even if the decline in the PCI and *Ip* started a few hundred years before, the really arid conditions characteristic of HS1 should have started at 18.4 kyr BP coinciding with the abrupt increase in xerophyte percentages. In addition, as both declining trends of PCI and *Ip* for the beginning of HS1 are relatively gradual/transitional (not as fast as during the end of HS1), we took a middle point from this declining trend coinciding with the abrupt increase in xerophytes.

97/98: Please add “(Fig. 3b, c)” after SST reconstructions and “Cacho et al., 1999; 2006” to the references.

Done.

102–104: Please rephrase the sentence because the SST records published by Cacho et al., 1999; 2006 originate from the Alboran Sea as well.

Yes, we agree. We have rewritten the sentence.

109–111: Please add PCI because it shows the same pattern.

Yes, we also agree. We have also included the PCI as it is also showing a general lowering trend related with a decreasing moisture pattern.

112: Please replace “(Fig. 3a, b)” by “(Fig. 3b)”.

Thank you. Done.

136–157: The presented explanations and records are not strong enough to conclude an early HS1 and Bølling-Allerød in the Mediterranean.

We think the reviewer is right. We have proposed several possible causes that could have triggered the early environmental response in our region. However, we have also included uncertainties with the radiocarbon dating that could generate this early HS1 record in Padul (or even a combination of both factors: early environmental response and radiocarbon dating uncertainties).

159–169: Please add comparisons with other regional records.

We thank the reviewer for the suggestion. We have included references of other regional records presenting environmental reconstructions for the BA and YD periods. These records suggest climate conditions similar to our Padul record.

166–169: Xerophytes decrease at first. How can that be explained? How is the lower boundary of the YD defined in your record? Better mention the Ip value to suggest arid conditions. In general, it would be nice to see a detailed pollen diagram in the supplement to comprehend the stated climate variations.

Thank you for the comment. However, the lower boundary of the YD is not defined by xerophyte percentages but mainly by changes in the *Ip* values (as the reviewer suggested). Comparing xerophyte percentages (Fig. 3c of the new version of the manuscript) with respect to *Ip* values (Fig. 3e), we can observe that the lower boundary of the YD is well defined by a decrease in *Ip* at ca. 12.9 kyr BP, whereas xerophytes are not decreasing (note the inverse xerophyte values) until 12.6 kyr BP. We apologize for not including this in the previous version. We have changed this paragraph in order to better clarify the boundaries of the YD period.

In addition, we have also included a detailed pollen diagram with the most characteristic pollen taxa in the Supplementary Information (Fig. S1). The pollen diagram also shows the CONISS cluster analysis, which helped us to confirm the climate variability for this period deduced by the pollen data.

185–188: The D/O-record for 20-11 kyr is well defined and does not show a ~2 kyr cyclicity.

Thank you for the comment - we agree. Bond et al. (1999) suggested that the D/O cycles seem to be an amplification of the 1-2kyr cycle. Therefore, we have modified the phrase.

244: I appreciate that you provide the data in an online repository. However, I suggest adding the complete palynological dataset to the repository for replicability.

Yes, we agree. We have uploaded the complete palynological dataset to the PANGAEA data repository (https://doi.pangaea.de/10.1594/PANGAEA.904053, *dataset in review*).

Figure 2–5: Please indicate all sources of data.

Thanks for the comment. We have included the link of the data repository at the end of the Figure 3 caption (Fig. 2 in the previous version). Sources are included in Figure 4 (Fig. 3 in the previous version). With respect to the Figure 6 (Fig. 5 in the previous version), we have added the reference of the source of the ^{10}Be flux data (i.e., Adolphi et al., 2014), whereas the source of the pollen data from Padul record has already been included in the Figure 3 (as well as in the section *Data availability*).

Figure 2a: The uncertainty of the age-depth model is underestimated where no dates are available. Please use a model that accounts better for uncertainties. In addition, please add the dates that you rejected to Fig. 2a, e.g. in a different color.

We agree with the reviewer. In this new version of the manuscript we built a new Bayesian age-depth model to have a better control of age uncertainties and improve the Padul-15-05 age model for the last 30 kyr BP. Again, we would like to apologize for the misunderstanding concerning the dated materials for the six new radiocarbon samples, as they were not bulk sediments but organic plant residues. Therefore, the six new samples have also been included in the new Bayesian age-depth model. See the new Figure 2 and Tables S1 and S2 to see the new Bayesian age-depth model and included/rejected radiocarbon dates for the last 30 kyr BP.

Figure 4: I suggest to use always “xerophyte percentages” instead of “raw xerophyte data” and “raw xerophyte percentages” (also in Supplementary Information line 120). In

addition, please indicate the meaning of the green lines (confidence interval) in the figure caption. Which periodicity is shown by the first peak in Fig. 4d and why is it not mentioned?

Thank you for the suggestions. We have changed those expressions to “xerophyte percentages” and we have included the meaning of the green lines (confidence intervals) in the figure caption. The fist periodicity peak observed in Fig. 5b (Fig. 4d in the previous version) has to be an artefact as it shows a cycle with a periodicity between 1689 and 5068 years (frequencies between 0.0001973 and 0.0005919) for a time series of 7600 years (^{10}Be flux data, from 18.6 to 11 kyr BP). This is explained at the end of the figure caption.

Supplementary Information (SI): The Supplementary Information is a rather extensive compilation of additional details. I appreciate the methodological details here. However, I suggest including the previous studies to the main text because they contain important data for comparison. For an even better comparison, I suggest adding this study to table S1.

