Reply on RC1:

The authors describe a study that derives surface displacement from InSAR data in an effort to determine changes in active layer thickness in the QTEC. The manuscript addresses an important topic because understanding of changes in permafrost conditions and the implications for ground stability is important for informed engineering design and adaptation to a changing climate. However, I have some concerns with the interpretation of results and their validation. My expertise is related more to permafrost related processes rather than use of InSAR data and my comments are therefore related to interpretation of the surface displacement results.

Thank you for your time in evaluating our manuscript and your insightful comments. Please found our response below. The line numbers correspond to the tracked-change version, all markup mode of our new submission.

The amount of surface displacement including ongoing subsidence of the ground as permafrost thaws depends on the surficial material characteristics, especially the ground ice content. Excess ice (ice that when melted exceeds the water holding capacity of the material) content is especially important for thermokarst processes which have implications for infrastructure. A large change in ALT therefore does not necessarily result in large changes in surface elevation because thaw of ice-poor material will yield less displacement than an equivalent amount of thaw in ice-rich material. No information on surficial geology or the potential for ice-rich material has been presented in the manuscript, and this is important for the interpretation of the displacement results. It is also unclear whether the occurrence of excess ice (and the ice segregation process) has been considered or only the formation and melt of pore ice. See additional comments below.

Thank you for your comments. Accordingly, we generate maps of geology and ground ice content.

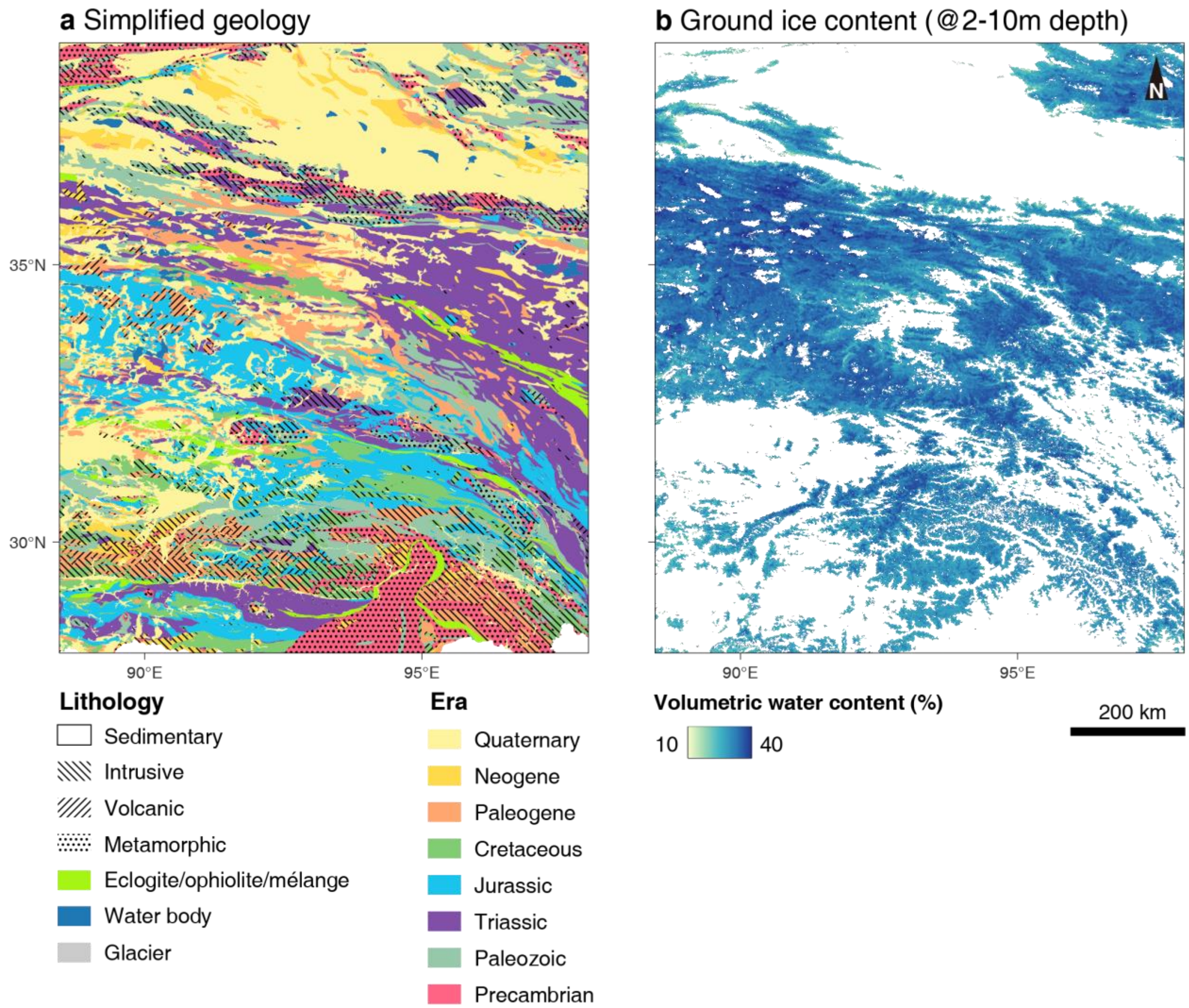


Figure. Geological map and ground ice content map.

There might be two major misunderstandings that we would like to clarify. One likely misunderstanding is the approach we use to infer the active layer thickness. Before demonstrating our approach, we would like to recall the definition of two relevant terms: **volumetric water content** and **ground ice content.** Although the term "ground ice content" does not appear in our manuscript, the reviewer references it several times in the comments.

- The **volumetric water content** is the ratio between of the volume of water and the total volume of host materials, i.e., the total volume of water, ice (if any), soils, and air. In this study, we apply the soil moisture derived from remote sensing analysis as the volumetric water content in the thaw season when the ice completely thaws. As the remote sensing analysis fails to capture the soil moisture in the freeze season due to snow/ice land cover (e.g., reported NULL for vast land), we turn to invert the volumetric water content in the freeze season based on the in-situ observations of ALT.

