Authors reply #2 on referee comments on the revised manuscript "The influence of surface characteristics, topography, and continentality on mountain permafrost in British Columbia" by A. Hasler et al.

Dear Editor, dear Referees,

Thank you for the time taken to review and comment the revised manuscript! We considered all your comments and changed the manuscript according to the comments below:

Comments to referee #1:

RC: Sect. 4.4: I suggest re-arranging this section, and as a general guideline present the results of this study first, followed by the discussion, as it has been done in 4.1-4.3. When starting to read this section, it does not really become clear how the rather lengthy introductory paragraph l. 414-l.442 will connect to the findings of the study. Some parts of this paragraph could also be moved to the Introduction, since it outlines in important research question which is to a large part the motivation for this study.

AC: This introduction paragraph is indeed clearly longer in section 4.4. We agree that shortening this paragraph will make a more consistent "results and discussion" section where results come first and the discussion follows after that.
We did not completely remove this introduction because some parts are needed to understand the way we present the results and to be consistent with the other sections (4.2 and 4.3). As suggested, we shifted some parts of the content to the introduction (L 82ff). References from the introduction paragraph have been shifted to the latter discussion of section 4.4 (L 514, 523).

RC: Sect 5: I suggest removing the first point on data processing, or transform it to an introductory statement like "Despite the inhomogeneous and inconsistent data quality, a "quasi-static" surface offset- / thermal offset-analysis could be performed"

AC: We erased this methodical outcome from the *Conclusions* and added a brief note on that to the introductory statement as suggested (L562). We added a sentence on that at the end of section 3.2 (L 260).

Comments to referee #2:

RC: The surface offsets show also high temporal variability at some sites. The temporal variability in the surface offset could be discusses in some more detail in respect to the SO uncertainty calculations and inter-annual variability among the sites in e.g. snow cover (e.g. L264). Do you have any idea on how representative your measurement period is and the presented SO values in respect to the last 20-30 years (see point below)?

AC: This is a tricky question, and you are right, it was not discussed satisfyingly in the revised manuscript. We may brake it down to three separate questions:

a) What is the characteristics of the temporal variability of SO?
b) How well does the observation period capture the SO and its variability?
c) Does the calculation of the SO uncertainty reliably indicate where a significant SO occurs?

We try to answer these questions with the following reasoning. Respective figures are attached below.

The variation in surface offset is mainly caused by variation in snow conditions and lesser by the radiation conditions (e.g. in near-vertical bedrock). It is not necessarily linked to inter-annual variability in MAAT or long-term air temperature trends. More important is the particular timing and evolution of the snow cover, which is highly variable in time and space. Accordingly, the annual precipitation sums or SWE (snow water equivalent) is only a rough proxy to predict a change in SO. However, all these aggregated meteorological parameters (MAAT, annual prec., SWE; cf. Fig. R1 below), shows a large inter-annual variability compared to long-term trends. The same is expected to be true for SO (there is no published study on that up to our knowledge) and our data (and other datasets e.g. PERMOS; pers. com. B. Staub) indicate that the surface offset changes from year to year for snow covered locations.

That leads us to the question if the snow (and radiation) conditions in our observation period are systematically different from the long term mean and if they show enough variability to get a representative SO und uncertainty estimate. Figure R1 shows the SWE records from three snow pillow stations where long-term data is available. They show that the years 2008 to 2011 have maximum SWEs in the typical range. SWEmax at these stations varies roughly ±40% and shows no obvious trend. The Snow Survey and Water Supply Bulletin from 2012 shows snow indices in the range of 75% to 140% (also based on snow pillow measurements) for the years 2008 to 2012 in the two regions closest to our filed sites (Figure R2). Based on that we can assume that the general snow situation during the observation period is representative for the last 30 years. However the particular situation for one location considering snow redistribution effects and data gaps does not allow to precisely quantify the SO and its uncertainty.

