GENERAL COMMENTS

The authors have done an excellent job addressing the referees' comments/questions and this revised version of the manuscript is much improved. I only have a few minor suggestions below:

We thank the reviewer for their comments which have further improved the manuscript. We describe our detailed responses below. We respond below with original reviewer text in **black,** author comments in **blue**, and manuscript amendments given in **red** with the corresponding updated line number.

-L8: loss "and restructuring".

MAP was not linked to restructuring as we defined it (i.e. change in C_R and N_R and bulk density).

- L10: move "was" before "comparable".

Changed

- L13: this sentence is very difficult to follow, please rephrase.

It was rephrased.

LN13: These results reveal large quantitative differences in C and N losses between global regions and their linkage to the broad range of climate conditions within Fennoscandia.

- L16: please remove "residual"

Changed

-L23: "decomposition of centuries of litter additions resulting" sounds weird, please rephrase.

It was rephrased.

LN21: Low temperatures and often waterlogged soil conditions reduce the rate of decomposition relative to litter additions resulting in the buildup of thick layers of soil organic material where the majority of C is stored

- L28: remove "yearly", that is not correct

Removed

- L31: would not make more sense to talk here about restructuring of C&N stocks instead of "habitat"?

This sentence emphasizes that additional factors affect ecological function, i.e. habitat restructuring. Here this is stated as change in the bulk density (e.g. affecting porosity and therefore fluid flow), and plant communities (e.g. effects on rhizosphere habitat). Change in residual C and N was addressed in the immediately following sentence.

- L36: please update with more recent references .

We are not aware of any recent references that update the observations and predictions of increased boreal fire extremity, though there are many new references expanding on the consequence of these patterns. If the reviewer is aware of any adequate ones we would be grateful for the information, and would be happy to include these references in the revised manuscript.

- L40: please define here in brackets what you mean by “long” and “short” term.

We narrowed it down to mean processes measured inter vs intraannually.

LN39: Both long (variation measured interannually) and short-term (intraannual) processes…

- L251: It would be good to say “all plots showed SOME visible charring…”

Changed

-L256 (and others): please give the same decimals for the average and the SD values

Changed

- L375: could you please comment on why such big differences of your results with those by Granath et al? For instance, Where they focusing on specific locations burnt at great severities? Please comment a bit if possible.

Also, here and the introduction, you may want to include the data from this recent study where they also quantify C & N losses in an area burnt by the 2018 fires in Sweden: Kelly et al. 2021 GCB DOI: 10.1111/gcb.15721

Granath et al. sampled at regular intervals across the largest burn scar originating from the 2014 fires in Sweden, and therefore did not have within burn scar selection criteria for those plots. We could assume the differences are from the extremity of the fire (e.g. crown fire, large size). However, the results from the highest severity plot in Kelly et al. 2021 are within the most extreme of all fires within Sweden in 2018, with crown fire, yet are substantially lower (0.8 kg C m^{-2}). We were hesitant to cite the results from Kelly et al. because they use similar control plot matching as our study but with low replication/spatial coverage and unclear controls on prefire C estimation. We try to address these points in the following text amendment:

LN435: Interestingly, this study found average C stock reduction to be nearly equivalent to that estimated in a Scots pine crown fire, selected for its high severity, within the largest, most extreme wildfire occurring in Sweden during 2018 (0.80 kg C m^{-2}) (Kelly et al., 2021). In contrast, the largest wildfires occurring in Sweden during 2014 released an estimated 4.50 kg C m^{-2} from Scots pine dominated stands, which lies just above the 93rd percentile of C loss estimates within the 50 plot network of the current study (Granath et al., 2021). The extreme value of the 2014 fire was produced from an averaging of regularly spaced ground samples across large portions of the burn scar and found no relationship between extent of crown fire and C emission levels (Granath et al., 2021; Gustafsson et al., 2019). These combined observations from Sweden exhibit an emission heterogeneity encompassing the entirety of typical pan-boreal variation that cannot be explained by presence of crown fire, overstory species, fire size, and perhaps their combined effect on observable fire intensity. This emphasizes the need to increase the context of studies of individual fire events by further sampling over broader environmental gradients, which may thereby give greater predictive power to known, and yet to be observed, sets of drivers of boreal wildfire C emissions (Veraverbeke et al., 2021).

-L384: “due to simultaneous heating throughout the depth of the fuel bed”, not clear, please rephrase.

LN454: due to heating of lower portions of the fuel bed.

- L428: I know the authors have edited this sentence but I still think it needs to acknowledge clearer the possibility of N being in inorganic forms within the ash/mineral component of the charred layer.

LN498: In addition to these inorganic forms, N may be stored…

-L440: really outdated references, plenty of more recent ones also suitable here.

We now reference the recent review from Makoto and Koike

Makoto, K. and Koike, T.: Charcoal ecology: Its function as a hub for plant succession and soil nutrient cycling in boreal forests, EcologicalResearch, 36, 4–12, https://doi.org/https://doi.org/10.1111/1440-1703.12179, 2021.

- L446: “comparably” to what? Also, this sentence is super wordy, please rephrase.
“Comparably” was in reference to the earlier comparisons to other systems (e.g. north america), but it is distracting here and removed.

LN517: As a result, underestimation of C and N losses may have occurred via burnt plots being biased to a greater prefire fuel load than their paired controls (systematic error) rather than these differences being approximately random (random error).

- L455: “a clear preferential removal of C relative to N due to fire” The Introduction of this paper actually says the opposite.

Indeed, it was counter to what we expected. We clarify this.

LN528: Counter to expectation, the large shifts in N_R and the C:N ratio in the char layer relative to lower layers in burnt plots show a clear preferential removal of C relative to N due to fire.

- Section 4.3: this current study focused on the fire season of 2018 what is one of the two most extreme over the last decades due to drought conditions (as the authors explain). I believe this needs to be acknowledge in this section, as the weather conditions assessed here are not the “normal” for the boreal forest of Sweden (although they may be close to what is expected in the near future due to climate warming, what can be a very interesting angle, I believe).

This is directly addressed in the following line

LN551: Therefore, the study design distinguished climate driven effects on fire severity with only minimal restrictions on site selection (non-sloping, non-wetland) thereby providing results that are generally representative for Fennoscandian, non-wetland forests under similar drought conditions of summer 2018. However, with its strong correlations to drought indices, anomalies of temperature and precipitation as well as fuel charring and remaining direct effects on emissions, more remains to be understood about how MAT (and in addition, intraannual distribution of MAP) relates to the fire regime across the conditions of fire seasons of differing extremity.

