Dr. Thomas A. Douglas
U.S. Army Cold Regions Research and Engineering Laboratory
9th Avenue, Building 4070
Fort Wainwright, Alaska 99703
Phone: 907-361-9555; Fax: 907-361-5142
E-mail: Thomas.A.Douglas@usace.army.mil

Dear Copernicus Editor, April 15, 2021

We have edited the manuscript "Recent degradation of Interior Alaska permafrost mapped with ground surveys, geophysics, deep drilling, and repeat airborne LiDAR" by ten co-authors and myself.

The revised manuscript is substantially improved by the constructive comments of Reviewer Wetterich and an anonymous Reviewer and we thank them for their time and effort. Of particular note we shortened the abstract, reorganized the major sections and some sub-sections, and addressed numerous grammatical and typographical edits.

Our detailed addressal of the Reviewer 2's comments is provided below. Original Reviewer text is in black, our comments are in blue, and the revised/updated text is in red with quotation marks.

We look forward to hearing from you.

Sincerely,

Thomas A. Douglas

RC2: 'Comment on tc-2021-47', Anonymous Referee #2, 14 Apr 2021

The article by Douglas et al. incorporates long-term monitoring of ground temperatures and thaw depths with LiDAR-based analyses, radiocarbon dating, and permafrost coring. This is an extremely well-planned and thorough investigation of permafrost near Fairbanks, Alaska. The study is clearly presented and explained.

The study is appropriate for The Cryosphere, and will likely be of interests to scientists and policymakers across multiple disciplines. In general, the conclusions are supported by the presented data, and the thawing and changes to the permafrost are clearly presented in many of the figures and tables. A very thorough, interesting and important study of Alaskan permafrost.

The only conclusion that seems like a reach is the calculation of potential carbon release for all of the yedoma-type permafrost in central Alaska. Given the many variables that can impact permafrost thaw and active layers (as well as variations in carbon-content even across yedoma-type permafrost), I question whether the authors can actually constrain that the total thaw of permafrost carbon in central Alaska to 0.44 Gt.

We thank the Reviewer for this constructive review and address each individual comment below.

Line 16 – long description is a bit confusing "ice rich high carbon content syngenetic yedoma permafrost"
We have broken this into two sentences for clarification:
"Of particular concern is thawing syngenetic "yedoma" permafrost which is ice rich and has a high carbon content . This type of permafrost is common in the region around Fairbanks, Alaska and in a region of Central Alaska that expands westward to the Seward Peninsula."

Line 24 – 500 m needs space between
This has been edited, as suggested, to"
"This study was conducted from 2013-2020 along four 400 to 500 m long transects near Fairbanks, Alaska."

Line 30 – I think "made" is the wrong word here. Confusing sentence.
The text has been changed to the following based on another Reviewer's suggestion and we feel it addresses this comment as well:
"At disturbed sites seasonal thaw increased up to 25% between mid-August and early October and suggests active layer depth measurements must be made as late in the fall season as possible because the projected increase in the summer season of just a few weeks could lead to significant additional thaw."

Line 38 – CO_2 subscript. Spell out carbon. "7-year"
The text has been changed to the following based on another Reviewer's suggestion and we feel it addresses this comment as well:
"Projecting our thaw depth increases, by ecotype, across the yedoma domain we calculate 0.44 Gt of permafrost soil C have been thawed over the past 7 years, an amount equal to the yearly CO_2 emissions of Australia."

Line 40 – comma after "cover"

This has been edited, as suggested, to:
"Since the yedoma permafrost and the variety of ecotypes at our sites represent much of the Arctic and subarctic land cover, this study shows remote sensing measurements, top-down and bottom-up thermal modelling, and ground based surveys can be used predictively to identify areas of highest risk for permafrost thaw from projected future climate warming."

Line 129 – maybe write (n=3) and (n=1)
This has been edited, as suggested, to:
"Our field investigations were organized along four transects crossing a variety of lowland (n=3) and upland (n=1) permafrost landscapes (Fig. 1)."

Line 260 – where are the cores located on Figure 2–6. Can you include labeled sample circles?
We have added circles for core locations in Figures 2-6 and changed the caption accordingly.

