Dear Editor and Reviewers,

We would like to express our sincere gratitude for your insightful comments and for your very thorough review of our manuscript. Your guidance has been extremely helpful as we look to clarify and strengthen our research on lightning-ignited wildfires in boreal forests.

Please find a summary of the key revisions we have made:

1. **Clarification of Methodology:** Many of the reviewer comments focused on the need for us to provide additional details surrounding the TMin methodology. We have addressed these comments by expanding upon the steps of the methodology.

2. **UTC vs Local time:** As we reviewed your feedback, we discovered that the Canadian National Fire Databases record start times in local time, as opposed to UTC as we previously thought. After confirming this with Natural Resources Canada, we updated our approach accordingly. The GlobFire dataset only provides start days, and thus, requires an assumed start time. Initially we had used midnight UTC, however, after reflecting upon our process we realized this should be changed to reflect peak fire-weather conditions, which occur at around noon local time. We believe that by making these adjustments, we significantly enhanced the quality of our dataset.

3. **ENTLN Detection Efficiency:** We appreciate the recommendation to elaborate on the detection efficiency of the ENTLN in Russia. While we have added additional supportive material, the proprietary nature of this data limits the level of detail we can provide. We have included as much information as possible, given these restraints.

4. **Additional Revisions**: While making the suggested adjustments to our manuscript, we noticed a few irregularities that have since been updated.

   - We updated the paper to distinguish more clearly the difference between the NA BoLtFire dataset as well as the comparison NA BoLtFire dataset (i.e.; NA BoLtFire ARD Version).

   - We updated the names of Table 2, Table B1, Table B2, and Table B3 to more accurately reflect that their values apply to the Agency Reference Dataset (after applying our methodologies), rather than to the North America BoLtFire Dataset.

   - When reviewing the Lightning Ignition Efficiency, we noticed they were calculated as a percent. Though this was mentioned in the description of Table D3, it was not consistently indicated throughout the paper. This has been rectified in the newest version to ensure consistency.

   - We expanded the descriptions of Table D6 and D7 to better reflect their content.

   - We corrected a value in Table B3 that had inadvertently been switched with its neighboring value.

   - Figure 4 was updated to properly reflect the new values for the BoLFire Dataset.

These modifications address the primary comments and suggestions provided to us by the reviewers. We believe they have significantly strengthened our manuscript. We are grateful for your detailed, constructive feedback, which has directly contributed to the clarity, accuracy, and overall quality of our work.

Thank you again for dedicating your time and expertise to our submission. We look forward to any further comments or suggestions you may have.

Sincerely,

The BoLtFire Dataset Team

RC1 Response

This manuscript presents a new database of lightning-ignited wildfires in boreal forests of North America and Eurasia. The new database is produced by selecting lightning candidates (measured by ENTLN) for wildfires detected by MODIS. The selection of lightning candidates is based on a spatio-temporal criterion. To evaluate the method of selecting candidate rays based on MODIS information, the authors compare the results with those obtained using national fire databases in North America, which are more accurate. Lightning-ignited wildfires in boreal forests play a crucial role in climate dynamics. However, significant uncertainties remain regarding these fires, primarily due to the limited availability of detection instruments, particularly in Eurasian regions.

The manuscript is well written, and the results are interesting. The database could be very useful to investigate lightning-induced wildfires in boreal forest. However, there are still significant questions that the authors should address before the manuscript can be published.

We would like to thank the reviewer for their kind comments and for their in-depth feedback. It was invaluable to help strengthen the paper and our dataset. We are grateful for the time and effort they invested in reviewing our manuscript.

Line-by-line comments

- Line 10: "The frequency and severity of fire weather have increased under climate change, particularly in high-latitude boreal forests.". I think this is not clear. See Xing and Wang (2023, https://doi.org/10.1029/2023JD038946).

It seems the wording of this sentence is incorrect, and has been updated to reflect the citations in section "I. Introduction."

"The frequency and severity of fire weather has been projected to increase under climate change, particularly in high-latitude boreal forests. "

- Section 2.3.1:

*** I think the authors should provide a estimation of the Detection Efficiency of ENTLN in Russia. Maybe compare with ISS-LIS lightning measurements?**

While we agree that this information would provide valuable insight; unfortunately, this is proprietary data and is not something we are allowed to publish at this time. We have added additional information to section 2.3.1 Lightning data, in order to provide a bit more context.

"Due to both geopolitical limitations and the mid-range nature of the ENTLN, flash level detection in Russia is low. However, storm level detection remains around 50%. As there are no sensors located in Russia, all lightning is detected by sensors in neighbouring countries."

*** Do you use flashes or strokes measured by ENTLN?**

As mentioned in 2.3.1 Lightning data, "Only cloud-to-ground flash data are used in this study."

(To provide additional clarity requested by another reviewer, this sentence has been updated to "Only cloud-to-ground flash data from 2012-2022 are used in this study.")

- Line 194: What are "non-native forests"? Please define.

We agree that this wording is incorrect and updated it to be more reflective of the correct land cover naming convention.

“Non-forest land covers (land covers that clearly have no dominance of trees; Table A1) were excluded from the analysis.”

- Lines 127.128: It seems you have used a very simple classification in which you only mention fire embracer species and post-fire resprouter species. What reference or references did you use to classify tree species into fire-related strategies? You may take a look at the references included within the Table S1 in Moris et al. (2022, https://doi.org/10.1007/s10980-022-01478-w) for some more comprehensive classifications.

The focus of this portion of the manuscript was to provide background information on how wildfires play a crucial role in not only forest regeneration, but also landscape dynamics. It highlights how general species compositions can influence fire behavior; we used Rogers et al. (2015) and Stocks et al. (2001). A deeper analysis is outside the scope of this paper.

- Line 128: What do you mean by “can regenerate independently”, and “that require species members to regenerate”.

We agree that this statement was unclear, and have added the below additional information as well as supporting citations.

