



Challenges from Climate Change to All Season Roads in Canada

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Synopsys

- What is Permafrost?
- Canadas North and Associated Transportation Infrastructure
- Climate Change in the Arctic
- Challenges to Road Infrastructures
- Mitigation Options
- Conclusions

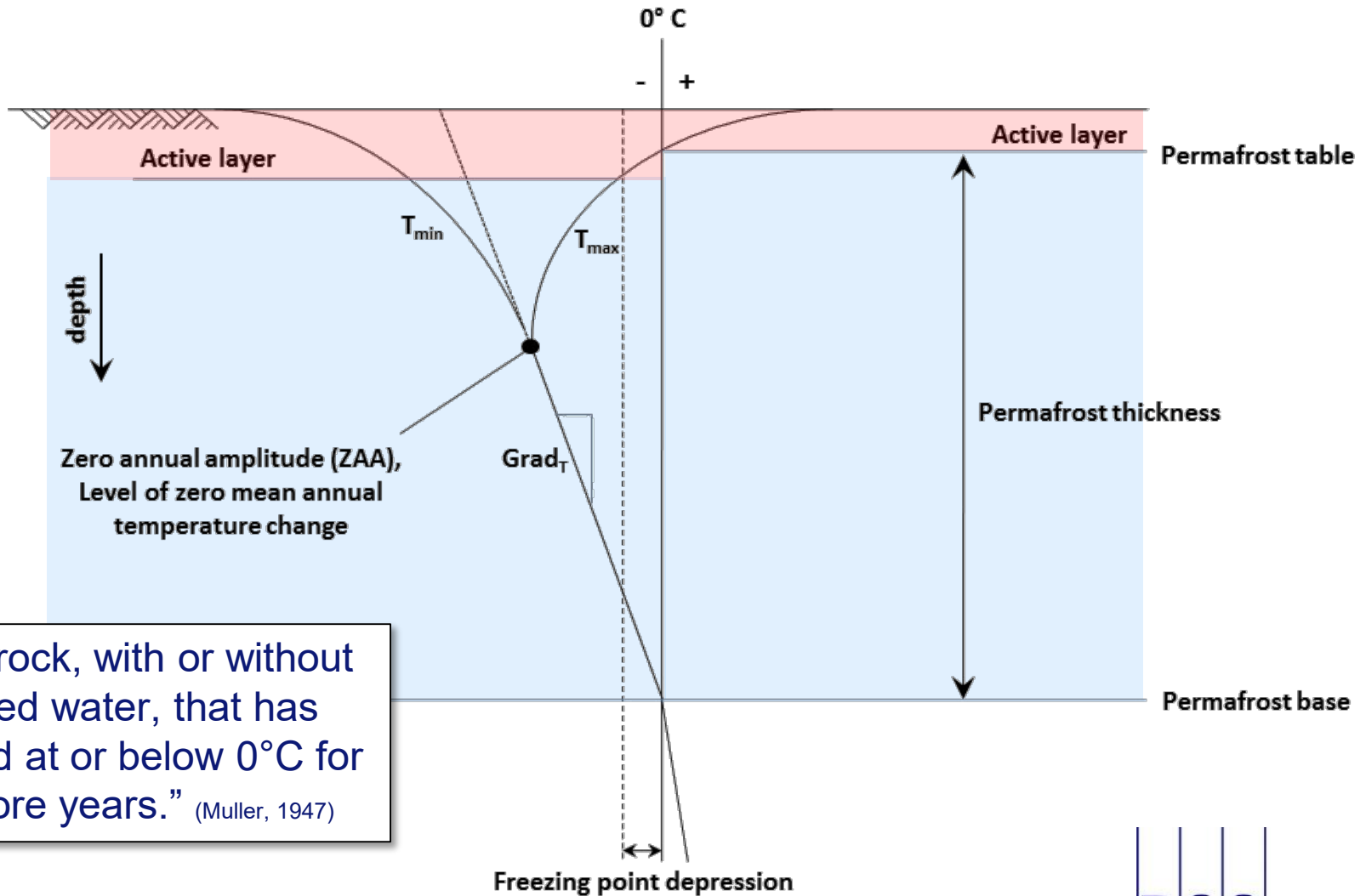


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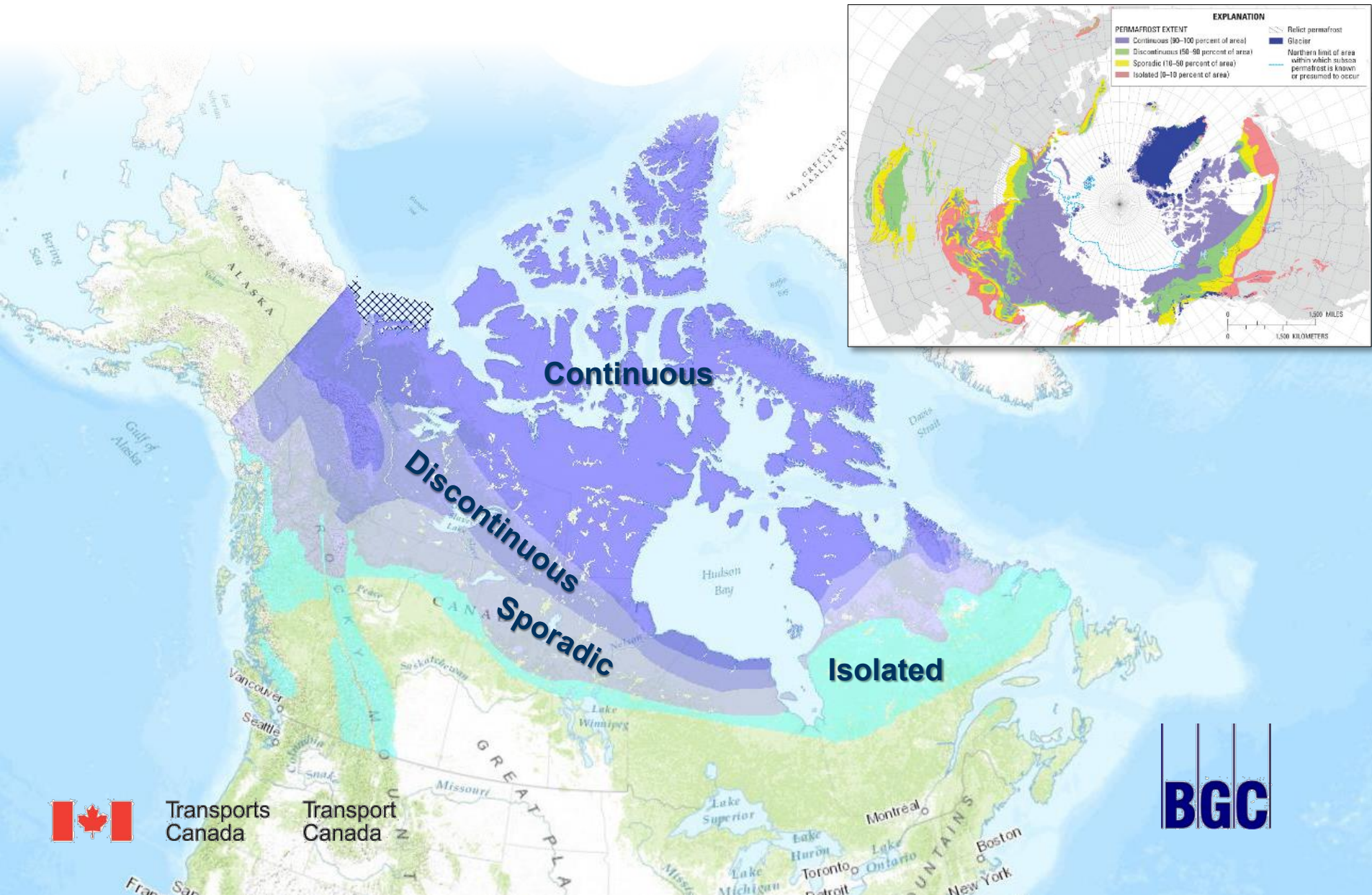
Permafrost



“Soil or rock, with or without included water, that has remained at or below 0°C for 2 or more years.” (Muller, 1947)



