

Thank you again for your revised manuscript entitled “Change in Frozen Soils and Its Effect on Regional Hydrology in the Upper Heihe Basin, on the Northeastern Qinghai-Tibetan Plateau” (tc-2017-158).

The revised material adequately incorporates most of the reviewer’s comments, and should be suitable for publication in TC with further revision. Most revisions stem from points raised by the referee’s comments, but there is still a question that remains in relation to tc-2016-289 with respect to code availability, data used, and scripts used to perform the modelling. Most figures also need some work to generate a common look and feel. The revisions are for the most part minor, but will take some time.

General comments

With respect to Referee #1

Referee #1 makes the general comment that taliks are to be expected, and you responded that talik development is not substantial and include a figure. However, I do not see that you addressed the question in the paper. Please incorporate the finding into your results, and discuss the implications in your discussion. I agree with the reviewer that taliks are often expected when permafrost changes to seasonally frozen ground. I wonder if the lack of taliks is a relict of modelling and therefore an underestimate, or if there is a likely explanation that is physically based. The relevant figure is probably best included in your supplementary material.

Referee #1 [13]: Your reply is adequate, but you need a line of explanation in the manuscript to reflect your answer.

With respect to Referee #2

Referee #2 [Q1]: The important issue is raised here that an assumption of zero heat flux is simply not intuitive, and I expect that this assumption will continue to raise questions. Indeed, Fig. 12b seems to suggest a bottom-up degradation of permafrost as thaw depths are comparatively invariant. Top-down thaw would lead to more widespread talik development as expected by Referee #1. Is this pattern of permafrost degradation highlighted in Fig. 12b a function of the model calibration and spin up, or is it related to actual increases in freezing season air temperatures whereas summer thaw season air temperatures are relatively stable. This is an issue that needs to be addressed clearly.

We need a paper that is strong, and without distractions so that the important points shine through. I strongly suggest that you revise the manuscript with the general assumption that there **is** a geothermal heat flux, and abandon any comparison with a model scenario that does not include such a flux. This is a major revision that will affect figures and text. Are there no deep boreholes in the region, or heat flux models for the region, from which to obtain an estimate? If so, please look into using them. Your estimate of 0.2 W/m² seems reasonable, but how does this compare with published values for QTP (e.g. Wu et al., 2010, *Global and Planetary Change*: 72: 32-38)?

Referee #2 [Q37]: Please re-visit the text with respect to this question and include discussion about temperature inversion. The effect is not related to vegetation or soil conditions, but relates to accumulation of cold, dense air in valleys. Bonnaventure et al. (2012), *Permafrost and Periglacial*

Processes, 23: 52-68) incorporated inverted surface lapse rates in their model of Yukon Territory permafrost distribution, and it may be a useful reference for you.

Referee #2 [Q39]: Regarding annual averages, please indicate in the text why you did not use annual averages, but instead had to rely on measurements from specific dates. Please discuss any implications due to this choice.

With respect to code, data and scripts

Your novel approach was of interest to the reviewers, and will be to other readers who will want to apply the approach to new areas, or test model-to-model results, or examine the reproducibility of experiments, uncertainties, and goodness of fit. I suggest that you indicate where the model code, data, and scripts used are publicly available.

With respect to figures and tables

The figures require a common appearance so the work does not look like the figures were drafted by different co-authors. This includes figures in the supplementary material.

Use similar colours to show similar things. For example, simulation and observation should keep the same color coding in all figures. See Fig 5 versus Figs. 4 and 6.

Some figures have boxes around panels, while others do not. Please be consistent.

Graph axes: tic marks inside or outside? Some figure panels are only enclosed on 2 sides, while the majority have 4 sides.

Font sizes are often too small: Fig. 2; Fig. 3; Fig. 4; Fig. 6; Fig. 7; Fig. 11, panels c, d, and e; Fig. 12; Fig. 13.

Fig. 15 fonts and overall scale is much larger than the rest.

Axes labels, panel titles, and tables: Label/title and text within brackets need to be separated by a space. E.g., "Depth(m)" becomes "Depth (m)" or "(a)T1 (2011-09-25,4132 m)" becomes "(a) T1 (2011-09-25,4132 m)". Carefully check Fig.2b , Fig. 3; Fig. 5; Fig. 6; Fig. 7 (Precipitation); Fig. 9; Fig. 10a; Fig. 11; Fig. 12; Fig. 13 (Actual evapotranspiration); Fig. 14; Fig. 15.