“Fire-adapted forests can typically be classified into two distinct categories; (1) forests with species that can regenerate independent of their species members and (2) forests that require species members to regenerate. The first category includes species such as conifers which store their seeds in insulated serotinous cones that only open to heat or hardwoods which regenerate from the root layer after a fire (Stocks et al., 2001). The second type are conifers that release their seeds yearly as the cones mature (Stocks et al., 2001).”

- Lines 229-230: Please mention again that this phrase applies for lightning candidates outside the perimeter.

We agree and have updated the sentence as requested to provide more clarity to the reader.

"If multiple potential candidate lightnings are found outside the perimeter, the stroke closest both spatially to the perimeter and temporally to the start date is selected as the ignition point.”

- Line 172: I think you should include where you downloaded the Canadian and Alaskan data from, like a website address.

All used datasets are cited and available in Table A3. We agree that this was not clear in the text and have added this information to the original sentence.

"We used the Canadian National Fire Database Fire Point and Polygon datasets along with the Alaska Fire History Location Points and Perimeter Polygons datasets to assess our BoLtFire dataset (Table A3). "

- Table A1: Based on Table A1, I do not think that forest vs non forest are the most appropriate names. Maybe “natural vegetation” or something like that could be more suitable. For example, the forest class included shrublandsand and grasslands. In addition, why is “Permanent Snow and Ice” included in the forest class?

We agree that the original naming convention was incorrect, and have changed this to "Dominant Forest Land Covers" and "Non-Forest Land Covers." Originally, fires located in "Permanent Snow and Ice" land covers were utilized in order to ensure fires located on the edge of the Boreal and the Arctic were included within the dataset, but we also understand that this land cover typically does not contain a dominant amount of trees, and has thus, been removed from the code.

- Lines 196-197: Why these 3 fires did not have a country?

We agree that this statement could have been more precise, and have updated it to make it clear as to why the fires were removed (please see 4.3 Limitations for additional information).

"We removed three fires as they did not fall within a country boundary of the World Bank Official Boundaries dataset."

- Section 2.6: It is not clear to me that 14-days window is enough for boreal forests in Eurasia, where the holdover times tend to be long compared with other regions. Could you provide some references to support this? If not, could you maybe analyze how the results would change by using another quantiy?

We agree that (1) additional information surrounding LIW in Eurasia needs to be included in the paper, and (2) a more thorough justification as to why 14 days was selected, needs to be made. To resolve this, we included the following sentence in the I. Introduction section:

"From an Eurasian perspective, when reviewing lightning ignition in the boreal forests of northeast China, Gao et al. (2024) found that around 80% of LIW occurred within 1km of the igniting lightning and within 24 hours; while Moris et al's (2023) analysis of Xu et al.'s (2022) LIW data in eastern Siberia shows a maximum holdover time of 8 days, with most occurring in 24-48 hours. Conversely, from a North American perspective, Scholten et al. (2021) reported that fire managers in Alaska and Canada have started reporting extreme holdover times, where fires "hibernate" over winter (up to seven or eight months) only to re-emerge the following fire season as "overwintering fires."

Additionally, the below was added to the 4.3 Limitations section:

"To minimize the possibility of these false positives, we deliberately selected a 14-day temporal window and a 10 km spatial window based on previous research, and our own observations of our data. Had we increased the size of either of these windows, we could have inadvertently matched a lightning candidate to a fire that may not have been ignited by lightning."

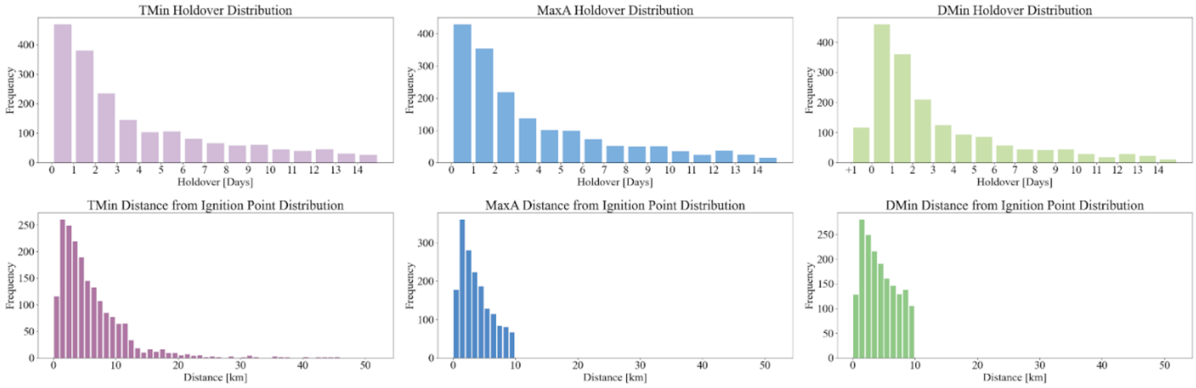
- Table 2. How can the approaches "MaxA" and "Dmin" have a different proportion under the colum "% Total". If both method use 10 km and 14 days from the ignition point, that should provide the same number of fires matched. However, I can see in Figure 2 that you allowed for a holdover time of -1 day in Dmin. I guess the difference must come from this aspect. Why only for Dmin? And not for MaxA? The start date for a point is the same no matter what selection criterion you apply.

Following Schultz et al., 2019, the Dmin contains a +1 day if no lightning candidates are found within the 15-day window. The below information was added to section "2.7 Agency reference comparison and analysis" to provide additional clarity.

"Max A, proposed by Pineda et al. (2014), and selects the stroke with the maximum index A while setting the tmax to 7 days and the Smax to 14 days. The Dmin, introduced by Schultz et al. (2019), searches backwards day-by-day from the reported start date until either a matching flash within a 15-day window (tmax) and 10km (Smax) is found or this temporal window is exhausted. If multiple flashes are found, then the one closest to the ignition point is selected. To compensate for possible misreporting of start dates, if no flash was found within the temporal window, then a day after the reported start date was searched."

