A Classification Framework for Permafrost Terrain

Niek Jesse Speetjens
Stephan Gruber
Trevor Lantz

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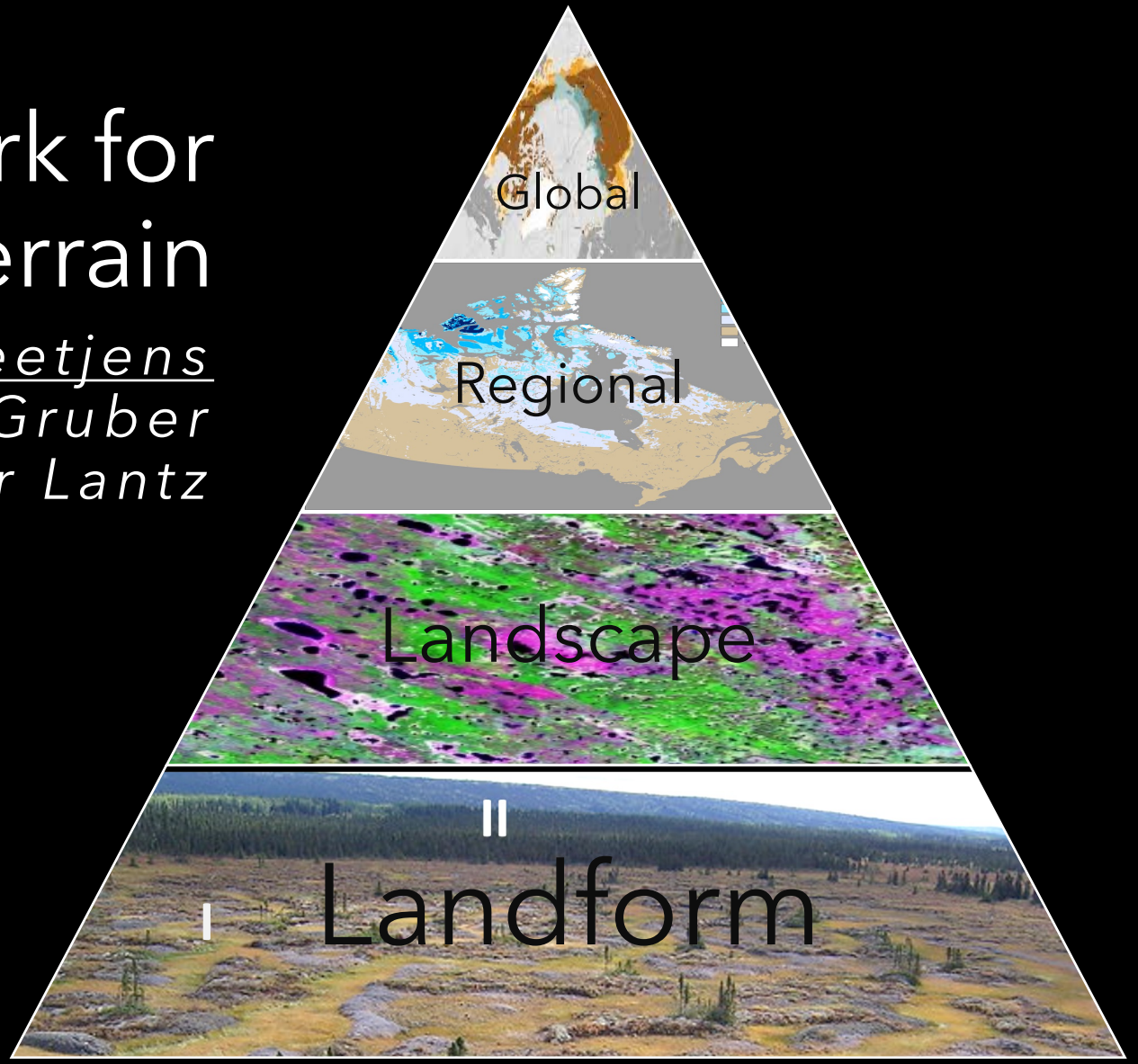

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~~A Classification Framework for~~ Holy Grail of Permafrost Terrain

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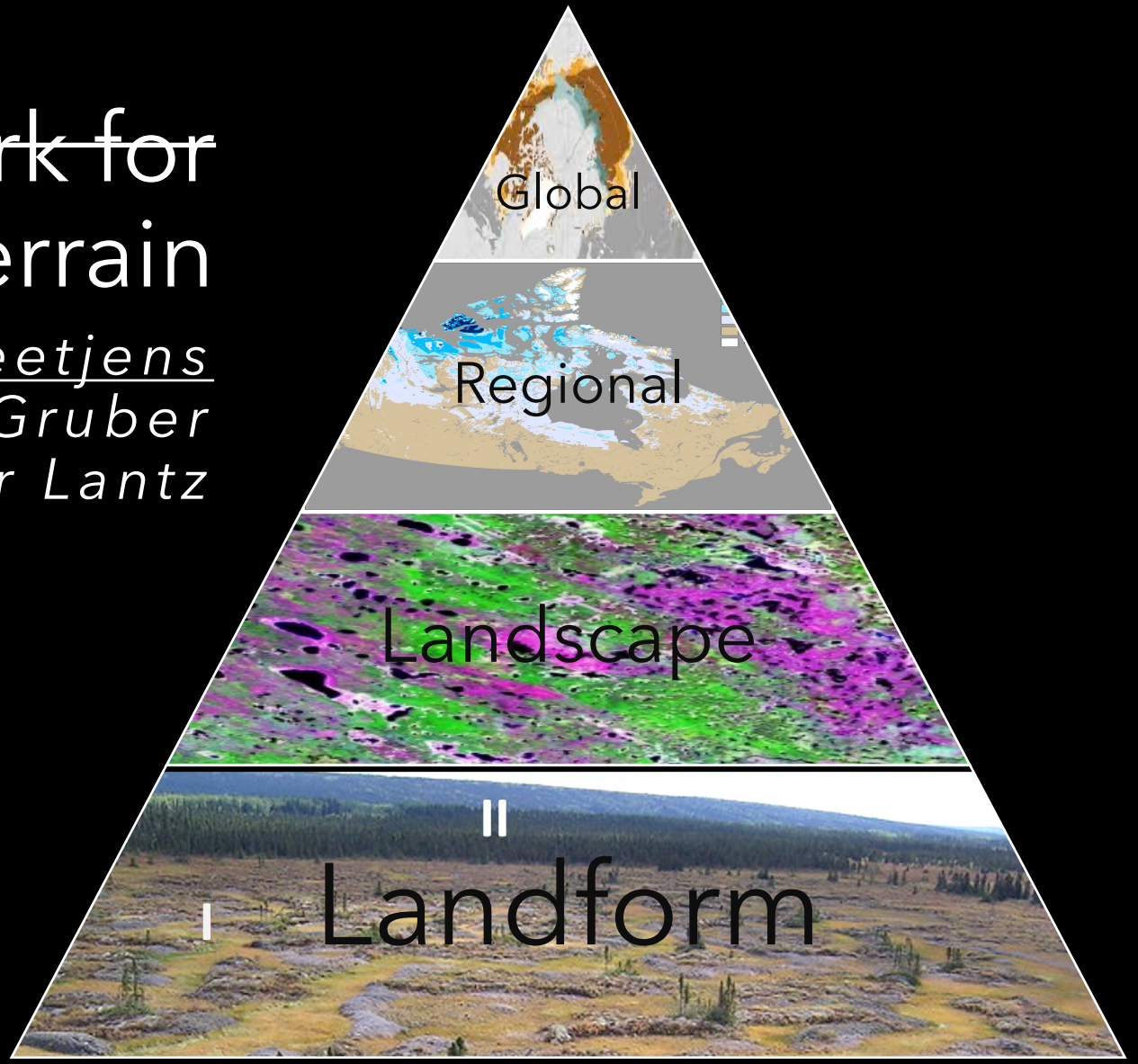