We think to consider this ambiguity by the conservative estimation of the SO uncertainties and are confident that SOs are typical for the last 30 years for all location where a "significant" SO is postulated. The technical aspects of the uncertainty calculation were shortened according to the suggestions of both referees in the first review. This calculation is a min-max difference if more than 50% of the running annual means (which is about 70 % of raw data) are available (Fig. 2a in manuscript), hence, even if we do not capture the entire variance typical for the last 30 years, this min-max spread for the short observation period indicates the range where long term mean offsets are likely expected. A very conservative estimation of the uncertainty of the MATs and the related SO is performed if less data is available (Fig. 2b). The only case where the uncertainty can be small (< 1°C) is if we have sufficient data and the SO stay ratter stable (MAAT and MAGST parallel; cf. Fig. 2a).

These aspects have been introduced at different places in the second revision: We explain the characteristics of SO variation (L221) and why a few years capture a large part of this variability where the SO calculation is described (L 288ff). We generally revised the first paragraph in section 4.1. We emphasize the conservative estimation of the spreads and our confidence in the existence of SO where indicated as “significant” (L 294).

RC: L135-L141 and L262-265: The air temperature and precipitation trends referred to are quite old and end in 2003. Please include a more updated reference or make a simple own analyses based on climate data from nearby weather stations in the region. This would also add information on the specific temperature and precipitation and snow conditions during the actual observation period.

AC: There is no recent study on air temperature trends based on observational data for the study region. According to data from two near-by meteo stations (Fig. R3 and R4 below), there is no obvious trend in MAAT (and precipitation) since 1990. A pronounced increase in MAAT from 1970 to 1990 is responsible for the long term trend described in Egginton et al. (2005) (Fig. R3). The snow water equivalent is observed and regularly published in the *Water supply and snow survey bulletin*. The values of the snow water equivalent in the two regions in the period 2008 – 2012 were typical for the last 30 years (Fig. R1 and R2).
We introduced a note on the air temperature development as well as the precipitation and snow characteristics during observation period (L152ff).

RC: L352 and L365: Suggest to not using the term “thermal diode effect” since the thermal diode model” has been removed.

AC: Here the term relates to the variable thermal conductivity of the frozen und unfrozen moss/peat according the Williams and Smith (1989). Is does not reference to the snow diode model. We clarified: “caused by the seasonally variable thermal conductivity of the moss layer (thermal diode)” on L 390 and “(…) thermal offset effect of the organic soil layer” on L 404.

RC: L348: Use “lower” air temperature (not colder)

AC: changed

RC: Figures: For better readability please increase the size of fonts used at axis and legend in Figures 1, 2 and 3 (similar to the other figures).

AC: We modified figure 1, 2, 3, 4, and 5. The other three figures are provided with sufficiently large fonts (please use 2-columne layout for fig. 6 and 7; they are scale to 16.3 cm with 300 dpi).