- Figure 2. I think two aspects would be beneficial in this figure. First, to use the same scales for the Y axes. Second, I understand you use difference scales for the Tmin distance distribution given the large differences in values. However, it would help for the comparison if you include a smaller plot within this plot, in which you show the distance distribution between 0 and 10 km in the same wa. This way we can observe the differences with the other two plots from MaxA and Dmin.

We agree with your suggestion and have made the necessary updates. Please see the updated Figure 2 below:



- Figure 2. Have you plot the distance distribution using 1km bars for the 3 methods? And if so, do they look similar to other studies of lightning fires? From my personal experience, the distance distribution may be useful sometimes to detect if something is wrong with the lightning-fire matching. For example, when the harmonization of times are done not correctly, the matching suffers from "artificial" time lags (e.g., 1, 2 or more hours due to different time zones) causing that the selection may be different for a part of the fires. Have you double checked that this is not the case in your validation exercise for MaxA and Dmin? Maybe this concern doesn't apply to you if all times are given in days for the fires. Therefore, everything may be correct and your distance distributions really reflect the distribution from a suitable matching…

Thank you for this helpful suggestion, we believe we have validated this correctly.

- Table B2. You forgot to include the unit of holdover time in days. I don't think you need to put the distances to centimeters.

We have added the unit of holdover time in days and have updated the distance to just reflect meters.

- Lines 315-318: I have missed something here, or something that I don't really understand. How did you calculate the overall accuracy of Table B3? What is a correctly and an incorrectly matched? For that, don't you need a "true" match? Or you simply classified as "correctly matched" if the selected strokes was reported inside the perimeter and as "incorrectly matched" if they were outside the perimeter? If so, please, explain it. In my opinion, it's not clear what you have done here.

We agree with the reviewer that this process was not clear. To resolve this, we have added and updated the following:

"To better understand the capacity of the methodologies to locate the igniting flash within the perimeter, a review of the agency reference dataset was conducted as the dataset includes the ignition location. Within the agency reference dataset, 246 of the fires had ignition points located outside of the fire perimeter, and 2,178 are located within the fire perimeter (where the ignition of the fire should most likely occur). To determine the accuracy, the candidate lightnings of all three methodologies were compared to the actual ignition point location (inside vs outside the perimeter)."

In addition, calling that as "correctly or incorrectly" match is misleading in my opinion (if you are using inside vs outside the perimeters). I suggest that you use a different term if possible. A selected stroke may have occurred inside the perimeter of the stroke but because of the location accuracy of lightning data the stroke is simply reported outside the perimeter. That's the whole point of using spatial buffers to find and select igniting lightning, we don't know the exact ground location of lightning.

Thank you for your feedback. There appears to be some confusion here. The location of each candidate lightning is compared to the location of the ignition point of that fire identified by the agency reference dataset. We consider the agency reference dataset to be our source of truth. In other words, if the agency reference dataset shows that the lighting occurred within the fire perimeter, and our methodology results in the same, then it is labeled as "correct." If the agency reference dataset shows that the lighting occurred within the fire perimeter, but our methodology shows that it did not, then it is labeled as "incorrect." To help make Table B3 more easy for the reader to understand, we have updated "correct" and "incorrect" to be: "Ignition Point Inside Perimeter (1)" and "Ignition Point Outside Perimeter (0)." Though we will continue to use the verbiage, "correct" and "incorrect."

- Line 415: To avoid misunderstandings, it may be useful to clarify that you are calculating LIE for only a part of the lightning fires (e.g. > 200 ha), and not for all fires. Furthermore, as explained in Table C1, you are missing many lightning fires in NA, and so the LIE given in this manuscript are only indicative to compare LIE among regions using the same methodology, not to give insights about the LIE itself.

We agree that our original statement could cause confusion. To mitigate this, we have updated the statement to make it clear that these results are only for fires that are larger than 200 ha.

"The BoLtFire dataset reveals variations in the incidence of lightning ignition efficiency (LIE) across both continents<u> for fire sizes of at least 200 ha (Table D3)."</u>

General comments

- I understand that the original dataset is the GlobFire Fire Perimeters. A biome, fire size and land use class filters are applied. But after that, all polygons are used to find a matched stroke? If there is a matched stroke, then the perimeters is included in the database? If so, the main limitation of this dataset is that not all fires included in it must be lightning-caused fires. Simply, the dataset includes fires for which there is a match and possibly lightning ignition source, but it gives no indication about the fire cause. This must be clearly reflected, but it can be misleading otherwise. Potential users of the dataset must know that some of the fires are possibly human-caused fires.

We agree that our previous statement was unclear, and could cause confusion for readers. We have added syntax that clearly states that it is not absolutely certain that these fires were caused by lightning.

"More specifically, the precise geolocation of lightning paired with spatially explicit information on wildfires allows us to <u>better</u> distinguish lightning from human-caused ignitions by matching wildfire and lightning location data (Larjavaara et al., 2005; Nash and Johnson, 1996; Wotton and Martell, 2005). .....<u> Unfortunately, it is currently not possible to use these methodologies to definitively identify - with absolute certainty - that a fire was ignited by lightning."</u>

It is true that Table C1 gives an indication about how many missing lightning fires there are may be in the BoLtFire dataset, and how many might be human fires (assuming that the 483 fires not match with agency data are actually human-caused fires), but as you know, this does not have to reflect the situation in Eurasia.

This is a factual statement, unfortunately, there are no agency reference datasets in Eurasia that are publicly available. This type of analysis of the Eurasia BoLtFire dataset is thus not possible. This is discussed in-depth, in the section: "4.3 Limitations."

In conclusion, I think you should explain a bit clear how the BoLtFire dataset was created, and mention clearly in the section on limitations that this dataset does not explore fire cause (i.e., not all the fires has to be caused by lightning), even if the majority are natural.

