Assessing Groundwater-Driven Advective Heat Transport and Its Influence on Permafrost Stability in Alaska

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1. Abstract

Geotechnical modeling techniques to model permafrost mainly take into consideration conductive heat transfer and ignore advective heat transfer related to groundwater movement. This study attempts to observe the amount of influence from groundwater movement on permafrost stability. A statewide DRASTIC Index is developed to quantify the potential for groundwater infiltration and associated advective heat flux into the subsurface. The index incorporates key parameters, including depth to groundwater, recharge, aquifer characteristics, soil properties, topography, vadose zone conditions, and hydraulic conductivity. The DRASTIC index is compared with long-term observations of active layer thickness from Circumpolar Active Layer Monitoring (CALM) stations distributed across Alaska. The results highlight the significance of groundwater-mediated heat transfer in influencing permafrost stability and demonstrate the applicability of hydrogeological indices as proxies for advective thermal transfer processes.

2. Objective

This study aims to develop and apply a DRASTIC-based vulnerability model to quantify subsurface heat transport potential and assess the influence of groundwater-driven processes on permafrost stability,, and validate the results using long-term observations from Circumpolar Active Layer Monitoring (CALM) stations.

3. Data

CALM (Circumpolar Active Layer Monitoring)[1] stations are standardized field monitoring sites established to measure the thickness of the active layer. The study heavily relies on the data from these 61 CALM stations inside Alaska to observe how permafrost responds to the DRASTIC Index.

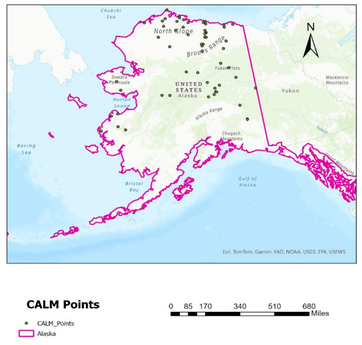

Figure 1: Locations of CALM stations across Alaska

4. DRASTIC Index

DRASTIC Index : 5Dr+4Rr+3Ar+2Sr+1Tr+5Ir+3Cr

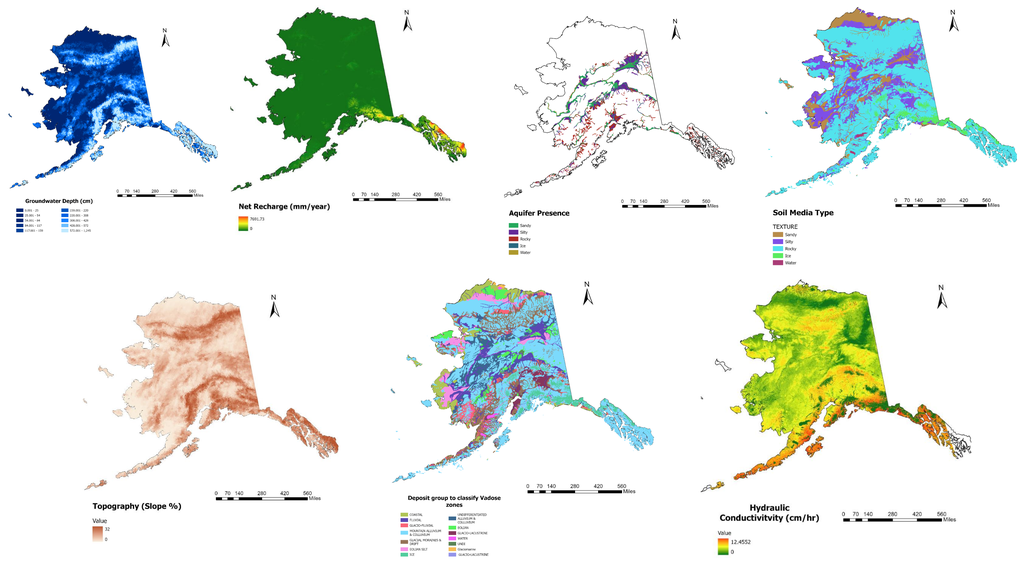

Figure 2: DRASTIC parameters across Alaska: depth to groundwater (D), net recharge (R), aquifer media (A), soil media (S), topography/slope (T), impact of vadose zone (I), and hydraulic conductivity (C), used to compute the DRASTIC Index.

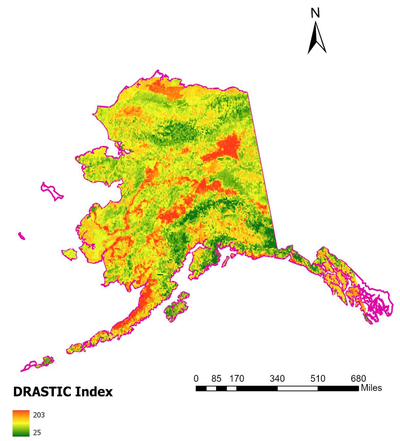

Figure 3 : DRASTIC Index map of Alaska.

5. DRASTIC Index and Permafrost

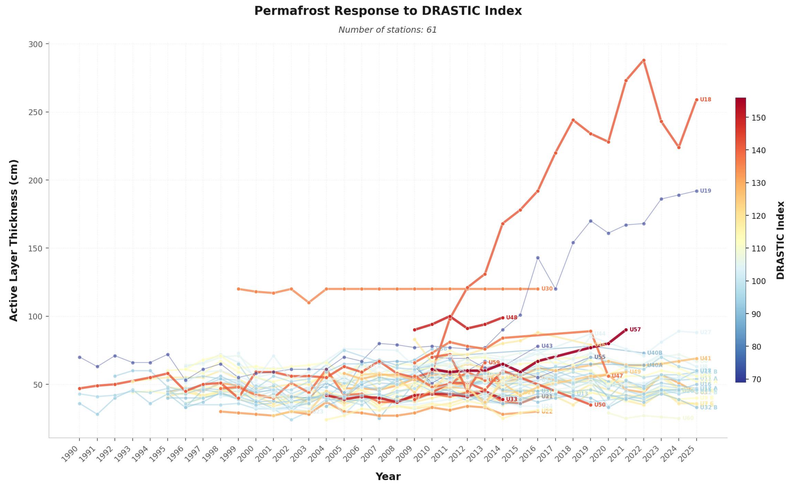

Figure 4: Temporal variation of active layer thickness at CALM stations with DRASTIC Index values across Alaska.

6. Conclusion

From the study it was found that Stations with higher DRASTIC index values generally show greater active layer thickening rate, suggesting water infiltration rate plays a meaningful role in permafrost degradation. However, the DRASTIC index alone does not fully explain permafrost dynamics.

7. Acknowledgement

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8. References

[1]. Circumpolar Active Layer Monitoring (CALM) Network. (n.d.). *Circumpolar Active Layer Monitoring (CALM) program*. George Washington University. http://www.gwu.edu/~calm