Framework for Assessing Ecological Responses to Permafrost Degradation

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Degradation Factors

Climate Warming

Landscape Position

(slopes vs flats)

Groundwater Movement

Soil Texture (silt vs gravel)

Ice Morphology

(segregated vs wedge ice)

Ice Content (ice-poor vs

ice-rich)

Degradation Mode

Glacial Thermokarst

Thermokarst Lake

Collapse-scar fens

Collapse-scar bogs

Collapse-scar pits

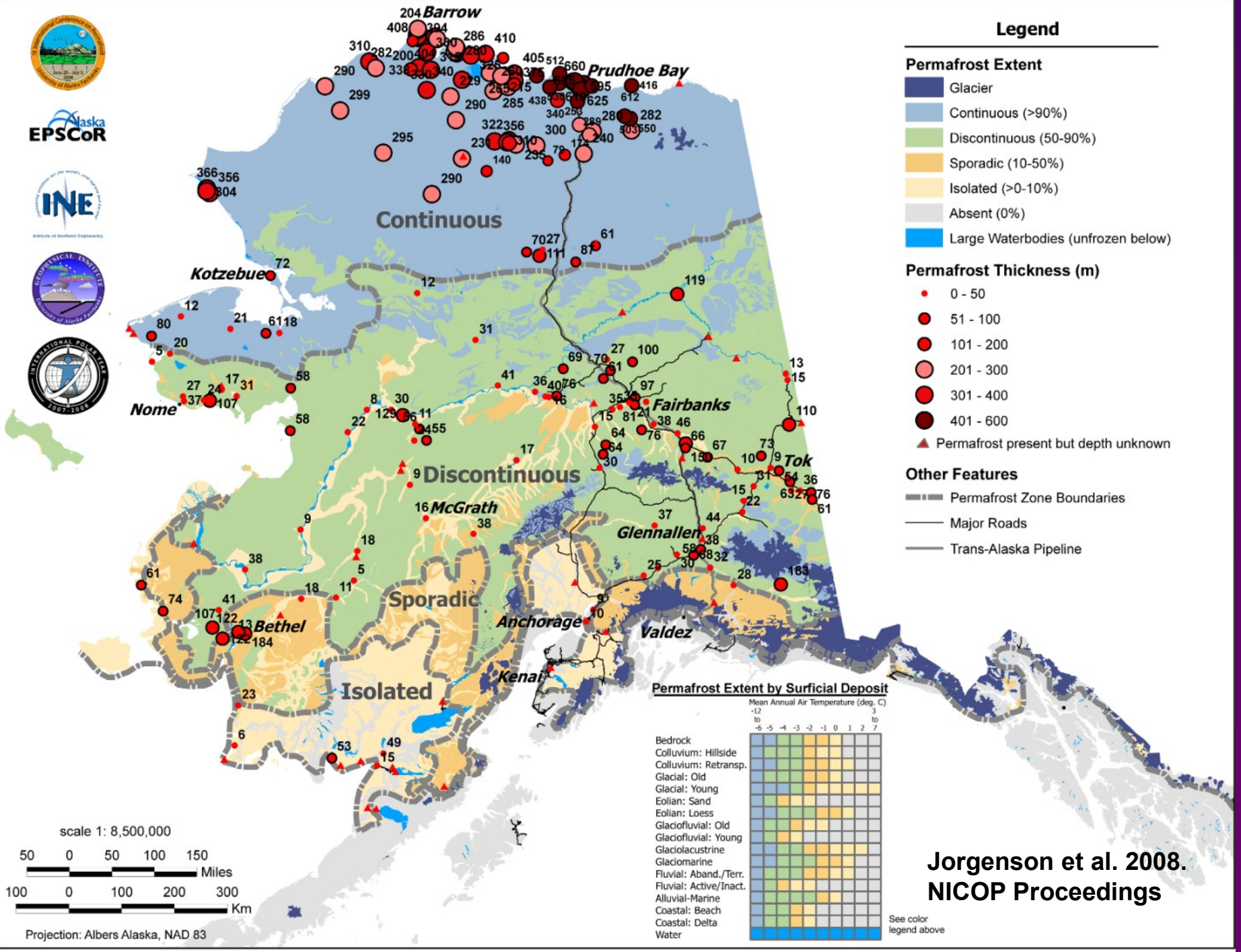
Mixed Pits and Polygons

Water tracks and Gullies

Piping with Pits

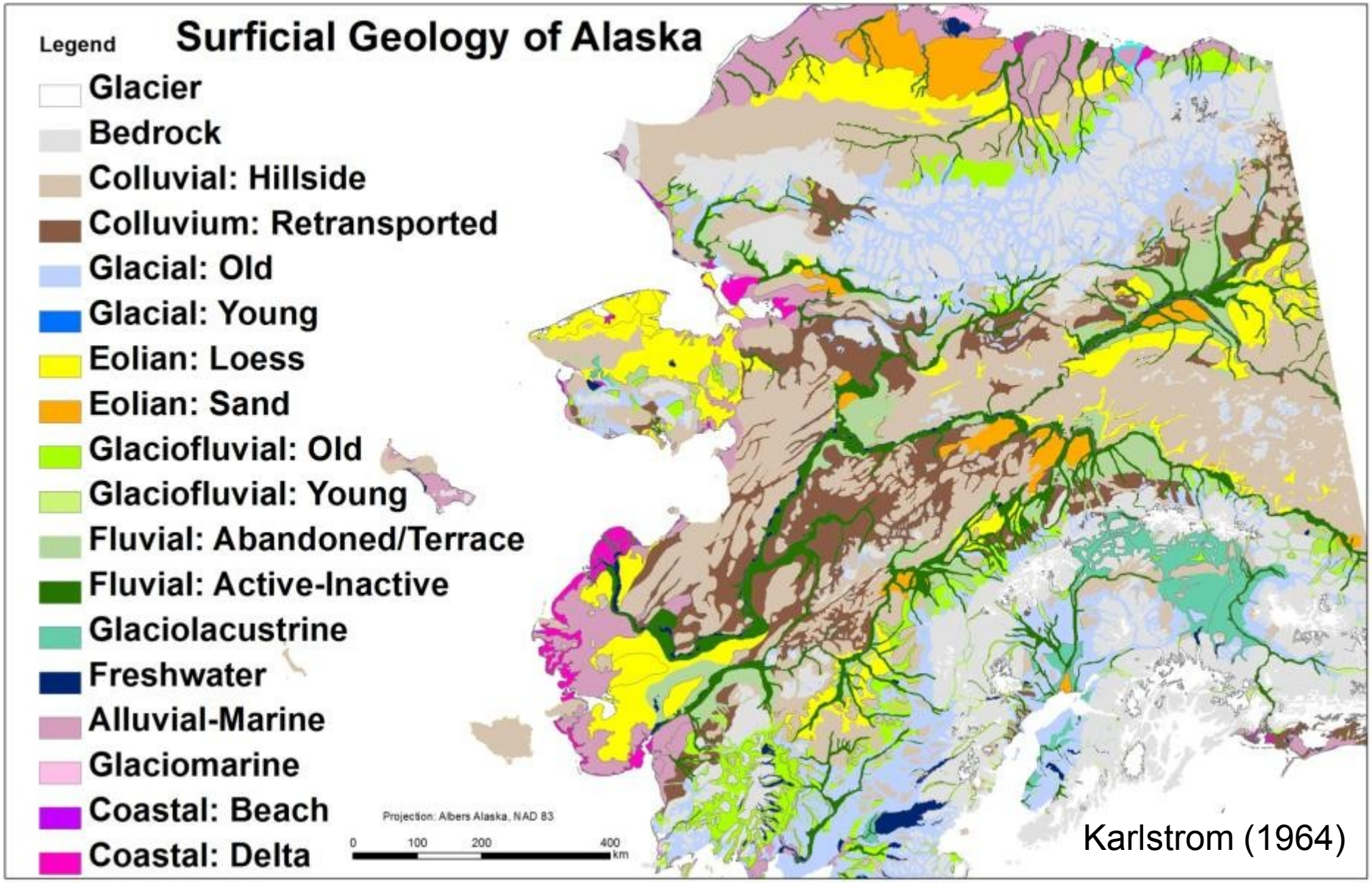
Mounds and Hummocks

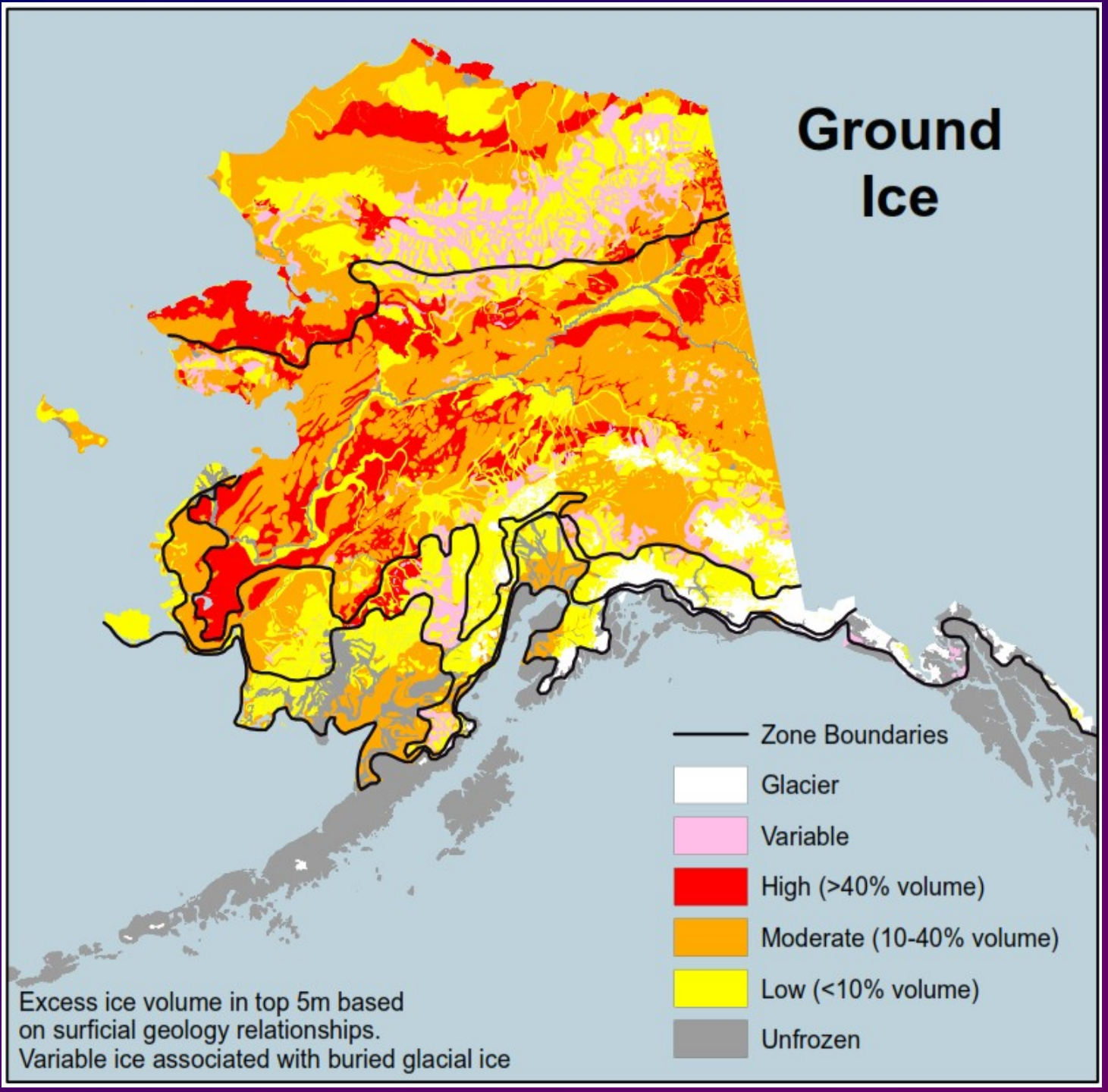
Nonpatterned



Jorgenson et al. 2008. NICOP Proceedings

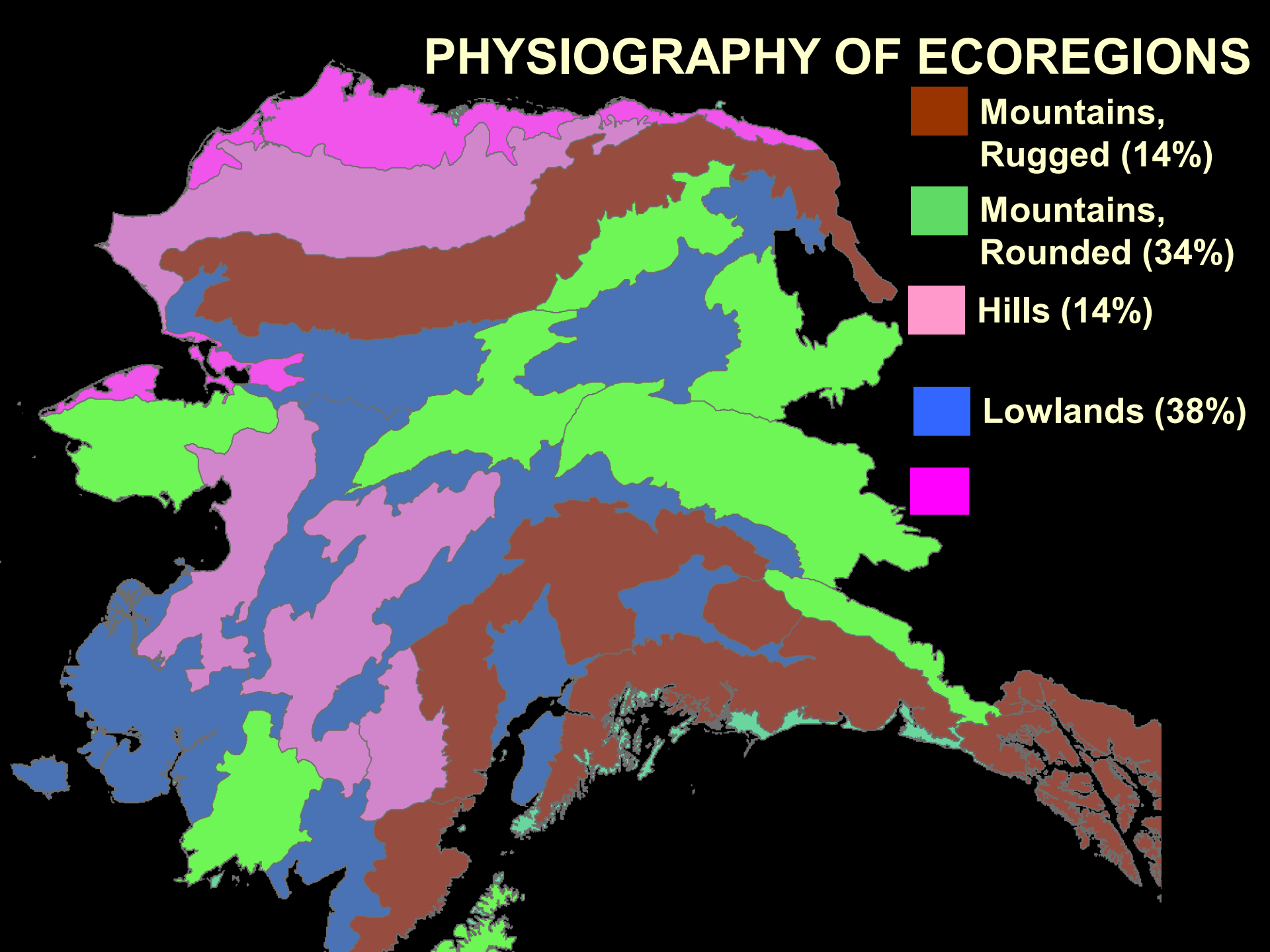
Surficial Material Gradients



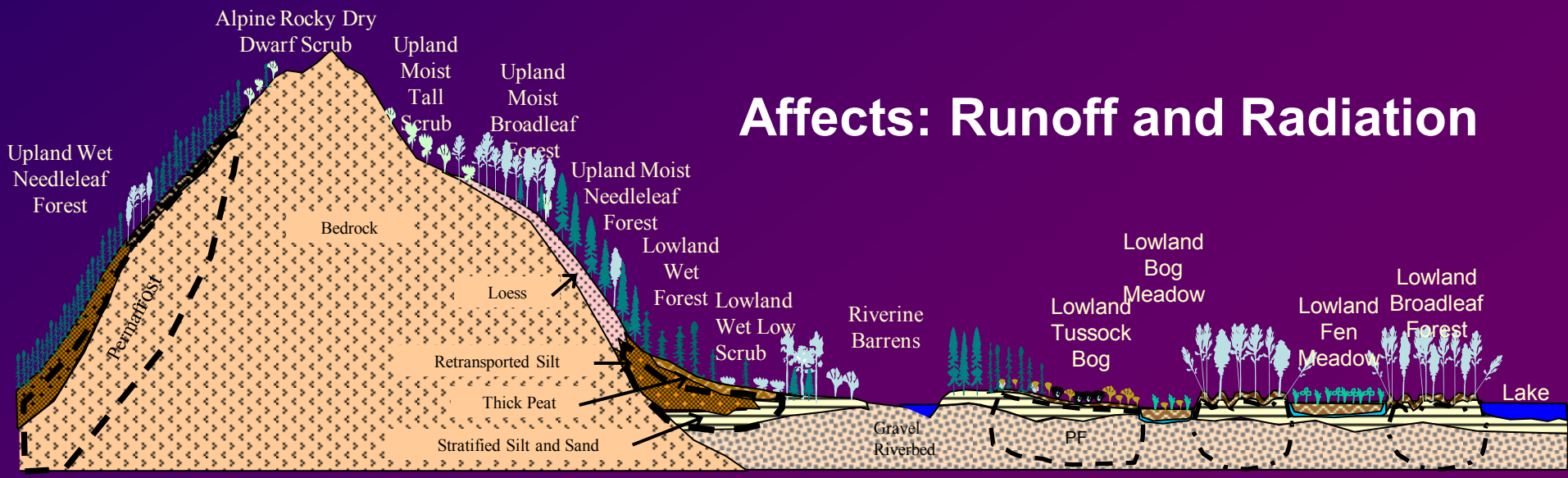


