We thank the reviewer for helpful and in-depth comments. We will address those in a revised version and believe that this will make the manuscript stronger. In this file, the original comments are copied with our responses in bold underneath.

Major Comments

The study by Zeng et al., titled "Geographically divergent trends in snowmelt 1 timing and fire ignitions across boreal North America," reported the influence of snowmelt timing on fire ignitions across the ecoregions of boreal North America. They found spatially divergent trends in early (late) snowmelt that led to an increasing (decreasing) number of ignitions in the northwestern (southeastern) ecoregions between 1980 and 2019. Early snowmelt is a proxy for early ignition but may also result in a cascade of effects from early desiccation of fuels and favorable weather conditions that lead to earlier ignition. This indicates that snowmelt timing is an important trigger for land–atmosphere dynamics.

Overall, this paper is logical and worthy of publication. However, minor revisions are required prior to publication.

Please note the following points.

1. The major limitation of this paper was the incorrect use of the term "snowmelt." While snowmelt is also associated with snow cover, the authors must understand that the majority of snowmelt occurs at 100% snow cover. The term "snowmelt" used in this paper is incorrect and should be corrected throughout the paper, as it is more accurate than the terms "snow disappearance date" or "snow disappearance timing." Otherwise, the readers may fail to understand the authors' analyses. I believe that the title also needs to be revised.

   We appreciate the thorough explanation and we will use the term snow disappearance in the revised manuscript.

2. The authors used surface data from ERA5 as the climate drivers of snowmelt and ignition timing, but ERA5 is a model estimate, and surface data are known to have bias. The bias is particularly large at high latitudes because of the lack of land-based observations and thus differs from ground-based data. It is necessary to demonstrate the validity of using ERA5 in this study with a reference.

   Thank you. We have added a paragraph in our method section demonstrating that the use of ERA5 reanalysis data is acceptable for high latitude regions. Line 226-227:

   "ERA5 reanalysis data have been used before in other studies that investigated extreme weather events and fires in the northern high latitudes (Gloege et al., 2022; Parisien et al., 2023). Furthermore, several of the ERA5 variables, such as precipitation, surface temperature, and specific humidity have been validated with ground observations over the study region (Alves et al., 2020)."

   Alves, M., Nadeau, D. F., Music, B., Anctil, F., & Parajuli, A. (2020). On the performance of the Canadian Land Surface Scheme driven by the ERA5 reanalysis over the Canadian boreal forest. Journal of Hydrometeorology, 21(6), 1383-1404.

   Gloege, L., Kornhuber, K., Skulovich, O., Pal, I., Zhou, S., Ciais, P., & Gentine, P. (2022). Land-Atmosphere Cascade Fueled the 2020 Siberian Heatwave. AGU Advances, 3(6), e2021AV000619.

Parisien, M. A., Barber, Q. E., Flannigan, M. D., & Jain, P. (2023). Broadleaf tree phenology and springtime wildfire occurrence in boreal Canada. Global Change Biology.

3. (4) Surface relative humidity was used to model snowmelt timing, but I do not consider it as a good indicator of atmospheric dryness because surface relative humidity varies significantly depending on temperature. Instead, I recommend using the surface saturation deficit. The model in Figure 6 should also be recalculated using the saturation deficit because temperature and relative humidity vary almost identically, which is not desirable as a variable in a hypothesized model.

The surface saturation deficit is in essence very similar to vapor pressure deficit that is often used in fire studies. Both variables quantify the difference between the available moisture in the air and the air's total moisture capacity at saturation. In response to your comments, we have considered an alternative model in which we modelled snow disappearance timing with vapor pressure deficit (VPD) rather than relative humidity (RH).

