Delineating relations among hydrology, geochemical conditions and catchment characteristics of lakes and rivers in Old Crow Flats, Yukon

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Introduction and Approach:

Van Tat (Old Crow Flats; OCF), Yukon is the traditional territory of the Vuntut Gwitchin First Nation who are concerned of climate change impacts across the landscape and on water resources (Fig. 1). Notable landscape responses include lake drainage, thaw slumps, shrub growth, and fire. The last 17 years has seen wet summer conditions to 2019 followed by drier summers and more snowfall during winter (e.g., Fig. 2). Here, we describe ongoing research integrating biogiochemical analyses and remote sensing to identify changes and associated downstream biogeochemical impacts.

Interannual differences in surface water was identified using water masks derived from Landsat 5, 7, and 8 Tier 1, Collection 2, Level 2 archives. Bands were calibrated for cross-sensor comparison. Water masks of suitable accuracy comprised pixels with seasonal median modified normalized difference water index (MNDWI) values above the histogram minimum minus 0.02. Other classification approaches (e.g., random forest) were deemed too conservative. Interannual differences were calculated for each set up adjacent years (e.g., 2006 - 2007, 2007 - 2008, etc.).

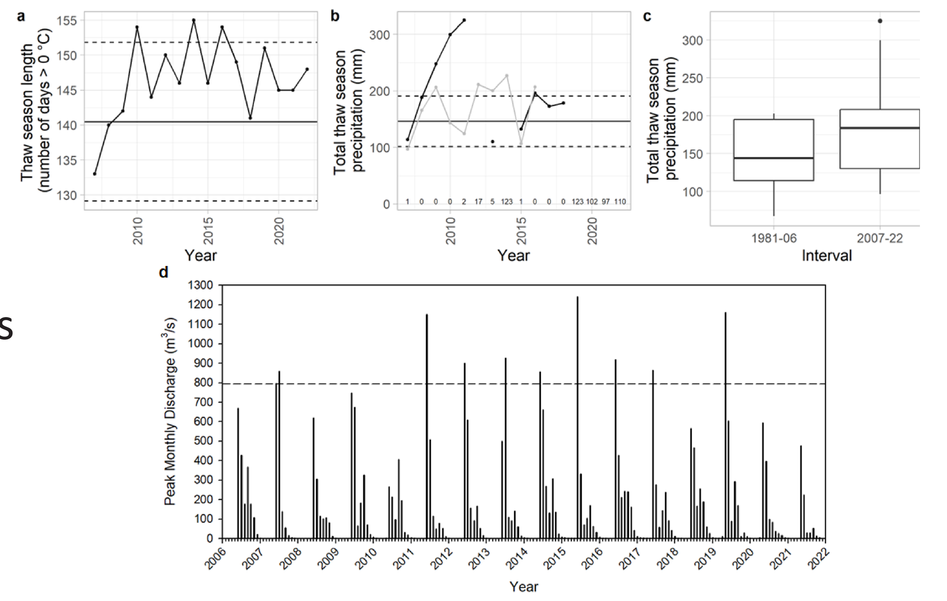

Fig. 2. Climate data for 2006 - 2022 including a) number of thaw season days, b) total thaw season precipitation compared to long-term average and standard deviation (dotted line), c) total thaw season precipitation comparison boxplots, and d) Old Crow River peak monthly discharge.

Water samples have been collected at creeks across Old Crow Flats (OCF) since 2007 for water isotope and chemistry analyses. Deuterium-excess (d-excess) and isotope mixing models were used to evaluate spatial and temporal patterns in lake connectivity to the drainage network. Water chemistry data including $\delta^{13}C$ isotopes are providing additional insight of carbon sources and other nutrient cycling spatial patterns.