Ground ice associated with surficial deposits

Jorgenson et al. 2008. NICOP Proceedings

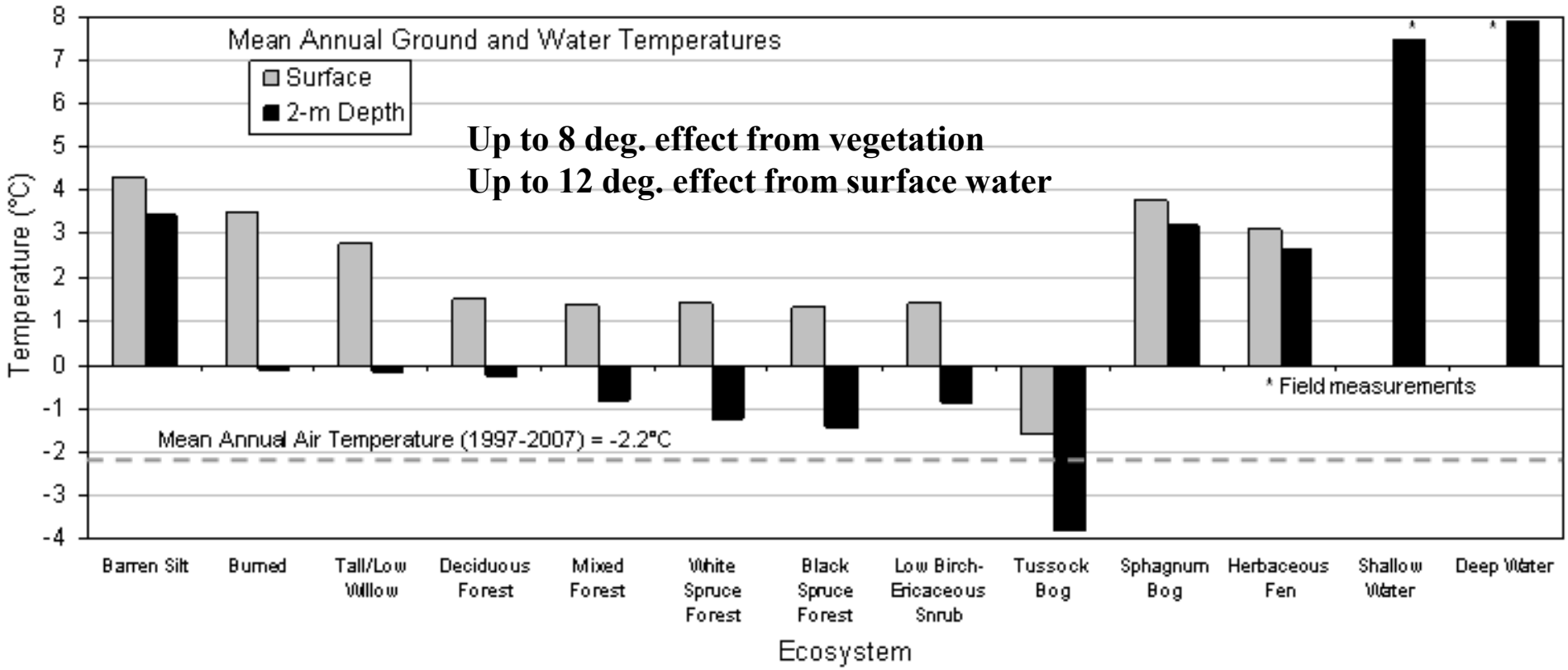

PHYSIOGRAPHY OF ECOREGIONS
Mountains, Rugged (14%)
Mountains, Rounded (34%)
Hills (14%)
Lowlands (38%)

Topography



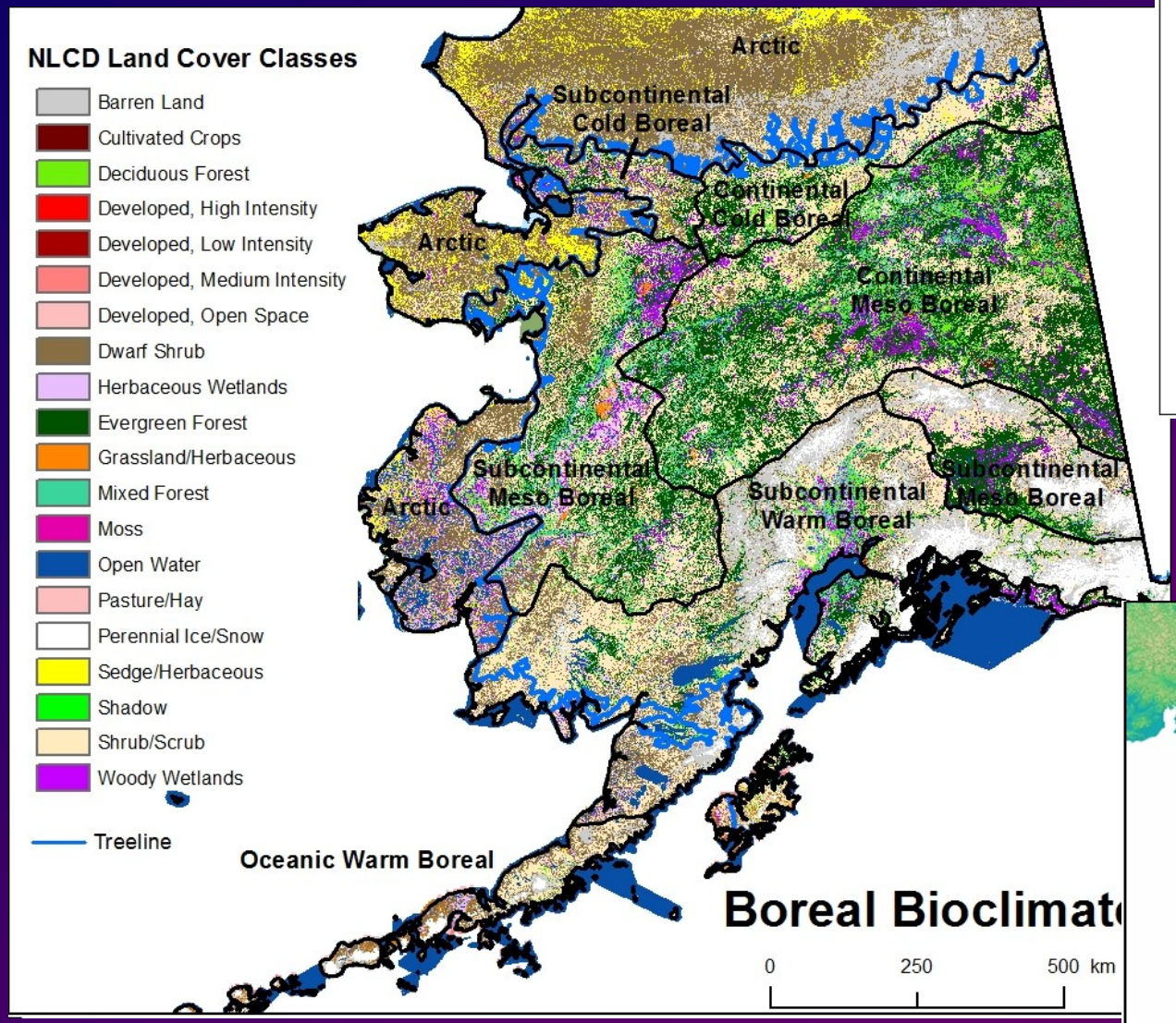
Affects: Runoff and Radiation

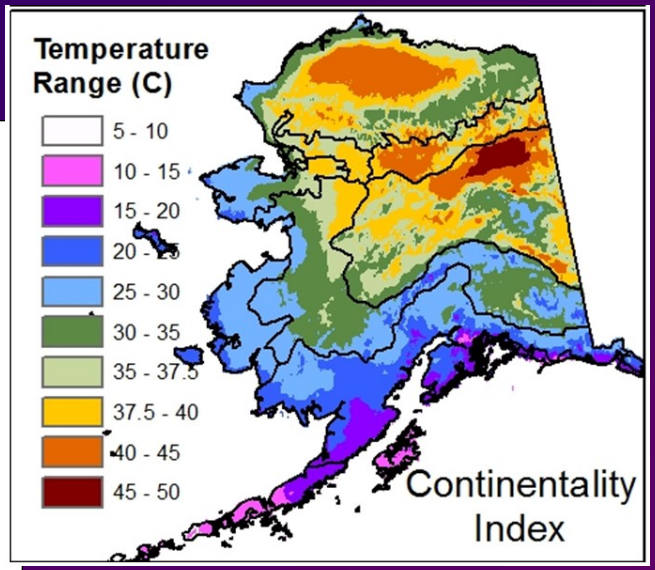
Effects of Vegetation and Water on Ground Temperatures