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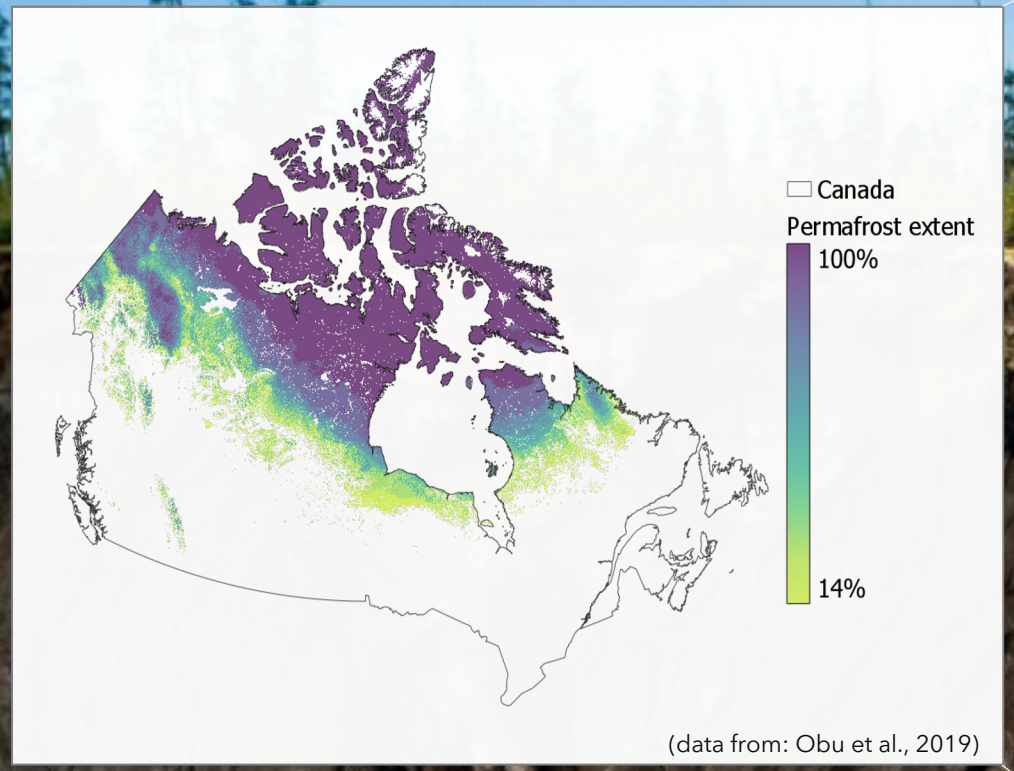
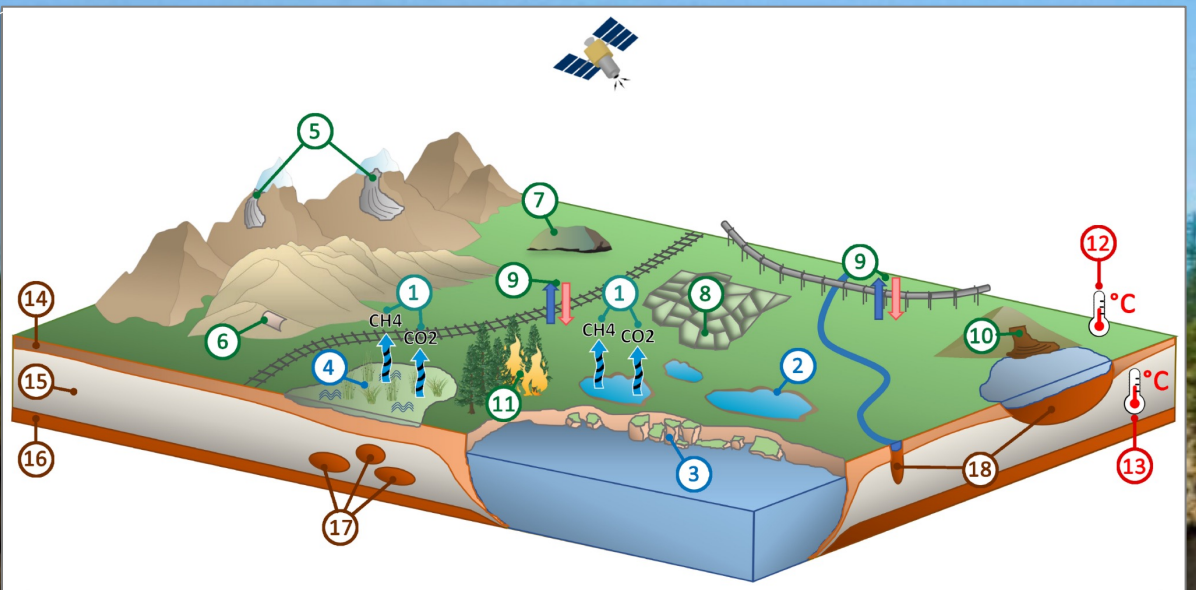
Image source: Nunataryuk Permafrost Atlas (Westerveld et al., 2023)

Permafrost Country



(data from: Obu et al., 2019)



Atmospheric Features and Processes:
1: *Greenhouse gas emissions*

Surface Water Features and Processes:
2: Surface water extent dynamics
3: *Coastal erosion*
4: Bog/fen development

Surface Land Features and Processes:
5: Rock glaciers
6: Landslides
7: Pingo development
8: Patterned ground
9: *Frost heave and thaw settlement*
10: Thaw slumps
11: *Wild fires*

Thermal Features and Processes:
12: *Land surface temperature dynamics*
13: *Ground temperature dynamics*

