

Dear Dr. Ran,

I have read your revised manuscript entitled “Climate warming over the past half century has led to thermal degradation of permafrost in the Qinghai-Tibet Plateau” (tc-2017-120). Overall the paper is improved. There are still a few sections that need some clarification and some new minor edits. In addition, I have repeated my earlier comments on figures that were overlooked in the last revision. Once these are looked after, I think that the paper will be ready.

Best regards,

Peter

Minor comments:

P2, L1: “the carbon” becomes “carbon”

P2, L28: “used index, i.e. MAAT and MAGT, the MAGT is the most direct indicators of the thermal” becomes “used indices (i.e. MAAT and MAGT), MAGT is the most direct indicator of the thermal”

P2, L31: “Although the potential problems of the MAAT in predicting permafrost degradation are well known, for example, the performance of the MAAT model is generally affected by the thermal inertia of deep soil layers and geothermal flux (Smith and Riseborough, 2002; Jin et al., 2006; Wu et al., 2010a), the MAAT is easy to measure and has high spatial representativeness” becomes “The potential problems of using MAAT to predict permafrost degradation are well known, such as the neglecting the influences of thermal inertia of deep soil layers or geothermal heat flux (Smith and Riseborough, 2002; Jin et al., 2006; Wu et al., 2010a). However, MAAT is easy to measure and has high spatial representativeness”

P3,L1-4: Change to “measurements of MAATs are available. However, MAAT measurement stations are sparse on the QTP, especially in the western region. In previous studies MAAT measurements were interpolated onto grids based on digital elevation models (DEMs), but the uncertainty of the gridded MAAT is substantial because of the locations of weather stations and heterogeneity of the surface characteristics, including snow cover and vegetation (Vancutsem et al., 2010).”

P4, L13: “and near surface air temperature and the” becomes “and near surface air temperature, and thus the”

P4, L15: “The variation in the uncertainty is mainly related to the underlying surface type such as snow cover and vegetation” becomes “Variation and uncertainty in estimated near surface air temperatures are mainly related to surface conditions such as snow cover and vegetation”

P4, L17-20: “Additionally, the highly accurate remote sensing-based snow cover and vegetation products are also available. Overall, the high resolution remote sensing-based LST and the long-term in situ MAAT measurement can be integrated to monitor the permafrost thermal state.

Therefore, the objective of this study is to evaluate the thermal degradation of permafrost including temporal changes, spatial changes in the map plane, and spatial changes with elevation over the QTP from 1960 to 2010 by integrating multi-criterion remote sensing observations and an air temperature observation network” becomes “Highly accurate remote sensing-based snow cover and vegetation products are now available to reduce some of the uncertainty, and solar radiation and cloud cover can be accounted for. Therefore we propose that high resolution remote sensing-based LST and the long-term in situ MAAT measurement can be integrated to monitor the permafrost thermal state. The objective of this study is to evaluate potential thermal degradation of permafrost including temporal changes, spatial changes in the map plane, and spatial changes with elevation over the QTP from 1960 to 2010 by integrating multi-criterion remote sensing observations and an air temperature observation network.”

P3, L3 – P4, L3: “The system was proposed based on the MAGT measurement as an index by analysis of the three-dimensional zonation of the high altitude permafrost (vertical, latitudinal, and aridity). It is a high level summary of high altitude permafrost zonation. The MAAT index was given according to the statistical relation between MAGT, elevation, and the in situ MAAT measurement (Cheng, 1984).” Becomes “The system is a high-level summary of the relation between MAGT measurements and the three-dimensional zonation of high altitude permafrost (elevation, latitude, and aridity). Cheng’s (1984) system relates air temperature to permafrost conditions according to the statistical relations between MAGT, elevation, and in situ MAAT measurements.

P4, L3: Move “On the QTP, a MAAT of  $-2\text{ }^{\circ}\text{C}$  has typically been used to distinguish permafrost from seasonally frozen ground (Cheng, 1984; Ran and Li, 2016).” to Line 15, in front of “Additional, a MAAT of  $-1\text{ }^{\circ}\text{C}$  is simply used to distinguish likely thawing permafrost from seasonally frozen ground in this paper.” Change “Additional, a MAAT of  $-1\text{ }^{\circ}\text{C}$  is simply used to distinguish likely thawing permafrost from seasonally frozen ground in this paper” to “ Here we use a MAAT of  $-1\text{ }^{\circ}\text{C}$  is to distinguish likely thawing permafrost from seasonally frozen ground because ...” You need to indicate why your threshold is different.

