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IMPACT OF EXTREME WARMING IN 2023 ON PERMAFROST IN NORTHWESTERN CANADA

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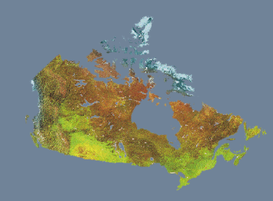
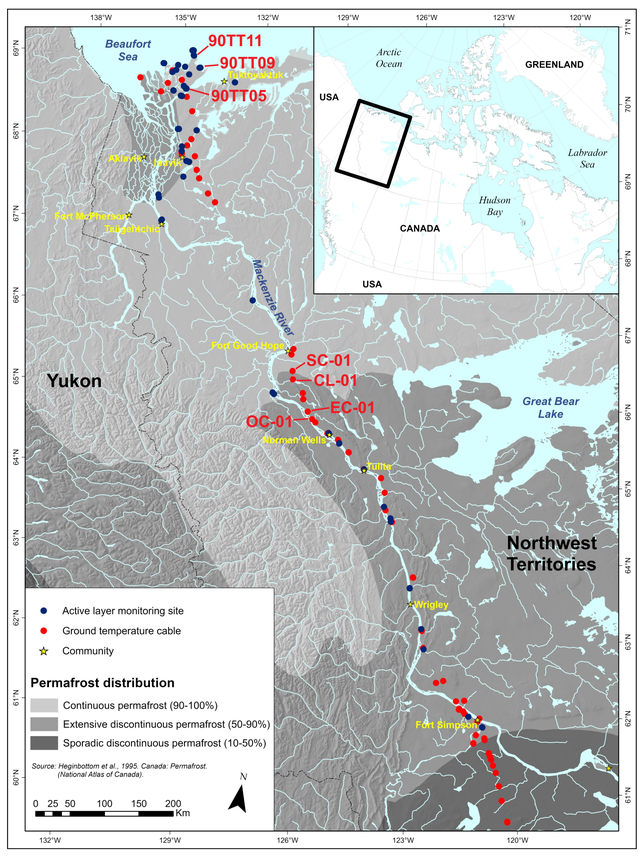


Introduction

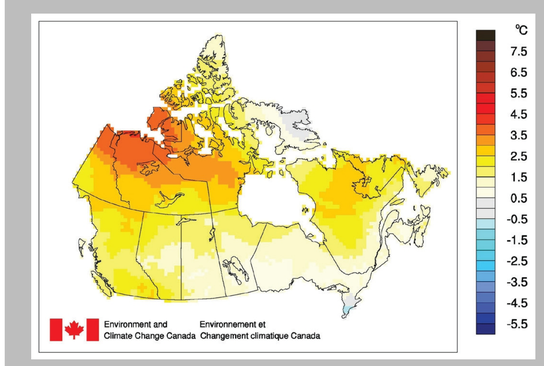
Annual mean air temperature in 2023 was the warmest on record in northwestern Canada. Average July 2023 temperatures in the Mackenzie Valley, NT were up to 6°C above the 1991-2010 normal. Earlier investigations of the impact of extreme warm years (e.g. 1998) on the cryosphere highlighted extremes in summer thaw penetration in permafrost environments. This poster presents preliminary analysis of thaw depth and ground temperature to investigate the impact of the warm conditions in 2023 on permafrost in the Mackenzie Valley.



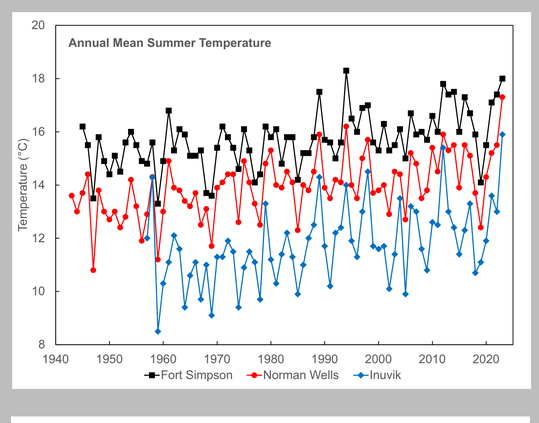
Permafrost monitoring sites in the Mackenzie Valley, NT. Cables installed in boreholes are used to measure ground temperatures at several depths and thaw tubes are used to determine active layer thickness. Sites referred to in figures are identified on the map.