Subsurface Features and Processes:
14: Active layer thickness dynamics
15: Permafrost
16: Unfrozen ground
17: Cryopeg
18: Talik

(Philipp et al., 2021)

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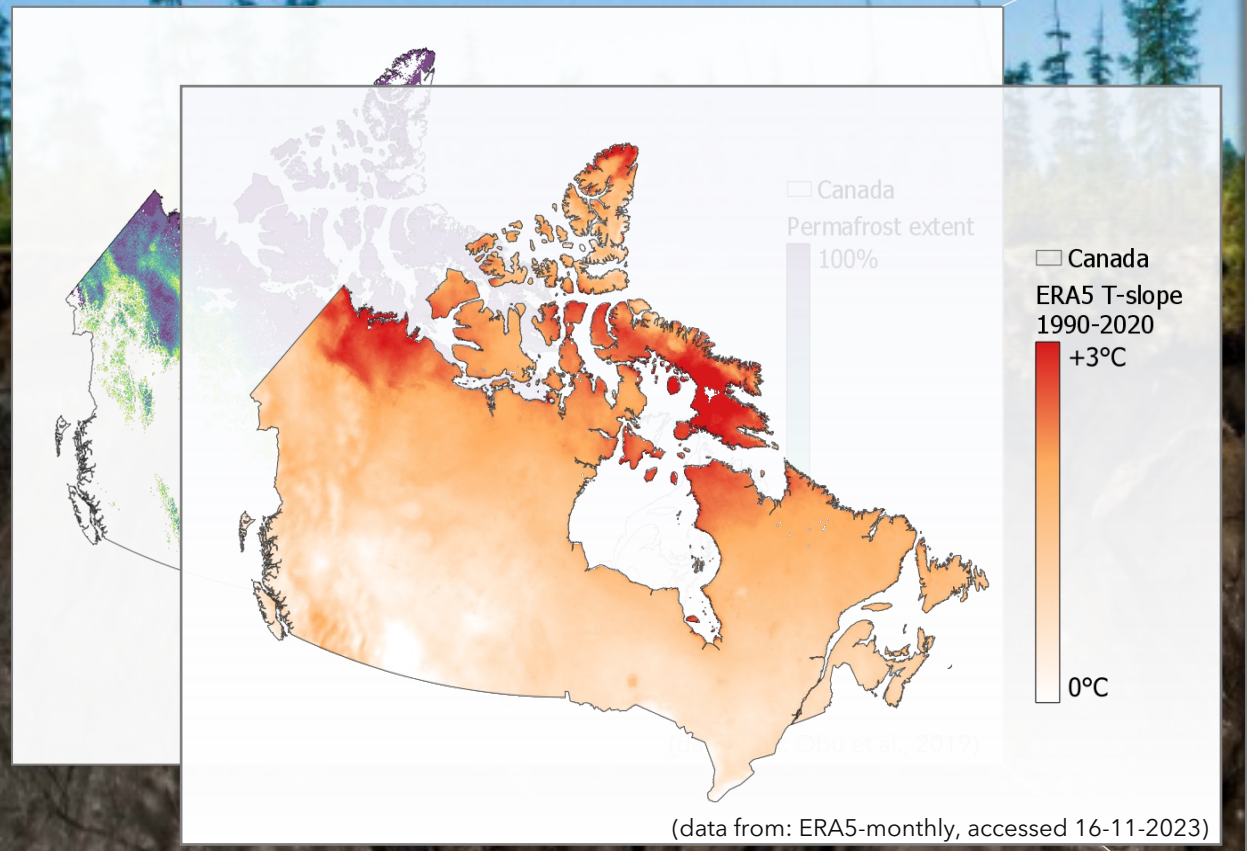
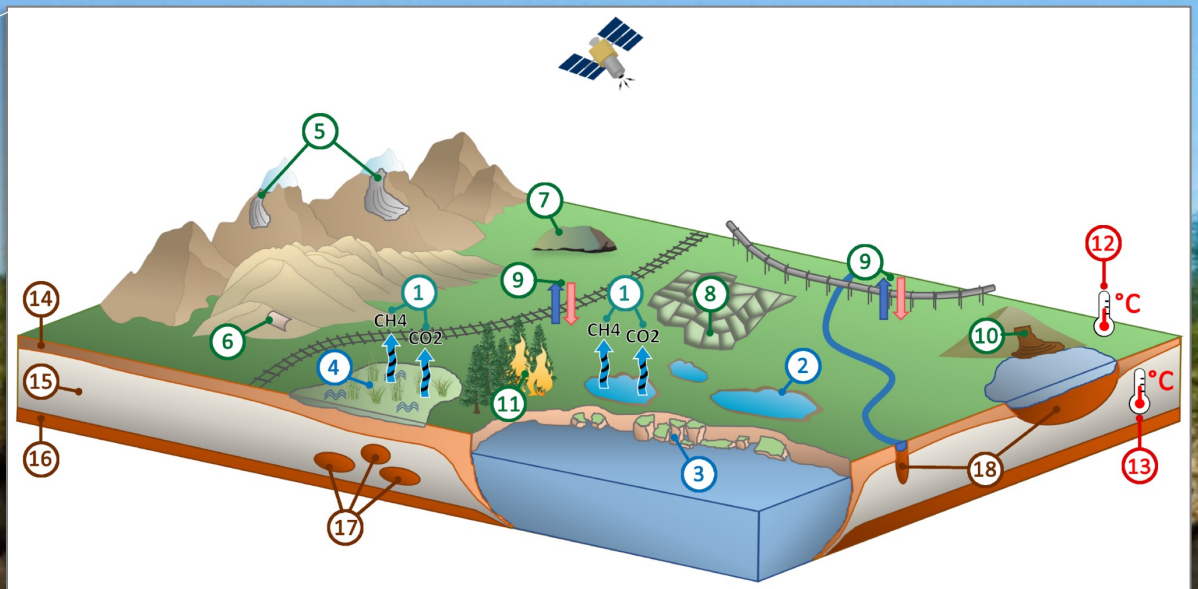
Permafrost Country



(data from: ERA5-monthly, accessed 16-11-2023)



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(Philipp et al., 2021)

