Permafrost Engineering in a Warming Climate

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2017 Connaught Summer Institute in Arctic Science:
Atmosphere, Cryosphere, and Climate
July 17-21, 2017 • Nottawasaga Inn • Alliston, ON

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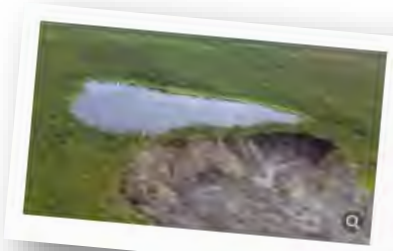

A lake in the Northwest Territ... about to

BOB WEBER
The Canadian...
Published W...
Last upd...

Gas pipelines supplying Europe 'in real danger ... exploding tundra' - top scientist

...violent eruptions caused by 'thawing methane gas',

Rural Alaska

'The permafrost is dying': Bethel sees increased shifting of roads and buildings

Global warming causing record rock falls in the Alps ...arns expert

Climate change: Mu... whiplash,' warns mete...

Canadians can expect extreme shifts in weather ...

The Canadian Press Posted: Aug 22, 2015 9:29 AM ET | Last Up...

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Faint hopes for ... lowest on recor...

Arctic melt 'happening even faster ...

By Seth Borenstein, The Associated Press Poste...

Iqaluit gets a month'...

Nunavut's capital has had 66.6 millimetres ...

By Patricia Bell, CBC News Posted: Jul 11, 2015 5:0...

...creased summ...
...apses

...erian Times

...siness City Focus Sport Culture Science Health & Lifestyle Ecology Weird & Wo...
...Profile

Global warming could happen quicker in Russia's coldest region

By Anna Liesowska
24 February 2015

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Churchill, Man., weighs risk of climate change on future of port, railway

Warming climate opens up opportunities for port but could pose problems for railway

...ity in high mountains?

Christian Huggel,[1]* John J. Clague[2] and Oliver Korup[3]
[1] Glaciology, Geomorphodynamics & Geochronology, Department of Geography, University of Zurich, Zurich, Switze...
[2] Department of Earth Sciences, Simon Fraser University, Vancouver, BC, Canada
[3] Earth and Environmental Sciences, Potsdam University, Germany

BUSINESS

In Alaska: Too Many F... Not Enough Snow

The state nearly set a record for number of acres burned this ... the Iditarod once more had to be moved north.

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How often do you discuss climate change with...?

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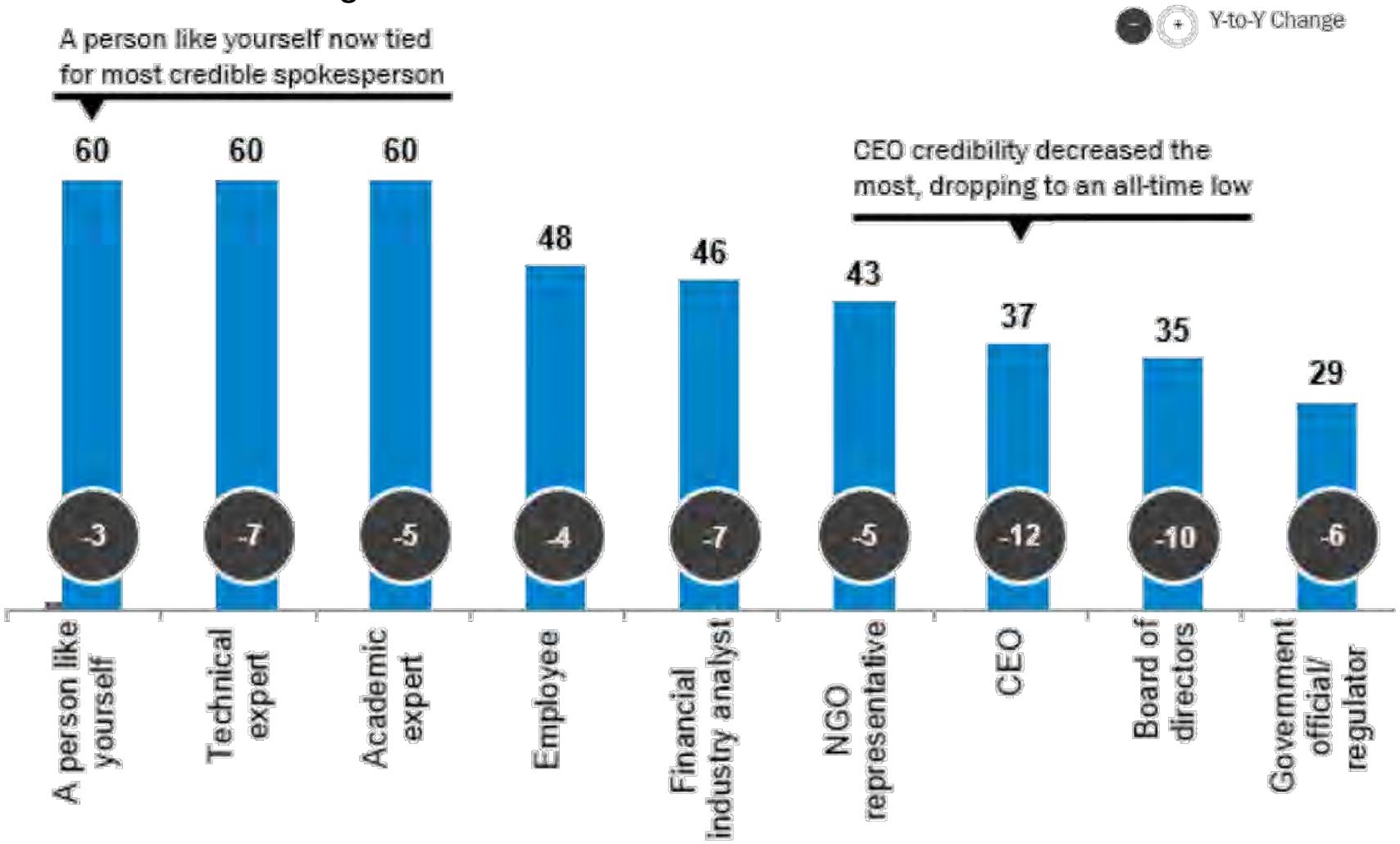
Most Trusted Spokespeople

Percent who rate each spokesperson as extremely/very credible, and change from 2016 to 2017



Edelman Trust Barometer 2017

Topics

- Permafrost ?
- Problems
- Facts
- Uncertainties
- Challenges
- Conclusion

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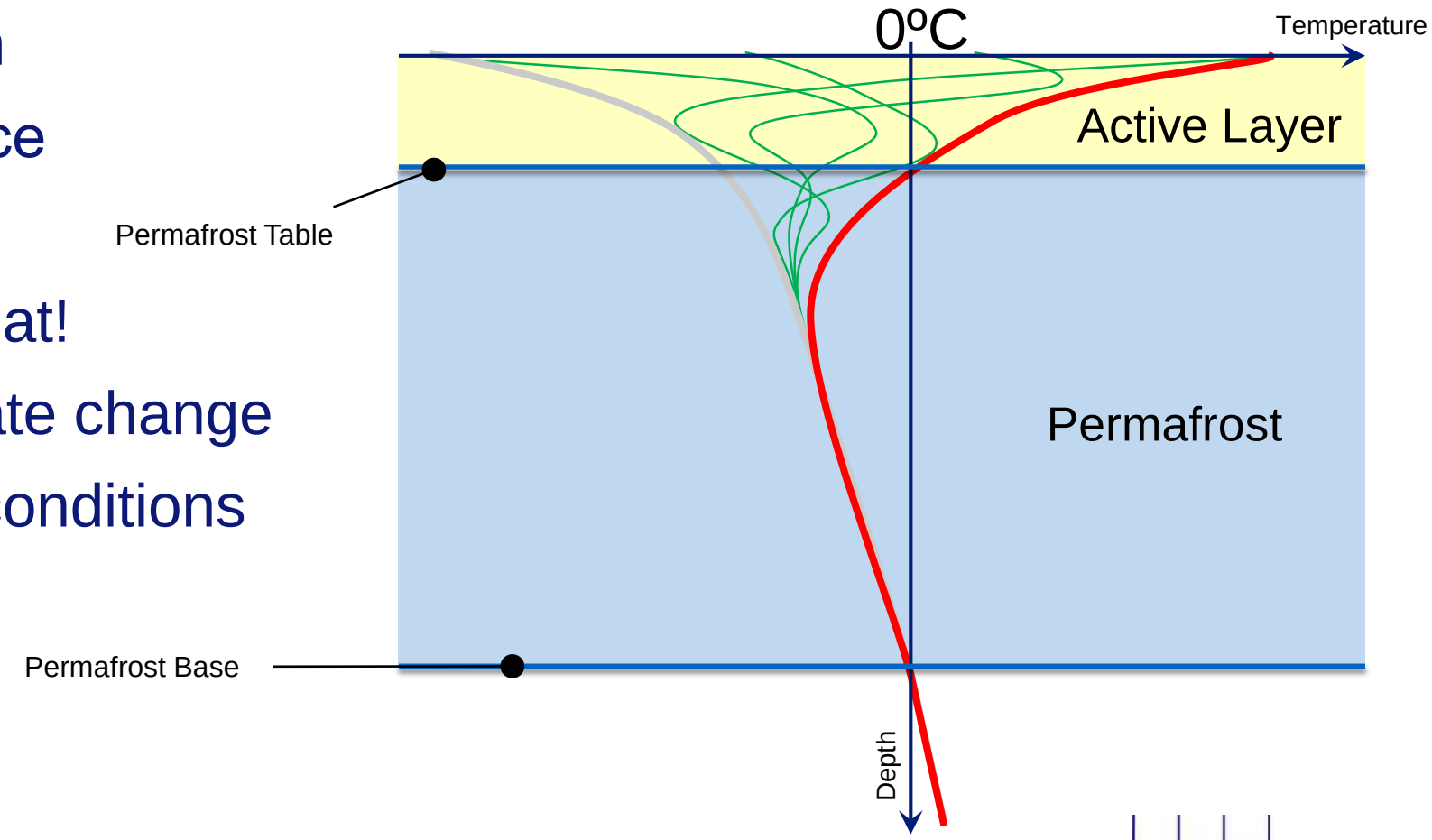
What is Permafrost?