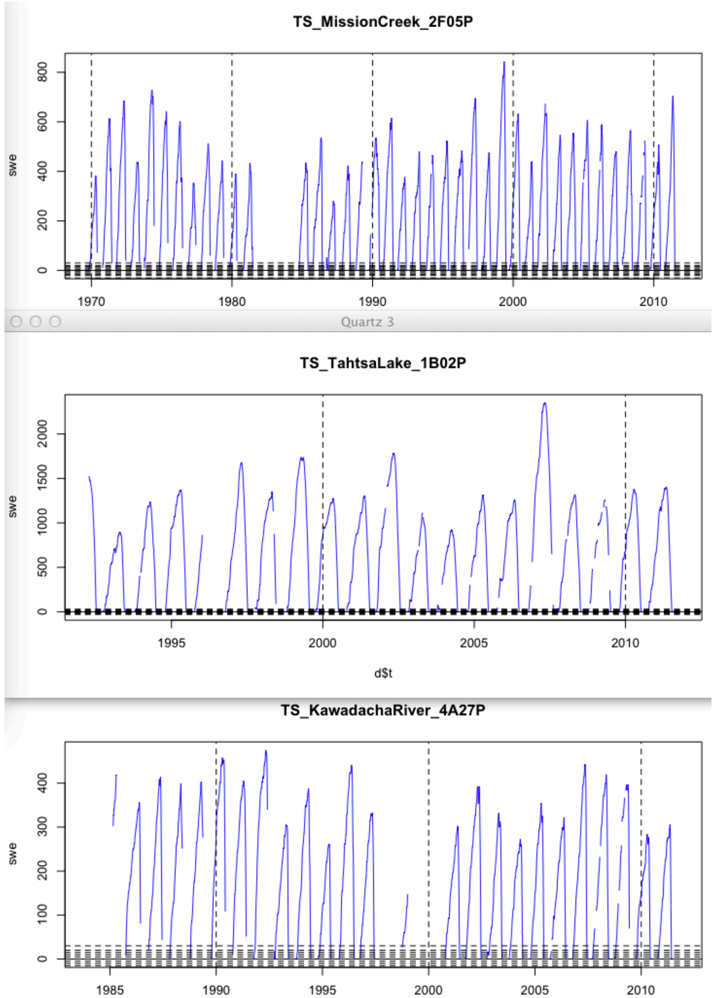
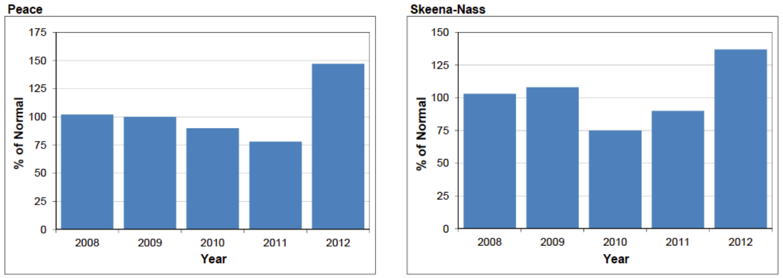


Fig. R1: **Snow water equivalent (SWE)** at three snow pillow sites in British Columbia (Mission Creek is in south BC, Tahtsa Lake is in Coast Mtn. near Hudson Mbay Mt. field site; Kawadacha River in Rock Mtn. near PIN field site)

% of SEW from normal in January



% of SEW from normal in April

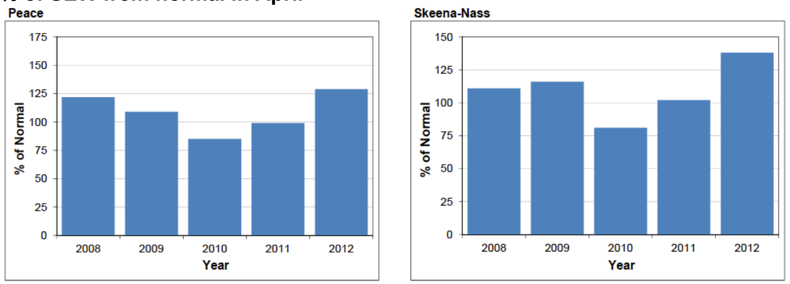


Fig. R2: **Snow Basin Index Graph** from Snow Survey and Water Supply Bulletin. Top: January; bottom April; normal refer to the period 1981 – 2010.

Source:

River Forecast Center: Water supply and snow survey bulletin – January 1st, 2012, available at: http://bcrfc.env.gov.bc.ca/bulletins/watersupply/archive/2012/2012_Jan1_SnowBulletin.pdf, 2012a.

River Forecast Center: Water supply and snow survey bulletin – April 1st, 2012, available at: http://bcrfc.env.gov.bc.ca/bulletins/watersupply/archive/2012/2012_Apr1_SnowBulletin.pdf, 2012b.

