Comments on "**New insights into the environmental drivers of the circumpolar ground thermal regime**" by Olli Karjalainen et al. submitted to The Cryosphere

General

This paper statistically related circumpolar observations of mean annual ground temperature (MAGT) and active-layer thickness (ALT) with climate, soil and vegetation variables. Based on the results, they provided some new insights into the major factors controlling the spatial distributions of MAGT and ALT. The analysis compiled a large number of circumpolar observations and the corresponding climate, soil and vegetation data, and the statistical modelling methods have not been seen often in permafrost studies. The results are interesting, especially by comparing the differences between permafrost and non-permafrost regions. I am not an expert of the statistical modelling methods. I assume they are valid and other reviewers can pay more attention to them.

Major comments

The analysis used thawing-degree-days (TDD) and freezing-degree-days (FDD) and other variables. It is valid for ALT since thawing occurs when air temperature (Tair) > 0 °C, and is related to TDD according to Stefan solution (especially in temporal variations). For AMGT, annual mean air temperature should be a major factor to consider. To assess the relative importance of cold season and warm season, winter mean and summer mean air temperatures are better choices than TDD and FDD since the length of the days is not a factor. I wonder why these factors were not chosen in the analysis. An important finding of this paper is that FDD were the main factor determining the spatial distribution of AMGT in the permafrost region while TDD dominated in the non-permafrost region. The days in a year when Tair < 0 °C are longer in permafrost region than in non-permafrost region. This difference automatically contributes to your results. If this effect is the major reason, I feel it is quite natural or understandable (the longer the more important) and should not be treated so sensationally as a significant finding. Any way, it would be meaningful and interesting to see the relationships between AMGT and annual mean, winter and summer mean Tair.

This study is to understand the factors affecting the spatial distributions of MAGT and ALT. The factors and mechanisms could be vey different from that controlling the temporal variations. The paper should make that clearer, including the title. It should be cautious about assuming factors controlling spatial distribution will automatically controlling the temporal changes (Lines 194-199). The paper used "divers", "driving" frequently. The words usually have a sense for temporal changes in climate change studies. For spatial distribution, it is better to avoid it. The relationships and impact indicators are based on statistical analysis. They depend on data, methods, and factors selected for analysis. It should be cautious to use the word "drive", just say "a factor has a close relationship with … or has large impacts statistically on …", especially when no strong physical processes and mechanisms to support the results. I like the phrase "new insights" in the title. The text should keep that cautious sense in the text.

Some minor points

Line 9: "The thermal dynamics of permafrost shape Earth surface systems and human activity in the Arctic …". "The thermal dynamics of permafrost" means temporal changes, which is different from the focus of the paper (spatial distribution). The word "shape" probably overstated the importance of the thermal dynamics.

As mentioned above, the title: "…driver of the circumpolar ground thermal region", Line 16: "main driver of MAGT in permafrost conditions" and similar sentences other places. These sentences give me a sense that they are drivers of temporal changes rather than factors influencing or determining spatial distributions of MAGT and ALT. The paper should make that clearer.

Line 17-19: The last sentence of the abstract is about temporal changes the authors like to infer from spatial patterns to temporal changes. It is problematic as I mentioned above. The term "initial ground thermal conditions" is not very clear, probably should say "the current ground thermal conditions". "local-scale topography-soil-driven variability", probably should be "local-scale variability in soil and topography" or simply "local-scale soil and topography".

Line 21: "geocryological development", the word "development" probably should be "dynamics".

Line 28: "activity", using plural.

Line 36: "ground temperatures are higher than air", adding "temperature" after "air", or "ground is warmer than air".

Line 59: "geographically comprehensive datasets of field-quantified MAGT (n = 784) and ALT (n = 298) observations.". Feels strange. How about "circumpolar field observations of MAGT and ALT". The number of sites in brackets can be described in methods section.

Line 63: "possible variation …", not very clear/direct. Using "differences" instead of "variation".

Lines 71: "MAGT values shallower than two meters …" should be "MAGT measured at less than two meters …" . Delete "systematically".

Line 85: "presenting", should be "representing"

Lines 94-98: You calculated TDD and FDD based on monthly climate data. Did you interpolated to daily or directly based on monthly averages? It is generally ok directly using monthly data based on the test of Frauenfeld et al. (2007. doi: 10.1002/joc.1372). You may refer to this paper for proof.

The tables and the figures are quite interesting. However, I feel the result section is a bit weak. I hope it can provide more detailed description, explanation and analysis of the tables and Figures.

Line 184: This study did not include any sites with permanent snow cover, you may delete "or permanent snow cover".

In discussion section, temporal changes were inferred from the spatial statistical results. The author should be cautious about that and clearly indicate the assumption.

Figures 2a-c: one color legend probably is enough. Figure 2d: the units of TDD and FDD should be °C d.

Figure 4: I am not familiar with the GAM. It would be useful to briefly describe how the response shapes are calculated and what do they mean? What is the unit of solar radiation?