Referee #2

The following comments pertain to the manuscript “Yukon-Kuskokwim River Delta 2015 fire burn depth measurements and unburned soil and vegetation organic matter and carbon content collected in 2019”. Overall, I think the findings presented in this manuscript are of high scientific importance and I applaud the authors for conducting this work. Having said that, I have a few major issues with this manuscript. The first one concerns the language of this manuscript. If my understanding of this manuscript is correct, the findings presented here stemmed from field data collected in a single burn scar in YKD. While these findings are important in their own rights, the authors (mostly in the results and discussion sessions) made a lot of statements that are obviously overly strong. Tundra wildfires, while being overall understudied, vary substantially based on climate, terrain, species composition, etc. As a result, while this study shows that the YKD fire that it looked into had a similar emission rate to the Anaktuvuk River Fire (ARF), they still represent two cases out of many more tundra fires, many of which are much less severe than the ARF. Therefore, the authors should be very careful when they make statements concerning “tundra fires”. You can indicate that the YKD fire and the ARF likely represent the upper level of the impacts of tundra fires (in terms of carbon emission and radiative forcing), but you can’t just hint that these are representative situations.

My second major issue with this manuscript is the fact that while it has a substantial discussion session, it fails to discuss the sources of uncertainty introduced by the methods that were used. For example, this study used dNBR as the indicator for burn severity, however, there have been studies that show that dNBR may not be a very good burn severity indicator in the tundra (Loboda et al 2013) and that there may be better indicators (Chen et al 2020). Another major potential source of uncertainty stems from the fact that the emission factors the authors used were from boreal fires, which as the authors state in the method section may lead to an overestimation. However, this overestimation wasn’t further discussed in the discussion.

Additionally, in terms of dNBR, there have been a lot of studies showing the caveats associated with dNBR when it is used in high northern latitude settings (eg, Chen et al 2020). The author failed to take these into account completely. Additionally, the authors never showed the audience how the YKD fire that they picked compared with other tundra fires. This is a piece of critical information that is needed for a wider audience to understand the scientific importance of your work.

Loboda, T. V., French, N. H., Hight-Harf, C., Jenkins, L., & Miller, M. E. (2013). Mapping fire extent and burn severity in Alaskan tussock tundra: An analysis of the spectral response of tundra vegetation to wildland fire. Remote Sensing of Environment, 134, 194-209.

Chen, Yaping, Mark Jason Lara, and Feng Sheng Hu. "A robust visible near-infrared index for fire severity mapping in Arctic tundra ecosystems." ISPRS Journal of Photogrammetry and Remote Sensing 159 (2020): 101-113.

Chen, D., Loboda, T. V., & Hall, J. V. (2020). A systematic evaluation of influence of image selection process on remote sensing-based burn severity indices in North American boreal forest and tundra ecosystems. ISPRS Journal of Photogrammetry and Remote Sensing, 159, 63-77.