- Fig. 1: please include scale.

This has been added.

- I still think having a couple of real pictures could be very good for the reader (it does not need to show the whole range of burn variability but a few examples to give an idea).

Agreed, we include 4 photos of what we could consider the most typical appearance of the plots.

LN313: Example photographs of 4 burnt plots are provided in Fig. 2.

Figure 2. Four separate burnt plots were photographed approximately 1 year after fire. Trees show charring of boles and enhanced exposure of roots due to fire-reduced organic layer height. A surface char layer is covered with a thin layer of new litter additions composed of mostly needles and patchy regrowth of understory.

GENERAL COMMENTS

(Comment) This study quantifies carbon and nitrogen consumption from 50 fires in boreal forests of Sweden. The novel dataset is an important contribution to the scientific community and will fill data gaps associated with fuel consumption from Eurasian boreal fires. This study assesses the influence of climate and fuel availability on C and N emissions and redistribution within boreal forest ecosystems. However, minor adjustments are required to make the overall presentation well-structured and clear.

We thank the reviewer for their overall positive assessment, and their comments which have further improved the manuscript. We provide detailed responses below with original reviewer text in **black,** author comments in **blue**, and manuscript amendments given in **red** with the corresponding updated line number.

- The authors used a “space-for-time substitution” approach in which measurements performed in an unburned (control) plot adjacent to a burned plot were assumed to be representative of prefire conditions. Although this approach has been proven useful for studying fire effects, it also has limitations as the heterogeneity between matched plots can be high. The manuscript explains how the authors tried to overcome these limitations while selecting control plots. However, more data on vegetation composition, structure, and soil type are needed to show that paired plots were indeed similar.

We now state that we used Swedish Forest Agency data to select only pine dominated stands of at least 30 years of age.

LN125: To further isolate fire effects in response to variation within a single ecosystem type, Swedish Forest Agency data on tree species was used to select only Scots pine (Pinus sylvestris) dominated stands. These stands were determined to be at least 30 years of age using data from the Swedish University of Agricultural Sciences (Dept. of Forest Resource Management, 2015).

Field measurements revealed 5 of these plots were actually spruce dominant, though the 3 plots with greater than 1% plot-wide canopy blackening were pine dominant. Therefore, spruce stems were not responsible for plot-wide canopy fire.

LN301: The 50 burnt plot overstories were largely dominated by pine with a percentage of spruce stems between 25-50% in 5 plots, between 50-75% in 3 plots and 2 plots with greater than 75%. Birch stems were less than 25% in 44 plots and between 25-50% in 6 plots, of which only 1 of the 6 was spruce dominant. All plots showed some visible charring of tree boles though only 3 plots had greater than 1% plot-wide canopy blackening. These plots were pine dominant, with 2 having less than 1% spruce while the other had 6 spruce of the 27 stems within the sampled area.

We clarify the separate usages of control and burnt plot bole diameters.

LN226: Bole diameters from the burnt plots were used to investigate the influence of overstory vegetation C, N and composition on C and N loss. Bole diameters from adjacent control plots provided plot-pair estimates of increased canopy blackening/browning and mortality as well as differences in species dominance, C and N to be tested for their influence on C and N losses over the 50 plot network.

We add that overstory and understory were not related to C or N in the soil within control plots. There was a relation of organic layer C and N and percentage spruce stems in control plots, though the regression was heteroscedastic. We did not investigate this relationship further because plot-pair differences in overstory C or N, understory coverage (prefire) and percentage spruce stems did not relate to overall estimates of C or N losses. While mismatch in vegetation may be responsible for error in specific plot pairs, we find no evidence that the error is significant across the 50 plot network.

LN314: Control plot soil C was not correlated to its overstory aboveground C (p= 0.959), understory C (p= 0.285) or their sum (p= 0.962). Replacing C with N also showed no significant correlations. However, the percentage of spruce stems in control plots was correlated to organic layer C (p= 0.033,r= 0.302) and N (p= 0.007,r= 0.378), though with noticeable heteroscedasticity in the regression fit. Regardless, individual plot-pair differences of estimated overstory C (p= 0.824), understory prefire plot coverage (p= 0.384), and percentage spruce stems (p= 0.971) were not related to C losses. The same is true for N. Therefore, there is likely no significant impact of plot-pair vegetation mismatch on the estimates made in this study over the 50 plot network.

Soil type in Sweden is relatively homogeneous across the landscape, typically podzols when in non-wetland areas (Olsson et al., 2009). Available soil type maps, however, are too coarse to have been used in plot selection (e.g. https://apps.sgu.se/kartvisare/kartvisare-jordarter-25-100.html). We assume the most important soil properties are the organic layer mass (which is the more flammable portion of the soil profile) and the drainage. Unfortunately, we had no measurements of prefire organic layer mass in the control plots and had to estimate it from control plots. However, drainage (for which we used TEM) was constructed from upscaling of national soil surveys and incorporated with topography (LN114). We believe this variable captures the most important effects of soil type on soil carbon build up and removal due to fire.

LN128: The relatively dry Swedish forested area is predominantly made up of podzols with distinct separation of a low C mineral layer from a high C organic layer above (Olsson et al., 2009). It is assumed the dominant properties of these layers that affect fire severity are soil drainage (TEM) and fuel loading (organic layer C). Additional soil property data sources were not available at high enough resolution and therefore no further classification of soil properties between and across plot-pairs was performed to determine site selection.

- The methods section is missing a detailed description of the different ecosystems sampled across Sweden and fire severity in studied plots. Field pictures could be useful.

See response above where we now further elaborate on our selection of ecosystem, i.e. non-wetland, pine dominant stands on podzols. We include 4 photos of what we could consider the most typical appearance of the plots.

LN313: Example photographs of 4 burnt plots are provided in Fig. 2.

Figure 2. Four separate burnt plots were photographed approximately 1 year after fire. Trees show charring of boles and enhanced exposure of roots due to fire-reduced organic layer height. A surface char layer is covered with a thin layer of new litter additions composed of mostly needles and patchy regrowth of understory.

- Due to the large number of statistical analyses conducted, the results at times quite difficult to follow as currently presented. The manuscript would greatly benefit from additional figures and tables with models results (regression coefficients, metric scores). Please also consider restructuring the methods section. The description of the so-called compartment compositional variables (CCVs) is unclear to me. Including a table listing all the different variables used in the regressions would facilitate the interpretation of the results. Some statistical techniques are used in the results section without adequate prior description in the methods section (quadratic regression, path analysis).