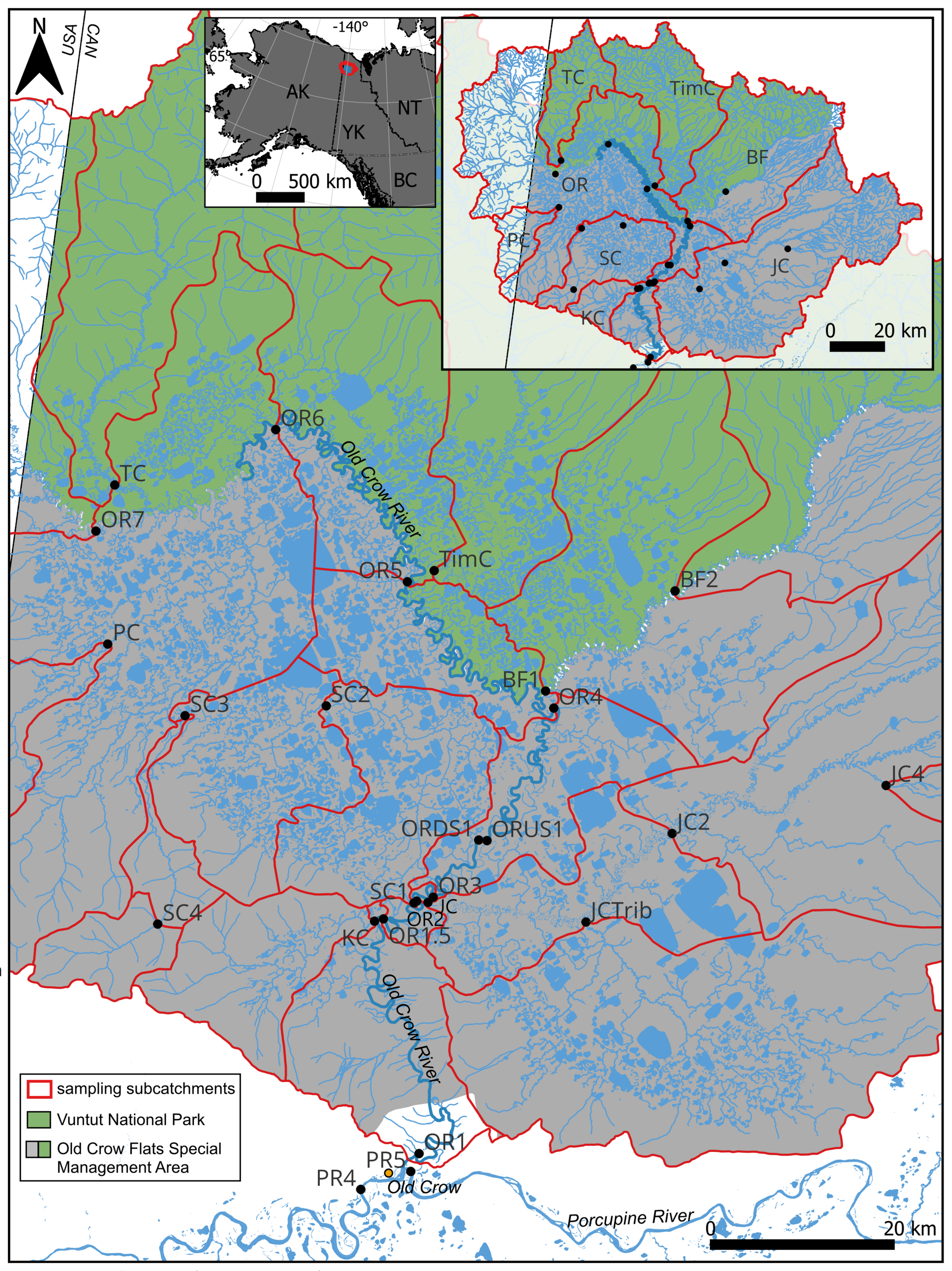

Fig. 1. Map of Van Tat (Old Crow Flats) with subcatchments and sampling sites superimposed.

Key Findings:

- Inter-annual differences in water masks highlight recent lake drainages (Fig. 3)
- Water mask interannual differences identify wet vs. dry years and reveal overall stability at the watershed-scale for 2006 - 2023 (Fig. 4).
- Deuterium-excess (isotopes) are more variable late in the record with low values indicating greater lake input (Fig. 5).
- Isotope mixing model shows seasonal and interannual timing of source water proportions. The Schaeffer Creek (SC) sub catchment shows elevated lake water contributions during fall late in the record (Fig. 6).
- Some temporal correspondence was found between water mask interannual differences (lake drainage; Fig. 3, 4) and isotope data (Fig. 5, 6).