While we appreciate and understand where the reviewer is coming from, we would disagree that this dataset does not explore fire cause. The goal of this manuscript is to explore potential fire cause, specifically looking at lightning ignited wildfires in boreal forests. We believe, the reviewer could be referring to their previous suggestion about how lighting methodologies are not "foolproof" ways to define fire cause, which we agree with and have added the below small section "4.3 Limitations":

"Moreover, as there is currently not a foolproof method for identifying lightning ignited wildfires using these methodologies, there is a chance that some of our BoLtFire dataset fires have been misclassified. Based on the spatial and temporal window that was selected, we assume – but cannot definitively confirm (especially in Eurasia) – that these fires were ignited by lightning. To minimize the possibility of these false positives, we deliberately selected a 14-day temporal window and a 10 km spatial window based on previous research, and our own observations of our data. Had we increased the size of either of these windows, we could have inadvertently matched a lightning candidate to a fire that may not have been ignited by lightning."

- I think that I understood correctly you method. You simply applied the minimum holdover time selection criterion (see Moris et al. 2020 and 2023), and if no lightning strokes (or flashes?) are located within the perimeter and 14 days, then you applied the maximum index A selection criterion using the 10 km buffer around the fire perimeter and the distance to the perimeter as the distance used for the index A. I have a few doubts and comments about your method:

A) In these two sentences, "The first candidate lightning found within the perimeter is designated as the candidate lightning and the ignition point. If multiple potential candidate lightning are found, the one closest in time to the ignition date is chosen", I assume that this is equivalent to the minimum holdover time method. Thus, I don't really understand the part "The first candidate lightning found within the perimeter". If only one stroke is found within the perimeter, no selection is needed, so what is the "first candidate"? In addition, the second sentence is enough to explain that you applied the minimum holdover time for all CG strokes reported within the perimeter (allowing for a maximum of 14 days).

We agree that our explanation of the methodology could have been more specific. We have updated the below statement to resolve this.

"If only one flash is found within the perimeter, it is designated as the candidate lightning and the ignition point. If multiple potential candidate lightnings are found, the one closest in time to the ignition date (12:00 noon local time, converted to UTC) is chosen."

B) I think it would be great if you explicitly cite or use a terminology that allows the reader to be aware that your selection criteria were already used in the past extensively. After all, your approach is based on a 2-step process in which you applied the minimum holdover time and, and if necessary, the maximum index A subsequently. The main novelty of your approach is to use perimeters instead of points for the stroke selection. For instance, Pineda et al. (2022, https://doi.org/10.1016/j.agrformet.2022.109111) applied first a 3-day temporal window, and if no lightning were reported within that period, a maximum of 10 days were then allowed.

Since the Temporal Minimum Distance (TMin) essentially leverages Minimum Holdover within the fire perimeter, and, what is essentially, the Maximum Index A outside the perimeter, the following citations were included to make it clear - even though no previous methodologies (to the best of our knowledge) first looked within the fire perimeter before then searching outside the buffer - it is still built upon previous methodologies.

“To address this, a Temporal Minimum Distance (TMin) methodology is proposed. Based on previous methodologies (Larjavaara et al., 2005, Nash and Johnson, 1996; Pineda et al., 2022, Wotton and Martell, 2005), this approach searches for a candidate lightning first within the fire's perimeter starting from its ignition date and searches until a candidate lightning is found or a 14-day window has been reached.”

C) I am curious about the temporal aspect of your approach. You applied the minimum holdover time, and you only had information on data for the fire discovery. If, for instance, a fire has a “StartDate” on July 12th, the first stroke (within the perimeter) before 23:59:59 on that day will be selected as the ignition source? For instance, if there are only 2 strokes on that day inside the perimeter, one at 23:55 and one at 00:12, which one will be selected?

Previously, any fire without a start time was defaulted to midnight of the start date. Based on your feedback we have re-thought our methodology and have decided to shift this to 12:00 noon local time, to better reflect the point at which wildfire conditions are generally most favorable. The below information was added to the text.

2.3.3 Agency reference fire occurrence records

“The Alaska Fire History Location Points dataset provides fire-specific information, including fire ID, discovery date and exact discovery time, out date, estimated fire size, and cause.”

2.4 Processing of the lightning and wildfire datasets

“After the initial filtering, all fire start dates were set to 12:00 noon local time, and then converted to UTC for the lightning matching process. Noon was selected as the start time for every fire, as this information is not available within the GlobFire dataset and 12:00 noon local time is when wildfire conditions are most favorable (Van Wagner, 1987; Vitolo et al., 2020).”

2.5 Processing of the agency reference datasets

“The Alaska Fire History Location Points dataset include the discovery time of each fire, to the second. Fire start times are not available within either of the Canadian agency reference datasets. The fire start times were also set to 12:00 noon local time then converted to UTC for the lightning matching process.”

D) In addition, are the time of fires and lightning strokes using different time zones? I guess lightning data are in UTC, but what about the fire dates? The fire start dates used local times or UTC? For example, the difference in local time between Kamchatka and Alaska must be almost one day. If the start dates that appear in the fires are based on local times, this could have an influence in the matching? For instance, for ignition points with local times reported in hours and/or minutes, in countries like the USA, it’s absolutely fundamental to harmonize the times of lightning and fires before the matching due to the different time zones.

Next to the shift of 12:00 noon local time, all datasets were converted, if necessary to UTC to allow for temporal comparison. Updates to the text can be found in our comment to the previous question.

E) Finally, I am confused about how you named your approach “Temporal Minimum Distance (TMin)”. I thought it was something involving the closest distance, such as the method used by Schultz in the USA (i.e. DMin), but your method mainly applies the minimum holdover time (in combination with the maximum index A if needed). To me, “Minimum time” reflects better what you have done for the selection, although it’s true that it doesn’t add the second potential step on maximum index A.

