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Interactive comment on "Presence of rapidly degrading permafrost plateaus in southcentral Alaska" *by* B. M. Jones et al.

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REVIEW

Benjamin M. Jones, Carson A. Baughman, Vladimir E. Romanovsky, Andrew D. Parsekian, Esther L. Babcock, Miriam C. Jones, Guido Grosse, and Edward E. Berg PRESENCE OF RAPIDLY DEGRADING PERMAFROST PLATEAUS IN SOUTHCENTRAL ALASKA

GENERAL COMMENTS:

This manuscript is based on complex study of degrading frozen peat plateaus in the area of warm isolated permafrost. Such studies are very important because permafrost degradation strongly affects environment and infrastructure. Permafrost dynamics near

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the southern margin of the permafrost region is extremely complicated and has been studied very poorly, so this paper makes a significant contribution to permafrost science.

Thank you for the general praise Misha and for the very helpful and constructive review. We address each of your comments and suggested edits below in red bold text.

The manuscript contains unique information and is clearly written, and I strongly support its publication. Though I don't have any major concerns, I believe that this manuscript needs some minor revision. These are my main recommendations:

1. I recommend to add several more references:

Kuhry, P. 2008. Palsa and peat plateau development in the Hudson Bay Lowlands, Canada: timing, pathways and causes. Boreas 37(2): 316–327. DOI: 10.1111/j. 1502-3885.2007.00022.x

Sannel, A.B.K., Kuhry, P. 2008. Long-term stability of permafrost in subarctic peat plateaus, west-central Canada. The Holocene 18(4): 589–601.

Sannel, A.B.K., Kuhry, P. 2011. WarmingâĂŘinduced destabilization of peat plateau/thermokarst lake complexes. Journal of Geophysical Research 116, G03035, doi:10.1029/2010JG001635, 2011

Zoltai, S.C. 1993. Cyclic development of permafrost in the peatlands of northwestern Alberta, Canada. Arctic and Alpine Research 25(3): 240–246.

Riddle, C.H., Rooney, J.W., 2012. Encounters with relict permafrost in the Anchorage, Alaska, area. Proceedings of the Tenth International Conference on Permafrost, Salekhard, Yamal-Nenets Autonomous District, Russia, June 25–29, 2012, 1, pp. 323–328.

Jorgenson, T., Shur, Y.L., Osterkamp, T.E. 2008. Thermokarst in Alaska. In Proceedings of the Ninth International Conference on Permafrost, Vol. 1, June 29–July 3, 2008, Fairbanks, Alaska, Kane DL, Hinkel KM (eds). Institute of Northern Engineering, Uni-

versity of Alaska Fairbanks; 869–876.

Jorgenson, T., Kanevskiy, M., Shur, Y., Osterkamp, T., Fortier, D., Cater, T., Miller, P. 2012. Thermokarst lake and shore fen development in boreal Alaska. In Proceedings of the Tenth International Conference on Permafrost, Vol. 1 International contributions, June 25–29, 2012, Salekhard, Russia, Hinkel KM (ed.). The Northern Publisher: Salekhard, Russia; 179–184.

Riordan, B., Verbyla, D., McGuire, A.D. 2006. Shrinking ponds in subarctic Alaska based on 1950–2002 remotely sensed images. Journal of Geophysical Research 111, G04002, doi:10.1029/2005JG000150, 2006

Nossov, D.R., Jorgenson, M.T., Kielland, K., and Kanevskiy, M. (2013) Edaphic and microclimatic controls over permafrost response to fire in interior Alaska. Environmental Research Letters 8 (3), 035013, doi:10.1088/1748-9326/8/3/035013.

Kanevskiy, M., Jorgenson, T., Shur, Y., O'Donnell, J.A., Harden, J.W., Zhuang, Q., Fortier, D. 2014. Cryostratigraphy and permafrost evolution in the lacustrine lowlands of West-Central Alaska. Permafrost and Periglacial Processes 25 (1): 14–34. DOI: 10.1002/ppp.1800

O'Donnell, J.A., Harden, J.W., McGuire, A.D., Kanevskiy, M.Z., Jorgenson, M.T., Xu, X. 2011. The effect of fire and permafrost interactions on soil carbon accumulation in an upland black spruce ecosystem of interior Alaska: implications for post-thaw carbon loss. Global Change Biology 17: 1461–1474. DOI: 10.1111/j.1365-2486.2010.02358.x

We appreciate the recommendations for incorporating additional references to these important research efforts and findings. We have incorporated a number of these references into the revised manuscript. These are highlighted above in red, italicized text.