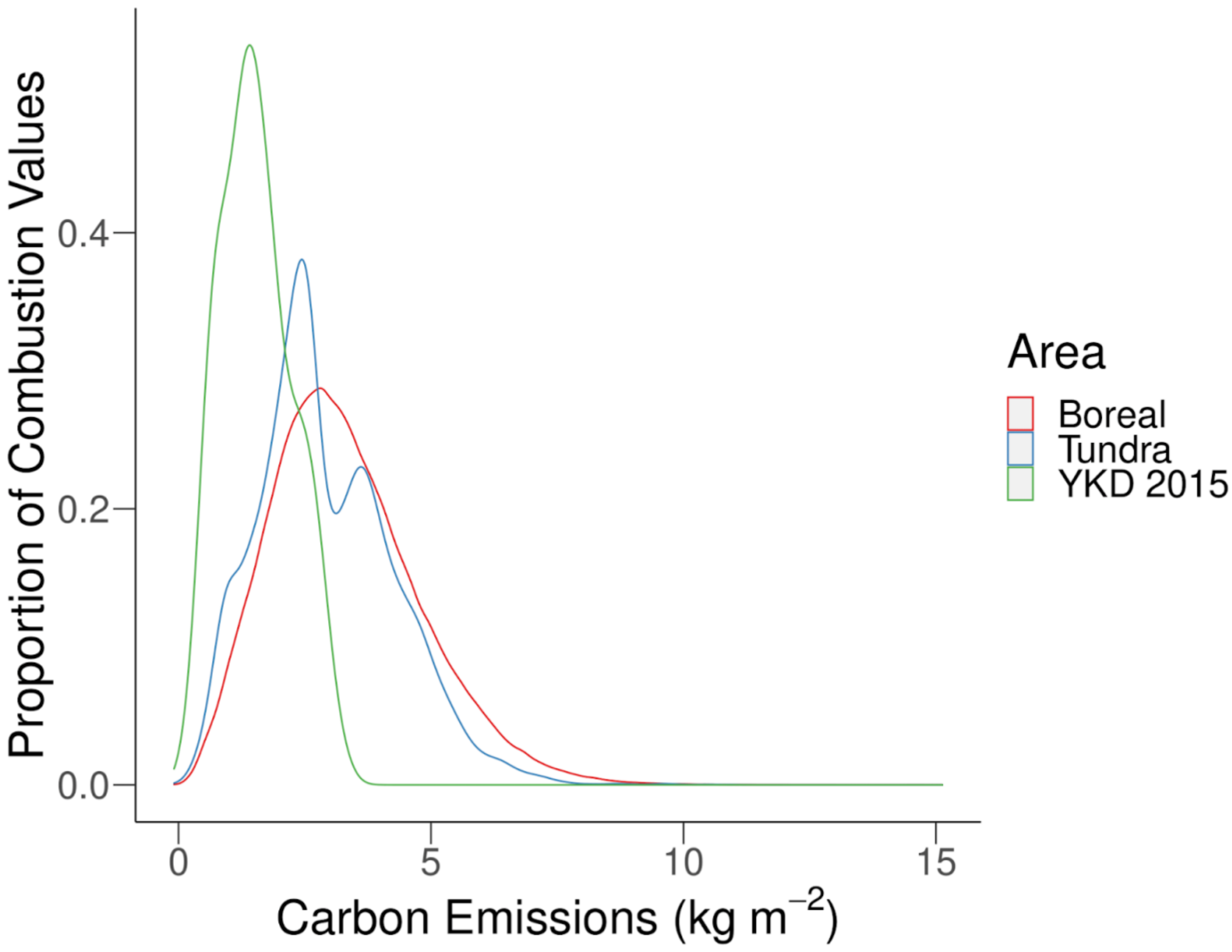
RESPONSE: Thank you for your helpful feedback, as it allows us to more accurately represent the scope of our findings and their importance to the scientific community. While our initial text generalized our results to all tundra fires, we will both scale back the language of our results and provide context for the fire season we measured compared to other fires in Alaska. First, we will clarify that our results represent combustion from a single tundra fire season in Alaska and may not be representative for all tundra wildfires. Instead of generalizing our results to all tundra fires, we will state that on a per unit area basis, the fire season measured herein, the ARF fire, and boreal fires have relatively similar levels of combustion, which suggests emissions rates per unit burned area from tundra fires can be comparable to boreal fires. These changes will be made in the discussion and in response to your line-specific comments below.

