Reply to RC2:

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

First, what attributes of fire are being recorded here? It's long been a goal of what we might call "Quaternary paleofire" studies to separate the effects of fire frequency and fire magnitude, including severity and area burned, but there seems to be little consensus there, any many studies simply fall back to using "fire activity" as a not totally ambiguous descriptor. In high (cm-scale) resolution lake records, peaks in charcoal are generally thought of as individual fires within the catchment of a lake, distinct from background levels related to extra-local fires and the general level of biomass burning in a region, with the magnitude of the peaks providing some kind of index of fire severity. The record here probably represents more of a regional index, which in Quaternary studies are often shown as smooth composite curves constructed using multiple records in a region, with the composite curve usually interpreted as a measure of area burned. It would be good to discuss a little what particular attributes of fire the charcoal represents (i.e. not individual fires, more likely regional biomass-burning levels), and to explicitly state what is meant by the term "fire activity". (More discussion can be found in Marlon, 2020, Quaternary Research doi:10.1017/qua.2020.48.)

Yes, thank you for your feedback, we will add some information in our manuscript on what the charcoal represents in this study's context and state what we therefore define as fire activity. The charcoal records in this study represent a regional expression, likely of multiple fires from nearby emergent landmasses. One processed rock sample in this study represents ~2 kyr (and is thus very likely more than the fire return interval) and therefore represents an averaging of the overall signal. In addition, the geological setting is a marine setting that is below storm wave base, but in close proximity to emergent landmasses. This indicates that wind, riverine runoff and ocean currents all impact transport to the depositional site. Multiple landmasses surrounding the Cardigan Bay Basin likely are the source of terrestrial input to the basin and influenced the charcoal content. Hence, the charcoal abundance records presented here represent a regional expression in the Cardigan Bay Basin of burning on the nearby emergent landmasses. For a Mesozoic study, this sample resolution is relatively high and the time constraint is also as exact as it can be (except for the unique case of a 200 Myr old varved lake deposit in Falcon-Lang, 2000). This is different from Quaternary studies that are often carried out on lake sediments and can therefore infer more about the fire frequency. The use of fire activity in this MS is defined as the 'occurrences of wildfires in the region'.

In a revised manuscript we will add in a paragraph that discusses the fire signal presented in this manuscript and a definition of fire activity in this context.

Second, the "intermediate-productivity gradient hypothesis" of Pausas and Bradstock (2007) was originally proposed and tested in an environment where vegetation productivity was clearly and solely linked to the moisture gradient. Pausas and Ribeiro's (2013) extension of the idea to the globe, while still focused on productivity as represented by NPP, relates NPP to temperature, and Daniau et al. (2012) show that fire activity, in both charcoal records from the LGM to present, and in satellite remote-sensing data, depends not only on effective moisture, but also temperature. Temperature is often invoked in the discussion to explain features in the sedimentary record and paleoclimate in general, so it would be good to do two things: 1) discuss the idea that the productivity gradient isn't strictly related to effective moisture,

Thank you for the feedback. Fuel moisture is controlled by relative humidity, which is a balance of temperature and precipitation/water availability. In Pausas & Ribeiro (2013) it is concluded that temperature is an important factor in high productivity ecosystems, because temperature increases lead to increases in drought and flammability "(i.e. drought-driven fire regimes)". In a revised manuscript we will explain the role of temperature in the intermediate fire-productivity hypothesis.

and also 2) discuss the paleoclimatic setting of the record (and why temperature is also a useful variable for explaining the record).

Unfortunately, no temperature reconstructions are available on this resolution for this period (see also response to previous comment). Lower resolution temperature reconstructions exist (mostly of sea floor temperature from benthic and nekto-benthic molluscs) of other locations (Korte & Hesselbo, 2011; Korte et al., 2015; Price et al., 2016; Robinson et al., 2017) and indicate an overall predominantly warm temperature in the Sinemurian and Pliensbachian (>28 °C sea surface (Robinson et al., 2017)).

For other time periods, such as the Cenozoic temperature reconstructions are available on orbital time scales. The carbon-cycle and temperature (via potential CO_2 feedbacks) do vary over 20 kyr time scales in the Cenozoic (Westerhold et al., 2020). At mid-latitudes precession dominates temperature responses in orbitally driven insolation models (Laepple & Lohmann, 2009).

We focussed on the humidity changes of seasonal contrast because the temperature influences the fire regime via droughts (see previous comment) and this is what we do have data for in our study. Clay mineralogy indicates changes in hydrolysis with high precipitation/evaporation being a necessary factor to drive clay mineral transformation in soils prior to incorporation in the marine sedimentary record.

In a revised version of the manuscript, we will include some text on the existing records of the Sinemurian/Pliensbachian climate, the evidence that temperature fluctuates on an orbital time scale, and the limitations that sparse current palaeotemperature reconstructions for the Sinemurian/Pliensbachian place on investigation of this topic.

