# Changing Permafrost Conditions in the Sahtu Region of the Central Mackenzie Valley, NWT – a Warming Ice-rich Landscape in Transition

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## INTRODUCTION

Permafrost in the Sahtu region of the central Northwest Territories is generally warm, relatively thin and discontinuous, and in most parts of the region strongly impacted by climate change. Ground temperatures in have warmed by ~ 0.1°C per decade since 1984, part of a broader trend of warming air and ground temperatures across circumpolar regions. These warming effects, coupled with changes in precipitation, are impacting peatlands, watersheds and hillslopes through the region.

We present a synthesis of projects across the central Mackenzie Valley covering degrading dendritic peat plateaus and permafrost mass-wasting in the central Mackenzie River Valley.

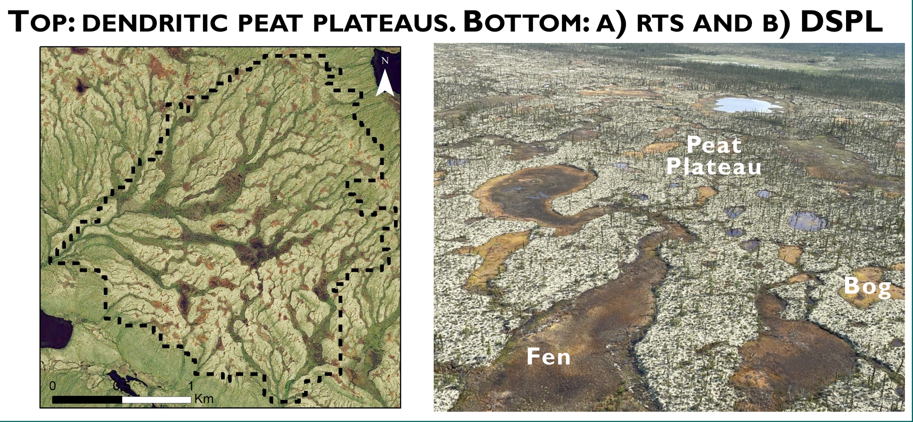
## METHODOLOGY

### Dendritic peat plateau* (DPP) degradation

- Quantify changes in thermokarst expansion and to better understand how this climate-sensitive element of the permafrost landscape has evolved over the last ~75 years.
- SPOT 6/7 1.5 m resolution imagery from 2018 and aerial photographs from 1949-1970.
- Thermokarst expansion was assessed on three different peat plateaus across the central Mackenzie valley.
- Fine-scale peat plateau mapping (1:500) assessed rates of thermokarst expansion.

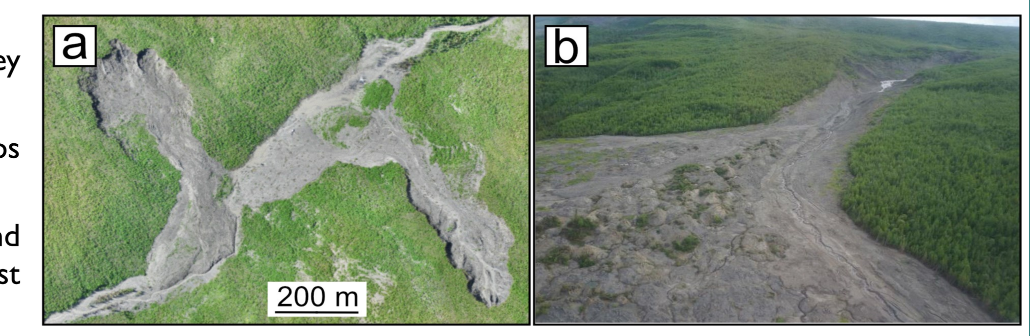
*Definition: DPPs are peat plateaus that are dissected by dendritically-oriented fen Collapse scars and bogs are present as internal and isolated depressions.

Top: dendritic peat plateaus. Bottom: a) RTS and b) DSPL




### Permafrost mass-wasting In the Mackenzie Valley foothills

- We present mapping and analyses of permafrost mass-wasting features in the central Mackenzie Valley foothills.
- We use annual satellite imagery to map the frequency and magnitude of : a) retrogressive thaw slumps (RTS) and b) deep-seated permafrost landslides (DSPL) from 1984-2020.
- Past forest fire extent and climate data were compared to permafrost mass-wasting distribution and dynamics to infer relation between fire activity, climate drivers of thaw, and widespread permafrost slope failure.






