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The Cryosphere Discussions

Interactive comment on "Permafrost and surface energy balance of a polygonal tundra site in Northern Siberia – Part 2: Winter" *by* M. Langer et al.

M. Langer et al.

mlanger@awi.de

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We thank the reviewer for the constructive comments on our manuscript. We carefully considered all comments of the reviewer which are highlighted in bold. Changes done in the manuscript are marked in italic.

This manuscript reported surface energy fluxes and balance measured/estimated at an arctic tundra site and a pond site of polygonal permafrost region in two winter seasons. It is obvious that tremendous efforts had been made to obtain such dataset in harsh arctic winter conditions. Such datasets

are rare in high arctic regions and its potential application could extend to permafrost and land surface modeling, or other surface energy related studies. By this alone, this reviewer believes that the data and results of this study are worth to be published in The Cryosphere or other peer reviewed cold region journals. However, this reviewer also found that the current manuscript was a hard read and lack of focus. The authors may need to do some major revisions, mostly structural adjustments, to meet the final publishing standard of a peer reviewed journal.

In the revised version of the manuscript we sharpened the focus of the study. This includes a more specific Introduction (see Sect. 1) and a completely restructured Discussion (see Sect. 5) which now more specifically addresses the results of this study.

(a) The title "Permafrost and surface energy balance of a polygonal tundra site in Northern Siberia" is not exactly matching the contents. This study is mainly about surface energy balance, not much reported in this part was about permafrost features (e.g. active layer, permafrost temperature etc.). I would suggest something like "Surface energy balance at a polygonal permafrost site in Northern Siberia". Deep borehole observations and soil water measurements may be reported in another paper. This would make the paper much more focused.

We changed the title to: "The surface energy balance of a polygonal tundra site in northern Siberia ..." to more accurately reflect the content of the paper. We also reduced the content concerning the thermal state of permafrost in Sect. 5. However, soil water freezing and the deep soil temperatures are essential for the coupled system of soil-snow-atmosphere energy exchange, as the ground heat flux is one of the most important terms in the wintertime energy balance. Therefore, we believe that it is

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important to include information of the processes giving rise to the ground heat flux (i.e. soil water freezing and temperature change in deep soil layers).

(b) The current manuscript is not a standalone paper. Its acceptance for publication totally depends on the successful publication of its first half. At current status, the readers have to frequently check back to its first part in order to fully understand this part. At the same time, there are many statements and paragraphs (mostly in introduction, study site, methods and conclusion sections) are repeated in both parts. I would suggest either make them independent papers or reduce the duplicated parts. It is even possible to integrate them into one paper with more focusing, concision and structural organizing (details will be discussed in following points).

The first paper on the summertime energy balance is now published. Both manuscripts has been made more independent by extending the description of the methods (see Sect. 2) and reducing the references to the companion paper. Furthermore, the introduction (Sect. 1), the Discussion (sect. 5) and the conclusions (Sect. 6) have been rewritten in order to remove unnecessary duplications. The description of the study site (Sect. 2) now focuses more specifically on the winter landscape. In the revised version of the manuscript, only the paragraph "The annual surface energy balance" (Sect. 5.2) makes extensive use of results of the first part of the study. However, we believe that providing an assessment of the the annual budget (which necessarily contains data from the summer and winter part) is an important aspect of the study, which is only possible as the measurements have been conducted over an entire yearly cycle. Sect. 5.2 has been completely revised to sharpen the focus of the paragraph.

(c) I believe the authors should focus on reporting the direct observations / measurement-based estimations of energy balance features at the tundra and

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pond sites, and reduce the indirect implications and application potentials. The implications and application may be briefly stated in introduction, but not necessarily appeared as a whole subsection (e.g. section 5.3).

In the revised version of the manuscript, the focus is put on the observations and measurements. Section 5.3 "Implications for modeling permafrost-snow-atmosphere interactions" has been completely revised to only include two points which we consider potentially important for larger-scale atmospheric models: 1.) the magnitude of the ground heat flux (60% of the energy lost through net radiation provided by refreezing of active layer and soil cooling), which might not be accounted for in simplified representations of soil thermal processes as implemented in larger-scale atmospheric models. 2.) the considerable subgrid heterogeneity of the refreezing of the active layer, which implies a subgrid variability of the soil volume, in which microbial decomposition of organic material leading to greenhouse gas emissions occurs. As greenhouse gas emissions from permafrost areas (which potentially depend on a number of factors, such as soil moisture and soil temperature, in a highly non-linear manner) are to be included in General Circulation Models in the future, information on subgrid variability of the refreezing process in Siberian permafrost areas (which are potentially the main source areas for greenhouse gas emissions from permafrost) is of relevance.

