Recent streamflow trends across permafrost basins of North America

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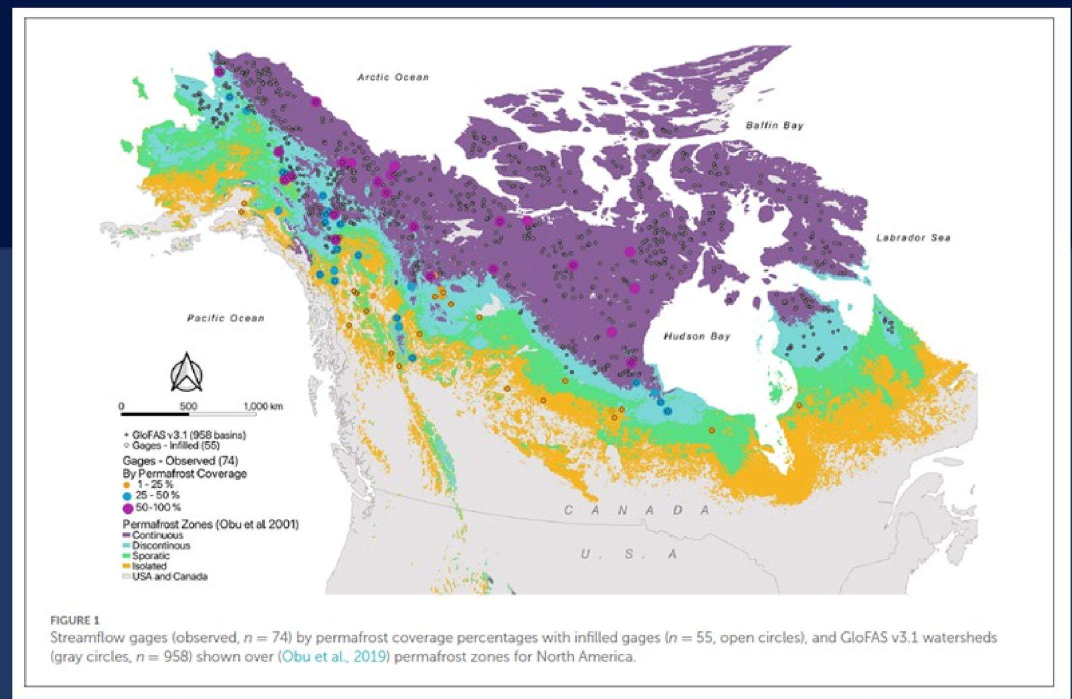
Motivation

Climate change impacts, including changing temperatures, precipitation, and vegetation, are widely anticipated to cause major shifts to permafrost with resulting impacts to hydro-ecosystems across the high latitudes of the globe. However, it is challenging to examine streamflow shifts in these regions owing to a paucity of data, discontinuity of records, and other issues related to data consistency and accuracy. A first step toward understanding how climate impacts permafrost hydrology is understanding how it already has.

Objectives

- identify a high quality set of observed streamflow gages on which to perform our analysis
- determine the key drivers of streamflow change by utilizing novel datasets and traditional and new methods to identify important influences of observed trends
- carry out studies to estimate trends for seasonal and annual timescales over the recent past for each streamflow system