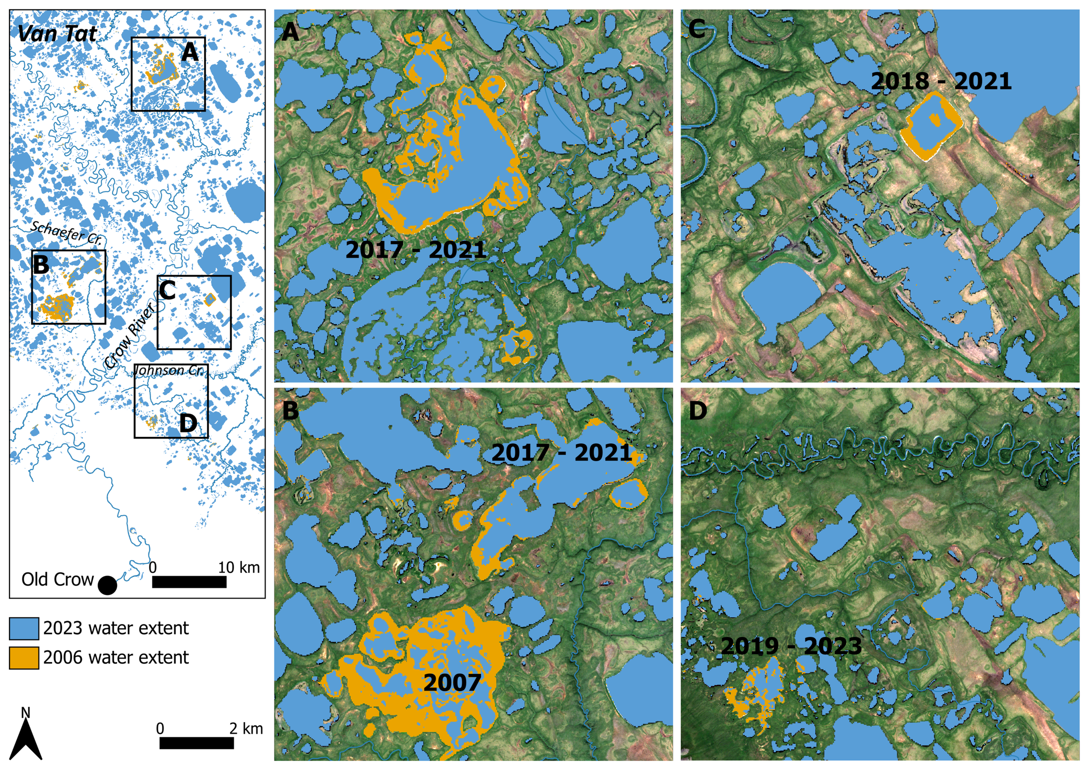

Fig. 3. Examples of lake drainage locations in OCF since 2006 identified using interannual water mask differences.

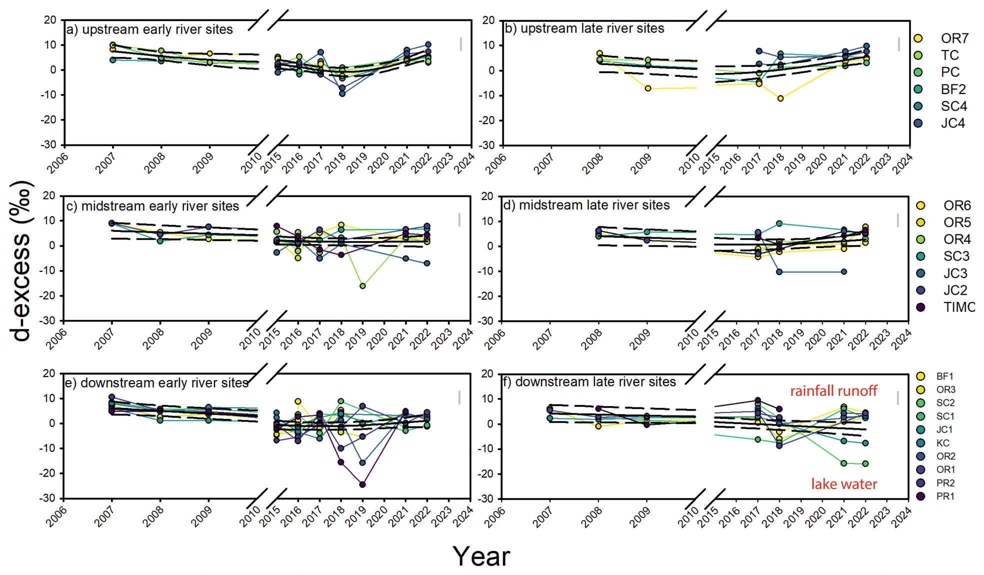

Fig. 5. Time series of d-excess for a,b) low-order to e,f) high-order creeks in spring (left) and fall (right).

