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The Cryosphere Discussions

Interactive comment on "Scaling-up Permafrost Thermal Measurements in Western Alaska using an Ecotype Approach" *by* W. L. Cable et al.

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The authors present a case for using ecotypes, which can be measured and spatially quantified using remote sensing techniques to assess the general state of permafrost. The idea and work presented here is of particular value to not just the permafrost community alone, but also biogeochemists and climate scientists that wish to understand the current state of the pan-Arctic permafrost and how changing ecological communities and permafrost co-evolve. The authors provide a well-articulated discussion that links ecotypes and plant community succession to the development of permafrost, both establishment and degradation. Here the authors use a cluster analysis to measure attributes, which then provides a nonsubjective approach to classifying the sites into categories. Though not to the extent of linking ecotype maps to permafrost as presented here, other studies in the Arctic have successfully used cluster analysis approaches

to link vegetation, elevation, organic layer thickness, surface hydrology in polygonal tundra permafrost environments, and therefore are worth mentioning. As correctly stated, if ecotypes and the direction of ecological succession are good diagnostic tools for permafrost conditions, then the combination of ecotype identification and remote sense can be used to evaluate subsurface permafrost conditions in sparsely monitored areas, such as the pan-Arctic. Therefore, I recommend this manuscript for publication in The Cryosphere Journal following minor revisions.

As stated above the authors motivate this work by providing a justifiable link between ecotype and permafrost establishment and degradation. However, the use of cluster analysis has been employed to link other landscape characteristics that can be measured using remote sensing to permafrost and carbon flux conditions. See introduction discussion in Wainwright et al (2015), which provides descriptions of other Arctic studies that employ zonation and cluster analysis to classify permafrost conditions to characteristics easily measured from remote sensing data (e.g Hinkel et al., 2003; Muster et al., 2012; Hubbard et al., 2013), some of which have noted that vegetation usually clusters well with other important thermal conditions. Plant communities or ecotypes are often related to landscape geomorphology, disturbance intervals, and many other environmental conditions. Furthermore, why this work is so compelling, at least to me, is that ecotypes themselves as well as the plant community sessional stage can be a product of these combined conditions and therefore may well function as a system condition integrator. In my opinion it would be beneficial to the cyrosphere community if the authors also included a discussion about how the ecotype classification differs or adds to the work that links other landscape characteristics to permafrost conditions.

Hinkel, Kenneth M., et al. "Spatial extent, age, and carbon stocks in drained thaw lake basins on the Barrow Peninsula, Alaska." Arctic, Antarctic, and Alpine Research 35.3 (2003): 291-300.

Hubbard, Susan S., et al. "Quantifying and relating land-surface and subsurface variability in permafrost environments using LiDAR and surface geophysical datasets." Hy-

drogeology Journal 21.1 (2013): 149-169.

Muster, Sina, et al. "Subpixel heterogeneity of ice-wedge polygonal tundra: a multi-scale analysis of land cover and evapotranspiration in the Lena River Delta, Siberia." Tellus B 64 (2012).

Wainwright, Haruko M., et al. "Identifying multiscale zonation and assessing the relative importance of polygon geomorphology on carbon fluxes in an Arctic tundra ecosystem." Journal of Geophysical Research: Biogeosciences 120.4 (2015): 788-808.

My second somewhat major suggestion is to re-organize the result section of the paper. To me the most important results of the manuscript start on page 9 Line 14 and go to the end of the results section including section 4.3, which is buried in the middle of the results section. Following the top down approach of technical writing, where the main result and conclusion should be presented first, I would move these results to the top of the section before section 4.1. Section 4.1 and the first half of Section 4.2 'Ground Thermal Regime Analysis seem to be out of place and I would consider them only supporting results to the main message, which is how ecotypes and permafrost conditions are linked, which then produces the ground temperature map. This of course is my preference in technical writing (and reading for that matter), which I hope will help improve an already good paper and increase its impact.

The following are minor suggestions that I hope will improve the quality of the manuscript.