A period "." is required at the end of the last sentence of most figure captions.

Specific comments

Throughout: change passive tense to active tense. E.g. line 415, change "an increasing trend of active layer thickness in the permafrost regions was observed (3.5 cm/10yr), which had a significantly positive correlation with annual mean air temperature." to " Simulated active layer thickness in permafrost

regions increased (3.5 cm-decade), and correlates positively with annual mean air temperature ($p=XXXX$).” Indicate the level of significance.

Throughout: Please carefully reduce the word count. This is a long manuscript that can be written more succinctly.

Throughout: Please refer to “supplementary material” rather than “supplemental file” or supplement material”.

Throughout: please convert cm values to either mm or m.

Throughout the text, figures, and tables: please be consistent in how units are related to each other. E.g., “ $\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ ” versus “ $\text{mol}/\text{m}^2/\text{s}$ ”. The former is preferred.

Throughout: “Soil temperature” is used throughout, but you really mean “ground temperatures”. Soil implies weathering, etc., that is unlikely at great depths. This change likely affects figures, captions, and the main text.

Line 1. Suggest changing title to “entitled “Change in Frozen Soils and the Effects on Regional Hydrology, Upper Heihe Basin, Northeastern Qinghai-Tibetan Plateau”

Line 38: Change “degradation” to reduction in permafrost extent”. Existing text could imply that ground ice in permafrost is contributing to groundwater recharge.

Lines 58 to 63: Sentence are still not clear. Perhaps change to: “Intensive field observations on frozen soils were typically carried out a small spatial scales over short periods. Consequently, regional patterns and long-term trends are not captured. Long-term meteorological and hydrological observations are available, but they do not provide information on soil freezing and thawing processes ...”

Lines 69 to 72. Both reviewers took issue with this sentence. It is still too vague. Please delete “by simplified ways” and provide some explanation of the simplifications.

Lines 86. Change to “Consequently, cryospheric ...”

Line 88. What is meant by “thin and warm”? Report thicknesses and temperature ranges published in the literature.

Line 163. Change “based on the” to “from a”

Lines 274-275. Delete sentence and work idea into text on Line 279.

Line 279. Change to “... with a constant thickness of 10 cm to try to replicate the maximum freezing depths according to field observations.”

Line 342. Uncertainties in the simulations may relate to the estimates of ground heat capacity and thermal conductivity derived according to Farouki (1981), but the results are similar to the findings of Ou et al. (2016) ...”

Lines 384 to 387. Change to “Compared to the decadal mean for 1971 to 1980, mean air temperature for the 2001 to 2010 period increased by approximately 1.2 °C, with a larger increase in the freezing season (1.4 °C) than in the thawing season (1.1 °C) (Figure 9 and Table S2).

Lines 465 to 472. These sentence are not well written and do not read easily. Please revise.

Line 478. Delete comma after frozen ground.

Lines 477 to 480. Change “decreased, which led” to “decreased, leading”

Line 482. Change “in the permafrost area and seasonally frozen soils” to “from the entire basin”.

Lines 494 to 496. Re-write and combine sentences so that it reads more easily.

Lines 497 to 499. Delete the first 2 sentences and change to “Figure 15 shows the large difference in runoff variation with elevation between the freezing and thawing seasons.”

Line 526. Change order of words: “soil liquid” to “liquid soil”.

Lines 555 to 557. Indicate the year the decrease was observed.

Lines 582 to 585. Include potential for temperature inversion in this discussion.

Line 586: change “lateral heat” to laterally advected heat”

Line 589: Change “when high groundwater flow rate events occur” to “where groundwater flow rates are high.”

Figure 1. White background conveys no information/context for meteorological stations. If you show the colorized DEM (elevation) for the whole panel, the study area will remain obvious due to the encircling black polygon.

Figure 3. Too much wasted space. Try to reduce figure size. Move panel titles inside of the panels. Keep temperature scales the same; really only need 4 degrees of freedom in each figure, or keep a uniform temperature range of -2 to 4 °C. Depth scale range in e and f are half of a-d. for comparative purposes it would be helpful if all depth scales were the same range, 2-44 m. Panel e, “°C” is offset below the axis title.

Figure 4. Figure labels: second and subsequent words are not to be capitalized. E.g., “Soil Depth (m)” becomes “Soil depth (m)”. Dates shown on x-axis are annual. Simplify labels to show only the year. Axis title can be changed to “Year”. Change color scale in panels a and b so that the 0 °C isotherm is clear.

