Response Letter of X Li's to reviewer' comments on MS No. essd-2024-187

Anonymous Referee #2

This paper presents 6 years of data in four areas of Northeast China at paired burned and unburned sites, including ground temperature, soil moisture, and soil nutrients. The four areas represent a chronosequence of time since fire, allowing for interpretation of the impacts of fire on permafrost over time.

The dataset is not new or unique (there is similar data from Canada and Alaska), but the location is new as there is little previous work on the impacts of fire on permafrost in China. The methods are not new, most are standard for permafrost science. I am surprised that the authors did not use a temperature logger that stored hourly measurements (e.g. Onset HOBO U23 Pro v2 Temperature/RH Data Loggers) as that would've eliminated the need for weekly visits to the sites and would've allowed them to collect much more data with fewer gaps.

Response: Thank you very much for your suggestion about using a temperature logger that stored hourly measurements. In the initial data collection, the use of temperature logger was not considered. However, due to the COVID-19 pandemic in 2020-2023, the data could not be collected on time, and the cost of collection was also considered. Therefore, in 2023, we installed temperature loggers to automatically collect data every hour. However, unfortunately the temperature loggers were damaged by some curious people, resulting in lost temperature loggers and battery. In addition, since there was no network signal in the study area, the data could not be transmitted wirelessly. Therefore, when it was found that some time had passed since, which eventually led to the loss of some important data. At present, we are also thinking of a better solution to avoid the temperature logger's destruction and data loss as much as possible.

The dataset is complete, and I was able to access and download it from the given identifier. It is useable in its current format and size. I do feel that the data could be useful in the future, particularly for those conducting modelling studies or as a baseline for future changes in permafrost conditions. There is one inconsistency within the data, see my major comment below, so I'd like the authors to provide an explanation for that. I do not feel that the meta data is sufficient unless accompanied by the current manuscript under review. I would like to see more information about the sites and the data collected in the metadata, as well as an explanation for the data gaps.

Response: Meta data are automatically generated by the data website and cannot be changed by ourselves. Thus, I have added a metadata description to upload to the data list.

The article length was appropriate and it was well structured. There were some grammatical errors throughout, but especially in the conclusion. The figures and tables were good but overall not enough detail in the captions (see minor comments below for specific places).

Response: Thank you very much for your suggestions. We have corrected the grammatical errors of the whole article and given a more detailed description of the figures and tables captions.

Major comments:

The introduction is quite general. For example, I don't feel that it is relevant to mention tundra fires as your data is for the hemiboreal environment. Your focus is on hydrothermal regimes and nutrients, but you didn't give any background on post-fire permafrost soil moisture literature or any nutrients other than carbon.

Response: According to your suggestions, we have revised the ***Introduction***. The contents about tundra fire had been deleted, and the background information about the hydrothermal state and nutrients changes of permafrost after fire had been added. In Lines 71-83, 93-102.

"In the boreal zone, 6-11 years after fire, mean annual ground temperature (MAGT) increased by 1.5-2.3°C (Li et al., 2021; Munkhjargal et al., 2020; Nossov et al., 2013; Smith et al., 2015), even mean annual ground surface temperatures in burned areas were still 2-3°C higher than that in unburned areas 80 years after fire (Brown et al., 2015). Meanwhile, 25 years after fire, the active layer thickness (ALT) could increase by 2.75 m, and ALT could not recover to the pre-fire level even 36 years after fire (Viereck et al., 2008). In Central Siberia, it generally takes 70-80 years for the active layer to return to the pre-fire state (Kirdyanov et al., 2020). In addition, forest fires result in decrease in soil moisture content, which in turn affects ground thermal regimes (Nossov et al., 2013). Moreover, changes in ground hydrothermal regimes and ALT would decline and progressively dwindle with ecosystem recovery and organic layer regrowth over time under a stable or cooling climate (e.g. Holloway et al., 2020; Rocha et al., 2012)."