- It is a thermal condition
- Permafrost ≠ Ground Ice
- Active Layer
- If ground ice: Latent heat!
- Slow response to climate change
- Controlled by surface conditions



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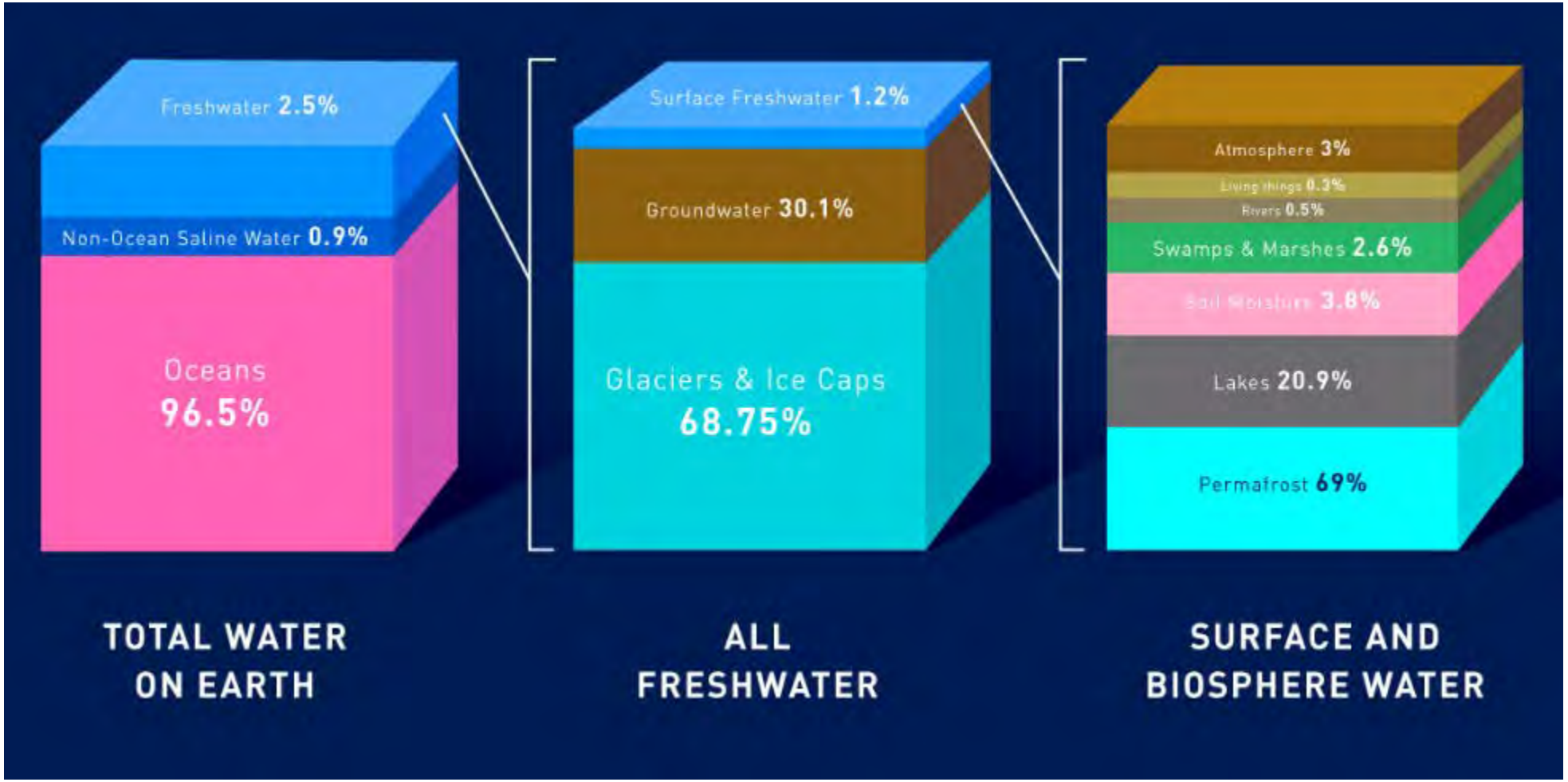
Permafrost - Water



Futurism 2017

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Ice Age

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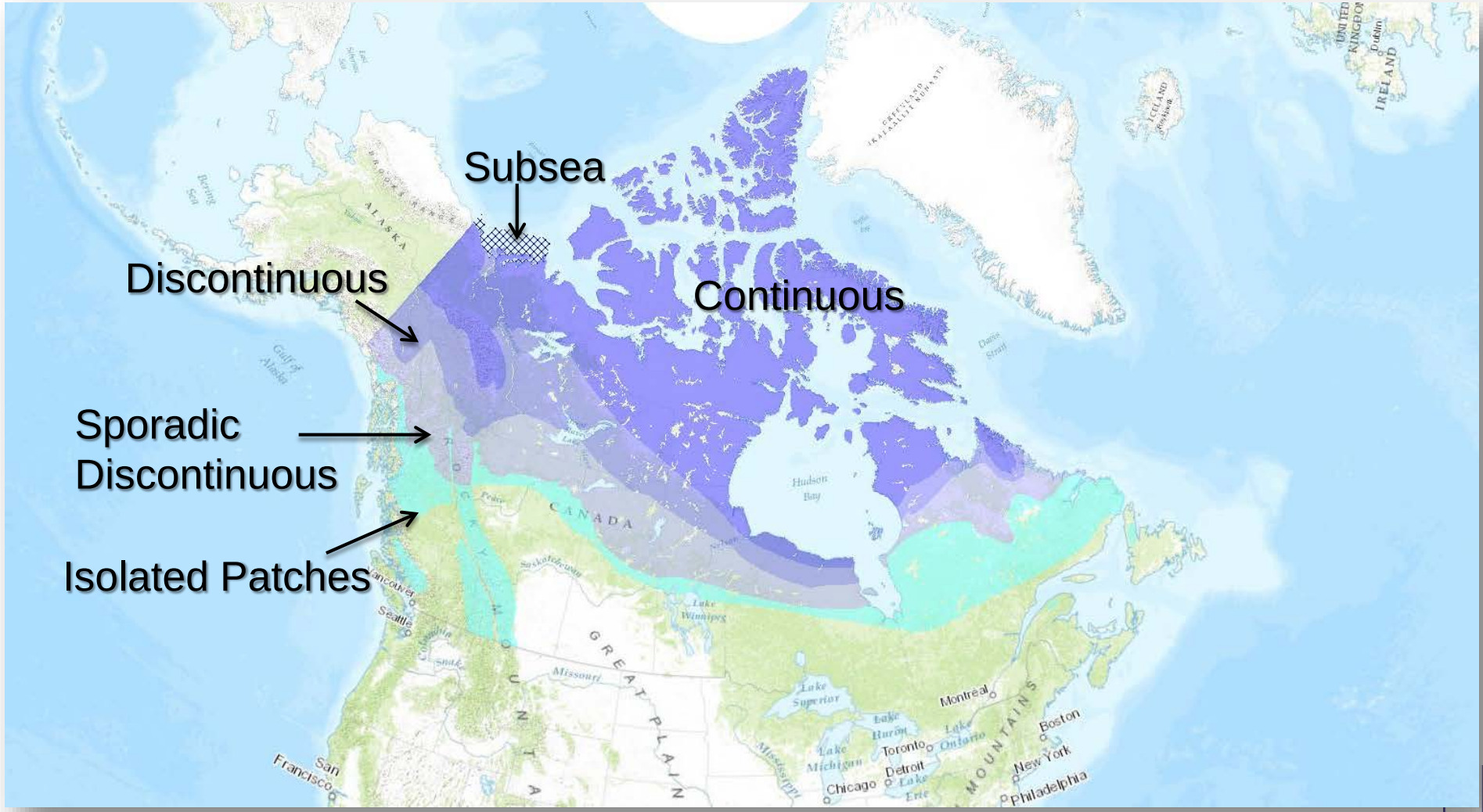
Where is Permafrost in Canada?



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Problems

- Infrastructure Failures
- Reports on Changing Environment
- Uncertainties in Design Parameters
- Science, Politics, Agencies and Public

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Permafrost Degradation

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Flooding

bgcen

Lake Outbursts

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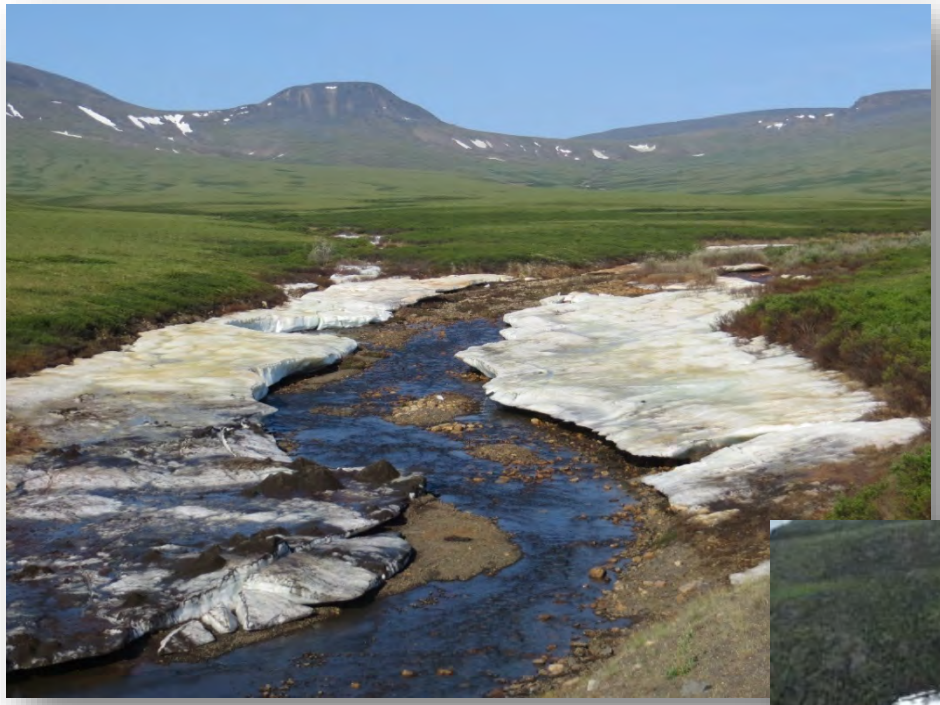
Aufeis / Icing



Morse and Wolfe 2014

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(c) Wikiwand

Changes, Changes, Changes

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

→ **New Hazards and new Risks**

Infrastructure Failure and Climate Change

- Climate warming does not act as a trigger for extensive deformations or failure of foundations on permafrost

In most cases, climate warming may act as an accelerator or catalyst for ongoing permafrost degradation associated with construction activity and existing infrastructure.

- In addition presence of taliks, saline permafrost, water flows, ice inclusions, precipitation can also cause thermal instability of the foundations.

