Review tc-2020-218: Kokelj et al.

The aim of the manuscript is to elucidate the [geomorphic, hydrologic and, to a lesser degree, sedimentary] processes and feedbacks that drive the [decadal] evolution of thaw-related mass movements and hillslope-channel coupling in ice-rich permafrost terrain of northwest Canada (lines, L108-111). The objectives (L121-123) are: " to better understand the (A) processes that drive the intensification of thaw-driven mass wasting and slope to stream coupling, (B) the distribution of catchment effects, and (C) their propagation across watershed scales,". The aim and objectives are important directly to the fields of permafrost geomorphology and hydrology, and indirectly to the fields of biogeochemistry, terrestrial and aquatic ecology, as well as to landscape management and ecosystem services. Personally, I would rephrase the objectives as aims (because the objectives given are really general statements of intent or goals) and identify specific objectives that signpost the ways in which the aims can be achieved and evaluated (because this is clearer in assessing how successfully aims are achieved). But to some degree this is a matter of author and journal preference.

The methods used apply high-resolution three-dimensional survey techniques (light detection and ranging, and drone-based structure-from-motion) and geographical information systems (e.g. to construct digital terrain models and determine stream ordering) to drainage basins whose area varies by orders magnitude in a study region of 1 million km^2 in NW Canada. This allows the authors to address terrain characteristics and functional geomorphic-hydrological relationships at localized to regional scales. The methods are appropriate to the aims and objectives, and are presented clearly, systematically and rigorously as far as I can tell, though I am not an expert in GIS analysis, and so I cannot comment usefully on pages 1-8 of the supplementary information.

The results are largely new, clearly structured and presented well. The data represent a major contribution to terrain analysis on ice-rich permafrost, and the authors should be congratulated for bringing together this large and complex dataset. In particular, the focus on location of mass movements within catchments of different area, achieved through simple application of Strahler stream ordering, nicely identifies the first and second-order basins as particular centres of landscape change, and takes up functional and historical geomorphologists' consideration of scale and morphometric issues developed mainly since the 1950s in other regions. The narrative is illustrated by effective figures and tables, though some minor points need clarification (see below). The three videos provide valuable supplementary information. The length of this section is fine.

The interpretation is generally excellent, leading this reader step by step through the reasoning and contextualisation within the wider literature. The latter was particularly strong, as there has been substantial previous research on thermokarst terrain and processes in northwest Canada. The length of the interpretation could perhaps be shortened by 10-20% to avoid repetition and bring out the key messages more clearly. Likewise, the conclusions, in my view, could you shortened to a number of key points, though again I appreciate that this is a matter of preference.

Overall, I think that this manuscript makes a substantial advance in our knowledge and understanding of the impacts of thaw-related mass movements on hillslope-stream coupling ice-rich permafrost catchments in northwest Canada. The approach used could be more widely applied in other regions of ice-rich permafrost (e.g. northern Alaska, NW Siberia and NE Siberia). I recommend publication subject to mostly minor revisions concerning points of clarification and typos, as listed below. Only two points of moderate significance are raised for consideration:

Moderate points

Slope thermokarst (lines, L135-137, 195-197): Active-layer deepening and surface subsidence beneath a hillslope could reasonably be included in 'slope thermokarst', so I think this study is focussing on the most visible type of slope thermokarst, i.e. mass movement types. Perhaps this distinction can be made. 'Thaw-driven mass wasting' (L657) is a more accurate description of the focus of this manuscript than is 'slope thermokarst', in my view.

Stabilization: a couple of sentences might be added to comment on the contrast between the recent decadal intensification of thaw-related mass movement and the stabilization of presumably the same terrain after the early Holocene climate warming. A reader might infer from the present argument that the recent trends are here to stay, which may be true for decadal and centennial timescales, but I wonder if the early Holocene landscape suffered even more change over even longer periods (millennial), and then stabilized, preserving abundant buried ice. The

authors insights into thaw and terrain change may help elucidate negative feedbacks the thermokarst system, as Lawson, Shur and others have done successfully in terms of thermokarst around ice wedges etc.

Minor points

L59: Prince of Wales Strait: mark on Fig. 1

L62: North America's largest delta may be the Mississippi, a few thousand km^2 larger than the Mackenzie. Please check.