## DENDRITIC PEAT PLATEAUS DEGRADATION (1949-2018)

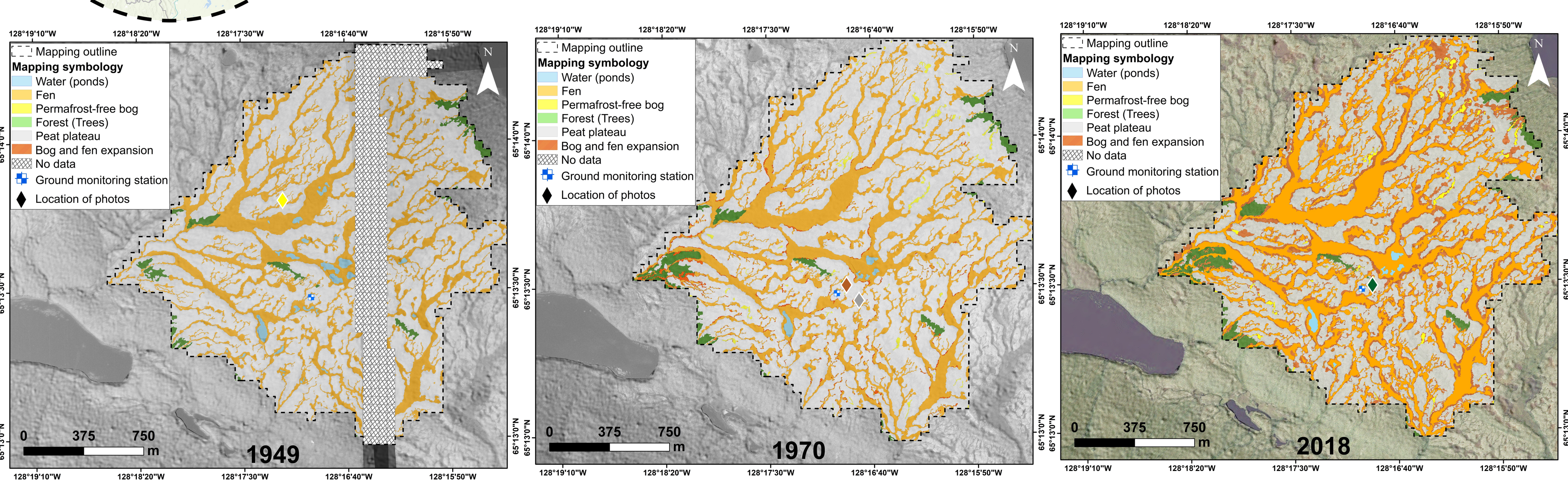
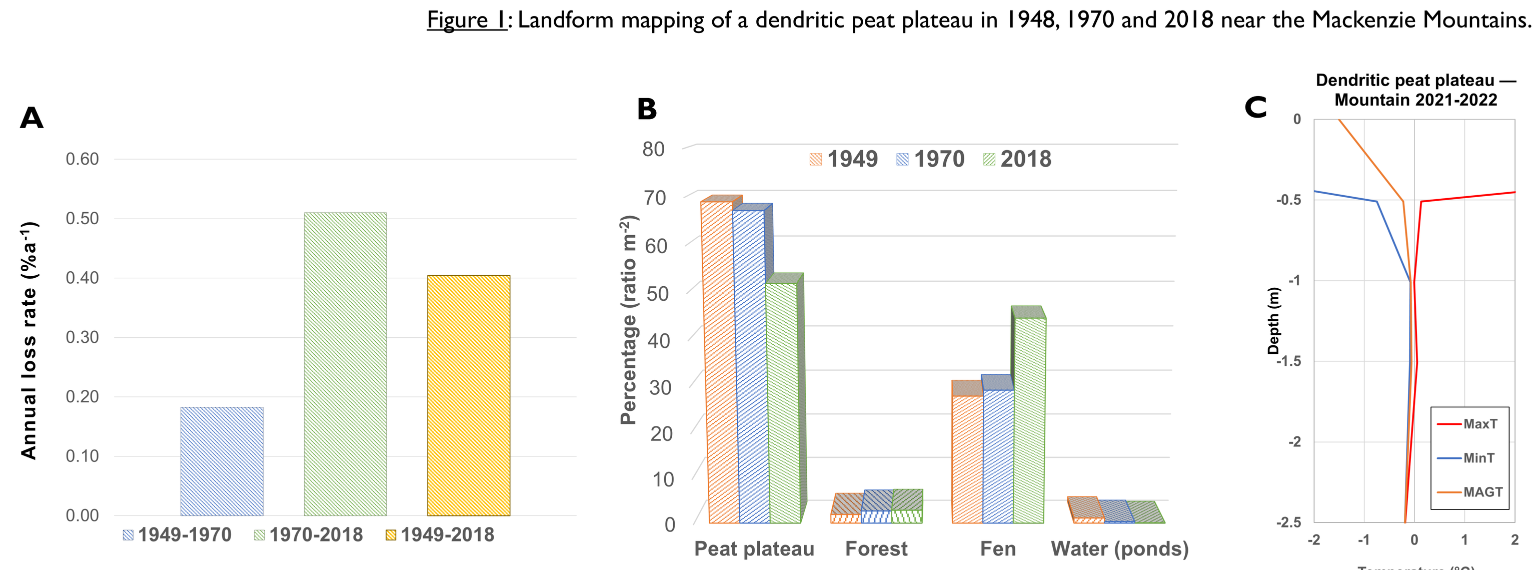