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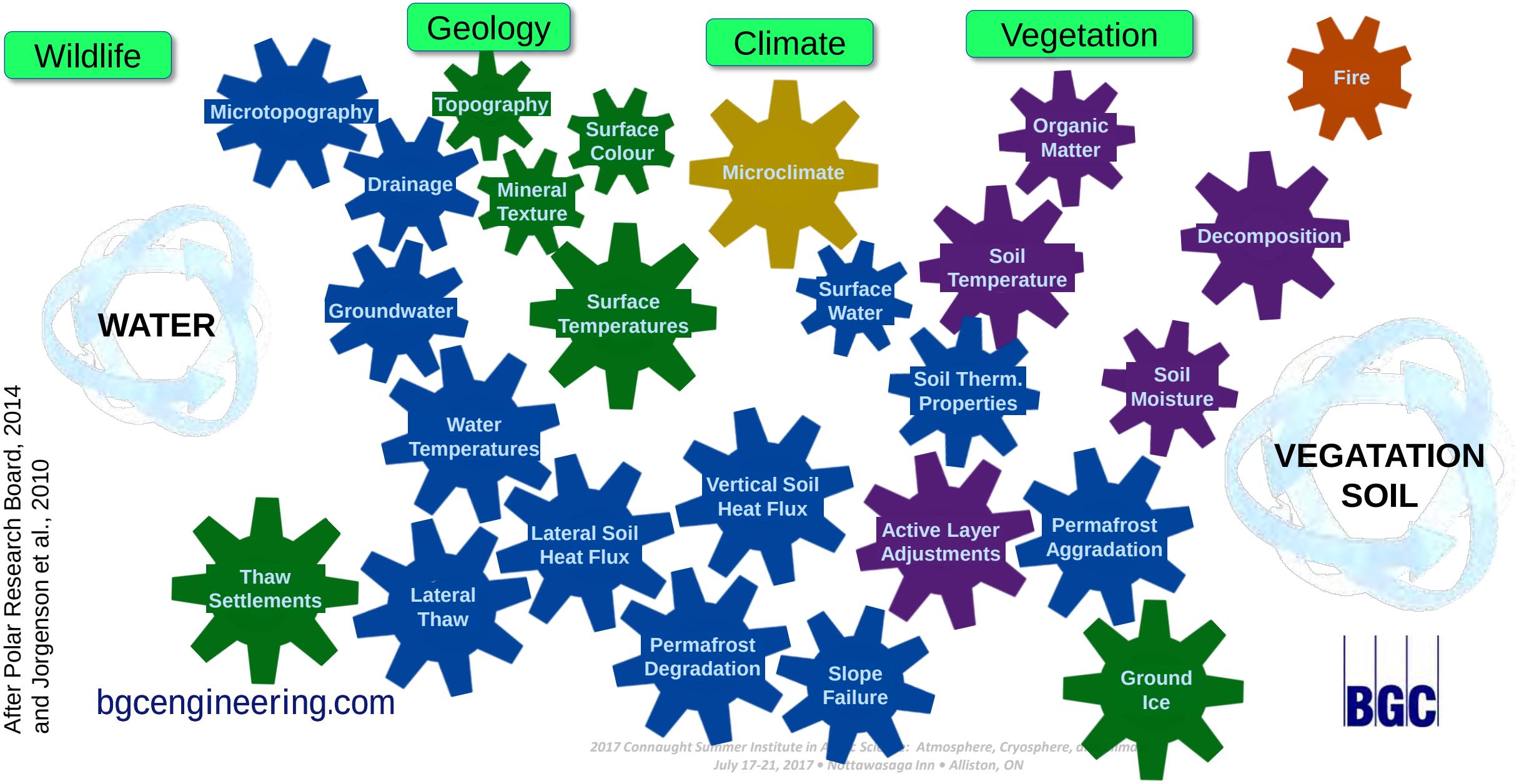
Instanes, 2003

Permafrost and the Environment



After Polar Research Board, 2014
and Jorgenson et al., 2010

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A Changing Environment

- Sea ice conditions have changed; the ice is thinner, freezes up later and melts earlier. Similar observations have been made for lake ice.
- Aniuvat (permanent snow patches) are decreasing in size. There is more rain, and the snow and ice form later in the year and melt earlier.
- The weather is unpredictable. It changes faster than it used to with storms blowing up unexpectedly.
- Water levels have gone down, making it hard or impossible to travel by boat in certain areas.
- Temperatures are warmer throughout the year.
- New species have been observed.
- The land has been observed to be drier and the stability of the permafrost is changing.
- The length and timing of the traditional Inuit seasons have changed.

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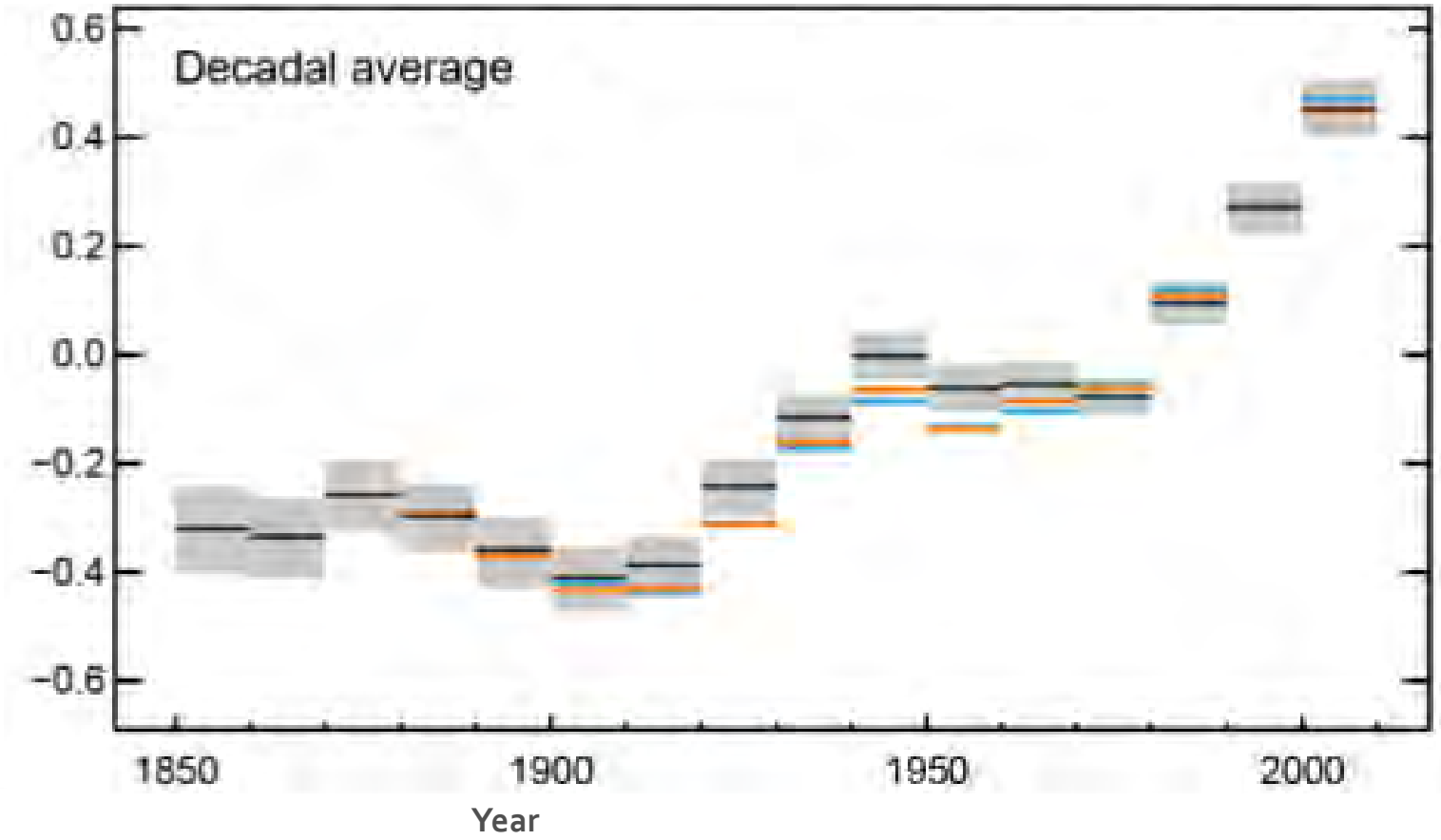
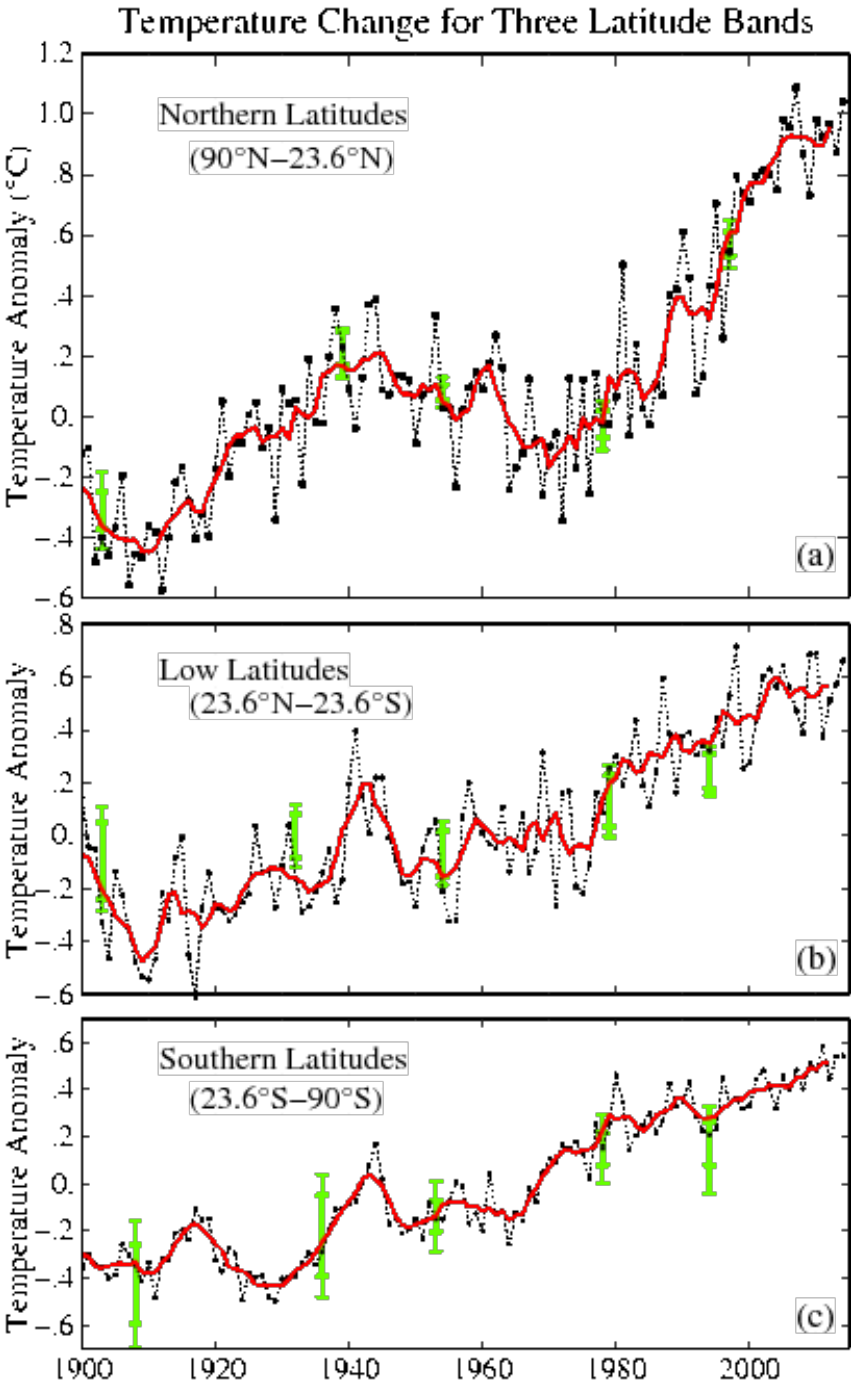
Temperatures

