From: zhdl@ms.xjb.ac.cn

Authors replies to the review comments

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Dear Prof. Natalia Piotrowska:

We are very grateful to your comments which helped us to improve the revised manuscript. According to your valuable suggestions, we try our best to modify our manuscript. Thank you very much for your attention and consideration again.

Sincerely yours

Dr. Dongliang Zhang

Sept. 8th, 2025

Replies to Reviewer #1 (thank you ! From Dongliang Zhang):

This paper presents a new microcharcoal record from Mongolia, along with 23 published charcoal records, to provide a regional synthesis of biomass burning in the Altai-Sayan Mountains, Siberia. These published records originate from relatively recent publications; I assume macro-charcoal records and may have reasonable chronological control. Given the rarity of records in Siberia, such new pieces of evidence will undoubtedly advance our understanding of regional patterns and drivers of biomass burning. However, upon close inspection, the paper appears to be of poor quality in the sense that it relies heavily on bold statements rather than providing a typical scientific explanation of the findings and suffers from insufficient information in the methods section. It therefore requires a truly major makeover before publication. A detailed, but not exhaustive, list of comments is provided below.

25-26" …vegetation zones of the Altai-Sayan Mountains and adjacent plains…" which adjacent plains? This information should be provided already in the abstract

Reply: Thank you for your suggestion. We added them (i.e., west Siberian Plain, Kazakhstan Hills and Junggar Basin) in the abstract.

27, since when in the Holocene? Such statements are common throughout the manuscript

Reply: Thank you for your question. We changed "since the Holocene" to "in the Holocene interval".

30 What is a "combustible component"?

Reply: Thank you for your question. We rewrite this sentence: in the western Sayan Mountains, it stemmed from the substantial expansion of fire-resistant *P. sylvestris*.

120-126. The aim to include 23 records comes abruptly, without providing a regional context for where these records originate. Upon further examination of the manuscript, it presents a synthesis of a large part of western and central Siberia, Asia; however, the introduction of these sites into a broader spatial context is not provided.

Reply: Thank you for your question. We rewrite this sentence: (2) Identifying ecotonal heterogeneity in fire regimes through comparison with other already-published paleofire records (n=23) in the nearby regions.

l139-147, these lines belong to results, not methods?

Reply: Thank you. We deleted the related sentences.

l150-151 "A 2100-year reservoir correction was primary forest coverplied to all radiocarbon ages prior to calibration (Sun et al., 2013)"???? This sentence does not make sense. Please extend the explanation of why a 2100-year reservoir was applied.

Reply: Sorry for our mistaken. We rewrite this sentence: A 2100-year reservoir correction was applied to all radiocarbon ages prior to calibration due to old carbon-influenced 2099 ^{14}C BP on the surface sediment (Sun et al., 2013).

L156 24 or 23 sites as an introduction?

Reply: Done.

L210 such method was applied for all records? Please provide the type of charcoal used in other records (micro and macrocharcoal). Please separate more clearly what has been done at the new site from what has been done at all sites.

Reply: Thank you. We added the type of charcoal for all records in Table 1.

L220 This part describes what GAM is, but not what is being achieved with GAM in this study. Which are the dependent variables? Was the percentage of pollen used? Which species are included in the primary forest?

Reply: Thank you for your question. The dependent variable is charcoal influx. We used the pollen percentage to calculate and the forest forest includes *Abies, Betula, Larix, Picea, P. sibirica* and *P. sylvestris*. We added the related description in the revised manuscript.

3.3. Data processing for comparison. This part is extremely poorly written. What is meat synthesized? What is the average method?

Reply: Thank you. We rewrite the related sentences: Since the sample resolution at most study sites is approximately 200 years, a 200-year time slice was selected to perform linear interpolation on the transformed charcoal Z-scores. Subsequently, the interpolated data were averaged to characterize the charcoal influx conditions across different regions.

Results and discussions. Generally, the chapters are very general and imprecisely described. They are made of many bold sentences rather than explanations of potential drivers of biomass burning. Particularly, the link with the amount and type of biomass available is very superficially discussed. Furthermore, the jumps from single to cumulative charcoal record (Z-score) make the story difficult to follow. Why not focus on the trend in cumulative charcoal record, thus regional biomass burning and the potential drivers, followed by sites that show exceptions from the regional trends and explanations?

Reply: Thank you for your suggestion. We rewrite the related part.

(p=0.00)?

Reply: Thank you. We changed it.

It contains a mix of charcoal and biomass burning, as they will represent different things. Ideally, use the same terminology.

Reply: Done. We used the charcoal influx in the revised manuscript.

l251, which multi-proxy records? Only charcoal was used here.

Reply: Thank you, you are right. We changed it.

l271 How can microcharcoal morphology signify anthropogenic fire?

Reply: Sorry for our mistaken. We deleted it.

The 297 Rybanya site does show the dominance of Larix in the original pollen record, nor are the increases in fire at 4 ka linked to megadroughts; instead, they are associated with dry peatland conditions (l 299).

Reply: Thank you. We rewrite it: ~8.5-~6 cal. kyr BP: Rybnaya Peat exhibits a second phase of higher charcoal influx, linked to two interrelated changes: increased proportion of dark taiga and fire avoiders (e.g., *P. sibirica* and drier conditions (Feurdean et al., 2022).