- **Ground ice content** is usually represented as a percentile of volumetric water content. We download the ground ice content between 2 and 10 m's depth from the National Tibetan Plateau Data Center / Third Pole Environment Data Center (https://data.tpdc.ac.cn/zh-hans/data/bd7fc972-3707-4c9c-90c4-aae6bfbc3cbf). According to the dataset introduction, the ground ice content was obtained by incorporating 644 in-situ observations and 13 environmental variables using random forest method. The ground ice content is reported at depths of 2-3 m, 3-5 m, and 5-10 m. We average the ground ice content and visualize the results as below.

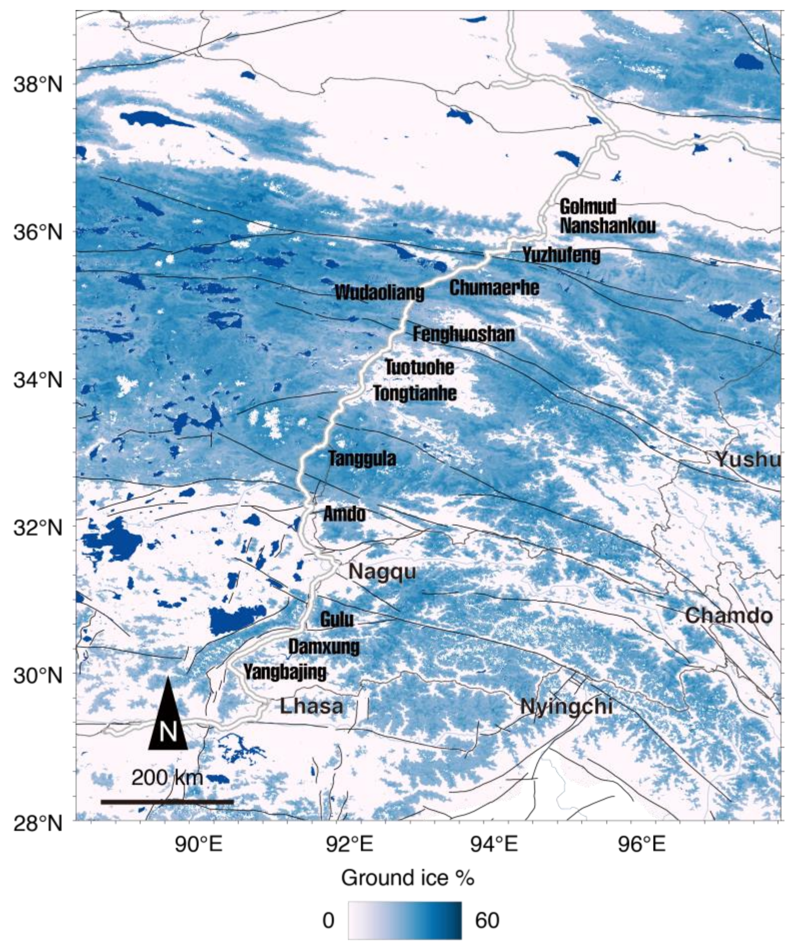


Figure. Mean ground ice content at depth of 2-10 m (Data source: National Tibetan Plateau Data Center / Third Pole Environment Data Center).

The schematic view below illustrates the frost-heave to thaw-settlement transition in the active layer. Panel a represents the freeze season and panel b represents the thaw season. Water, ice, and soil blocks are separated to facilitate the math derivation. Vertical gray bars represent the frozen parts of the active layer during the freeze time epoch, and vertical brown bars represent the thaw parts of the active layer during the thaw time epoch. *h* is the active layer thickness, and *δ* is the seasonal amplitude of vertical deformation due to the transition between ice and water in the active layer. In our approach, we only need the volumetric water content in freeze season (*n*) to represent the thickness of unfrozen water, and the volumetric water content in thaw season (*N*) to represent the thickness of unfrozen and melt water assuming the ice completely thaws. In other words, we do not need the ground ice content. If observations about ground ice content in the freeze and thaw seasons are available, we would be able to improve this model by quantifying the portion of unfrozen water; however, we cannot find direct observations on seasonally ground ice content. To avoid confusion, we do not put the new figure about ground ice content in our manuscript.

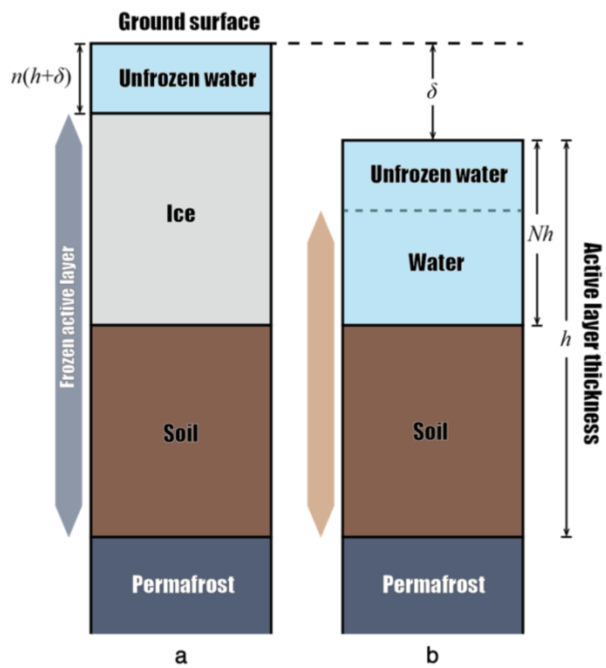


Figure. The schematic view below illustrates the frost-heave to thaw-settlement transition in the active layer.

The other likely misunderstanding is that we do not intend to obtain a change in ALT (added in lines 108 and 219). We disentangle the secular and seasonal ground deformation from December 2014 to September 2022 based on Sentinel-1 InSAR processing. We use the averaged seasonal ground deformation spanning these eight years to infer characteristic ALT, an averaged value spanning the same time and at the same resolution of our derived ground deformation results (120 meters). For large-scale quantification of ALT, we simplify the physical process by presuming an overall water balance of the active layer and do not consider the excess ice (and the ice segregation process) (added in lines 111 and 217, 238).