"In addition to soil organic carbon, forest fires potentially also reduce soil nitrogen and phosphorus stocks, inducing shifts in nutrient cycling (Certini, 2005; Gu et al., 2010; Knicker, 2007). For example, one year after wildfire in interior Alaska in the boreal zone, soil carbon content was about 1071-1420 g/m^2 less at the sites of burned soils than that of unburned soils, and; burned soils had lower nitrogen than unburned soils, higher calcium, and nearly unchanged stocks of potassium, magnesium, and phosphorus (Neff et al., 2005). As a result, wildfires in boreal forest had been considered to trigger strong positive feedbacks on climate warming via massive emissions of biogenic major greenhouse gas (Koven et al., 2015; Ramm et al., 2023)."

You're using a chronosequence, but I find it hard to know which sites are where in the sequence. Maybe a schematic showing time since fire and then the names of the sites would help. It will help the reader be able to interpret the results better, especially as time since fire is extremely important to infer post-fire impacts on permafrost. For example, Figure 3 is interesting to me, particularly because 3 of the areas show differences in MAGT between the burned and unburned sites at depths of 20m, except for MG. I'm wondering if this is because MG is the end of the chronosequence, decades after fire, and things have returned to pre-fire conditions, but I had to scroll around and find it on page 8. I think in general more attention needs to be paid to this in the paper. All the results should be interpreted with this in mind, which is currently lacking in the paper.

Response: Agreed and done.

According to your suggestions, we have marked the post-fire time on the figures. For MG, it is the early stage of the fire, and the effect of the forest fire on the soil temperature had not yet reached the depth of 20 m. Thus, the difference between the burned and unburned sites was relatively small. At the time of the initial submission, we analyzed the data in chronosequence, but according to the editor's request and suggestion, this paper is a data description article and should refrain from making data interpretations,. Asa result, the analysis and interpretation of the data had been deleted and only described the changes in the data. However, in order to help the reader to better interpret the results, the post-fire time has been added to the figures according to your comments.

Minor comments:

Abstract

Line 31: I wouldn't consider a 6-year dataset to be long-term.

Response: Agreed and done. Changed "long-term datasets" to the "The datasets". Line 31

Introduction

Line 78: There are many other references about wildfire, permafrost and carbon. Some examples:

O'Donnell JA, Harden JW, McGuire AD, Kanevskiys MZ, Jorgenson MT, Xu X. The effect of fire and permafrost interactions on soil carbon accumulation in an upland black spruce ecosystem of interior Alaska: implications for post-thaw carbon loss. Glob Chang Biol. 2011;17:1461-1474.

Genet H, McGuire AD, Barrett K, Breen A, et al. Modeling the effects of fire severity and climate on active layer thickness and soil carbon storage of black spruce forests across the landscape in interior Alaska. Environ Res Lett. 2013;8(4):045016.

O'Donnell JA, Harden JW, McGuire AD, Romanovsky VE. Exploring the sensitivity of soil carbon dynamics to climate change, fire disturbance and permafrost thaw in a black spruce ecosystem. Biogeosciences. 2011a;8:1367-1382.

Dieleman C.M., Day N.J., Holloway J.E., Baltzer J., Douglas T.A., Turetsky M.R. 2022. Carbon and nitrogen cycling dynamics following permafrost thaw in the Northwest Territories, Canada. Science of the Total Environment, 845(1), 157288. https://doi.org/10.1016/j.scitotenv.2022.157288

Response: Agreed and done.

We added these citations at the end of the sentence as advised. Check citations in Lines 85-86 and added references in ***References***.

Line 82: What about permafrost that is not ecosystem-protected? What about low ice-content sites that don't experience thermokarst or "abrupt thaw"? Much of the boreal forest that is of this type and would still release carbon post-fire. I think it's important to not focus only on ecosystem-protected or sites prone to thermokarst (unless your data applies only to those settings, then I think much more detail would be required in this introduction).

Response: Agreed and done.