In addition, we will compare per unit area combustion from our study with all fires between 2001 and 2018 in boreal and tundra systems in Alaska, estimated via remote sensing and geospatial machine learning techniques, by adding a density plot to the appendix. A sample of that plot is given below. While field measurements of tundra combustion are currently lacking, but necessary to validate remotely sensed combustion products, our field measurements fell within the range of remotely sensed combustion in tundra and boreal systems. We will make note of this trend in the text by stating that:

> "Compared to remotely sensing-derived estimates of combustion, our per unit area *in situ* measurements are on the low end but comparable to large-scale means across Alaska between 2001 and 2018 ([Figure Below]). However, more representative field measurements in tundra fires are needed to validate remotely sensed combustion measurements, as the currently available gridded products (Potter et al. 2022; Scholten et al. 2021; Veraverbeke et al. 2017a; Veraverbeke et al., 2015a) are driven entirely by measurements in boreal forests."

In addition to adding this context in the discussion, we will add context for our fire season's size and dNBR values in the methods, results, and discussion sections. The 2015 YKD fire season burned roughly three times the annual average tundra burned area in Alaska between the years 2001 and 2018 but accounted for only a little more than half of the Alaskan tundra area burned in the year 2015 alone. Within the YKD, the 2015 fire season burned more area than any other year between 2001 and 2018. Most years in that time frame burned less than 10,000 hectares. In comparison, the 2015 YKD fire season burned 54,154 hectares. This context will be added in the first paragraph of the discussion. The dNBR values for the fire season we studied were intermediate compared to dNBR values for tundra and on the low side but within the range of values for boreal fires in Alaska generally. These contextual changes will clarify that while definitive conclusions about how our focal fires translate to other tundra fires cannot be made presently, the results of our study highlight the need for more attention to tundra wildfires from a climate perspective. We elaborate more on these contextual changes in response to your line-specific comment below as well.

We will expand the discussion section describing sources of uncertainty introduced by our methodology to add more description of the sources you mention here. First, we will describe that despite dNBR being the most widely used metric to assess fire severity, its accuracy may be diminished in high latitude tundra systems by environmental and methodological factors. We appreciate the studies you suggested, and we will cite them in our manuscript. In the text, we will note that other metrics have shown promise in tundra systems, but how these results translate to other tundra systems remains to be explored. Second, throughout the manuscript we will note that our low severity fire class likely includes unburned patches of tundra, leading us to potentially overestimate combustion in low severity areas. Finally, we will reiterate in the discussion that since emissions factors for tundra fires are not available, we used boreal emissions factors, potentially leading us to overestimate gaseous emissions from woody vegetation. As noted in the discussion, our model was parameterized with data from various sources and is publicly available via GitHub. Since data on tundra wildfires is lacking to date, our parameterization could only approximate tundra fires. However, as these parameters are updated for tundra systems in future literature, our model can be updated. In addition to this general response, we address your detailed comments individually below.



References for general comment:

Potter, S., Veraverbeke, S., Walker, X. J., Mack, M. C., Goetz, S. J., Baltzer, J. L., Dieleman, C., French, N. H. F., Kane, E. S., Turetsky, M. R., Wiggins, E. B., and Rogers, B. M.: ABoVE: Burned Area, Depth, and Combustion for Alaska and Canada, 2001-2019, ORNL DAAC, Oak Ridge, Tennessee, USA [data set], https://doi.org/10.3334/ORNLDAAC/2063, 2022.

Scholten, R.C., S. Veraverbeke, R. Jandt, E.A. Miller, and B.M. Rogers.: ABoVE: Ignitions, Burned Area, and Emissions of Fires in AK, YT, and NWT, 2001-2018, ORNL DAAC, Oak Ridge, Tennessee, USA [data set], https://doi.org/10.3334/ORNLDAAC/1812, 2021.

Veraverbeke, S., Rogers, B. M., and Randerson, J. T.: CARVE: Alaskan Fire Emissions Database (AKFED), 2001-2013, ORNL DAAC, Oak Ridge, Tennessee, USA [data set], https://doi.org/10.3334/ORNLDAAC/1282, 2015a.