The methods section has been restructured to isolate and further improve the description of how the CCVs and ratios of C stocks are produced. The CCVs are also now tabulated in the manuscript.

LN238: During sample processing each ecosystem compartment was sorted by weight into categories to produce rough metrics of their composition and structure, here called compartment composition variables (CCVs). This sorting is described in the immediately following and summarized in Table 1. All samples were dried at 40◦C for at least 3 days. Dry moss/litter samples were weighed and visual estimates for percentage volume of needles, broad leaves, woody material, moss and lichen were multiplied by total weight to form CCVs. This broadly categorized, visual estimation, along with the assumption of equal category density, is meant to test for general effects of variation in proportions of surface fuel types on total soil fuel buildup and fire severity. CCVs for understory were determined by sorting the sampled understory plant material and measuring dried weights of the functional groups graminoid, forb, shrub, and pteridophyte. Mineral and duff samples were sieved to 2 mm and 4 mm respectively. The Weights of the coarse and fine fractions formed a pair of CCVs for each of the layers. CCVs for the overstory were collected as the individual aboveground and belowground categories from the allometric equations.

A new “Statistical model construction” section has been added to describe the reasoning behind the building of path diagrams. The main variables used in the diagrams are now tabulated. This section better describes the usage of CCVs to improve these models. The quadratic model used linear multiple regression as described in LN277. We state in the following text amendment that we test variable transformations in our linear regressions. We now include supplementary info with 6 charts of the main simple linear regression results as well as the 2 parabolas resulting from the C/N vs MAT relationships.

LN277: All regression analyses used the ordinary least squares approach to estimate a function for a single response variable based on linear combinations of the predictor variables and an intercept term. Simple regression was performed using the stats.linregress method from SciPy (Virtanen et al., 2020) providing significance (p), correlation (r), and slope (b). Multiple regression was carried out with the OLS class in the Python 3 statsmodels package (Seabold and Perktold, 2010) with models evaluated inorder of increasing Akaike information criterion (AIC) (Akaike, 1974). Standardized regression coefficients (β) were produced by normalizing all variables (i.e. converting z scores) before regression. When multicollinearity of explanatory variables in multiple regression was present, the condition number of the model provided by the corresponding OLS object was required to be less than 10 Alin (2010). Regression variables were also assessed in their squared, square-root, natural log, exponential and reciprocal transformations.

Multiple regression results were organized into path diagrams based on the assumption that regional climate (i.e. MAT and MAP at the km scale) and soil drainage (TEM) had a causal influence on the development of measured forest and fire attributes with negligible reverse effect. A clear causal direction of prefire forest properties influencing time-of-fire processes, which together influence C and N losses, is established by the temporal division of these measures across and within a discrete fire event. Therefore, variables in path diagrams are grouped into a causal order of climate/drainage to prefire to time-of-fire to postfire (i.e. C and N losses) properties. The main variables used in model construction are presented in Table 2.

Once causal models using the main variables were established, CCVs were added to the prefire variable category to test for their significance ($p < 0.05$) and increased explanatory power (decreased AIC) of C and N losses in multiple regression as well as their direct correlation to all model variables. This was done by using the original variables and again but replacing the moss/litter, understory and overstory compartments each with their first two principal components produced by the PCA class in statsmodels. This same analysis was performed using ratios of C and N stocks present in the sampled control plot compartments. These ratios were aboveground (overstory, understory) to belowground (soil), moss/litter to duff, understory plus overstory to duff and organic to mineral.

SPECIFIC COMMENTS
INTRODUCTION:

- L40-42: “Particularly, the strongest driver of per area emissions of C in boreal wildfires appears to be total fuel (i.e. potentially combustible organic material) which is strongly controlled by long term forest moisture (Walker et al., 2018, 2020).”

(Comment) Please consider using carbon combustion (area-normalized C emissions) in the rest of the manuscript instead of “per area emissions” as it will make it easier to read. Moreover, this statement has been shown only for boreal North America. Please make it clear that these findings relate only to this part of the boreal biome. Fuel availability is also mainly controlled by stand age and local drainage conditions (Walker et al., 2020)

“Per area C emissions” is changed to “area-normalized C emissions” where present. We have addressed the remaining concerns in the following amendment.

LN40: Particularly, in North American boreal forests, the strongest driver of area-normalized emissions of C in boreal wildfires appears to be total fuel (i.e. potentially combustible organic material) (Walker et al., 2018, 2020a, b). The accumulation of fuel itself has been found to be strongly related to stand age and long-term moisture levels (a factor of drainage conditions, evapotranspiration and inputs through precipitation and ground flow) (Walker et al., 2018, 2020a, b).

- L42-44: “However, in order for this fuel to be available to ignite and sustain fire, it must be both sufficiently dried and spatially arranged to be amenable to high heat and oxygen exposure during an active fire.”

(Comment) This sentence is not clear to me. Please consider rephrasing it. Fuels do not ignite anything but are ignited by humans or lightnings. What do the authors mean by “spatially arranged”?

We agree the dual meaning of “ignite” to both cause and succumb to fire is confusing and that “spatially arranged” is unclear. We rephrase with the following:

LN44: However, in order for this fuel to be available to be ignited and sustain fire, it must be both adequately dried and physically located within sufficient proximity to high heat and oxygen exposure during an active fire.

- L61-66: “Boreal C emissions due to a single wildfire can be calculated by multiplying total area burned by estimates of C emissions per area (French et al., 2004; van der Werf et al., 2017). While total area burned may be evaluated directly through remote sensing (Giglio et al., 2018; Ruiz et al., 2012), per area C emissions are generally derived from labor intensive field sampling which is extrapolated to the larger scale either directly or through weighting by remotely sensed data (e.g. topography, vegetation cover, aerosol density) or poorly constrained free parameters such as total fuel load (French et al., 2004; Soja et al., 2004; van der Werf et al., 2017; Veraverbeke et al., 2015; Kaiser et al., 2012)."

(Comment) This paragraph needs further clarification. Summarizing the different approaches used to model C emissions from fires in a single sentence is challenging and makes it difficult to follow. Please add the reference to Seiler and Crutzen (1980) while explaining how C emissions are estimated (product of burned area, fuel consumption (fuel loads × combustion completeness) and emissions factors). Field measurements are generally used to calibrate C consumption models in response to environmental variables but also fire-severity indices (e.g. differenced Normalized Burn Ratio). What do the authors mean by "free parameters"?