Third, throughout the manuscript the term "seasonal climate" is used in a casual way. Not until line 328 is it clear that it's a seasonal contrast in effective moisture that is being emphasized, but orbitally related changes in the annual cycle of temperature are also important particularly in mid-latitude, mid-continental regions. So it would be good to be more explicit, and avoid terms like "seasonal climate".

The studied sediments are deposited in a marine setting, surrounded by islands in the Laurasian Seaway (not really a mid-continental setting). But we understand the role of temperature (see reply above) and we will refine our definition of seasonal contrast. Extremes and lows in seasonal contrast in this study are inferred from clay mineralogy and existing literature. The alternating phases of high kaolinite (accelerated hydrolysis, with annual high humidity + high temperature) and high smectite (relatively slower hydrolysis, annual dry season + warm temperature).

In a revised manuscript we will discuss the relationship between absolute and relative humidity with respect to seasonality, temperature, and sustained fires.

Specific comments/replies:

Throughout: Hyphenate compound words, e.g. “Present-day” (line 19), “fuel-moisture status (line 27).

Will hyphenate compounds words throughout in a revised version of the MS in cases where there is any risk of ambiguity in meaning in line with journal house style.

Line 21: Replace “whereas” with “where”. Will change this.

Line 31: Replace “heightened” with “greater”. Will change this.

Line 31: Seasonality of what? Moisture? Temperature?
As discussed above, we will refine this in a revised version of the manuscript.

Line 34-35: “… more pronounced seasonality during eccentricity maxima, explained by the overall cooler climate …” This implies to me that indeed there is some dependence upon temperature. Yes, but here we indicate the global background climate and temperature instead of annual changes in temperature. As there is evidence of global cooler temperatures during the Late Pliensbachian Event (Korte et al., 2015).

Line 47: “Shifts” implies to me a change in distribution or pattern. Change to “… explain changes in biomass abundance, moisture availability, and fire frequency or magnitude.” Yes, thank you, we will change this.

Line 53: “productivity limited (minima) and the optimum fire-window (maxima)” Reverse the order. The modes are minima or maxima, the explanations are productivity limitation or not. We are here talking about the modes in the fire regime, which are caused by climatic forcing.

Line 67: Replace “ingredients” with “determinants”. Will change this.

Line 67-68: This might be a good point to add an in-line definition of “fire regime”. Will add this in.

Line 68-69: “high moisture and biomass production, for example in tropical rainforests.” It’s likely that temperature as well as moisture is responsible for high productivity in tropical climates. But how does high biomass productivity limit fire? Fire is often limited in high productivity systems (Pausas & Ribeiro, 2013), due to the high humidity in these systems. We will rephrase this sentence in a revised version of the manuscript.

Line 76: Replace “lowers” with “decreases”. Will change this.

Line 84: I’m not sure “biases” is the right word because it implies that the optimum would occur somewhere else along a moisture gradient owing to the influence of grassland fires. That it doesn’t is basically the take-home message of the paper. So maybe grassland fires “reinforce” the generalizations? Yes, good point, thank you. We will change it in a revised version of the manuscript.

Line 109 (Fig. 1): Explcitly label the SPB and LPE intervals in the figure, so it can stand alone without its legend. Will label the SPB and LPE intervals in the figure in a revised version of the manuscript.

Line 110: Define “mbs” here (as well as on Line 130). Will do this.

Line 116: “Orbital filters of the 100 kyr and 405 kyr cycle based on the Ca and Ti elemental records in

the depth domain from Ruhl et al. (2016).” I see bandpass filtered time series for the Ca record in Rohl et al. (2016), but not for Ti. Also, you’re confusing the bandpass filter with the filtered time series. “Orbital filters” is jargon in this context.

Yes, we will change orbital filters to bandpass filters. And spectral analysis in Ruhl et al. 2016 has been carried out on the Ca, Ti and Fe records. However, only the Ca and Fe records are used to create bandpass filters. The bandpass filter we show in this manuscript is based on Ca. Therefore, we will adapt this in the text in a revised version of the manuscript.

Lines 155-156: I’m not sure I understand the sample counts here. Should one of the “macrocharcoal”s be replaced by “microcharcoal”? No both are macrocharcoal counts. The 50 macrocharcoal samples are an additional set of samples to elongate the record into the cooling event of the Late Pliensbachian and are unpublished (interval 934-951 mbs), whereas the 204 macrocharcoal samples (interval 951-934 mbs) have been previously published in Hollaar et al. 2021.

Line 193: “a syringe following Stokes [sic] law…” Replace with “a syringe (following Stokes’ law). Will change this.

Lines 207-211: This paragraph confused me at first. I think it should be reorganized to describe the stratigraphy of the whole core first, then that of the two intervals analyzed in detail here. Thank you, we will recast this paragraph in a revised version of this manuscript.