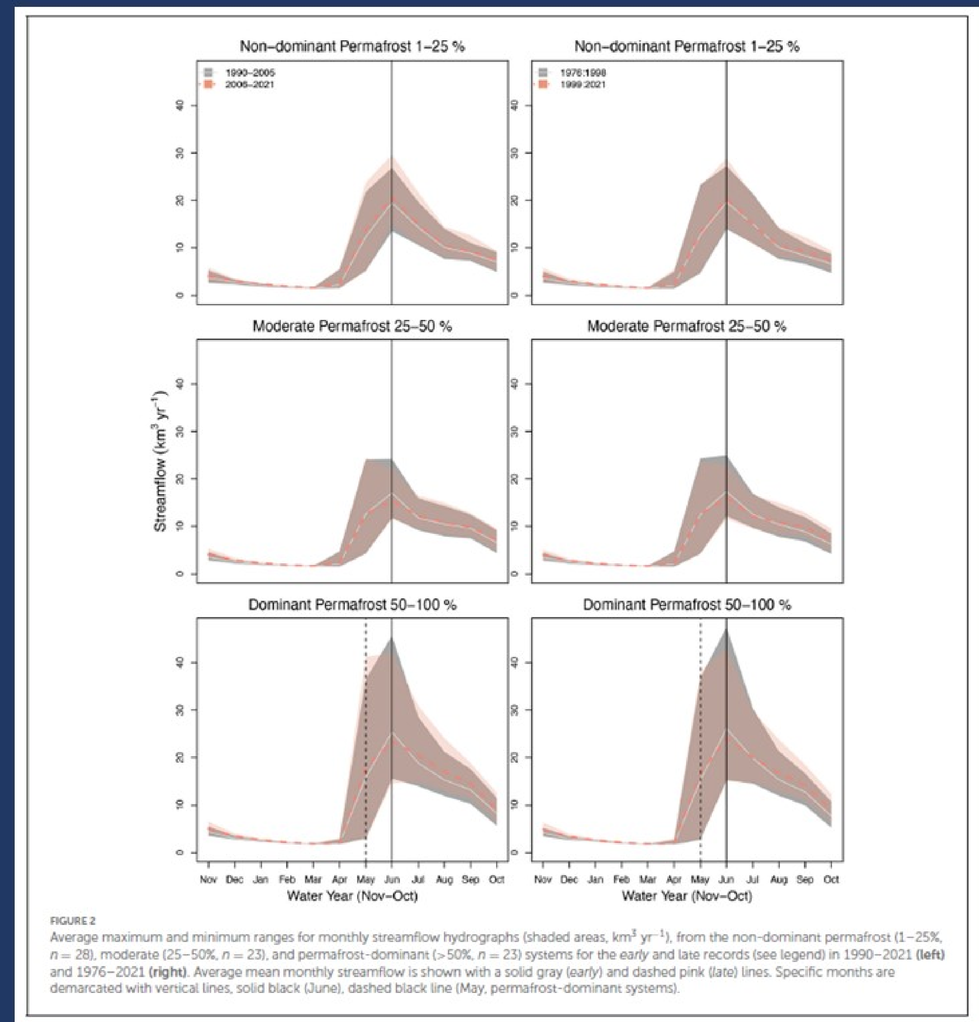


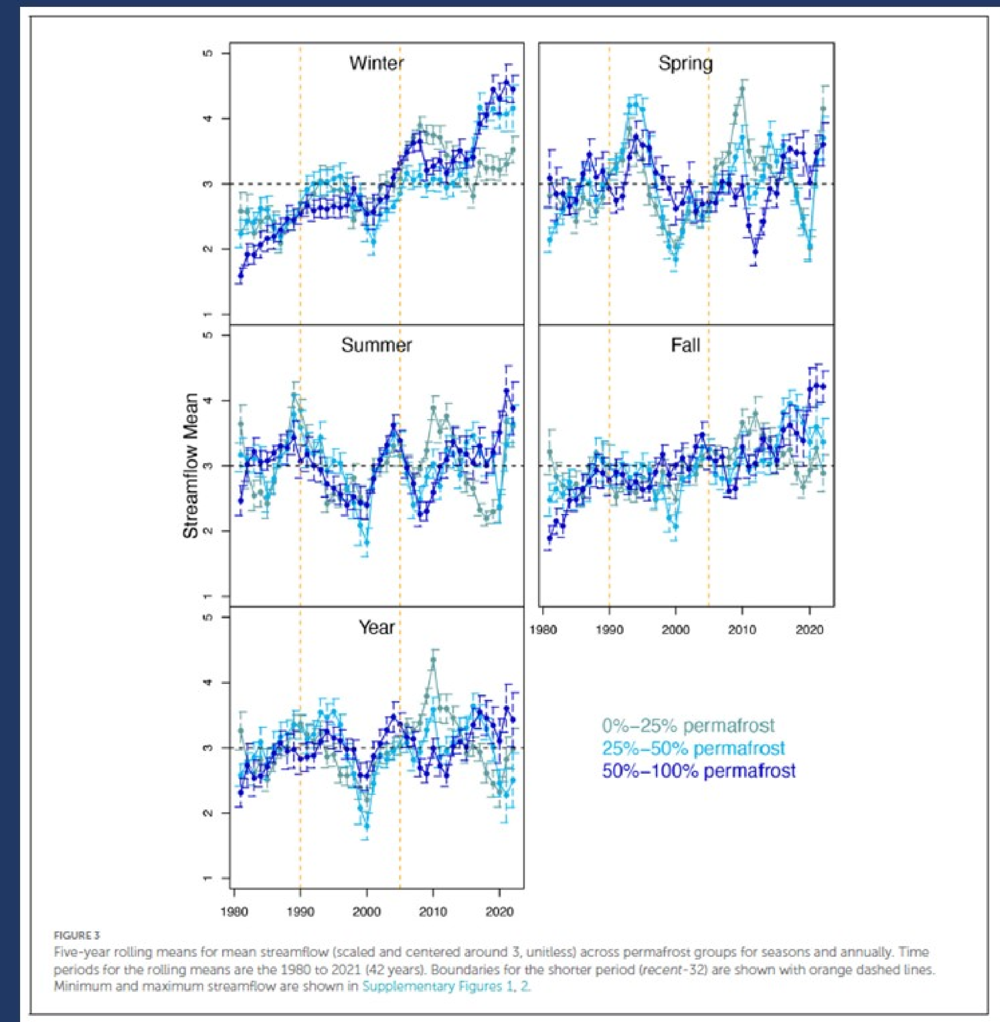
Methods

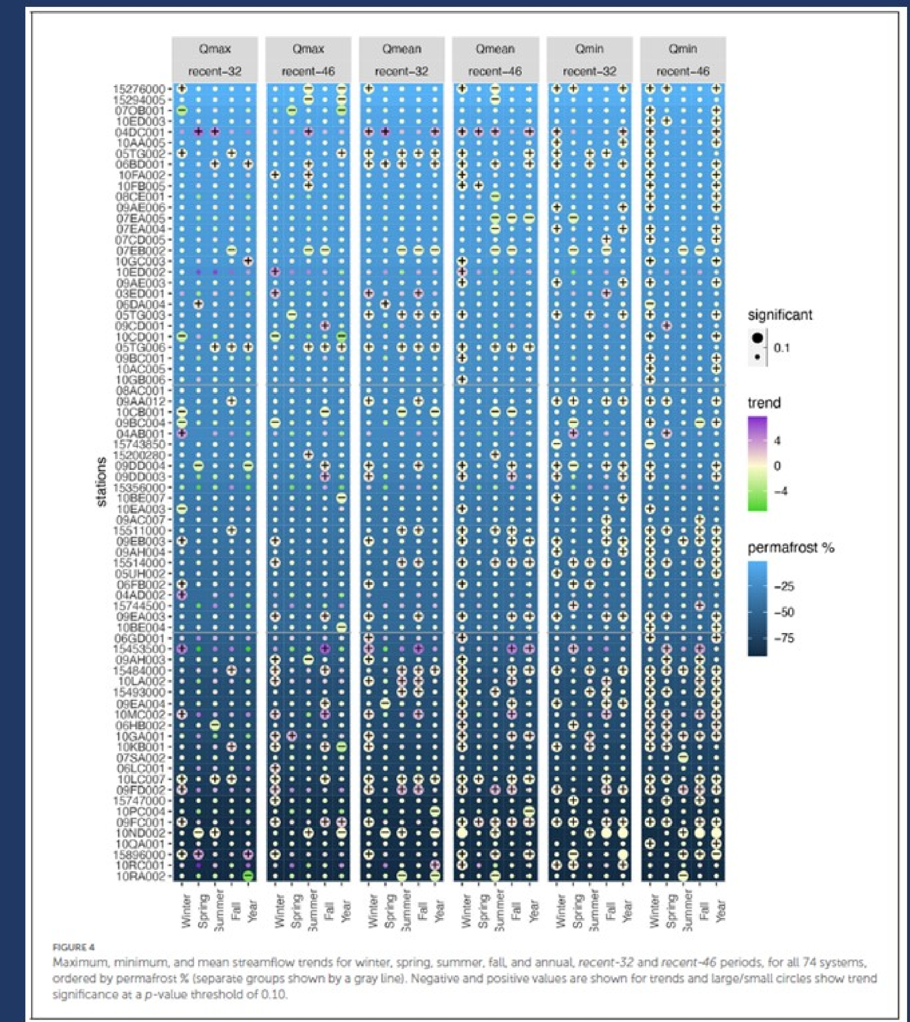
rabpro river and basin profiler

We used gages from the USGS and HYDAT streamflow databases, downselected for multiple criteria to improve quality (n=77). We computed watersheds and their characteristics (e.g., glacier presence, permafrost %, climate stats) using our RabPro software tool. We divided the systems into permafrost-dominant (>50%, n=23), -moderate (26-50%n=23), and -unimpacted (1-25%, n=31) systems. We looked at the entire recent record (1990-2019), and the 1st (1990-2004), and the 2nd (2005-2019) 15 years of the recent record. We calculated trends and significance using Mann-Kendal, Sens slope approaches, along with simple difference metrics with a focus on maximum and minimum streamflow at seasonal and annual time scales. For machine learning methods, we randomly selected 991 basins from GloFAS v 3.14 as a proxy for the permafrost-affected sites and computed trends. We tested 24 machine learning methods; the top models are presented here. To investigate the climatic drivers of streamflow changes, we extracted temperature, precipitation, rainfall, snowfall, and snow water equivalent from ERA5-Land Reanalysis products.

Results







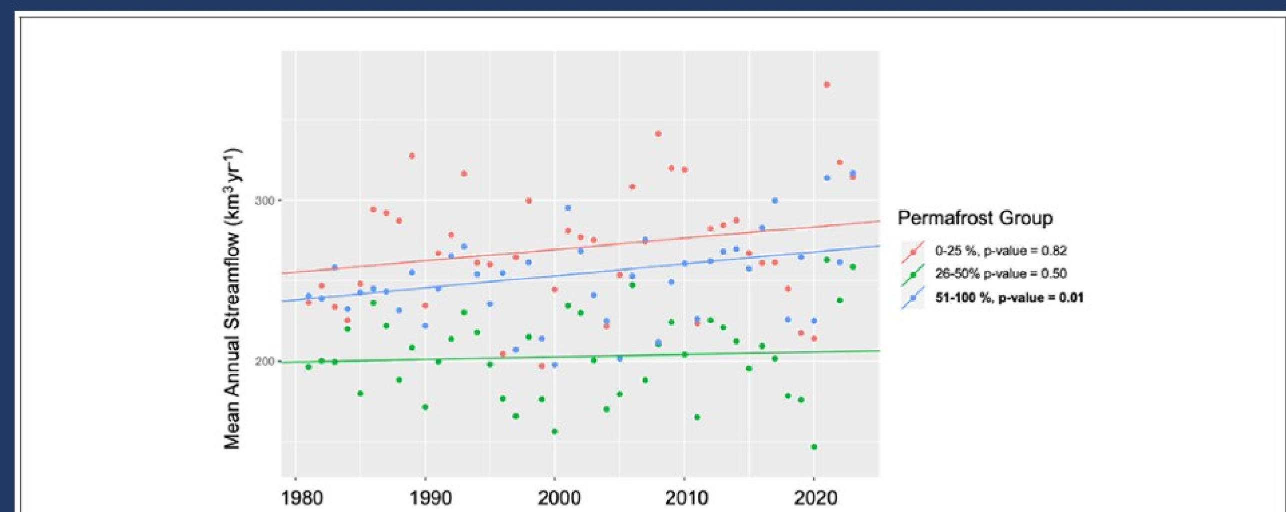
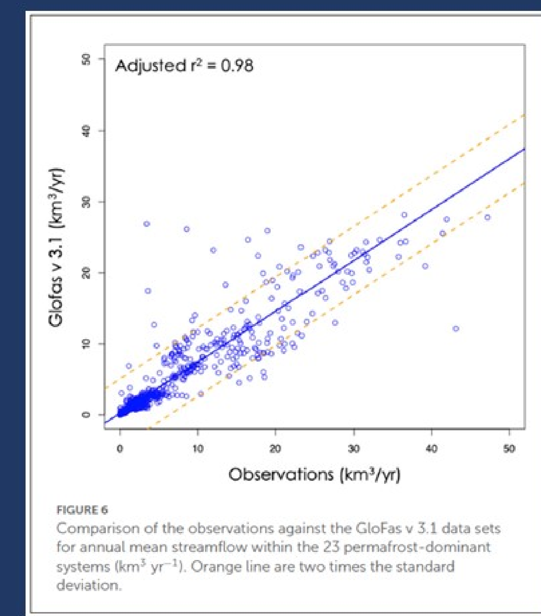
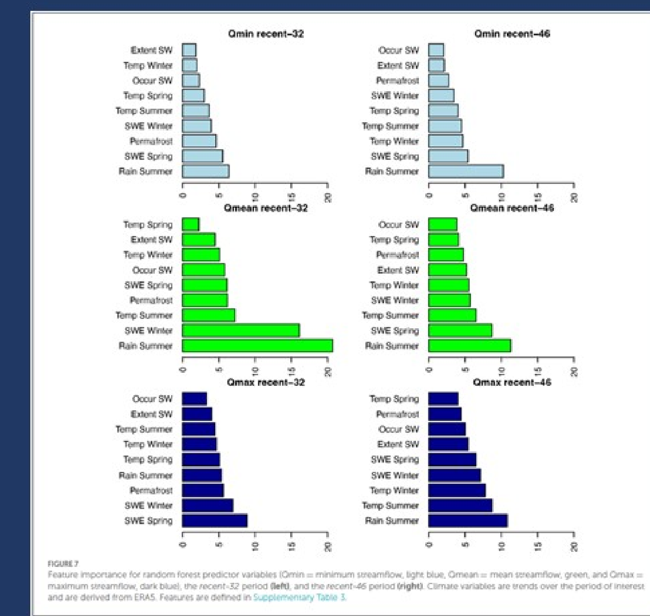