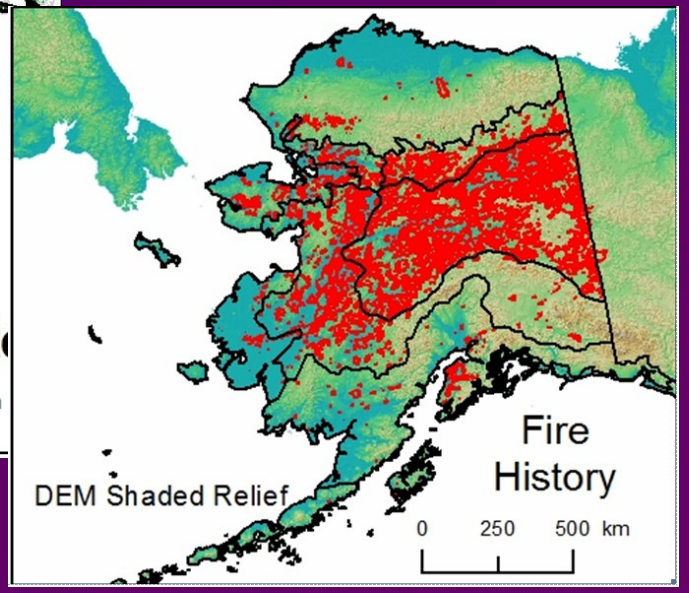


Effects of ecosystem properties and water are about twice as large as predicted climate change

From: Jorgenson, M. T., Romanovsky, V., Harden, J., Shur, Y., O'Donnell, J., Schuur, E. A. G., Kanevskiy, M. and Marchenko, S. 2010. Resilience and Vulnerability of Permafrost to Climate Change. Canadian Journal of Forest Research 40: 1219-1236.


NLCD Land Cover Classes
Barren Land
Cultivated Crops
Deciduous Forest
Developed, High Intensity
Developed, Low Intensity
Developed, Medium Intensity
Developed, Open Space
Dwarf Shrub
Herbaceous Wetlands
Evergreen Forest
Grassland/Herbaceous
Mixed Forest
Moss
Open Water
Pasture/Hay
Perennial Ice/Snow
Sedge/Herbaceous
Shadow
Shrub/Scrub
Woody Wetlands
Treeline
Arctic
Subcontinental Cold Boreal
Continental Cold Boreal
Arctic
Continental Meso Boreal
Subcontinental Meso Boreal
Arctic
Subcontinental Warm Boreal
Subcontinental Meso Boreal
Oceanic Warm Boreal
Boreal Bioclimat
0 250 500 km


Temperature Range (C)
5 - 10
10 - 15
15 - 20
20 - 25
25 - 30
30 - 35
35 - 37.5
37.5 - 40
40 - 45
45 - 50
Continentality Index

