We thank the reviewers for their helpful comments and suggestions, and appreciate their time reviewing our paper. We have integrated their feedback and believe the paper is improved. We provided point-by-point responses to reviewer comments and questions, below, and here we summarize the primary updates or changes in the revised text:

1. Modified text to highlight what aspects of the discussion stem directly from the results we present vs. previous work.
2. Modified the text where we compare our results to previous studies projecting 21st century fire activity in the Rocky Mountains, clarifying the consistency with the work from Westerling et al. (2011), and Littell et al. (2019).
3. Analyzed the tree-ring data in two time periods, and integrated this into the figures and text. We also provided a paragraph in the “Materials and Methods” section describing how the tree-ring data were used.
4. We also updated the contemporary area burned statistics by including data from 2019 (previously absent). While there were no fires above the 405-ha cut-off for MTBS dataset, the contemporary (and future) FRP statistics changed slightly, by including an additional year. In this process, we noticed a small calculation error in how the 2020 fire perimeters were summarized. None of these changes alter the key messages in the paper.
5. Finally, we added a supplementary figure illustrating the time series of area burned and VPD for the subalpine forest in the focal study area, only, complementing Fig. 1B in the main text.

**Reviewer #1:**  
Suitable Quality?:   
Yes   
  
Sufficient General Interest?:   
Yes   
  
Conclusions Justified?:   
Yes   
  
Clearly Written?:   
Yes   
  
Procedures Described?:   
No

In addition to replying to specific comments related to methods and procedures, we have added text to the “Materials and Methods” section, primarily describing how we integrated existing tree-ring records into the study.

Supplemental Material Warranted?:   
Yes   
  
Comments:   
  
This paper compares 2020 forest fire activity to the paleo record, finding that the recent fire season is unprecedented and exceeds even previous maxima reconstructed during the early MCA. I think the question is relevant, the analysis is well-sourced and likely to be sound, and the paper is probably suitable for acceptance following some minor revisions. I do feel that the paper does not necessarily support the point made in the abstract, that "the 2020 fire season illustrates how subalpine forests are undergoing broad-scale readjustment to a warming climate, exceeding the range of variability shaping these ecosystems for millennia".

We have edited this text in the abstract to focus specifically on subalpine forest fire activity – vs. “broad-scale readjustment.”

Right now, the paper seems to be three main points that get a little jumbled:   
1) The FRP from 2000-2019 is not unusual in the paleo context.   
2) The 2020 fire season was so severe and unprecedented that its inclusion drops the FRP to 112 years, a value unprecedented even in the early MCA.   
3) Having observed an extreme 2020 fire season, we can then re-interpret the entire recent period in the context of climate change.

These are indeed the three main points. We have edited the text to refine and sharpen how these three points are presented, to highlight how they are (and are not) related to each other. The 2020 fire season, now that it’s “in the rearview mirror” is the event that has clearly pushed 21st-century fire regimes outside the range of variability of the past 2000 years. This interpretation is also based on (a) the trend of increasingly fire-conducive climate and area burned over the past two decades, and (b) climate and fire projections that suggest these systems will not return to late-20th century rates of burning. If 2020 happened in the absence of directional climate warming, the implications would be different.

The connection to climate change is presented in Figure 1B, which agrees with the literature that increased VPD is a primary driver in increasing fire. I like the analysis that states that four decades of no additional burning would have to follow 2020 in order to return to the late-Holocene average, as well as the projected FRPs given 1984-2020, 2000-2020, and 2010-2020 rates of burning shown in Figure S1.

Yes, these components of the study are important context for the implications of the 2020 fire season (and the 21st-century fire regime as a whole), as noted above. Note too that we modified the statistic quoted in the text, to add clarity on the time window referenced. The text now notes that it would take two decades of no burning for the \*2000-2040\* FRP to return to the late-Holocene mean. This is an important statistic to communicate the magnitude of the 2020 fire season, but the future scenarios presented in Fig. 2C and S2 are the more realistic projections of how 21st-century fire regimes will likely unfold.

