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Interactive comment on "A ground temperature map of the North Atlantic permafrost region based on remote sensing and reanalysis data" *by* S. Westermann et al.

Anonymous Referee #2

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Westermann et al. present a modelling scheme based on MODIS acquired LST and ERA-Interim reanalysis products in order to derive MAGST at 1 km at a continental scale. Subgrid variability is addressed by computing a distribution of MAGST's using a simple equilibrium model (CryoGrid 1) for each grid-cell. The approach is applied to approximately 5 million km2 in the North-Atlantic region. The approach is evaluated against a network of 143 boreholes (IPA 2010) and suggests a model accuracy > 2.5degC. The probabilistic approach allows a classification of each grid cell as continuous, discontinuous and sporadic permafrost.

In general I found the manuscript to be an interesting approach (and enjoyable read) that could be an important contribution to large area permafrost modelling and would

recommend publishing after consideration of the following suggestions and comments.

MAIN COMMENTS

1. TOPOGRAPHY AND SURFACE COVER The scheme accounts for subgrid variability by computing a range of physically plausible nf (roughly the offset between GST and surface T generally caused by snowpack) and rk (roughly the offset between GST and temperature at depth) parameter values. You mention rk to be primarily dependent upon water content of the soil but also of significance is the thermal properties of the surface cover itself – blocky, vegetation, fine grained material etc. Is this somehow considered in computing variability? Another very important source of subgrid variability, even at the 1 km scale is topography, particularly elevation and aspect (although reduced influence in northern climates). It would be nice if this could somehow be considered in some kind of ruggedness index as obviously this effect on uncertainty is far greater in a steeper region of coastal Greenland compared to flat regions of the Russian Arctic.

2. UNCERTAINTY OF ERA-INTERIM AIR TEMPERATURE FIELD You address some of the downscaling issues with using a coarse scale product such as ERA-Interim and I agree with the simple approach for your application. However, you don't discuss the spatial variability of bias in a reanalysis product such as ERA-Interim which rely on stations / upper air measurements to constrain the weather model. Such variability could lead to strong differences in regional patterns of bias. Some references (if available) on the performance of ERA-Interim in the North could be useful. You mention the finding that model levels below grid level do not yield as good results and in general this was found to be related to poor representation of the surface boundary layer. One significant effect of this that is worth mentioning is that valley inversions are not captured in the temperature field.

3. UNCERTAINTY OF ERA-INTERIM SNOW DEPTH There are well documented biases in reanalysis precipitation fields (eg Schmidli et al 2006) and such coarse resolu-

tion of ERA-Interim will never capture the variability of snowdepth in complex topography which in turn has a large effect on spatial patterns of the ground thermal regime. I think these possible sources of bias should be mentioned in the scheme evaluation. Also, how are snowdepths at each grid cell used to determine the range of nf factors? I don't see this described anywhere.

4. UNCERTAINTY OF MODIS LST You mention in Section 2.2 the seasonal average cold biases of up to 3K and therefore question the reliability of MODIS. To overcome this problem you say you have a composite product of reanalysis and MODIS. However, the reanalysis is used to gap fill cloudy days. Does this mean the 3K bias is due to cloudiness or some other effects? It would be good to be clear how the composite directly addresses the bias in MODIS and is not just a gap filling strategy.

6. CLOUDINESS How is cloudiness detected and subsequently MODIS scenes rejected? Some details on methods, thresholds used would be useful.

7. BIAS There appears to be a cold bias in "North America" (Figure 3) compared to "Nordic" and "Russia". Do you have any suggestions why?

8. VISUALIZATION OF UNCERTAINTY Linking back to comment 1, among other factors – key sources of uncertainty would be related to ruggedness of topography in a grid cell. Would it be possible to devise an uncertainty map based around a topographic index? Another figure I would like to see would be a spatial representation of the variability of modelled values for each grid-cell. This would again give some insight into regional patterns of uncertainty at least with respect to the perturbed model variables. You could also overlay bias point values on this map from the borehole-modelled results.

TECHNICAL COMMENTS

1. P754 l6: on continental scale > at continental scales. 2. P755 l16:18: reads a bit like this sentence has just been thrown in there without too much context. 3. P755 l25:26:

which SWE product do you refer too and why do you not use instead of ERA-Interim snow-depth. 4. P756 l5 Schmid et al. 2012 could be a good reference here too. 5. P756 l18: on continental scale > at continental scales. 6. P756 l18: factor > variable? 7. Section 2.3: why was ERA-Interim chosen? 8. You mention SST and upper-air soundings but surface stations are a significant source of data. 9. P762 l6 round > ground 10. P762 l19 remove 'a' 11. P765 l10 "regime on <a> continental scale" 12. P769 l8 a proxy of temperature is measured and converted to LST via an algorithm 13. P769 l7:8 You mention that the strength of LST is to provide an actual measurement – perhaps its worth moderating that statement as there is a lot of algorithm going into deriving the final LST value. In that sense you could argue MODIS LST is closer to a modelled value. This separation is of course not black and white - but I think you would not classify MODIS LST similarly to a sensor directly at the ground surface.

REFERENCES

Schmidli, Jürg, Christoph Frei, and Pier Luigi Vidale. "Downscaling from GCM Precipitation: A Benchmark for Dynamical and Statistical Downscaling Methods." International Journal of Climatology 26, no. 5 (April 1, 2006): 679–89. doi:10.1002/joc.1287. Schmid, M.-O., S. Gubler, J. Fiddes, and S. Gruber. "Inferring Snowpack Ripening and Melt-out from Distributed Measurements of near-Surface Ground Temperatures." The Cryosphere 6, no. 5 (October 2012): 1127–39. doi:10.5194/tc-6-1127-2012.

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