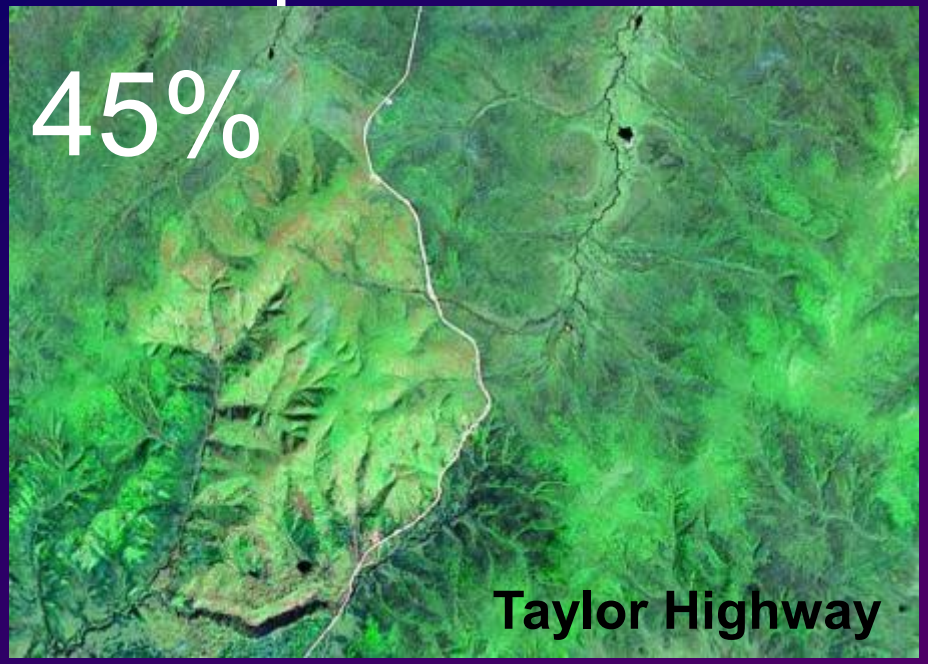

DEM Shaded Relief
Fire History
0 250 500 km

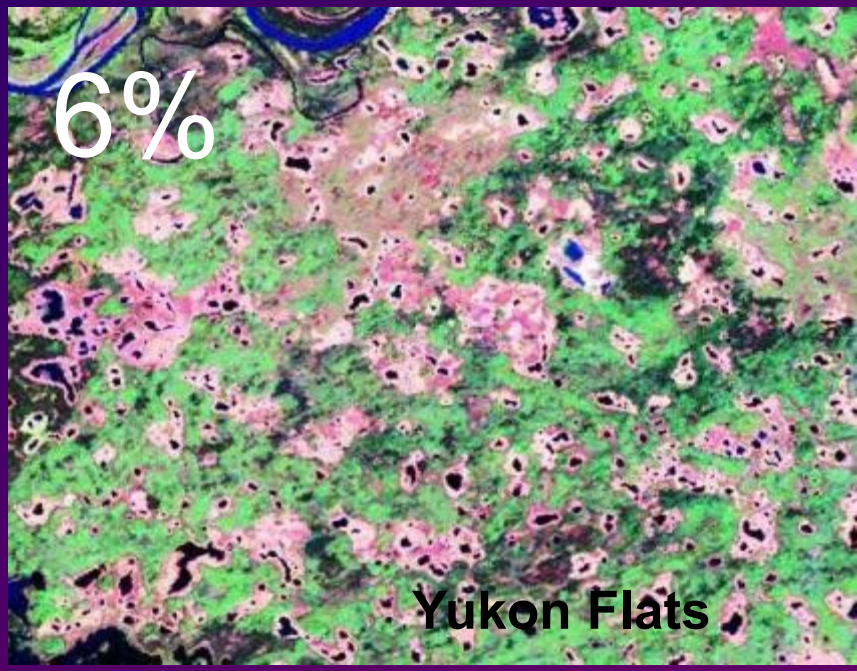
Upland

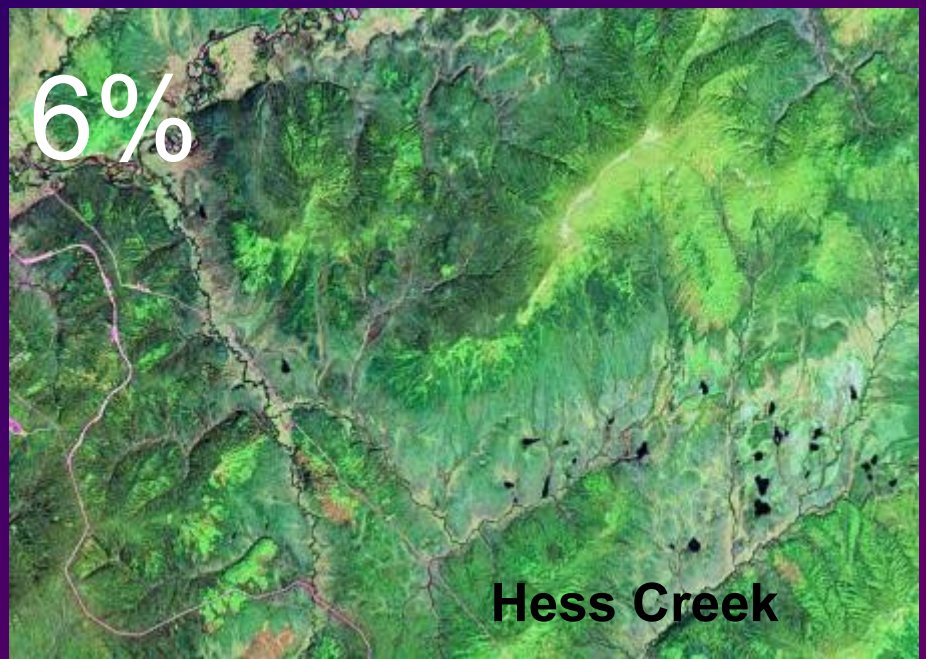
Lowland

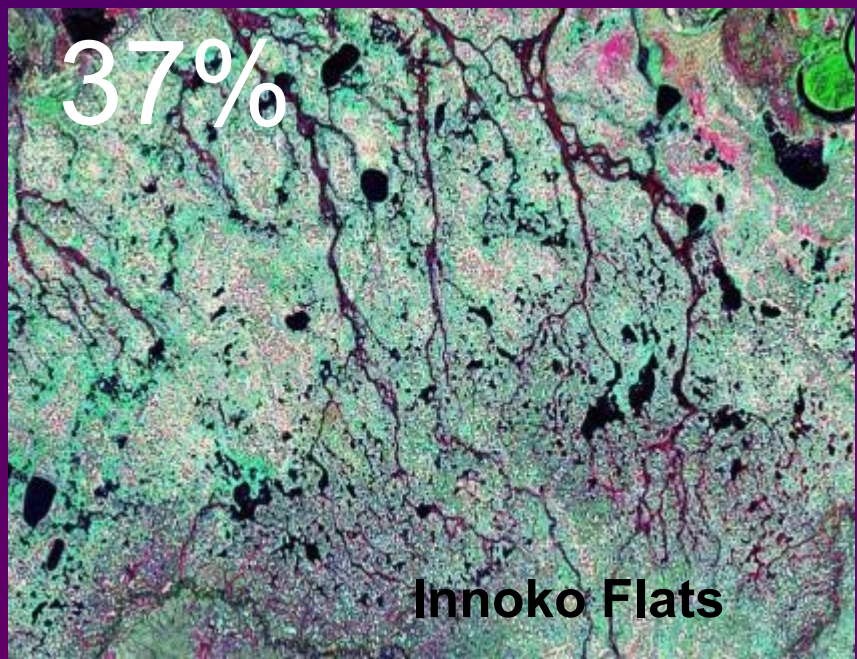
Rocky/Sandy

Loamy/Peaty









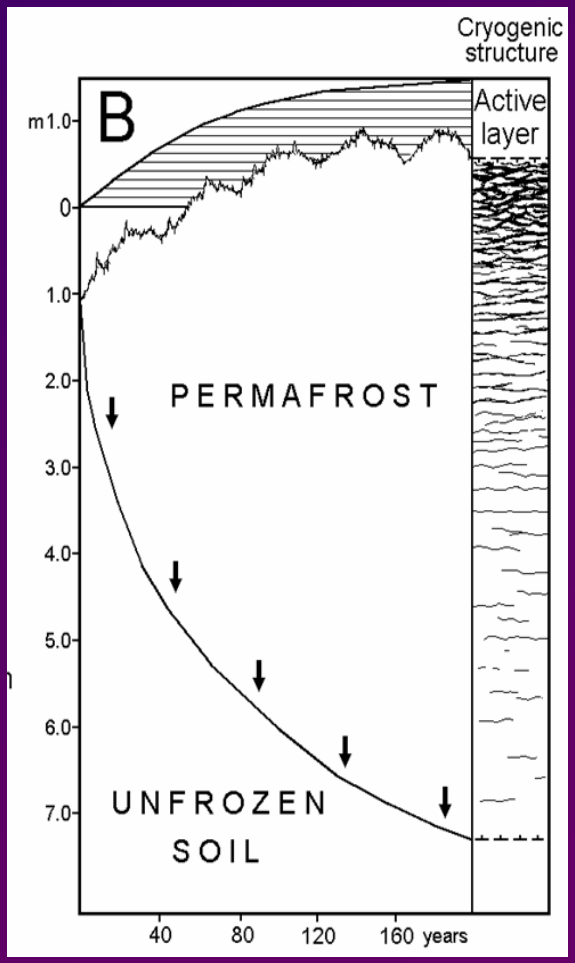
Rocky Uplands

Old Forest

Young Burn (1986)

Cryoturbation indicates a cyclic process of permafrost aggradation-degradation

Ecosystem Driven Permafrost

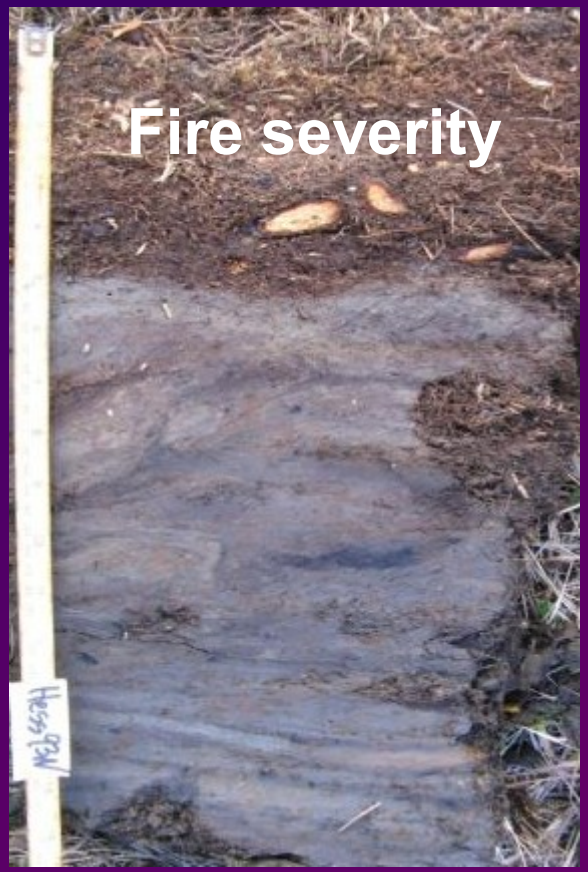


Drawing by Kanevskiy in Jorgenson et al. 2011

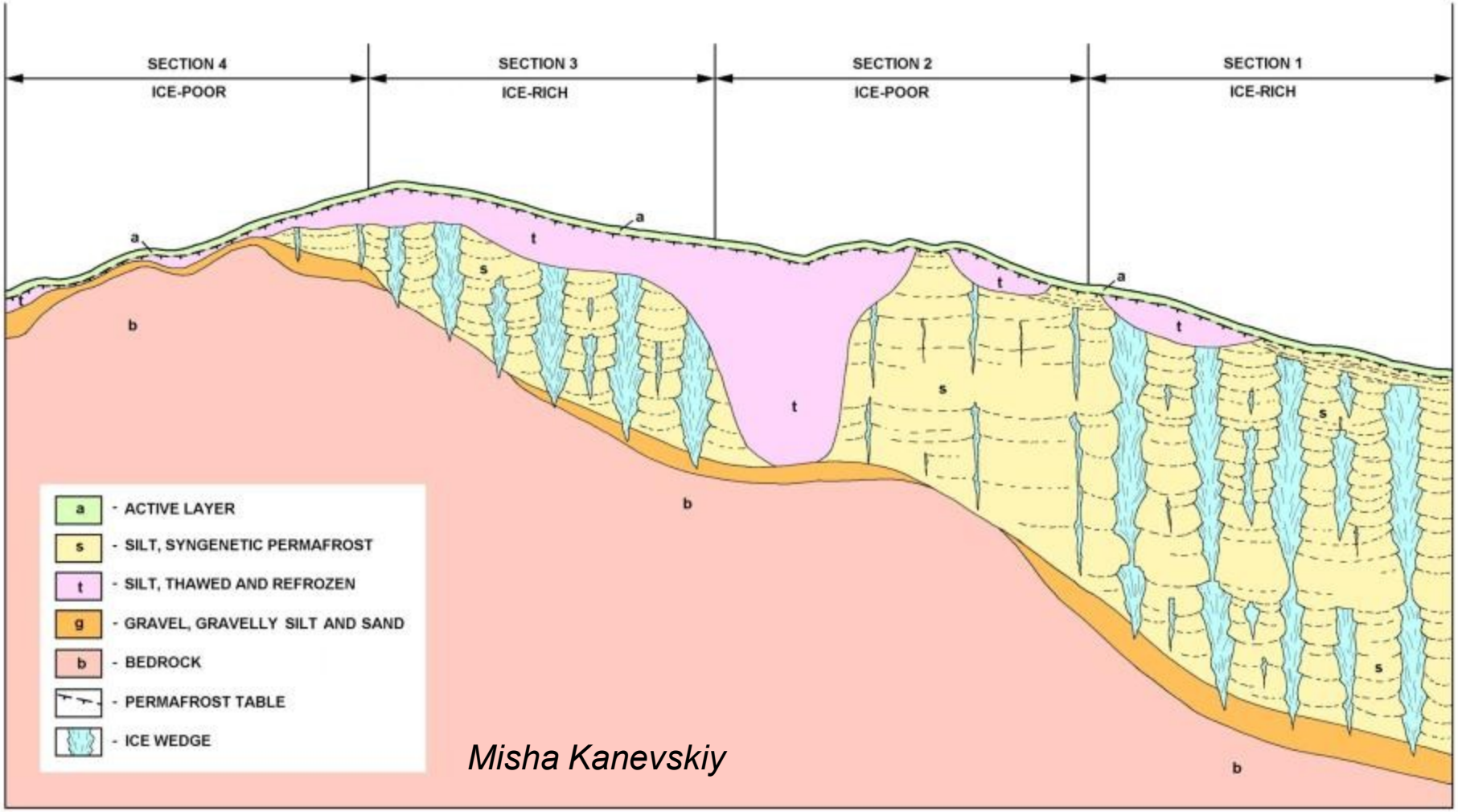
Old Forest

Young Burn (1993)