Color scale used in Fig. 12 is good. Plotting the isotherm as a black line would also help. In caption change "Simulation-Observation" to "difference (simulation – observation).".

Figure 5. Use annual increments on x-axis, label every 2nd or 5th year, and title "Year".

Figure 6. Panels are all too small and time series lines too thin. Does not reproduce well as a result. Perhaps move panel titles inside the panel to give more room. Show monthly tic marks, but label every second one, or label "J F M A M J J A S O N D". Figure caption: change "... Sunny slope station." To "...Sunny Slope station (2014 calendar year). Root mean square errors are indicated."

Figure 7. Indicate within every panel if it is a Calibration or Validation period, and perhaps enclose each pair in a box. Change caption to "...the Yingluoxia gauge, (b) the Qilian gauge, and (c) the Zhamashike gauge. For each gauge, the upper and lower panels show the calibration and validation periods, respectively. Nash-Sutcliffe efficiency and relative error coefficients are indicated."

Figure 8. Plot tic marks for each year. No need to indicate "-01" for month. X-axis title "Year". Change caption to "comparison of simulated monthly evapotranspiration with a remote-sensing-derived estimate (Wu, 2013) for the period of 2002 to 2012."

Figure 9. Y-axes in both panels should share the same scaling ratio so that the figure highlights the fact that freezing season temperatures are increasing at greater rates than thawing season temperatures. Time series labels: Space between depth interval and unit. Change caption to "Simulated ground temperature changes in: (a) ... and (b) ...". Include a line about the linear regressions. What is the statistical significance of the slopes?

Figure 10. Panel b time series labels: change "Frozen depth of Seasonally frozen ground" to "Seasonally frozen depth". Change "Active layer thickness of permafrost" to "Thaw depth". Change caption text to "... annual maximum depths of seasonally frozen ground and thaw above permafrost." Include a line about the linear regressions. What is the statistical significance of the slopes?

Figure 11. Tic marks on panels d and e are not visible. Panel d: Capitalize "Sunny". Change caption to "Distribution of permafrost and seasonally frozen ground for two periods: (a) 1971-1980 and (b) 2001-2010. (c) Area where permafrost degraded to seasonally frozen ground between the two periods. Percentage of permafrost area for the two periods with respect to elevation on slopes that are (d) sunny or (e) shaded. Note that (d) and (e) share a legend."

Figure 12. Change caption to "Spatially averaged monthly ground temperatures simulated from 1971 to 2013 for two elevation intervals: (a) seasonally frozen ground between 3300 and 3500 m; (b) permafrost that degraded to seasonally frozen ground between 3500 and 3700 m." Show annual tic marks on x-axis, but perhaps label every 2nd or 5th year.

Figure 13. This figure needs work. Caption says actual evapotranspiration but the data are for simulated evapotranspiration. It is not clear which two panels are paired together. Labels are missing. Tic mark intervals and labels are different though time scale ranges are the same. Change caption to "Runoff and simulated evapotranspiration in (a) the freezing season and (b) the thawing season." Either report trend

lines and significance in caption or in the figure, or remove the trend lines. Are trend lines in the left-hand side panels for the simulated or observed data? This needs to be clear.

Figure 14. These are simulation results. Are these basin-averaged? Change caption to “(Basin averaged?) Annual water storage (equivalent water depth) changes simulated over the period of 1971 to 2013 for: (a) liquid water in the top layer of the ground (0-3 m); (b) ice in the top layer of the ground (0-3 m); (c) and ground water.” Indicate if trend lines are significant.

Figure 15. Needs work. Look and feel is quite different than other figures. Panel a is missing a properly scaled and labeled x-axis. There is a typo in panel c. Change caption to “Model simulated runoff changes from the 1971-1980 period to the 2001-2010 period with elevation for (a) the freezing season and (b) the thawing season, and (c) monthly averaged seasonal runoff in permafrost and seasonally frozen ground for the period of 2001 to 2010.

Table 2. Several column headings show words that are split across lines.

Figure S1. Capitalize “simulation” in legend. Add line to caption “Legend in (a) applies to all panels.

Figure S2. Change “Obs” to “Observations”. X-axis time scale should be adjust to even spacing by months.

Figure S3. Tic marks on x-axis should indicate years, with every 2nd or 5th labelled. Figure caption should be re-worded in a similar manner as Figure 12.