We agree that exhaustively describing approaches for estimating C emissions is difficult in a short space. Our intention is to highlight common methodologies that separate total burnt area from area-normalized emissions, since our study is concerned with meter scale patterns in addition to producing regional estimates. It is true that area-normalized emissions can be estimated as in Seiler and Crutzen, but it is not the only approach that can yield valuable results (also, we specifically do not use this approach). We rephrase in hopes to make these points more clear. "Free parameter" is a specific and common term used in modeling. We change the wording to just "parameters" to avoid confusion by being overspecific.

LN62: A general approach to estimating boreal C emissions due to a single wildfire can be taken by multiplying total area burned by estimates of C emissions per area (French et al., 2004; van der Werf et al., 2017). While total area burned may be evaluated directly through remote sensing (Giglio et al., 2018; Ruiz et al., 2012), estimating area-normalized C emissions entails a variety of approaches. These approaches are most often derived from the results of labor intensive field sampling or controlled burns which are extrapolated to the larger scale either directly or through weighting by remotely sensed data (e.g. topography, vegetation cover, aerosol density) or poorly constrained parameters such as total fuel load (French et al., 2004; Soja et al., 2004; van der Werf et al., 2017; Veraverbeke et al., 2015; Kaiser et al., 2012).

- L71: "C loss due to a group of Siberian boreal forest surface fires was found to be 0.88 kg C m-2 (Ivanova et al., 2011)"

(Comment) This study estimated C combustion from experimental fires. This should be mentioned because experimental fires may not represent wildfires conditions. Please consider adding results from Kukavskaya et al. (2017) that quantified C emissions from surfaces fires in pine forests of Central Siberia (1.65 ± 0.70 kg C m-2). See also Veraverbeke et al. (2021) for a review of C combustion estimates from field measurements in boreal regions.

This is a good point. We tried to compare estimates from similar forest types, but agree wider comparisons can be useful. We state these estimates are from experimental fire, include the Kukavskaya et al. estimates in the intro. We also include these estimates in the discussion.

LN74: C losses in surface fires in Siberian boreal pine forests were found to be 0.88 and 1.69 kg C m^{-2} under experimental and wild conditions, respectively (Ivanova et al., 2011; Kukavskaya et al.,2017). These are between one quarter to a half of what is typical in North American wildfire (3.3 kg C m−2) (Boby et al.,752010; Walker et al., 2020a).

LN432: Averaged total C loss was relatively low at 0.815±0.652 kg C m^{-2} (15.6%) compared to estimates from inland Alaskan black spruce stands (3.3 kg C m−2) (Boby et al., 2010). However, they were comparable to averaged losses from experimental Scots pine stands in Siberia (0.992 kg C m^{-2}) (Ivanova et al., 2011) though half that of surface wildfire in Siberian pine (Pinus sibirica) stands (1.69 kg C m^{-2}) (Kukavskaya et al., 2017).

- L90-92: “Space-for-time substitution (De Frenne et al., 2013) along with a control-impact design provided insight into the possible future conditions of Fennoscandian forests in a changing climate and fire regime”

(Comment) Do the authors refer to the comparison between burned and unburned plots? Have the terms “control-impact design” been used in other studies? If yes, please indicate the reference(s). Otherwise, I suggest replacing it with 'paired-sample' design (Boby et al., 2010).

We have replaced it with the suggested phrase and referenced Boby et al., 2010 and Granath et al. 2021

MATERIALS AND METHODS

- L109-111: “The first constraints on site selection were to avoid wetland or steeply sloping areas using prefire, topo-edaphic derived soil moisture data (TEM) provided by the Swedish Environmental Protection Agency (Naturvårdsverket, 2018) and elevation and slope data provided within the ArcGIS software environment.”

(Comment) What is the temporal and spatial resolution of the TEM product? Did the authors use a digital elevation model to retrieve elevation and slope? If so, please specify.

The resolution for TEM is 10 m. It will be made clearer that TEM is better interpreted as a metric of soil moisture potential or drainage and that climate (MAP and MAT) and drought (SPEI) variables intend to enhance estimates of temporal moisture levels. Yes, a digital elevation model was used. These issues are addressed with the following text amendment.

LN114: The first constraints on site selection were to avoid wetland or steeply sloping areas. 10 m resolution topo-edaphic derived soil moisture data (TEM) was provided by the Swedish Environmental Protection Agency (Naturvårdsverket, 2018). TEM was given as integer values ranging from 0 to 240 (in order of increasing moisture potential) and was based on the Soil Topographic Wetness Index (Buchanan et al., 2014) in areas where soil type information was available and on the two topographic indices Depth to Water (Murphy et al.,2007) and the Topographic Wetness Index (Beven and Kirkby, 1979) where soil information was unavailable.

These measures gave an estimate of soil drainage, which can be predictive of long term soil moisture (Walker et al., 2020b). Elevation data was provided by the Swedish Mapping, Cadastral and Land Registration Authority from a 50 m resolution digital elevation model (Lantmäteriet, 2021). Slope was calculated using the "slope" function within the ArcGIS software environment. Using these datasets all plots were selected to have below both 150 plot-averaged TEM units and 15◦ slope. This restricted the study to non-wetland ecosystem types, since wetlands tend to have markedly differing ecosystem functioning than relatively drier forested regions, and to retain focus on climate driven effects and their space-for-time substitution by reducing the effects of exogenous variables such as topography on models.

- L119-120: “Sentinel-2 infrared imagery was used to locate planned burnt plots near pixels showing the highest intensity within the mapped final burn scar perimeter.”

(Comment) Please indicate which bands and product types were used here to select burned plots (Top-Of-Atmosphere or Bottom-Of-Atmosphere reflectance products?). What does "intensity" mean here? Raw pixel value? Surface reflectance? Please specify.

The fires were mapped using the Normalized Burn Ratio (NBR) using bottom-of-the-atmosphere corrected bands 8 and 12 from Sentinel-2. “Intensity” here refers to the NBR pixel value. This is clarified in the following text amendments:

LN106: 50 burnt plots were selected from a pool of 325 fires identified during the summer 2018 period that had perimeters manually mapped by the Swedish Forest Agency. Mapping was produced from burn scars using the Normalized Burn Ratio (NBR) values based upon the Sentinel-2 bottom-of-the-atmosphere corrected bands 8 and 12.

LN138: The above mentioned Sentinel-2 imagery was used to locate burnt plots as close to the highest NBR pixel values within each of their mapped final burn scar perimeters while satisfying all other plot selection requirements.