2. I'm not satisfied with your explanations of low EIF values (0.09 to 0.13) calculated for your study sites (Pages 19-20, Lines 433-443). You wrote that "Lewkowicz et al. (2011) demonstrated that features with EIF values below 0.33 likely results from ice-

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poor permafrost and/or a high unfrozen water content of the permafrost," but in the cited paper high unfrozen water content is supposed to explain low electrical resistivities, not low EIF. I'm not sure there is any correlation between low EIF values and high unfrozen water content, because you already mentioned (Line 440) that frozen peat contains a lot of excess ice. Even in warm permafrost, only a fraction of pore ice transforms into unfrozen water, while relatively large (clearly visible) ice lenses and inclusions remain frozen (according to your description, "…frozen peat … appears to be ice-rich, with a number of ice bands, ice lenses, and ice inclusions"). Probably low EIF values in your case result mainly from the nature of peat, which keeps its volume upon thawing pretty well in comparison with ice-rich mineral soil.

Besides, you didn't provide any information on ice content of soils (except EIF). It will be good to compare ice content values obtained from frozen cores with EIF values. If you don't have such data, you may find some information obtained from similar peat plateaus of boreal Alaska or Canada. For example, our team has published several papers with some ground-ice data: see Jorgenson et al., 2012, 2013; O'Donnell et al., 2012; Kanevskiy et al., 2014. I also recommend to add photos and descriptions of your frozen cores to Results.

During the initial submission of this paper we opted to indirectly estimate excess ice fraction based on previous research by Lewkowicz et al. (2011). We do understand the short-coming of such an approach for better describing the permafrost characteristics at our study sites in southcentral Alaska. Based on this comment and further discussion among coauthors, we asked our colleague Eva Stephani to contribute to this paper through analysis and incorporation of frozen core material that we had archived in freezers at the USGS Alaska Science Center. We now include material in the methods section on core prep and analysis, a paragraph in the results section describing the peat and ground-ice characteristics, and two new figures showing the cryostratigraphy and ice contents for a core collected in the Browns Lake wetland complex as well as photos of sections of the frozen cores prior to processing. We have also removed the material on EIF since we now directly quantify the icy nature of the permafrost deposits. We really appreciate this recommendation and we think that addition of this component makes the paper more well-rounded.

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SPECIFIC COMMENTS:

Page 1, Line 24. I recommend to add “at some locations” or “the minimum depth” after “but.”

Thanks for this suggestion. We have modified the text here.

Page 5, Lines 111-118. I recommend to move this text to Methods.

Thanks for this suggestion. We have opted to retain this text here in the final paragraph of the introduction to highlight our objectives and study design. We also go into further detail on each of these aspects in the methods section.

Page 7, Line 148. I recommend to replace “These features are...” with “Degradation of permafrost plateaus is...” I also recommend to move this sentence to Introduction.

Thanks for this suggestion. We have modified the text here.

Page 13, Lines 298-300. You are talking about hummocks and depressions but you didn’t describe micro-topography in the paper. I recommend to add a short description to Chapter 2 (Study area).

Thanks for this suggestion. We have briefly described the microtopography in the methods section in the additional field surveys paragraph. We also show these results in Fig. 7b.

Page 19, Lines 422-431. You already presented these data in Results, so I recommend to shorten this paragraph.

Thanks for this suggestion. We have shortened this paragraph.

Page 22, Lines 489-499. Something is missing here.

Thanks for catching this mistake. We have fixed this sentence.

Page 22, Lines 495-496. I recommend to add several more references (see attached file).

Thanks for these suggestions. We have included these recommendations.

Page 23, Lines 520-522. I recommend to add several more references (see attached file).

Thanks for these suggestions. We have included these recommendations.

Page 24, Lines 545-546. I recommend to add one more reference (Shur and Jorgenson, 2007).

Thanks for this suggestion. We have included this reference here.

Page 47, Figure 7. I recommend to show expected permafrost boundary with dashed (or dotted) line (see attached file). Also it will be good to show the thickness of peat.