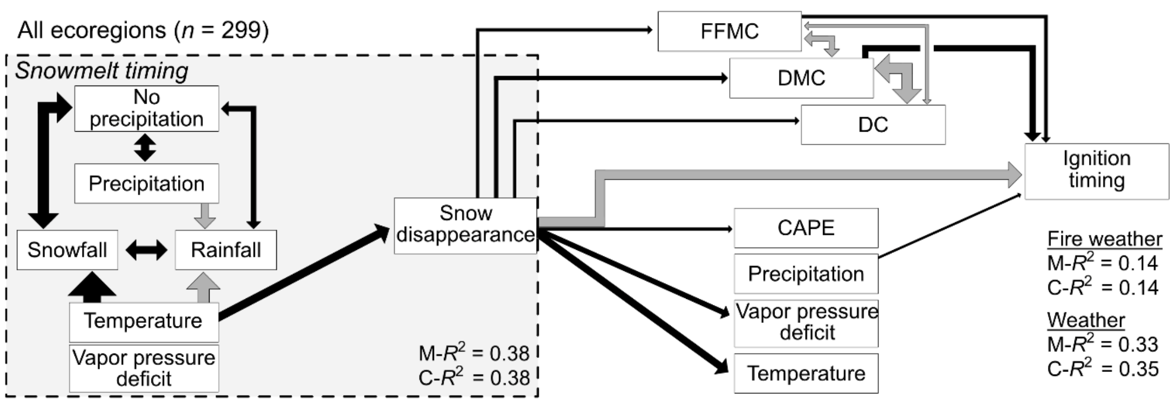

Fig. 1S The pSEM model as the initial model but relative humidity is substituted by vapor pressure deficit.

The overall model performance remained the same regardless of variable. The prediction of snow disappearance timing is similar using VPD or RH. The substitution of RH with VPD in prediction of ignition timing did not change the direction of convective available potential energy (CAPE), VPD, and temperature but slightly diminished their effect ($p > 0.05$). Only snow disappearance timing and precipitation remained significant contributors of earlier ignition timing ($p < 0.05$). Further, snow disappearance timing influenced VPD, similar as with RH. Part of this can be explained by the correlation between VPD and temperature as VPD was derived from RH and temperature. Therefore, we also ran a model in which temperature was excluded as it is also indirectly represented by the VPD.

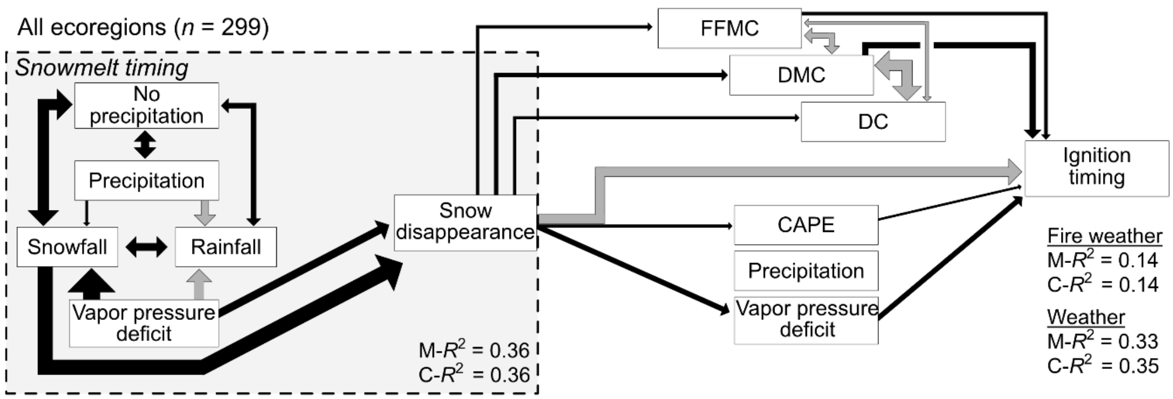

Fig. 2S The piecewise structural equation model as the initial model but relative humidity and temperature are substituted by vapor pressure deficit.

This resulted in similar results as our initial analysis, but the main difference is that RH and temperature were both represented through VPD.

We obtained similar results when modelling snow disappearance and ignition timing for ecoregions with earlier and later snowmelt timing when using VPD instead of RH (Figure S7 original manuscript).