Loamy Uplands



Conceptual Model of Yedoma at Hess Creek



Pleistocene Syngenetic Ice
Foothills Loess Belt

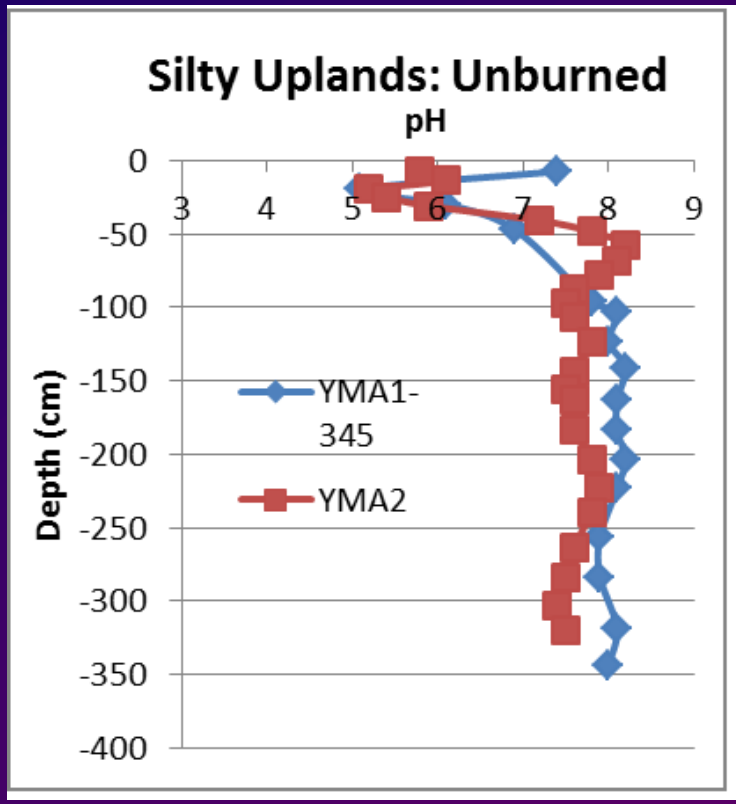
Kanevskiy et al. 2010. Quaternary Science Reviews

Differential Thaw Settlement in Yedoma, Fairbanks Area

Thawing of alkaline subsoils allows a broader diversity of responses

Advanced degradation of Yedoma (extremely ice-rich Pleistocene silt)

Upland Soil pH Profiles



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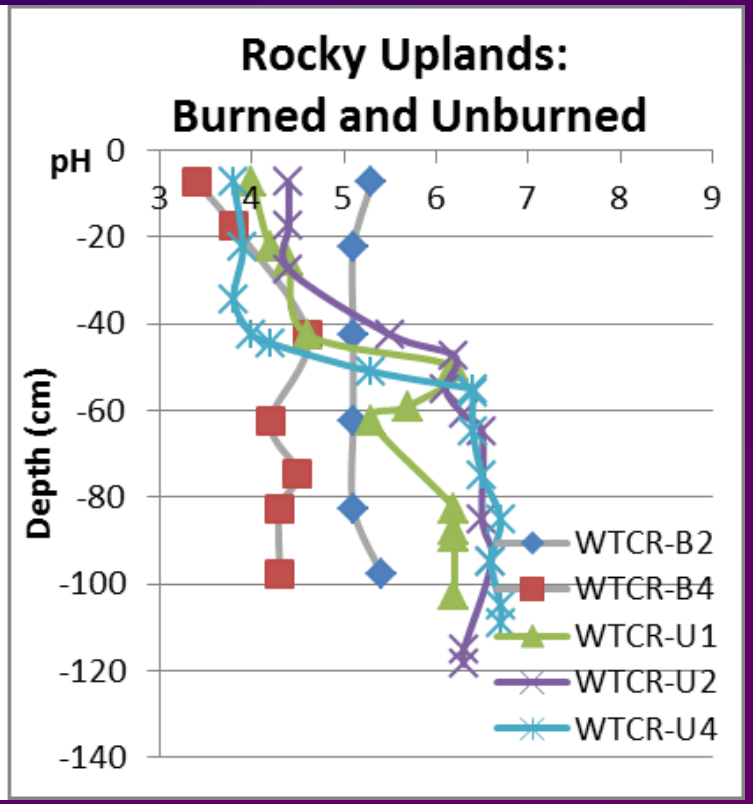