We appreciate this suggestion but have refrained from drawing the permafrost base boundary on Fig. 7b since we do not have the detailed information required to do this through our point measurements. We attempted to image this boundary continuously using GPR but were not able to resolve it. For these two reasons, we prefer to stick with our point data collection efforts in Fig. 7b. We now include a new figure that shows the thickness of peat and ground ice characteristics (Fig. 8).

More comments and suggestions (small edits mostly) are provided in the attached file.

Thanks for these additional minor edits Misha! We have incorporated all of them into the revised manuscript. You really helped us improve this paper.

Good luck!

Mikhail Kanevskiy, Institute of Northern Engineering University of Alaska Fairbanks

Please also note the supplement to this comment:
http://www.the-cryosphere-discuss.net/tc-2016-91/tc-2016-91-RC1-supplement.pdf

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Interactive comment on The Cryosphere Discuss., doi:10.5194/tc-2016-91, 2016.

The Cryosphere Discuss.,
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Interactive comment on "Presence of rapidly degrading permafrost plateaus in southcentral Alaska" *by* B. M. Jones et al.

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I write a short review for this paper even if I am editor of it as it turned out impossible to find a 2nd referee due to holiday and fieldwork season. I have already given feedback to the paper before publication in TCD and the authors have adopted my recommendations.

Thank you for the previous feedback on the paper Andreas. We appreciated the comments and suggestions prior to publication in TCD. We have incorporated your further suggestions below in the revised version of the paper.

The paper is an interesting and nicely integrative (ground measurements, ground surveys, geophysical surveys, remote sensing) study about a little investigated but important topic. The paper is well written. I ask the authors to consider the following remaining comments:

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- some PF temperatures seem very little below zero, in the range of logger accuracy. Some more explicit discussion about the logger accuracy with respect to your temperature results could be helpful.

Thanks for this suggestion. We have addressed this potential issue further by incorporating this text in the methods section: The manufacturer-specified accuracy of the thermistors is ±0.25 °C. Prior to deployment, we placed the data logger thermistors in a 0 °C ice bath for up to 45 minutes to estimate a calibration factor for post-processing of the data following download in the field. After calibration in a 0 °C ice bath, the precision of temperature measurements near 0 °C is limited only by the sensor-logger system sensitivity, which is 0.031 °C in this case. This means that the temperatures in our case were measured with the precision better than +/- 0.02 °C and changes in soil temperature exceeding 0.03 1°C can be recorded properly using this measuring system. This fact was established and demonstrated many times during our measurements in deeper boreholes using similar measuring systems when the annually measured temperature in some boreholes at deeper depths (50 m and deeper) will remain constant. These calibration techniques and measurement sensitivities are similar to improvements recorded for other measurement systems (Sannel et al., 2015; Cable et al., 2016).

- You don't mention much the role of snow depths, timing and distribution playing a role in the spatial pattern and temporal evolution of your PF. At least theoretically, also changes in snow cover could be in parts behind the spatio-temporal variations you found. You collect and show snow depth data for your field sites, but seem not to discuss these, and the role of snow in general in the phenomena and changes studied. Is snow in your study area too shallow to play an important role? Was this always the case for the time periods and time scales considered?

These are very good questions and a valid point to raise here. Unfortunately, we lack well distributed snow depth data for the study region and in particular on the permafrost peat plateaus over short as well as long time scales. Previous research on permafrost plateaus in colder regions indicate that preferential

warming in the winter and increased snow accumulation leads to enhanced permafrost thaw in boreal peatlands (Camill, 2005; Osterkamp, 2007). Since the Kenai Peninsula lowlands experience a semi-continental climate due to the rain shadow produced by the Kenai Mountains, a lack of winter snow fall may have contributed to permafrost persistence in this region by allowing relatively cold winter air temperatures to propagate into the sub-surface. In table 1 we show that average end of winter snow depth declined over the three year ground temperature observation period, whereas ground temperatures have remained stable to slightly warmed in some instances. Permafrost loss on the Kenai Peninsula is likely associated with higher air temperature, particularly during the winter season, wildfires that remove the protective ecosystem cover, groundwater flow at depth, and lateral heat transfer from wetland surface waters in the summer. But the role of snow cover warrants further study in the region.

Interactive comment on The Cryosphere Discuss., doi:10.5194/tc-2016-91, 2016.