P4, L5: “unstable type in the system” becomes “unstable type in this system”

P4, L10-11: “In the extreme case, thawing permafrost appears thermally stable, because heat is used for phase change rather than temperature change and MAGTs appear stable despite being nearly  $0\text{ }^{\circ}\text{C}$ .” Becomes “In the extreme case, thawing permafrost that is nearly  $0\text{ }^{\circ}\text{C}$  may appear thermally stable, because heat is used for phase change rather than temperature change.”

P4, L12: “MAAT index,” delete the comma.

P4, L24: Italicize “ $m$ ”, the number of explanatory factors.

P4, L29: “(  $n \times m$  )” becomes “( $n \times m$ )”

P5, L1: ““(  $n \times 1$  )” becomes “( $n \times 1$ )”

P5, L2: Italicize “ $n$ ”, the number of MAAT observation stations

P5, L8-13: This is a mix of results and methods. Also, it is a bit hard to evaluate the outcome of this analysis without knowing about the input data sets (that are introduced later on). Text relating to results should be moved to Page 8, somewhere in the first paragraph after Line 10.

P5, L13: If one model has the best explanatory power, why did you use 5 models, and which 5 of the 6 did you use? It is not at all clear.

P5, L14-25: “The SAGA (System for Automated Geoscientific Analyses) (Conrad et al., 2015) is used to implement the GWR. Specifically, the GWR for multiple predictor grids geoprocessing tool is used. The Gaussian weighting function and the global search range are used.

Due to the unavailability of the vegetation, snow cover, and LST datasets during the 1960s to 2000s, the effect of the dynamics of vegetation, snow cover, and LST on MAAT during this period is unknown. This will inevitably cause some errors in the estimation of MAAT. Recent studies show that vegetation is increasing overall during the past 30 years, and the 20 snow cover is decreasing overall during the past 15 years over the QTP (Wang et al., 2016; Huang et al., 2017). The effect of vegetation and snow cover change on MAAT and its feedback process is highly complex. For example, the vegetation-snow interaction effect on MAAT is related to humidity (Zhong et al., 2010; Wang et al., 2013; Wu et al., 2015; Yuan et al., 2017). However, we believe this error mainly occurs at the local level in the nature vegetation dominated areas (Wang et al., 2016; Huang et al., 2017), and it can be partially compensated by the in situ time series MAAT measurement over the QTP for the 25 past 50 years.”

Becomes

“The GWR is implemented in SAGA (System for Automated Geoscientific Analyses) (Conrad et al., 2015), using the GWR for multiple predictor grids geoprocessing tool with a Gaussian weighting function and a global search range.

Due to the unavailability of vegetation, snow cover, and LST datasets during the 1960s to 2000s, the effects of the dynamics of vegetation, snow cover, and LST on MAAT during this period are unknown. This will inevitably cause some errors in the estimation of MAAT. Recent studies of the QTP show overall that vegetation increased during the past 30 years and snow cover decreased during the past 15 years (Wang et al., 2016; Huang et al., 2017). The effect of vegetation and snow cover change on MAAT and related feedback process are highly complex. For example, the vegetation-snow interaction effect on MAAT is related to humidity (Zhong et al., 2010; Wang et al., 2013; Wu et al., 2015; Yuan et al., 2017). However, we believe that such effects mainly occur at the local level in vegetation dominated areas (Wang et al., 2016; Huang et al., 2017), and they can be partially compensated by in situ time series MAAT measurements over the QTP for the past 50 years.”

P5, L27: “50 years. The statistical significance”: becomes “50 years, and the statistical significance”

P6, L1: “condition is evaluated from two perspectives” becomes “condition is assessed from two perspectives”

P6, L4: “is evaluated at two levels” becomes “is assessed at two levels”

P6, L5: “level, the spatial distribution of the degradation is evaluated. At the level of the permafrost types, a transfer matrix” becomes “level the spatial distribution of the degradation is evaluated, and at the level of the permafrost types a transfer matrix”

P6, L13 and L25: “(2015; 2017)” becomes “(2015, 2017)” as the authorship is the same.

P6, L15: “and the daily” becomes “and that the daily”

P6, L21: “Wang, et al.” becomes “Wang et al.”

P8, L12: “mean determination coefficient of the model is approximately 0.95” becomes “mean coefficient of determination of the model is approximately 0.95” What is this a mean of? I thought that Model 6 produced the best results? How did you arrive at 0.95, when all values reported in Table 2 are lower?

P8, L17: “°Ca<sup>-1</sup>” becomes “°C a<sup>-1</sup>”

P9, L10: “Overall, the warming climate has caused a degradation of permafrost thermal condition.” Delete as it repeats what is said at the beginning of this section.

P9, L16: “The degradation of thermal condition has occurred” becomes “Degradation of permafrost thermal condition has likely occurred”

P9, L17-18: “The degradation of permafrost condition in the western QTP was serious during the 1960s to the 1970s.” So you mean substantial, instead of serious? You need to make it clear what this sentence means in terms of spatial variation, because it is not clear as written.

