Comments from referee #2 and responses of the authors concerning manuscript I.Beck_esurf-2015-7

Comments to the author from Reviewer 2

The paper shows an interesting application of d-GPS in discontinuous, thaw-sensitive permafrost area. The paper addresses two distinct subjects; the first being the application of a methodology to monitor ground surface movement, the second being acquiring new knowledge in regard of the yearly ground surface movement of permafrost mounds. The first objective is addressed by the other reviewer, so we will focus on the second objective of the survey that remains somehow unclear to the reviewer.

Although the technical value is clearly explained, the purpose of the study from a permafrost science perspective is unclear. It is largely due to the fact that the study lacks permafrost oriented data allowing reaching the full understanding of the results. We can assume that the question of the active layer dynamic is at the centre of the study; yet it in unclear if the active layer, to which subsidence and uplift movements relate to, has been monitored. What is the thickness of the active layer on the sites? Any idea about what is permafrost thickness too? What were the depths of the thaw fronts at the time of D-GPS measurement? Note: Active layer depth and thaw depth are not the same; the text should be checked to use proper vocabulary.

The vocabulary used has again been checked and the expression 'active layer depth' has been replaced by 'thaw depth', since 'active layer' is indeed not the correct terminology for the results in this study. Concerning the data on thaw depth, please refer to our response to the reviewer's next comment.

An easy assessment to do would have been to set up few (one in each type of land cover) inexpensive 4 channel Hobo loggers to monitor the progression of thaw front in the first two meters (we assume that the active layer thickness should be around 1.5 m). Cheap TDR probes are also available on the market, they could have been used to monitor humidity in the active layer; the water supplying ground ice aggradation being a key factor for the uplift. Maybe the CEN would have been of some help in this simple matter. With a least effort, the thaw depth could have been measured using a frost probe at each visit. It is unclear if such data exists (see comment about P 264 line 16).

We are grateful for this advice. Hobo loggers would have been useful, but were unfortunately not available at that time. Such loggers were installed in October 2011 which was too late for the timing of this study, but a frost probe was used to identify the thaw depth during the field visits. This data has been previously published in May et al., 2014.
To clarify this point we have added the following sentence to Section 3 (Data and methods):
[…] Thaw depths were also measured at the same time as the other field measurements were obtained, using a frost probe.[…] (page 6, line 7).

Some clarifications are required in regard of some climate factors. The addition of one figure (based on fig 4) integrating climate data such as mean monthly air temperature for all the period of the study, and not only the months where the measurements were made, would bring support to authors' interpretations. A snow survey is also missing.
We are grateful to the reviewer for this suggestion. The monthly air temperature has now been added to Figure 4. Concerning the snow data, please refer to our response below to the comment on the 'Results/discussion' section (pp. 261-263).

Picture of field condition during winter would improve understanding of the results.

We have added an appropriate photograph from the field visit in April 2010 (Fig. 6). Please see also our response below to the comment on the 'Results/discussion' section (page 261-263).

The reviewer thinks that the article would have greatly beneficiate of the missing active layer and climate related data. If such data exist, they should be incorporated. Nevertheless the reviewer thinks that the article is suitable for publication providing clear statement of its limitations in the understandings of the active layer/permafrost processes, and minor modifications aiming to improve both readability and value. Minor corrections are required, such as few missing references to check out.

Specific comments

In 'Abstract' line 1 and 'introduction' line 1: Author should replace 45% of permafrost underlying canada's land by 40-50%.

Permafrost-affected soils cover about 40 – 45 % of Canada. […] (page 1, line 17).

P 253 Line 1: "Permafrost ../.. has a significant effect on the global climate." Should it not be the other way?

Permafrost underlies 40 - 45% of Canada and is significantly affected by the global climate[…]. (page 2, line 13)

P 253 Line 10 – 14: The authors can remark that per nature, ground temperature in these mounds are already warm (>-2_C) and therefore predisposed to thaw in a warming climate.

We appreciate this comment. The following information has now been added:

[…] Characteristic landforms of the discontinuous permafrost zone, such as palsas and lithalsas (Fig. 1 a), are also likely to suffer as a result of increasing soil temperatures, especially as the ground temperature in these features is usually already >-2°C.[…] (page 2, line 21).