Figure 1: Landform mapping of a dendritic peat plateau in 1948, 1970 and 2018 near the Mackenzie Mountains.




Looking for more information about the **dendritic peat plateaus**?

SCAN ME

Figure 2: **A** — Average annual loss rate of dendritic plateaus near the Mackenzie Mountains for 1949-1970 (blue), 1970-2018 (green), and total rate for 1949-2018 (orange). **B** — Proportion of the analyzed area covered by four different classes for 1949, 1972 and 2018. **C** — Annual range in ground temperature at the dendritic peat plateau near the Mackenzie Mountains in 2021-2022.

## PERMAFROST MASS-WASTING (1984-2020)

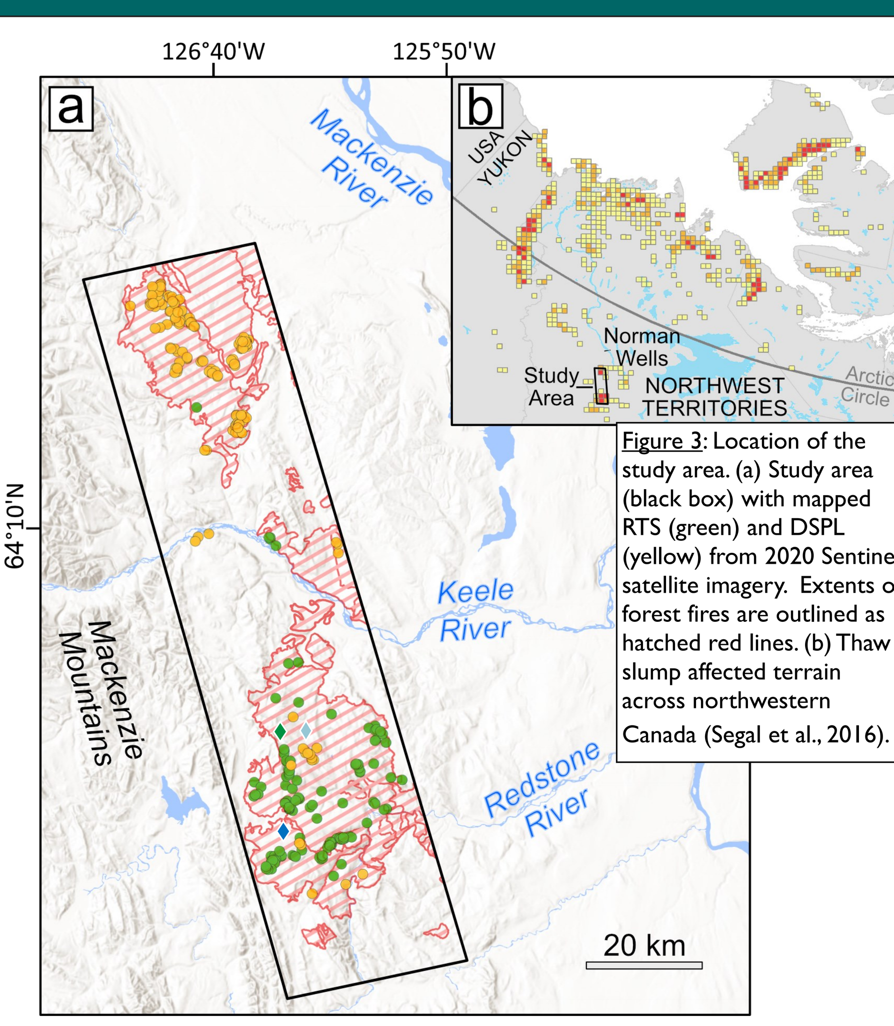