Temporal Minimum Distance (TMin) was decided upon as it is a two step process that looks for flashes that occur temporally closest to the start date and then searches for those within the perimeter. If no candidate lightnings are found, the method then searches outside the perimeter, selecting the flash that is temporally closest (minimum distance) to the start time and spatially closest (minimum distance) to the perimeter. We agree that there are a variety of possible naming conventions that could be just as accurate, but this is the one we selected.

- It would be nice to see the distribution of how many strokes are considered for the selection in each fire in the TMin approach versus MaxA and Dmin approach. Given that using a perimeter, and especially a large perimeter will ensure that more strokes are gathered before applying the selection criteria. This can be seen in the column "% Total" of TMin, where the number of fires with a selected stroke increases with fire size. I guess the TMin approach uses, generally, more strokes to select the most likely one.

We agree and have implemented this suggestion. We have conducted a short review of the overall fire class sizes and have included them in 3.1.1 Candidate lightning agreement as well as TableB1.

"The average number of possible candidate lightning flashes per LIW was highest for MaxA and DMin for Small, Moderate, and Large fires (Table B1). Though for XLarge and Mega fires, TMin found more possible candidate lightning flashes. Though this makes sense, as the TMin first searches within the fire perimeter, and if no flashes are found, then it searches a 10km buffer outside the perimeter; while the MaxA and DMin search inside a 10km buffer around the ignition point. If the fire is within a smaller perimeter, the TMin would only find flashes within that smaller perimeter as opposed to the MaxA's and DMin's 10km buffer."

Table B1: Cumulative count of the amount of candidate lighting flashes per LIW by fire class.

Matched Agency Reference Dataset Fires by Methodology									
Fire Size	TMin			MaxA			DMin		
	LIW Count	Total Flashes for Matching	Average Flash per Fire	LIW Count	Total Flashes for Matching	Average Flash per Fire	LIW Count	Total Flashes for Matching	Average Flash per Fire
Small	707	9,013	12.75	673	12,963	19.26	696	13,793	19.82
Moderate	843	6,046	7.17	767	12,820	16.71	784	13,627	17.38
Large	276	2,182	7.91	220	2,907	13.21	223	3,102	13.91
XLarge	34	745	21.91	24	326	13.58	24	339	14.13
Mega	23	814	35.39	16	264	16.50	16	287	17.94
Total	1,883	18,800	9.98	1,700	29,280	17.22	1,743	31,148	17.87

RC2 Response

Review Results

1. The study appears to have been undertaken to create a dataset of lightning-caused wildfires across the boreal forest and to characterise lightning-caused wildfires. However, the classification results show no novelty in the characteristics of lightning-induced wildfires that have been identified.

We would like to thank the reviewer for their critical review of our manuscript. Their time and insights are appreciated. We politely disagree, however, that our manuscript lacks novelty, as we will explain in the answers below.

No analysis examples are provided by applying the dataset.

We appreciate the interest in seeing additional analyses, however, we respectfully disagree with the critique. The primary aim of our study is to introduce and describe the BoLtFire dataset—a novel dataset of lightning-ignited wildfires in boreal forests; as the intent of this paper is to be a dataset paper (and ESSD a journal dedicated to the publication of research data sets). We have included a basic analysis of our dataset in section "3.2 Evaluation of TMin and the BoLtFire Dataset" to demonstrate its capacity. Unfortunately, performing an additional in-depth analysis falls outside the scope of this dataset-focused paper. We thus believe that the critique of "no analysis examples are provided" is not justified.

2. It seems to aim to complement data from forest departments in Alaska, Canada and other countries, but this makes no sense at all. It is well known that there are estimation errors in the area burned and other factors.

We believe there might be some confusion, as the goal of this research was not to complement known datasets, but to build a dataset for lightning ignited wildfires across the entire boreal forest, including Eurasia. To the best of our knowledge, there is currently not a publicly available dataset that indicates LIWs for the entire boreal, especially one that covers Eurasia. Further, it is unclear to us why creating such a pan-boreal, consistent dataset would make "no sense at all".

3. In addition, there are problems with the data used for the analysis.

In particular, the lightning strike data are from different detection systems in different regions, which means that there are obvious deviations in the data sets obtained.

We suspect that there might be a misunderstanding here, as all lightning flash data were provided by the same system. Earth Networks Total Lightning Network (ENTLN) provided flash data for this research for the years 2012-2022. Lightning flash data was not provided by other systems. Though, there are deviations in the detection efficiency across the network which was discussed in section "2.3.1 Lightning data." To provide additional clarity we have updated the below sentence:

"Only cloud-to-ground flash data <u>from 2012-2022</u> are used in this study."

In regards to deviations within the dataset, we would agree with this statement. We believe we have sufficiently discussed this in the section "2.3.1 Lightning data" (please see paragraph below). While we would agree that having a more specific detection efficiency for Russia would be helpful, this is unfortunately proprietary and not something we are able to divulge at this time. To provide additional information surrounding the detection efficiency in Russia, we have updated the below paragraph.

"Detection efficiency refers to the percentage of flashes or strokes detected by the network and can vary depending on the location and the distance between the sensors and the lightning event. Relative detection efficiency assumes a uniform detection efficiency across the network. The ENTLN's cloud-to-ground stroke detection efficiency across the CONUS is reported to be greater than 90 % (Lapierre et al., 2020), with relative detection efficiency values ranging from 85 % to 100 % across the Americas and similar levels in Europe and Australia (Bui et al., 2015). Significant improvements have been observed over the years due to advancements in processor technology (Mallick et al., 2013; Mallick et al., 2015; Zhu et al., 2017; Zhu et al., 2022). The most recent processor has achieved a stroke classification accuracy of 94 % and has reduced the median location error from 215 meters to 92 meters when compared to ground truth data in Florida (Zhu et al., 2022). Globally, this upgrade has resulted in a 149 % increase in the overall global detection of pulses, with North America showing a 145 % gain, Asia a 142 % gain, and Europe a 152 % gain. However, in more remote areas, detection efficiency tends to be lower, and location errors can extend up to several kilometres. Due to both geopolitical limitations and the mid-range nature of the ENTLN, flash level detection in Russia is low. However, storm level detection remains around 50%. As there are no sensors located in Russia, all lightning is detected by sensors in neighbouring countries."