However, I'm not sure this study demonstrates long-term trends in burning, nor does it have to. I think it is perfectly sufficient for publication to note the severity, in paleo context, of the 2020 fire season. I would suggest an (optional!) minor revision to more clearly differentiate between what is explicitly shown in this study (2020 was severe, observed fire activity correlates with observed VPD) and what is supported by existing literature (VPD will increase, post-fire conditions will be more stressful for tree regeneration).

Thank you for your comments and suggestions. We have updated the text in several places to better differentiate what comes from our findings vs. the existing literature, primarily on the topic of post-fire tree regeneration, in the third-to-final paragraph of the “Results and Discussion” section, but also highlighting two studies that explicitly project future fire activity in the Rocky Mountains, based on future climate projections.

Regarding “long-term trends in burning” – area burned in the Central Rockies study area indeed increased significantly since 1984 (recognizing that from the paleo perspective, this is not “long-term”). We report this finding -- (ρ = 0.40, p = 0.015) -- in the first sentence of the “Result and Discussion section.” We also cite three papers that also support varying versions of the link between increased in fuel aridity and increased annual area burn over recent decades (in the second sentence of “Results and Discussion” section). And, while 2020 is the major contributor to this increase in area burned – not necessarily “severity” (which is not quantified yet) – the significance of 2020 depends on the longer context. As noted above, we add addition evidence of (a) increased area burned over the previous two decades (correlated with increasingly fire-conducive climate), (b) increased temperatures outside the range of variability of the past 2000 years, and (c) finally, 21st-century fire rotation periods outside the range of the past 2000 years.

Small corrections:   
  
Page 2: thus so to do potential management (get rid of to?)

Thank you for noticing this typo. We have modified this sentence to read: “… and thus so too do potential management…” We also separated and added citations to link to the causes of increased fire activity and the management and policy solutions, separately.

Page 3: "the time required to burn an area equal in size to subalpine forests in our focal study area" I was confused by this- do you mean the time required to burn all the subalpine forests?

No…the fire rotation period does not mean the time required to burn all the subalpine forests. The original text is a slight modification of the precise definition of “fire rotation period.” We have added some text to how we present this definition, and how it is applied in this study.

Page 3: :drops the FRP to 378 yr"   
do you mean increases the period?

Yes, this should have been “increases.” We change this text to highlight the 1984-2020 FRP of 204 years, to match what’s displayed in Fig. 2C.

"Extreme winds over hourly and daily time scales drove extraordinary growth of individual fires in 2020" worth noting that eg ref (15) explicitly notes that using climatological winds (excluding day-to-day variability in wind speed) results in potential underestimates in the projections of dry extremes.

This is an interesting point. Indeed, many fires in 2020 were driven by extreme winds (in Colorado and beyond, e.g. in OR and WA), raising the question of how such winds may or may not change in upcoming decades. In the text here, we simply want to balance the emphasis on how climate enables widespread burning – as in 2020 and in the past – with some acknowledgement that processes operating at finer scales are also critical in understanding individual fires and/or fire seasons. We feel a specific note about potentially underestimating future climate/weather projections does not fit tightly with the rest of the text in this paragraph, and thus prefer to keep the text unchanged.

Figure 1A   
I find this figure extremely hard to read. It's very difficult to differentiate between 1984-2018 fires, 2020 fires, and lake sites with recorded early MCA fire events.

Thank you for this feedback. We have modified Fig. 1A to improve clarity, by increasing the color difference between 2020 fires and those from 1984-2019, and by changing the color of circles used to identify lakes sampled. We also removed grid lines in the map to help declutter panel A. And finally, based on comments to include more information on the tree-ring records, we added the location of the tree-ring based fire history reconstructions used in the study.

Figure 1B caption   
"Percentages above red bars are the proportion of total area burned contributed by the given year." I assume this is total burned area integrated over the observed time period 1984-2020?

Yes, this assumption is correct. We have modified the caption to read: “…proportion of total area burned (from 1984-2020) contributed by the given year.”

Note too: We have updated this figure and caption by now adding area burned data for 2019, which happened to be 0 ha burned (by fires larger than the 405-ha cutoff used by MTBS).

