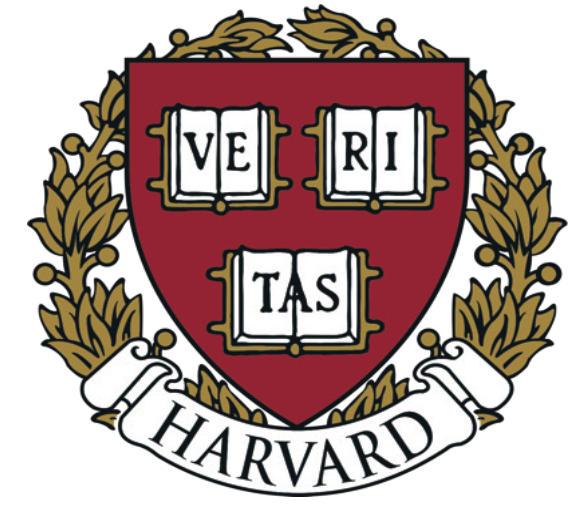


Tracking aquatic carbon changes with satellite-derived indexes for lake-landscape connectivity



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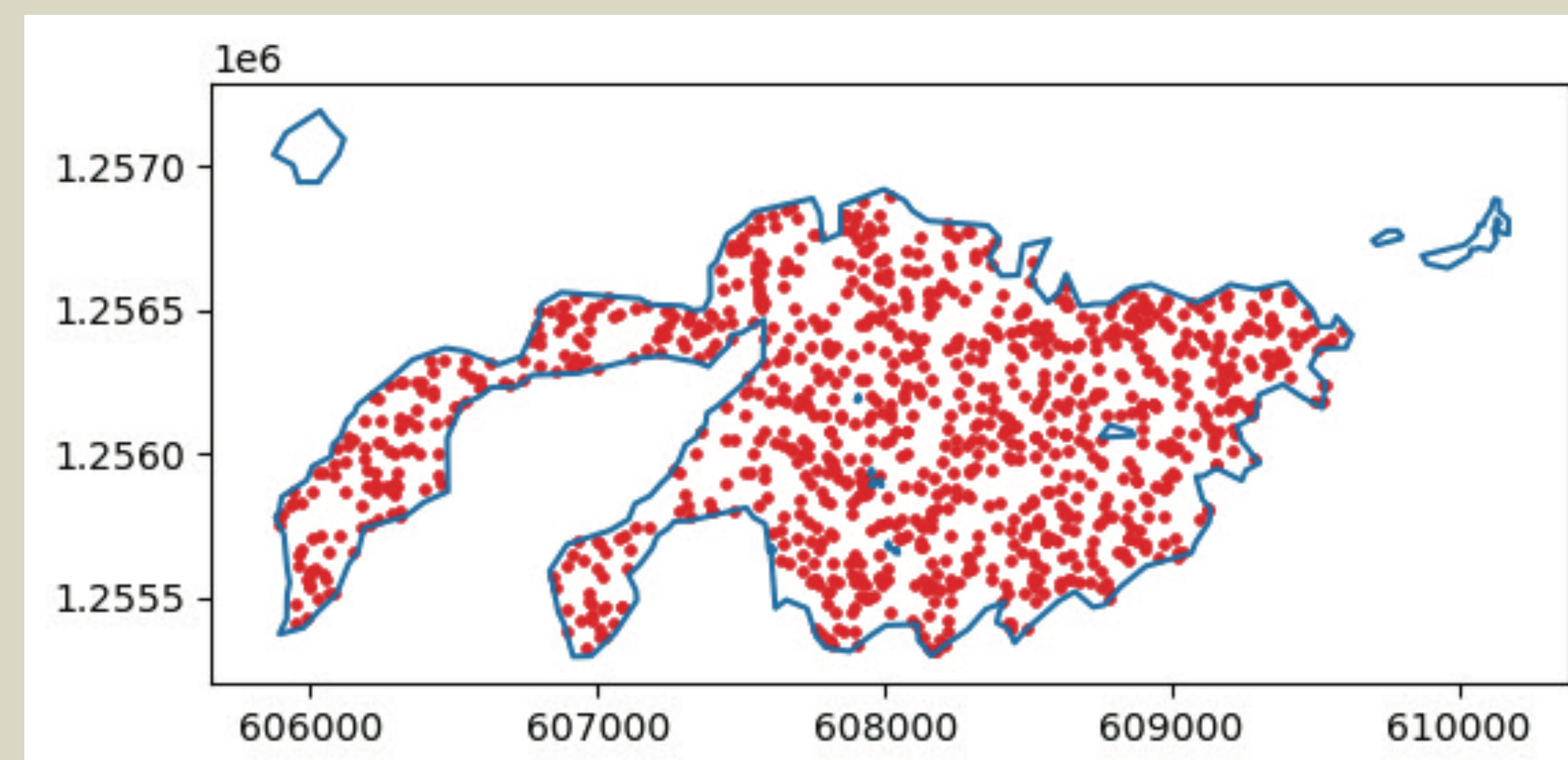


