Arctic Infrastructure & Domain Awareness Research

within the

UAA College of Engineering
UNIVERSITY of ALASKA ANCHORAGE

Presented by

Aaron D. Dotson, P.E., Ph.D., Associate Professor

for

Thomas Ravens, Ph.D., Associate Dean of Research

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Hanover, NH, CRREL, May 16th – 18th, 2018

Permafrost Characteristics of Alaska

Torre Jorgenson, Kenji Yoshikawa, Mikhail Kanevskiy, and Yuri Shur
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Ben Jones
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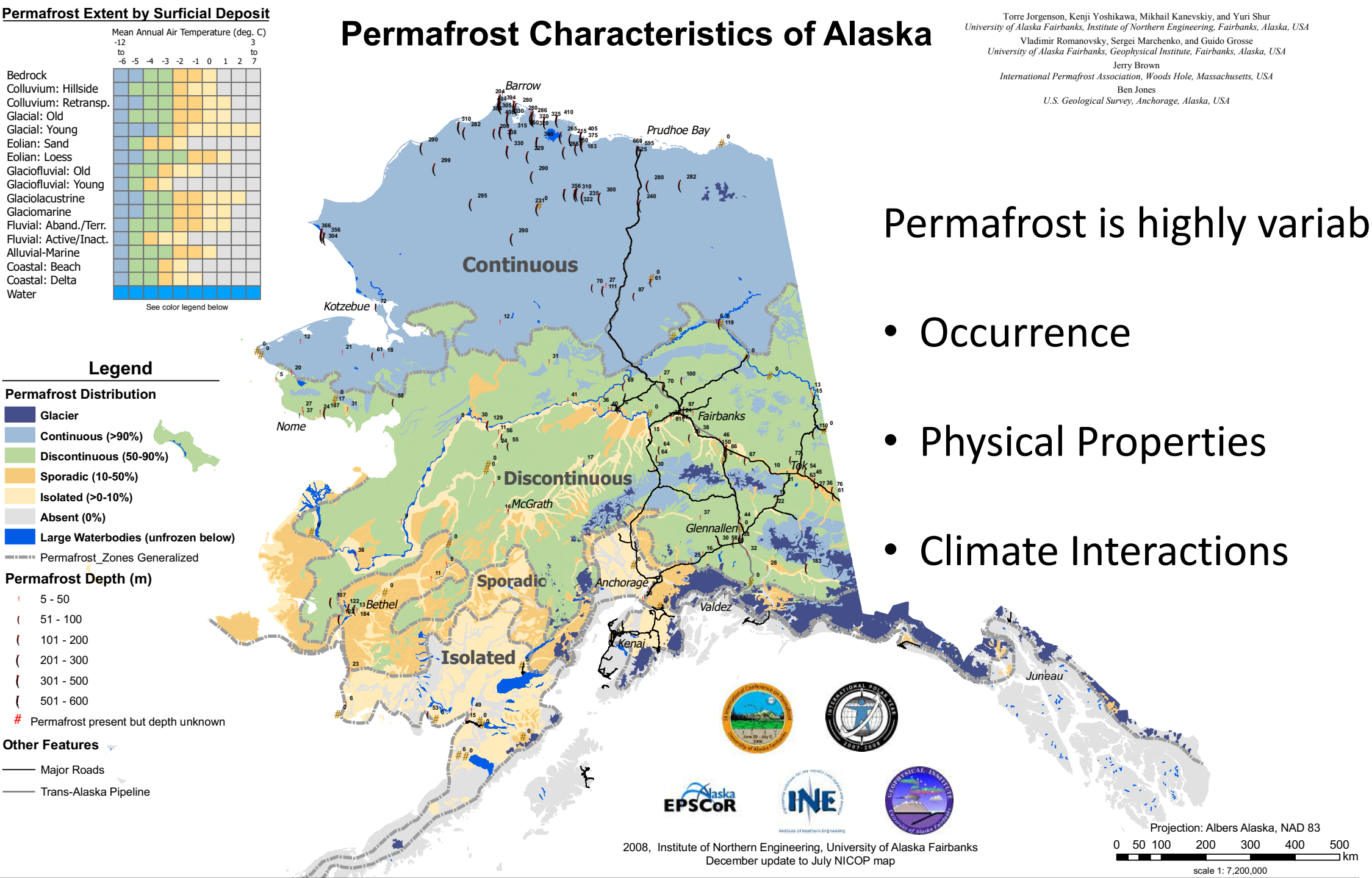

Permafrost is highly variable in its:

- Occurrence
- Physical Properties
- Climate Interactions

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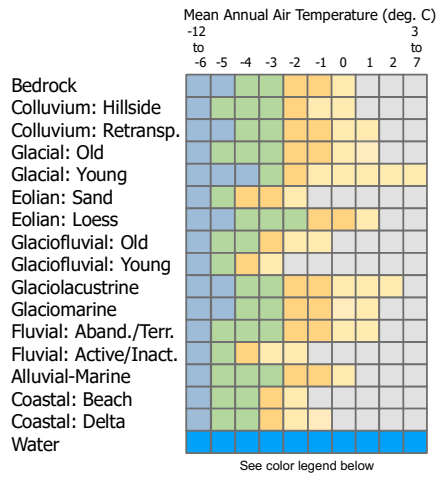
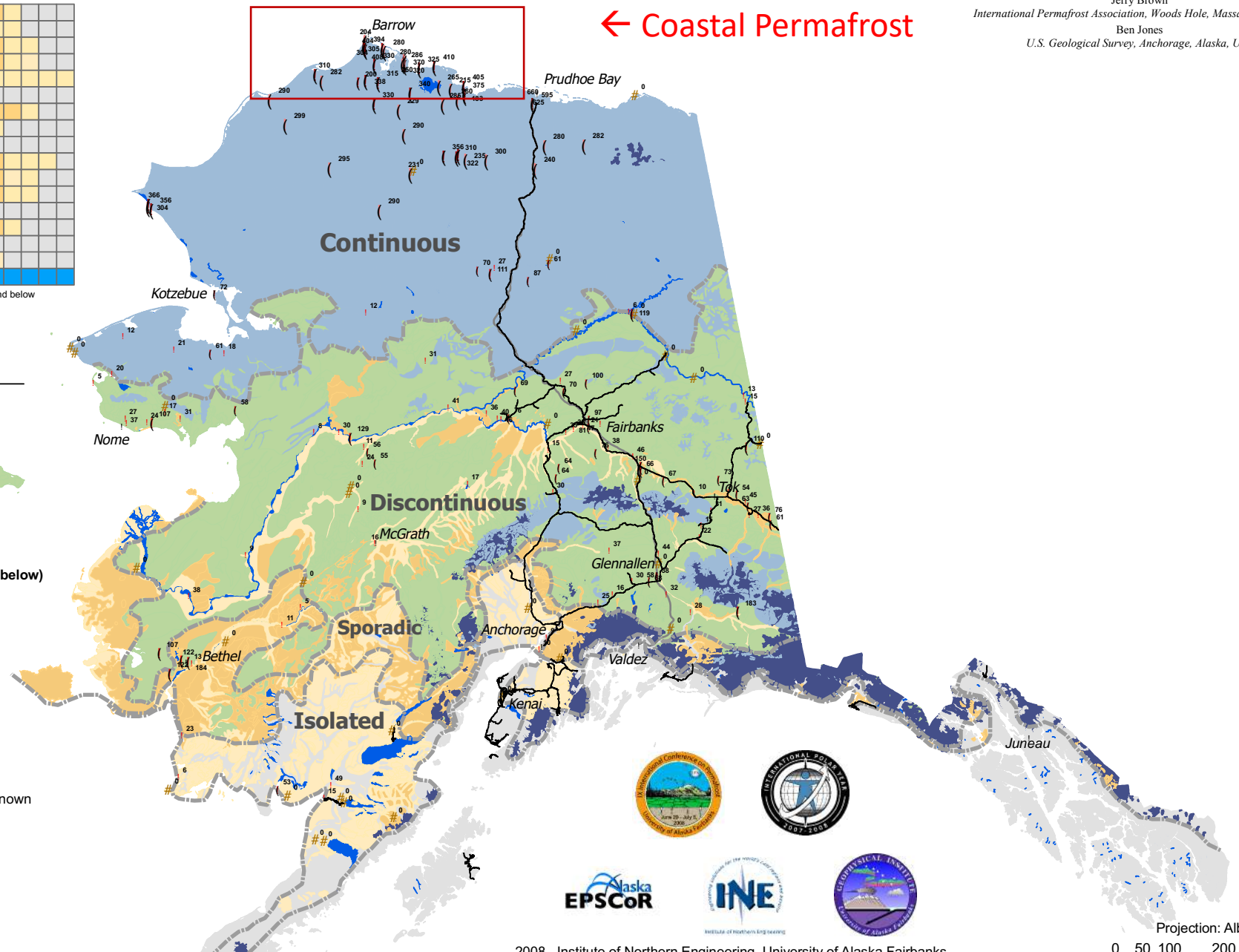
Permafrost Extent by Surficial Deposit