Figure S1   
The same marker is used for Higuera et al 2014 and this study's sediment charcoal records, which is confusing. The y-axis error bars (I presume) are obtained from bootstrapping and described in the caption. What appear to be x-axis error bars are (I think?) describing the time interval spanned by the reconstructions/observations- is this correct? It would help for readability to explicitly state this.

These are great points and we have update this figure and caption as follows: [1] used a unique symbol for the data from Higuera et al. (2014); [2] added text in the figure caption explicitly noting that the horizontal lines reflect the time period covered by each set of records; and [3] noted that the FRP statistics from the tree-ring records are the published statistics (vs. a new analysis of existing tree-ring data), as noted in another review comment.

Data and code availability   
For reproducibility, please indicate where the reconstruction data and analysis code can be obtained.

We will make all data and code used in this study available via a Dryad repository. I believe this information goes into a separate field in the manuscript upload process (vs. in the main text).

**Reviewer #2:**   
  
Suitable Quality?:   
Yes   
  
Sufficient General Interest?:   
Yes   
  
Conclusions Justified?:   
Yes   
  
Clearly Written?:   
Yes   
  
Procedures Described?:   
No

In addition to replying to specific comments related to methods and procedures, we have added text to the “Materials and Methods” section, primarily describing how we integrated existing tree-ring records into the study.

Supplemental Material Warranted?:   
Yes   
  
Comments on Significance Statement:   
  
This paper follows up on prior modeling studies for northern US Rockies forests that predicted an increasing tempo and intensity of severe fire seasons for subalpine forests, far outside historical and reconstructed fire regimes for the region. The authors put the extreme 2020 fire season in a paleo-fire context, and demonstrate that Rocky Mountain fire regimes are moving outside the range of the last 2000 yr. This has important ramifications for ecosystem management in one of the largest extant forest regions of the contiguous united states, and clear implications for other subalpine forests around the world.   
  
Comments:   
  
Rocky Mountain subalpine forests now burning more than any time in recent millennia By Philip E. Higuera, Bryan N. Shuman, Kyra D. Wolf is a valuable contribution to the literature, putting in context recent extreme fire seasons-especially the 2020 fire season-as well as recent modeling literature that predicts increasing fire activity and decreasing fire rotation periods in US Rocky Mountain forests.   
  
  
While overall I recommend publication, I do have some comments and questions.   
  
1) On Page 5, the assertion :   
  
It is the emergence of unprecedented burning by 2020, however, that is surprising. While this is consistent with the predicted development of novel fire regimes across the Rocky Mountains by mid-century (15, 16), our results demonstrate the emergence of these changes several decades earlier than anticipated.   
  
Is not a correct use of the cited literature. In particular, reference #15 (Westerling et al 2011). That paper simulated wildfire in US Rocky Mountain forests next to the study region used here, and clearly predicts fire seasons of similar to greater magnitude in the US Northern Rockies as was observed in the 2020 fire season in the central US. Westerling et al simulated 1000 iterations each for ~150 yr for three different climate scenarios, and Figure 2 of that paper clearly shows fire seasons where the median and range of annualized simulations in the first decades of the 21st century in all three climate scenarios are comparable to or exceed (for the Greater Yellowstone Ecoregion they used) the scale of the 2020 fire season for the central US Rocky Mountain region used in the study reviewed here.

Thank you for identifying this important point and encouraging clarification. We see now that our focus on mid-century projections in the original text was too precise – i.e., more precise than the projections and differences between the GYE and our Central Rockies study region allow. We don’t feel it justified to directly compare FRPs from Westerling et al. (from the GYE) to our Central Rockies study area, b/c the HRV in these two regions differ (i.e. YNP burned more in the past relative to subalpine forests in our focal study area, as well-described by tree-ring and lake-sediment records), nor do we feel this is central to our point here. We have modified this text in the penultimate paragraph of the “Result and Discussion” section to highlight consistency between our results and projections for the GYE (Westerling et al. 2011) and Central Rockies (Littell et al. 2019), and very low likelihood that burning would return to late-Holocene levels.

Figure 3 also shows fire rotations in the warmest and driest climate scenario used by Westerling et al falling well below the fire rotations estimated here by Higuera et al for a nearby subalpine forest region. Arguably, observed climate in the region may so far be best approximated by the warmest and driest scenario used by Westerling et al.