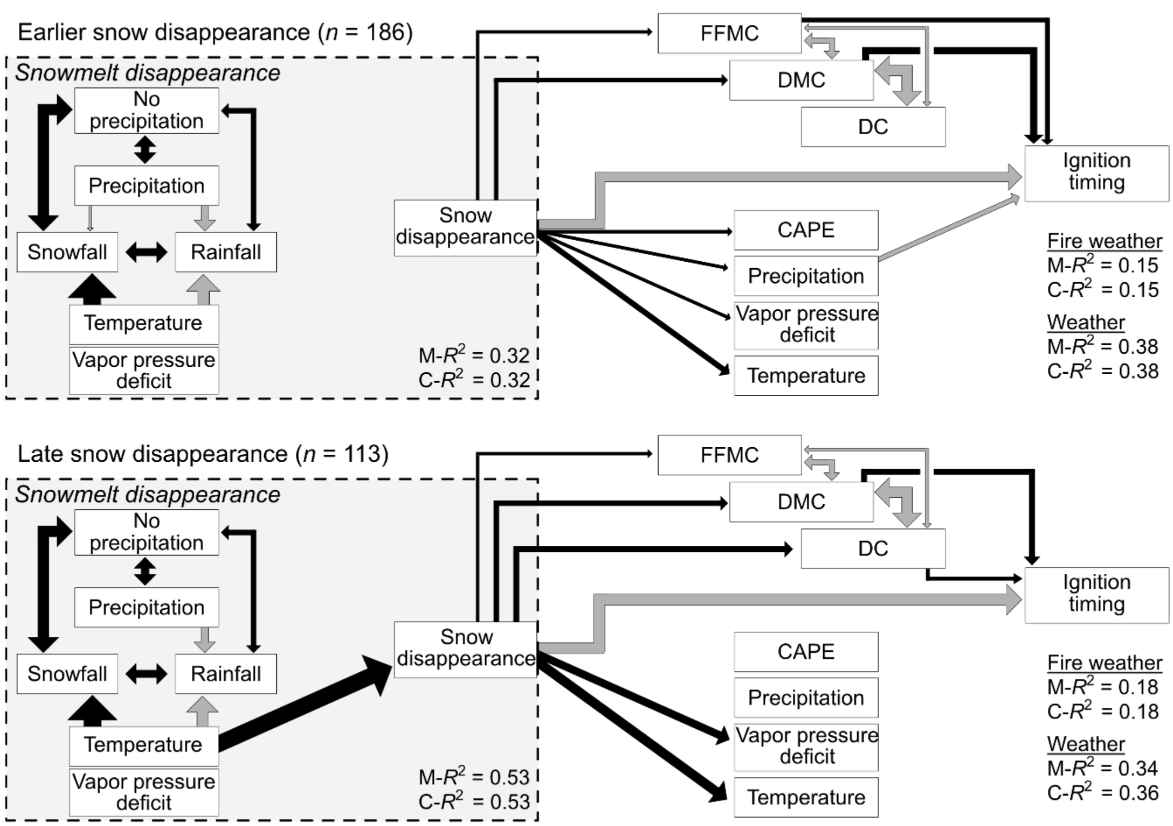

Fig. 3S The piecewise structural equation model for ecoregions with earlier and later snow disappearance timing as the initial models but relative humidity is substituted by vapor pressure deficit.

The inclusion of VPD diminished the influence of other weather variables on ignition timing (Fig. 3S). The only difference was that VPD influenced ignition timing insignificantly (p > 0.05) compared to the model with RH in ecoregions with later snowmelt timing (Fig. S7b original manuscript). The diminished effect of other weather variables was caused by the effect of VPD. We also run the models where temperature is excluded (Fig. 4S), which gave similar results as we observed for the model for all ecoregions (Fig. 2S).