Line 287 – are these radiocarbon years or calibrated years? Also, need to include the radiocarbon methods earlier in the article. Maybe include a table of the results.
This is similar to comments of another Reviewer which we addressed as follows:

We have added a new Section "4.3 Radiocarbon dating" and a new Section "4.4 Air and ground temperature measurements" as suggested.

We have edited the text to clarify "calibrated years before present (cal YBP) as follows:
"We obtained ^{14}C ages from wood fragments collected from three Geoprobe core samples through Geochron Laboratories (Chelmsford, Massachusetts, USA). An age of 10,360 +/- 360 calibrated years before present (cal. YBP) ($\delta^{13}C$: -27.7 ‰) was measured at a depth of 1.02 m in the tussock area at 306 m on Farmer's Loop transect 1 (Supplementary Table 1). At 358 m along the same transect and also in the tussock area at 0.67 m depth the ^{14}C age was 10,160 +/-160 cal. YBP ($\delta^{13}C$: -28.0 ‰). Along the Farmer's Loop 2 transect, in the spruce forest at 420 m and at a depth of 0.49 m depth a wood fragment yielded a ^{14}C age of 7,200 +/-190 cal. YBP ($\delta^{13}C$: -28.7 ‰)."

We have added/clarified all of the requested sample information to Table S1 but the analytical laboratory did not provide sample mass.

Line 367 – "deep end?" What do you mean here?
We mean the deepest end of season active layer measurements and have changed the text to:
"By mid-July the disturbed and mixed forest ecotypes exhibit the most seasonal thaw and these ecotypes have the deepest end of season active layer depth measurements."

Line 370 – What is the importance of 1.2 m? Why is this the depth that many of the measurements are from?
This depth represented "stable" permafrost in areas where we established temperature measurements. In most places where thermistors have been installed the areas are still frozen year round. Typical thaw depths across our field sites in areas of stable permafrost are less than a meter so 1.2 m is a depth for long term temperature measurements.

We have added/edited the following in section "**3.2 Field survey measurements, coring, and meteorology**" (which was renumbered based on suggestions of another Reviewer:

"Onset HOBO U23 Pro v2 two channel external temperature loggers were installed at depths of 1.2 m at nine locations across our field sites at locations where this represents permafrost."

Line 375 – add "that" between established and vegetation, if you want.
Another Reviewer made this same suggestion and it has been changed to:
"Previous studies have established that vegetation provides"

Line 378–9 – this sentence reiterates ideas that have already been stated. You could delete.
We respectfully request to keep this sentence in here because it reiterates a fundamental aspect of our work that we hope can inform remote sensing applications- ecotype:thaw depth and ecotype:permafrost relationships can help support broader scale assessments.

Line 384 – Just during this period of time (after 2013)? Were active layers deepening before this?
This is in specific relation to our field site locations and measurements so this has been clarified to:
"In many locations at our field sites, active layer depths have increased since 2013 to greater than 2 m which is greater than typical winter freezeback."

Line 390 – "would increase" instead of increases.
This has been changed, as suggested, to:
"As such, if vegetation were to change from tussocks or spruce to a mixed forest or disturbed (i.e. no moss or forest vegetation) land cover the potential risk of top-down permafrost thaw would increase considerably."

Line 403 – what is "cookie cut"? Please explain.
This is a term used by some in the GIS community that is likely more commonly understood by non-GIS people in lieu of the word "clip." We have clarified it to:
"Using the regions mapped as yedoma as a "cookie cut" clipping from ecotype maps that cover all of central Alaska (Jorgenson and Meidlinger, 2015; Raynolds et al., 2019) we calculate the five ecotypes in our study represent 90% of the total land cover on top of yedoma permafrost."