We are unsure about the reviewer's concern "A large change in ALT therefore does not necessarily result in large changes in surface elevation because thaw of ice-poor material will yield less displacement than an equivalent amount of thaw in ice-rich material." First, our study does not examine changes in ALT. We add in line 219 "Note that we do not intend to infer temporal changes of ALT in this study due to short time frame". Second, the phrase "an equivalent amount of thaw" is ambiguous; it is unclear whether it refers to an equivalent volume of ice/water thawed or to an equivalent temperature forcing that drives thaw. Third, we are unsure what materials mean by "ice-rich" and "ice-poor"—whether it refers to permafrost only or the combined active layer–permafrost column. To clarify, to achieve a regional inversion ALT, we attribute the seasonal ground deformation only to the seasonally interchangeable transition between liquid water and frozen water in the active layer, and assume that the total amount of water, regardless of the states, is overall balanced. To enhance our determination of active layer thickness, we consider the volumetric water content in the freeze and thaw seasons when the ground surface reaches the highest and the lowest, respectively. To put it short, our subject is the transition between liquid water and frozen water in the active layer, rather than the thaw of ice-rich or ice-poor materials. Therefore, the derivation of ALT is based on the intrinsic density difference between water and ice. We further clarify our method in section 2.4.

Validation of the modelled ALT values using field data is also unclear. A lot of data has been collected in the QTEC that facilitates estimates of ALT and also descriptions of subsurface material characteristics, including ice content and thaw sensitivity. The lack of clarity regarding how this field-based information was utilized makes it difficult to evaluate the validity of the analysis used to derive the ALT results.

We elaborate our methods, especially on how the field data of ALT being used in this study. Presuming an overall water balance of the active layer, we can estimate ALT (H) based on the seasonal amplitude of the vertical displacement δ from the projection of the radar's line-of-sight measurements. **Note that we do not intend to infer temporal changes of ALT in this study due to short time epoch. We extract the averaged seasonal amplitude of ground deformation from December 2014 to September 2022 to infer the characteristic ALT during the same time frame.**

$$H = \frac{\rho_i + n(\rho_w - \rho_i)}{(N - n)(\rho_w - \rho_i)}\delta \quad (2)$$

where ρ_w and ρ_i are the density of water and ice, and here we apply 1,000 and 917 kg/m^3 respectively; n and N are the volumetric water content in dry frozen and wet thaw conditions, respectively. Here we assume that the soil moisture in October, when the land surfaces reach the lowest, represents the volumetric water content during the wet thaw condition (N). Launched in 2015, the Soil Moisture Active Passive (SMAP) mission provides a global-scale soil moisture monitoring approach through its L-band radar (operation ceased in early 2015) and L-band radiometer (operational to date). This study employs the SMAP's Level 4 "root zone" (0-100 cm) soil moisture across the QTEC region. Monthly average soil moisture in QTEC from 2016 to 2022 were acquired via the Google Earth Engine platform, incorporating data at 3-hourly and 9-km resolution. Nonetheless, due to snow cover, the volumetric water content in dry frozen condition (n) can not be observed directly (Du et al., 2025), and it is not viable to be represented by the soil moisture products from SMAP. **Previous studies simply applied a constant 5% (e.g., Li et al., 2023; Zhang and Wu, 2012).** **Here we fully utilize available in-situ ALT measurements in QTEC to constrained n at those sites (Eq. 2; Table S1).** Thereafter, we use the spline interpolation to generate a **spatially continuous** map of n. Next, we compute the ALT **using Eq. 2** at the same resolution of the inputting seasonal displacement amplitude. Although this workflow involves uncertainties originated from parameters themselves in the dry QTP environment, the derivation of ALT is based on simplified physical processes, instead of data-driven machine learning. **More complex physical processes, such as ice segregation, can be incorporated in future work for specific sites where detailed information on the subsurface condition is available.**

Regarding the in-situ ALT measurements in QTEC, we summarize the statistics in Table S1 in the supplementary materials.

Table S1. In-situ active layer thickness measurements using in this study. We obtain the volumetric water content in thaw season (*N*) from soil moisture data. We use the in-situ active layer thickness measurements, seasonal amplitude of ground deformation, and the volumetric water content in freeze season altogether to constrain the volumetric water content in dry spring (*n*) at the location of in-situ active layer thickness measurements.

no.	lon	lat	station	ALT H_m	source of ALT H_m	sea_defo_m	*N*	*n*
1	94.09	35.72	XD13	2.8	Zhao & Sheng (2019)	0.0104	0.1247	0.0832
2	94.05	35.71	XD04	1.30		0.0061	0.1222	0.0704
3	94.12	35.71	XD11	2.30		0.0116	0.1229	0.0668
4	93.91	35.45	BQ03	3.30		0.0357	0.1356	0.0160
5	93.9	35.36	BQ04	3.40		0.0187	0.1402	0.0791
6	93.91	35.24	BQ06	2.90		0.0099	0.1372	0.0991