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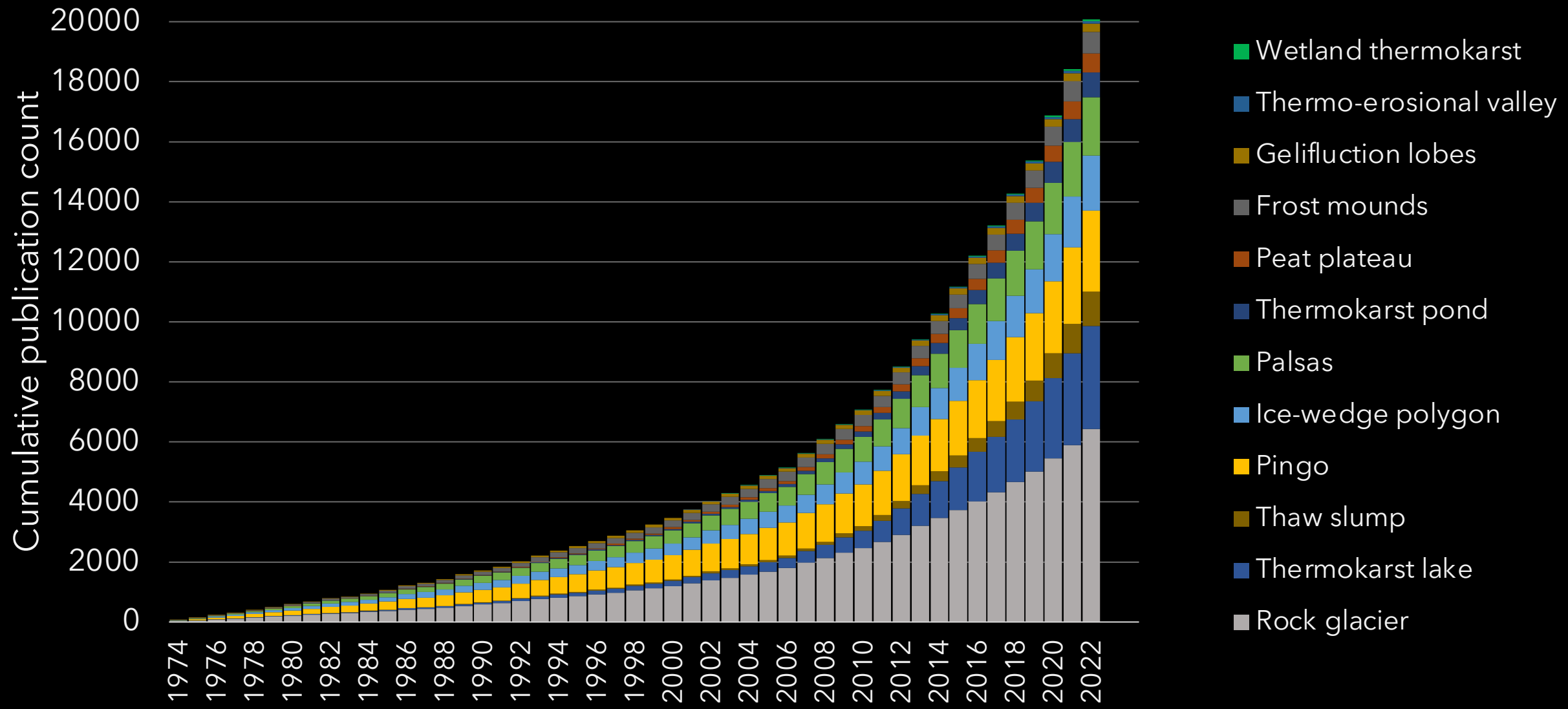
Cumulative Occurrence of Permafrost Landform Terms in Scientific Literature



Data from: Digital Science's Dimensions platform, https://app.dimensions.ai

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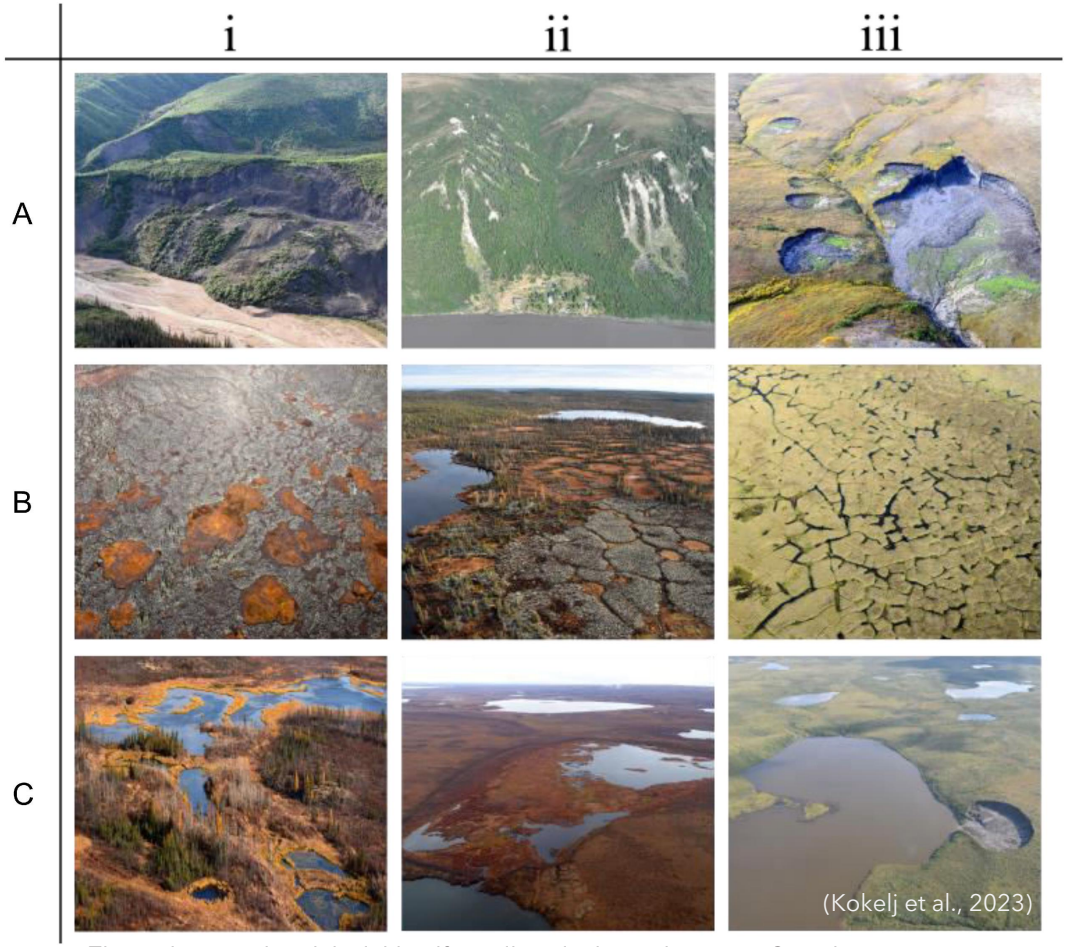
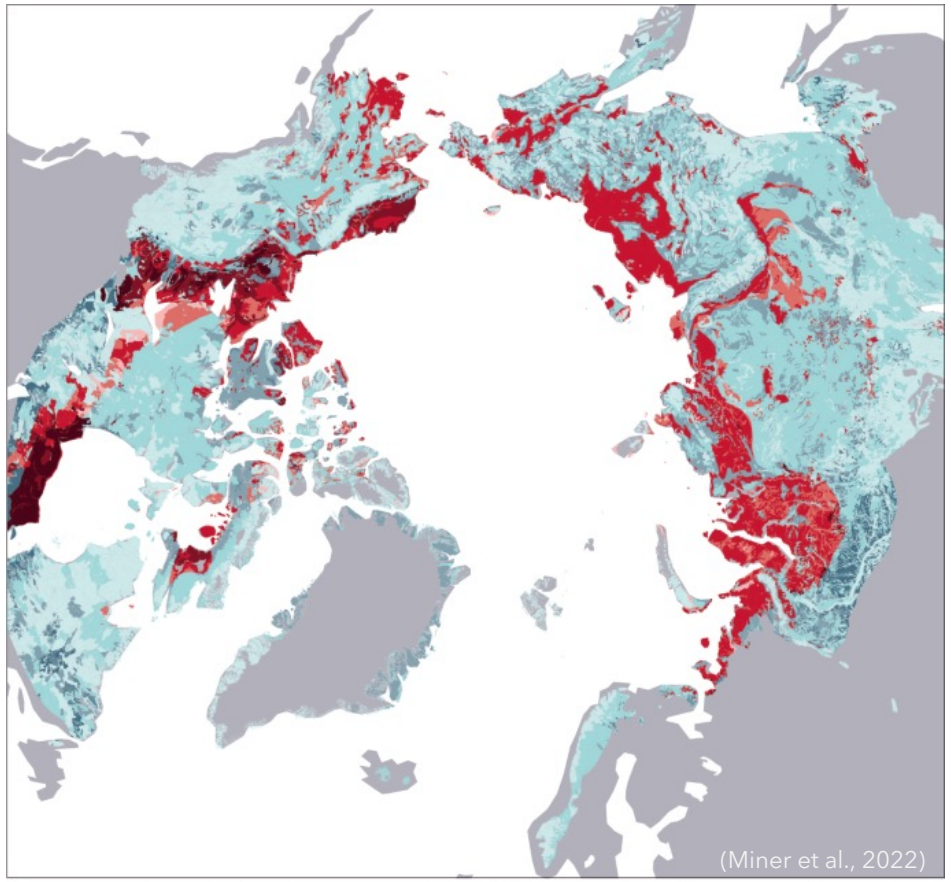
Permafrost Landscapes and Landforms - Indicators of Conditions, Processes and Change Trajectory