Aquatic vegetation is expanding northwards, like woody vegetation, yet lake waters are browning.

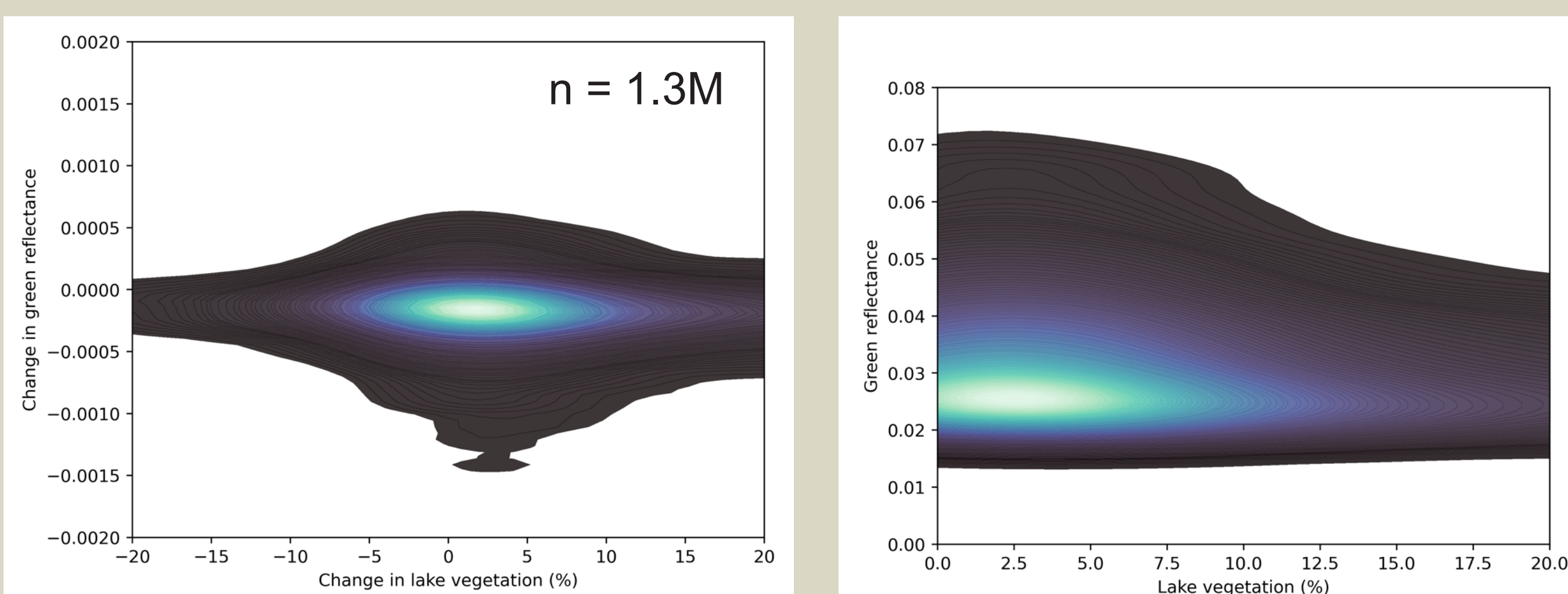
Lake water chemistry is changing in the Arctic