7	93.95	35.17	BQ02	2.80		0.0275	0.1380	0.0293
8	94.04	35.08	BQ07	1.90		0.0084	0.1429	0.0934
9	94.43	35.01	BQ11	2.10		0.0271	0.1589	0.0159
10	94.58	34.98	BQ13	3.20		0.0200	0.1799	0.1102
11	92.93	34.83	BLH	4.06	Chen (2018)	0.0177	0.2310	0.1821
12	92.92	34.86	BLR1	1.76	Qin et al. (2017)	0.0231	0.2206	0.0747
13	91.65	33.01	TGL	2.12		0.0105	0.1728	0.1174
14	92.9	34.77	FHS	1.70		0.0089	0.2524	0.1933
15	92.88	34.69	FH1	2.50	Wu et al. (2008)	0.0091	0.1850	0.1442
16	91.87	32.7	TG1	3.00		0.0343	0.2285	0.1009
17	94.05	35.62	KM2	1.83	Wu et al. (2012)	0.0144	0.1291	0.0417
18	93.96	35.62	BD1	2.47		0.0050	0.1292	0.1066
19	93.45	35.36	CM5	2.84		0.0364	0.1499	0.0082
20	93.22	35.28	CM7	4.80		0.0162	0.1564	0.1186
21	93.11	35.2	WD3	1.93		0.0233	0.1526	0.0190
22	93.03	35.07	HR3	2.36		0.0276	0.2046	0.0747
23	92.9	34.67	FH2	1.76		0.0119	0.1731	0.0978
24	92.74	34.58	YM1	3.32		0.0229	0.1582	0.0815
25	92.73	34.48	WL1	3.09		0.0224	0.1564	0.0758
26	92.34	34.01	KL1	2.40		0.0233	0.1655	0.0576
27	92.34	33.94	KL5	3.38		0.0147	0.1643	0.1156
28	91.75	33.07	TG4	2.77		0.0175	0.1770	0.1066

29	91.53	32.51	TJ1	3.50	Wu et al. (2015)	0.0156	0.2278	0.1776
30	92.93	34.83	BL1	3.38		0.0177	0.2310	0.1724
31	92.94	34.85	BL4	2.07		0.0214	0.2203	0.1050
32	92.94	34.84	BL6	2.48		0.0239	0.2244	0.1167
33	93.01	35.05	Yu-7	3.50	Wu et al. (2017)	0.0134	0.2213	0.1782
34	93.01	35.05	Yu-6	2.00		0.0134	0.2213	0.1461
35	92.9	34.73	CH1	1.65	Xie et al. (2012)	0.0239	0.2399	0.0787
36	92.73	34.47	CH3	2.80		0.0158	0.1560	0.0930
37	94.08	35.72	QTB1	1.65	Xie et al. (2015)	0.0104	0.1243	0.0541
38	93.27	35.29	QTB6	3.32		0.0057	0.1546	0.1353
39	91.9	33.1	QTB15	2.35		0.0191	0.1765	0.0859
40	93.58	35.41	DK1048+620	3.28	Niu (2021)	0.0307	0.1267	0.0230
41	93.09	35.22	QT08	2.42	Zhao et al. (2021)	0.0218	0.1567	0.0567
42	92.92	34.82	QT03	2.57		0.0345	0.2369	0.0872
43	92.89	34.73	Ch01	2.01		0.0107	0.2287	0.1692
44	92.34	33.96	QT05	3.19		0.0201	0.1579	0.0878

References for the Supplementary Materials:

Chen, J., Liu, L., Zhang, T., et al. (2018). Using persistent scatterer interferometry to map and quantify permafrost thaw subsidence: A case study of Eboling Mountain on the Qinghai-Tibet Plateau. *Journal of Geophysical Research: Earth Surface*, *123*(10), 2663–2676.

Niu, F. (2022). Demonstration monitoring data for disease treatment of permafrost project in South Asia Channel – long-term monitoring demonstration for subgrade stability of Chumar River of Qinghai Tibet Railway (2003–2021). National Tibetan

Plateau Data Center National Tibetan Plateau Data Center. https://doi.org/10.11888/Cryos.tpdc.271933

Qin, Y., Wu, T., Zhao, L., et al. (2017). Numerical modeling of the active layer thickness and permafrost thermal state across Qinghai-Tibetan Plateau. *Journal of Geophysical Research: Atmospheres*, *122*(21), 11,604-11,620.

Wu, Q., Hou, Y., Yun, H. & Liu, Y. (2015). Changes in active-layer thickness and near-surface permafrost between 2002 and 2012 in alpine ecosystems, Qinghai–Xizang (Tibet) Plateau, China. *Glob. Planet. Change*, *124*, 149–155.

Wu, Q., Yu, W. & Jin, H. (2017). No protection of permafrost due to desertification on the Qinghai–Tibet Plateau. *Sci. Rep.*, *7*, 1544.

Wu, Q. & Zhang, T. (2008). Recent permafrost warming on the Qinghai-Tibetan Plateau. *Journal of Geophysical Research: Atmospheres*, *113*, D13108.

Wu, Q., Zhang, T. & Liu, Y (2012). Thermal state of the active layer and permafrost along the Qinghai-Xizang (Tibet) Railway from 2006 to 2010. *Cryosphere*, *6*, 607–612.

Xie, C., Zhao, L., Wu, T. & Dong, X. (2012). Changes in the thermal and hydraulic regime within the active layer in the Qinghai-Tibet Plateau. *J. Mt. Sci.*, *9*, 483–491.

Xie, C., William, A. G., Zhao, L., Wu, T. & Liu, W. (2015). Temperature-dependent adjustments of the permafrost thermal profiles on the Qinghai-Tibet Plateau, China. *Arct., Antarct., Alp. Res.*, *47*, 719–728.

Zhao, L. & Sheng, Y. (2019). Permafrost and Its Change on the Qinghai-Tibet Plateau. (Science Press).

Zhao, L., Zou, D., Hu, G., Wu, T., Du, E., Liu, G., Xiao, Y., Li, R., Pang, Q., Qiao, Y., Wu, X., Sun, Z., Xing, Z., Sheng, Y., Zhao, Y., Shi, J., Xie, C., Wang, L., Wang, C., & Cheng, G. (2021). A synthesis dataset of permafrost thermal state for the Qinghai–Tibet (Xizang) Plateau, China. *Earth System Science Data*, *13*(8), 4207–4218.

The manuscript also requires editing to improve, language, terminology and clarity.

Thank you for letting us know. We have improved the language and clarity through the text.

Additional comments on the manuscript are provided below.

Additional Comments

L31-104 Introduction – This needs much work. Better organization and reduction of text to focus on only the information that is relevant would be beneficial. Some of the statements are unclear or incorrect. Editing is required to improve language.