FIGURE 5
Regional mean annual streamflow averaged across 55 gages. Non-dominant (red) and moderate (green) are not significant, while only dominant permafrost systems are significantly increasing. The non-dominant and dominant permafrost systems have a similar trend (~32 km^3 yr^{-1} for 46 years).

Trends Analysis

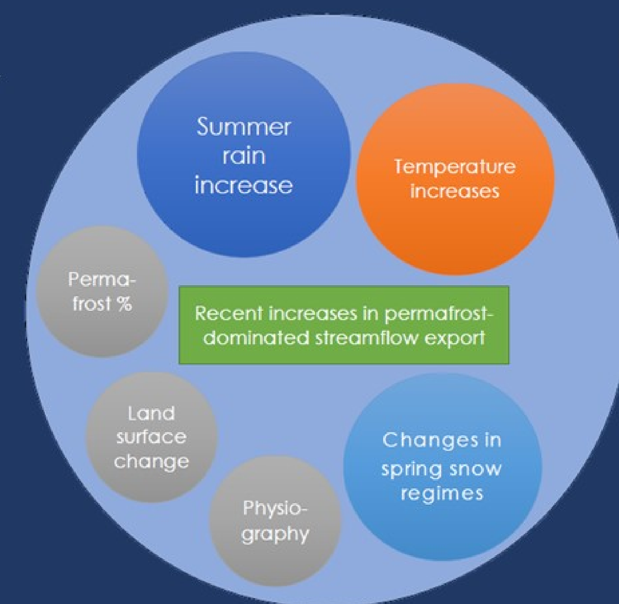
Explain-ability





Conclusions

- Overall trend of increasing minimum streamflow for permafrost-containing watersheds across the seasons and annual periods considered.
- Climatic factors (precipitation and temperature) are primarily driving trends, but permafrost coverage shows importance for the most recent 32-year period.



- The changes in streamflow trends observed in this study are reflective of deepening active layers and thawing permafrost, indicating that the entire hydrograph is undergoing change within permafrost-dominant streamflow systems as the Arctic moves towards a warmer future under climate change.

References

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