- L120-121: “This gave greater certainty that the plots experienced a more developed fire effect rather than peripheral heating alone.”

(Comment) This sentence is not clear to me. What do the authors mean by "developed fire effect" and "peripherical heating"? Did they use a remotely sensed fire severity index such as dNBR (differenced Normalized Burn Ratio) to assess fire effects within burned plots? If so, please expand this section.

We agree this is unclear. The values we used were NBR (viewed within and outside the burn scar). We did not use dNBR, but see how dNBR could have been useful. Because we did not sample the entire burn scar we had to make a judgment of which portions to sample. While we did not compare NBR values between burn scars, we decided that sampling near the highest values within each burn scar would add valuable consistency to plot selection. This hopefully avoids seeing differences in fire effects by, for example, sampling one scar near the perimeter (where reduced emissions may occur due to the fire “dying out” there) and one near a more intensely burning inner region. This is discussed in the following amendment:

LN138: The above mentioned Sentinel-2 imagery was used to locate burnt plots as close to the highest NBR pixel values within each of their mapped final burn scar perimeters while satisfying all other plot selection requirements. This method intended to add consistency to plot selection within the larger burn scars by placing sampled regions within the most developed portions of each fire. Thereby, the potential for observed differences in fire effect between burn scars due to varied spatial proximity to the fire periphery is assumed to be reduced. NBR values were otherwise not used for comparison across separate burn scars. Visual and infrared image processing was performed in May 2019 through the brandkarta web application provided by the Swedish Forest Agency. No criteria for fire severity were used for plot selection outside of their detectability using the above methods and data sources.

- L131-133: “Stand appearance and age were examined with historic, visual images provided by the Swedish National Land Survey verifying time since last disturbance had been at least 30 years for plot pairs and that stand structure between plot pairs appeared physically connected over this period.”

(Comment) What kind of images were used to assess stand structure? Aerial or satellite images? Please specify. Please consider rephrasing the last part of this sentence. It is unclear what "physically connected" means here.

They were mostly aerial photos, some as far back as 1950. But satellite images were also used occasionally. The idea was not to produce a quantitative metric for stand structure but to get a visual confirmation that stands were intact for at least 30 years back. By physically connected we mean just having a visual confirmation that the plots are not interrupted by artificial structures such as roads and not disturbed by disturbances such as logging or fire. This is better explained in the following amendment:

LN154: As a complement to the quantitative overstory data, stand appearance and age were examined with aerial and satellite images provided by the Swedish National Land Survey. This gave quick visual verification that plot pairs, and the area between them, had not been disturbed by fire or logging over the past 30 years and that stand structure appeared homogeneous and uninterrupted by roads or other artificial structures.

- L134-135: “Due to their documented effects on C emissions (Walker et al., 2018), long and short term approximations of moisture were considered in this study. Long term moisture approximations were separated into a topo-edaphic component (TEM) and climatic component (MAP and MAT). Short term moisture was approximated over the first 6 months of 2018 using the Standardized Precipitation-Evapotranspiration Index (SPEI) with data from the SPEIBase (Beguería et al., 2019) (i.e. spei06 2018-06) to capture the extended desiccation process leading up to each fire. SPEI was also compared to summer 2018 anomalies in temperature and precipitation, i.e. the difference in the 2018 June, July, and August average of these values from those during the same months averaged over the period from 1961 to 2017.

(Comment) It is not clear why the authors defined the long- and short-term changing factors as “approximations of moisture”. I would suggest replacing these terms because they are ambiguous. Further details about the different products used in this study are needed (TEM, MAT, MAP, SPEIBase) including temporal and spatial resolutions. The authors mentioned documented effects from Walker et al. (2018), but mainly short-term fire characteristics (date of burn, fire weather indices) were assessed as potential drivers of C emissions in black spruce stands of Northwest Territories (Canada). If the authors are aware of previous studies that used the same products to evaluate their influence on fire-induced C emissions, please provide the reference(s). The last sentence is not clear. It seems that the authors compared SPEI, a drought index, with temperature and precipitation anomalies, but what does it mean by “compared”? Did the authors perform regression? Please specify.

It was meant that instantaneous moisture levels are consistently fluctuating and they need to be approximated over some time interval (similar to how MAT is an approximation of typical instantaneous temperature levels). We have rephrased this to reduce ambiguity.

LN158: Due to their documented effects on C emissions Walker et al. (2018), metrics related to both short-term and long-term soil moisture conditions were considered in this study.

TEM was given at 10 m resolution.

LN114: Topo-edaphic derived soil moisture data (TEM) was provided at 10 m resolution by the Swedish Environmental Protection Agency (Naturvårdsverket, 2018).

MAT and MAP were given at 4 km resolution.

LN136: MAT and MAP values were derived from daily values averaged over the period 1961-2017 that were extracted from a 4 km resolution hydrological modeling dataset provided by the Swedish Meteorological and Hydrological Institute..

We more specifically state that TEM is analogous to “drainage” metrics previously observed to relate to fire emissions.

LN160: TEM was considered to be representative of the soil drainage which has been observed to relate to C emissions in separate study (Walker et al. 2018).

Due to limitations on information on timing of the 2018 fires, data on many fire weather conditions commonly used to predict fire activity was unavailable. SPEI is commonly used to assess drought, and drought indices (including SPEI) have been related to fire activity in boreal Eurasia. These two concepts we now cite. We are unaware, however, of SPEI relating directly to C emissions in this region. The MAT and MAP anomalies were used to replace more instant fire weather parameters, and were tested with regression for their correlation to SPEI and C and N losses.

LN163: The shorter term moisture balance of summer 2018 was assessed with the Standardized Precipitation-Evapotranspiration Index (SPEI) due to its common use for this metric and observed relationship to fire activity in boreal Eurasia (Chen et al., 2021; Ponomarev et al., 2016). SPEIwas calculated over the first 6 months of 2018 at 0.5◦spatial resolution data from the SPEIBase (Beguería et al., 2019) to capture the extended desiccation process leading up to each fire. Due to limited temporal information on 2018 fire activity, common fire weather metrics were unavailable and were instead approximated by summer 2018 anomalies in temperature (∆MAT) and precipitation (∆MAP), i.e. the difference in the 2018 June, July, and August average of these values from those during the same months averaged over the period from 1961 to 2017. These two metrics were used in regression for direct comparison to SPEI and to explain C and N losses.