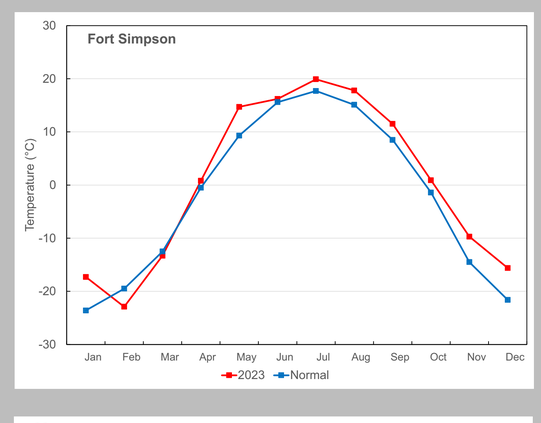
Summer Air Temperatures

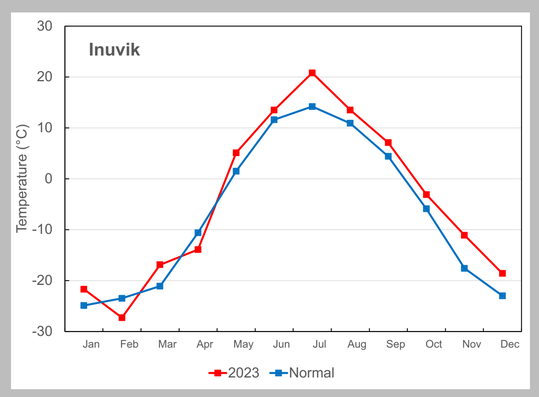
Air temperatures from Environment and Climate Change Canada weather stations in the Mackenzie Valley indicate summer 2023 was the warmest on record in the central and northern Mackenzie Valley (Norman Wells and Inuvik) and the second warmest in the southern part of the region (Fort Simpson). Throughout the region, monthly mean summer (June, July, August) temperatures were above the 1991-2020 normal. July temperatures in 2023 were more than 3°C above normal in the central and northern Mackenzie. (Data from Environment and Climate Change Canada)

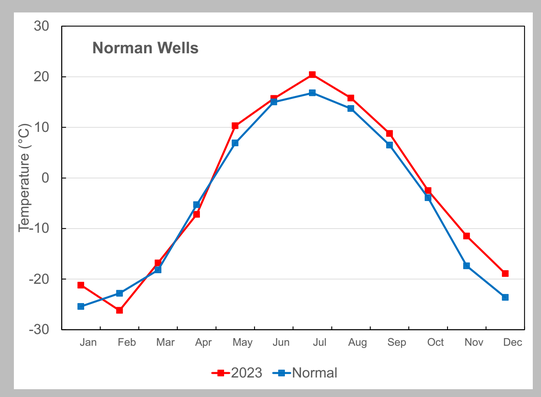


Summer 2023 air temperature anomalies relative to 1961-1990 mean (from Climate Trends and Variations Bulletin, Environment and Climate Change Canada).