Thermokarst and periglacial landform diversity in northwestern Canada.



Permafrost-affected soil carbon content: kgC m^{-2} (% region vulnerable to type of thawing)

Rapid thawing
■ >139 (8%) ■ 139–105 (10%) ■ 104–70 (60%) ■ 69–36 (19%) ■ 35–0 (3%)
Gradual thawing
■ >139 (4%) ■ 139–105 (3%) ■ 104–70 (26%) ■ 69–36 (39%) ■ 35–0 (28%)

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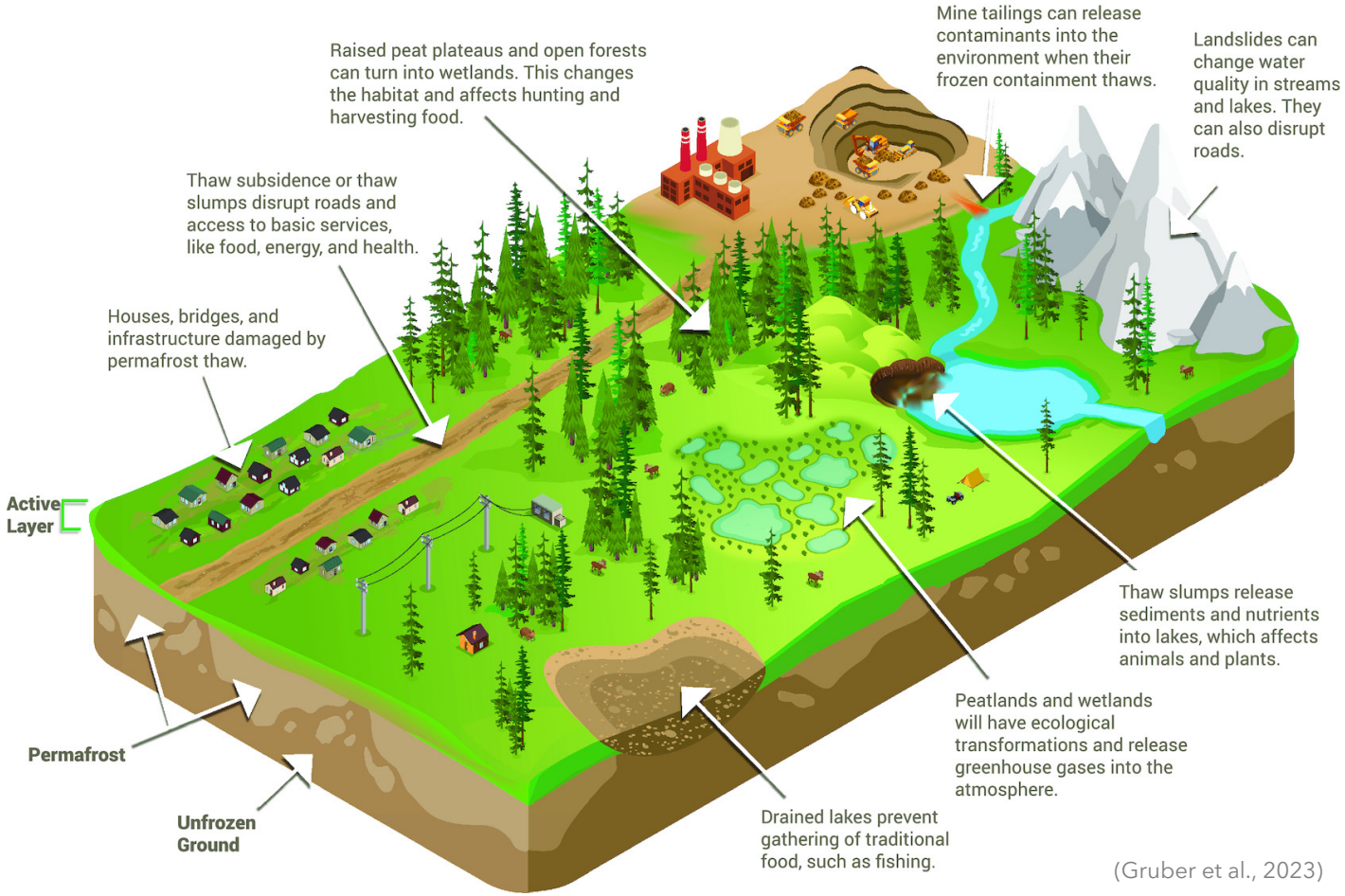
Permafrost Landscapes and Landforms - Indicators of Conditions, Processes and Change Trajectory