- L151-152: “Each compartment was further sorted by weight into sets of characteristic components, here called compartment compositional variables (CCVs), which are to be specifically defined for each compartment in the following sections.”

(Comment) What exactly are the CCVs? It is not clear what this refers to from the following subsections. Please provide further details or examples. It would be worth adding a table (in the supplementary materials) to list all the CCVs used in this study.

- L164-165: “Four mineral soil samples were taken using a 3 cm diameter corer at four corners of a square each 15 m from the plot center.”

(Comment) Please indicate what type of corer was used to extract mineral soil samples. What was the purpose of collecting mineral soils since they were not likely to burn?

The corer was a 40 cm long, 3 cm diameter gouge auger corer.

LN197: Four mineral soil samples were taken using a 3~cm diameter, 40~cm long gouge auger corer at four corners of a square each 15~m from the plot center.

The purpose of sampling the mineral layer was to have a near complete estimate of C&N stocks in the stands and to have confirmation that there is no change in C or N in the mineral layers due to heating or vertical transport.

- L166-169: "Duff samples were taken near the mineral cores by excavating four soil volumes, trimming the mineral and moss/litter layers off the bottom and top of the volumes respectively, and then gently cutting right angles with sharp scissors to measure the 3 dimensions in millimeters (collected samples were at least 400 cm3 each)."

(Comment) Please indicate how the "soil volumes" were extracted. It is not clear from this paragraph whether the authors collected soil layers on the same profile (duff samples near the mineral cores, moss/litter layers trimmed from the soil volume).

An oversized block was dug (about 25x25cm^2) with a shovel from the same plot corners as the mineral samples. The moss/litter and mineral were discarded.

LN199: Duff samples were collected at the same plot corners as the mineral cores by excavating four soil volumes of approximately 25 X 25 cm^2 area, trimming and discarding the mineral and moss/litter layers off the bottom and top of the volumes respectively, and then gently cutting right angles with sharp scissors to measure the 3 dimensions in millimeters (collected samples were at least 400 cm^3 each).

- L178-179: "Individual tree bole diameter (sampled at 130 cm height above the forest floor) and species were recorded within each plot perimeter for all trees of at least 5 cm diameter at measurement height."

(Comment) Why did the authors not measure trees smaller than 5 cm in diameter? These trees are more likely to burn, thus contributing to carbon emissions.

We decided against estimating C emissions from the trees for reasons described throughout the manuscript (e.g. low observation of damage, low percentage C loss from trees in other forests with high tree damage). We observed very few trees less than 5 cm in the plots and assumed they had negligible contribution to stand C and would not work accurately with the allometric equations we used which were developed for more mature trees. However, we do not have a quantitative measurement of their C. We agree their measurement would have better substantiated these assumptions. Potential "trees" such as birch were commonly present in their shrub form and included in understory C estimates.

LN212: Trees less than 5 cm were uncommon and assumed to contribute negligibly to biomass and C emissions.

- L179-181: “If a fallen tree was charred only on its lower (in standing orientation) portions, it was deemed standing during fire ignition and its measurements were included if its base was within plot boundaries.”

(Comment) It seems that the amount of dead and downed woody debris and its consumption by fire was not quantified in the sampled plots. Yet it plays a fundamental role in C storage, influences other nutrient cycles, and controls forest fire behavior. Can the authors provide more information about this?

Yes, it is true that downed woody material can have these influences. We tested some documented survey techniques for larger downed woody debris, but did not develop confidence that they would apply well in our forests. This is because Swedish forests typically have a low abundance of dead wood on top of the forest floor with variation that is difficult to detect and quantify. We therefore assumed we would introduce large amounts of subjective error without substantial increases in the overall C loss estimates. We did however find it easy to quantity finer woody material mixed in with the moss/litter layer and so incorporated the so-called CCVs to test for the “heaviness” of the soil fuel load on C emissions. We did not test whether moss/litter woody material amount correlates to aboveground downed woody debris.

We clarify these in the methods section and comment in the discussion how woody material may contribute to fire characesterics and merits further study.

LN181: While larger dead wood lying on top of the forest floor (woody debris mixed in the moss/litter layer was sampled in this study) can contribute to C andN stocks and their losses due to fire, this material is typically of low prevalence in Sweden, difficult to accurately measure andlacks standard methodology to estimate its consumption by fire (Jonsson et al., 2016). Therefore, focus was retained on the variation of the larger and more precisely measurable ecosystem C and N pools in soil and living vegetation.

LN541: Of particular interest would be further investigation of the potential effect of dead wood structure on C and N stocks and fire severity, which remains understudied in boreal wildfire research.

- L190-192: “Only bole diameters from the burnt plots were used to investigate the influence of overstory vegetation on C and N loss, while bole diameters from adjacent control plots were ignored.”

(Comment) Since tree diameters were not measure in control plots, how did the authors make sure that stand characteristics were similar between paired burned/unburned plots?

We had written unclearly. Control plot diameters were measured, but their direct relation to C and N loss was ignored. This is clarified in the following amendment:

LN226: Bole diameters from the burnt plots were used to investigate the influence of overstory vegetation C, N and composition on C and N loss. Bole diameters from adjacent control plots provided plot-pair estimates of increased canopy blackening/browning and mortality as well as differences in species dominance, C and N to be tested for their influence on C and N losses over the 50 plot network.

- L194-198: “To reduce sampling error due to small areal coverage of the plot, the sample patches were chosen by performing transects through the entire plot noting visual estimates of coverage and proportions of plant functional groups (i.e. graminoids, forbs, shrubs, and pteridophytes) which were applied in selecting representative patches for the portion of the plot that was vegetated, which was always all non bare rock surface. These values were applied to a visual estimate of non bare rock surface area of the burnt plots as an approximation of its prefire understory coverage.”

(Comment) It is not clear how the transects were performed. Were fractional coverages estimated in vegetation quadrants or at the plot level? Please consider rephrasing this section.

We walked back and forth across each quadrant to survey it completely. We sampled each quadrant individually based on its corresponding assessment. We then aggregated the samples and applied that result to a plot wide coverage estimate. This is made more clear in the following:

LN231: To reduce sampling error due to their small areal coverage of the plot, the sample patches were chosen by performing 4 quadrant-wide surveys noting visual estimates of coverage and proportions of plant functional groups~(i.e. graminoids, forbs, shrubs, and pteridophytes). These were applied in selecting representative patches for the portion of the quadrant that was vegetated, which was always all non bare rock surface. The conglomerated biomass density and composition for the 4 samples were applied to the visually estimated non bare rock surface area of an entire burnt plot to approximate its prefire understory coverage.