L301-304. I am puzzled by the superficiality of these statements: " The GAMs analysis reveal the divergent fire-vegetation relationships: (1) Negative correlation at Rybnaya/Plotnikovo (canopy >75%): Reduced understory fuels and microclimatic humidity limit fire spread; (2) Positive correlation at Shchuchye Lake (canopy <65%):Open structure promotes flammable grass undergrowth."

Reply: Thank you. We rewrite it: GAM analysis reveals divergent fire-vegetation relationships across sites (Table 2, Fig. S2 and S3), rooted in differences in canopy cover and associated fuel microenvironments: (1) Negative correlation at Rybnaya

and Plotnikovo Mires (canopy cover >75%): Dense canopies reduce understory light availability, maintaining high microclimatic humidity and limiting the growth of herbaceous understory fuels. Humid conditions keep surface fuels moist, while sparse understory fuels reduce fire intensity and spread—together, these factors create an inverse relationship between canopy cover and charcoal influx. (2) Positive correlation at Shchuchye Lake (canopy cover <65%): Open canopy structures allow more solar radiation to reach the understory, promoting the growth of flammable grassy undergrowth. Grasses dry out quickly and ignite easily, serving as ignition fuels that trigger larger fires; the open environment also facilitates air circulation, which accelerates fire spread—these factors lead to a positive association between canopy openness (and associated grassy fuels) and charcoal influx.

L436-438 could you provide an approximate location of timber and treeline limit, consequently, the amount of biomass available

Reply: Thank you. We checked the vegetation distribution from Unkelbach et al. (2021) and found above 2800 m a.s.l. the slopes are dominated by alpine tundra, followed by dry steppe vegetation mainly consisting of grasses and sedges, and the valleys below 2200 m a.s.l. are covered by open grasslands of grasses, sedges, forbs and shrub species. Forested areas dominated by Siberian larch (Larix sibirica) do only occur on north-facing slopes at elevations between 1700 and 2500 m a.s.l. Azonal vegetation on bare rock areas or in and around freshwater habitats occur sporadically. Therefore, we rewrite this part.

L440, do you imply here that the steppe provided more biomass than the forest? Sometimes this study suggests that a low forest cover resulted in reduced biomass burning, while at others, it indicates that a steppe contributed to an increase. Could you provide a finer interpretation of biomass amount and the fuel type?

Reply: Thank you for your question. We changed the related description. I am sorry that we can not answer the question about the relationship between biomass amount and fuel type.

L493 and elsewhere, where you talk about human impact. Through what type of activities can humans increase their burning activity?

Reply: Thank you for your question. We checked the related articles and changed the our sentences.

L505. These sentences do not make sense: “Specifically, the increase in Siberian pine and European larch since the Holocene has led to a significant decline in fir, birch, larch, and spruce components, resulting in a notable decrease in combustible materials at the three sites” and does not make sense: "Although Holocene biomass burning in the Khangai Mountains exhibits an overall gradual decline, it can be categorized into two distinct phases: an increase over the past 2,000 years, followed by a gradual decline post-2000 year (Unkelbach et al., 2021; Barhoumi et al., 2024)"

Reply: Thank you. We modified them.

(1) The main forest cover exceeds 80%, indicating that material availability is not a limiting factor for regional charcoal influx. The decline in Holocene biomass in Region E is primarily driven by increasing fire-resistant *P. sylvestris* has reduced the overall flammability of forest ecosystems.

(2) Holocene charcoal influx in Region F can be divided into two distinct phases: a rising trend before the past 2000 years, followed by a gradual decline afterwards (Unkelbach et al., 2021; Barhoumi et al., 2024).

L540 Wrong, please see above.

Reply: Thank you. We modified it: ~8.5-~6 cal. kyr BP: Rybnaya Peat exhibits a second phase of higher charcoal influx, linked to two interrelated changes: increased proportion of dark taiga and fire avoiders (e.g., *P. sibirica* and drier conditions (Feurdean et al., 2022).

Fig. 1: How was this regionalization produced? It is nowhere described the basis for grouping the sites into these regions. Was it the site's proximity? Similarity in climate or vegetation cover?

Reply: Thank you for your question. The overall framework of this paper centers on the Altai Mountains, aiming to discuss the Holocene fire dynamics under different vegetation conditions and their relationships with the corresponding vegetation types. These sites were included in the study area because they cover diverse vegetation zones, which facilitates a better understanding of the fire dynamic processes under different vegetation covers and the relationships between fires and various vegetation types.

Fig. 3, and the results of the paper. The new record is located in the steppe region. Why was only the tree composition presented and discussed in the manuscript, when the herbaceous composition and diversity provided the most biomass to burn? Are these trees long-distance transported?

Reply: Thank you for your question. The herbaceous component was not selected for Achit Nuur because, considering the overall context of the paper, most study sites are surrounded by forests—thus, the woody component was chosen for analysis. If there is a negative correlation between charcoal influx and the woody component, this would in turn reflect a close relationship between charcoal influx and the herbaceous component.

Fig 4. The records in panel c seem to stop at 8-9 ka, but why does the average value extend to 12 ka?

Reply: Thank you for your question. Since the record of the Shchuchye core extends to 12 ka, the regional average has also been extended to this time point (12 ka).

Region C seems to average sites stretching along an elevation gradient, thus lots of climatic conditions and vegetation composition

Reply: Thank you for your question. Your observation is correct, and we also noticed this issue during the preparation of the paper. Chudnoye Mire and other three sites (Tundra, Mokhovoe and Kuatang Mire) were grouped together because they exhibit relatively consistent Holocene fire trends and are geographically close to one another.