Permafrost that is not ecosystem-protected and areas with low ice-content and that does not experience thermokarst or "abrupt thaw" also release large amounts of carbon after permafrost degradation. These are suitable for different types of boreal permafrost. The original purpose of this sentence was to emphasize the permafrost in this study area. The permafrost in Northeast China belongs to the ecosystem-dominated permafrost, but it is also the unstable permafrost, which will degrade rapidly or even thaw completely under the joint disturbances of climate change and forest fire. Thus, we have made some modifications as advised. Lines 94-102.

Line 104: Often complex how?

Response: Unlike tundra, which has less variations in topography, the terrain in the northeastern Da Xing'anling Mountains, NE China is more complex. Thus, forest fires can occur in gullies, hillsides and hilltops. Meanwhile, forest fires mainly occur in spring and autumn in Northeast China, but there are more fires in spring. Due to the low precipitation and dry climate in spring, the ground surface litter layer is thick and dry. There is more precipitation in autumn, the snow accumulation period begins, and the leaves are moist. Summer precipitation is concentrated, if there are forest fires, most of them are lightning fires. Winter is covered by thick snow, so fires are rare. Therefore, the occurrence of fires in the Da Xing'anling Mountains has strong seasonality.

Section 2

Line 138: How was fire severity classified? What does "severely burned" indicate (i.e., a proportion of the organic layer lost, entire destruction of the canopy, etc.)?

Response: Fire severity is divided according to Lines 216-233.

Fire severity can be divided according to the loss of organic layer and forest canopy immediately after fire. Several years after fire, the fire severity should be classified according to the differential Normalized Burn Ratio (dNBR) calculated from the remote sensing images of the fire areas in the same year of fire.

Figure 1: It's unclear to me where the permafrost region is in (a). More description is needed in the figure caption. Are the pink areas in the Landsat images burned areas?

Response: The light blue areas in Figure 1a is the permafrost region. Figures 1c to 1f were the false-color composite image of the remote sensing image, the pink areas are the burned area, and the green area are the unburned areas. These descriptions are also added to the figure captions. Lines 170-173.

Line 161: Why were these locations selected in particular?

Response: Because forest fires in the Da Xing'anling Mountains, NE China often occur in the primeval forest and cannot be easily accessed by walking or driving. Therefore, in order to observe the permafrost environment in the burned areas, we need to select the areas that can be reached on foot or using vehicle, so that the drilling rig could enter the research sites and drill the observation holes of soil temperatures. Secondly, in order to observe long-term post-fire changes in the permafrost environment, we choose the burned area from 1987 to 2015, so that the chronosequence can be used to observe longer-term changes of permafrost after fire. In addition, the selected areas have consistent topography and vegetation types.

Line 172: How do you know the pre-fire organic layer thickness? Organic layers vary substantially over short distances, I'm surprised the window for the site is only 5cm pre-fire, unless it was only measured in one spot.

Response: The organic layer thickness data here are all measured values in this study areas (four areas). In the vicinity of the burned areas of several meters to tens of meters, we selected the unburned area as the control site, that is, the unburned site in the paper. The organic layer thickness of the unburned sites and the burned sites were measured in 2016. The organic layer in the unburned areas in the Da Xing'anling Mountains, NE China is relatively thick, generally between 40-60 cm. That in the burned area is much thinner.

Table 1: A relatively large amount of organic layer remains after the fires at all of the site (minimum 20 cm). I think it's important to note this somewhere in the paper, as this minimizes post-fire changes (less active layer thickening and ground temperature increase) than if, for example, less than 5 cm remains.

Response: We have mentioned relevant information about the thickness of organic layer in the appropriate places in the article. We have added this sentence

"*Moreover, changes in ground hydrothermal regimes and ALT would decline and progressively dwindle with ecosystem recovery and organic layer regrowth over time under a stable or cooling climate (e.g. Holloway et al., 2020; Rocha et al., 2012).*" in Lines 80-83.

Line 189: Why do you provide less details for the GL sites than the other sites? How far apart were they, when did measurements commence and how long after fire?