The introduction includes an overview about Qinghai-Tibet Engineering Corridor (QTEC) (one paragraph), the thermokarst processes threaten the facilities (one paragraph), monitoring tools especially recent progress on ground deformation monitoring using InSAR (two paragraphs), recent progress on the retrieval of active layer thickness over the QTEC (one paragraph), and a summary about this study (one paragraph). We have tried to shorten the Introduction by moving the recent progress on the retrieval of active layer thickness over the QTEC to the methods/results section but found it might be inappropriate and confusing. We retain them in the Introduction to provide background context. We improve our language through the text. We do not paste our revisions here because there are multiple paragraphs. Kindly please refer to our manuscript for revisions.

L31-35 –Note it is thaw of ice-rich material that can result in ground deformation so it is not necessarily caused directly by climate change. Use "thermokarst processes" rather than "thermokarst disasters". A disaster depends on the consequences of the process and whether they are important with respect to infrastructure, human life for example. Note, the active layer is not part of permafrost. The last sentence in the paragraph about GCOS is not really necessary. It is sufficient to refer to active layer thickness as an indicator of permafrost change.

We update the relevant sentence. Now it reads "The contemporary thaw of ice-rich materials drives ground deformation and thermokarst processes in QTEC".

We update the term and use "thermokarst processes" throughout the text.

Thank you for pointing out the issue in our description. We update the definition of active layer, and it reads "The active layer is the surface layer that seasonally thaws downward in summer and freezes bidirectionally in winter above the permafrost."

We agree that the last sentence in the paragraph about GCOS is not necessary and have removed this sentence.

L44-55 – When describing rates of change, the period over which the change has occurred should be given. Here and elsewhere in the paper – refer to permafrost thaw rather than melt. Several statements are unclear or use poor terminology. Repetition needs to be reduced.

We update relevant words and use "permafrost thaw" through the text.

L57 – Delete "dynamic" redundant ("changes" is sufficient)

We have removed "dynamic".

L57-60 – I assume you are referring to topographic surveys that utilize GNSS, i.e. measuring surface elevation. Surface displacement isn't directly measured but derived from elevation measurements made over time.

Extensometers, inclinometers, and GNSS can be used to measure displacement at locations where the sensors were installed. We have shortened this sentence. Now it reads "While field observations of temperature, soil moisture, and displacement deliver accurate permafrost status at isolated site, they are labor-intensive and spatially limited across the QTP."

L63-65 – It is incorrect to say InSAR-derived displacement patterns directly reflect permafrost dynamics. They reflect changes in surface elevation. Surface displacement can be caused by various processes including groundwater withdrawal, sediment compaction, crustal movements etc. Slope movements aren't necessarily triggered by permafrost change. The attribution of changes requires knowledge of the local conditions including materials and their thermal state, and geologic/geomorphic processes etc. – result of analyses of different types of data.

Thank you for your suggestions. We update the text and now it reads "Time-series interferometric SAR (InSAR) further enables detection of ground deformation at regional scales. However, InSAR-derived displacement patterns do not, by themselves, directly indicate permafrost dynamics: they capture changes in surface motion that may arise from multiple processes (e.g., ground ice melt and thaw settlement, slope instability, groundwater changes, sediment compaction). Robust attribution to permafrost-related mechanisms therefore requires integration with local ground conditions and thermal state, as well as supporting geologic and geomorphic context and complementary datasets (e.g., topography, temperature, and land cover)."

L73 – "linear subsidence" is unclear – is this vertical subsidence?

Yes, it is. Now it reads "They documented an annual vertical subsidence rate of up to 20 mm/yr."

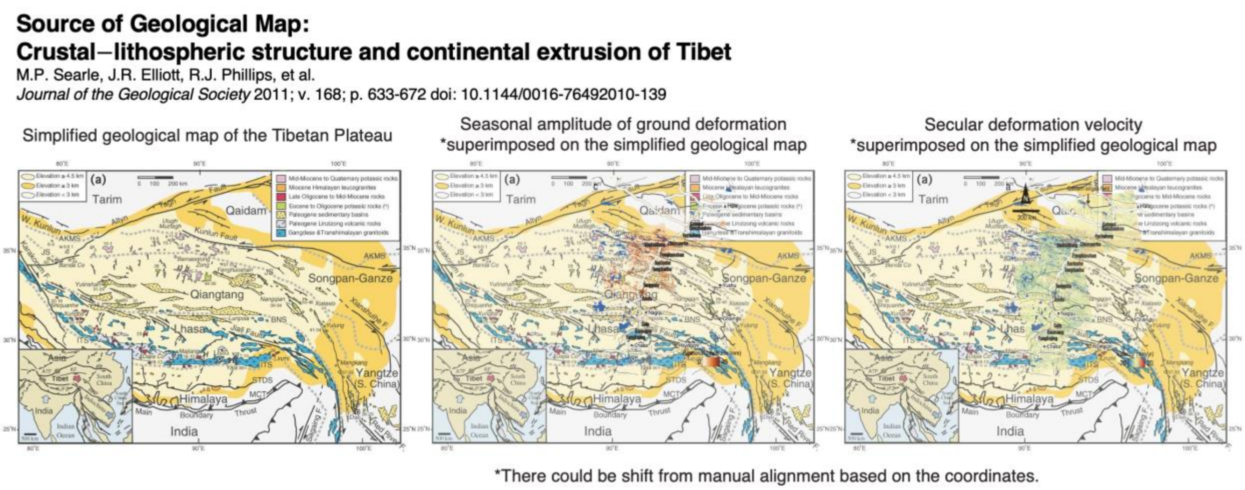
L76-79 – Is this rate for seasonal movement or cumulative over several years?

It is the average rate over several years. Now it reads "the annual subsidence rate faster than 2 mm/yr".

L98-104 – Is information on surficial geology and ground ice content used. Knowing ALT on its own is sufficient when determining displacement patterns. Is excess ice considered?