Veraverbeke, S., Rogers, B. M., Goulden, M. L., Jandt, R., Miller, C. E., Wiggins, E. B., and Randerson, J. T.: ABoVE: Ignitions, burned area and emissions of fires in AK, YT, and NWT, 2001-2015, ORNL DAAC, Oak Ridge, Tennessee, USA [data set], https://doi.org/10.3334/ORNLDAAC/1341, 2017a.

Here are my more detailed comments.

Line 38 “AK”: Spell out Alaska.

RESPONSE: Will change.

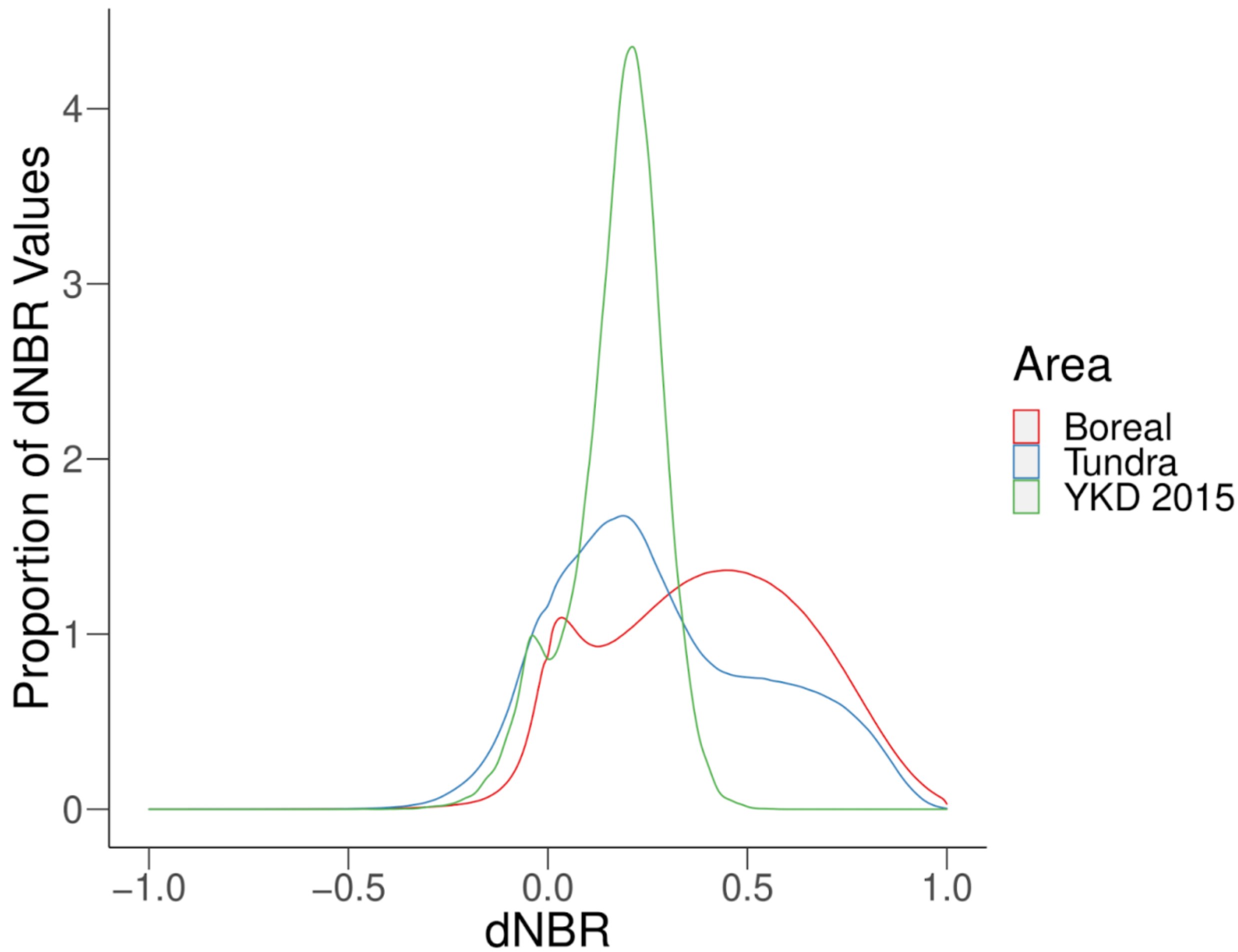
Line 64 “North slope”: North Slope

RESPONSE: Will change.