Response: Lines 186-187 are also descriptions of GL site, not only the Line 189, including distances apart they and the measurement time. The description of these sites is the same.

Line 201-203: Why were these thresholds chosen?

Response: This is the common method of international fire severity division, and it is also a standard means of division. According to the Cocke et al., (2005) and Roy et al., (2006), the dNBR optimality values for these average changes are 0.241 for grass and 0.57 for shrub. Therefore, these values are selected as threshold values through the classification of fire severity by vegetation burn status and the comparison with dNBR (Key and Benson, 2006; Escuin et al., 2008).

Cocke, A. E., Fulé, P. Z. and Crouse, J. E.: Comparison of burn severity assessments using Differenced Normalized Burn Ratio and ground data, Int. J. Wildl. Fire, 14, 189-198, 2005.

Escuin, S., Navarro, R. and Fernandez, P.: Fire severity assessment by using NBR (normalized Burn ratio) and NDVI (normalized difference vegetation index) derived from LANDSAT TM/ETM images. Int. J. Remote Sens., 29(4), 1053-1073, 2008.

Key, C. H. and Benson, N. C.: "Landscape assessment (LA)." FIREMON: Fire effects monitoring and inventory system 164: LA-1, 2006.

Roy, D. P., Boschetti, L. and Trigg, S. N.: Remote sensing of fire severity: assessing the performance of the normalized burn ratio. IEEE Geosci. Remote Sens. Lett., 3(1), 112-116, 2006

Table 2: I'm finding this table hard to interpret. For the last three columns, upon first glance, it looks like they only apply to site AL-S and GL-U. I was wondering why no ground temperature measurements were taken for all the other sites. But I think it is just the way the table is organized. Can you rethink this to make it more clear?

Response: Ground temperature measurements were taken for all the other sites. Because the observed depth of ground temperature, time period, and monitoring frequency are the same at all sites, so the tables for all sites are combined into one. For clarity, we have added a specific description to each site based on your suggestions.

Line 238: What are complex changes? Please describe.

Response: At depths of 0-3 m, changes in soil moisture content (ice content), organic matter and lithology are the most significantly. Therefore, compared with those at depths of 3-20 m, changes in soil nutrients and ground temperature are more dramatic.

Thus, it was changed the sentence to the

"*At depths of 0-3.0 m, samples were collected every 10 cm in depth in soil strata with more significant changes of soil organic matter and lithology near the ground surface.*" Lines 270-272.

Line 271: How were they quality controlled?

Response: During each measurement, the multi-meter Fluke 189® device is used to check whether there are abnormal values in each cable of the ground temperature line, and the cables with abnormal values are measured multiple times and recorded in detail. Record data when the measurement is stable.

Figure 3: Why do all the areas except MG show a large difference between burned and unburned sites?

Response: Since MG is only 2-7 years after a fire, soil temperature is in the increasing stage. Form Figure 3a, there is a significant difference between the severe burned site and the unburned site at depths of 0-8 m. With the increase of post-fire time, soil temperature will continue to rise. Thus, the difference in soil temperature of other three areas is larger than that of MG.

Line 296: What dates were annual averages (e.g. MAGT) taken over? Calendar year?

Response: The date has been given in the figure caption and is the average from 2017-2022 (6 years).

Table 3: Similar to Figure 3, it's curious that the unburned MAGT at 0.5 m depth for MG was warmer than the burned. Any explanation for this? This is also shown on Figure 4a and Figure 7a.

Response: Because the journal requires as little interpretation of the data as possible, according to the editor's request, the reasons for the data interpretation were deleted.

This is mainly due to the formation of a large number of thermokarst ponds (alas) on the ground surface in summer at severe site in MG, with water depths of up to 10–20 cm in summer, which results in a decrease in the near-surface soil temperatures.

Line 350: Any ideas why it decreased only at MH-S?