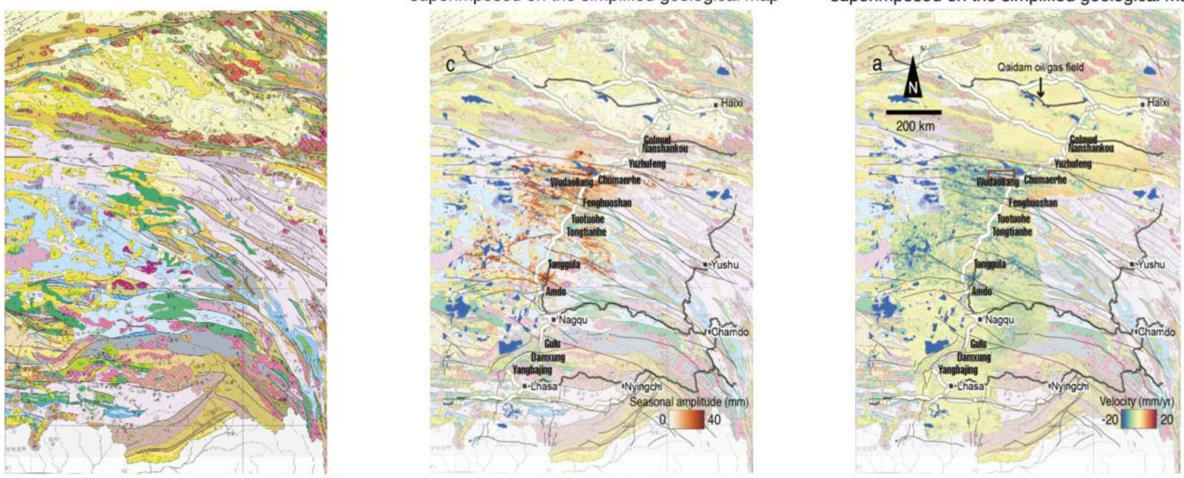
We incorporate the volumetric water content in the freeze and thaw seasons to infer the active layer thickness. By assuming a complete thaw in the ground surface reach the lowest when the volumetric water content can be represented by soil moisture, our approach does not require information about the ground ice content and excess ice. But we also note that if the seasonal estimates of ground ice content are available, we can better know the unfrozen water in the freeze and thaw seasons and thus improve this model. Because such datasets are unavailable, we do not introduce ground ice content in our interpretation. Please find our earlier response for more information.

We collect geological maps from the four sources (i, Searle et al., 2011; ii, Online Geological Map of Tibetan Plateau https://osgeo.cn/map/m02c2/; iii, 1:1.5 million geological map of Tibetan Plateau and its surrounding areas https://www.tpdc.ac.cn/zh-hans/data/ce047b38-72b4-46a7-8fbe-c9019e6dd5cf/; iv, 1:1.5 million geological map of China). The former three do not have GIS shapefiles. As ALT is essentially inferred from seasonal amplitude of ground deformation in the vertical direction, we superimpose our deformation products on the geological maps for a qualitative analysis. We show below the seasonal amplitude of ground deformation and secular deformation velocity from the descending line-of-sight Sentinel-1 as examples.



Source of Geological Map:
Online Geological Map of the Tibetan Plateau
https://osgeo.cn/map/m02c2/ (Please visit this URL for the legend)

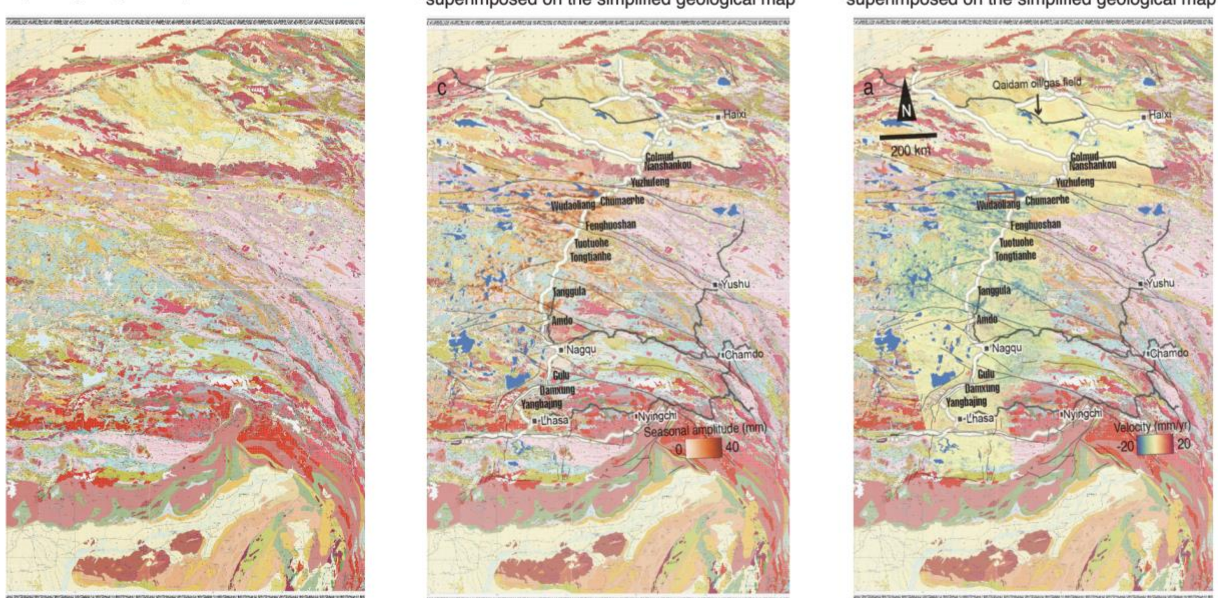
Simplified geological map of the Tibetan Plateau | Seasonal amplitude of ground deformation *superimposed on the simplified geological map | Secular deformation velocity *superimposed on the simplified geological map



*There could be shift from manual alignment based on the coordinates.