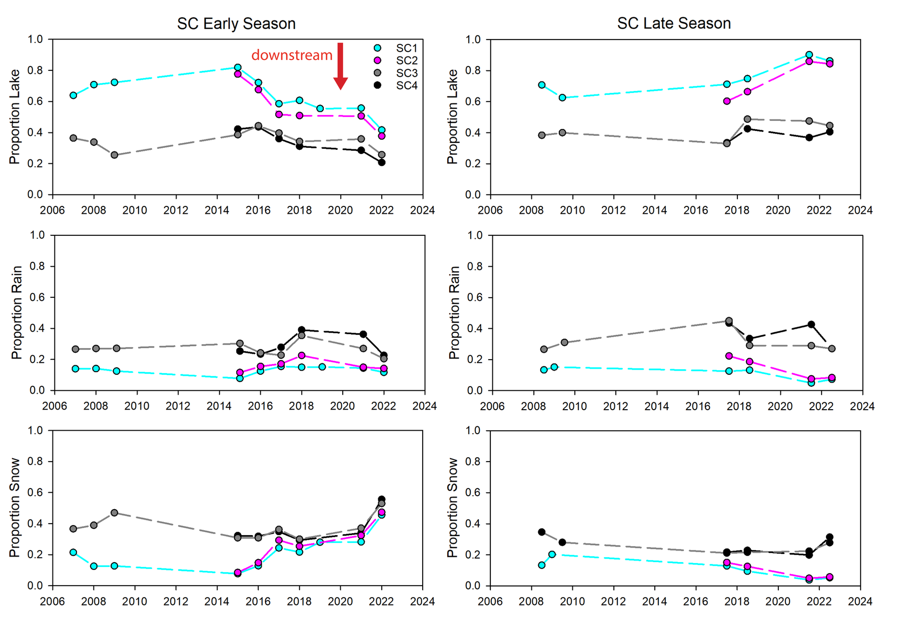

Fig. 6. Water isotopes mixing model time series for Schaeffer Creek in spring (left) and fall (right).

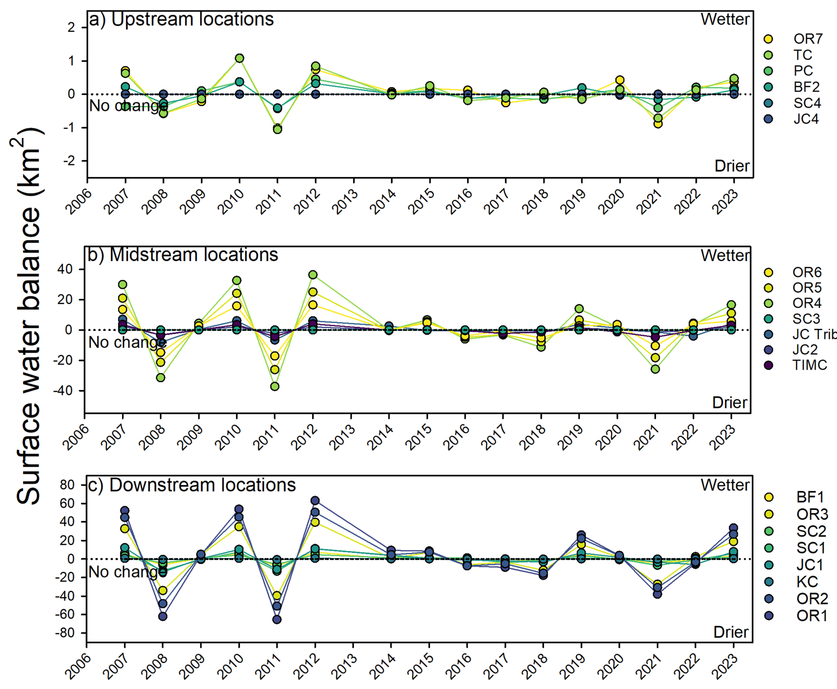

Fig. 4. Time series of interannual water mask differences for a) low to c) high order creek subcatchments.

Water chemistry results show clear differentiation among subsets of lakes and rivers according to location in OCF and catchment size (Fig. 7). The northern and western headwater subcatchments have lower DOC, and other nutrients, but have higher DIC, pH, and ions. Southern headwater subcatchments show the opposite (e.g, higher DOC). Higher order creeks show mixing from these two categories.

Similar to the southern headwater creeks, peripheral lakes with large catchments have higher nutrients (e.g., DOC) while more central lakes with small catchments have lower nutrients, higher ions, DIC, and C isotope values.