- L200: “All samples were dried at 40 °C for at least 3 days.”

(Comment) Were sampled dried to constant mass? If so, please mention it.

We did not measure mass during the drying process but assumed that samples had achieved constant mass after this period.

- L227: “When C and N stocks were described as losses their distribution was negated.”

(Comment) This statement is not clear. Please consider rephrasing it.

We hope this rephrasing adds clarity:

LN274: When described as losses, C and N stock differences between control and burnt plots were expressed as a positive number.

- L240-242: “The effects of C and N stock distribution amongst forest compartments were tested by entering the per plot ratios of the sums of different combinations of compartment C and N stocks into regression analyses both directly and to improve all models presented in the results section.”

(Comment) It is difficult here to understand what the authors wanted to test. The authors mentioned “different combinations”, but they are not clearly explained. Please provide details about the statistical tests performed in this section.

Agreed. This issue is addressed within a new subsection within the methods called “Statistical model construction”. The ratios were treated in the same analysis as the CCVs and are more specifically defined in the following:

LN292: Once causal models using the main variables were established, CCVs were added to the prefire variable category to test for their significance ($p < 0.05$) and increased explanatory power (decreased AIC) of C and N losses in multiple regression as well as their direct correlation to all model variables. This was done by using the original variables and again but replacing the moss/litter, understory and overstory compartments each with their first two principal components produced by the PCA class in statsmodels. This same analysis was performed using ratios of C and N stocks present in the sampled control plot compartments. These ratios were aboveground (overstory, understory) to belowground (soil), moss/litter to duff, understory plus overstory to duff and organic to mineral.

RESULTS

- L249-251: “The 50 burn plot overstories were largely dominated by pine with a percentage of spruce stems between 25-50% in 5 plots, between 50-75% in 3 plots and 2 plots with greater than 75%. Birch stems were less than 25% in 44 plots and between 25-50% in 6 plots, of which only 1 of the 6 was spruce dominant.”

(Comment) This could also be included in the "Materials and Methods" section in a site description paragraph with information on understory vegetation and soil types.

We expanded upon vegetation characteristics within the methods section as described above. Because we dedicated much of the methods section to how we performed onsite plot measurements we feel this specific information is better suited as “Result”.

- L261: 3.2 C and N losses and restructuring

(Comment) Please add some numbers about C and N losses in this subsection. The quantification of C and N losses from Swedish boreal fires is supposed to be one of the main objectives of this study. However, estimates are only provided in the "Discussion" section.

These are added.

- L270-272: "About three quarters of the moss/litter C was removed from burnt plots, comprising about half as much as the total amount of C that was removed from the duff layer."

(Comment) Please provide more specific percentages of C consumption in the different soil organic layers.

These are added.

- L294-295: "Fire-induced increases in bulk density of the soil layers counteracted C and N loss due to these depth changes."

(Comment) This statement is not clear. How might post-fire changes in bulk density offset direct C emissions from fires? The term "counteracted" is not appropriate and should be replaced.

It was meant that in the equation calculating C stocks the decrease in depth is counteracted by an increase in bulk density, which mitigates the overall change in C. But we agree this leads to vagueness when thought of outside the equation and the paragraph works better with the omission of this statement.

LN355: Bulk density of both the duff and moss/litter layers increased significantly and, along with producing a dense char layer, fire had a strong densifying effect on the organic layer (Fig. 4b). No significant change in bulk density occurred in the mineral layer due to fire.

- L317-319: "Multicollinearity between the organic layer C:N ratio and CO ($p = 0.003$, $r = -0.411$, $b = -1.96$ kg C m-2) and NO ($p < 0.001$, $r = -0.578$, $b = -92.2$ kg N m-2) did not produce a high condition number in these models (1.55 for C, 1.93 for N) suggesting they are robust to these covariations (Alin, 2010)."

(Comment) The methodology used to derive condition numbers has not been described before. Please indicate how these numbers were obtained.

We used the OLS class from the python3 statsmodels package to do multiple regression. It had a condition number output. This is clarified in the following amendment in the methods section:

LN292: When multicollinearity of explanatory variables in multiple regression was present, the condition number of the model provided by the corresponding OLS object was required to be less than 10 (Alin,2010).

- L322-326: “CCVs and distribution of C and N stocks amongst control plot compartments could not improve these models explaining CO and NO losses in multiple regression with CO and NO respectively nor could they significantly explain the build up of organic layer fuel in control plots or production of char C or N. Relations either did not suitably meet the basic assumptions of regression, were deemed to be confounding or lacked supporting causal mechanism and were at a high risk of omitted-variable bias.”

(Comment) This paragraph is difficult to follow. More information is needed to describe the multiple regression and the combination of variables used here.

How the CCVs were used is clarified in the new “Statistical model Construction” section.

LN292: Once causal models using the main variables were established, CCVs were added to the prefire variable category to test for their significance ($p < 0.05$) and increased explanatory power (decreased AIC) of C and N losses in multiple regression as well as their direct correlation to all model variables. This was done by using the original variables and again but replacing the moss/litter, understory and overstory compartments each with their first two principal components produced by the PCA class in statsmodels. This same analysis was performed using ratios of C and N stocks present in the sampled control plot compartments. These ratios were aboveground (overstory, understory) to belowground (soil), moss/litter to duff, understory plus overstory to duff and organic to mineral.

- L327: 3.4 Climatic drivers of fire-induced C and N loss

(Comment) There is no mention of applying a quadratic model fit to the variables in the methods. Plots and tables with regression coefficients, p and R2 values would be extremely helpful. This could be included as supplementary materials. Similarly, there is no clear description of applying a path analysis in the methods, although there are two figures showing results from this statistical approach. More details are needed to explain path analysis including the different assumptions on which this technique is based. Are all the relations described in both path diagrams (figures 4 and 5) statistically significant? If so, please specify (in figure captions for example).
Why did the authors not instead use structural equation modelling instead, which overcomes many of the limitations of path analysis, including non-linear relationships?

The methods described linear multiple regression (LN277). The quadratic fit is just linear multiple regression with MAT and MAT^2 as explanatory variables. The resulting model can then be plotted in lower dimensions on 2 axes with C loss as a function of MAT (i.e. $C(MAT) = b_1MAT+b_2MAT^2+c$), which was a negative parabola. We clarify that we used variable transformations within linear regression. We also remove the term “quadratic fit” and defer the plotting to a separate sentence and direct to plots in the supplementary information to aid in visualization.