Terrestrial landscape change is well-documented in the Arctic (Myers-Smith et al., 2019; Pastick et al., 2019; Wang et al., 2019), with trends towards vegetation greening and northwards expansion of the tree line. Aquatic changes have also been observed with lakes trending towards browner water dominated by internally-cycled carbon. New data shows aquatic vegetation trends match terrestrial vegetation (Liu et al., 2025). Yet water column greenness is declining (Kuhn & Butman, 2021). Here, we investigate remote sensing metrics for tracking these changes and characterizing water organic geochemistry.

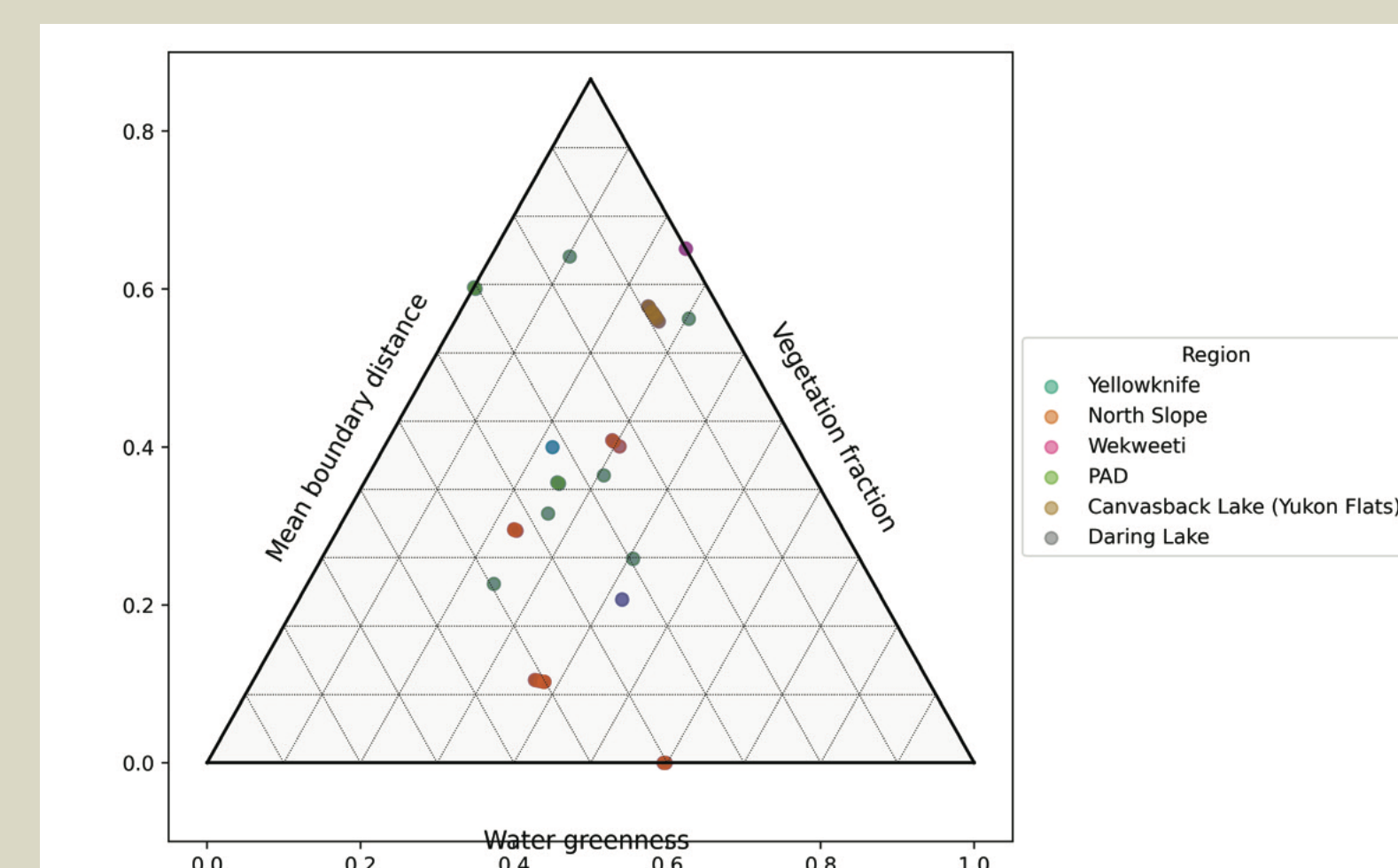
Remote sensing can measure water and aquatic vegetation greenness, plus lake morphology.