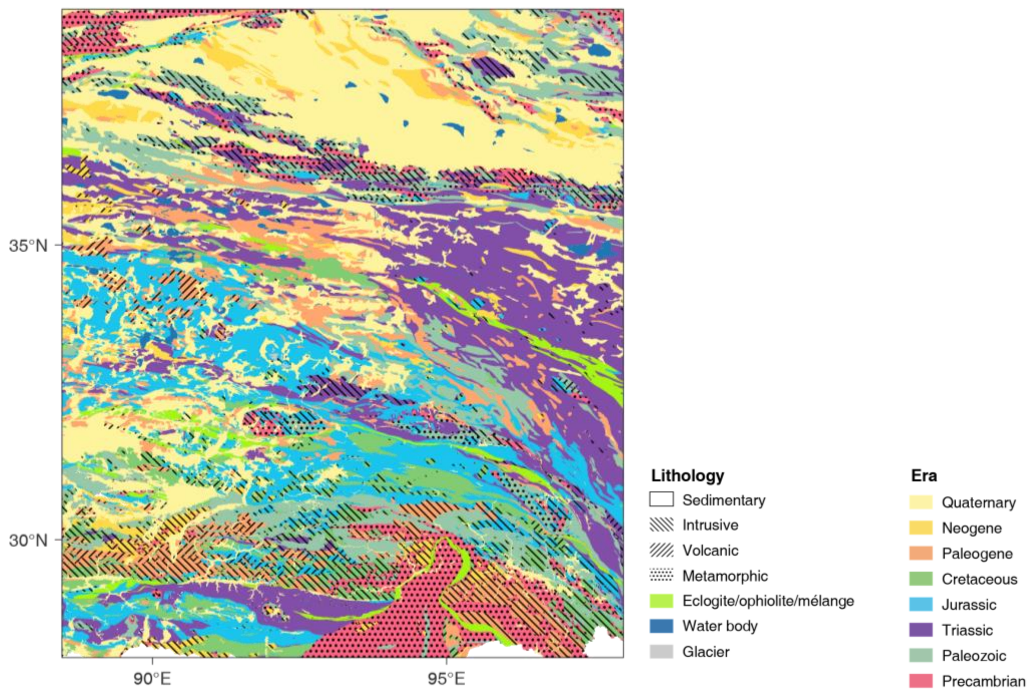
Source of Geological Map:
1:1.5 million geological map of Tibetan Plateau and its surrounding areas
https://www.tpdc.ac.cn/zh-hans/data/ce047b38-72b4-46a7-8fbe-c9019e6dd5cf/ (Please visit this URL for the legend)

Simplified geological map of the Tibetan Plateau | Seasonal amplitude of ground deformation *superimposed on the simplified geological map | Secular deformation velocity *superimposed on the simplified geological map



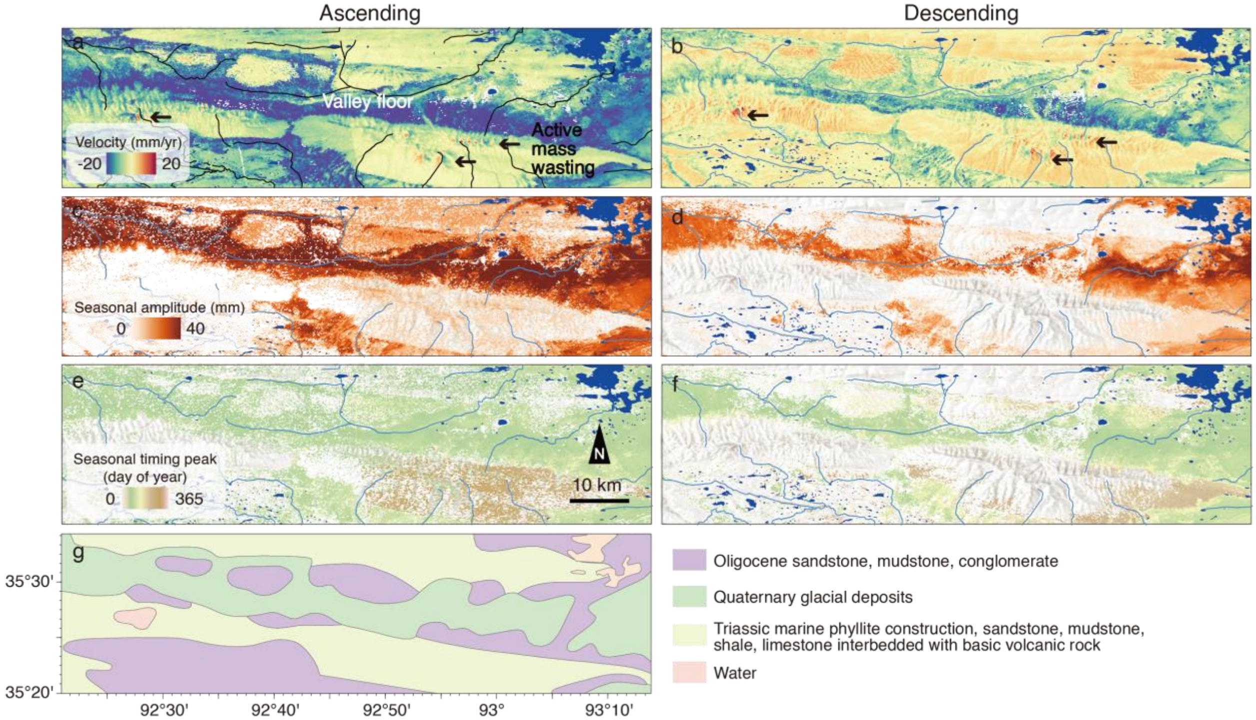
*There could be shift from manual alignment based on the coordinates and water body margins.

We add in line 255 “Overall, the association between displacement and geological conditions is inherently stochastic”. We also add the figure below in the supplementary material.



(Add in the supplementary material) Figure. Geological map (Source: 1:1.5 million geological map of China).

Nonetheless, in our enlarged area of interest around Wudaoliang in Fig. 4, a belt of large displacements overlaps with Quaternary glacial deposits (another source of geological map shows Quaternary alluvial plain; see the second figure below). We add in line 278: "When referring to the geological map, we note such pronounced displacements are well aligned with the extent of Quaternary glacial deposits, suggesting a local impact from the surficial geology".