← Coastal Permafrost



Legend

Permafrost Distribution

- Glacier
- Continuous (>90%)
- Discontinuous (50-90%)
- Sporadic (10-50%)
- Isolated (>0-10%)
- Absent (0%)
- Large Waterbodies (unfrozen below)
- Permafrost_Zones Generalized

Permafrost Depth (m)

- 5 - 50
- 51 - 100
- 101 - 200
- 201 - 300
- 301 - 500
- 501 - 600
- # Permafrost present but depth unknown

Other Features

- Major Roads
- Trans-Alaska Pipeline

2008, Institute of Northern Engineering, University of Alaska Fairbanks
December update to July NICOP map

Projection: Albers Alaska, NAD 83

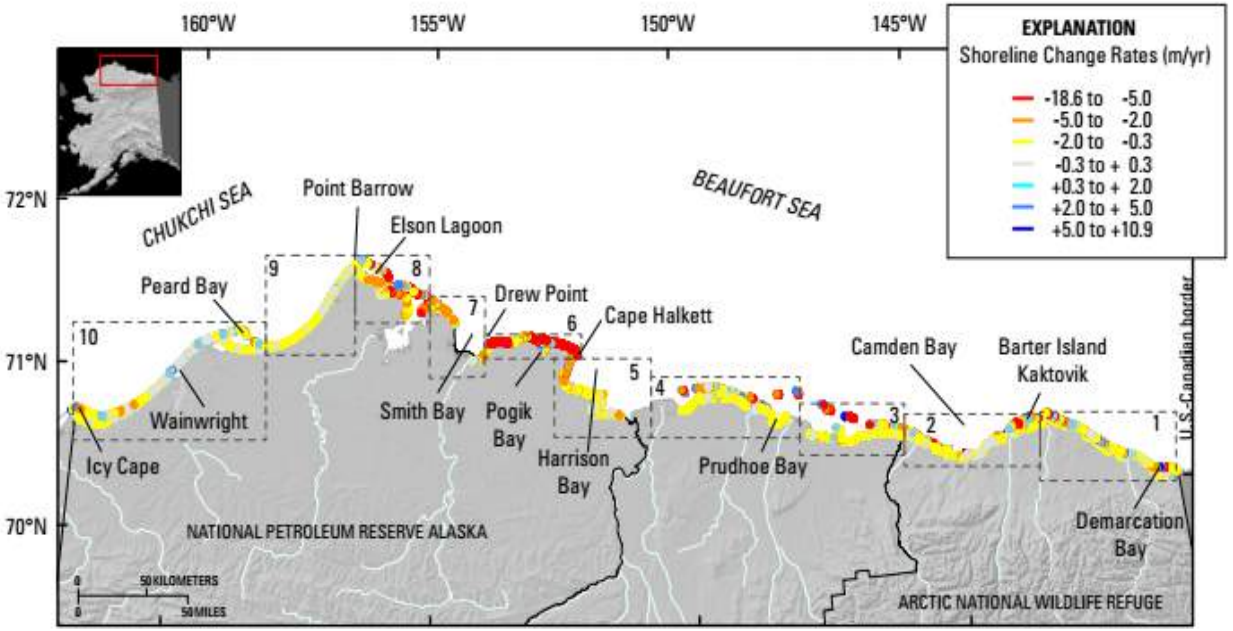
0 50 100 200 300 400 500 km

scale 1: 7,200,000

Arctic Coastal Erosion Rates and Mechanisms

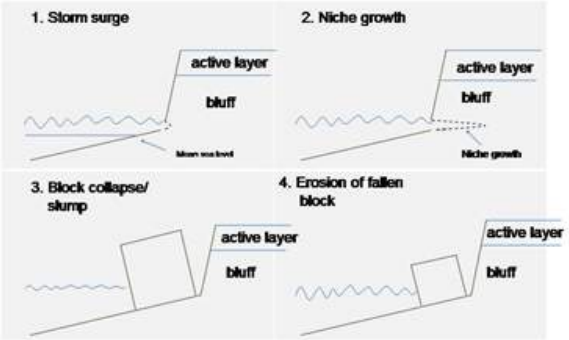
Niche erosion / block collapse

bluff face thaw / slump

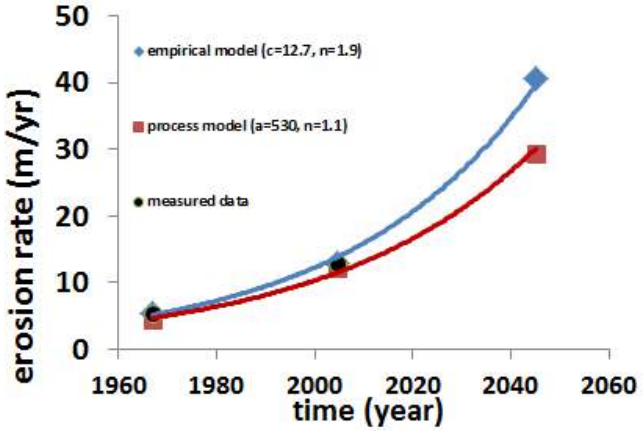


erosion rate

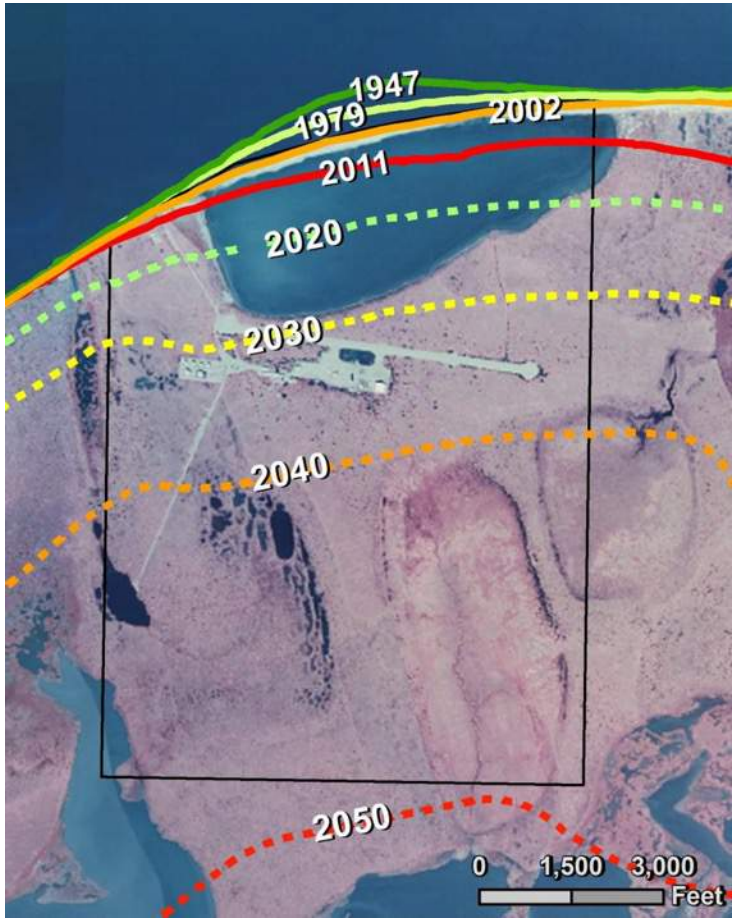
Process-based Arctic Coastal Erosion Modeling – niche erosion / block collapse at Drew Point