Line 97: More information about how this particular fire compares with other tundra fires (both from YKD and other tundra regions in Alaska) is needed (in terms of size, overall dNBR, etc).

RESPONSE: We will add a few pieces of information to put the YKD 2015 tundra fire season in context. We will add this information throughout the methods, results, and discussion where it is appropriate. First, as stated in response to your general comment, we will make comparisons based on burned area in the first paragraph of the discussion. The 2015 YKD fire season burned roughly three times the average annual burned area in Alaskan tundra between the years 2001 and 2018 but accounted for only a little more than half of the tundra area burned in Alaska in the year 2015. The 2015 fire season had the largest burned area within the YKD compared to the years 2001 to 2018. Most years in that time frame had burned areas less than 10,000 hectares. In comparison, the 2015 YKD fire season burned 54,154 hectares.

Also, we will compare the dNBR values from our study to dNBR values for all fires in Alaskan tundra and boreal systems. Differenced NBR for the fire season in this study was intermediate to dNBR for all tundra fires in Alaska from 1989 to 2019 and on the low side but within the range of dNBR for Alaskan boreal fires during this same timeframe. We will add our means of obtaining this information to the methods and the data will be cited in the results and as a density plot in the appendix. A sample of that plot is shown below. As mentioned in our general comment, we will compare the per unit area combustion from our focal fires to other remotely sensed per unit area combustion measurements for tundra fires in Alaska.



Line 105: Where did you get the burn scars? This needs to be specified.

RESPONSE: The burn scars were found using the Alaska Large Fire Database (Kasischke et al., 2002). We will mention this in the current section 2.1 and the methodology section 2.4 that describes fire severity.

Kasischke, E. S., Williams, D. and Barry, D.: Analysis of the patterns of large fires in the boreal forest region of Alaska. International Journal of Wildland Fire, 11, 131–144, https://doi.org/10.1071/wf02023, 2002.

Line 181 dNBR's full name has already been given previously.

RESPONSE: We will replace the full name with the acronym.

Line 181 "Key and Benson 2006": This reference should be provided when dNBR was first mentioned.

RESPONSE: We will add this citation where dNBR is first mentioned in the introduction.

Line 183: CFMASK algorithm: this needs a citation.

RESPONSE: We will add the citation Foga et al. (2017).

Foga, S., Scaramuzza, P. L., Guo, S., Zhu, Z., Dilley, R. D., Beckmann, T., Schmidt, G. L., Dwyer, J. L., Joseph Hughes, M., and Laue, B.: Cloud detection algorithm comparison and validation for operational Landsat data products, Remote Sensing of Environment, 194, 379–390. https://doi.org/10.1016/j.rse.2017.03.026, 2017.

Line 191 “We excluded estimates derived from tussock measurements because burn depth estimates from tussocks correlated negatively with remotely sensed fire severity.”: Is this a part of the analysis that isn’t included in the manuscript? More information needed.

RESPONSE: We had misplaced the supplemental figure reference that should have been at the end of this sentence at the end of the prior sentence. Figure A4 [original submission], which will be properly referenced, contains the analysis we conducted to show that “tussock measurements correlated negatively with remotely sensed fire severity.” While we did not further analyze explicitly what drove this trend, due to resource and time limitations in the field, we will add hypotheses and an imperative for future work on the subject in this paragraph.

Line 199 “low severity burn”: Unburned islands almost certainly exist within the burn scar that the authors focused on. Since there is no "unburned area" class, the "low severity" class most likely includes unburned areas, which is why this class should be called something like "unburned/low severity".