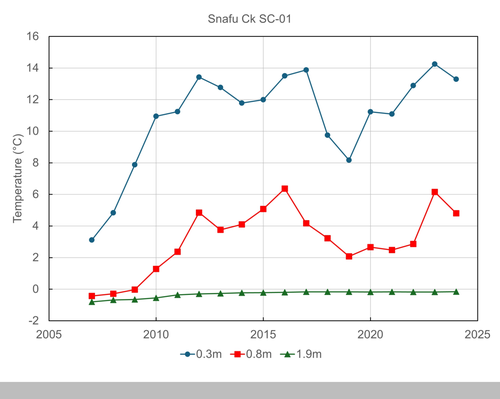


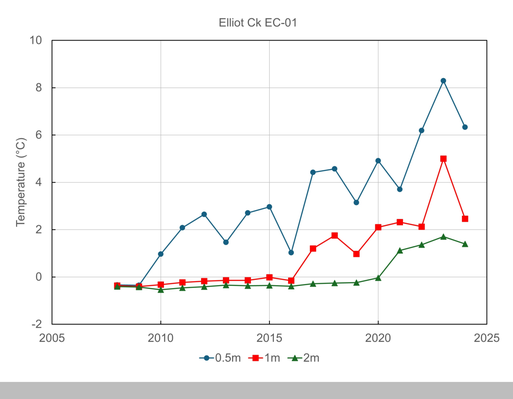


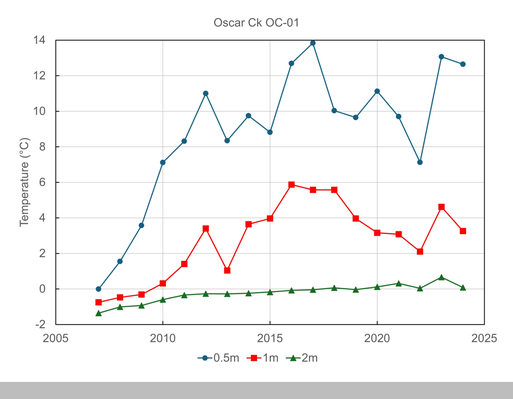


August Mean Ground Temperatures

At sites between Norman Wells and Fort Simpson, shallow August mean ground temperatures were greater in 2023 than 2022. In the upper 1 m, temperatures were among the highest recorded during the 2007-24 monitoring period. At SC-01 and EC-01 shallow ground conditions were the warmest on record.