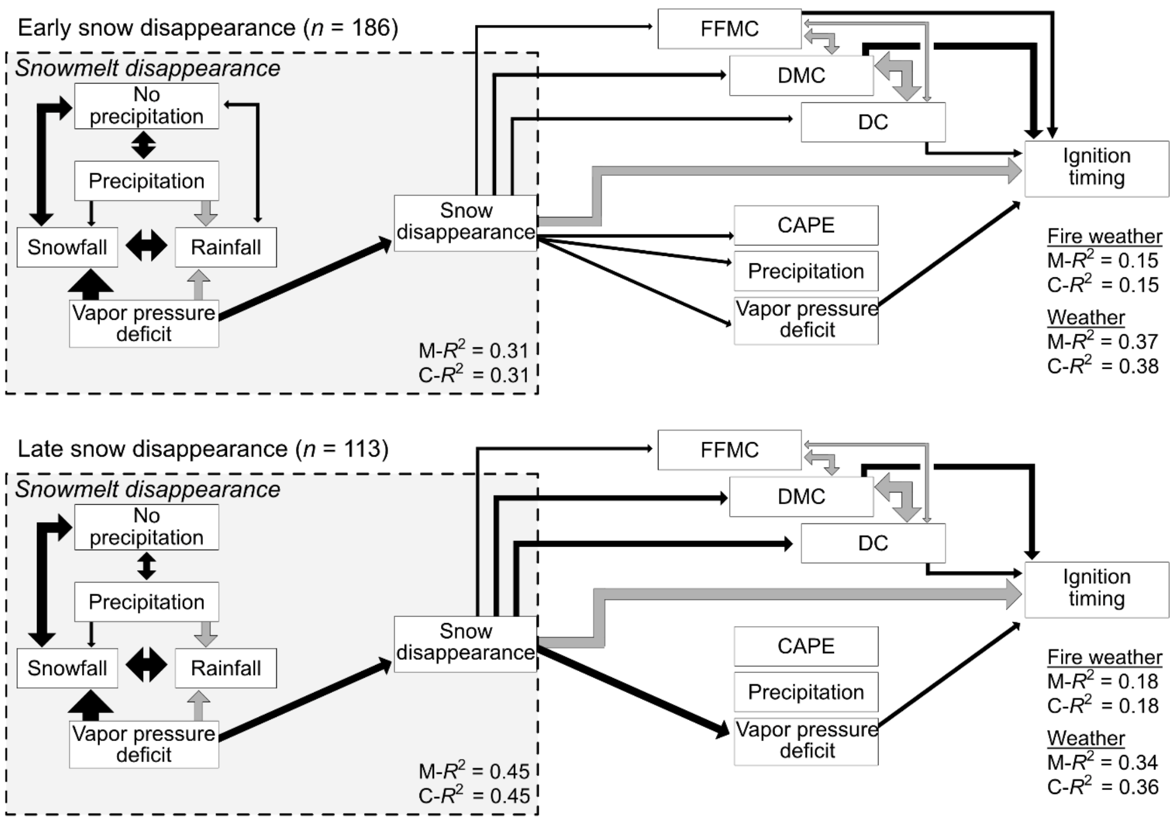

Fig. 4S The piecewise structural equation model models for ecoregions with earlier and later snow disappearance timing as the initial models but relative humidity and temperature are substituted by vapor pressure deficit.

In summary, we understand the reviewer's comment, but found that the inclusion of VPD did result in very similar model structure as the original models with RH, albeit with slightly lower performance. We will therefore keep our models with RH as the main analysis in the revised manuscript, and we will add the alternative models with VPD as supplementary figures.

4. Figure 4d shows that there was more variation than a positive correlation, but we cannot say that there was a positive correlation. I would like to have this figure removed or a rationale added to say that the correlation was strong for those with large variations.

We agree that there is large variation in the data. We will keep the figure 4d but will include a paragraph describing the correlation and variation we observed in the data:

"We also found that the trends in snow-free and fire season length tended to correlate positively with each other with a prolonging of the fire season of 0.9 days per decade for every day per decade increase in the snow-free season (p = 0.08) with large variation between ecoregions (the trends in

snow-free season lengths explained 45 % of the variation in the trends in fire season length) (Fig. 4d)."

5. I could not understand what is written in 3.4 the Ignition timing and fire size, or what is expressed in Figure 5. It is necessary to explain the view shown in Fig. 5 in more detail in the text.

   We understand that the section may not have conveyed the message clearly. We will restructure and rewrite this section for clarity in the revised manuscript.