REPONSE: Thank you for pointing out this additional uncertainty in our analysis. Here, we will note the potential inclusion of unburned islands within low severity areas. Throughout the manuscript we will rename the low severity burn class to low severity/unburned. In the discussion of caveats of our study and in the results, we will mention this as a potential source of uncertainty.

Line 239 “similar to the framework employed in Randerson et al. (2006) and Huang et al. (2016).”: Even though you provided the references for the method you used in this study, a basic description of the said method should be provided in this manuscript since the audience, including the reviewer, should be able to understand your method without going to the source materials. Also, when directly apply the methods described in previous studies, you need to briefly explain the settings of those studies so that you can show the audience that the methods are actually applicable.

RESPONSE: We agree that our original wording implies we are using methods from these studies, but we do not detail said methods or their applicability. Our intention with these references was to show that the general framework of calculating radiative forcings based on combustion metrics is standard practice, rather than that our methods were taken explicitly from either of these publications. Where our methods adopt specific workflows and equations is detailed throughout the rest of our methods section. We will reword this sentence with these citations to say that our approach is standard practice, but not yet applied to tundra systems in our specific manner.

Line 240 “these equations”: Similar to my previous comment, here "these equations" sounds really strange since no equations were actually given in this paper.

RESPONSE: Similar to our previous response, we agree that "these equations" is ambiguous. We will rewrite the sentence to explain that our model was driven by the combustion metrics we calculate. We will also switch the sentence with the one prior for clarity. The final text will read:

> "The radiative forcings model was driven using the average amount of organic matter lost across fire-wide burn severity classes and vegetative reference points. Computing the radiative forcing of gaseous and aerosol emissions has been done for boreal fires (e.g., Huang et al. 2016, O'Halloran et al., 2012, Randerson et al., 2006), but has yet to be applied to tundra systems."

Huang, S., Liu, H., Dahal, D., Jin, S., Li, S. and Liu, S.: Spatial variations in immediate greenhouse gases and aerosol emissions and resulting radiative forcing from wildfires in interior Alaska, Theoretical and applied climatology, 123, 581-592, https://doi.org/10.1007/s00704-015-1379-0, 2016.

O'Halloran, T. L., Law, B. E., Goulden, M. L., Wang, Z., Barr, J. G., Schaaf, C., Brown, M., Fuentes, J. D., Göckede, M. and Black, A.: Radiative forcing of natural forest disturbances, Global Change Biol., 18, 555-565, https://doi.org/10.1111/j.1365-2486.2011.02577.x, 2012.

Randerson, J. T., Liu, H., Flanner, M. G., Chambers, S. D., Jin, Y., Hess, P. G., Pfister, G., Mack, M. C., Treseder, K. K. and Welp, L. R.: The impact of boreal forest fire on climate warming, Science, 314, 1130-1132, https://doi.org/10.1126/science.1132075, 2006.

Line 307-310: Throughout this paper, there are many paragraphs like this that consist of a few sentences. This not a good scientific writing practice and these paragraphs should be rewritten to be merged into bigger paragraphs.

RESPONSE: Here and throughout the paper, we will combine these small paragraphs to make larger ones.

Line 352 "Both models were corrected for spatial autocorrelation between transect locations.": how?

RESPONSE: We will specify that it was in choosing the model with the lowest AIC score across five correlation structures, described in the following sentence, that we corrected for spatial autocorrelation.

Line 410-418: As i pointed out previously, your low severity class includes unburned areas, as a result, you likely have overestimated the emissions here.

RESPONSE: Here and in the discussion, we will note our possible overestimation of emissions, because the low severity areas likely contain patches of unburned tundra.