This is a good point. As noted above, we don’t believe it’s justified to directly compare the FRPs (between the GYE and Central Rockies), but the relative changes in the FRPs shown in Fig. 3 in Westerling et al. likewise support this point. We have integrated this into the modified text noted above.

A correct use of the literature would be to say that central US Rockies fire activity observed to date in the 21st Century is highly consistent with Westerling et al's predictions for the neighboring GYE.

Agreed, an we have modified the text to emphasize this point.

Note that approximately around 2060, Westerling et al's simulations predict for the GYE that availability of continuous fuels may become the dominant limitation of fire extent, which is distinct from what has been observed so far in either region, but something which Higuera et al do speculate could eventually apply to the central US Rockies. These should not be confused with the predictions closer to the scale of what was predicted (and what has actually occurred) in the first decades of the 21st century.

Thank you for pointing this out. We discuss the potential role of fire-fuel feedbacks in the third-to-final paragraph in the “Results and Discussion” text, adding some text highlighting the reduction in forest density reconstructed in some areas of the study region after the MCA. Interestingly, given the historically longer FRPs in the Central Rockies (relative to the GYE), we also point out that there is an abundance of long-unburned forest in the focal study area to sustain increased burning, for at least several decades. It would be interesting to see similar fire projections as Westerling et al. did for the GYE, for the Central Rockies. Littell et al. (2019) provide projections for both the GYE and our Central Rockies ecosections, and they suggest similar relative increased in log(area burned) in each region.

2) in Figure 2, Tree-ring derived fire rotation period values and 95% confidence intervals are indicated on the graph, referencing citations 8, 12, 14, and 19. It is not clear from the text whether the authors are (1) citing a previously published synthesis of tree ring studies in the region or (2) calculating it from the raw data used for these four original citations. If it is the former, then the authors here should clearly state where these values were first published. If it is the latter, then this should also be addressed in the methods and materials section and/or online supplement.

The tree-ring based fire rotation period (FRP) statistics in Fig. 2 were calculated from FRP values presented in the cited publications; these values are also summarized by Baker (2009, Table 8.1 in this textbook). So, it was more like #2 above in the original text: we did not do any reinterpretation of the raw stand-age data used to calculate the published FRP values.

In the revised text, in response to suggestion below, we have now calculated FRP values for one of the four studies called upon, to provide FRP estimate for two distinct time periods. This is now fully described in the “Materials and Methods” section.

A related question did come to mind, looking at this figure. If the authors here are in fact using tree-ring (fire scar) data from previous studies to calculate a 300 year FRP, it would make sense to also use these annually-resolved paleofire records to show how recent observations over 10, 20 or 37 (1984-2020) compare to a moving window of fire widespread fire incidence as registered by the fire scar records. This would make an excellent complement to the work they have already done with the longer but less-resolved lake sediment records. While I don't expect that analysis would qualitatively change the conclusions here, it would make for a stronger paper.

This is an interesting suggestion that we considered carefully. While we do not believe it’s justified analyze the tree-ring data at the decadal scales suggested here (for reasons described below), we did complete an analysis that divided the tree-ring fire history data into two time periods. This is now described in the “Materials and Methods” text, and reflected in Fig. 2C and S2.

The tree-ring data used are not “fire scar” records, as commonly used to reconstruct non-lethal fires in low-elevation, low-severity fire regimes. The four studies called upon in our paper are all from stand-replacing fire regimes; as such, the authors estimated past fire extent using tree rings to reconstruct stand age, and using some fire scars (e.g. on the edge of high-severity patches) to resolve the precise fire years. In the original publications, the FRP statistics are reported either over the entire time period of the study (i.e. Sibold et al. 2006), or for multi-century periods representing the historical range of variability, plus a period from the mid-1800s to mid-1900s, representing fire activity after Euroamerican arrival (all other studies). Annual-scale analyses from this work is focused on fire-climate relationships (e.g., Sibold and Veblen, 2006), and not really fine-scale changes in fire activity; this is mainly because of tradeoffs between space and time that are inherent in FRP calculations.

