Reply to RC1:

We thank the reviewer for the positive and constructive feedback given on our manuscript. The answers follow below:

General Comments

The authours present an interesting test of the intermediate productivity aridity hypothesis. I quite like the combined use of clay / phytoclasts / charcoal as multiple lines of evidence to address their objectives. Overall, I enjoyed the reading manuscript and was interested in the authours' findings. Thank you to the authours for sharing!

Their link with grasses is interesting though potentially not hugely important for the conclusions. It is evident from your results that sufficient fuels existed to support fire, and I assume that some analogous fuel existed that served a similar role then that grass does today. I was a bit disappointed not to see a stronger link with grasses as a specific pyrophylic biome component and fuel, as it is one of the pieces in the abstract that made me interested to read more. I may be missing an important point, and if I am I encourage you to add more information in your introduction to set readers like me up to understand your point about grasses. Perhaps it is that biomes that contain grass serve as the basis for the intermediate productivity hypothesis and without them the hypothesis should fall apart. Currently it reads that grasses are important for current global fire patterns, and then there is not much direct follow-up. Please clarify this argument.

Thank you for pointing this out. In the introduction we explain that the current global fire pattern is dominated by grasslands, such as tropical savannah systems. This is an ecosystem in which intermediate levels of productivity and aridity occur and fire activity is high. Because >80% of the burnt area globally in the present day occurs in grasslands, grasslands reinforce the generalization of the intermediate productivity gradient. However, the intermediate-productivity gradient explains optimum fire conditions along an aridity – productivity gradient in which biomass, fuel moisture and temperature are important factors of the fire regime. Hence, independent of the type of vegetation the intermediate-productivity gradient should apply. In this study we test that for the Early Jurassic world, in which grasses were not yet evolved. Vegetation/fuel during the Early Jurassic in NW Europe was a mixture of gymnosperms, cycads, horsetails, ferns and mosses. Unfortunately, we do not currently have pollen and spore data form the Mochras borehole, so we cannot make direct inferences about the type of vegetation present in our study intervals. However, some literature suggests that fern savannahs can lead to large intense fires, in a similar way as grass savannahs (Harris, 1981; Van Konijnenburg-Van Cittert, 2002; Collinson et al., 2007, 2009). But there is currently no data on the occurrence of this biome in the Early Jurassic, with only evidence found in the Cretaceous. Hence, if present, we don't know how widespread this biome might have been in the Early Jurassic and where it would occur. Therefore, we cannot make any inference about an alternative for the grass biome in the Early Jurassic of the Cardigan Bay Basin.

In a revised version of the manuscript, we will clarify this by:

Add to the conclusion: "This study illustrates that the intermediate-productivity gradient holds up during two contrasting climatic states in the Jurassic <u>at a time well before grass Savannah existed</u>."

L81: delete "However".

L84: add "However, although the intermediate-productivity gradient of the present day is reinforced by the dominance of grasslands, grasses do not need to be included as the intermediate-productivity gradient explains the impact of climate and seasonality on all vegetation types. The crucial concept is that an optimum fire window exists when sufficient fuel builds up and connectivity exists in one season, followed by a drier season in which fuel moisture levels lower and fire can spread more easily."

You discuss charcoal largely in terms of overall abundance. Given that you consider fine and coarse charcoal, would it be possible to do any sort of discussion on fire intensity? E.g., greater coarse charcoal has been linked to larger more intense fire activity that generated sufficient convective energy to distribute larger particles. My experience is more with lakes and this may not translate to your system. But if it is possible it might be an interesting addition to discussion or future work. Perhaps you will see more or less intensity along the productivity-aridity gradient?

Thank you for the suggestion about the link of charcoal size and fire intensity. It would be interesting if we could say anything about fire intensity based on this dataset, but unfortunately microcharcoal (10-125 µm) and macrocharcoal (>125 µm) in the marine Jurassic borehole cannot be used for this. For this geological location charcoal is derived from the surrounding emergent landmasses, either by wind or river, and likely further influenced by both shallow and deep marine currents.