Line 458 "here we … frequent tundra fire regimes": this statement needs to be modified significantly. what you can confidently say is that the particular wildfire that you visited emitted a lot of carbon and has a warming effect. However, with the field data that you collected, you can't make a statement indicating this is the case for all tundra wildfires. In fact, this is very likely not the case for many, if not most tundra wildfires, since tundra wildfires can be quite low in severity.

RESPONSE: We modify this first discussion sentence to focus on our fire season singularly rather than all tundra fires. Additionally, rather than suggesting that all tundra fires represent an under-studied source of greenhouse gas emissions, we will state that our findings suggest increasingly frequent tundra fire regimes, which may include high severity fires, are an under-studied source of global greenhouse gas emissions. The final text will read:

> "Here we describe a tundra wildfire season that combusted significant amounts of carbon and had a positive warming effect on the atmosphere due to its gaseous and aerosol emissions over an 80-year time horizon. Our findings suggest that increasingly frequent tundra fire regimes are an under-studied source of global GHG emissions."

Line 463: I don't like how this statement is worded because it incites misinterpretation. You should just say that the emission per unit area is similar between this fire and ARF. That is fair. Additionally, you are comparing this fire with ARF (which is also fair), but you didn't give any other comparison between the two (such as size, species composition, burn severity). These contexts are important for readers to understand the scientific importance of your findings.

RESPONSE: We agree the wording of this sentence is misleading. We will separate it into two sentences to describe the Anaktuvuk River fire separately and added context for that fire, including that it was twice the size, of mostly moderate to high severity, and in tussock tundra. The sentences will read:

> "In total, we estimate that about 0.911 Tg of carbon was released from 54,154 hectares of burned area in the YKD…[other inserted material for revisions]... Total carbon loss was driven by a similar per unit area carbon emission rate as the 2007 Anaktuvuk River fire (Mack et al., 2011), which was roughly twice the size of the one reported here and burned predominately moderate to high severity in a tussock tundra ecosystem (Jones et al., 2009)."

Jones, B. M., Kolden, C. A., Jandt, R., Abatzoglou, J. T., Urban, F. and Arp, C. D.: Fire behavior, weather, and burn severity of the 2007 Anaktuvuk River tundra fire, North Slope, Alaska, Arctic, Antarctic, and Alpine Research, 41, 309-316, https://doi.org/10.1657/1938-4246-41.3.309, 2009.

Mack, M. C., Bret-Harte, M. S., Hollingsworth, T. N., Jandt, R. R., Schuur, E. A., Shaver, G. R. and Verbyla, D. L.: Carbon loss from an unprecedented Arctic tundra wildfire, Nature, 475, 489-492, https://doi.org/10.1038/nature10283, 2011.

Line 473"Carbon loss per area from tundra wildfires are within the range of total above- and belowground carbon loss from boreal wildfires, approximately 0.5 to 4 kg m-2 (Walker et al., 2020a; Walker et al., 2018b; Rogers et al., 2014)": This is another instance of overgeneralization.

While this fire and ARF may have carbon emission per unit area that is similar to that of boreal wildfires, you can't say so for all tundra wildfires.

RESPONSE: We will tone back the decisiveness of our conclusion in this sentence by specifying "loss per area from [these] tundra wildfires." We will also adjust the concluding sentence of that paragraph from "While carbon loss per area of tundra wildfire is similar to boreal wildfires…" to say "Although data from the Anaktuvuk River and YKD fires shows carbon loss per unit area can be similar between boreal and tundra wildfires…"

As mentioned in our general response, we will add a comparison of per unit carbon emissions between the fire season measured in our study and remotely sensed combustion of tundra and boreal systems in Alaska with text and an appendix figure. This comparison shows that with respect to remotely sensed combustion measurements, our *in situ* per unit area measurements are on the low end but comparable. We will note that while more representative field measurements are needed in tundra ecosystems to clarify the relationship between tundra and boreal emission rates, the data from our fire season suggests that tundra wildfires should be studied more intensively from a climate perspective.