4. With regard to fire data, hotspot data is only used for the period from 2012 onwards, even though there are 20 years of data available from 2003 onwards. This results in a poor analysis of fire data and no mention of the major fire in the Republic of Sakha in 2021. There are doubts about the assessment of wildfires in Eurasia using the wildfire dataset.

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2021 Russia wildfires

https://en.wikipedia.org/wiki/2021_Russia_wildfires

Hayasaka, Hiroshi. 2021. "Rare and Extreme Wildland Fire in Sakha in 2021" Atmosphere 12, no. 12: 1572. https://doi.org/10.3390/atmos12121572

Hayasaka, H. Fire Weather Conditions in Boreal and Polar Regions in 2002–2021. Atmosphere 2022, 13, 1117. https://doi.org/10.3390/atmos13071117

We believe there might be some confusion surrounding the availability of the ENTLN lightning flash data. To mitigate any additional confusion, Table A3 was updated to make it clear that lightning flash data from 2012-2022 was used for this research. Additionally, the sentence: "Only cloud-to-ground flash data are used in this study." has been updated to: "Only cloud-to-ground flash data from 2012-2022 are used in this study." Since lightning location data was not available from 2003 until 2011, we were unable to perform the lightning matching process for this timeframe.

Regarding the Sakha wildfires, we are a bit confused about this statement. This is a pan-boreal dataset and we do not focus on one specific fire event, we focus on all of them. We would also like to mention that both our original - and our new - BoLtFire datasets contain fires in the Sakha region during this timeframe.

Additionally, The ENTLN does not have sensors within Russia, so lightning detections in Russia rely on sensors in neighboring countries. We are aware that this might cause some LIW to not be included within the dataset, and discussed this in the section "4.3 Limitations." To the best of our knowledge, there is currently no publicly available LIW dataset in Eurasia nor one that encompasses all of Russia, to compare our results to.

We believe we sufficiently discussed this limitation, within our "4.3 Limitation" section, specifically with the below:

"Additionally, as the ENTLN currently has no sensors located in Russia, this could create larger spatial errors or possibly not detect some lightning strikes. Since our lightning matching methodology heavily depends on the detection of lightning strikes, these factors could influence not only the likelihood of a correct match but also the selection of the candidate lightning strike in the absence of the "correct" match. Finally, as the currently available reference datasets are limited to boreal forests, we were only able to assess the BoLtFire dataset with those resulting fires within Canada and Alaska. Fire records from other agencies, especially those in Siberia and Russia are difficult to obtain or might be inaccurate (Stocks et al., 2001). As tree canopies can obscure fires (Johnston et al., 2018; Kolden et al., 2012), and as surface fires are more prevalent in Eurasia than the crown fires dominant in North America, omission rates could be higher in Eurasia."

Once again, thank you for your time and for your feedback!

RC3 Response

Reviewer 3

In this manuscript, the authors present a dataset of lightning-ignited wildfires that they created using proprietary data on lightning strike times and locations, and wildfire perimeters from GlobFire. The manuscript is generally well-written, but with a few places that could use a little more clarity. To my knowledge this dataset is novel, and could lead to important advances in understanding of boreal wildfire occurrence. I think it is publishable after some minor revisions.

We would like to thank the reviewer for their kind and thoughtful feedback.

My specific comments are below:

89-92: I think this statement could be modified. MCD64 and FIRECCI are raster-based products that do not delineate events from pixels of burned area, and therefore ignition location would not make sense. FRY does not to my knowledge provide fire events. There are 3 event-based global products, where MCD64 pixels are delineated into events, that I am aware of. These are FIRED (Mahood et al 2022), the global fire atlas (GFA; Andela et al 2020); and GlobFire (Artes 2019). FIRED does have (crudely) estimated ignition locations (the centroid of all pixels that burned on the first day of the event), and I'm not sure about the other two. I do know that none of those products have cause of ignition. Therefore, I think that while it is worth mentioning MCD64 and FireCCI, those are datasets of burned pixels, not wildfire event datasets.

We agree with this suggestion, and have updated the original sentence as follows:

“Although global remote sensing-based burned pixel datasets do exist - such as Collection 6 MCD64A1 burned area (Giglio et al., 2018) and FIRECCI5 (Lizundia-Loiola et al., 2020) - as well as global remote-sensing based fire patch datasets - such as FRY (Laurent et al., 2018) - they lack ignition location and cause. Consequently, a comprehensive pan-boreal forest lighting-ignited wildfire dataset does not currently exist.”

98: suggestion: reword to "... that do not rely on pre-existing ignition locations..." or something along those lines

We agree with this suggestion. We have included "pre-existing" to our original statement to make it more clear that these ignition locations are not known when implementing this approach.

"Develop and implement a new approach to identify lightning-ignited wildfires that do not rely on pre-existing ignition locations and benchmark this new approach with a regional test case using the Canadian National Fire Database and Alaska Fire Service datasets."

170-171: Please cite the Canadian and Alaskan datasets

All used datasets are cited and available in Table A3. We agree that this was not clear in the text and have added this information to the original sentence.

"We used the Canadian National Fire Database Fire Point and Polygon datasets along with the Alaska Fire History Location Points and Perimeter Polygons datasets to assess our BoLtFire dataset (Table A3). "

243: the DMin and MaxA methodologies don't seem to be described anywhere. Please provide a short description.