Figure 3: Location of the study area. (a) Study area (black box) with mapped RTS (green) and DSPL (yellow) from 2020 Sentinel satellite imagery. Extents of forest fires are outlined as hatched red lines. (b) Thaw slump affected terrain across northwestern Canada (Segal et al., 2016).

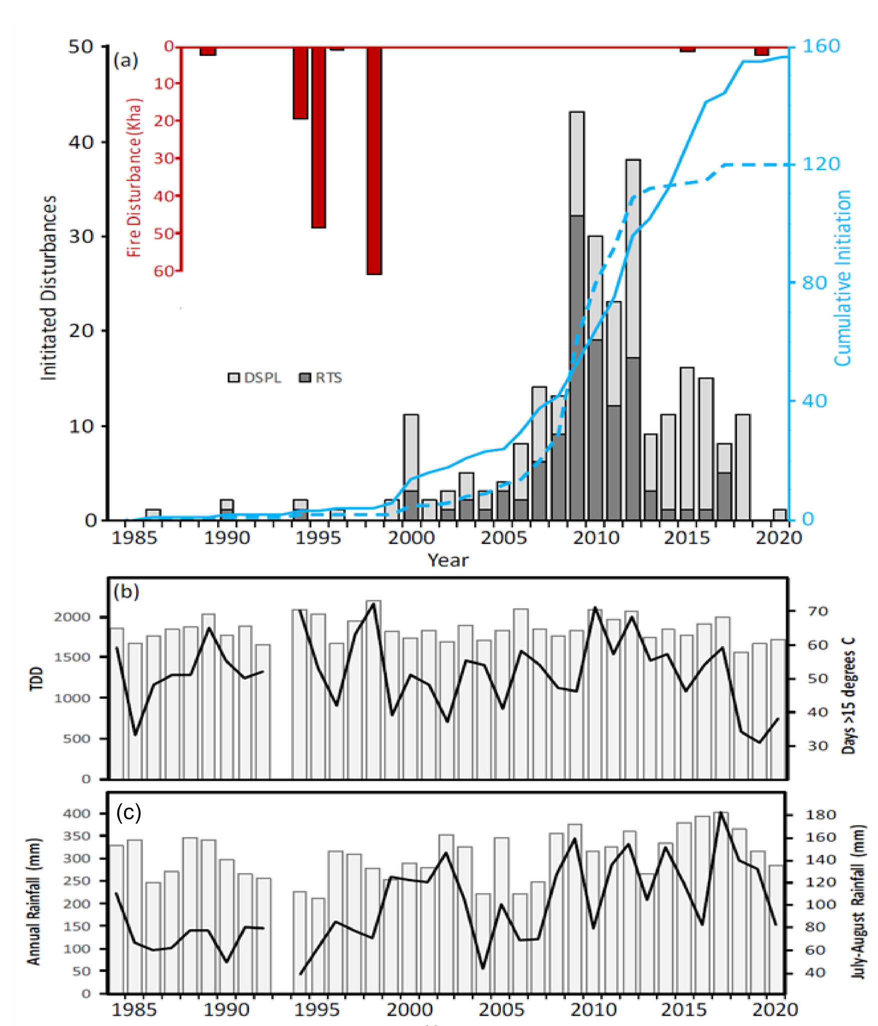



Figure 4: **Above**. (a) Frequency of permafrost slope failure with fire areas from 1984–2020. Year of initiation and number of individual RTS (dark) and DSPL (light). Blue lines indicate RTS (dashed) and DSPL (solid) cumulative initiations. Total area of annual fire disturbance in the study area indicted by red bars. Climate parameters from Norman Wells: (b) thaw degree days (bar) and days above 15°C (line); (c) mean annual rainfall (bar) and July-August precipitation (line).