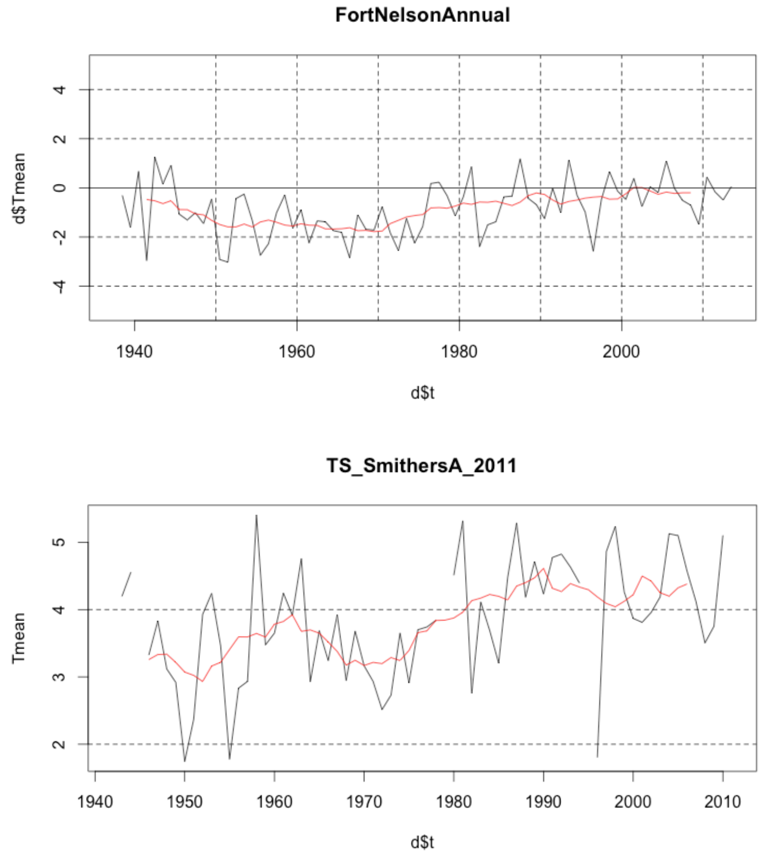


Fig. R3: **MAAT (black) and 10-years running mean (red);** data from Environment Canada)

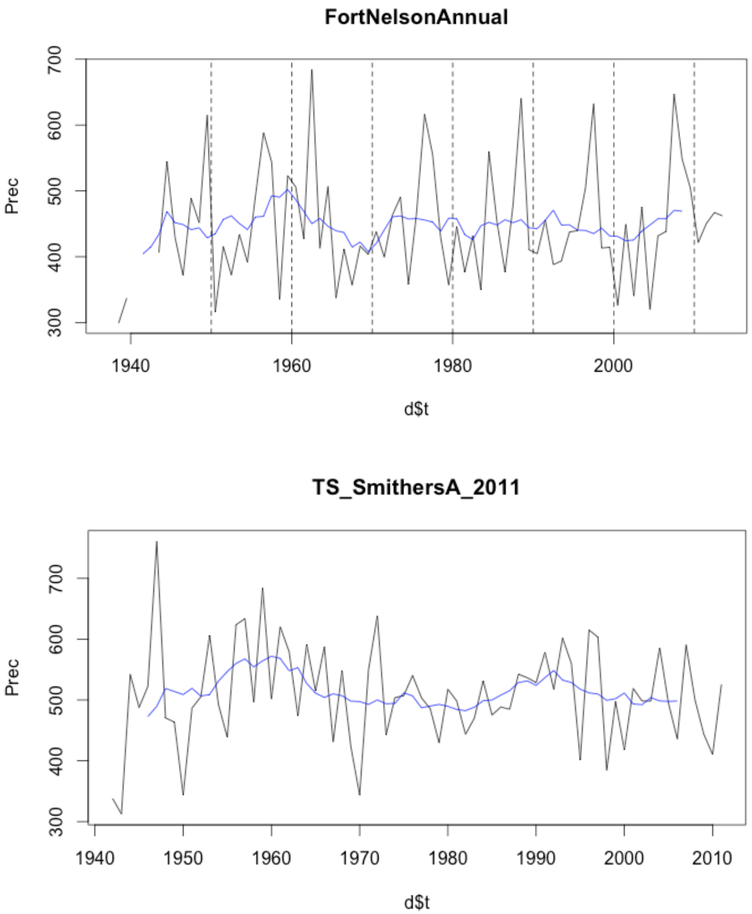


Fig. R4: **Annual precipitation sum (black) and 10-years running mean (blue);** data from Environment Canada