We agree that both the MaxA and DMin methodological description are missing. These have been added to the section “2.7 Agency reference comparison and analysis”

"Max A, proposed by Pineda et al. (2014), and selects the stroke with the maximum index A while setting the tmax to 7 days and the Smax to 14 days. The Dmin, introduced by Schultz et al. (2019), searches backwards day-by-day from the reported start date until either a matching flash within a 15-day window (tmax) and 10km (Smax) is found or this temporal window is exhausted. If multiple flashes are found, then the one closest to the ignition point is selected. To compensate for possible misreporting of start dates, if no flash was found within the temporal window, then a day after the reported start date was searched."

250-255: The sentence "The BoLtFire dataset successfully located a fire if it was within seven days (before or after the start date) and 10 km (Fusco et al., 2019)" seems to be repeated.

Thank you for catching this! The repeated sentence has been removed.

289: Wording is a little weird to me, essentially due to the use of the word 'time' twice. Maybe instead say longer holdover times were exponentially less frequent.

In order to make this sentence more clear, it has been edit:

"In all three methods, the holdover time showed an exponential decrease over the observed period (Figure 2; Table B1). After being applied to the agency reference dataset, the holdover for over 50 % of candidate lightnings among the three methodologies (TMin: 57.51 %, MaxA: 58.88 %, and DMin: 65.75 %) were found within the first 3 days (Day +1/0-2; Table B1); over 88 % within the first 10 days (TMin: 90.23 %, MaxA: 92.00 %, and DMin: 93.80 %).

Figure 1: specify in the figure or in the caption that the grey outline is the wildfire perimeter and the dotted line is the buffer.

We agree with this suggestion, and in order to add additional clarity to Figure 1, we have added the below additional information to distinguish between the fire perimeter and the buffer.

Figure 1: Visualization of the temporal minimum distance process, where lightning candidates are first searched for within the fire perimeter before then searching the buffered area if one is not found. The grey polygon depicts the fire and its associated perimeter, while the dotted line represents the 10km buffer.

Figure 3: It might be nice to include the candidate lightning ignition points in these figures. The Landsat 8 basemap is a little busy and perhaps unnecessary. It might be a little easier to look at if it's in the natural projection of the polygon.

We agree that Figure 3 has opportunities for improvement. We have updated this image to focus on just one of the fires. We have also included the agency reference dataset ignition point (orange fires), the possible candidate lightings (light orange lightings) and the selected candidate lighting flash (large yellow lightings).

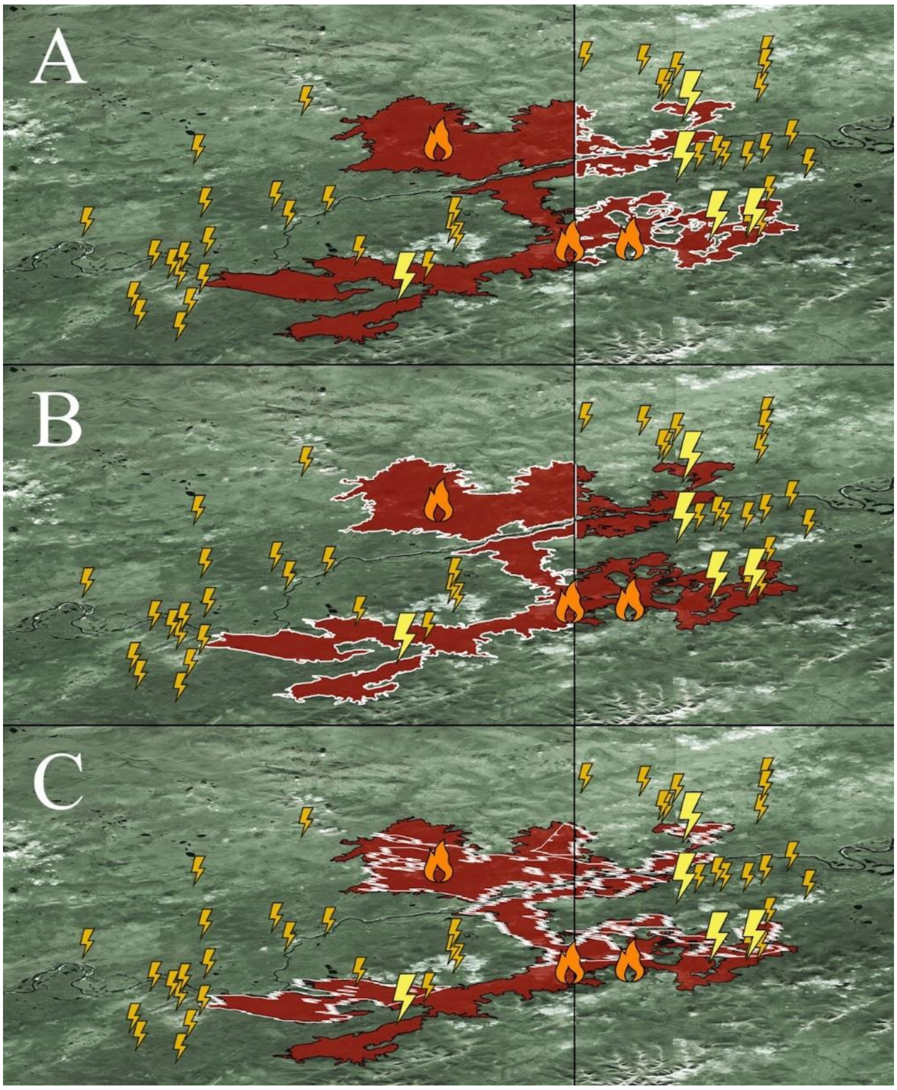
A
B
C

Figure 5: increase font size and resolution: legends are illegible.

We agree and apologize for the illegibility of this figure! This has been updated.