… at multiple scales, and to multiple stakeholders



(Gruber et al., 2023)

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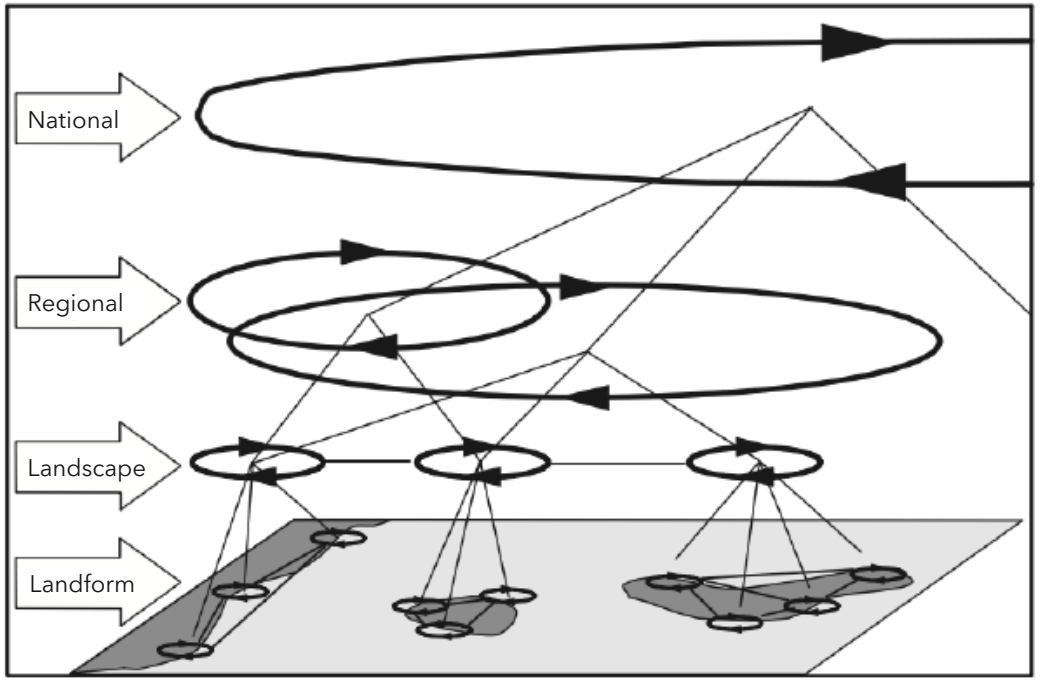
Permafrost Landscapes and Landforms - Indicators of Conditions, Processes and Change Trajectory

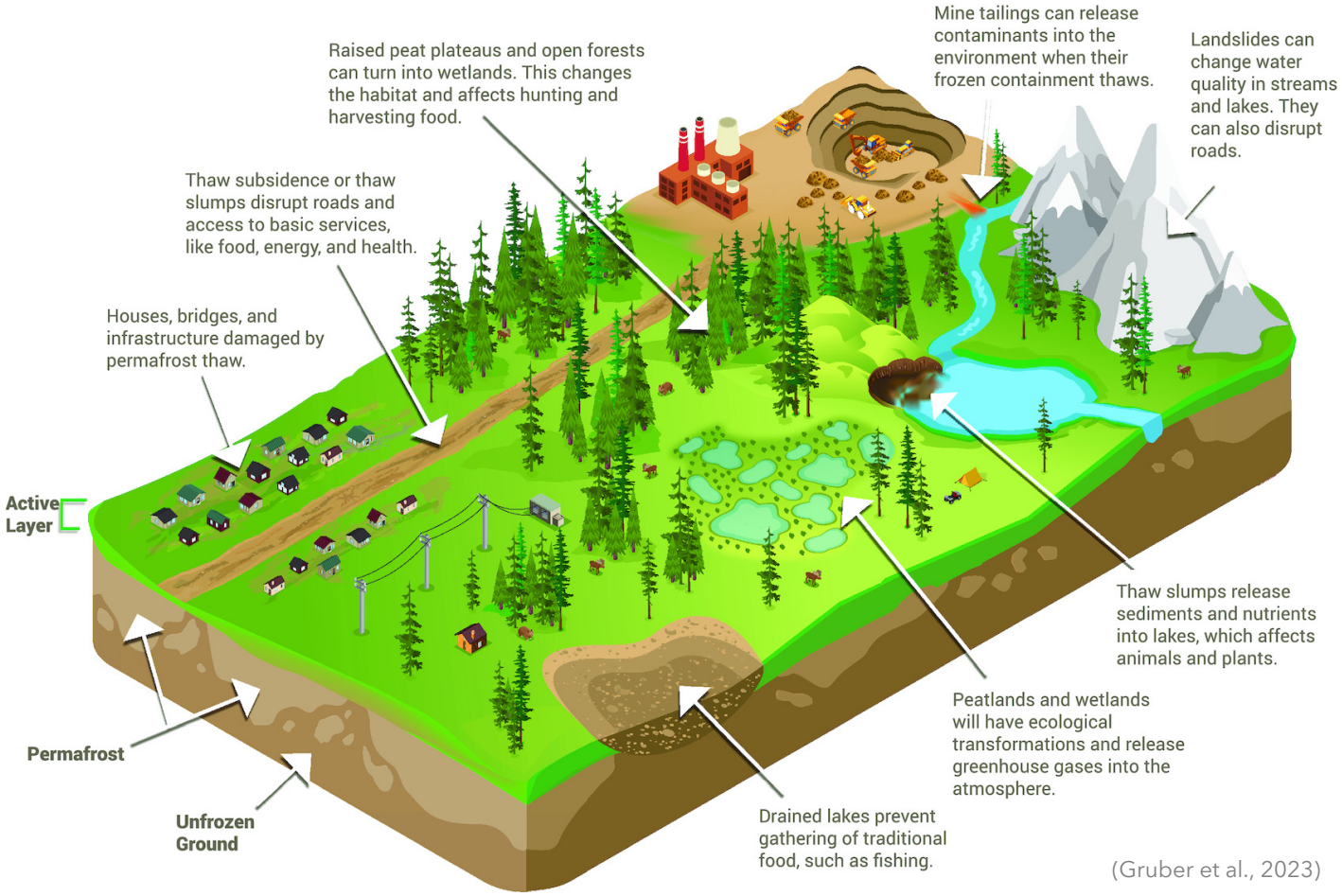
… at multiple scales, and to multiple stakeholders

NESTED APPROACH:

All scales are necessary and have to be linked



(Adapted from: Fanning et al., 2013)



(Gruber et al., 2023)

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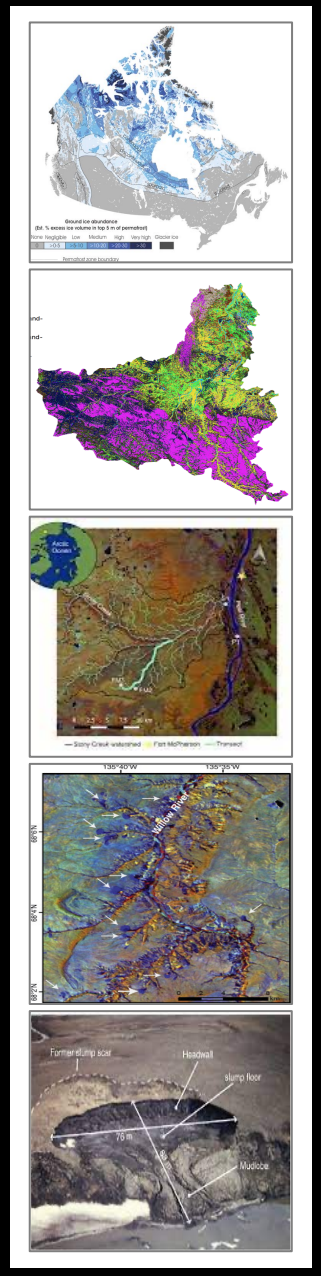
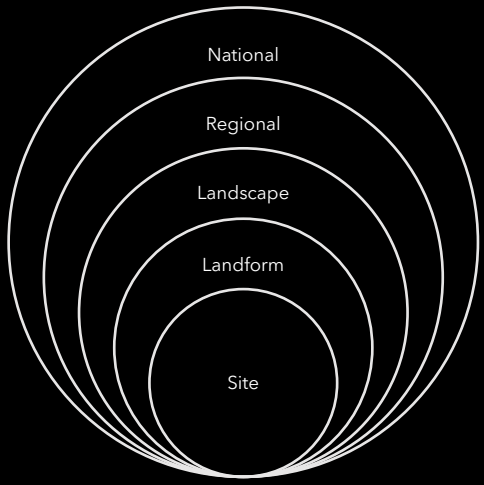
Scale



Driving variables

- MAAT, eco-region, surf. geol., …
- MAAT, eco-region, surf. geol., …
- MAAT, topography, snow, vegetation, …
- MAAT, topography, snow, vegetation, aspect, wind…
- MAAT, micro-relief, snow, vegetation, aspect, wind…



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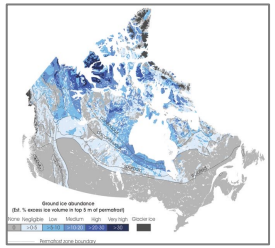
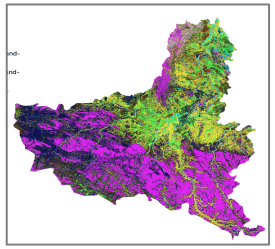
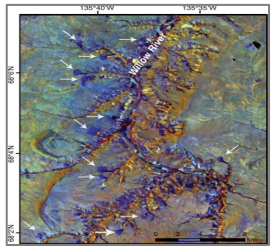
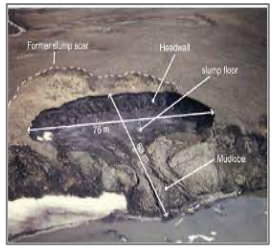
Scale

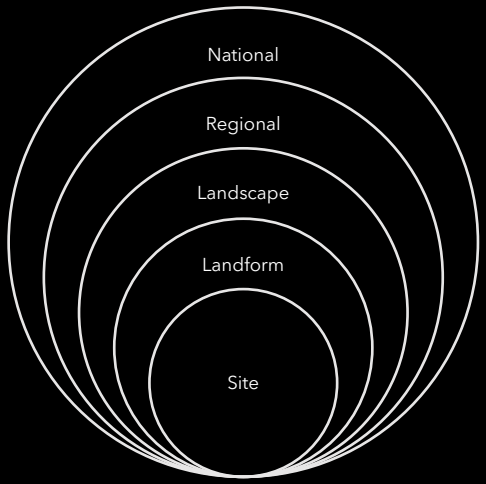








Driving variables	Relevant processes
MAAT, eco-region, surf. geol., …	Active layer deepening, thermal regime shifts, …
MAAT, eco-region, surf. geol., …	Active layer deepening, ecosystem shift, …
MAAT, topography, snow, vegetation, …	Hydrological regime shifts, Talik development…
MAAT, topography, snow, vegetation, aspect, wind…	Active layer detachment, vegetation shifts, …
MAAT, micro-relief, snow, vegetation, aspect, wind…	Thermal contraction, diff. frost heave, …



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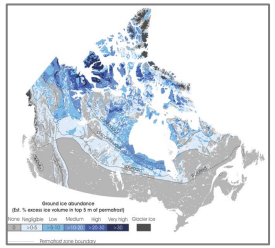
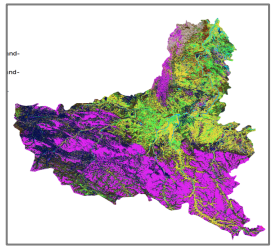
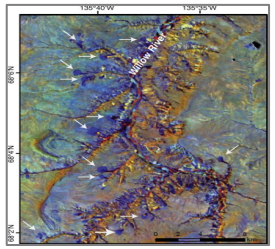
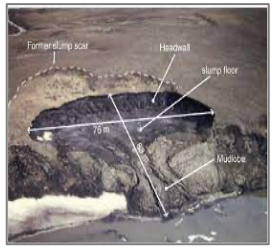
Scale



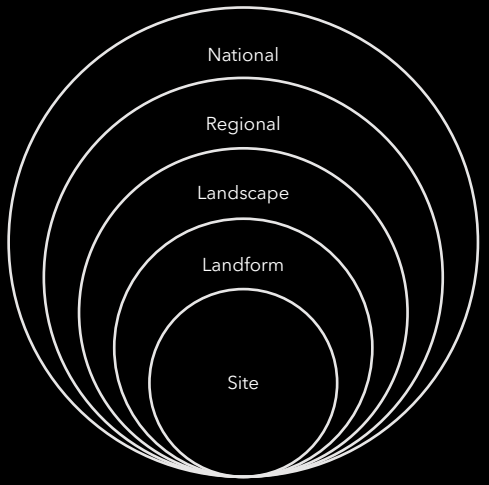






Driving variables	Relevant processes	Physical features
MAAT, eco-region, surf. geol., …	Active layer deepening, thermal regime shifts, …	Permafrost extent
MAAT, eco-region, surf. geol., …	Active layer deepening, ecosystem shift, …	…
MAAT, topography, snow, vegetation, …	Hydrological regime shifts, Talik development…	…
MAAT, topography, snow, vegetation, aspect, wind…	Active layer detachment, vegetation shifts, …	Polygonal structures, slump scars
MAAT, micro-relief, snow, vegetation, aspect, wind…	Thermal contraction, diff. frost heave, …	…