Permafrost Distribution



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Highway System in Canada



Typical Design Concept

- Protect the Permafrost
- Drainage Control



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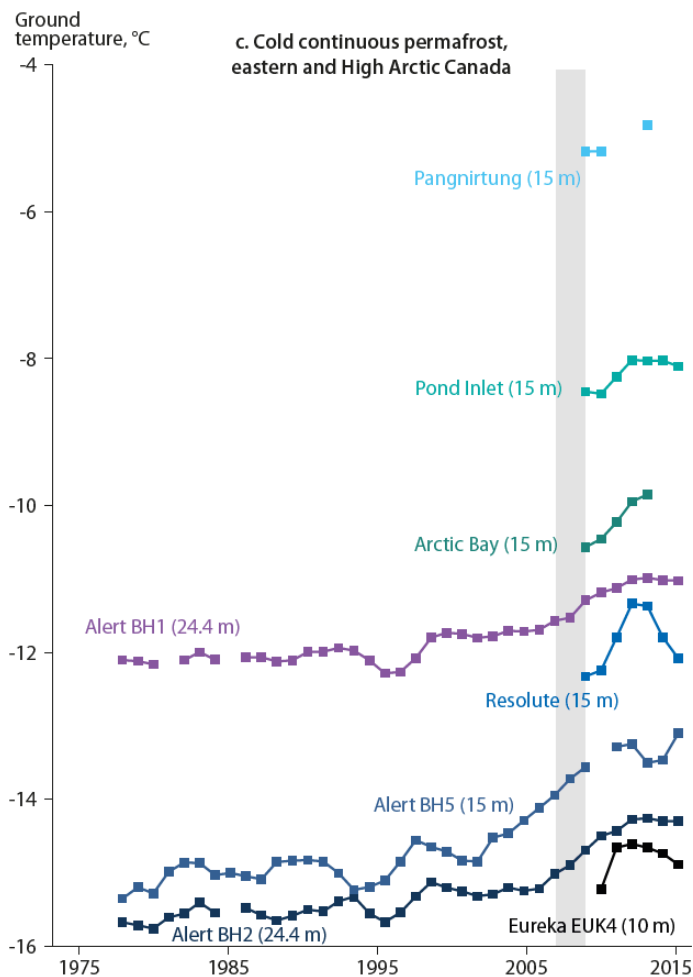
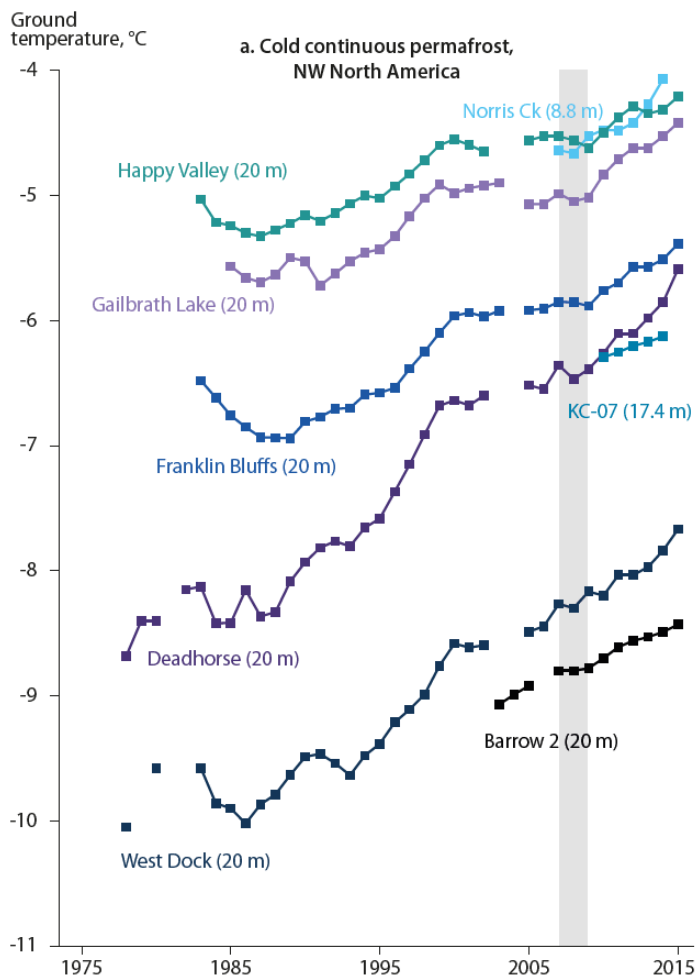
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State of Climate - Canada

- Both past and future warming in Canada is about **double the magnitude of global warming**
- Northern Canada has warmed and will continue to warm at **even more than double the global rate**
- Precipitation has increased in many parts of Canada, and there has been a shift toward less snowfall and more rainfall
- Reductions in summer rainfall are projected for parts of southern Canada
- Extreme rainfall amounts will go 30-40% and the frequency of extreme hourly rainfall will go ~400%
- Extreme warm temperatures have become hotter
- Increased risk of water supply shortages in summer
- Coastal flooding is expected to increase in many areas of Canada due to local sea level rise



Permafrost Temperatures



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Ground Temperatures / Permafrost

- Affected by air temperature and rate of change
 - E.g. +1°C in 10 years vs. +1°C in 50 years
- But also other parameters including
 - Snow Cover (Drift)
 - Precipitation (pattern)
 - Vegetation / Evaporation / Snow (re)distribution
 - Hydrology / Freshet / Aufeis
 - Cloud Cover / Solar Radiation



Why is it so Challenging?

- Design and construction of infrastructure in permafrost is challenging even w/o climate change.
- Every structure affects the thermal regime with a varying degree of uncertainty.
- Uncertainties related to climate change are very high because of higher order effects.
- Design is not based on average conditions.