Thanks for these constructive suggestions. The previous studies from Camuera et al. (2018, 2019) are included in the main text.

We totally agree in adding the interpretation of this study in new Table 1 (Table S1 in the previous version) along with the rest of the studies for a better comparison of environmental interpretations between studies/records. In addition, this Table 1 has been moved from the Supplementary Information to the main text.

Table S2: Please add source (reference or this study) to each date.

Thank you for the suggestion. We have added letters (^{a} and ^{b}) for identifying samples analyzed in previous studies and those analyzed for this study.

SI 54: Please add one or two sentences about the recent vegetation.

Thanks for the comment. We agree. We have included the most characteristic vegetation from the Padul wetland and surrounding areas.

SI 91–93/100: Please indicate which taxa are mesothermic and which are steppic.

Ok, done.

SI 107–109: Is this new or already published data? Please clearly indicate.

Thank you for the suggestions. In the Supplementary Information we have clarified that the inorganic geochemical composition of the entire Padul-15-05 record (the last ca. 197 kyr BP) was published in Camuera et al. (2018) and was done to observe orbital-scale environmental changes for the last 2 glacial-interglacial cycles.

SI 120–125: Which parameters were used for the Ip analysis? Could you add Ip to the first sentence?

The parameters used for the xerophytes and *Ip* data were the same (value of 2 for segments parameter and value of 3 for the oversample parameter). Nevertheless, we have removed the spectral analysis of *Ip* data. *Ip* values from Figure 3e (Fig. 2e in the previous version) are represented in a logarithmic scale, resulting in an inaccurate spectral analysis. In addition, we have also removed the sentence (and the related figure) about the spectral analysis of xerophytes for the age period between 18.4 – 15.6 kyr BP

(only HS1), as it was not showing any additional information with respect to Figure 5a (Fig. 4a in the previous version).

SI 120–137: Why were exactly these datasets used? Why is there only one analysis for HS1?

We used the dataset from xerophytes as it is the most characteristic and abundant group of pollen taxa responding to environmental and climate oscillations in Padul during HS1. As the reviewer says, there is only one spectral analysis for HS1, using the xerophytes time series. However, we have removed this spectral analysis from xerophytes for the HS1, as it is not showing any additional information with respect to the spectral analysis for the age range between 20 and 11 kyr BP (new Figure 5a in this new version of the manuscript).

Technical corrections:

74: Please edit format of reference.

We don't know what is wrong with the format of this reference. However, we have revised all references and the format.

167: shown.

Thank you. Changed.

SI 125: Please add "(CI)" after "Confidence Interval".

Thanks. We have added (CI).

SI 129: analyses.

Thanks, but it is not necessary as we have changed the sentence.

REFERENCES

Adolphi, F., Muscheler, R., Svensson, A., Aldahan, A., Possnert, G., Beer, J., Sjolte, J., Björck, S., Matthes, K., and Thiéblemont, R.: Persistent link between solar activity and Greenland climate during the Last Glacial Maximum, Nature Geoscience, 7, 662, https://doi.org/10.1038/NGEO2225, 2014.

Bond, G. C., Showers, W., Elliot, M., Evans, M., Lotti, R., Hajdas, I., Bonani, G., and Johnson, S.: The North Atlantic's 1-2 kyr climate rhythm: relation to Heinrich events, Dansgaard/Oeschger cycles and the Little Ice Age, Mechanisms of global climate change at millennial time scales, 112, 35-58, https://doi.org/10.1029/GM112p0035, 1999.

Brix, H., Sorrell, B. K., and Lorenzen, B.: Are Phragmites-dominated wetlands a net source or net sink of greenhouse gases?, Aquatic Botany, 69, 313-324, https://doi.org/10.1016/S0304-3770(01)00145-0, 2001.

Camuera, J., Jiménez-Moreno, G., Ramos-Román, M. J., García-Alix, A., Toney, J. L., Anderson, R. S., Jiménez-Espejo, F., Kaufman, D., Bright, J., and Webster, C.: Orbital-scale environmental and climatic changes recorded in a new ~ 200,000-year-long multiproxy sedimentary record from Padul, southern Iberian Peninsula, Quaternary Science Reviews, 198, 91-114, https://doi.org/10.1016/j.quascirev.2018.08.014, 2018.

Camuera, J., Jiménez-Moreno, G., Ramos-Román, M. J., García-Alix, A., Toney, J. L., Anderson, R. S., Jiménez-Espejo, F., Bright, J., Webster, C., and Yanes, Y.: Vegetation and climate changes during the last two glacial-interglacial cycles in the western Mediterranean: A new long pollen record from Padul (southern Iberian Peninsula), Quaternary Science Reviews, 205, 86-105, https://doi.org/10.1016/j.quascirev.2018.12.013, 2019.

Dong, W., Shu, J., He, P., Ma, G., and Dong, M.: Study on the Carbon Storage and Fixation of Phramites autralis in Baiyangdian Demonstration Area, Procedia Environmental Sciences, 13, 324-330, https://doi.org/10.1016/j.proenv.2012.01.031, 2012.

Meyers, P. A., and Lallier-vergés, E.: Lacustrine Sedimentary Organic Matter Records of Late Quaternary Paleoclimates, Journal of Paleolimnology, 21, 345-372, https://doi.org/10.1023/A:1008073732192, 1999.

Meyers, P. A.: Applications of organic geochemistry to paleolimnological reconstructions: a summary of examples from the Laurentian Great Lakes, Organic Geochemistry, 34, 261-289, https://doi.org/10.1016/S0146-6380(02)00168-7, 2003.