L77: insert 'ice-rich' into this topic sentence, because thermokarst activity will not really affect permafrost with little or no ground ice, e.g. '…evolution of circumpolar ice-rich landscapes…'

L85: specify the nature of 'Arctic change' in the topic sentence as this encompasses many things, e.g. 'of environmental change in Arctic terrestrial and aquatic systems'.

L93: 'have' [subject is plural]

L106: do you mean 'thickness' (an interval) rather than depth (a single point), i.e. permafrost thickness?

L108-113: please shorten and simplify this long, complex sentence. It's a bit difficult to follow.

L121-124: this key sentence identifies the **aims** of the study. I think it would be clearer to simplify and rephrase along the lines 'The aims of the present study are (1)…' rather than squash them into a long introductory clause. The geographical region is of secondary importance relative to the more generic aims. Also, please specify the type of processes in (A), e.g. geomorphic, thermal …, and the nature of the distribution in (B), e.g. spatial and/or temporal.

L130: append 'climate' to 'cooling Holocene'.

L141: Tuktoyaktuk Coastlands [with an 's']

L144: clarify what is meant by 'fluvial patterns', e.g. river channel morphology, bedform architecture, sediment transport…?

L145: indicate Mackenzie Delta on Fig. 1

L151: indicate Amundsen Gulf on Fig. 1

L178: replace 'middle' with 'medium'

L181-184: indicate approximate depth of mean annual ground temperatures as much of the deeper layers of permafrost on Banks and Victoria islands etc. will be much warmer than -10oC.

L192: insert 'other' before 'glacigenic materials' as tills are glacigenic.

L200: **datasets**: it's essential to identify all of the datasets used in the study rather than the non-specific word 'include'.

L210: clarify what is meant by 'a continuum of slump features'. Continuum in what sense: activity, size, aspect…?

L228: **subsidence**: did some of the volumetric change on the slopes resulted from permafrost thaw and thermokarst subsidence beneath slump-floor sediments (cf. Burn 2000, CJES 37:967–981) or can this process be discounted?

L238: **volumetric erosion**: careful, the study is not directly measuring erosion but inferring erosion based on measurement of volume change. So an explicit parameter such as 'volume change' or 'disturbance volume' (L344) is more appropriate. There may be a better term, as I'm not familiar with GIS methodology.

L240: **active or recently-active scar and debris tongues**: on what criteria were these identified as such? e.g. lack of living vegetation or some indirect evidence of vegetation? L493 mentions bare or sparsely vegetated landforms. I find it difficult to know from many GIS studies what actually is being observed directly and what is being inferred.

L245, and supplementary L277: '**including'**: it is clearer to identify all of the criteria for designating a slump as '2'. Were there any other criteria besides the two mentioned, e.g. turbidity in rivers, as per caption of Figure S3ii?

L275: insert ‘and’ after ‘2010’.

L299: “All mapping was reviewed for accuracy and consistency.” Please explain how or cite a reference that does.

L319: data are treated as plural in this sentence; previously (e.g. L166, 209) they are treated as singular. Please ensure consistency.

L331: routing … ‘was’

L365: **intensifying** slope thermokarst: this implies that the rate of growth or the increase in number of slumps or both factors is accelerating in all cases. Is this correct for all slumps or just for some, e.g. CB?

L366: ‘**eroded volume**’: again, can you be sure that thermal erosion accounted for all of the missing volume, or might thermokarst subsidence have contributed to the missing volume?

L383: delete ‘retreat’ because the photograph shows the headwall but not its retreat.

L384: Ditto ‘erosion’; the photograph showed ‘eroded glaciofluvial deposits’, not their erosion. Also, add ‘s’ to ‘deposit’.

L387: again, the photograph in panel d does not show ‘initial stages of incision’, but an incised channel. Panels c and e may show evidence of side valley erosion, but they don’t show any erosion itself.

L390: please indicate (e.g. with an arrow) the snow patch, as it’s not obvious to me at least.

L383 & 390: please clarify the caption ‘Elevation normalized debris tongue profiles…’. The y axis of the plot shows thickness, so I think this should be added to the caption, e.g. ‘elevation normalized profiles of debris-tongue thickness’. Also, there are in total three white dashed lines on panels b, f and g, but four lines depicting profiles on the plot in panel h.