External Hazards

Retrogressive
thaw slump



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Dempster Highway, NWT ~km 30



Icing / Aufeis - Drainage



Coffey 2018



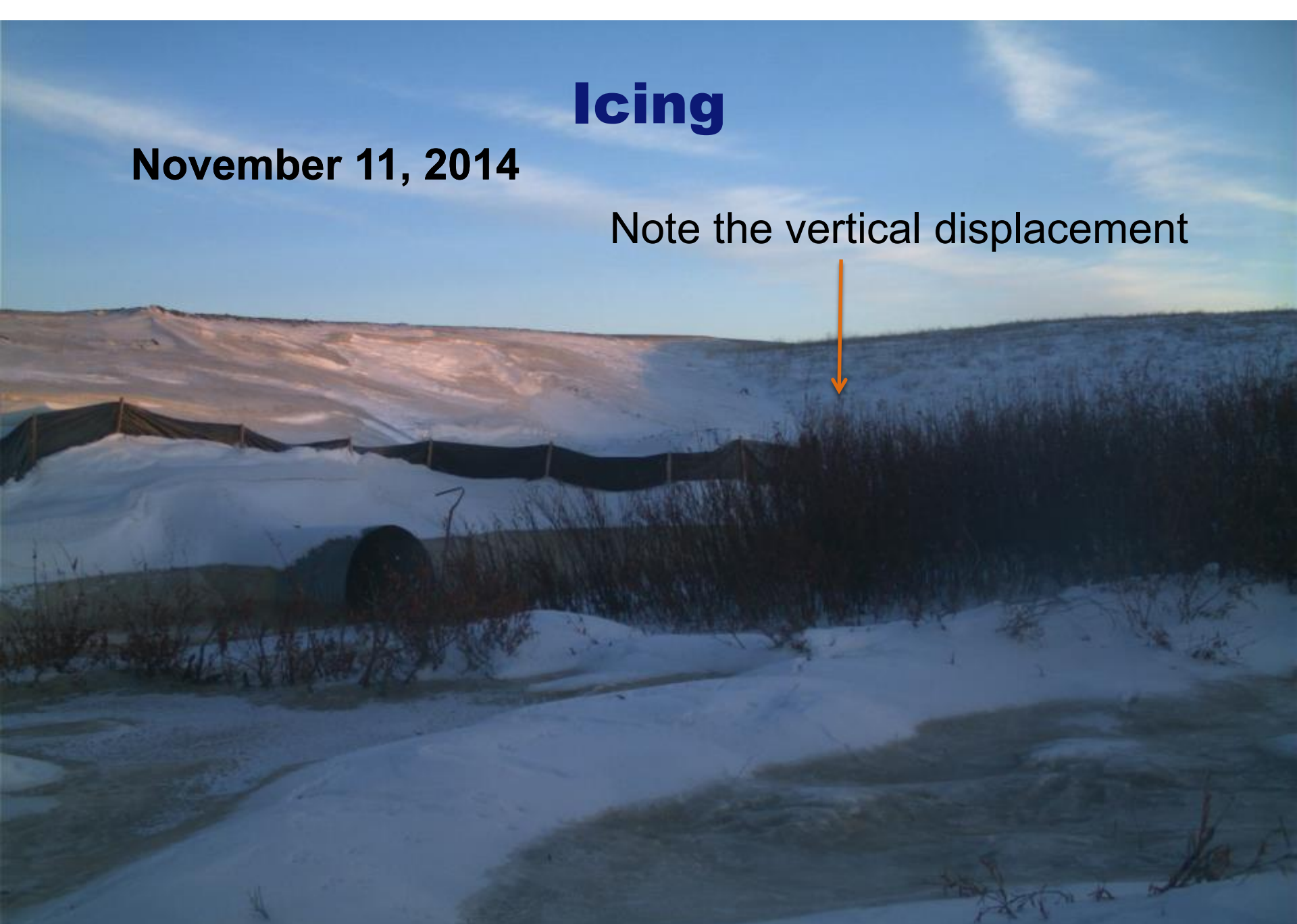
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Icing

November 11, 2014

Note the vertical displacement



Flooding



Changes, Changes, Changes

- Active layer thickening
- Permafrost degradation – Sinkholes
- Aufeis formation
- New mass movements
- Flooding
- Coastal erosion

New Hazards and new Risks

Higher Order Effects → Increased Uncertainty



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Mitigation Options

- Air Convection Embankments
- Heat Drains
- Air Ducts
- Thermosyphons
- High Surface Albedo
- Gentle Slopes
- Gravel Surface
- Geotextiles
- Drainage Control





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A photograph of a sunset over a field of tall, golden-brown grasses. The sun is low on the horizon, casting a warm glow across the sky and the grass. The sky is a mix of orange, yellow, and blue. The grasses are in the foreground, and the horizon is visible in the distance.

Thank you / Merci



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