Larger *in situ* charcoal particles are generally found in terrestrial biomes and their depositional environments, in soils, lakes and mires. In contrast, smaller charcoal particles that are wind-blown could potentially end up in a marine environment, as well as in more distal terrestrial settings. Experimental research showed that riverine transport has the potential to carry the larger charcoal particles further away from shore, with the smaller charcoal particles becoming water saturated at a shorter distance and settling down closer to the shoreline (Nichols et al., 2000). In addition to this, other studies have indicated that larger charcoal particles (up to 7 cm) can be windblown and travel up to 50 km from the original source, depending mainly on their morphology (Woodward & Haines, 2020). Combined, charcoal size, shape, properties, wind direction, plume height, but also riverine and marine transportation, all have a different impact on the travel distance of different charcoal size classes. Hence, it too difficult to construct any hypothesis on fire intensity from our two charcoal size classes in the Mochras borehole.

Specific Comments

The methods are generally intuitive as written. I had one major point of confusion: the number of samples taken and used for each analysis in each period was unclear. I suggest that you make a table showing these numbers explicitly. It would support the methods and support the reader in interpreting your results from SBP and LPE, which had different resolutions.

Thank you for the feedback. In a revised version of the manuscript, we will incorporate a table with an overview of the samples per interval and proxy for clarity.

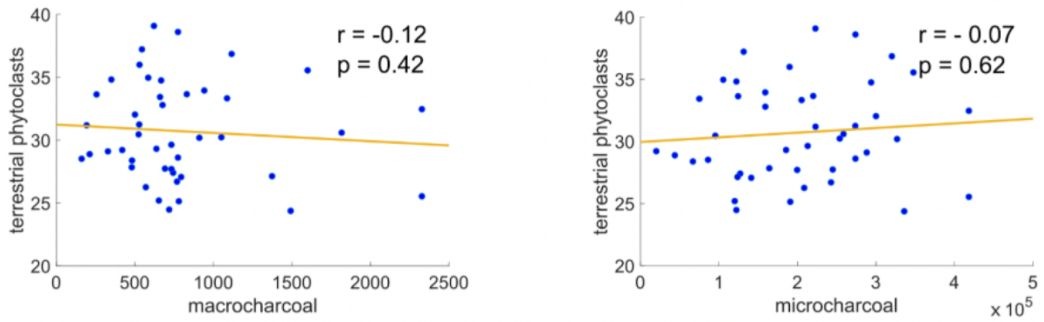
The results are fair as written. I have three suggestions: 1) I find it difficult to follow and be confident in your conclusions about terrestrial phytoclasts and charcoal particles given visual analysis alone. I see the importance for your conclusions that charcoal not be related to terrestrial inputs. I suggest that you demonstrate this relationship (or non relationship as you suggest) by some formal statistical test, perhaps a Mann-Kendall test.

We have used a Pearson's correlation in our study to illustrate that there is no statistical evidence that terrestrial organic matter (phytoclasts) and charcoal abundance correlate. A very weak correlation for microcharcoal and phytoclasts for the Late Pliensbachian Event (LPE) exists, and no correlation for microcharcoal and phytoclasts for the Sinemurian–Pliensbachian Boundary (SPB) interval. No correlation between macrocharcoal and phytoclasts is found in either interval. In a revised version of the manuscript, we will add in the Pearson correlation into the methods section.

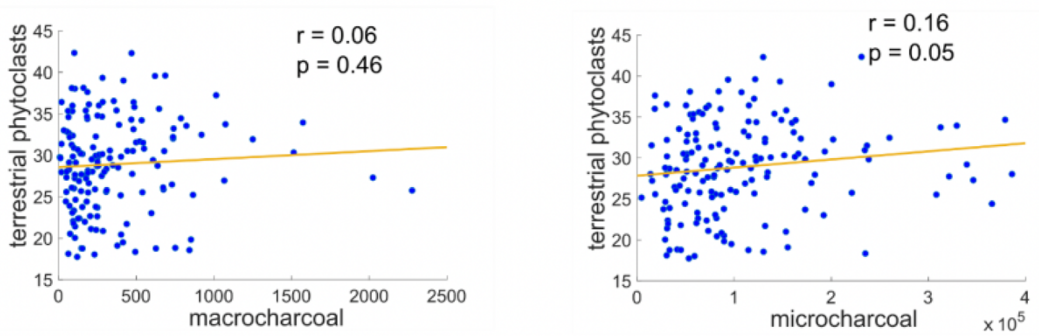
As extra evidence that there is no influence from terrestrial runoff to the charcoal record, we normalized the microcharcoal for the LPE interval with XRF terrestrial elemental data, following the method of Daniau et al. (2013) in Hollaar et al. (2023). Here we show that XRF total terrestrial elemental corrections do not change the charcoal pattern found in the LPE interval. Also, the overall abundance of wood is higher during the LPE in the Mochras borehole (Ullmann et al., 2021), whereas the charcoal abundance is overall higher during the SPB (L299-307).