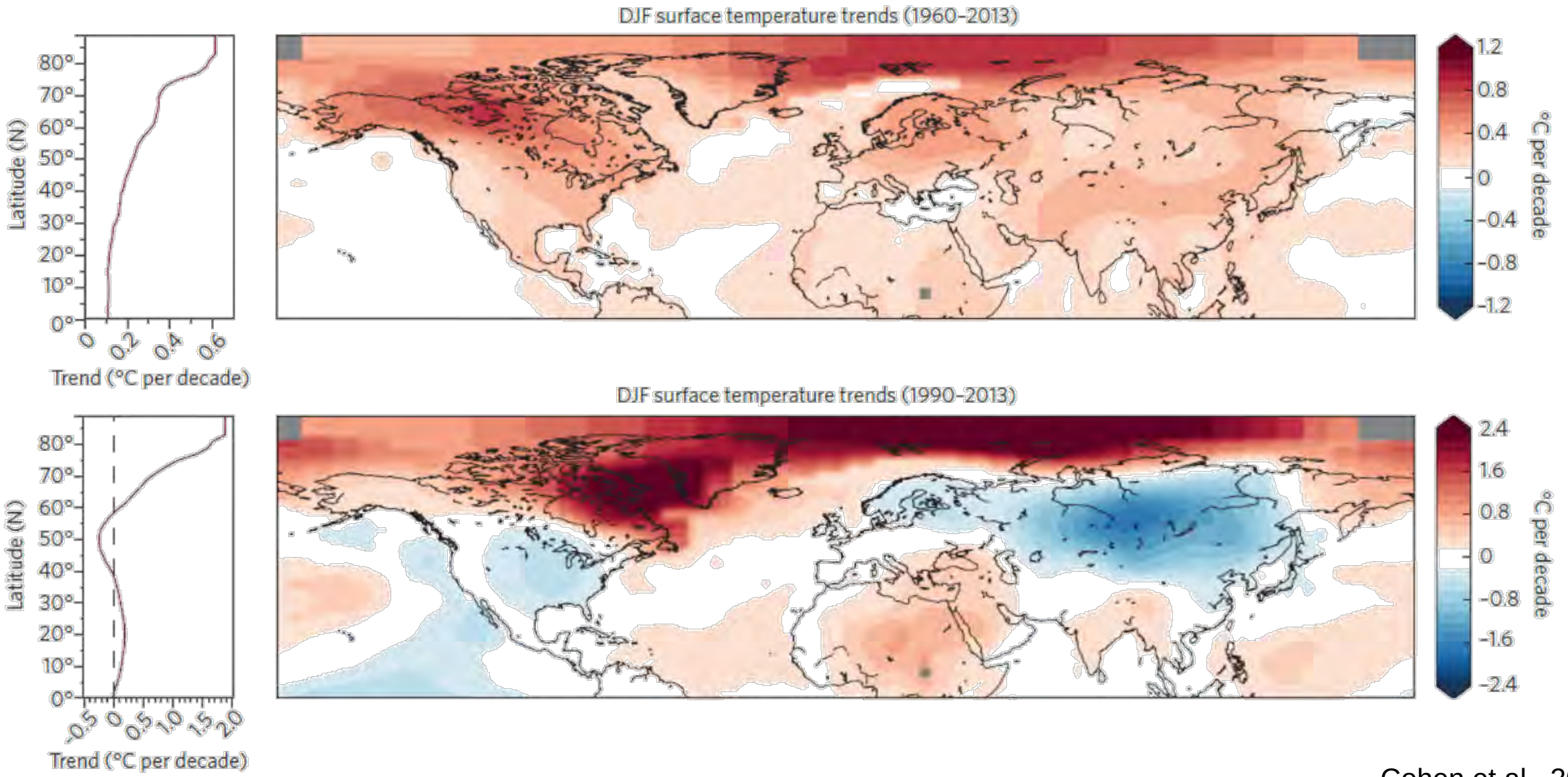


Globally averaged combined land and ocean surface temperatures



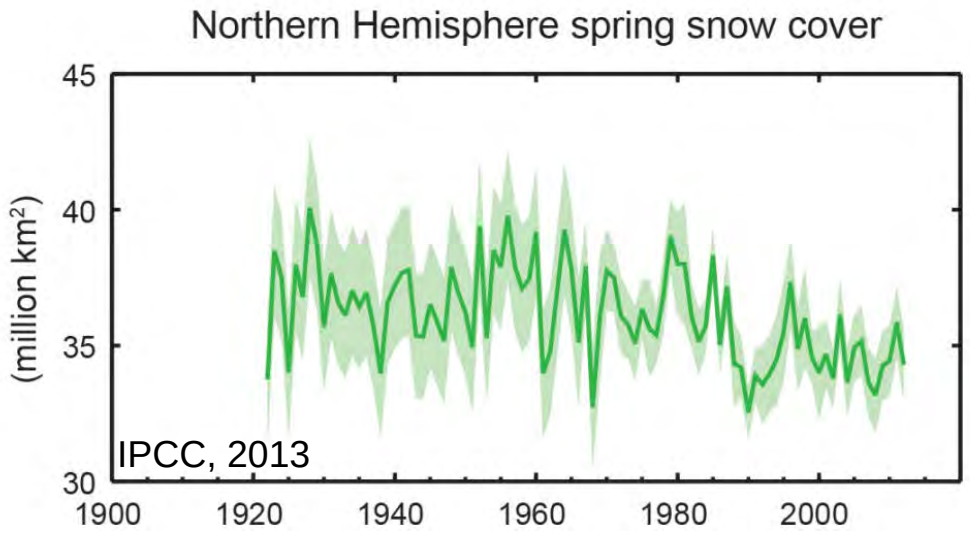
IPCC, 2014 – AR5

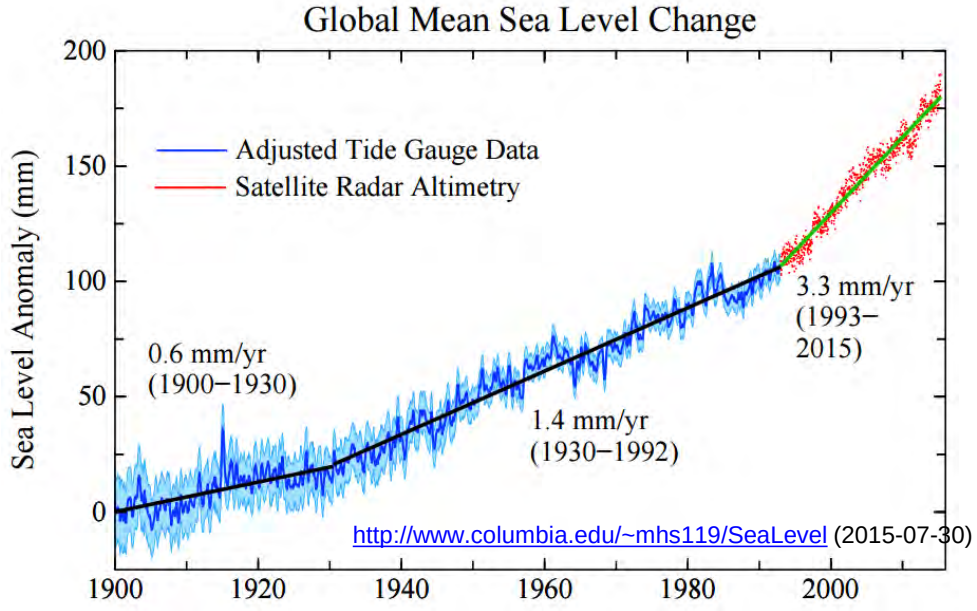
Arctic Temperatures

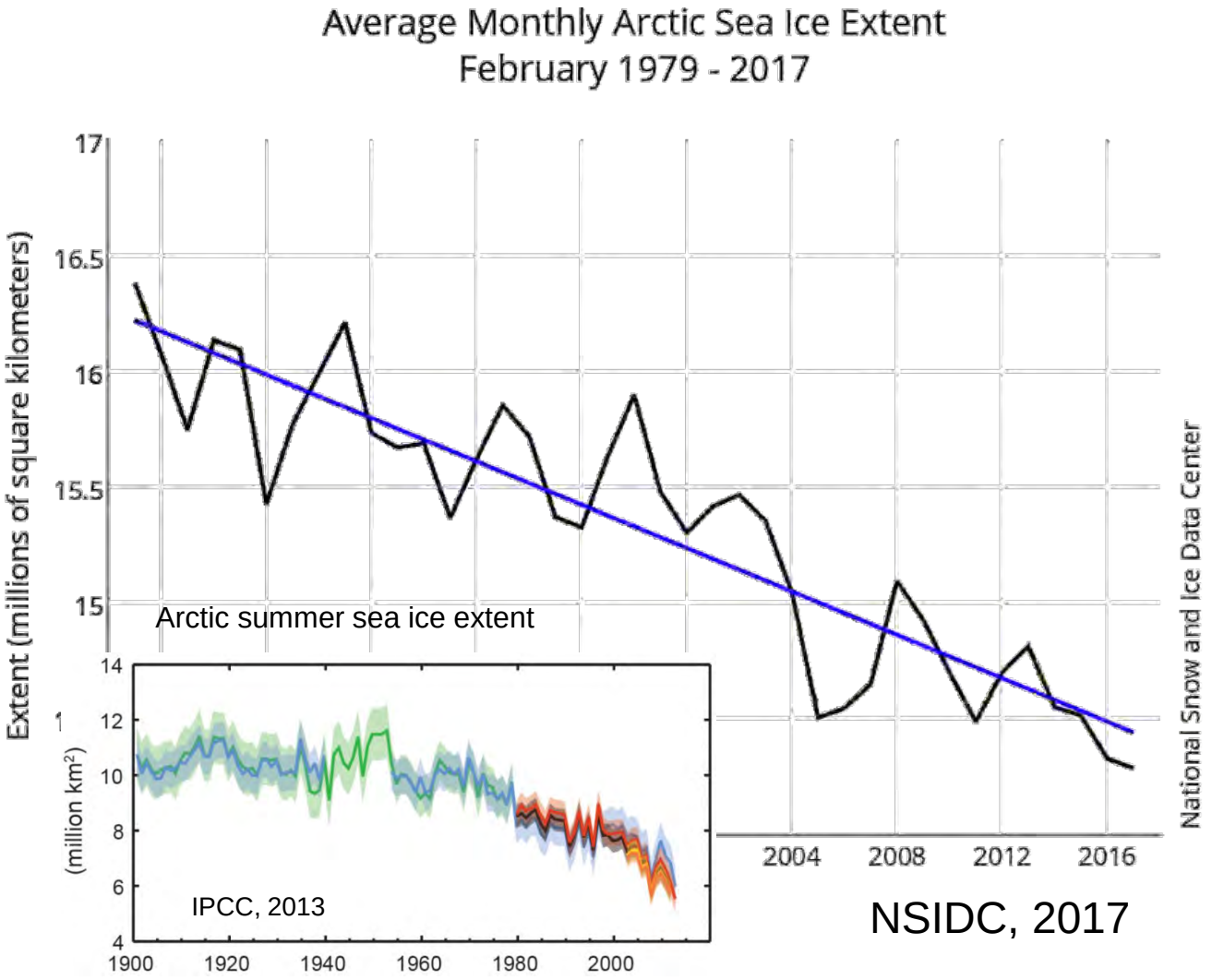


Cohen et al., 2014

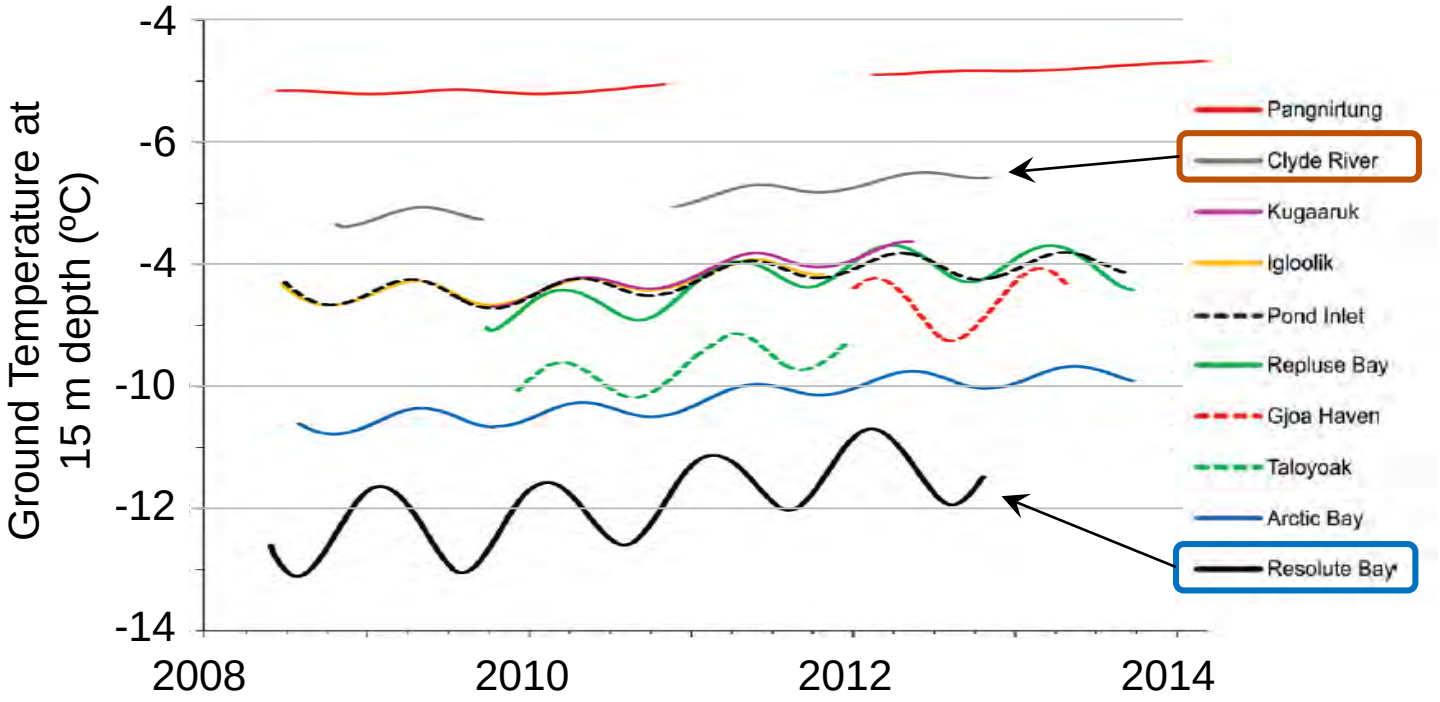