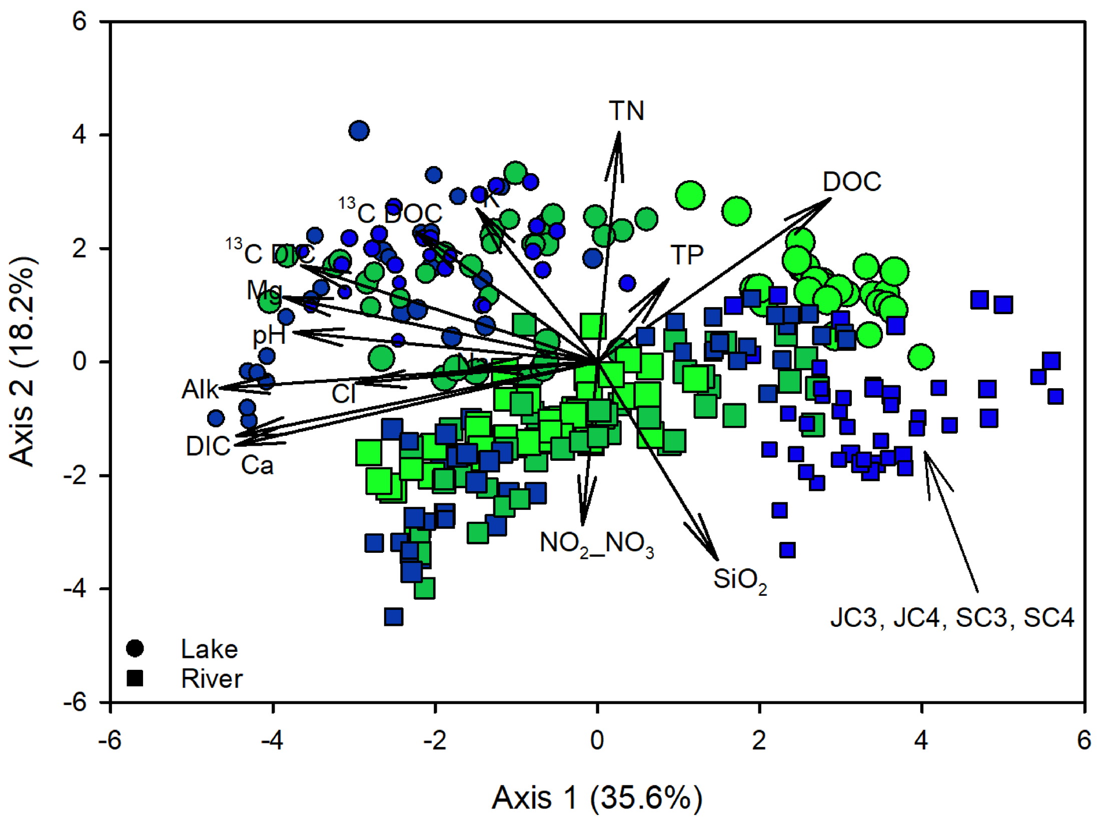

Fig. 7. Multivariate exploration of biogeochemical parameters. Point size represents catchment size.

Water chemistry results show that the proportion of lake source water increases with stream order (Fig. 7, 8).

Implications of increased lake drainage frequency and overall enhanced lake-river connectivity will result in greater export of nutrients (e.g., DOC, TN, TP) downstream. This may be enhanced by catchment greening (e.g., increases in catchment carbon sequestration), or altered by fire.