L394: if this refers to slump area as opposed to e.g. headwall height, then it is clearer to rewrite, e.g. ‘…the area of FM2 was an order of magnitude greater than …’

L397-8: ‘Increasing thaw-driven sediment flows…’: please clarify if this refers to their number, magnitude, rate or …

L401-402: ‘pinning of the stream channel to the valley wall (Fig. 2c)’: please indicate this (e.g. with an arrow) on Fig. 2c, as it’s not very clear to me where the stream channel is.

L402: better to replace ‘massive deposits’ with ‘thick deposits’, as the former, in the context of sedimentary deposits, suggests that they lack sedimentary structures, which may or not be the case, as they are not described.

L406: ‘abrupt transition from small valley-side thaw slumps into larger, more dynamic features’: I’m not sure that the data on area of slump CB support this, as within 7-9 years of slump initiation CB was 25,900 m^2 (by 2011), i.e. growing at a few thousand m^2 per year, whereas 4 years later it was 33,370 m^2, which suggests a broadly similar rate of expansion. What does look to have been abrupt, is the sudden evacuation of slump-floor deposits since 2017.

L434: delete comma after ‘geomorphology’

L493, 525-6 and Fig. 6: **large translational slides**: what criteria are used to identify these landforms and to distinguish them from thaw slumps? Are they different from active-layer detachments? How do you identify bedrock control?

L495: Fig. 5a is first mentioned after Fig. 6 (L493). Please correct numbering.

L498: depth of maximum thaw: how is this value determined? Do you mean the maximum concavity depth in L506?

L511: ‘from 2002 to 2018’

L515-16, 739-41: “Normalizing by catchment area and differencing with the preceding time interval, the thaw slump component of surface lowering amounts to 0.1 mm yr-1 for 1986-2002 and 0.8 mm yr-1 for 2002-2018.” This seems to me to be a rather strange and spurious parameter to calculate because surface lowering in thaw-slump terrain is not uniformly distributed, but focussed in discrete locations. An alternative, perhaps more meaningful parameter to

calculate would be volume lost per unit area (cf. sediment yield), because this does not imply that the lost volume is uniformly distributed across space.

L529: were [km are plural]

L546: box and whisker plots: please state what each part shows, e.g. horizontal line denotes median, … dots indicate outliers …

L547: narrative specifies 'concavity thicknesses' whereas Y axis on panel f is … 'depth'. Please ensure consistency.

L555: the proportional circles are grey rather than black.

L559-560: 'Willow Lake (outlined in Orange)': where is this on panel c? Lower case for orange or simply add a label 'Willow Lake'. Please renumber panels to avoid three panels all labelled b, and three labelled c. 'The abandoned channel is shown in dark blue': in panel c the lakes look to be coloured dark blue in Fig. 6. Or are you referring to the unlabelled panel? This is difficult to follow the caption without sequential labels on all panels and text placed accordingly.

L586-591: This summary of literature is more appropriate for a discussion than a results section.

L589: indicates (with 's'; compilation is singular)

L602 & 604: both 2017 and 2018 are indicated in caption but only 2017 is shown on panels a to c.

L606: streams and rivers: what is the difference? Insert 'of' before 'the Peel…'

L661: suggest [plural subject]

L672: '**rapid aggradation of channel beds'**: perhaps 'rapid aggradation of valley fills or sediment bodies' is more appropriate. Deposition of the valley fill in Fig 2 looks to have been mainly by debris-flow processes rather than channel processes (cf. L716-20). The channel shown in Fig. 2d has incised its bed.

L693: is complex [subject is singular]

L752: is magnified [subject ('the significance') is singular]

L775: what is a 'discordant volume'?

L823: 'persistent perturbation': please specify the timescale of persistent or omit. Over decadal and possibly centennial scales, the perturbation may well be persistent. But geologically (multi-millennial and longer scales), the perturbation is certainly major but transitory, as the conceptual framework proposed by Ryder, Church, Ballantyne and others infers a pulse of sediment movement that declines over time.

L839: again, please clarify what timescales are referred to as 'long-term'. L844 identifies centennial timescales.

SuppL381: correct to 'cloud-free'