We have looked into a Mann-Kendall test, however, this will test the hypothesis that a time series has a trend. It is unclear for us how this test can help to statistically underpin that the trend within two proxies/time series is the same or not. In addition, even though a trend in two data series can be similar, this does not mean that the individual sample points correlate. The latter is the important factor regarding the influence of the abundance of terrestrial phytoclasts and charcoal, as you want to know if individual spikes in charcoal correlate to highs in phytoclasts. For this purpose, a Pearson's correlation is sufficient (which we'll add in the methods in a revised MS). In the current text we indicate the r and p values of the Pearson's correlation. To further illustrate the lack of correlation we can show the scatter plots:

SPB:



LPE:



2) I suspect that Fig 4 is unnecessary, and I suggest that you remove it given that you do not refer to it in text (I checked with a search) and one could reasonably be expected to understand these distributions from Fig 2/3. If you want to keep Fig 4 I suggest you expand your discussion of micro- vs macro-charcoal partitioning and how that may be associated with fire intensity (which I think would be very interesting but may not be within your intended scope).

Figure 4 is referenced in L231: "Micro- and macro-charcoal are more abundant in the SPB compared to the LPE (Fig. 4)." The reason that this boxplot is included is to illustrate the higher charcoal abundance (in both size fractions) for the SPB compared to the LPE interval. This is an important argument for the LPE to be more fire-limited and closer to the aridity edge.

3) Fig 1 is difficult to read given its current size. I suggest that you either stack panel d below the other panels to allow all to be larger, or rotate the table to allow it to be larger.

Thank you for the feedback, we will move panel D to the bottom in a revised version of this manuscript.

4) Figure 1 and 5 do not work well with black/white printing or for folks who struggle to differentiate colours. Consider differentiating with shape or texture rather than colour.

Thank you we will revisit the layout of figure 1 and figure 5 and comply with the Copernicus article template illustrations to make the graphs colourblind friendly. We will change the pale grey and pale blue colours and enlarge Fig. 1 (by moving panel B to the bottom this is now possible) for better visibility.

Technical Corrections

1. Please include the methods you used to generate SI Fig 3 in methods.

Thank you, in a revised version of the MS we will add in L205 – 213: "In SI Fig. 3 we overlay the 3.2 – 10 m filter (based on Ruhl et al. 2016) derived from the macrocharcoal record with the normalized dataset of the macrocharcoal record."

2. The caption on SI Fig 3 is confusing, please edit for clarity.

In a revised version of the manuscript we will change the caption of SI Fig. 3 to the following: "SI Fig. 3: Macrocharcoal and the 10.2 – 3.2 m filter. (a) The macrocharcoal record (blue) of the LPE interval is linear detrended and the 10.2 – 3.2 m period is filtered out of the macrocharcoal record in Acycle. This filter represents the 100 kyr periodicity in the depth domain (Ruhl et al., 2016). The number of peaks corresponds to the number of short eccentricity cycles in the studied interval found by Ruhl et al. (2016) and do capture the ~5 m bundles observed in the macrocharcoal record. (b) The macrocharcoal record of the SPB is linear detrended (blue). The 10.2 – 3.2 m signal (orange) is filtered from the macrocharcoal record. The individual peaks capture the ~5 m peaks in macrocharcoal observed in this record. Also, nine peaks are observed, which is in agreement with Ruhl et al. (2016) who found nine 100 kyr eccentricity cycles for the same interval."

Please see attached highlights/comments

1. L64: concept will be changed to hypothesis.
2. L67: ingredients will be changed to parameter.
3. L104-105: "… allows for time constraints." Will be replaced by "provides an orbital scale time model for the Mochras borehole.".
   The point here is to inform the reader that the borehole our study is using, has already been astronomically constrained by 3 independent studies. Hence, we have a good age/depth model.
4. Panel e will be included in Fig. 1.
5. L130: Sinemurian – Pliensbachian and Late Pliensbachian interval (preference).
6. L130 double barrels will be adapted.
7. L177 double barrels will be adapted.
8. L324-325 reference will be added.
9. L335-336: reference to Fig. 2/3 will be included.
10. Derive/deduce (preference).
11. L420 change "long" to "405".

12. L422: ref. to Fig. 5 will be included.
13. L454: “period” will be added.
14. L462: ignition “and sustained fire spread” will be added.

References:

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