Above: We use the mean distance from all points on a lake shape to its shoreline as a diagnostic shape index. The index is low for irregularly shaped lakes, and high for large or circular ones, with weak dependence on lake area.

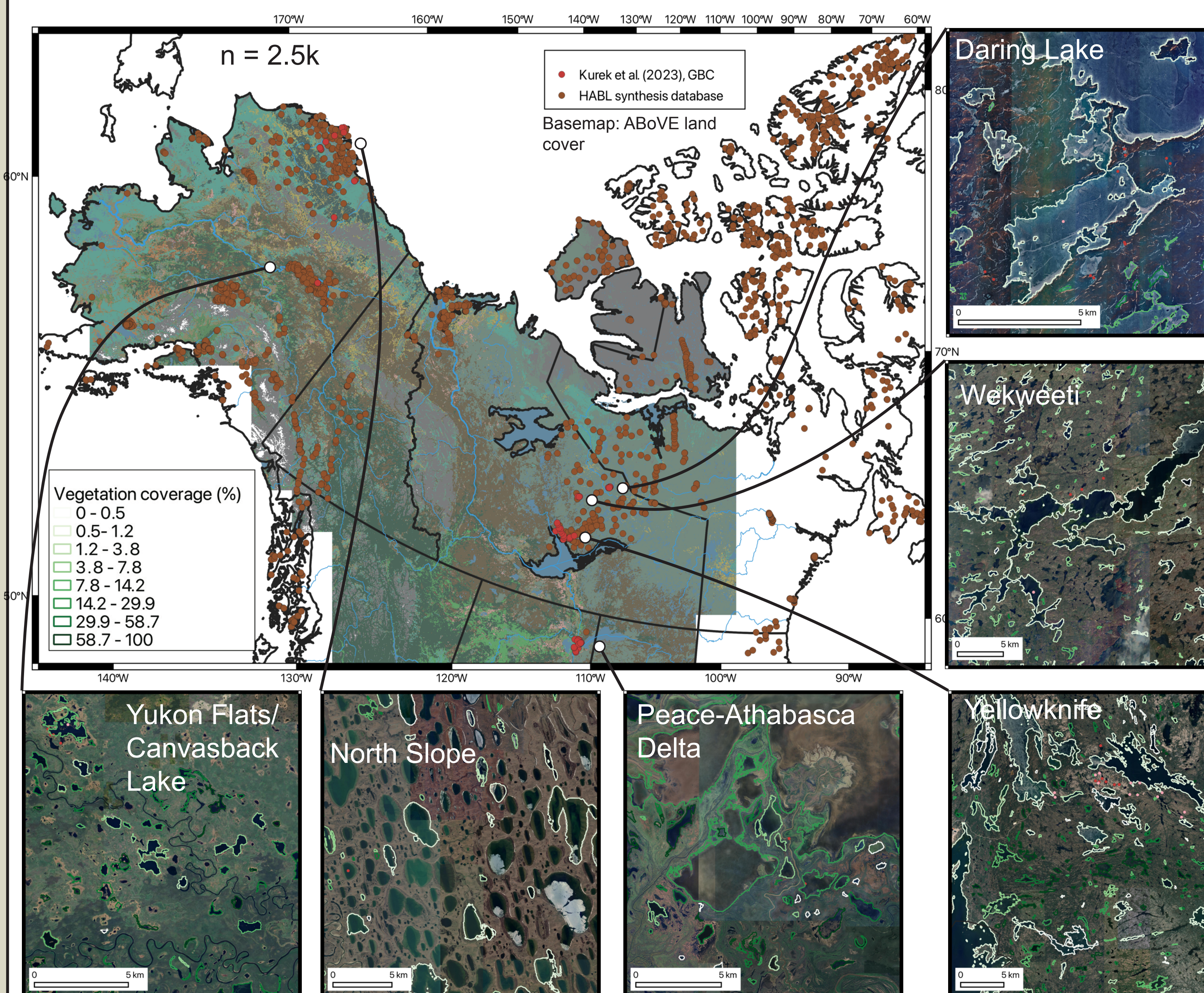


Above: We overlay published Landsat-derived maps of water green-band reflectance (Kuhn & Butman, 2021) and aquatic vegetation (emergent or floating-leaved) coverage (Liu et al., 2025) and find *no