Preconditions



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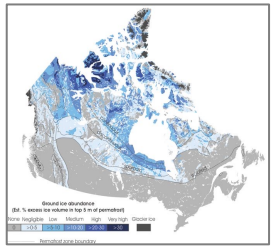
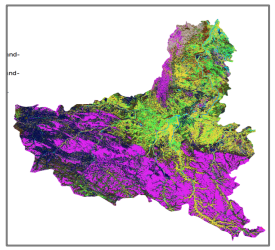
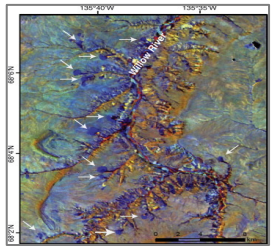
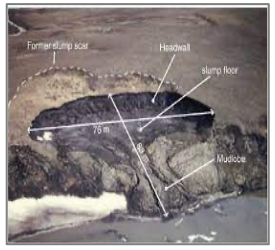
Scale









Preconditions

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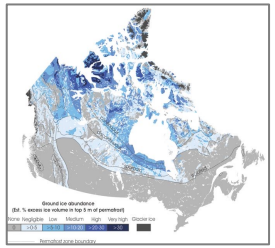

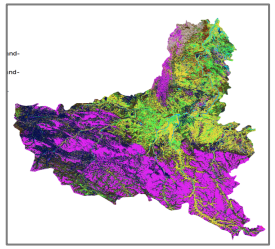

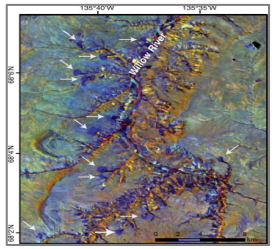

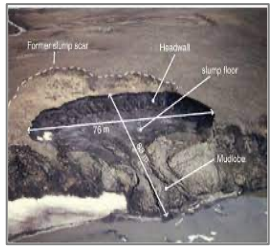

Preconditions

- …
- …
- …
- …
- …

x

Stakeholder requirement

- …
- …
- …
- …
- …

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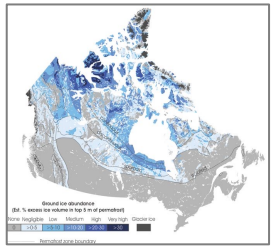
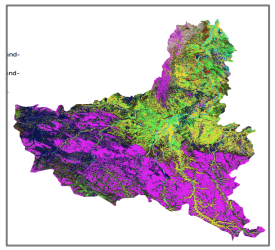
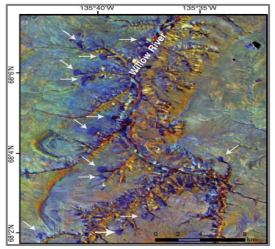
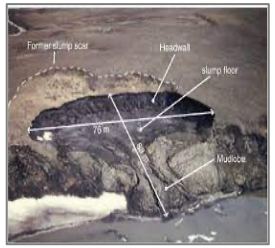
Scale









Preconditions

- …
- …
- …
- …
- …

x

Stakeholder requirement

- …
- …
- …
- …
- …

=

Functional classes

- …
- …
- …
- …
- …

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Your knowledge is needed!

nspeetjens@uvic.ca

Niek Jesse Speetjens

Let's talk!

(Gruber et al., 2023)

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References

1. Fanning, L., Mahon, R., & Mcconney, P. (2013). *Applying the large marine ecosystem (LME) governance framework in the Wider Caribbean Region*. https://doi.org/10.1016/j.marpol.2013.02.008
2. Gruber, S., Hayley, J., Karunaratne, K., King, J., MacLean, T., Marshall, S., & Moore, D. (2023). Considerations toward a vision and strategy for permafrost knowledge in Canada. *Arctic Science*. https://doi.org/10.1139/as-2023-0016
3. Kokelj, S. v, Gingras-Hill, T., Daly, S. v, Morse, P. D., Wolfe, S. A., Rudy, A. C. A., van der Sluijs, J., Weiss, N., Brendan O'neill, H., Baltzer, J. L., Lantz, T. C., Gibson, C., Cazon, D., Fraser, R. H., Froese, D. G., Giff, G., Klengenberg, C., Lamoureux, S. F., Quinton, W. L., … Young, J. M. (n.d.). *ON N1G 2W1, Canada; i Łı́ı́dlı ı Ku¸́¸Ku¸́¸ éFirstéFirst Nation, Lands & Resources, Fort Simpson, NT X0E 0N0, Canada; j Canada Centre for Mapping and Earth Observation*. https://doi.org/10.1139/AS-2023-0009
4. Miner, K. R., Turetsky, M. R., Malina, E., Bartsch, A., Tamminen, J., McGuire, A. D., Fix, A., Sweeney, C., Elder, C. D., & Miller, C. E. (2022). Permafrost carbon emissions in a changing Arctic. In *Nature Reviews Earth and Environment* (Vol. 3, Issue 1). https://doi.org/10.1038/s43017-021-00230-3
5. Obu, J., Westermann, S., Bartsch, A., Berdnikov, N., Christiansen, H. H., Dashtseren, A., Delaloye, R., Elberling, B., Etzelmüller, B., Kholodov, A., Khomutov, A., Kääb, A., Leibman, M. O., Lewkowicz, A. G., Panda, S. K., Romanovsky, V., Way, R. G., Westergaard-Nielsen, A., Wu, T., … Zou, D. (2019). Northern Hemisphere permafrost map based on TTOP modelling for 2000–2016 at 1 km2 scale. *Earth-Science Reviews*, *193*, 299–316. https://doi.org/10.1016/J.EARSCIREV.2019.04.023
6. Philipp, M., Dietz, A., Buchelt, S., & Kuenzer, C. (2021). Trends in Satellite Earth Observation for Permafrost Related Analyses—A Review. *Remote Sensing 2021, Vol. 13, Page 1217*, *13*(6), 1217. https://doi.org/10.3390/RS13061217
7. Westerveld, L., Kurvits, T., Schoolmeester, T., Mulelid, O. B., Eckhoff, T. S., Overduin, P. P., Fritz, M., Lantuit, H., Alfthan, B., Sinisalo, A., Miesner, F., Viitanen, L.-K., and the NUNATARYUK consortium (2023). Arctic Permafrost Atlas. GRID-Arendal, Arendal.

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