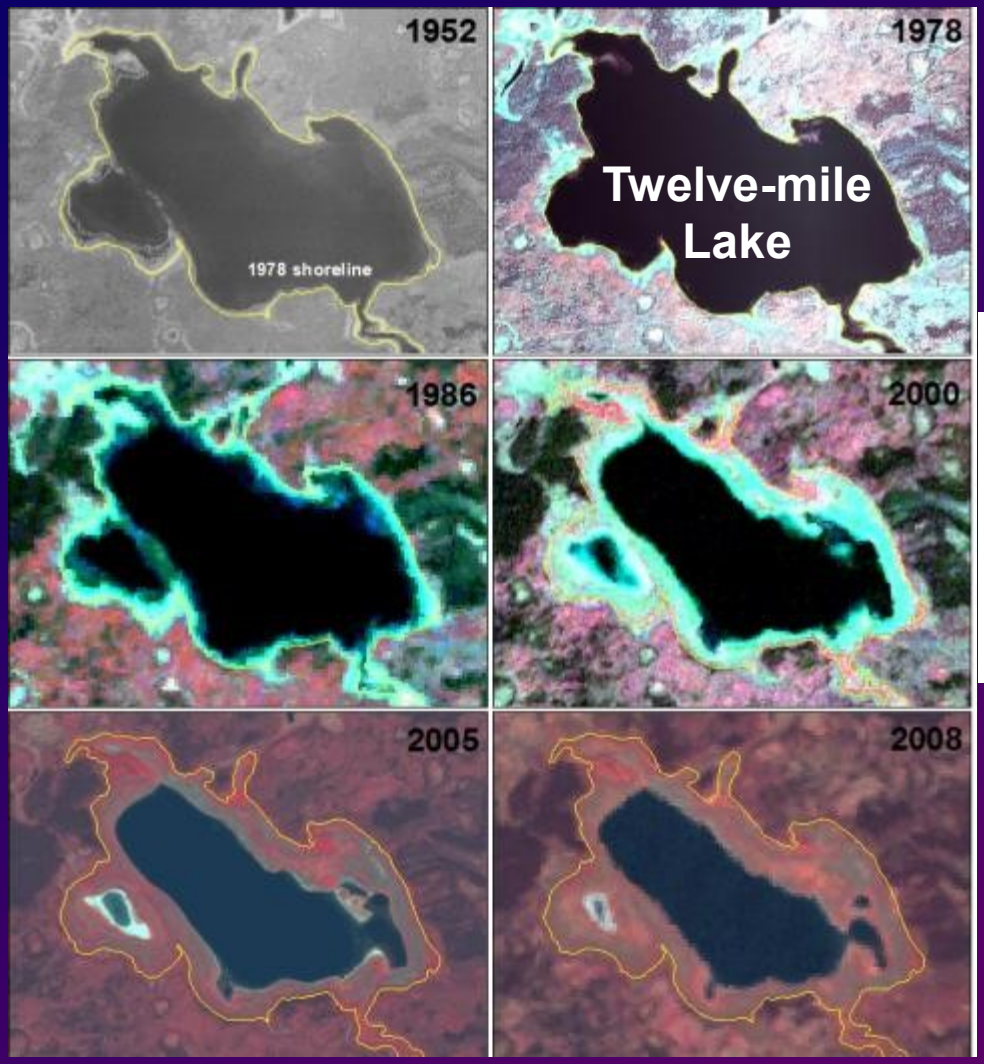
White Mountains

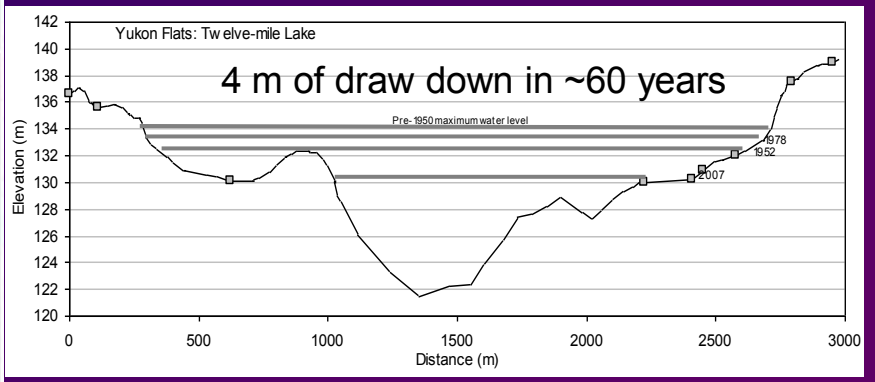
Sandy Lowlands

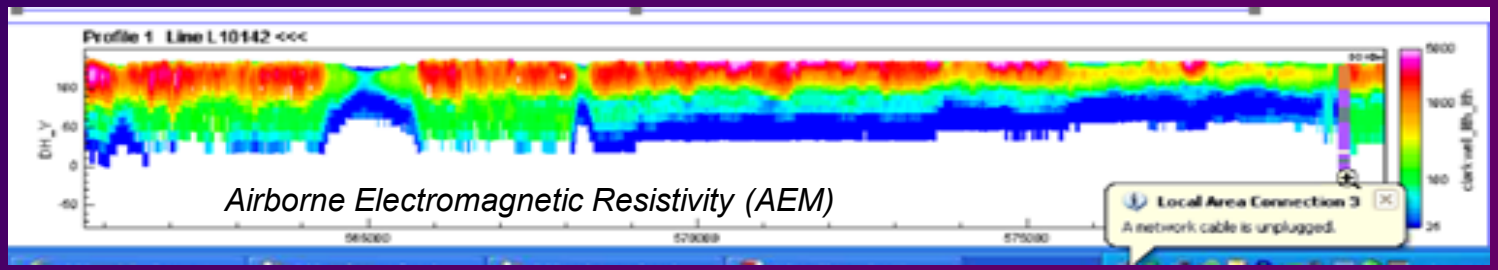
Water perched by permafrost aquatard
Formed on undulating sand sheet, not thermokarst