coupling* between their values (**left**) or multi-decadal change (**right**) on a per-lake basis. These two trends are happening independently, but are likely both climate-driven.



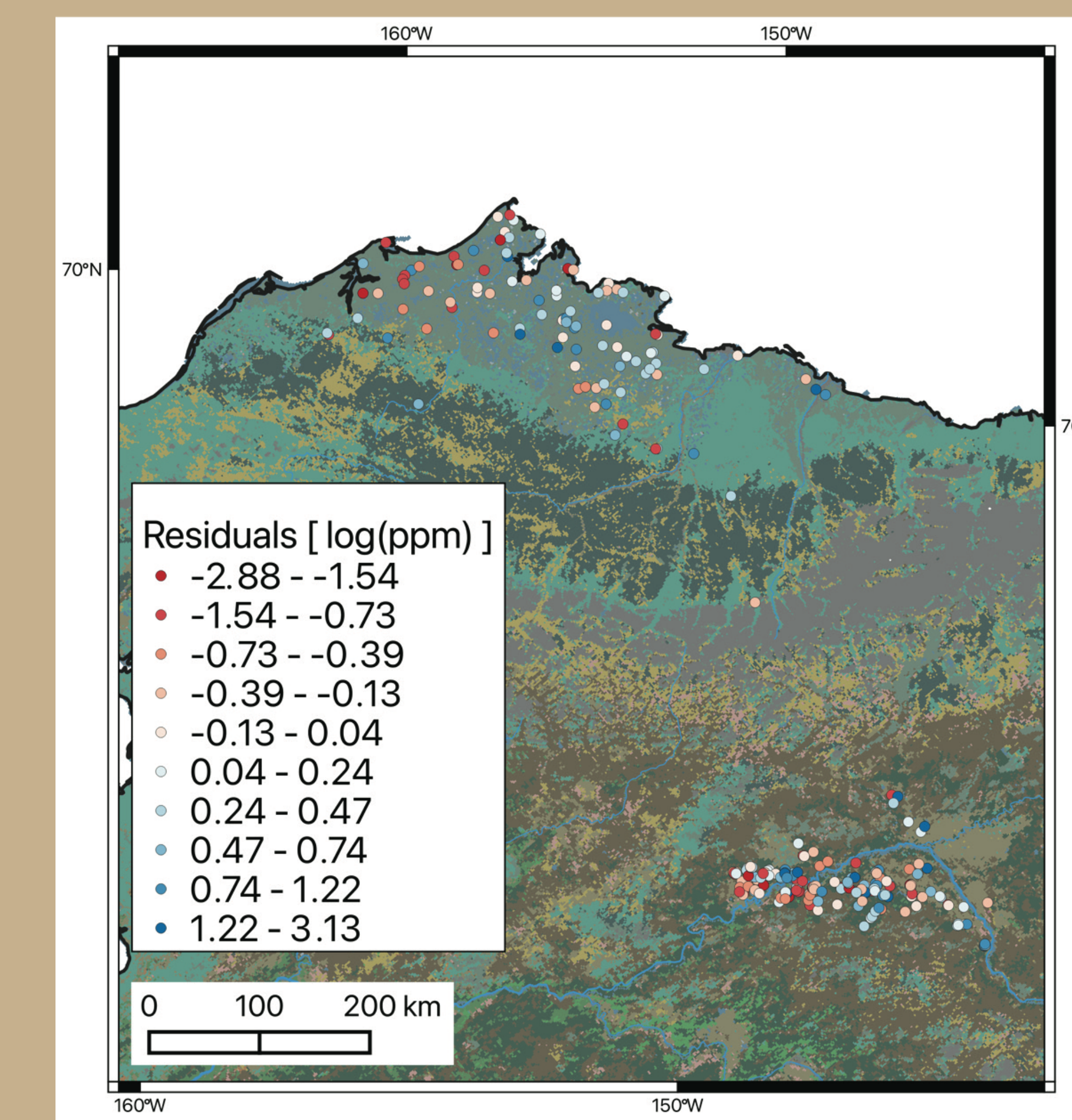
Left: Sampled lakes are plotted in parameter space against the three satellite metrics investigated. Since no strong clustering is evident, these metrics can be used to differentiate lake-specific parameters that are generally landscape-independent.