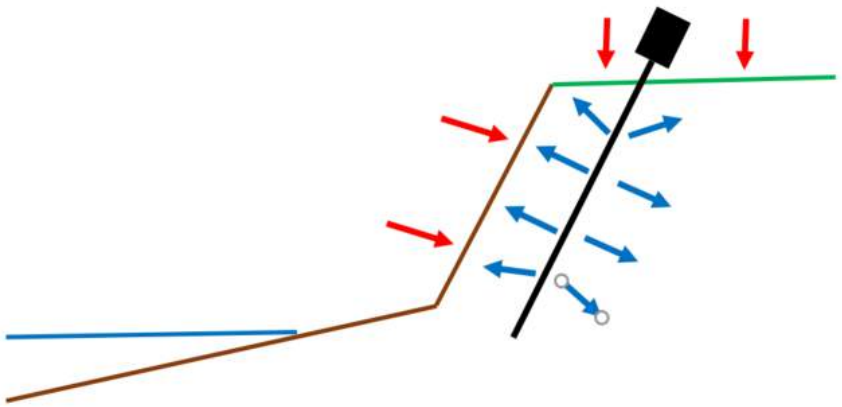
Time period	Measured erosion rate (m/yr)	Calculated erosion rate (m/yr)	Calculated fraction of time shoreline is block-free (%)
Aug. 1979 – July 2002	8.0 ± 0.9	8.0 ± 0.8	68 ± 3
Aug. 2002 - July 2007	14.1 ± 1.7	14.9 ± 1.4	78 ± 2



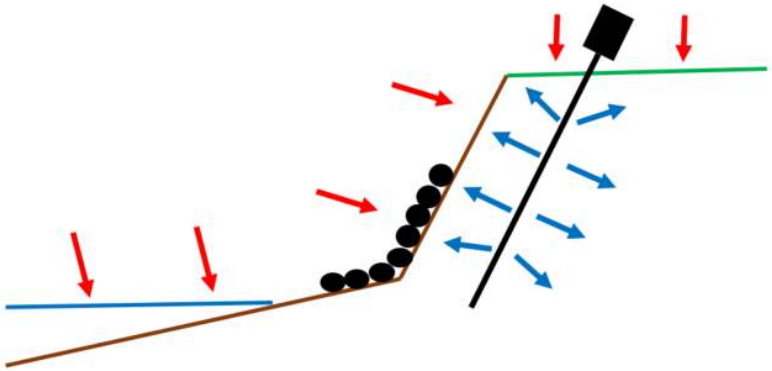
The environmental change is increasing coastal hazards like erosion and flooding, and causing loss of infrastructure, land, and security



Re-purposing the process-based coastal erosion model to be a coastal protection design tool, emphasizing thermal control of erosion.



Hybrid thermal siphon system



Hybrid thermal siphon system in conjunction with conventional rock revetment

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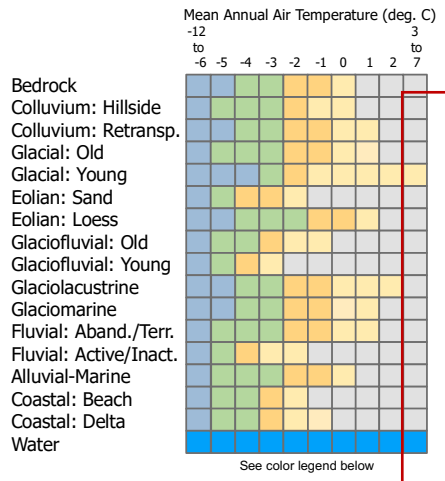

← North Slope

Barrow
Prudhoe Bay
Kotzebue
Nome
Fairbanks
Tok
McGrath
Glennallen
Anchorage
Valdez
Bethel
Kenai
Juneau

Continuous
Discontinuous
Sporadic
Isolated

Legend

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Temporary Infrastructure

- Pile Load Tests Using Spiral Legs to support Temporary Drilling Platform
  - Took place in Prudhoe Bay, AK
  - Could be repeated anywhere where removal of foundations is important

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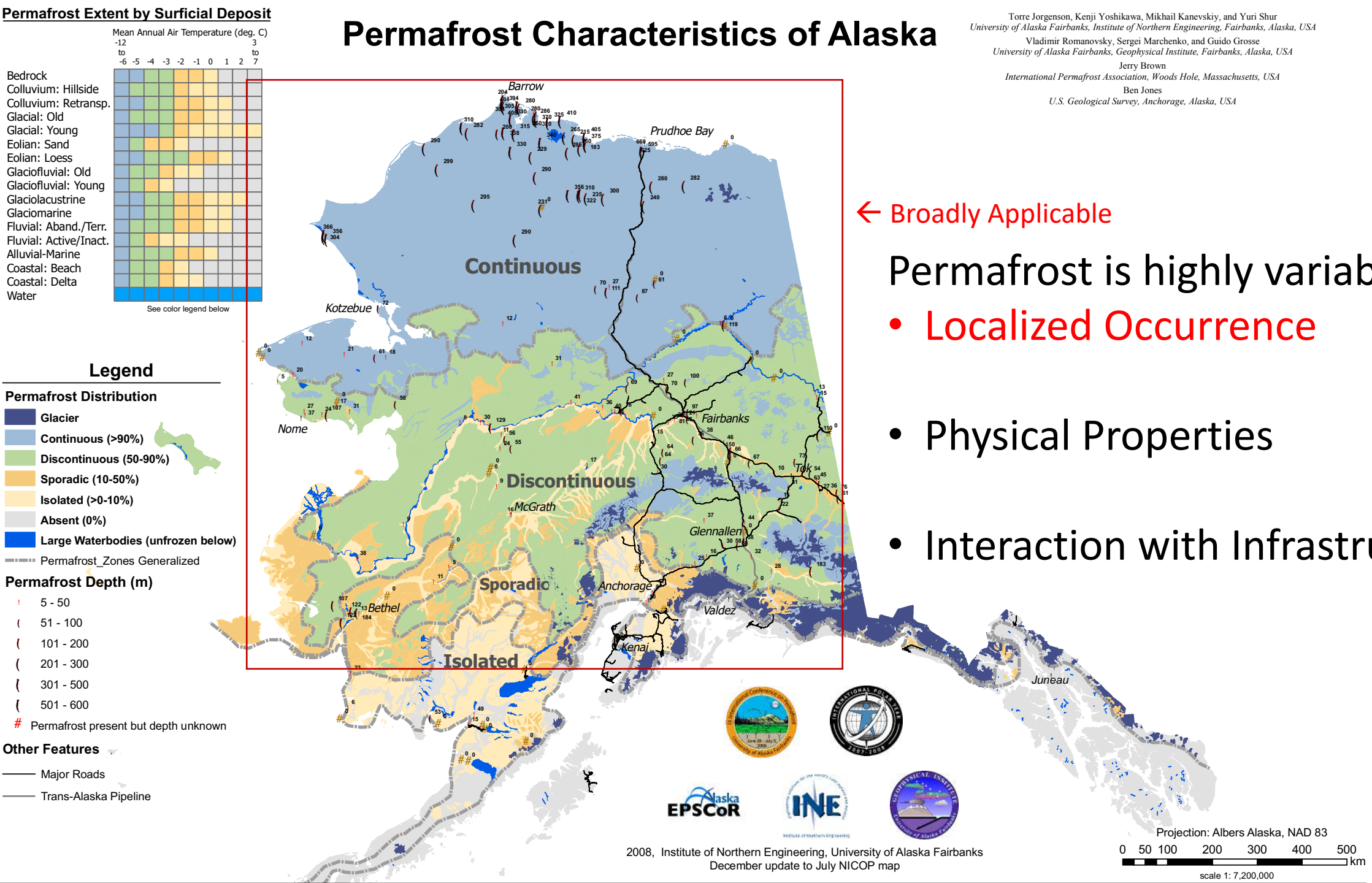