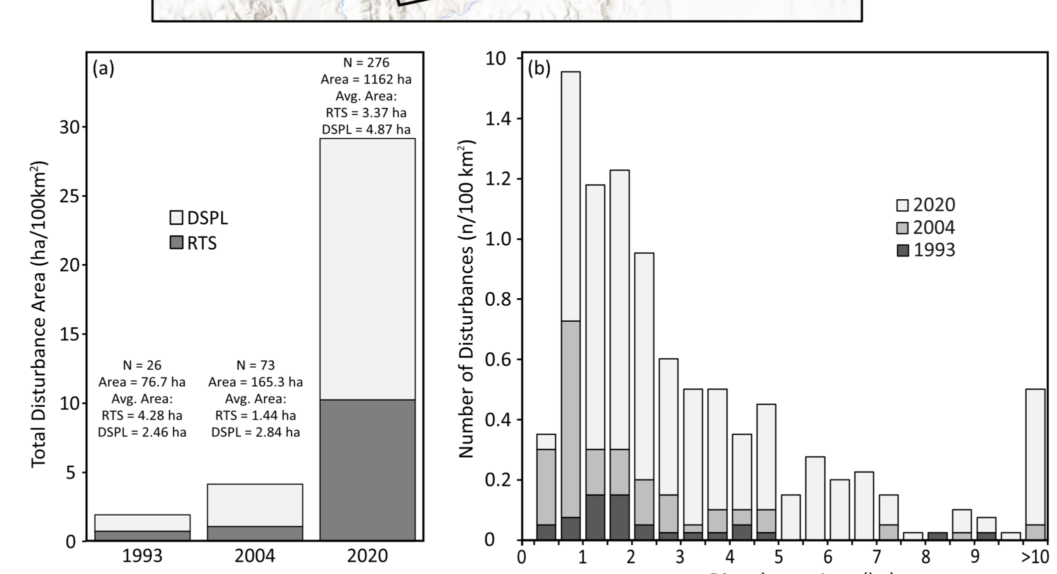



Figure 5: **Left.** (a) Increases in the frequency and size of RTS and DSPL in the central Mackenzie Mountain foothill study area from 1993, 2004, and 2020. (b) Comparison of total disturbance area of hillslope thermokarst. Mapped from Landsat (1993), SPOT (2004) and Sentinel (2020) satellite imagery.