Locations of in-situ samples with insets of lake vegetation coverage



Conclusion

The three satellite metrics (vegetation coverage, water greenness, mean shoreline distance) hold promise for characterizing their connections to terrestrial carbon sources and their sensitivity to landscape changes. Future work will also consider land cover and geomorphological properties and will seek to identify from remote sensing why certain lakes and watersheds are undergoing more change than others.



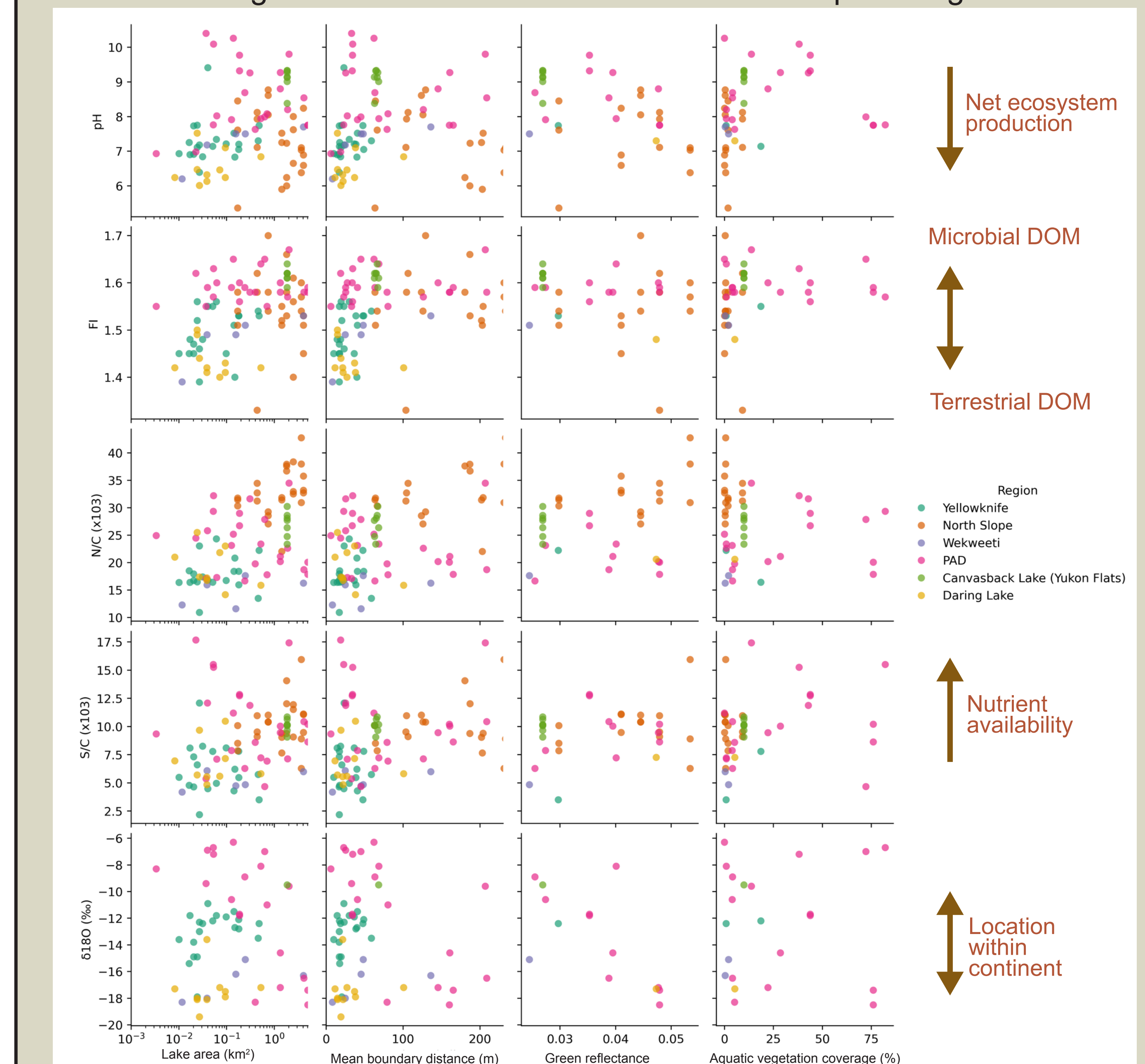
Left: Regression analysis for drivers of dissolved carbon dioxide shows spatial autocorrelation in residuals, implying there are spatial (i.e. observable with remote sensing) drivers not captured in the model. The model is based on land cover, hydrologic change, and lake morphology alone.

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Tracking changes in landscape-connected lakes

A fundamental property of lakes is their connection to their watersheds. Inflow, vegetation, a complex shape, or relatively small surface area can all increase a lake's connectivity to its watershed, which provides carbon and nutrient inputs. In changing Arctic landscapes, it is possible that highly landscape-connected lakes will be most sensitive to terrestrial trends and disturbances. We hypothesize that lakes with small mean boundary distances, aquatic vegetation and/or browning waters will be most sensitive to landscape changes.



Above: Five analytes are compared to remote sensing-derived metrics tracking landscape connectivity. These analytes [pH, florescence index (FI), Dissolved organic matter (DOM) nitrogen:carbon ratio, DOM sulfur: carbon ratio, H₂O δ¹⁸O] were chosen due to promising regression relationships with the remote sensing metrics. Nutrient concentrations normalized by carbon increase correlate with mean shoreline distance, likely due to C limitation. δ¹⁸O exhibits less scatter with boundary distance than with lake area, implying this metric better captures physical lake characteristics related to evaporation and inflow.

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Funding and acknowledgements

NASA ABoVE grant # 80NSSC22K1237,
Harvard Reginald A. Daly Fellowship. Basemaps courtesy Google Imagery