← Broadly Applicable

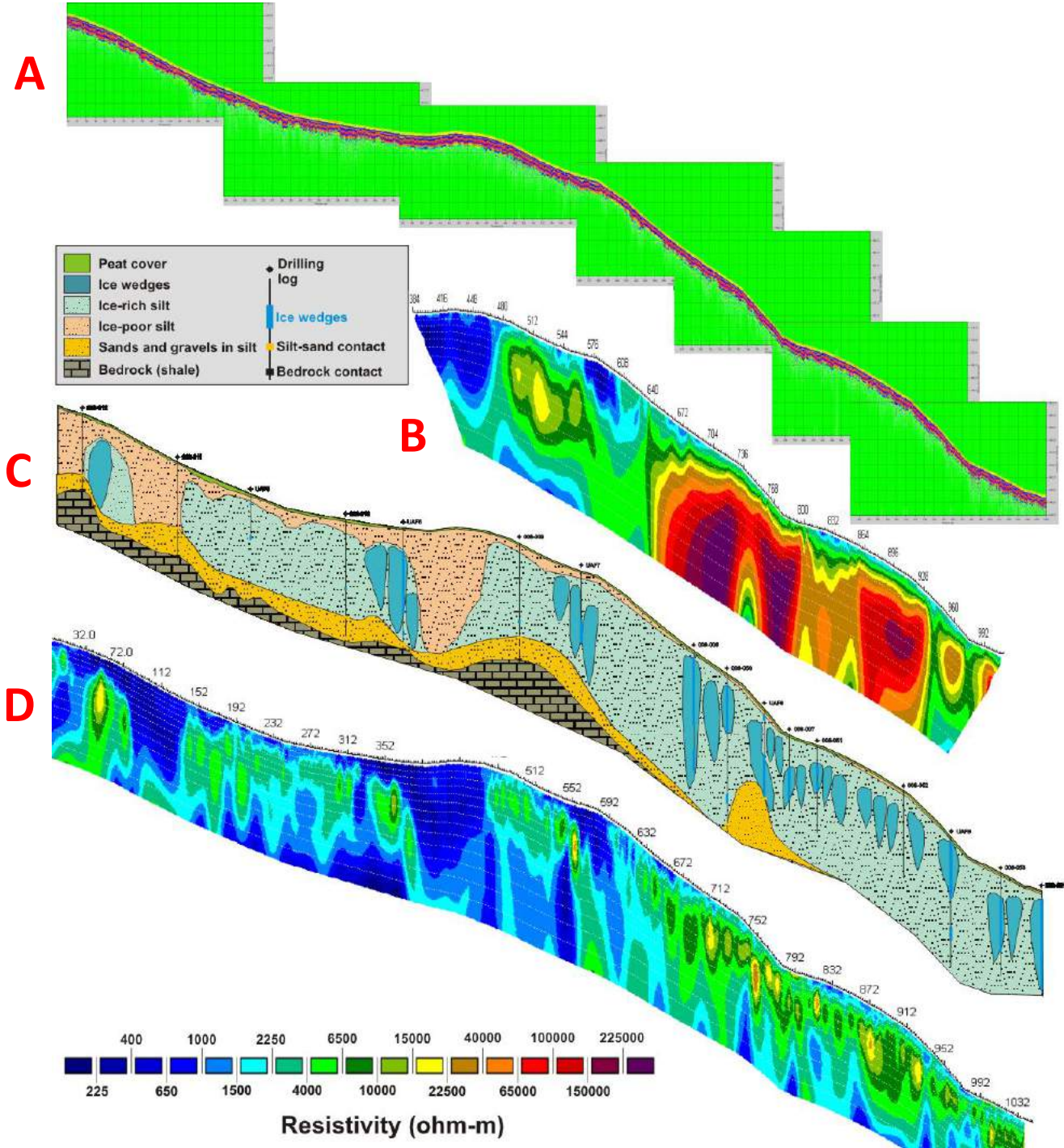
Permafrost is highly variable in its:

- Localized Occurrence
- Physical Properties
- Interaction with Infrastructure

Localized Occurrence

Geophysics – Goldstream Road
Fairbanks, AK

a) Ground Penetrating Radar
b) DC – Electrical Resistive Tomography
c) Conceptual model
d) CC – Electrical Resistive Tomography



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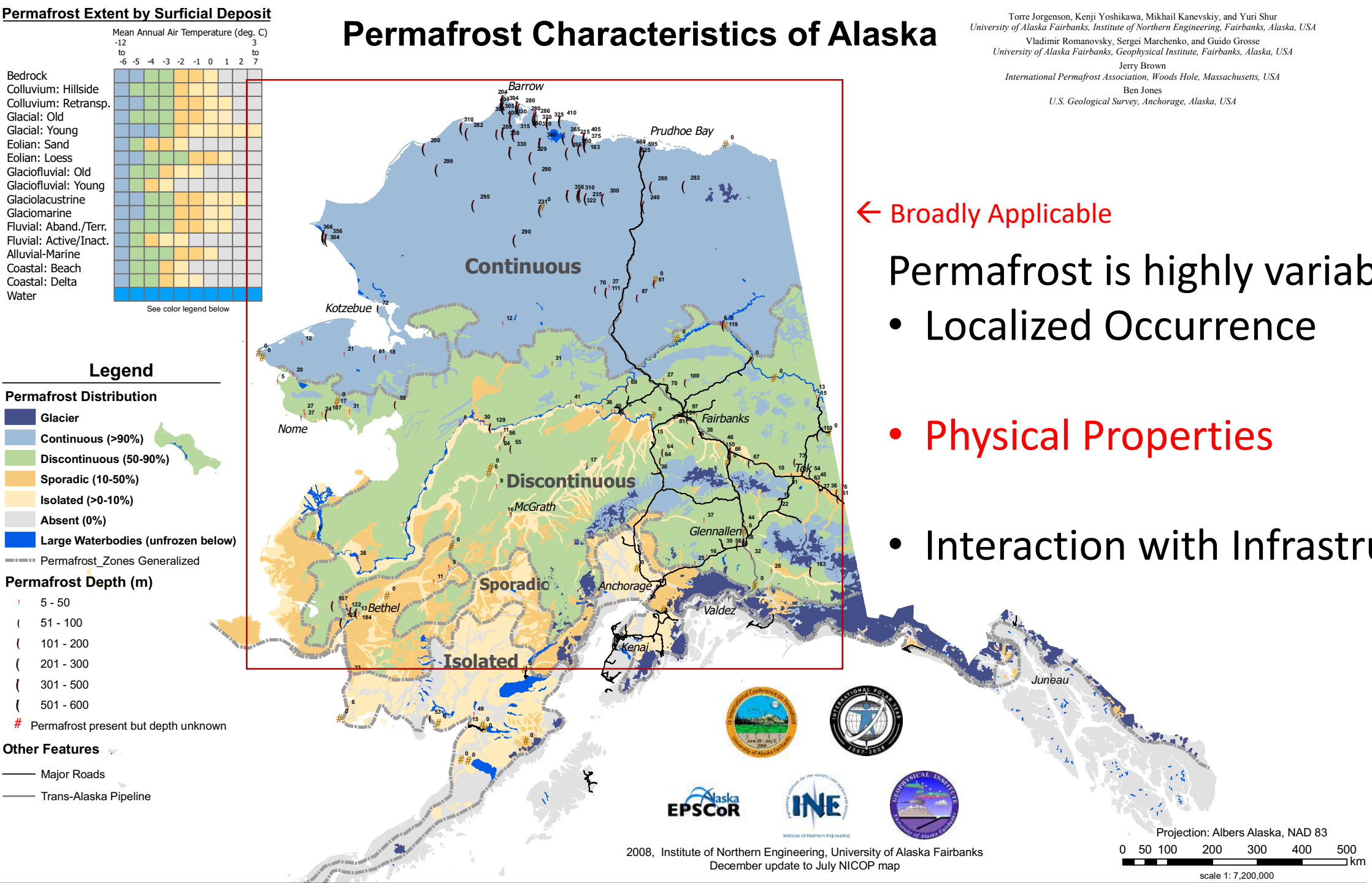