Cryosphere, Sea Ice & Sea Level

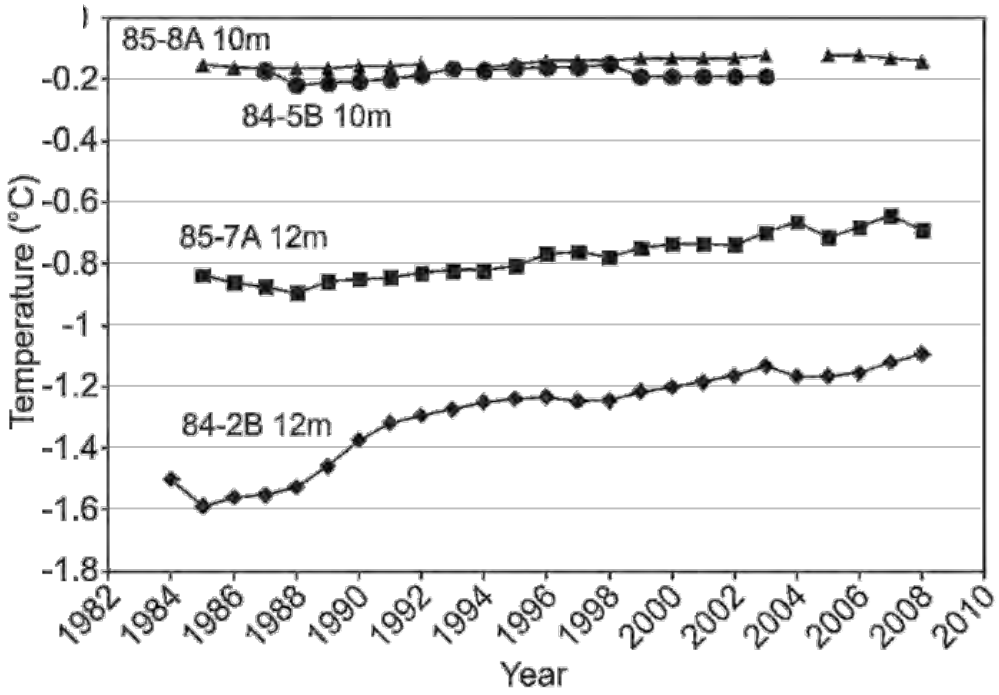




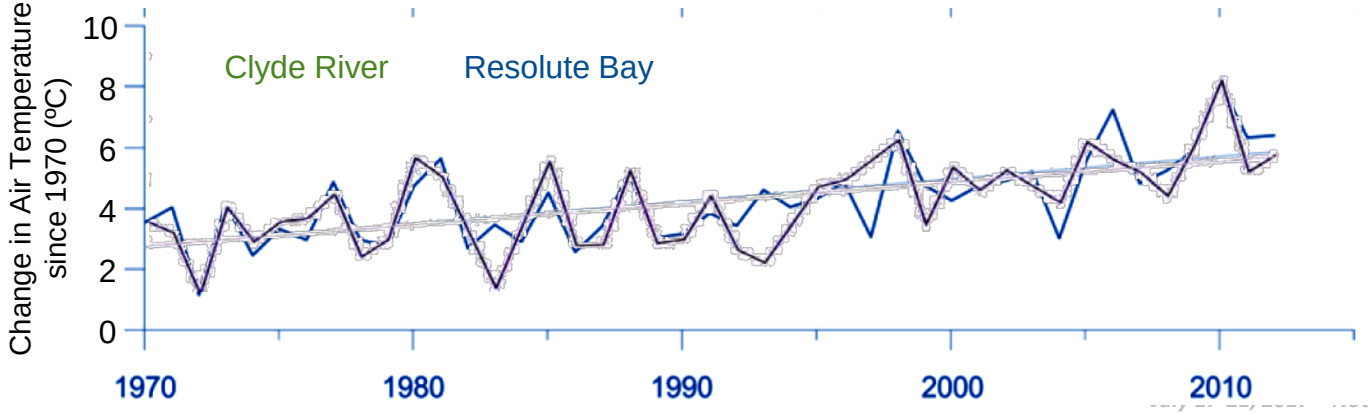


Permafrost Temperatures





Smith et al., 2010



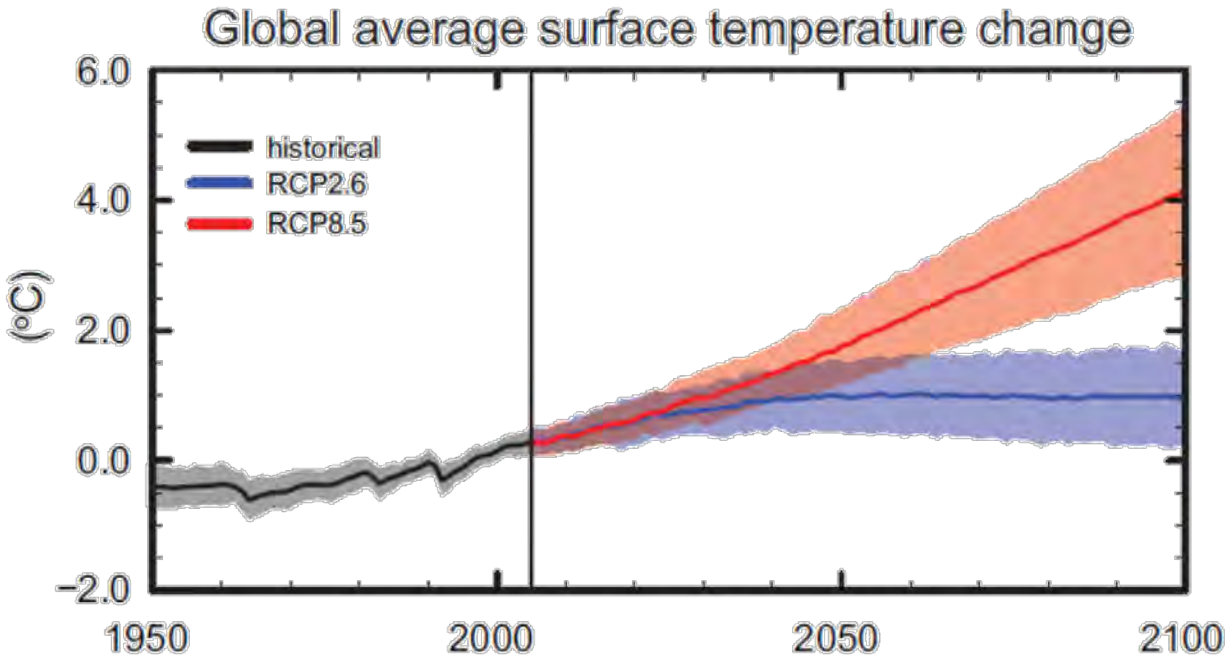
Ednie and Smith, 2015

Engineering Design

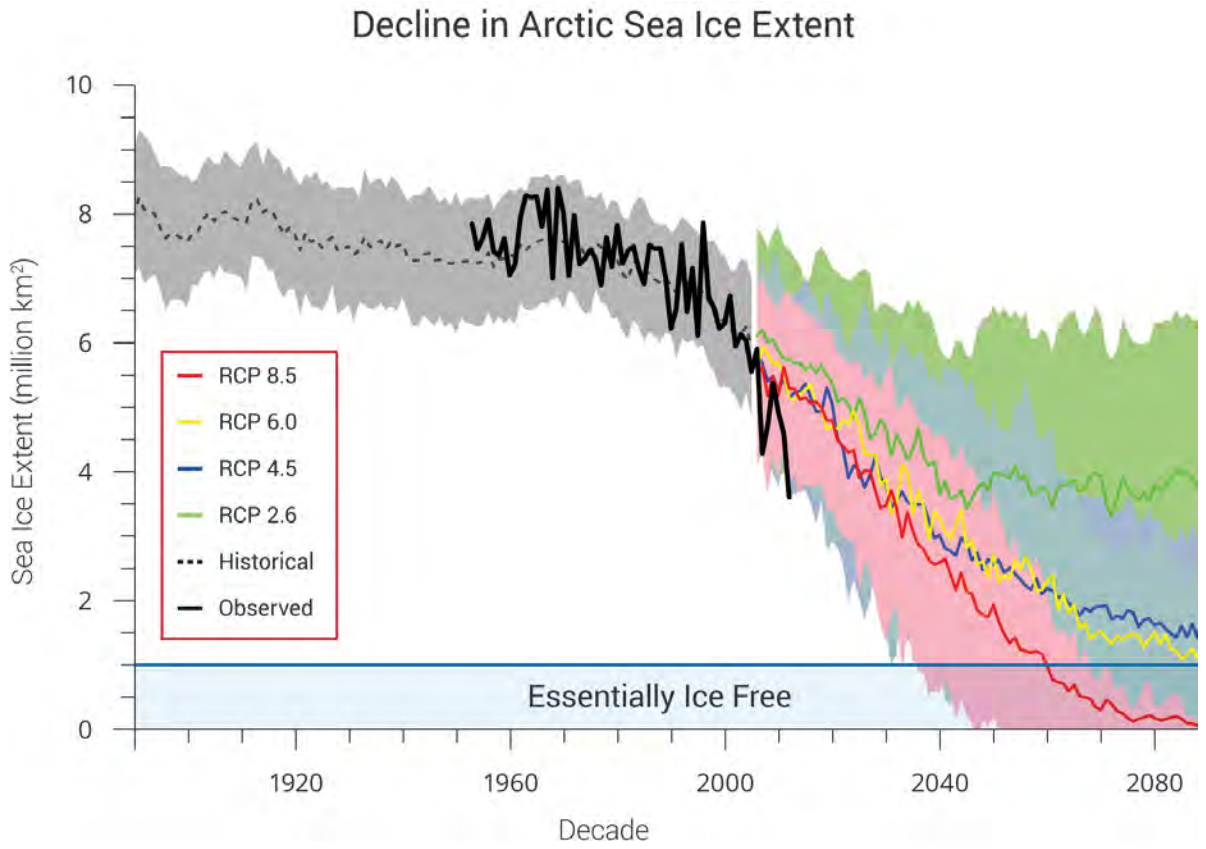
How can/does Climate Change Impact Engineering Design in Cold Climates?