Lines 212-213: "we compare the charcoal and clay records visually with the 100 kyr and 405 kyr filters based on Cabe and Ti…" Do you mean you compared the charcoal and clay records with the filtered Ca and Ti records? Yes.

Line 230: "… with bundling of peaks ever ~4-5 m." I'm not sure I see that, but ok. We will indicate the phases of high-low charcoal abundance in the figure in a revised version of the manuscript.

Line 233: "… in the context of the orbital filters" See earlier comment—"orbital filters" is jargon. Also, which time series is being filtered? Yes, will change it to Ca derived bandpass filters.

Lines 235-236: "The macrocharcoal abundance shows ~5 peaks throughout the studied interval." It would be helpful to label these. I see one peak at about 1239 m. We will label the 5 phases of relative increases in charcoal abundance.

Line 242: "The peaks in the macrocharcoal record occur on a 100 kyr time scale." How is this demonstrated? Based on the Ruhl et al. 2016 Ca 100-kyr bandpass filter and the correspondence of the alternating phases of high and low charcoal abundance. In addition, we have filtered the 100 kyr cycle signal in depth domain from the macrocharcoal record (SI Fig. 3).

Lines 244-254: Same comments and questions as for Fig. 2. We will indicate the relatively high phases of charcoal abundance in Fig. 2 as well.

Lines 268-272: The boxplots suggest that the charcoal data have long-tailed distributions, and that the variances of the groups differ from one another. Does this have any impact on the comparison. Yes, the boxplots indicate that the variance of the LPE charcoal samples is greater compared to the SPB. This is the reason why we argue that the LPE indicates a wider range from humid (low to no charcoal) to arid (high charcoal) on Fig. 5.

Lines 314-315: "Smectite preferentially forms under a hot and seasonally arid climate, similar to a monsoonal climate system or the winter-wet climate of the Mediterranean zone." Because these climates differ substantially in the seasonality of moisture (hot monsoon/summer wet, Mediterranean/summer dry), it might be good emphasize just what aspect of those climates smectite reflects. (Presumably a pronounced dry season.) Also, which of the two climates are you imagining applies here?

Thanks, we will clarify that smectite indicates the presence of a dry season.

Line 315: What is an "accelerated hydrological cycle"?

Intensification of hydrolysis.

Line 324: Again, what exactly is varying seasonally? Temperature? Moisture?

As discussed above, we will refine extreme seasonality in regards of absolute and relative humidity with respect to seasonality, temperature, and sustained fires.

Lines 328-330: Ok, it sounds like it's seasonality of effective moisture.

Lines 344-345: Replace "orbital filter representing the ~100 kyr cycle" with "the ~100 kyr bandpass filtered time series of [macrocharcoal?]" We will replace this with "The orbital bandpass filter …. [] …. Mochras core (derived from Ca and macrocharcoal), … "

Lines 374+: "… where fire activity is plotted along an aridity and productivity gradient" Although Pausas and Ribeiro (2013), for example, discuss the variations of fire activity along a productivity (NPP) gradient, Daniau et al. (2012) show that fire activity, in both charcoal records from the LGM to present and in satellite remote-sensing data, depends on both temperature and effective moisture (see also Bistinas et al., 2014, Biogeosci. doi:10.5194/bg-11-5087-2014). Because NPP or productivity is not easily reconstructable, it may be advantageous to discuss the separate and joint influence on fire of temperature and effective moisture, which can be inferred from the evidence in the paper. In fact, temperature is invoked frequently in the discussion; it's not just moisture that explains the data.

Thank you for your feedback. Temperature further enhances the impact of humidity on fuel and fire. In essence, if humidity and fuel moisture status are very low, the fuels will still burn even if the temperatures are cooler. Temperature only modifies fuel moisture via relative humidity % and when it is warm, it can favour combustion to some extent.

On an orbital time scale the temperature would be more extreme, with higher temperatures during one season and colder temperatures during the other season. Effect on fire regime then depends on whether the warm or cold season occurs at the same time as droughts or rainfall (i.e. summer or winter rain).

However, as explained above, we do not have temperature data on this time scale for the Early Jurassic. The discussion in this manuscript in respect of fire and seasonal contrast (humidity) is based on the charcoal and clay records. The clay records are also affected by temperature (but only relative changes in regard of hydrolysis). From the fire perspective however, the most crucial factor is the presence of a dry season during maximum orbital configurations. This dry season allows the fuel moisture to drop and fire to ignite, sustain and spread more easily. This is why the focus is on seasonal contrast from a humidity standpoint in the current manuscript. In a revised version of the manuscript, we will include some information on the role of temperature on fire.

Line 392: "hyperbola". Ok, will change.

Fig. 5: The tiny pictures are nice, but way too tiny. We'll increase the landscape pictures in size.

References

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