1) Page2 Line16: Add 'compared to water' to the end of the sentence '. . .a fourfold increase.'

2) Page2 Line23-24: Change '. . .annual ground temperatures can be increased by several. . .' to '. . .annual ground temperatures can increase by several. . .'

3) Page2 Line24-25: Sentence is not needed, "However, total end of season snow depth is not the only thing that is important."

4) Page2 Line 30: May help to specifically point out to the reader that increased snow depth, which insulates the ground in winter will lead to warmer permafrost temps. Likewise on Page2 Line 21, may help to specifically point out that moss will cool the subsurface leading to colder permafrost. I believe that is the point that these paragraphs are making, and therefore should be stated clearly.

5) Page3 Line 21-24: "Present and future thawing of permafrost in these regions will have a dramatic effect on the ecosystems in this area because the permafrost generally has a high ice content, as a result of preservation of old, Late Pleistocene, ground ice in these relatively cold regions even during the warmer time intervals of the Holocene." How does the preservation of the old cold regions affect the ecosystems? This sentence seems to have 2 separate messages that are may be unrelated.

6) Page4 Line 8-11: Are two sentences describing how the plots were accessed necessary? Perhaps rephrase to only one sentence, "Due to the remote nature and inaccessibility of the sites by road, a small helicopter (Robinson R44) was used to access areas in the refuge beyond the reach of waterways." By the way, the helicopter bit is pretty cool!

7) Page5 Line21-23: At this point it is not clear that the near surface temperature (3cm) is an important part of the analysis, and the 29 day moving average seems unnecessary. Latter in the paper it becomes clear that you do use it. Perhaps it would help if before this point some mention of why near surface temps are important and that they fluctuate a lot was added.

8) Page5 Line 26: The phrase, ". . .function fit to data pass through each measurement point. . ." is awkward, try to rephrase.

9) Page5 Line 31: '. . .at this site is shown. . .' Replace 'this' with KC1. Also I noticed throughout the manuscript that 'this' is used a lot, when it would help to be more specific and clearer to say what 'this' is.

10) Page6 Line 17: Again 'this' in "Fovell (1997) used this approach" is vague. Did Fovell use the cluster or rule-based approach?

11) Page6 Line 20: May be helpful to reference figure 6 here for an example of a dendrogram.

12) Page12 Line1-6: The tussock discussion is interesting in that it details how plants and ecosystems can govern environmental conditions. My question is, wouldn't the thermal conductivity of the tussock have to be high or relatively higher than snow to able to conduct energy from the subsurface to the atmosphere in order for the winter cooling affect to happen. While not within the scope of this paper, modeling schemes maybe able to define what thermal conductivities of tussocks are necessary to have a cooling effect, or what densities of tussocks sticking up above the snow are necessary.

13) Page12 Line29-33: The discussion of the interaction between the river disturbance and plant community succession is an important result/discussion point of the paper as it provides another example of 1) the interaction between geomorphology and ecology, and 2) how plant community succession determines the physical environment (i.e subsurface temperature). I would suggested that this point be highlighted more as it could provide further evidence as to 1) why ecotype classification can be used to map permafrost conditions and 2) that understanding the interaction of disturbance and the direction of plant community succession will help inform permafrost evolution.

14) Page13 Line 8: What do you mean by grid-based approaches? Finite difference and finite-volume or spatially distributed GCM's models come to mind. CLM and many spatially distributed models have plant functional type representation and ways of simulating ecotypes and the effects of those types on permafrost. Here I agree that models should link ecological types to the physical environment, but what is to limit grid based models from doing this?

15) Page12 Line 25: Is it appropriate to bring up funding here? Financial constraints at some point limit most studies as has already been acknowledge on page 4 line 8,

but is this publication the appropriate place to discuss the lack of money in sciences? I know Robinson R44 helicopters are expensive, despite being supper cool. However, it may be better to discuss the benefits of continued and additional data gathering, which would then provide motivation for continued funding. How might more measurements build confidence in the ecotype approach and reduce uncertainty in permafrost assessment.

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