- What is the project timeline?
- What are the knowns and what are the unknowns?
- What are the hazards and consequences?
- Adaptation measures?

Timeline: Short vs. Long-Term



IPCC, 2013



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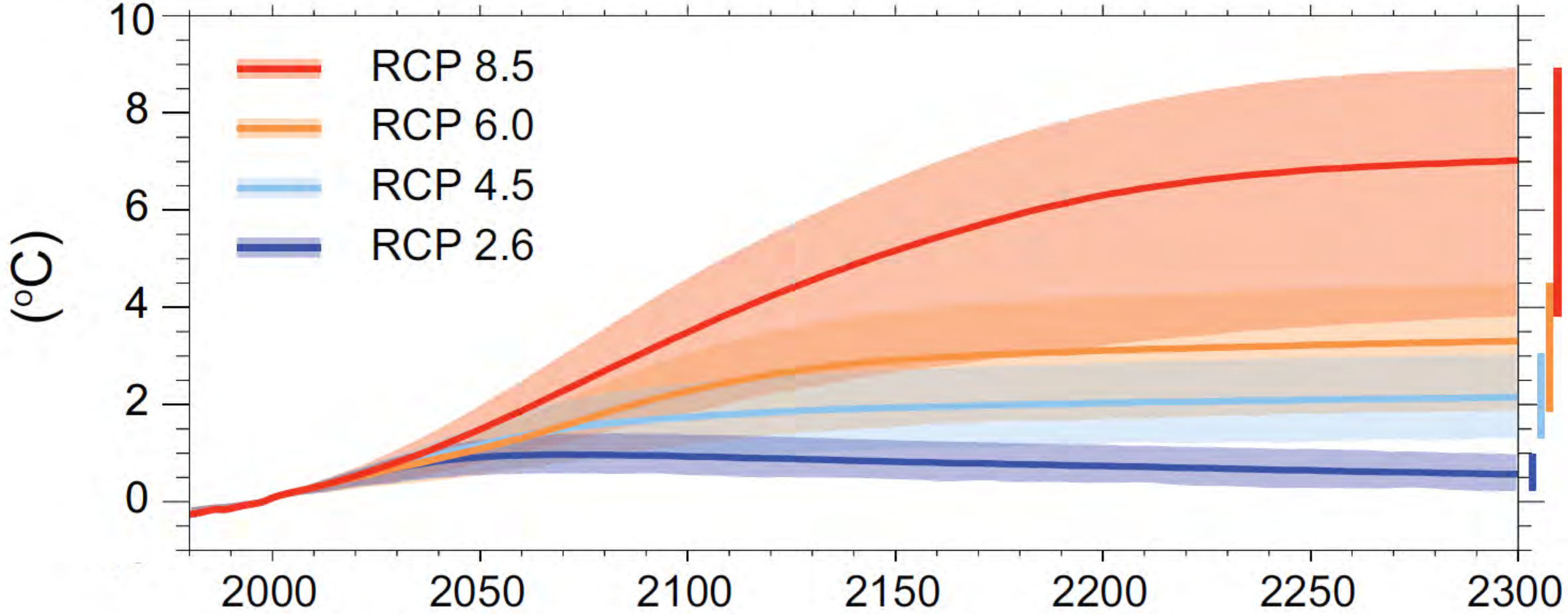
Long-term