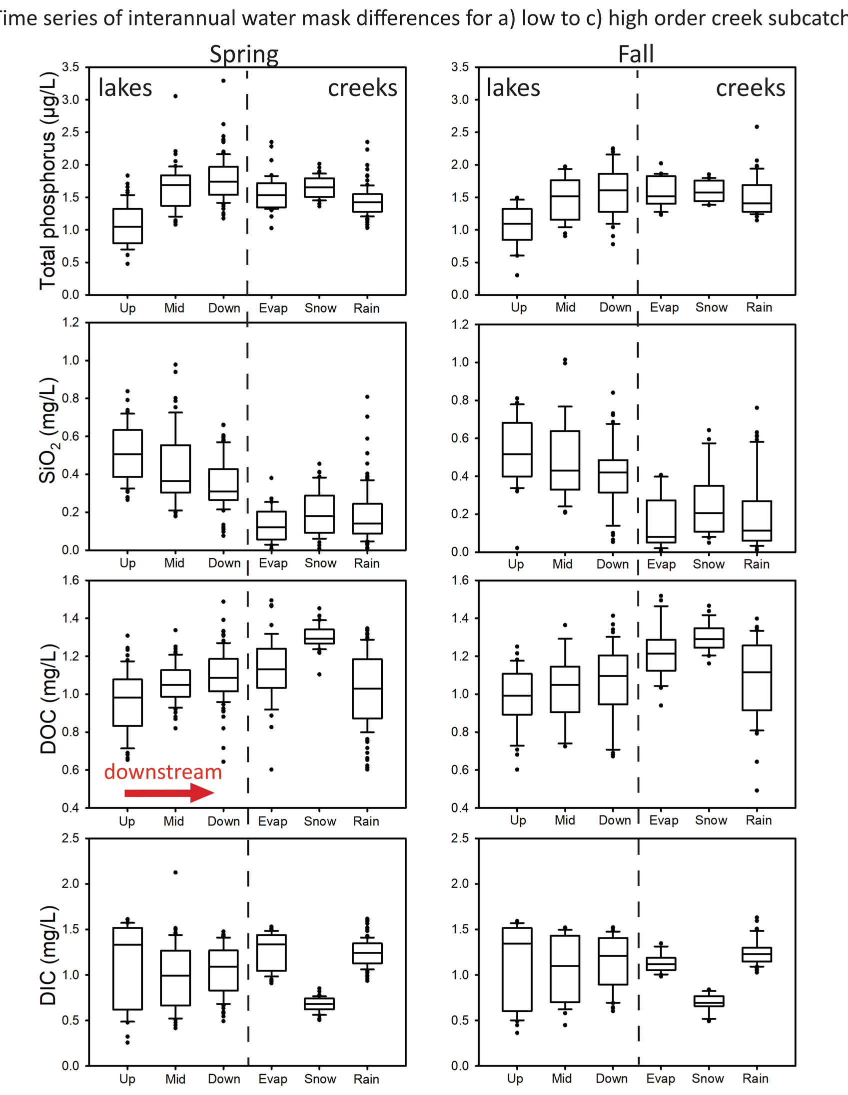

Fig. 8. Boxplots of water chemistry comparison among low-high order creeks and lakes.

Ongoing investigations:

Additional landscape changes including significant greening (shrub growth), and fire are being assessed using Landsat, Sentinel, and Planet Labs data archives.

Greening trends during 1986 - 2023 was statistically significant (Mann-Kendall $p < 0.05$) in OCF, especially across the south-facing ecotone and low-lying areas in the eastern Johnson Creek subcatchment (Fig. 9). There has also been significant browning in the southeast headwater portion of OCF watershed.