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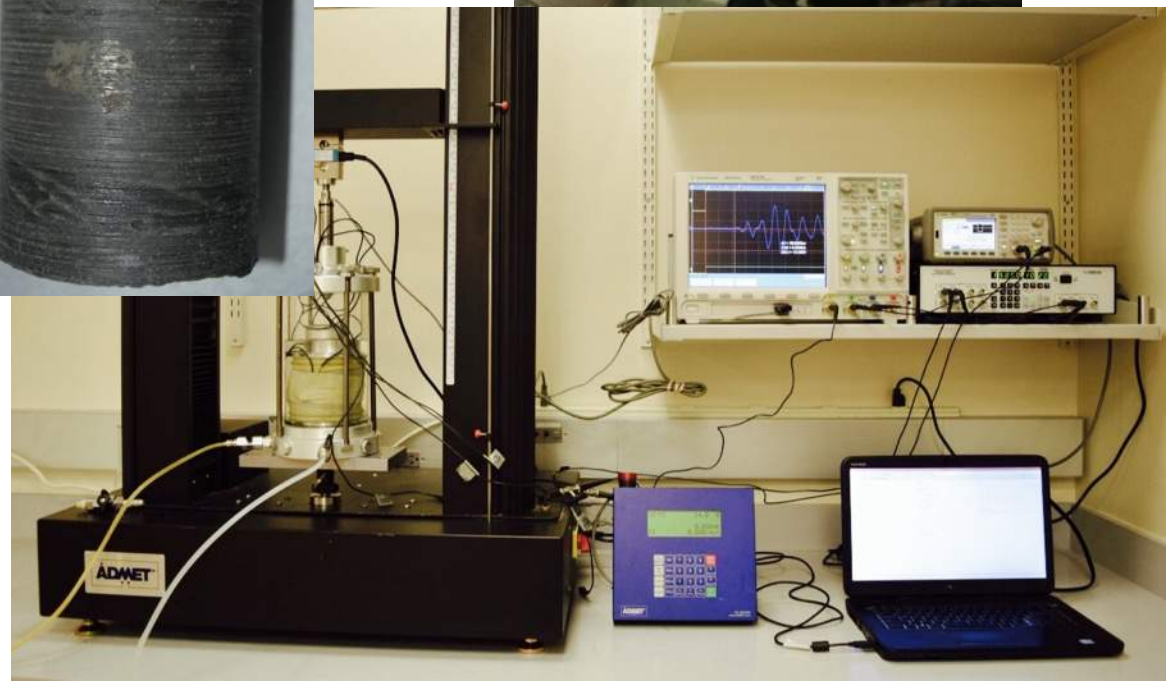
Quantifying Structure of Frozen Soils

- Cold room facilities for permafrost specimen preparation
- Lab for permafrost mechanical and creep property testing
- Permafrost thermal property during thawing including salinity effects



Simulating Fluid-thermal-structure interaction

Types of Potential Studies

- Heat transfer and phase change of permafrost;
  - Fluid motion in porous media;
  - Transport of water and water soluble components;

- Correlating water and permafrost properties;
- Dynamic mesh for subsidence and frost heaving.