## PERMAFROST STATE — MACKENZIE VALLEY HIGHWAY

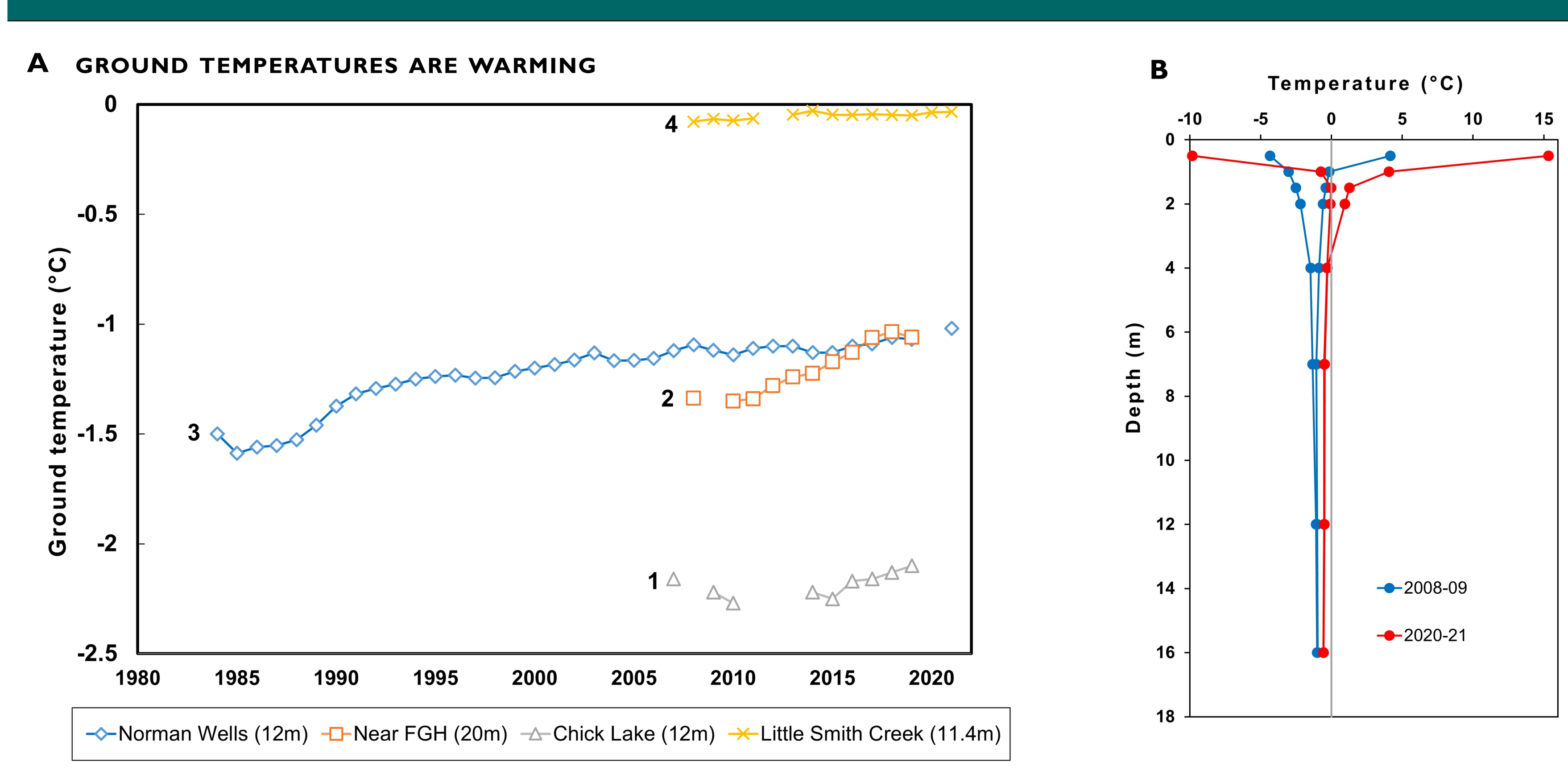



Figure 6: **A** — Permafrost temperature at selected long-term monitoring sites along the central Mackenzie Valley. **B** — Annual range in ground temperature at Oscar Creek near Norman Wells between 2008-2009 and 2020-2021.

## DISCUSSION & NEXT STEPS

- Degradation of dendritic peat plateaus depends on two processes: 1) thermal lateral erosion, and 2) formation of through-going taliks under peat plateaus that began to degrade primarily around the 1970s when the climate began to warm.
- We hypothesize that these are slowly expanding thaw networks ($0.40\%a^{-1}$), likely driven by basal permafrost thaw and expansion of fens along margins.
- Recent increases (2004-2020) in permafrost mass-wasting frequency (278%) and magnitude (602%) reveal a permafrost landscape in geomorphic transition.
- The sustained influence of legacy fire disturbances on the permafrost has preconditioned slope failure in this area. More than 92% of permafrost mass-wasting failure occurs in previously burned terrain, including 82% in areas severely burned in 1994, 1995, and in 1998.
- Compounding the effects of legacy thermal disturbance, increasing air temperature and precipitation have contributed to increases in slope failures in areas of warm permafrost.

**Future Work**

- Continue to identify DPP across the central Mackenzie Valley using a grid cells mapping approch.
- Mapping thermokarst lake changes throught remote sensing.
- Community level mapping of permafrost conditions for Sahtu communities.
- Characterization of deep-seated permafrost landslide settings and mechanics.

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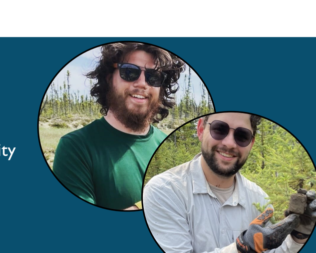

## Collaborators

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