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Interactive comment on "A statistical approach to represent small-scale variability of permafrost temperatures due to snow cover" *by* K. Gisnås et al.

Anonymous Referee #1

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General Comments The paper by Ginas et al. investigates the spatial variability of ground surface temperatures and the importance of snow cover variability. In particular, they consider the variability in snow cover that occurs over relatively small areas of 0.5 km2 which is less than the grid cell size generally utilized in permafrost models that incorporate average snow depths for grid cells of 1 km2 for example. In mountainous areas where strong winds and drifting snow can result in highly variable snow cover and ground thermal conditions, representation of sub-grid variability of snow cover is important for accurate predictions of ground thermal conditions under current and future climate. Ginas et al. propose a statistical representation of the sub-grid variability of ground surface temperature based on the snow cover distribution. The results of

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this work will be of interest to land managers and engineers for example, where local scale characterization of permafrost conditions is important for infrastructure design and assessments of human activity and development on landscape and ecosystem processes. The subject matter is appropriate for the Cryosphere and should be of interest to permafrost scientists and engineers and also to hydrologists, ecologists and the modelling community.

Arrays of temperature loggers established in 3 study areas along a climatic gradient in Norway, encompassing sporadic to discontinuous permafrost zones, are utilized to measured ground surface temperatures. Ground surface temperature data acquired for 2012-13 is analysed with information on snow cover determined through GPR surveys. The methodology is explained fairly well. The analysis and interpretation of results is generally sound and results are clearly presented and support the conclusions made in the paper. The paper is fairly well written and figures are utilized well. A few comments and suggestions for improvements are offered for the authors' consideration (see specific comments below). In my view, the paper is acceptable for publication with minor revisions.

Specific Comments Comments are keyed to page and line number

Pg 510, line 19-20 – Snow cover can also affect the freeze-back of active layer in the fall and winter.

Pg 511, line 1-3 – Suggested revision: "The strong redistribution of snow by wind results in accumulation of snow in deep hollows, while large open areas are bare-blown."

Pg 511, line 23 – Suggested revision: replace "implemented" with "established"

Pg 511-514 – Study site description: Information on surficial materials is not provided for all study areas and it would be good to include this. Information on moisture/ground ice conditions would also be useful. Sparse vegetation is mentioned for the Juvvasshoe

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site but there is no comment on the vegetation for the other sites – is it also sparse?

Pg 512, line 7 – Is there a more recent climate normal for the study area such as 1971-2000 or 1981-2010? This would be more representative of current conditions.

Pg 513, line 9 – Suggested revision: "... and indicates permafrost extends below a depth of 300 m" or "... and indicates permafrost is more than 300 m thick"

Pg 513, line 22-23 – It may be better to say that snow heights of 1.5 to 2.0 m are possible. (Was average density utilized to determine the snow cover thickness? – you could perhaps say something about how you arrived at these values.)

Pg 514, line 7 – Revise: "...estimated to be 1550 ma.s.l."

Pg 515, line 1-2 – The loggers were utilized to measure surface temperature throughout a complete year (or almost a complete year) but this sentence implies that temperatures were only measured during the winter season. Perhaps you could say that measurements were made over the hydrologic year that includes the winter season 2012-13.

Pg 515, line 12 – Was a random number generator utilized to select sites and achieve the random distribution.

Pg 516, line 3-4 – Are there any errors introduced due to packing of snow as the snowmobile travels over the surface?

Pg 517, line 11 – Define MAGST (mean annual ground surface temperature).

Pg 517, line 10-15 – Since you do not determine or discuss TTOP in this paper it may be misleading to refer to the TTOP approach here. You could just say that n-factors are used as transfer functions between air and ground surface temperatures and (as you correctly point out) represent the surface offset.

Pg 517, line 25-26 – Perhaps this statement should be incorporated into the discussion section. In this paper you do not really estimate TTOP but rather are focussing on

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improvements in characterization of GST which can be used with your model to determine TTOP and characterize permafrost distribution etc. In the discussion you could say more about how the improved estimates of GST can be used as model inputs to improve TTOP estimates etc.

Pg 518, Results section – You could possibly summarize your results in a table which would include mean and standard deviation for MAGST, snow depth, duration etc.

Pg 518, line 21-22 – Revision suggested: "...with ground surface temperatures close to 0°C at many of the measurement sites."

Pg 519, line 9-12 – Although snow cover is an important factor influencing nF, the amount of latent heat released by the active layer during freezing in fall/winter (which will depend on active layer thickness as well as substrate moisture conditions) can determine how important snow is as an insulator – see Smith and Riseborough (1998); Throop et al. (2012). Snow cover therefore has a greater effect on nF where permafrost is warmer and also where soil moisture contents are greater. It might be interesting to see if there is any difference in nF between wet and dry sites that may have similar snow cover. Variable moisture conditions could be responsible for some of the variability in nF (and GST).

Pg 519, line 19- Pg 520, line 8. Some clarifications are probably needed in this section. Snow depth determined from the GPR surveys are utilized to determine MAGST using CryoGrid. What is the resolution of the output and over how large an area is MAGST determined to produce the distribution shown in Fig. 5? It is not clear whether a point to point comparison between modelled and measured MAGST is presented or rather the modelled values (and distributions shown in Fig. 5) are for the entire area for which the snowcover distribution has been determined. The concern I have is that the same data are being used for model validation as those used to determine the relationships between snow depth and n-factors.

Pg 521, line 1-12 – You could probably say it is both the mean and variability that is

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important (i.e. more variability in GST when the snow cover varies around a mean value that is less than 1m than when it varies around a mean value that is greater).

Pg 523, line 2-6 – You might mention that this is important for determining local scale impacts on drainage and ecosystems resulting from changing permafrost conditions. It might also be worth mentioning that information at this scale is also required for infrastructure planning and design.

References Riseborough, D.W., and Smith, M.W. 1998. Exploring the limits of permafrost. In Proceedings of Seventh International Conference on Permafrost. Yellowknife, Canada. June 1998. Collection Nordicana Vol.57, pp. 935-941.

Throop, J., Lewkowicz, A.G., and Smith, S.L. 2012. Climate and ground temperature relations at sites across the continuous and discontinuous permafrost zones, northern Canada. Canadian Journal of Earth Sciences, 49: 865-876.

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