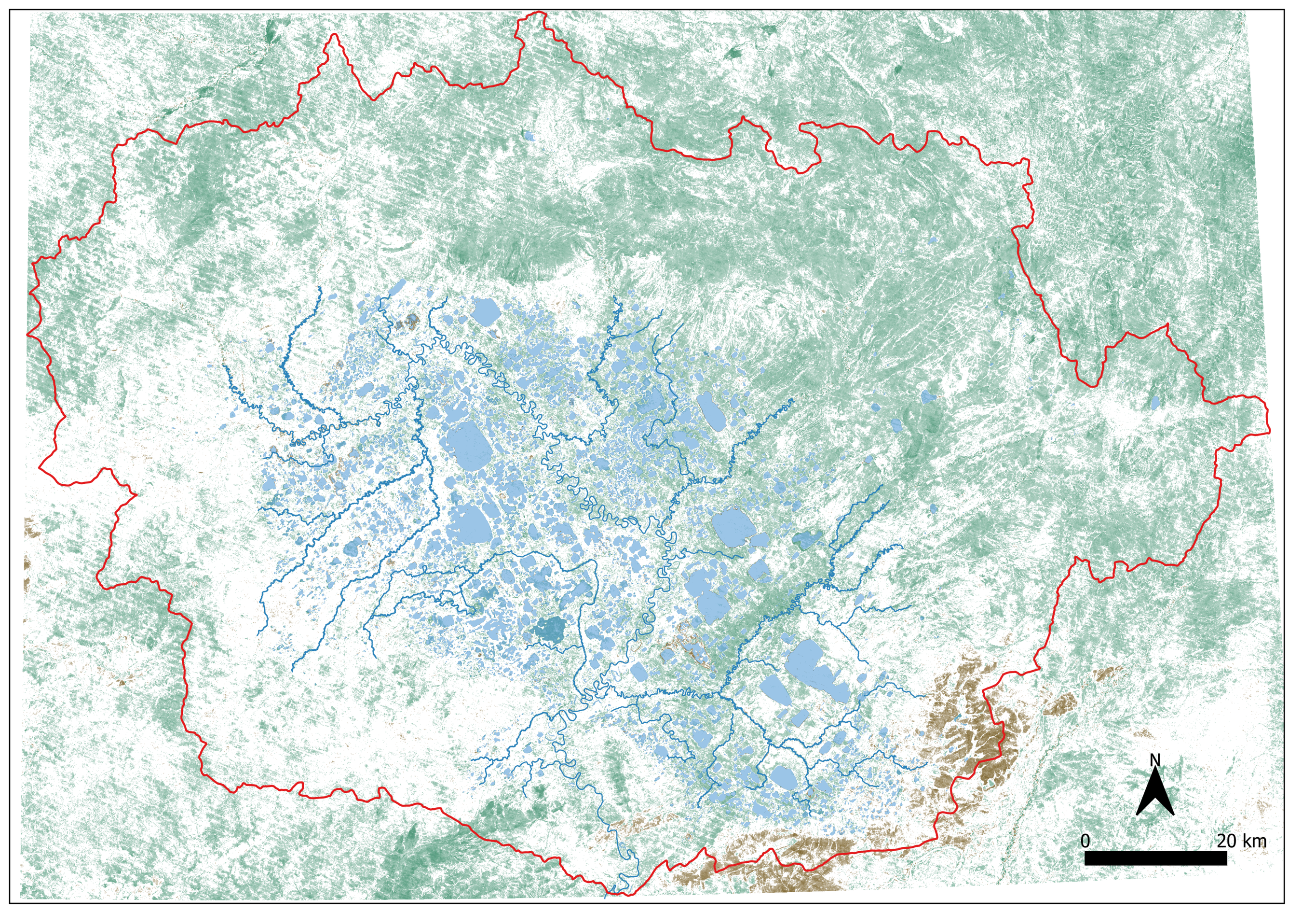

Fig. 9. Mann-Kendall trend analysis of NDVI for 1986 - 2023. Significant (p<0.05) values and slope represented green and brown gradients.

A widespread tundra **fire** burned across the eastern OCF during Aug 2023 (Fig. 10). Land cover classification revealed it was ~580 km², which was the most widespread fire at this latitude within the Canadian record since 1986 (Canadian Wildland Fire Information System Datamart, 2024; Fig. 11).