(d) Reorganizing the structure of the "Results" section may help to reduce the length of current manuscript. The current results were reported in several seasonal periods (e.g. spring, summer, fall and winter) and sub-periods (e.g. early, polar and late winter). While it highlights the seasonal features of the energy balance components, the readers are easily lost the whole picture of certain energy balance components. More over the readers have to refer back to the same figures (e.g. Figs 4-6) during each period and only look at one section of them at a time. I would suggest reorganize the results by energy balance components (e.g. net radiation, sensible heat, latent heat and soil heat flux etc.)

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and integrate their seasonality into each section.

We chose to follow the organization/structure of Part 1 of the study which is based on the the seasonal dynamics and has been published now (Langer et al., 2011). Moreover, this structure and data presentation facilitates future model validations of energy balance components.
One of the main applications of the field data on the surface energy balance reported in this study is the validation of modeling schemes for the surface energy balance. For this purpose, we believe that the current stucture is more appropriate as such models evaluate all components of the surface energy balance for a specific time or period. Therefore, we think that it is preferable to provide all findings on the surface energy balance for a certain period together.

(e) Many of the section 5 (e.g. 5.1 and 5.2) are conclusion rather than discussion while many points in section 4 more like discussion rather than results. I would suggest either revise the subtitles or adjusts their contents.

We agree with the reviewer and shifted a number of statements from the result section to the discussions. Moreover, the Discussion and the Conclusion sections have been completely rewritten to give the paper more structure and focus.

(e) Many of the section 5 (e.g. 5.1 and 5.2) are conclusion rather than discussion while many points in section 4 more like discussion rather than results. I would suggest either revise the subtitles or adjusts their contents.

We agree with the reviewer and shifted a number of statements from the result section to the discussions. Moreover, the Discussion and the Conclusion sections have been completely rewritten to give the paper more structure and focus.

(f) The orders of magnitude of energy balance components at the studied sites during the winter period are relatively small, and mostly only a small fraction of their values in southern sites or during summer periods. Some small errors (relative to the measurements in other southern locations) in the measurements or estimation procedures could lead to relative large error on the final energy balance or even shift its direction at this site. It would very helpful if more efforts (may be in the discussion section) could be made to estimate the possible error ranges or confident levels of each components and final energy balance.

In the revised manuscript, we provide measurement accuracies and error estimates for the single energy balance components, wherever possible (see Sect. 3). Only results, which are consistent in the light of this error assessment are considered. However, some factors giving rise to additional uncertainty (e.g. the different footprint areas of the sensors used to measure radiation and turbulent fluxes) cannot be quantified based on the presented data set. Therefore, a paragraph assessing the reasons for the relatively large closure term C during the early winter period has been added.

(g) Page 1394 Lines 10-12: The definition of "winter period" should not be changed in the two years although the measurement periods were different. You could indicate that some data were missing during 2008-2009 winter.

Definition of the winter period has been changed accordingly.

(h) Page 1394 Lines 14-17: Other than the differences between the tundra and pond sites, this study still considered a study of individual point scale. Extend the results to "spatially distributed" or "large scale modeling" seemed not very convincing to me.

We agree with the reviewer that a more cautious wording is required in terms of the spatial scales that are covered by this study. Therefore, we rephrased this part of the introduction accordingly.
The objectives of the study are to (i) identify the controlling and limiting factors of the winter time surface energy balance, (ii) evaluate differences in the surface energy balance between the most prominent landscape elements, namely the snow-covered tundra soils and freezing water bodies, and (iii) assess differences between the two winter seasons. The results are discussed with respect to modeling the arctic boundary layer and permafrost.

(i) Page 1394 Lines 24-25: should it be "the POLAR winter period is..."?

Done.

(j) Check the table numbering sequence, some tables referred in the text was mislabeled (e.g. table 6 should be table 3?).

Wrong labels are corrected.

(k) Page 1460 Line 8 and Line 21: "Looses" should be "loses"?

Done.

(l) Page 1422 Table 3: Qnet,p should be marked with indicators of instrument as for Qnet. The symbol (y) Qnet,p is not explained in the title.

$Q_{\mathrm{net,p}}$ has been labeled accordingly and $Q_{\mathrm{net,p}}$ is now explained in the title of Table 3.

(m) Page 1428 and 1429: please indicate the values are daily or other period averaged values?

The heat fluxes are hourly averages which is now explained in the figure captions.

References

Langer, M., Westermann, S., Muster, S., Piel, K., and Boike, J.: The surface energy balance of a polygonal tundra site in northern Siberia – Part 1: Spring to fall, The Cryosphere, 5, 151–171, doi:10.5194/tc-5-151-2011, 2011.

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