IPCC, 2013

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Data, Data, Data

AWS

Borehole Temperatures

Active Layer Thickness

GTN-P
Global Terrestrial Network for Permafrost

Biskaborn et al., 2015

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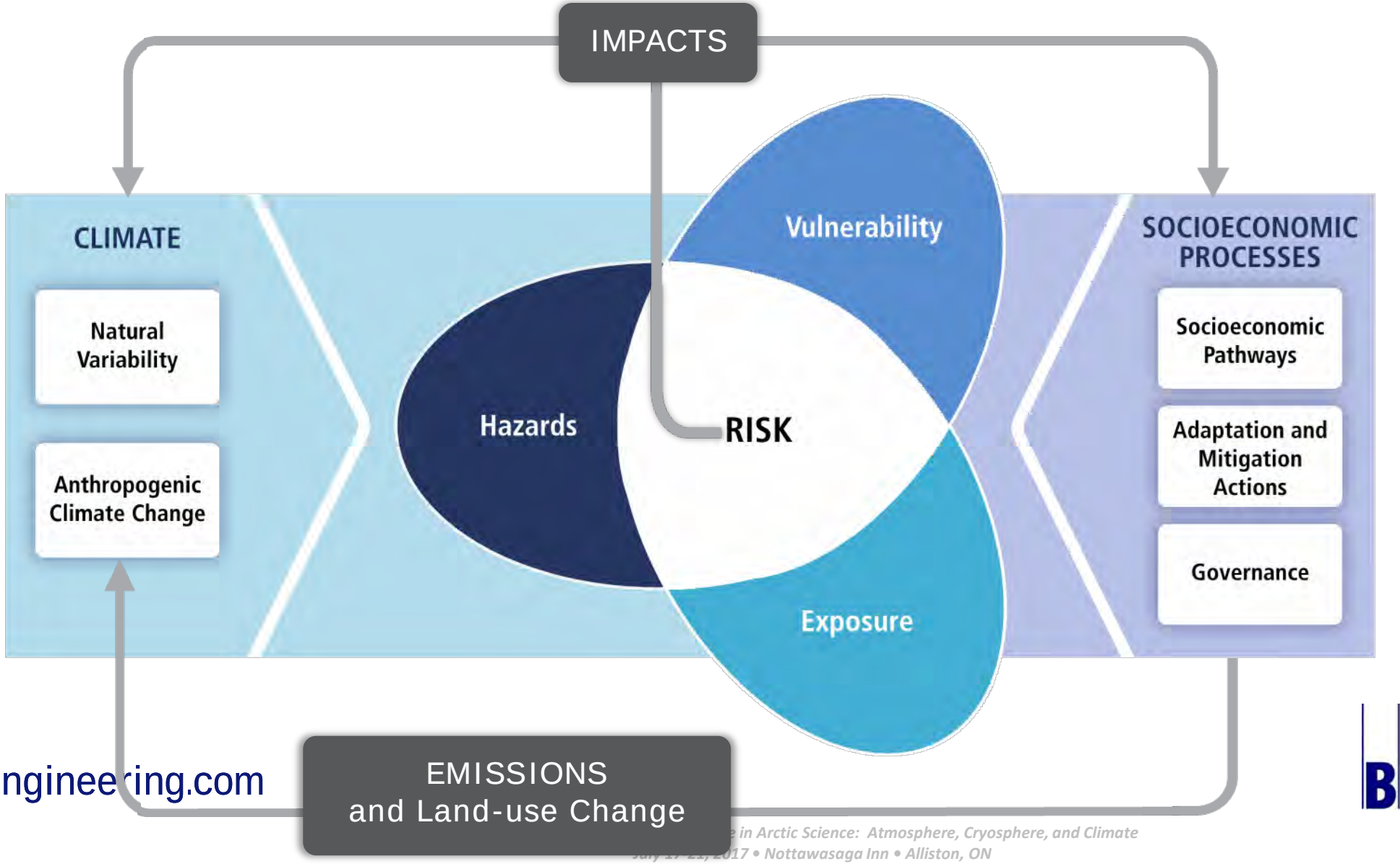
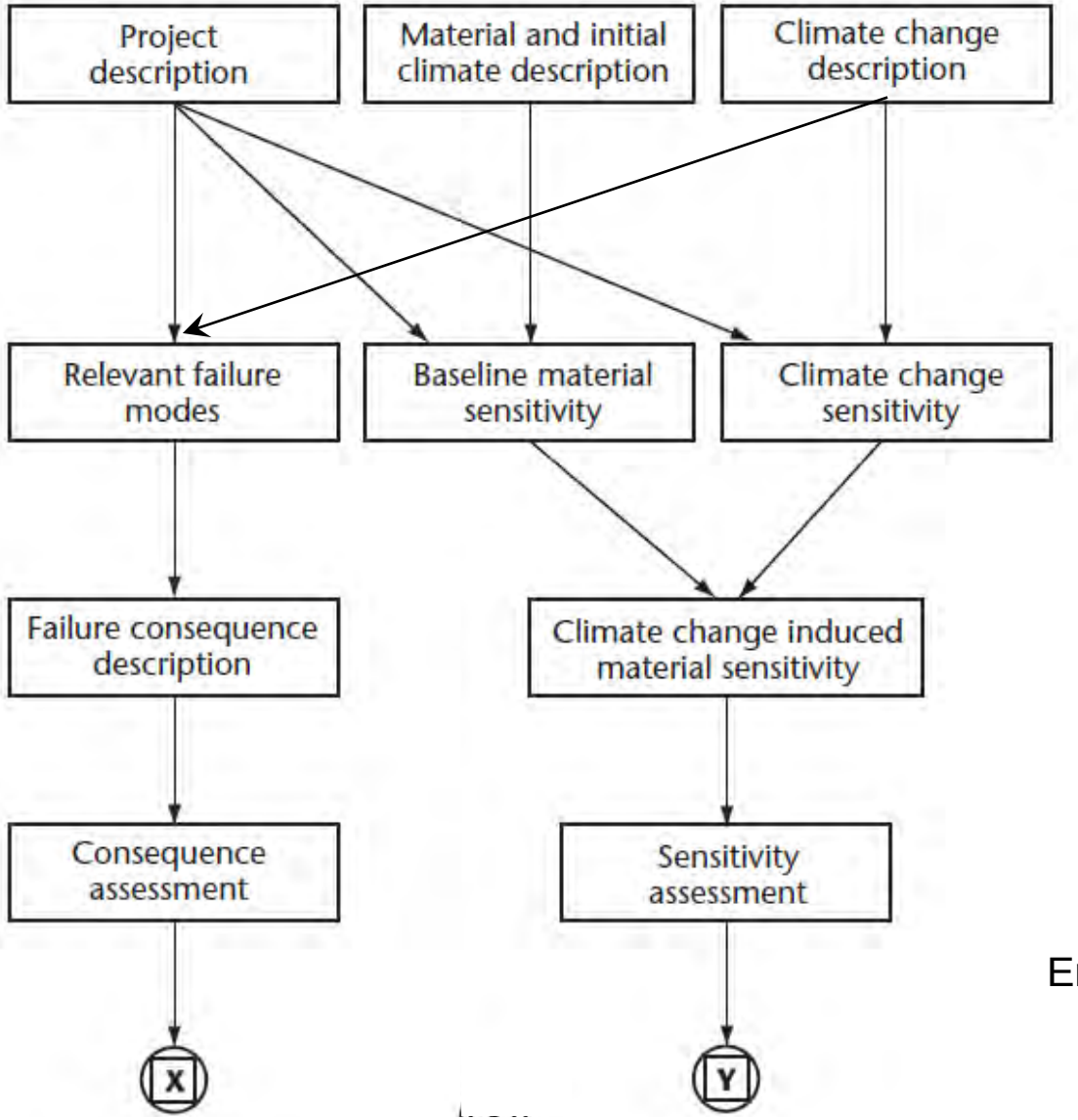
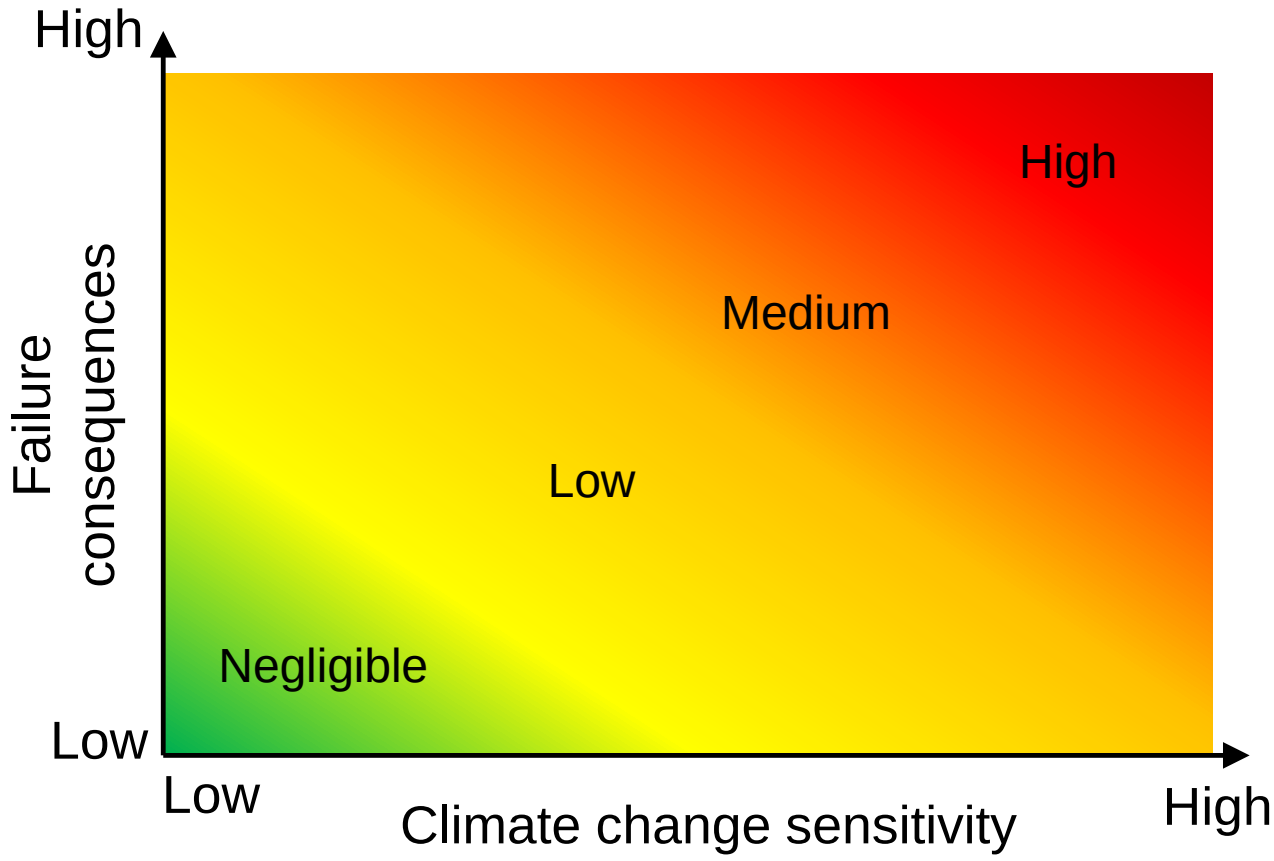
Climate Risk



IPCC, 2014

CSA Climate Risk Framework





Environment Canada, 1998; CSA, 2010

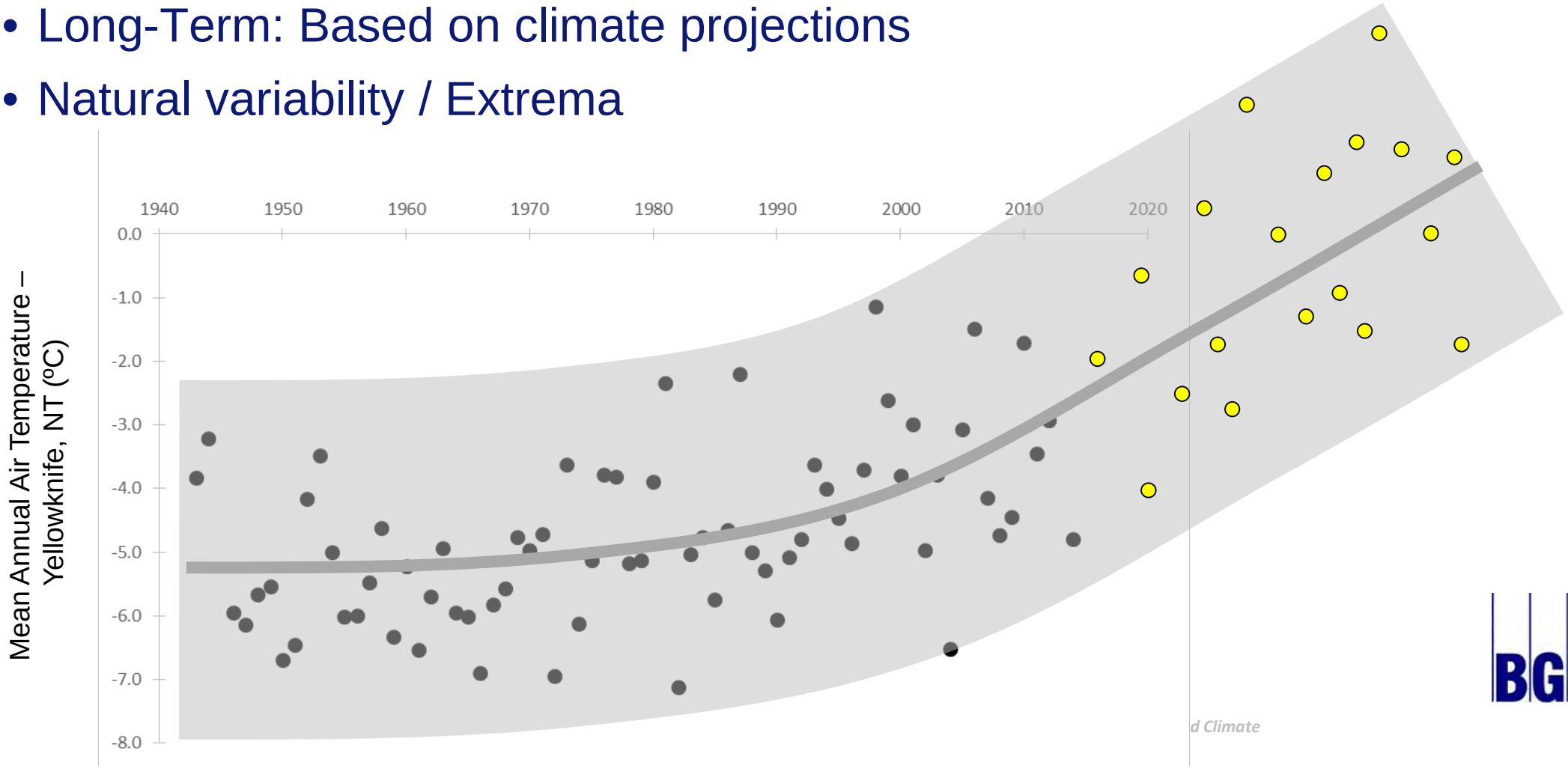
Climate Change Sensitivity

How does a climate element affect the environment and the infrastructure or structure?