(Updated by added a new panel g) Figure 4: Enlarged ground deformation decomposition results around Wudaoliang (the red box in Fig. 3a). a and b show the secular displacement velocity from ascending and descending results, respectively. c and d show the peak-to-trough seasonal displacement amplitude from ascending and descending results, respectively. e and f show seasonal timing (day) when the ground reaches the upmost (peak) in one calendar year ascending and descending results, respectively. g shows the geological map.

Figure. Visual comparison between the deformation fields and the geological map (Source: 1:1.5 million geological map of Tibetan Plateau and its surrounding areas).

L120 – “compiled” is probably more correct than “collected”

Updated.

L176 – What is meant by long-term – what is the period considered.

Now it reads ”the long-term ground deformation trend from December 2014 to September 2022”.

L213 – Replace “can hardly” with “can not”

Updated.

L222 – Is this based on cumulative subsidence over several years or just seasonal movement?

It is based on cumulative subsidence over several years. Now it reads “with rates ranging from a few to over 20 millimeters per annum from December 2014 to September 2022”.

L225 – Avoid words like “drastic”

We update the text to “localized subsidence”.

L226-227 – Permafrost isn’t required to have seasonal heave and subsidence as this can occur where only seasonally frozen ground is present. The change may have more to do with a change in surficial geology and frost susceptibility.

As shown in Fig. 6, the color dot suggesting seasonal ground deformation mainly occur on the dark blue background (permafrost region) instead of the light blue background (seasonally frozen ground). We describe that “seasonal displacements clearly cease at the boundary between permafrost regions to seasonally frozen ground regions”. We add in line 254 “Surficial geology and frost susceptibility may jointly regulate the ground deformation.”

L253 – Are displacements more pronounced here due to the surficial materials?

We believe the large displacements may result from variations in the volume of ground ice and the thermal conditions.

L262-263 – Occurs at/prior to the onset of thaw?

We use the frozen instead of thaw for the description following the temporal sequence. The highest surface position for most of the flat areas occurs in spring when the underlying water/ice-rich layer reaches its most frozen state.

L312-313 – It is unclear whether there is consideration of segregation ice (ice lens formation) which forms as water migrates to the freezing front or just the 9% expansion of pore ice. The segregation process is responsible for excess ice formation which is important for thermokarst processes.

We focus on the regional ground deformation and do not consider ice segregation. It is beyond the scope of this research to quantify the role of ice segregation in ground deformation encompassing such large region.

L315-321 – It takes time for changes in surface temperature to propagate to greater depths. Thaw may still be occurring at depth when onset of freezing occurs at the surface.

Thank you for your comment. We share the same core idea. Heat/temperature signals at the surface take time to propagate downward, so deeper soil temperatures lag behind land surface temperatures. We elaborate the process:

"In-situ measurements from the TGL permafrost station indicate that minimum temperatures at shallow depths occur in January—when surface freezing may already begin—whereas deeper layers continue cooling and do not reach their minimum temperature until March."

L333-335 – ALT can be derived from ground temperature measurements, frost probing and thaw tubes. I'm not sure that most would call extraction of stratigraphic profiles the most fundamental method of determining ALT.

Thank you for your suggestion. We update our description:

"The general method for determining active layer thickness involves directly measuring maximum seasonal thaw depth in the field (e.g., probing, pits/cores, thaw tubes), or indirectly inferring it from subsurface temperature profiles, calibrated heat-transfer models, or geophysical surveys (e.g., electrical resistivity tomography, ground-penetrating radar, seismic)."

L350 – Is excess ice considered?

No, we do not consider excess ice. We clarify the sentence:

"InSAR-derived time-series displacement provides a solution for quantifying large-scale ALT by leveraging the basic principle of density differences between ice and water assuming an overall water balance, regardless of the water states, in the active layer through our study period of eight years".

L361-362 – ALT is not directly measured using GPR surveys but interpreted from the data – requires additional site knowledge etc.

We update this sentence to "In the QTP, ALT is primarily measured using soil sensors, boreholes, or inferred from ground-penetrating radar imaging".

L380-388 – How do these derived values of ALT compare to measured values?

We use the in-situ measurements of ALT to constrain the corresponding volumetric water content in the frozen season. Therefore, the consequent spatially continuous map of our derived values of ALT is the same to the measured values. We attempt to effectively use the measured values of ALT in our model.

Relevant information is available in the method section:

"Here we fully utilize a limited number of in-situ ALT measurements in QTEC, constrain n at those sites where all other parameters are available (Eq. 2; Table S1). We use the spline interpolation to generate a map of n after removing anomalies. Thereafter, we compute the ALT at the same resolution of the input seasonal displacement amplitude (Eq. 2). Although this workflow involves uncertainties originated from parameters themselves in the dry QTP environment, the derivation of ALT is based on physical processes, instead of data-driven machine learning."

L413-415 – Refer to thermokarst processes rather than disasters.

Updated through the text.

L412 – Section 4.3 – The rest of the paper focussed on vertical displacements derived from InSAR. It isn't clear whether displacements derived from InSAR are used to generate the results presented here regarding thaw slumps etc. or some other technique given other satellite products are mentioned.

Because this study focuses on the Qinghai–Tibet engineering corridor, we report thermokarst statistics within buffer zones along the corridor to emphasize the need for sustained monitoring of ongoing deformation in this critical region.

L493-496 – Note that these studies do not consider infrastructure design in their analysis. This is important because infrastructure design will influence the impact of permafrost thaw on the infrastructure. These studies are often done at scales that are insufficient for more regional to local scale assessments which are required when considering infrastructure impacts.

Thank you for your careful thought. We add in the end of this section "Furthermore, the present-day studies do not usually consider how infrastructure is designed, built, or maintained, which may also impact the soil's thermo-hydro-mechanical properties in permafrost regions and greatly change how permafrost thaw affects damage. To support decisions for a specific corridor or community, finer-scale studies are needed that include local conditions and detailed engineering information about the infrastructure.”