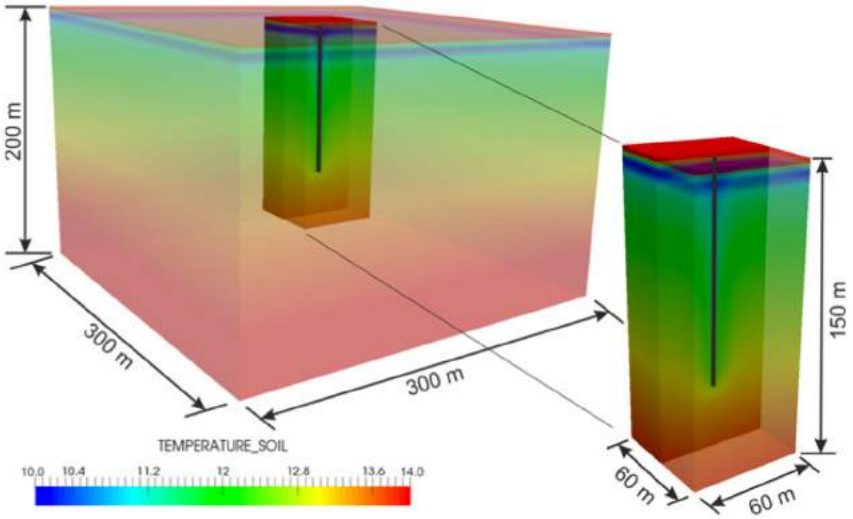


Image from: https://www.ufz.de/index.php?en=37482

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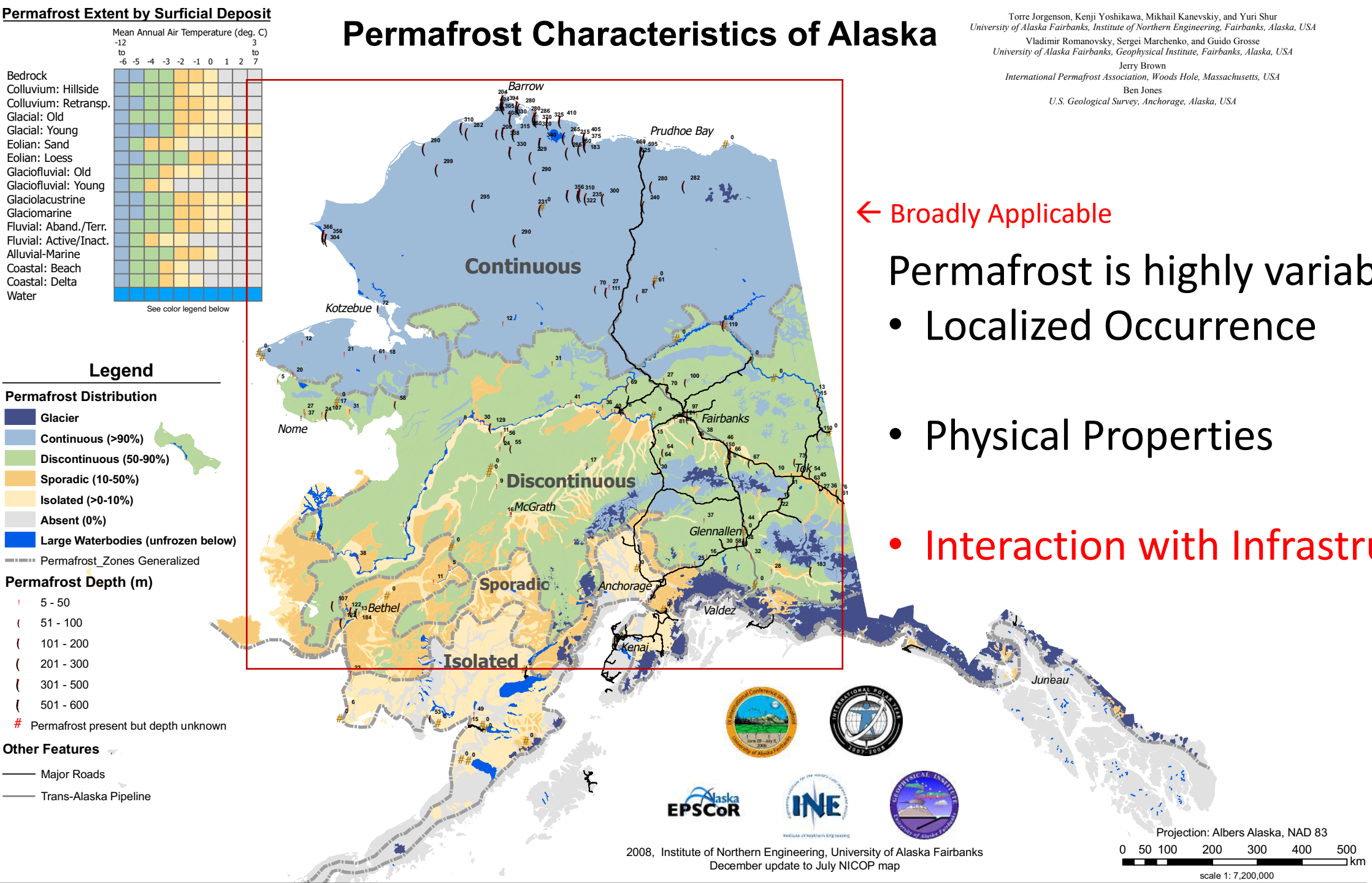

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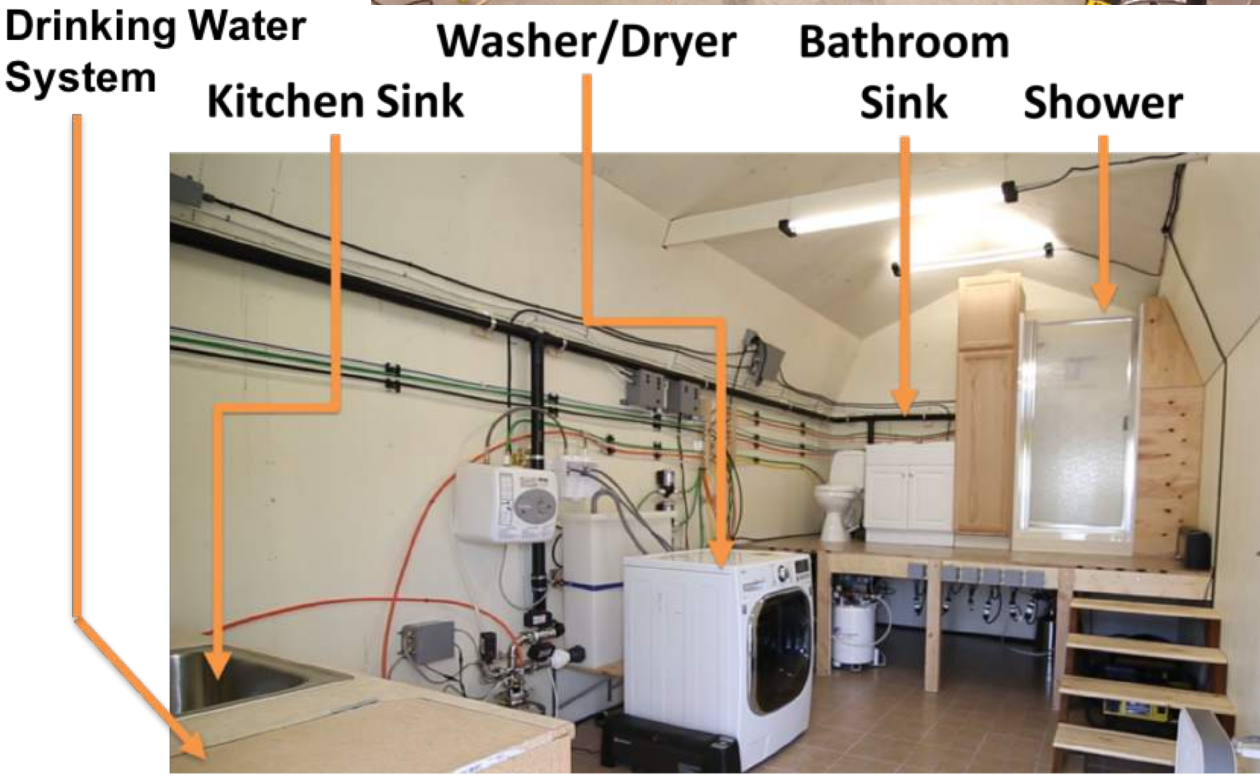
Piped Water & Sewer Infrastructure