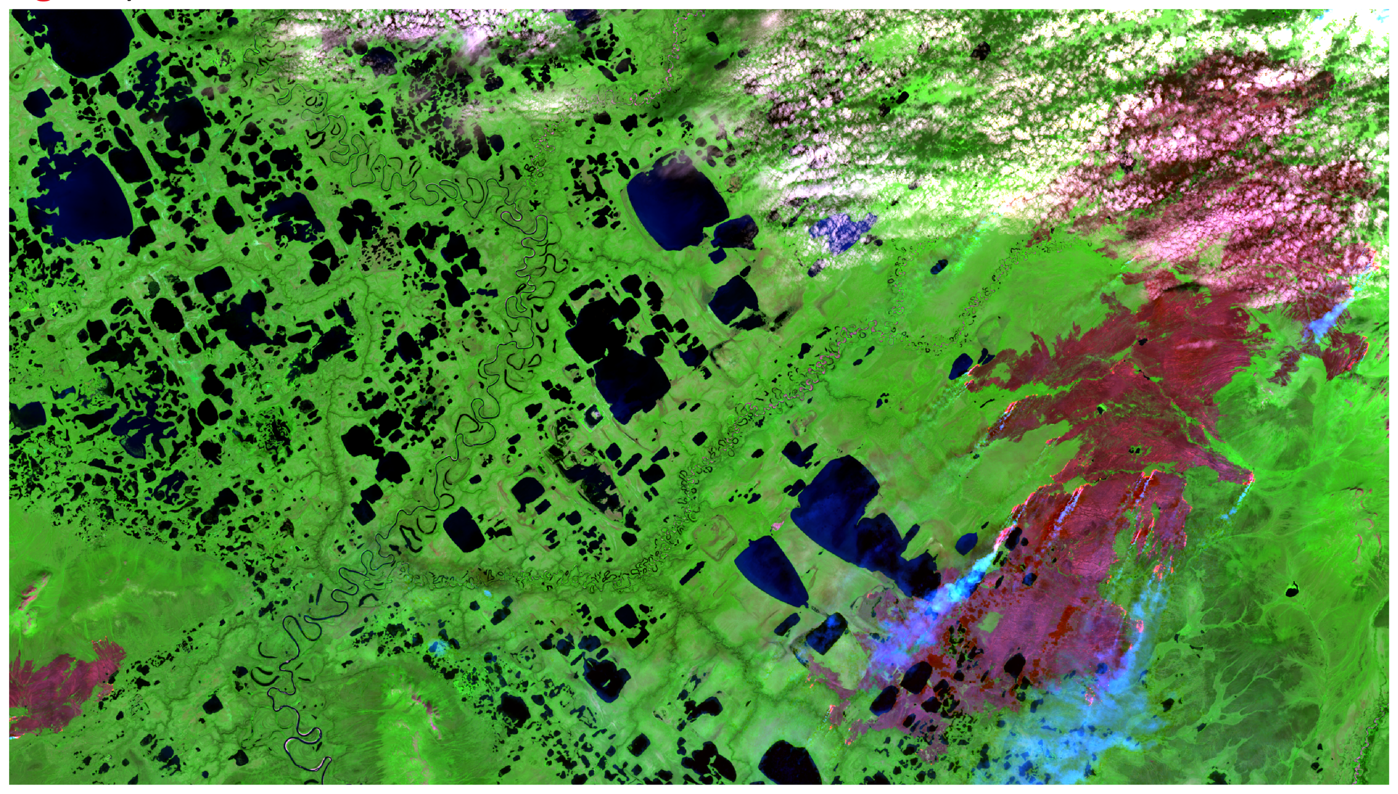

Fig. 10. Landsat 8 false colour composite (SWIR-NIR-RED) highlighting the fire on 12-Aug-2023.

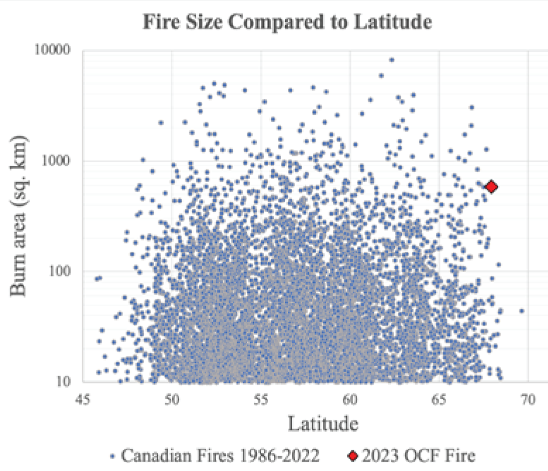

Fig. 11. Scatterplot of burn area and latitude.

Fig. 12. Photograph from helicopter on 2-Sep-2023

The fire spanned across wetland and drainage channels (Fig. 12) that are upstream from our existing long-term water hydroecological monitoring sites (BF and JC subcatchments). We will be sampling water from these sites during June 2024 to evaluate impacts of the fire on a suite of biogeochemical parameters.

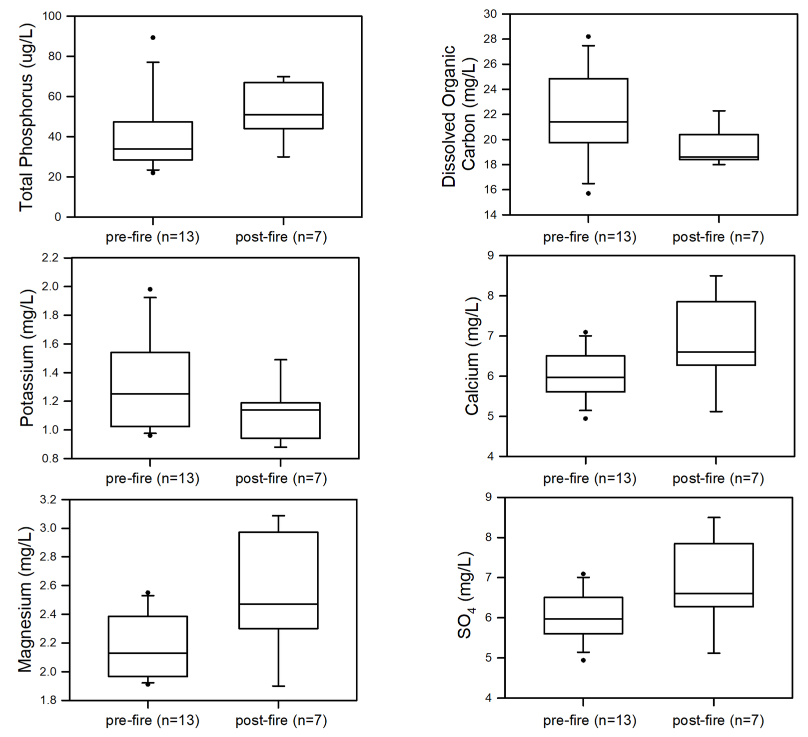

Fig. 13. Lake water chemistry comparison before and after catchment fire in 2017.

These data will be compared to lake water chemistry identified at an OCF monitoring lake (OCF55), where its catchment burned during 2017 (Fig. 13). Here, found increases in phosphorus, calcium, magnesium, and SO4, and decreases or reduced variability in DOC and potassium.