Our goal in plotting the tree-ring based FRP reconstructions is to provide an additional benchmark to which compare both the sediment-charcoal records (i.e., “are the sediment-based estimates reasonable based on what we know from tree-ring records?”) and the record of contemporary fire activity (i.e., “is contemporary burning also outside the HRV estimated from tree rings?”). We used a similar comparison between tree-ring and lake-sediment estimates in Higuera et al. (2014). The average tree-ring derived FRP from among eight watersheds presented in the original text provided a robust estimate of the FRP under the historical range of variability. Indeed, this is the intention of each of the original publications from which we draw the FRP values. The new analysis is generally consistent, and shows longer FRPs for the more recent time period, also generally consistent with the lake-sediment based FRP (Fig. 2C).

If we understand the reviewer’s suggestion correctly, it is to calculate FRP values from the tree-ring records over shorter time periods (e.g., 100-yr moving windows to compare to the sediment-charcoal records, or 20-37-yr moving windows to compare to the contemporary record). This is problematic for a few reasons, mainly related to calculating the FRP over too limited a spatial and/or temporal extent. Given the nature of the fire rotation period statistic, we know that if one “zooms in” in space and/or time, the range of FRP values will increase: there will be periods (e.g., decades or centuries) when the FRP is much higher or lower than the limits in Fig. 2C. An increasing range (i.e., max., min.) is expected any time values are averaged over smaller spatial or temporal domains.

The strength of our analysis is the area and/or time integrated into the varying calculations of FRP: the lake-sediment records sample 15-20 watersheds in any 100-yr period, and provide a range of variability over the past 2000 years; the tree-ring records span fewer “sub study areas” (8) but integrate 3-4+ centuries (and now c. 1-2 in each time period); finally, the contemporary record, while limited in time, spans all subalpine forests in the focal study area. This space-for-time substitution (in the contemporary record) is the best way to accurately characterize contemporary fire activity, particularly given all the evidence of increasing fire activity in recent decades, in the Central Rockies and West. We further play out varying plausible scenarios for the rate of burning for the rest of the 21st century, to provide some bounds on a likely 100-yr FRP (at the end of this century).

Minor comments:   
  
Page 2:   
  
"This trend is well linked to ..." - hyphenate "well-linked"

Thank you – corrected.

"Across different ecosystems and regions of the West, the causes of increasing fire activity vary, and thus so to .." - "to" should be "too"

Thanks for catching this typo. We have modified this sentence to read: “… and thus so too do potential management…”

Figure 2: the language:   
  
“…assume continued rates of burning between the 1984-2020 rate (highest FRP of 173 yr) and the 2010-2020 rate (lowest FRP of 68 yr)” is somewhat confusing. I would drop "lowest" and "highest", since the percent sites burned per century statistic on the left vertical axis clearly has lower values than the tree-ring derived FRP to which it is being compared to directly on the same graph.

Thank you for this suggestion, which we have integrated. The language of FRP is challenging, since higher values reflect less burning, and this suggestion alleviates that issue in this case.

Also, the text says percent, but are the numbers displayed on the left axis actually fractions?

Good catch: we have changed the values on the y-axis to truly be percentages.

Figure S2. "Paleo-fire sites are show as white circles" could be confusing to the wider PNAS audience. The authors should probably indicate the circles are showing all the lake sites where samples were used for this study, rather than sites of individual large paleofire events.

Good point. We modified this text to mirror the text in Fig. 1: “The 20 lakes with paleo-fire records are shown with white circles…”

Conclusion   
  
All in all, this is a great study and I am eager to see it in publication after some revision. I urge the authors to consider using the tree ring (fire scar) derived fire histories to put the recent decades in context in the same way they did with the lake data. If they have this data handy already, and I expect that they do, this would be a simple thing to do, and would greatly strengthen the paper. Also, they should be careful to correctly use the cited literature in providing context to their study results... the observed 2020 fire season is in close alignment with the simulation results from Westerling et al (2011).

Thank you for your comments and suggestions. While the finer-scale analysis of the tree-ring data may not be exactly what was intended, we believe this does improve the use of those data and appreciate the suggestion. We have also refined our reference and comparison to the Westerling et al. (2011) paper, and believe this has also improved the text.