- Changes in air temperature
  - Seasonal temperatures and natural variability
  - Min. and max., i.e. extrema
- Precipitation
  - Snow vs. rain
  - IDF
- Others, such as Ground Temperature, Active Layer Thickness, Frost, Sea Level, Chemistry, …

Example: Air Temperatures

- Short-Term: Based on historic data
- Long-Term: Based on climate projections
- Natural variability / Extrema



Ground Temperatures / Permafrost

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

Environmental Changes

- Taliks
- Permafrost Aggradation

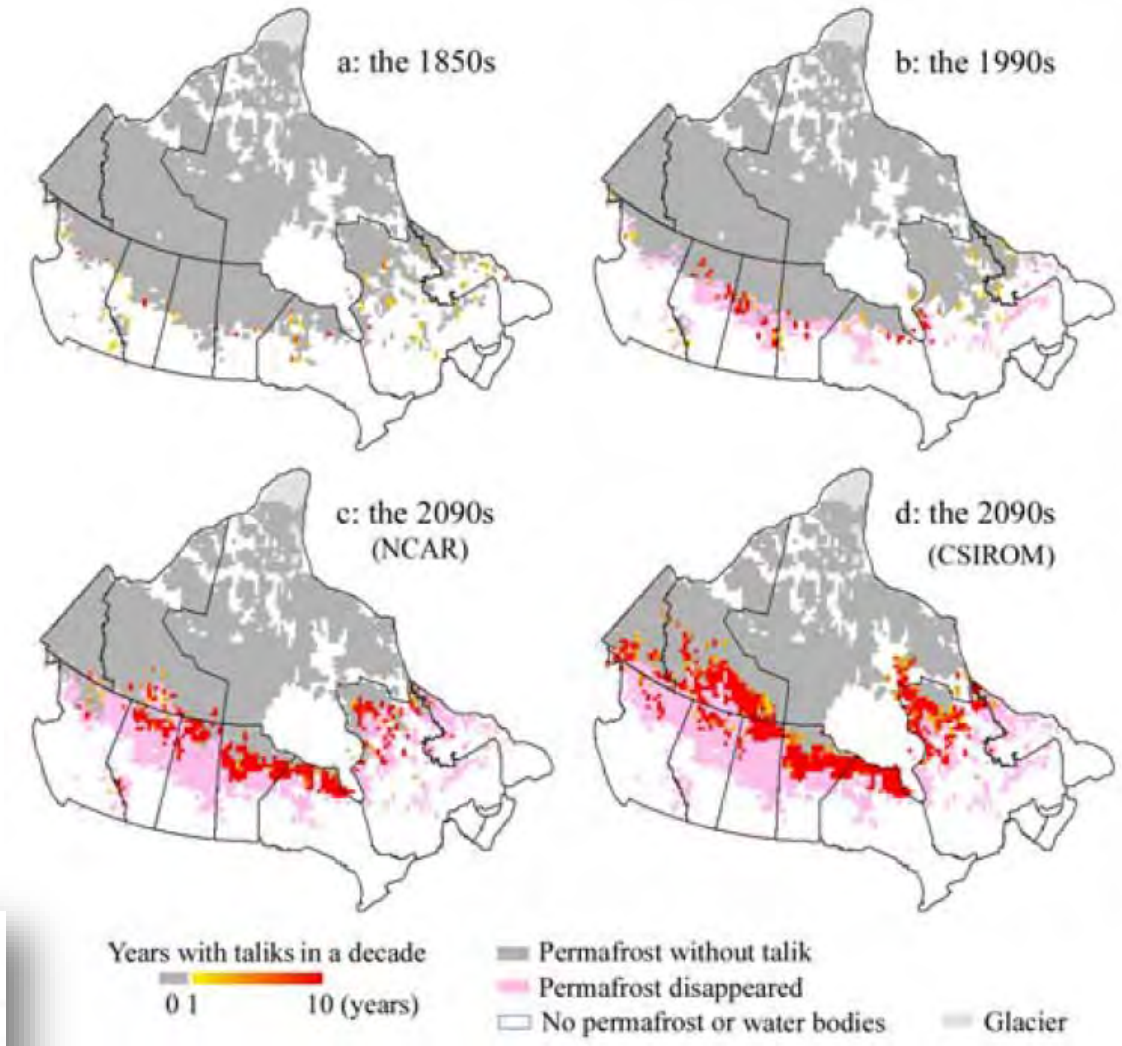
New permafrost is forming around shrinking Arctic lakes, but will it last?

Martin A. Briggs[1], Michelle A. Walvoord[2], Jeffrey M. McKenzie[3], Clifford I. Voss[4], Frederick D. Day-Lewis[1], and John W. Lane[1]

- Mass movements

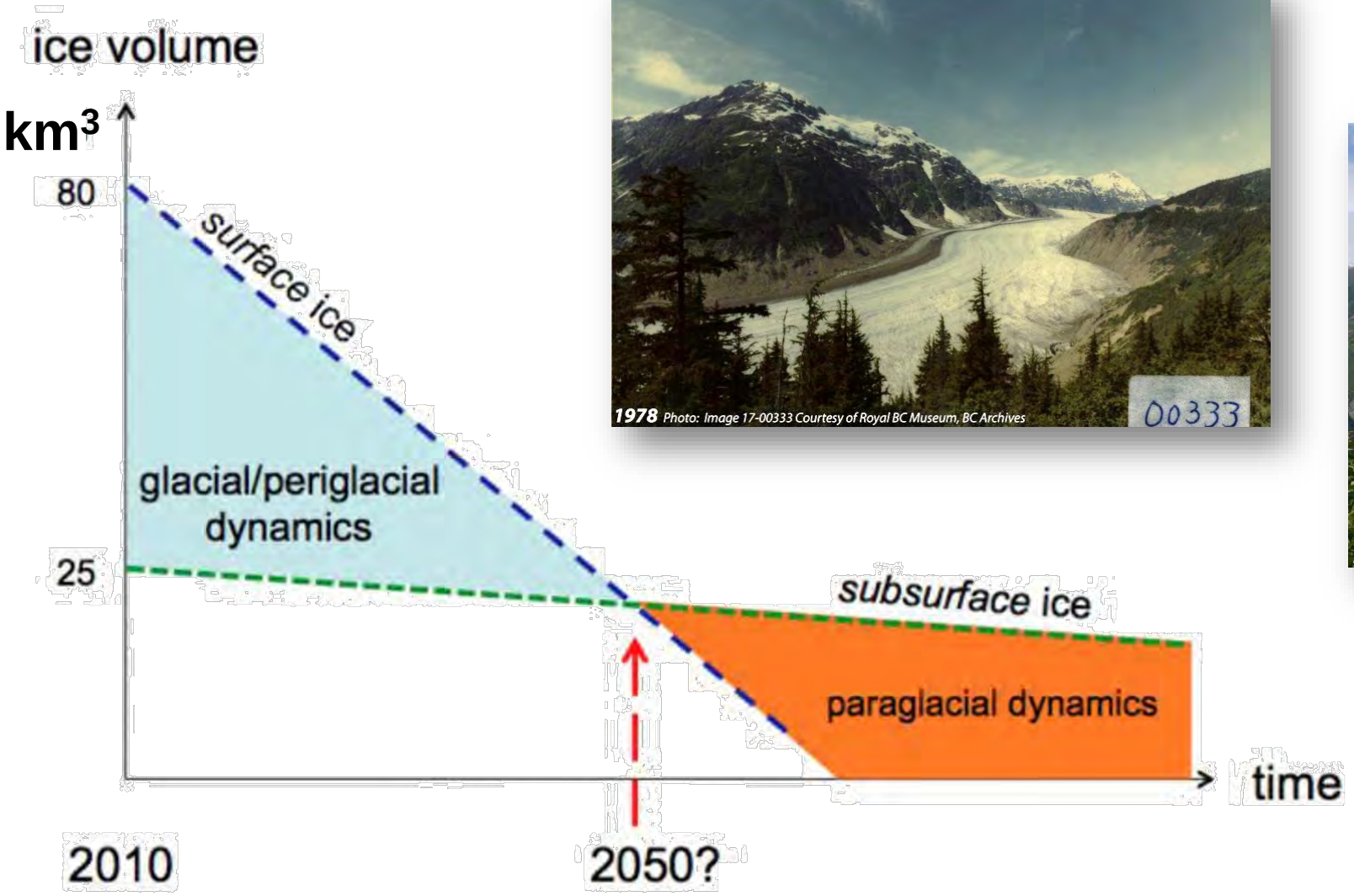
Increased precipitation drives mega slump development and destabilization of ice-rich permafrost terrain, northwestern Canada

S.V. Kokelj [a,*], J. Tunnicliffe [b], D. Lacelle [c], T.C. Lantz [d], K.S. Chin [e], R. Fraser [f]



Zhang et al., 2008

Glacier and Permafrost



Haeberli et al., 2016

GlacierChange.org

Summary

- Climate warming has stronger influence on ground and environmental stability in the Arctic than other areas
- Need to understand time horizon and data source
- Climate sensitivity based approach
- Asses terrain sensitivity to climate change and its implication on engineering design
- Consider potential increase in frequency and magnitude of extreme events
- Air temperature and precipitation projection to be used as proxies, not as the directly parameters for design
- Local climate and environmental data are critical for design
- Adaptive engineering

Prediction is very ecially uture

Climate Change Could Make Siberia an Attractive Place to Live

Although anticipated warmer temperatures promise to render the region more comfortable for people, the transformation might turn permafrost areas into inhospitable bogs.

EOS, July 12, 2017

Niels Bohr (1885 – 1962),
Danish Physicist

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