Response: There are two main reasons for this. First, at the MH-S site, ALT had reached 4.0-5.5 m from 2017 to 2020, and depth of influence of air temperature on ground temperature did not reach this depth. It can be seen from the AL-S site (Figure 8b) that ALT basically does not fluctuate. Secondly, at MH-S site, it had been 30-33 years after fire, vegetation had recovered well, and both ALT and soil temperature should be in the recovery stage, so ALT is in a downward trend. Other sites, ALT had been increasing due to climate change and fires.

Figure 9: I'd like to see these results described in terms of the chronosequence and how time since fire impacts soil moisture. Soil moisture varies over short temporal and spatial distances, so it would help add depth to your one off soil moisture measurements.

Response: When we submitted the manuscript for the first time, we analyzed and explained terms of the chronosequence. However, according to the requirements of the editor, this is a data description article, which cannot be analyzed and explained in great detail, so we re-wrote it in the present, more brief form. However, in order for the reader to see the trend of SMC over time, we added the post-fire time to the figures.

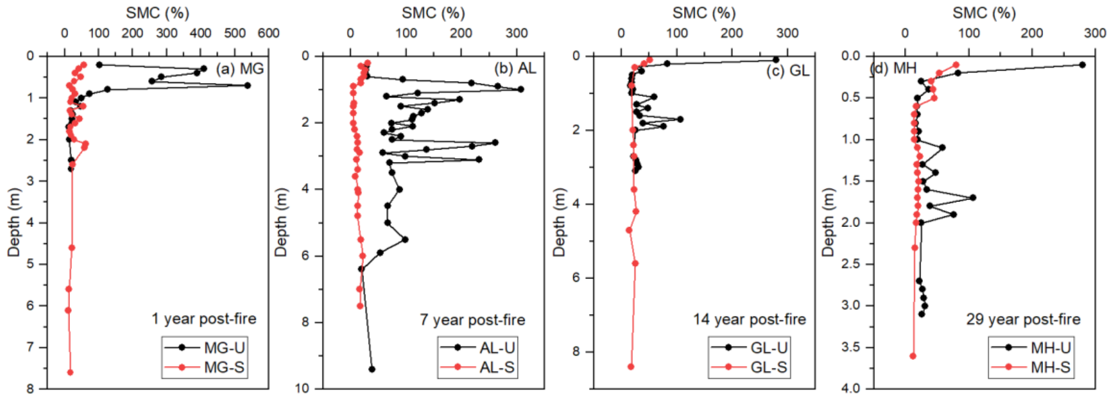

Figure 9. Variations in gravimetrically-based soil moisture contents (SMC) with different fire severity at eight sites in Mangui (MG), Alongshan (AL), Gulian (GL), and Mo'he (MH) on the western flank of the northern Da Xing'anling Mountains in Northeast China in 2016. Notes: The symbol U stands for unburned, S for severely burned, and; SMC, for soil gravimetric moisture content.

Figure 10: Same as above, it would be great if these results were described in terms of the chronosequence.

Response: Similar to the Figure 9 (SMC), we added the post-fire time to the figure.