Today's Challenges

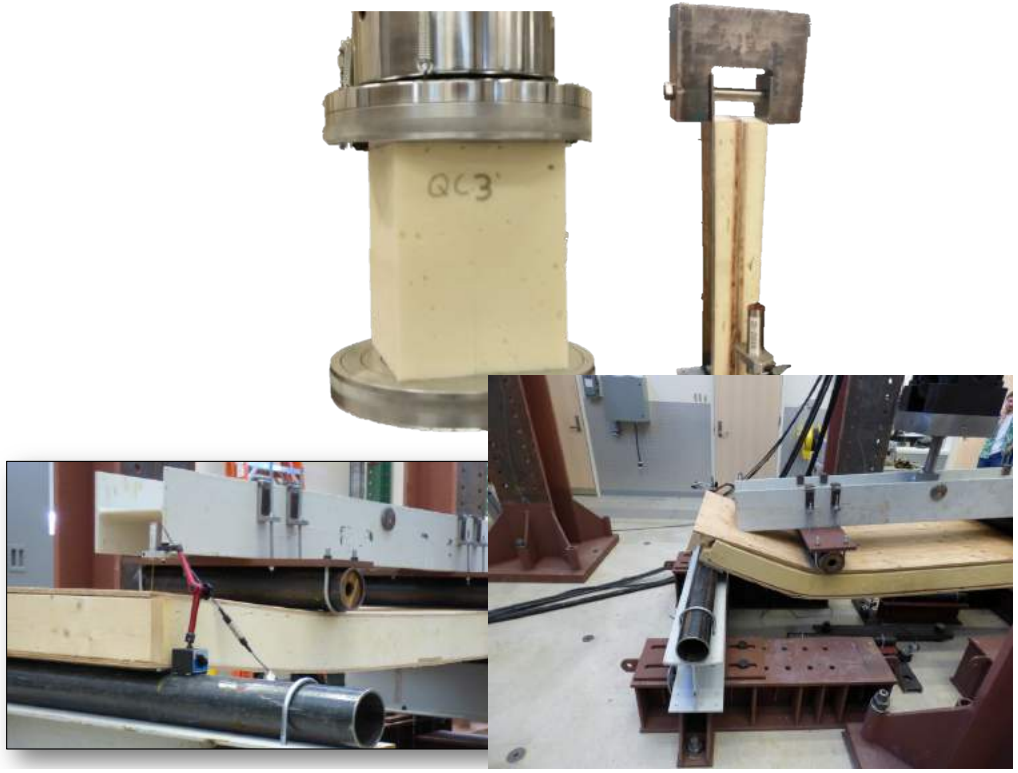
Modular Water & Wastewater Systems

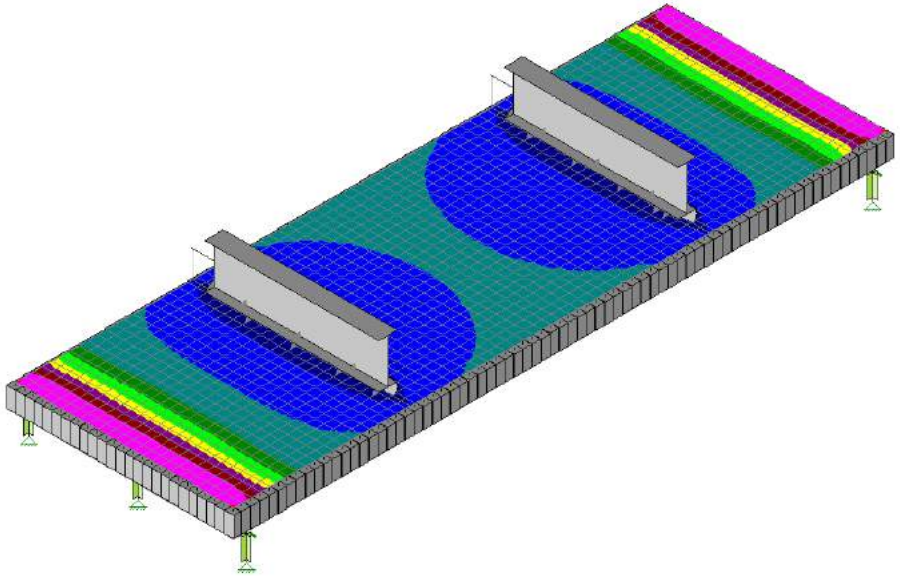


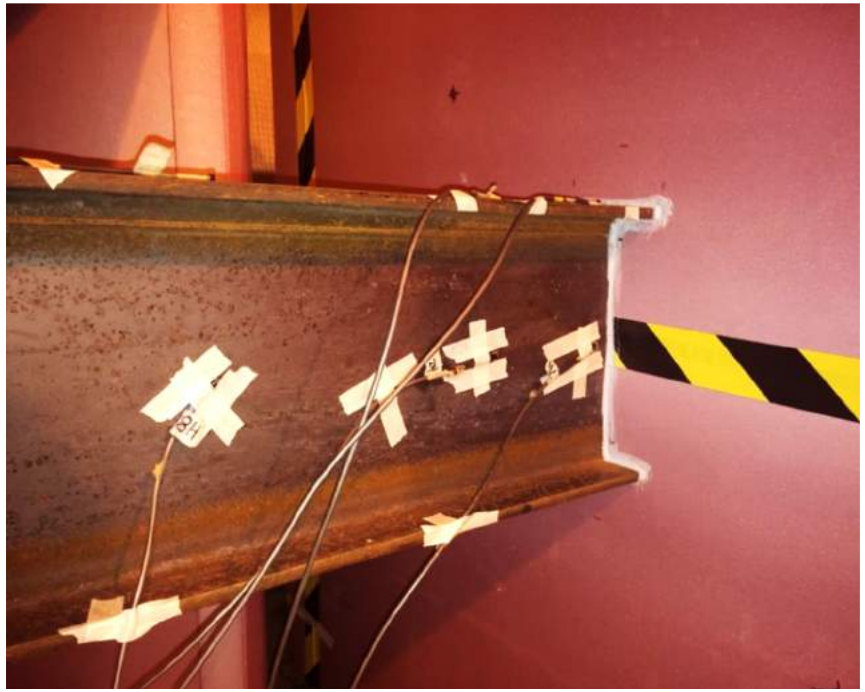
Adaptive Building Systems

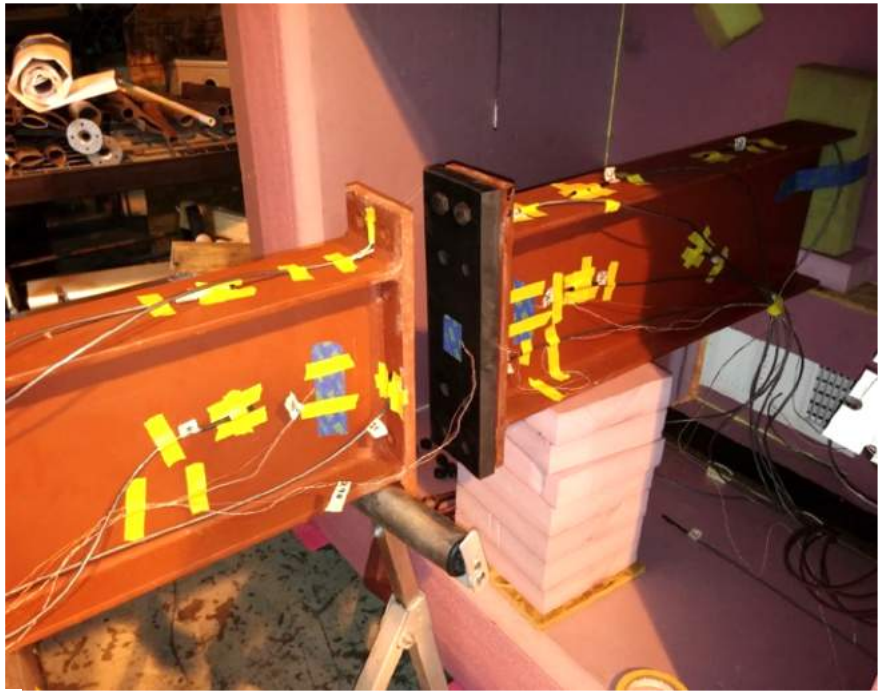
Common on-grade construction → New concepts for modern materials