   "Fire ignitions that occurred in the early fire season (20th percentile earliest ignitions) resulted in larger fires compared to fires that were ignited later in the season (80th percentile latest ignitions) in all ecoregions but the Alaska Tundra (Fig. 5B) and the Eastern Softwood Shield (Fig. 5P). This difference was significant in 8 out of the 16 ecoregions at $p < 0.1$ with the early ignited fires resulting in 77 % larger fires compared to fires ignited later in the season across the study domain (Fig. 5). On an ecoregional level, the early ignited fires grew between 30 and 600 % larger than late season fires. The largest difference in fire size between early ignited and late ignited fires were observed in the southern ecoregions (Table S9). Also, in these ecoregions, early-season fires accounted for more than half of the total burned area (Fig. 5 J, L, O and Table S9) whereas in the northern ecoregions early-season fires accounted for approximately one third of the total burned area. Across our study domain, the 20th percentile earliest ignited fires accounted for an average of 40.6 (standard deviation: 14.2) % of the total annual burned area (Table S9). Nonetheless, the largest early ignited fires on average were observed in the forested ecoregions of Alaska Boreal Interior (Fig. 5A), Taiga Plain (Fig. 5E), and Western Taiga Shield (Fig. 5G) (23 218 (standard deviation: 7 557) ha) compared to the other ecoregions (9 922 (standard deviation: 5 192) ha))."

   Also, we will add extra information in the caption of figure 5 in the revised manuscript:

   "Figure 5 Fire size as a function of ignition timing for all ecoregions (A-P). The 20th percentile day of ignition was set as threshold to discriminate between early (colored) and late season fires (gray). The colored dashed lines indicate the mean ignition timing and fire size for all early season ignitions while the gray dashed lines indicate the mean ignition timing and fire size for all late season ignitions. Significant difference between early and late ignited fires were indicated by * ($p < 0.1$) and ** ($p < 0.05$). Note the logarithmic scale for fire size."

Comments on specific points are provided below.

Line 35-36: After "... are heterogeneous across the Northern Hemisphere" in this sentence, we suggest citing Suzuki et al. (2020, doi:10.1002/hyp.13844).

We agree that the sentence needs references. We have added the Suzuki et al. 2020 and the Bormann et al., 2018 citations to show the regional differences across both Siberia and North America in line 37.

Suzuki, K., Hiyama, T., Matsuo, K., Ichii, K., Iijima, Y., & Yamazaki, D. (2020). Accelerated continental-scale snowmelt and ecohydrological impacts in the four largest Siberian river basins in response to spring warming. Hydrological Processes, 34(19), 3867-3881.

Bormann, K. J., Brown, R. D., Derksen, C., & Painter, T. H. (2018). Estimating snow-cover trends from space. Nature Climate Change, 8(11), 924-928.

Line 73: We recommend adding Bartsch et al. (2009, doi:10.1088/1748-9326/4/4/045021) to this citation.

The paper is a great addition to the sentence. We have added the reference to the revised manuscript.

Line 108-140: The entire section needs to be revised because snow disappearance timing, and not snowmelt timing, is mentioned here.

Thank you, we will revise the terminology manuscript and we will use the term snow disappearance timing in the revised manuscript.

Line 220-223: To demonstrate the validity of using ERA5 surface data, please cite the application papers on ERA5 surface data used in such analyses.

We agree and have will some text addressing this with adequate citations in the revision:

> ***"ERA5 reanalysis data have been used before in other studies that investigated extreme weather events and fires in the northern high latitudes (Gloege et al., 2022; Parisien et al., 2023). Furthermore, several of the ERA5 variables, such as precipitation, surface temperature, and specific humidity have been validated with ground observations over the study region (Alves et al., 2020)."***

Line 260: "andthe…" should be revised to "and the.."

Thank you for noticing this. We will change it in the revision.

Line 399-401: P may represent a narrow temporal window. Isn't it?

Yes, that could indeed be categorized as having a narrower temporal window comparable to Fig 3 A-I, K. We will change this sentence in the revised manuscript to:

"Ignitions occurred later and in a narrower temporal window in the northern ecoregions (Fig. 3 A-I, K) and Eastern Softwood Shield (Fig. 3 P) compared to the other southern ecoregions. Southern ecoregions also showed a more variable ignition timing at the beginning of the fire season (Fig. 3 J, L-P)"

Line 435-437: It does not appear consistent with Figure 4d.

See answer to point 4 of the major comments.

Line 447: "Boreal Interior, Taiga Plain, and Western Taiga Shield..." should be preferably revised to "Boreal Interior (Fig. 5A), Taiga Plain (Fig. 5E), and Western Taiga Shield (Fig. 5N)...".

Thank you. We agree for the readability this is better and will change it accordingly in the revised manuscript.