LN368: An even stronger correlation was found between control plot organic layer C and N stocks (here abbreviated C_o and N_o) and estimated losses of C_o ($p < 0.001$, $r = 0.736$, $b = 0.762$) and N_o($p < 0.001$, $r = 0.653$, $b = 0.665$) (Supplementary Fig. 3, 4).

LN284: Regression variables were also assessed in their squared, square-root, natural log, exponential and reciprocal transformations.

LN387: MAP had a directly proportional relation to both C_O ($p < 0.001$, $R^2 = 0.465$, $b = 0.0194$ kg C m^{-2} mm^{-1}) and N_O ($p = 0.012$, $R^2 = 0.352$, $b = 0.000416$ kg N m^{-2} mm^{-1}) losses (Supplementary Fig. 5, 6). In multiple regression, MAT and MAT^2 explained C_O ($p = 0.008$, $R^2 = 0.186$) and N_O ($p = 0.002$, $R^2 = 0.233$) loss. Using these model fits, C_O and N_o losses were plotted as functions of MAT as negative parabolas both with a peak near 4◦C (Supplementary Fig. 7, 8 . In multiple regression of the 3 variables the MAT and MAT^2 terms lost significance and MAP was the dominant explaining factor of C_O and N_O losses. MAT and MAP were not significantly related in simple regression ($p = 0.829$) however MAT and MAT^2 in multiple regression explained MAP ($p < 0.001$, $R^2 = 0.407$). Using these results, plotting MAP as a function of MAT again showed a negative parabola peaking near 4◦C. This suggests that the direct climate dependence of C_O and N_O losses were driven by MAP, with MAT relating indirectly through its association to MAP.

We did not use any techniques exclusive to path analysis but we used causal assumptions to organize the regression results in path diagrams. These assumptions are elaborated upon in the following amendment and tabulated in a new Table.

LN286: Multiple regression results were organized into path diagrams based on the assumption that regional climate (i.e. MAT and MAP at the km scale) and soil drainage (TEM) had a causal influence on the development of measured forest and fire attributes with negligible reverse effect. A clear causal direction of prefire forest properties influencing time-of-fire processes, which together influence C and N losses, is established by the temporal division of these measures across and within a discrete fire event. Therefore, variables in path diagrams are grouped into a causal order of climate/drainage to prefire to time-of-fire topostfire (i.e. C and N losses) properties. The main variables used in model construction are presented in Table 2.

All arrows in the path diagrams are statistically significant and that is now mentioned in the figure captions.

We considered many tools from structural equation modeling, and specifically path analysis, as well as other models (e.g. mixed effects, linear and nonlinear). However, within our study design we considered them to be unnecessary and to subtract from presenting our results in an as interpretable and comparable way as possible. We had no reasonable a priori justification for testing any specific nonlinear statistical methods and did not wish to risk spurious results by retroactively producing them from our acquired data.

- L350-352: “The organic layer C:N ratio in the N model was able to replace the direct effect of MAT, however with decreased model fit and inflation of variables which is suggestive of a confounding influence of the organic layer C:N ratio on MAT and NO loss. Again, CCVs and fuel distribution could not improve either model.”

(Comment) This paragraph is difficult to follow, especially because there are no numbers to rely on. It is unclear what the authors mean by “inflation of variables”. The authors refer to many models in the results section that are not adequately described.

Agreed. The text was meant to explain why C:N was included in the C model but not the N model. Adding C:N to the N model increased Akaike information criteria and the p values of MAT and C:N. Therefore it was excluded. The text is revised.

LN410: Adding the organic layer C:N ratio to this model increased the AIC and inflated the p values of itself and MAT to greater than 0.15, which is suggestive of a confounding influence of the organic layer C:N ratio on MAT and N_O loss. Again, CCVs and fuel distribution could not improve either model.

DISCUSSION

(Comment) The influence of short-term weather patterns on C emissions, as assessed by the SPEI, is not really discussed in this section. However, fire weather conditions dictate flammability and are often used to predict C emissions throughout the boreal forest. It might be interesting to elaborate on this point.

That SPEI was used in part as a substitute for commonly used , yet unattainable fire weather indices which is now elaborated upon in the methods.

The paragraph at LN543 discusses the effect of fire season drying on fuel availability and how these relate to fire weather. It is stated that the SPEI is used as a metric of these for short-term moisture levels.

LN162: The shorter term moisture balance of summer 2018 was assessed with the Standardized Precipitation-Evapotranspiration Index (SPEI) due to its observed relationship to fuel drying and fire activity in boreal Eurasia (Chen et al., 2021; Ponomarev et al., 2016). SPEI was calculated over the first 6 months of 2018 at 0.5◦spatial resolution within the SPEIBase data source to capture the extended desiccation process leading up to each fire (Beguería et al., 2019). Due to limited temporal information on 2018 fire activity, common fire weather metrics were unavailable and were instead approximated by summer 2018 anomalies in temperature (∆MAT) and precipitation (∆MAP), i.e. the difference in the 2018 June, July, and August average of these values from those during the same months averaged over the period from 1961 to 2017. These two metrics were used in regression for direct comparison toSPEI and to explain C and N losses.

REFERENCES

(Comment) Suggest adding the following references:

Kukavskaya, E. A., Buryak, L. V., Kalenskaya, O. P. and Zarubin, D. S.: Transformation of the ground cover after surface fires and estimation of pyrogenic carbon emissions in the dark-coniferous forests of Central Siberia, Contemporary Problems of Ecology, 10(1), 62–70, doi:10.1134/S1995425517010073, 2017.

Seiler, W. and Crutzen, P. J.: Estimates of gross and net fluxes of carbon between the biosphere and the atmosphere from biomass burning, Climatic Change, 2, 207–247, https://doi.org/10.1007/BF00137988, 1980.

Veraverbeke, S., Delcourt, C. J. F., Kukavskaya, E., Mack, M., Walker, X., Hessilt, T., Rogers, B. and Scholten, R. C.: Direct and longer-term carbon emissions from arctic-boreal fires: A short review of recent advances, Current Opinion in Environmental Science & Health, 23, 100277, doi:10.1016/j.coesh.2021.100277, 2021.

TECHNICAL COMMENTS

(Comment) Please find attached pdf with minor suggestions directly on the manuscript.

Thanks very much for the detailed attention. These suggestions were very helpful and incorporated in a new version of the manuscript.