Testing to Modeling

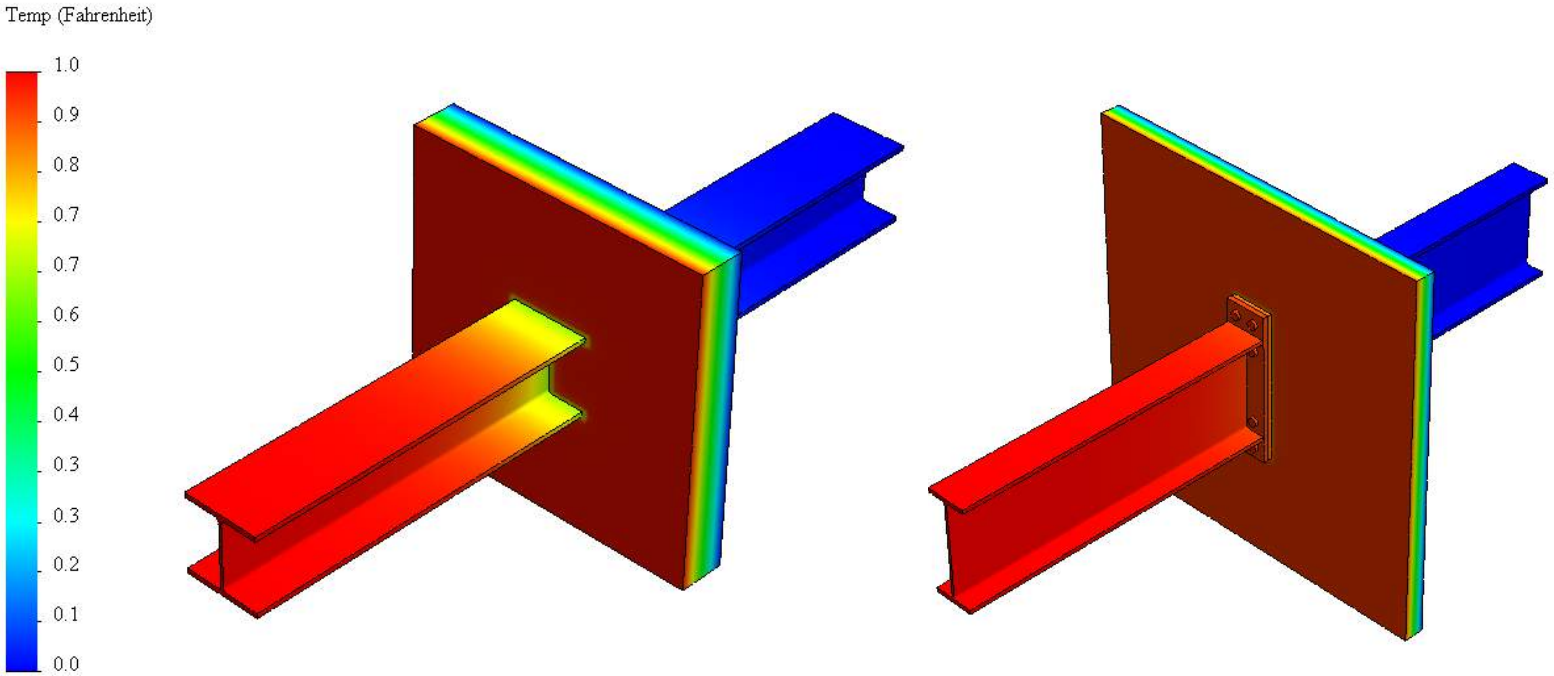


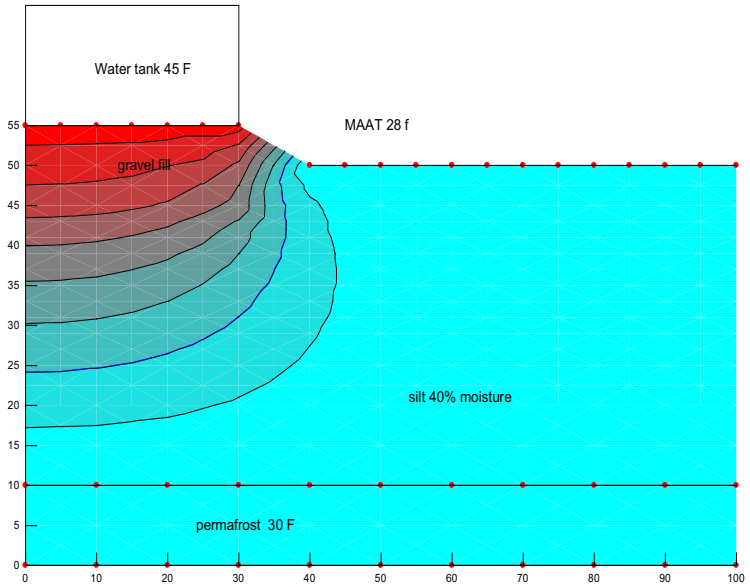






Integration of Thermal Modeling





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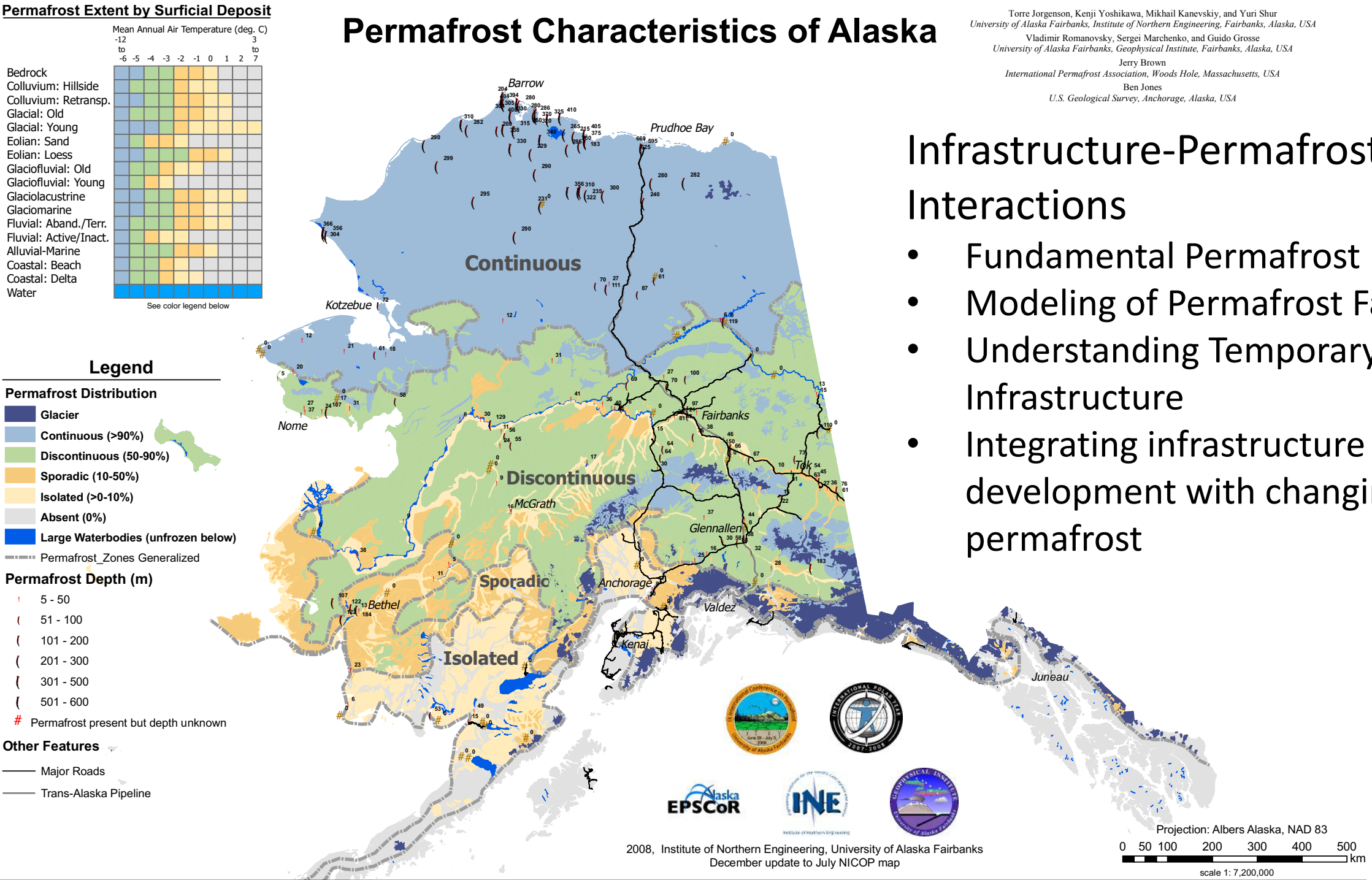

Infrastructure-Permafrost Interactions

- Fundamental Permafrost Knowledge
- Modeling of Permafrost Fate
- Understanding Temporary Infrastructure
- Integrating infrastructure development with changing permafrost

Thank you for allowing me to share!

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Research Presented

Thomas Ravens, Civil Engineering – Coastal Erosion & Sediment Transport
Hannele Zubeck, Civil Engineering – Temporary Foundations
Jens Munk, Electrical Engineering - Geophysics
Joey Yang, Civil Engineering – Mechanical Properties of Frozen Soils
Jifeng Peng, Mechanical Engineering – Fluid Flow in Permafrost
Aaron Dotson, Civil Engineering – Modular Water/Wastewater/Water Reuse
Scott Hamel, Civil Engineering – Adaptive Building Systems