P9, L26: “The reduction in the area” becomes “The potential reduction in the area”

P9, L30: “over a 21×10<sup>4</sup> km<sup>2</sup> (12.02%) located” becomes “over a 21×10<sup>4</sup> km<sup>2</sup> area (12.02%) located”

P10, L1: “has improved” becomes “has likely improved”

P10, L4: “This is because of the lack” becomes “This relates to the lack”

P10, L5-11: “The effects of snow or glacier cover may be more important than those of MAAT.” Important to what? What do you mean? What exactly are the effects that glaciers or long-lasting snow pack? Please carefully edit this section so that your point is clear. Are you trying to say that because the glaciers haven’t changed very much, that permafrost has also likely remained about the same?

P10, L12: “sensitivity. Of course, these need further investigation in the future” becomes “sensitivity, but this notion requires further investigation”

P10, L16: “the QTP has increased” becomes “the QTP has likely increased”

P10, L18-21: “The reduction in elevation is mainly due to the degradation of the very cold permafrost type in the Kailas Mountains. This caused the fluctuation of the mean elevation for very cold permafrost during the 1970s to 1980s and reduced its statistical significance (low R in Table 5) for the increasing rate of mean elevation over the past 50 years.” These statements are not clear. How does permafrost degradation cause a decrease (“reduction”) in elevation. This is contrary to your major findings. Please clarify.

P10, L20: do you mean  $R^2$ , instead of R?

P10, L31: “Zou et al., (2016) show that the difference is small. Within permafrost area, the” becomes “Zou et al. (2016) shows that the difference is small. Within permafrost areas, the”

P11, L10: “which are especially sparse in high mountain areas. First, the response time” becomes “which are especially so in high mountain areas. Beyond these uncertainties, the response time”

P11, L24-25: “Despite current warming, large permafrost areas may persist due to the thermal inertia of permafrost (Cheng et al., 2012). Second, the thawing of the base of the permafrost induced by the geothermal heat flux leads to the permafrost degrading from bottom to top (Jin et al., 2006; Wu et al., 2010a). The MAAT” becomes “To summarize, despite current warming, large permafrost areas may persist due to the effective thermal inertia of permafrost (Cheng et al., 2012). A final consideration is that the geothermal heat flux leads to thawing of the base of the permafrost (Jin et al., 2006; Wu et al., 2010a). However, the MAAT model”

P12, L2: “missed geothermal heat flux. Long-term” becomes “missing geothermal heat flux component thermal inertia of permafrost. However, long-term”

P12, L9: “zones will increase” becomes “zones will likely increase”

P12, L28: “disappearance” becomes “drainage”. Must be drainage if related to thermokarst.

P12, L29: “which may further affect greenhouse gas emissions and produce a feedback effect on climate change” becomes “which may affect greenhouse gas emissions and feedbacks to climate change”

P13, L1: “evaluates the permafrost” becomes “evaluates likely permafrost”

P13, L8: “ $^{\circ}\text{C a}^{-1}$ ” becomes “ $^{\circ}\text{C a}^{-1}$ ”

My previous comments on figures were overlooked and are repeated here with a few more minor comments. These changes are required:

In all maps: please move text away from other objects so that the words are clearly legible. Nearly all city and town names are affected.

Figure 1. Scale bar should span 1000 km as in other figures. Evergreen broadleaf forest, deciduous broadleaf forest, and grasslands are too similar in color to differentiate on the map. Delete the symbols and descriptions in the legend for “Boundary of China” and “Extent of QTP”

Figure 2. Change warming rates in map legend from, e.g., “-0.43 - -0.15” to “-0.43 to -0.15”. Also, change ( $^{\circ}$ /decade) to ( $^{\circ}$  decade $^{-1}$ ). Delete the symbol and description in the legend for “Extent of QTP”

Figure 3. “<3600 m” becomes “< 3600” and “>5800 m” becomes “> 5800”. “Elevation intervals” becomes “Elevation intervals (m)”. Also, change ( $^{\circ}$ /decade) to ( $^{\circ}$  decade $^{-1}$ )

Figure 4. Non-permafrost and Unchanged stability are the same color and can be confused. Please indicate areas by a different color such as grey in all panels. Also, if non-permafrost includes seasonally frozen ground and lakes, map out lakes in a different color and add to the legend, and re-name “non-permafrost” to “seasonally frozen”

Figure 5. There a lot of white on the maps. Please indicate with a symbol and description what it represents, i.e. seasonally frozen? The color of the lakes is hard to distinguish from the blue permafrost. Consider different colours, or higher contrast between colors.