Line 407–411 – Given the small region of the study and the variability in thaw dynamics across the region, I question whether the authors can constrain the organic carbon pool and potential loss from thawing across all of central Alaska. I think a better way to discuss this would be to calculate the total thawed permafrost and the organic carbon release from the study sites. They could then discuss how much more yedoma-type permafrost exists in Alaska – eluding to the potential magnitude of permafrost thaw, but not directly calculating it.
We developed this aspect of our research in an attempt to more broadly apply the results from our specific site scale measurements to a larger area of interest. This was partly to address comments made on an earlier version of the manuscript by Editor Morse. He suggested we provide a larger context than just our study sites. We feel the way this is presented limits over-simplification and adds impact to the paper. Few studies have identified links between top down thaw and potential carbon stocks. However, many studies have been synthesized to provide yedoma permafrost carbon stocks. We want to clarify that we have not measured carbon emissions from our sites. Also much of the Central Alaska region is extremely remote and there are few study sites or measurements. However the CALM sites across the region yield somewhat consistent results as our findings and this suggests the broader application we undertake.

We fully realize that we have to be careful in the broader application of our results and we have made an attempt to make sure we use generalized data and application. We are focused on a general calculation and assessment of the potential carbon that has been thawed. There is no mention of carbon cycle or gas production processes. We just identify the potential stocks thawed and relate them to a value (Australian emissions) that is easy to comprehend than the number itself. We are not weighing in on the fate of this carbon in soils or the atmosphere as part of the potential permafrost carbon feedback. As such, we feel that the way we have framed and presented this limits any direct assessment of greenhouse gas emissions. We note the other Reviewer did not make any comments to change this aspect of the manuscript and we respectfully request to keep this aspect of our Conclusions as it is.

Line 439 – does this decrease in elevation refer to all troughs? Is this the average? Was this calculated with LiDAR? Based on Fig. 7, it looks like trough subsidence only occurred near the lake/river – is there spatial variability?
This is a good point. We have clarified the text as follows:
"Some of the low lying troughs between polygons, particularly those along the thaw front next to the ponded area to the west, have dropped by 1-1.5 m in the decade from 2010 to 2020."

Line 442 – delete comma between May 2020
This has been edited, as suggested, to:
"We attribute this to this area being extremely low lying and more standing water being present in the troughs from snowmelt in May 2020 compared to 2010"

Line 447 – 108 or 10.8 or 10 8?
This was identified by another Reviewer. We have changed the text to:
"Examples are at the Creamer's Field transect at ~100 m; Farmer's Loop transect 1 at 68 m and 360 m; Farmer's Loop transect 2 at 8 m, 88 m, 116 m, and 408 m; and the Permafrost Tunnel transect at 64 m, 108 m, 140 m, and particularly at 328 m."

Line 487–480 – This sentence is confusing.
The word "represent" should not have bene plural. This has been changed to:
"Our study sites are well suited to support these types of analyses because the area contains warm permafrost, the climate has been warming since the 1970s, and our transects represent most of the land cover present in the boreal and taiga of the Arctic and subarctic."

Figure 2–6 – the caption references "white line" but there is no white line in the image.
The white line reference is for the white lines in Figure 1. Another Reviewer identified this same issue as well as other suggested Figure caption edits. We have edited the Figure captions for Figures 2-6 to (as an example):
"**Figure 2. The Creamer's Field transect from 0 to 246 m (white line in Fig. 1). Image a) is a Worldview 2 (© Digital Globe) true color image of the transect (white line) with terrain features and core locations (circles) identified, b) LiDAR, c) repeat thaw depth measurements in 2014, d) repeat active layer depth measurements from 2014-2019, and e) a 246 m electrical resistivity tomography transect corrected for ground surface elevation with boreholes identified as black boxes to true depth and numbers corresponding to the distance (in meters) of the borehole location along the transect. Stars with a "T" denote a thermistor location."**

Figure 2–6 – please show core sites
Core sites have been added to panel a and the caption has been edited to reflect this.

Figure 9 – in caption put space between October 1
Thank you for catching this. It has been changed to:
“**Figure 9. Soil temperature measurements at 1.2 m depth from October 1, 2013 to October 1, 2019 for the three study sites. Mean annual ground temperature (MAGT) values at 1.2 m for the period of record are also provided.**“

Figure 10 – try to make the locations and labels easer to see on the map of Alaska.
The locations and labels have been edited to make them clearer.