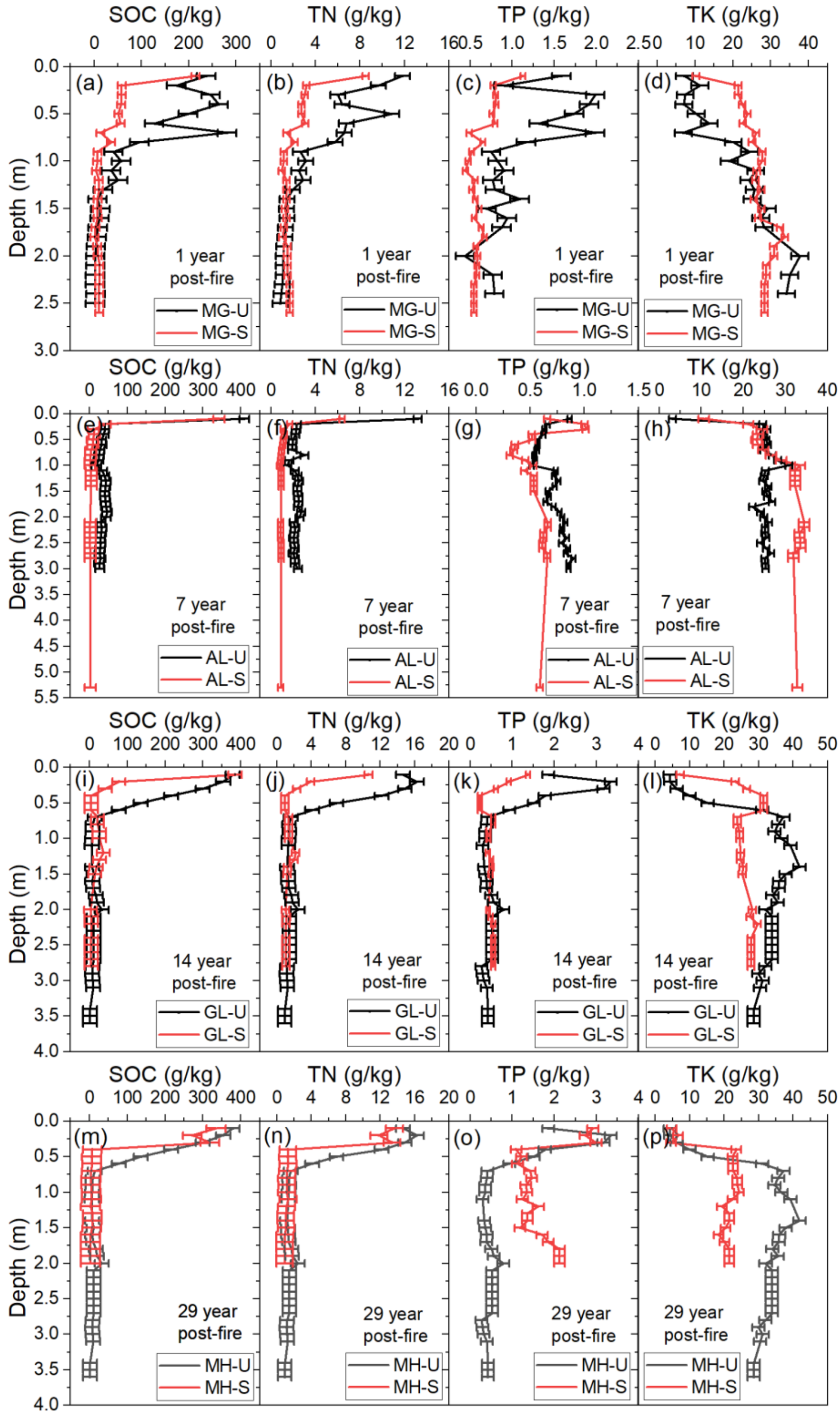

Figure 10. Variations in soil nutrients at eight sites in Mangui (MG, a to d), Alongshan (AL, e to h), Gulian (GL, i to l), and Mo'he (MH, m to p) on the western flank of the northern Da Xing'anling Mountains in Northeast China in 2016.

Notes: The symbol U stands for unburned, and S for severely burned. SOC stands for soil organic carbon; TN, for total nitrogen; TP, for total phosphorus, and; TK, for total potassium.

Line 425: Here you say SMC is decreasing, but you only have one measurement in time. How can you say it is decreasing? You haven't described the chronosequence at all in the results, so I don't think it's fair to conclude this.

Response: From Figure 9, SMC at severe burned sites were lower than those of unburned sites. Thus, the SMC decreased after the fire. This sentence does not mean that the "SMC is decreasing", because the preposition "by" need to follow by a gerund. Thus, the sentence is the

"*This is evidenced **by** increasing ground temperature, thickening active layer, decreasing SMC, and evidently changing soil nutrient contents.*" In Lines 459-460.