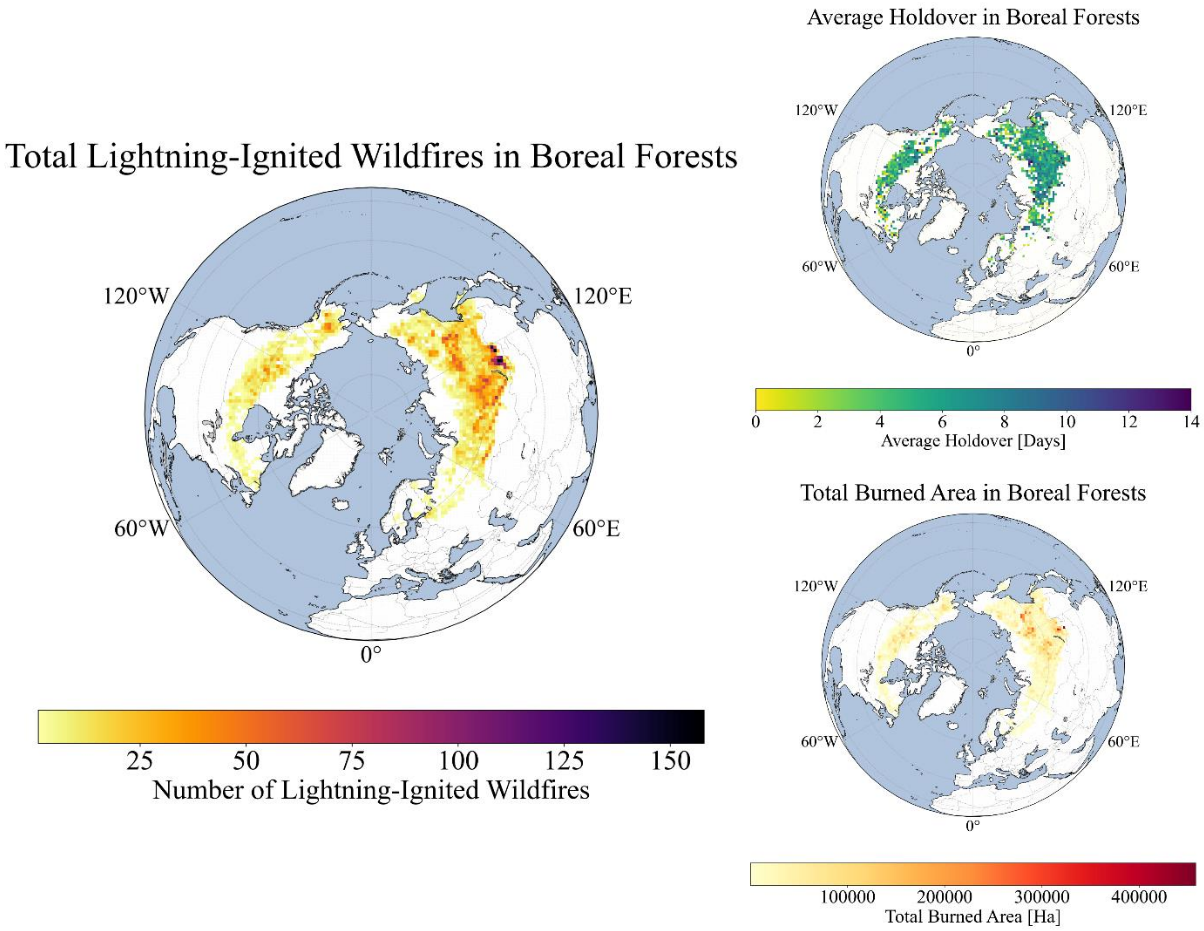

Table 1: Spell out the acronyms either in the caption or in the table.

We agree with this suggestion, and have updated Table 1 to clarify those acronyms that needed additional clarity.

Table 1: Description of variables provided for each lightning-ignited wildfire within the BoLtFire dataset.

Column Name	**Description**
FireID	Unique fire identification number
StartDate	Start date of the fire
EndDate	End date of the fire
FireYear	Year fire was discovered
AreaHa	Total burned area of the fire in hectares (“AreaHa” denotes Area in Hectares)
ClassSize	Fire class size; Small ≤ 1,000 ha, Moderate 1,000 ≤ 10,000 ha, Large 10,000 ≤ 50,000 ha, Extremely Large 50,000 ≤ 100,000 ha, Mega Fires > 100,000 ha

	(“ClassSize” denotes Fire Class Size)
BiomeName	Biome name based on Olson et al. (2001)
EcoBiome	Ecoregion Biome number based on Olson et al. (2001)
EcoName	Ecoregion name based on Olson et al. (2001)
EcoID	Ecoregion ID based on Olson et al. (2001)
Realm	Realm based on Olson et al. (2001)
LCDN	Land cover type number based on Friedl and Sulla-Menashe (2022) (“LCDN” denotes Land Cover Digital Number)
LCName	Land cover type name based on Friedl and Sulla-Menashe (2022)
Country	Country where fire is located based on World Bank (2020)
Continent	Continent on which the fire was located
HoldoverD	Holdover in days (“HoldoverD” denotes holdover in days, as a float.)
HoldoverRD	Holdover in days, rounded to the day ("HoldoverRD" denotes the holdover values Rounded to Days, rounded to the nearest whole integer)
IgnLat	Latitude location of the candidate lightning (“IgnLat” denotes the Ignition, Latitude position of the candidate lightning)
IgnLong	Longitude location of the candidate lightning (“IgnLong” denotes the Ignition, Longitude position of the candidate lightning)
DisPol	Distance to polygon if ignition point is outside polygon (“DisPol” denotes the Distance of the ignition point to the fire Polygon, when the ignition point is outside the polygon)
t_cnt_flsh	Number of possible candidate lighting flashes found for the fire (“TMin Count of Flashes”)
PerCheck	True(1)/False(0) if the candidate lightning is within the fire perimeter (“PerCheck” indicates the result of the Perimeter Check, if it is inside or outside the fire perimeter)