P 254 Line16: Sheng et al 2004 missing in the reference list.

This has now been added to the list of references.

P 255 Line 22: "mainly scatter". Should be noted "discontinuous"; Widespread or sporadic depending on the location.

It has been changed two times in the manuscript:

[…]The permafrost is sporadic (Fig. 2) and the study area covers the northern timber line; the mean annual ground temperature (MAGT) […] (page 5, line 7).

(caption of figure 2): […]. The approximate boundary between widespread discontinuous permafrost to the north and sporadic permafrost to the south […]

P 257 '3.1 Field Data' The paper will beneficiate if characteristics of the site were summarize in a table. It would lighten the text and would make comparisons easier.

Thank you for this very good suggestion. The following sentence has now been added, together with the table referred to (Table 2).

Table 2 summarizes the characteristics of the three lithalsas.

P 257 line 20-21: 'on the east-facing slope' Looks more like North facing to me.

[…]A pond has also formed on the north-facing slope of Lithalsa M, but its dimensions […] (page 6, line 26).

P 259 line 13: 'Few centimeters' 0-5, 5-10, 10-15 cm?

[…] vertical accuracy was reduced to within a few centimeters (~ 5 cm). […](page 8, line12).

P 261-263 'Results/discussion': The author would greatly beneficiate to include climate data in their article; a graph showing air temperature record from the CEN's station in the Valley, that allowing temporal comparison between air temperature trend and ground surface movement data seems mandatory, at least a table with monthly average could do the trick. Value for the only months of measurement are insufficient.
We are grateful for this advice. The monthly air temperatures (based on Nordicana data) have now been added to Figure 4.

The reviewer also thinks that even if the question of the vegetation is addressed, the issue of snow is not. Was there more or less snow accumulating during winters 2010 and 2011? How snow may impact the thermal regime of the mound, what is the snow accumulation/topography/wind pattern?
We thank the reviewer for this advice. The snow cover is of course very important for the thermal regime. However we have ignored it in our study since, due to wind erosion, the mounds had hardly any snow cover. We have now added the following sentence to the revised manuscript, together with a photograph taken in April 2010 (Figure 7) to support this statement.

Both the vegetation and the snow cover influence the thermal regime of the ground. However, since frost mounds are exposed features in the landscape any snow cover is usually quickly removed by the wind and they are commonly almost frost free (Fig. 6). The influence of snow cover on the mounds has therefore not been included in this study. (page 13, line 15)

P 261-262 I advise to put Results and Discussion in two clearly identified separated sections
We are grateful to the reviewer for this very good suggestion. **We have now separated the results and the discussion into two sections, Section 4.1 and Section 4.2. and have slightly rearranged the content to fit into these sections.**

P 264 Line 16 "records of the active layer depth" did the authors make a thaw depth survey? If so, why are the data not shown? "non-vegetated areas had very thin (< 5 cm) thaw depths in the summer (August)": is a zero missing (50 cm)? 5 cm seems a bit unrealistic.
Some measurements from the non-vegetated top of lithalsas were collected by the authors and, although the soil seemed to be very thin, there were certainly points were the soil had hardly thawed at all and the unfrozen layer was less than 5 cm thick. However, since the thickness of this layer varied between 5 and 60 cm the sentence has been changed as follows:
[…] non-vegetated measurement points is not surprising since the records of the thaw depths during the same year (2010) indicate that non-vegetated areas had very shallow (5-60 cm) thaw depths in the summer (August) compared to areas covered with shrubs or trees, where the thaw depth was up to 200 m (Beck et al., 2015) […] (page 13. Line 15).

Reference missing in text: Allard and Séguin 1987
the publication by Allard and Séguin (1987) is referred in the caption of Figure 2 ("The approximate boundary between widespread discontinuous permafrost to the north and sporadic permafrost to the south (based on Allard and Séguin, 1987) is shown in red")

Tait et al 2004.
This reference has now been deleted from the reference list.

Technical corrections Fig 6: Letter A is missing (top left)
This has been corrected. (Please notice that Figure 6 is now Figure 7.)