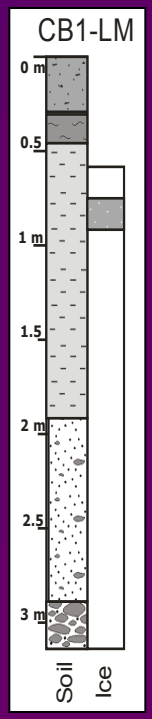
Yukon Flats

Lake drainage on the Yukon Flats in relation to thawing permafrost

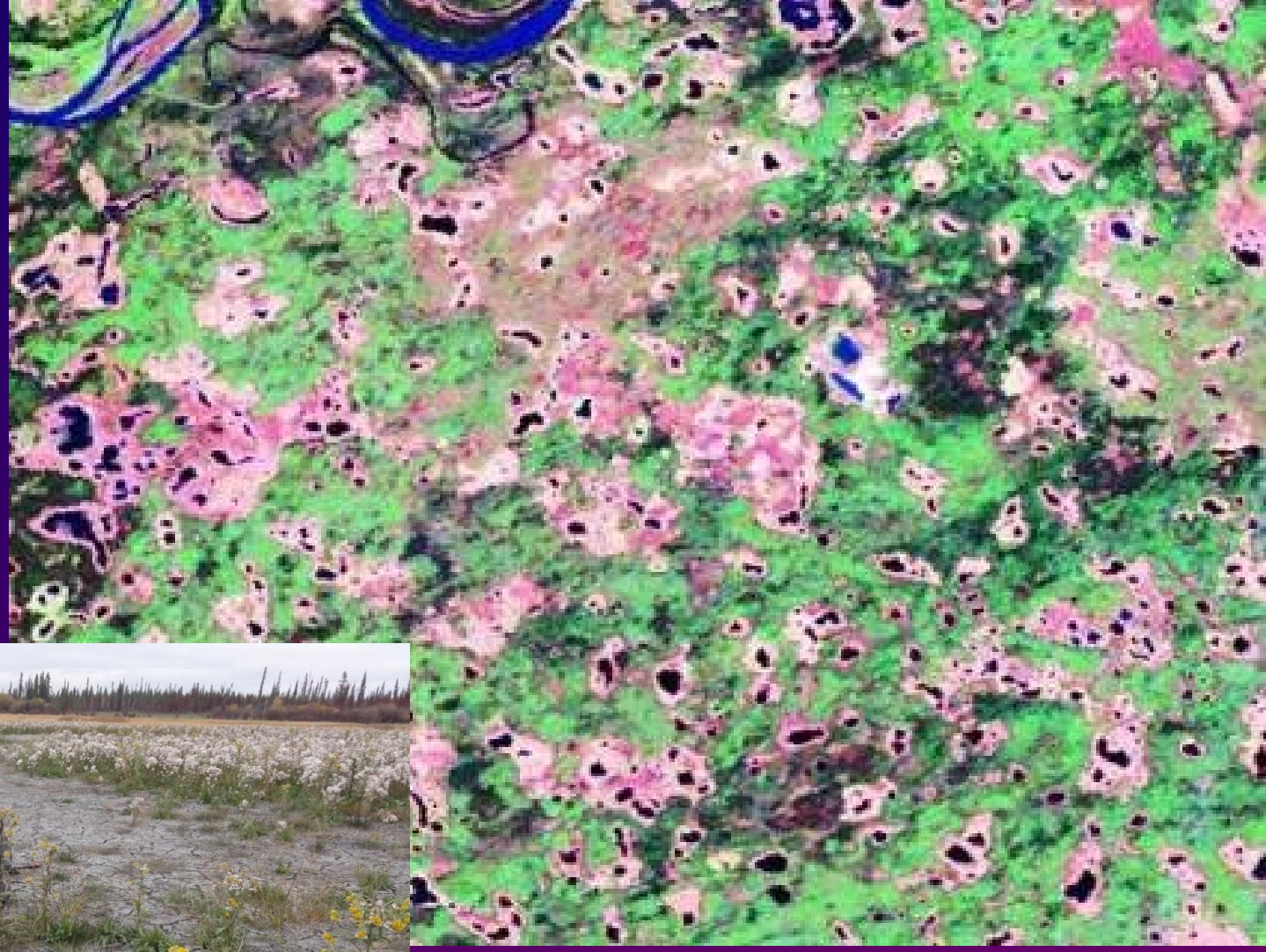








Minsley et al. - 2012 - Airborne electromagnetic imaging of discontinuous, GRL



Yukon Flats

Peaty Lowlands

Thermokarst Landforms:
Lakes
Bogs
Fens

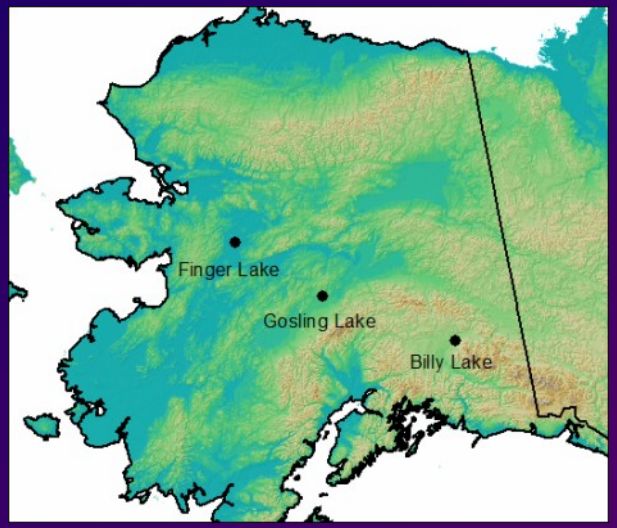
Innoko Flats

Hydrologic Reorganization and Ecological Shifts

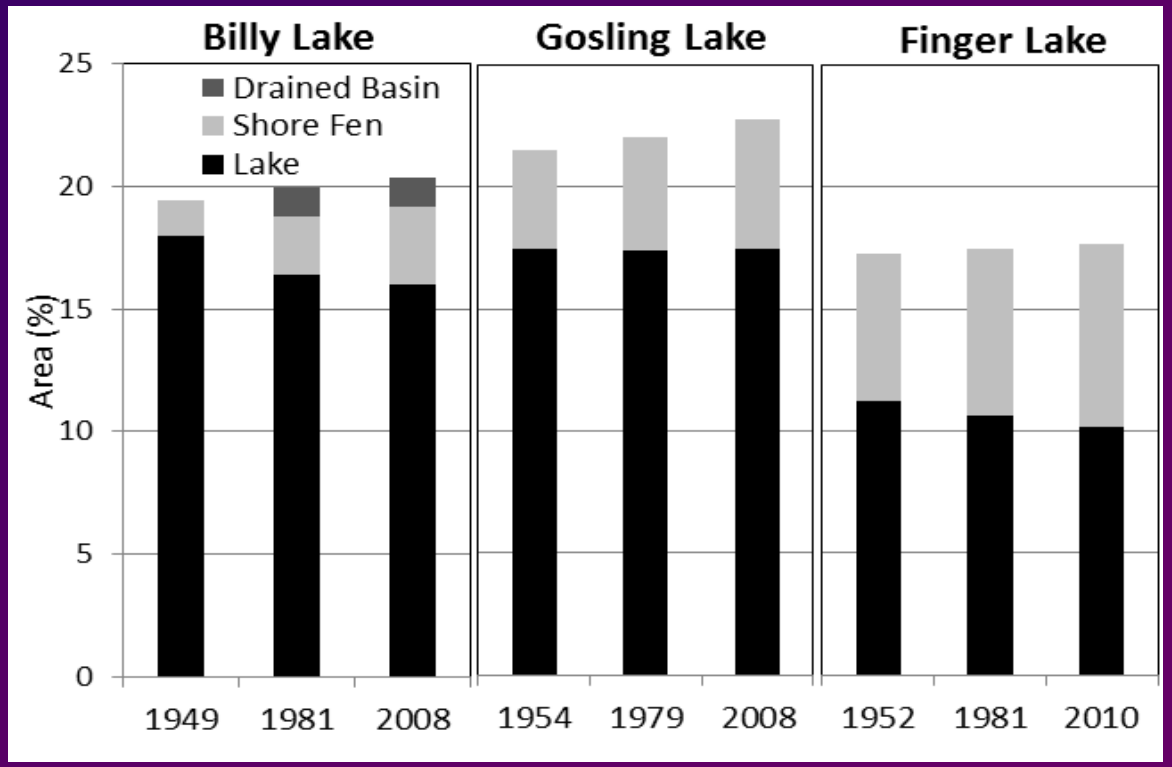
Innoko Flats

Epigenetic Ice in Lacustrine Sediments

Most Boreal Wildlife Refuges were designed around thermokarst lake habitat!!



Thermokarst Lakes and Shore Fens

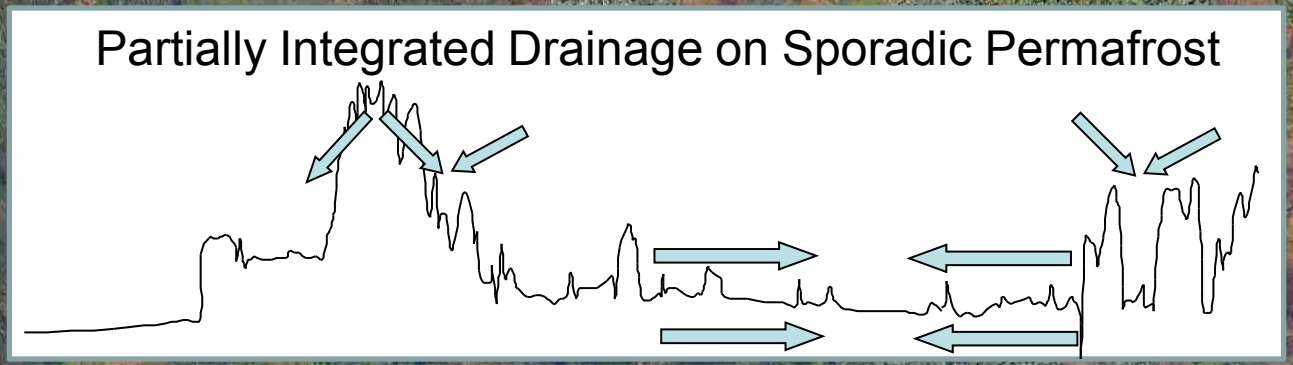


Thermokarst Fen, Tanana Flats

Moat

Groundwater mediated degradation

Thermokarst Bogs



Innoko Flats

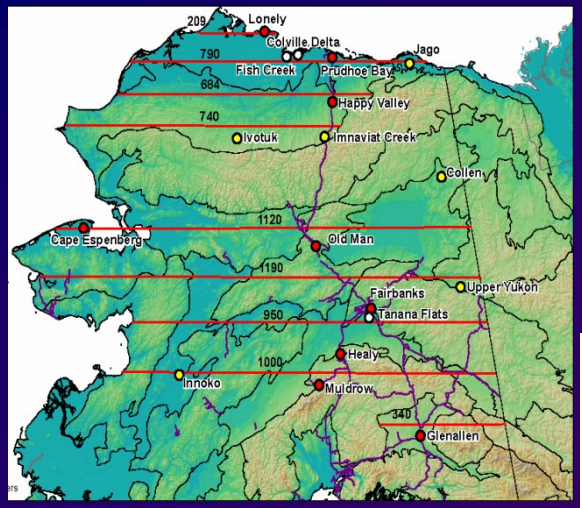
2010 Fire on Tanana Flats

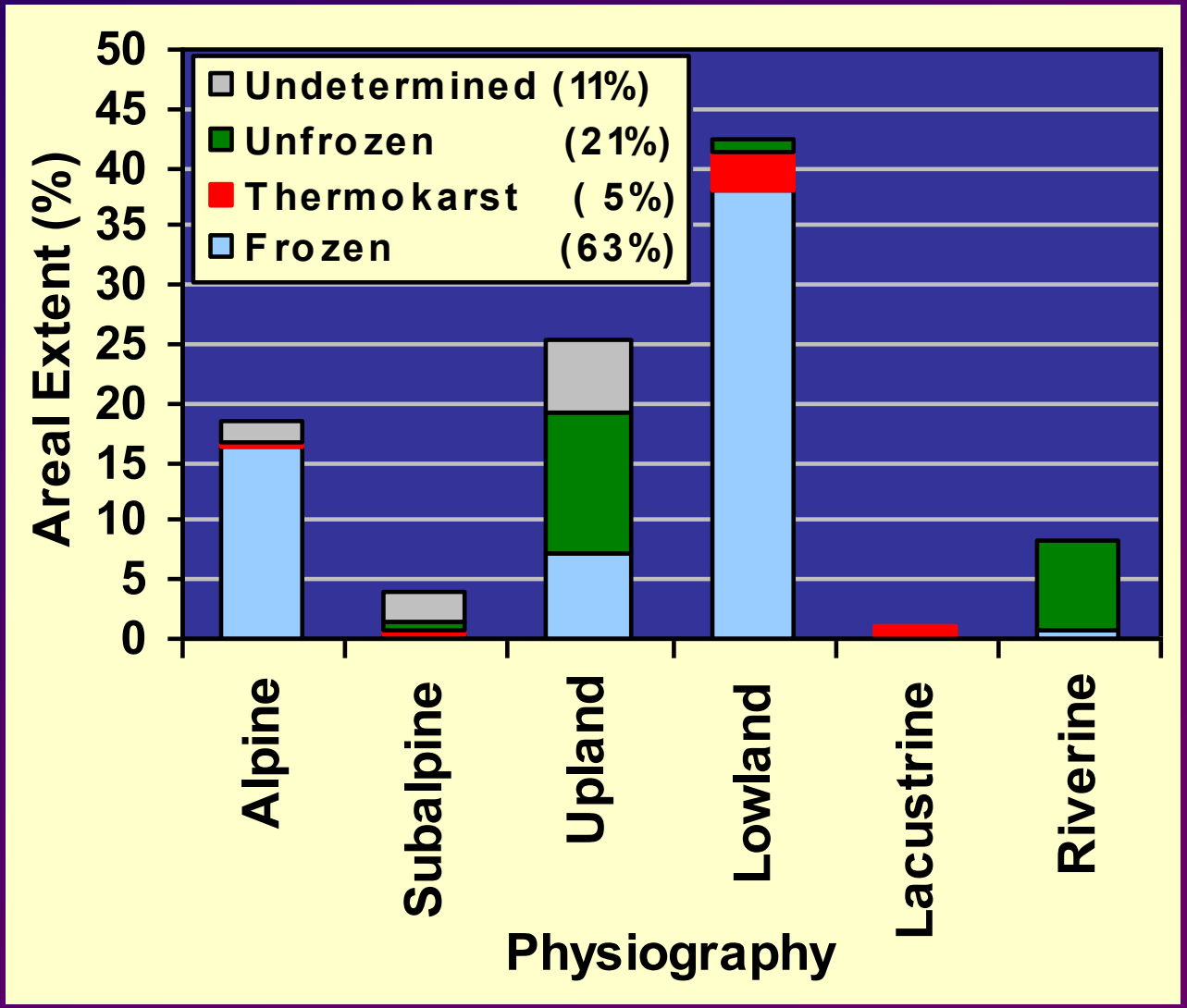
“warmer” permafrost with higher unfrozen water content may be more susceptible to rapid thawing

Fire-Permafrost Interactions: Thawing and Slope Stability

Active-layer detachment slides, Anuktuvuk River Fire

Extent of Thermokarst in Boreal Alaska





Jorgenson et al. 2008.
NICOP

Conclusions

- Permafrost dynamics are radically different across landscapes with differing topography and lithology.
- Differences in thaw, collapse, drainage and fire among landscapes have large effects on carbon and water stocks, and vegetation trajectories.
- Caution against extrapolating carbon and forest dynamics for particular landscape across broad regions. (Can have black spruce but…. responses very different).
- **Thermokarst landforms are diverse and cover 5% of boreal Alaska**
- **Extent of degradation in thaw stable uplands is unknown.**
- **Rates of thermokarst development are poorly known**