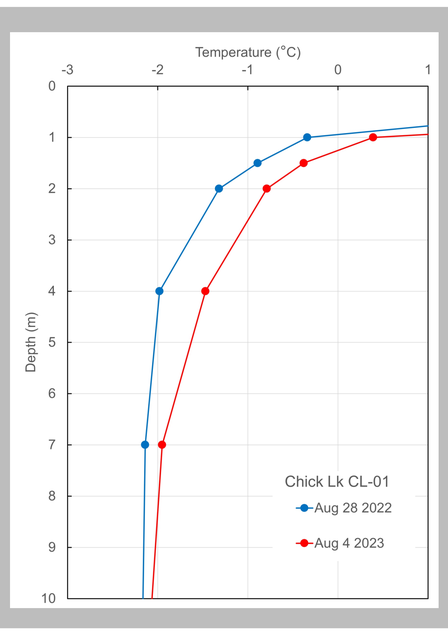


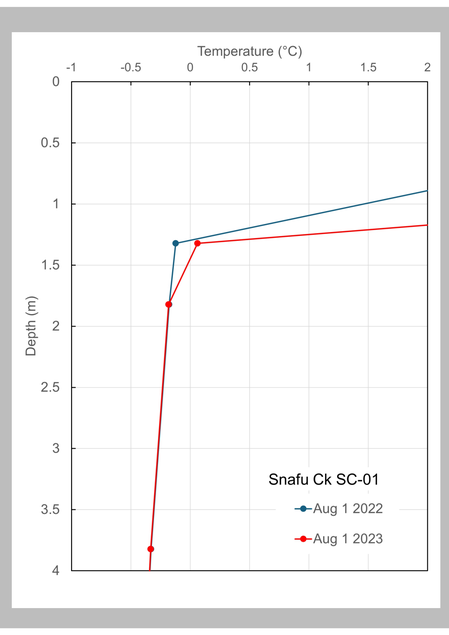


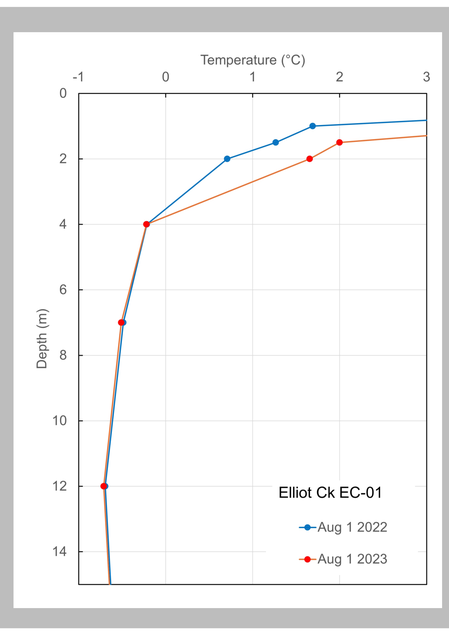
August Ground Temperature Profiles

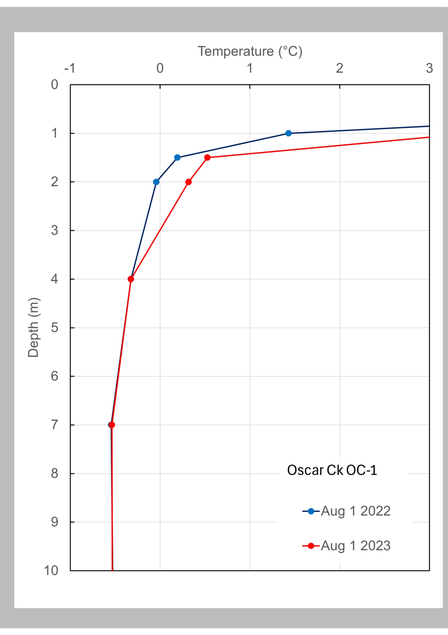
In the Central Mackenzie Valley between Norman Wells and Fort Good Hope, August ground temperature profiles indicate that shallow ground temperatures in 2023 exceeded those measured on the same date in 2022.

At CL-01, shallow ground temperatures (based on manual measurements) in early August 2023 had already exceeded those measured in late August 2022. The ground temperature profiles indicate that thaw depths in August 2023 exceeded those in August 2022.



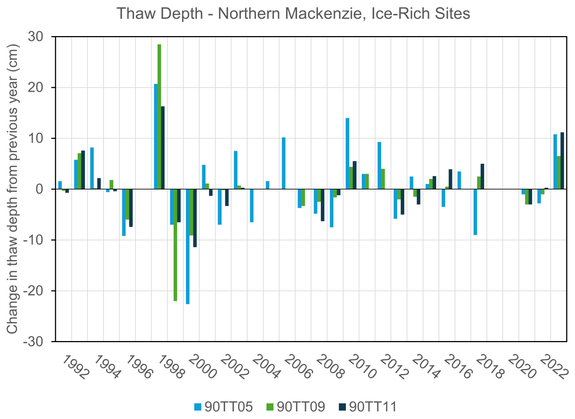






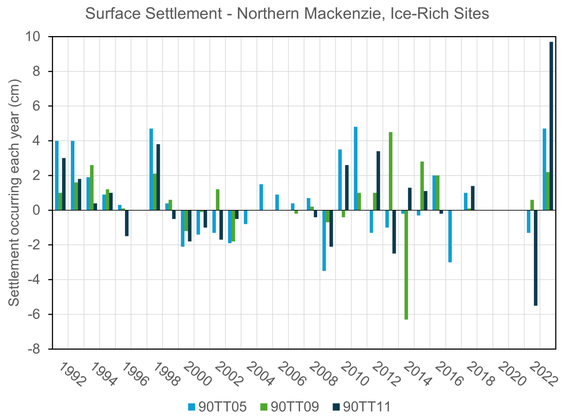
Thaw Depths

Thaw tubes are used to determine the maximum annual thaw relative to a fixed datum. Thaw depths measured during site visits at the end of July/beginning of August 2023 had reached or exceeded the maximum thaw depth in 2022 at half of the 24 sites visited. The increase in maximum thaw from the previous year is shown for three ice-rich tundra sites in the northern Mackenzie Valley that have the longest and continuous records. The additional thaw occurring in 2023 is among the largest on record. The highest increase in thaw on record occurred in 1998.



Ground Surface Subsidence

Thaw tubes also allow determination of ground surface position relative to a fixed datum. As ice-rich permafrost thaws, the ground surface subsides as ground ice melts. The time series of surface settlement occurring each year shows that substantial subsidence occurred in response to increases in thaw depth in 2023 for the three ice-rich tundra sites shown. For two of the sites the amount of settlement met or exceeded the amount occurring in other warm years including 1998.



Summary

The preliminary results indicate that shallow ground temperatures in summer 2023 were generally warmer than 2022 and among the warmest on record at many sites in the Mackenzie Valley. Increases in thaw depth also occurred although still less than the increase that occurred in 1998. The increase in thaw at ice-rich sites that occurred between 2022 and 2023 resulted in an increase in surface settlement. More detailed analysis will provide further insights into the impacts of extreme warming in 2023. These results in combination with analysis of the impact of other extreme warm years will improve understanding of the impact of climate change and variation on permafrost environments in northern Canada.

Acknowledgements

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Climate data presented in the poster are available from Environment and Climate Change Canada at:
https://climate.weather.gc.ca/
https://www.canada.ca/en/environment-climate-change/services/climate-change/science-research-data/climate-trends-variability/trends-variations.html
https://www.canada.ca/en/environment-climate-change/services/climate-change/science-research-data/climate-trends-variability/adjusted-homogenized-canadian-data.html

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