T-MOSAiC
Terrestrial Multidisciplinary distributed Observatories for the Study of Arctic Connections

RAPID ARCTIC TRANSITIONS DUE TO INFRASTRUCTURE & CLIMATE
RATIC

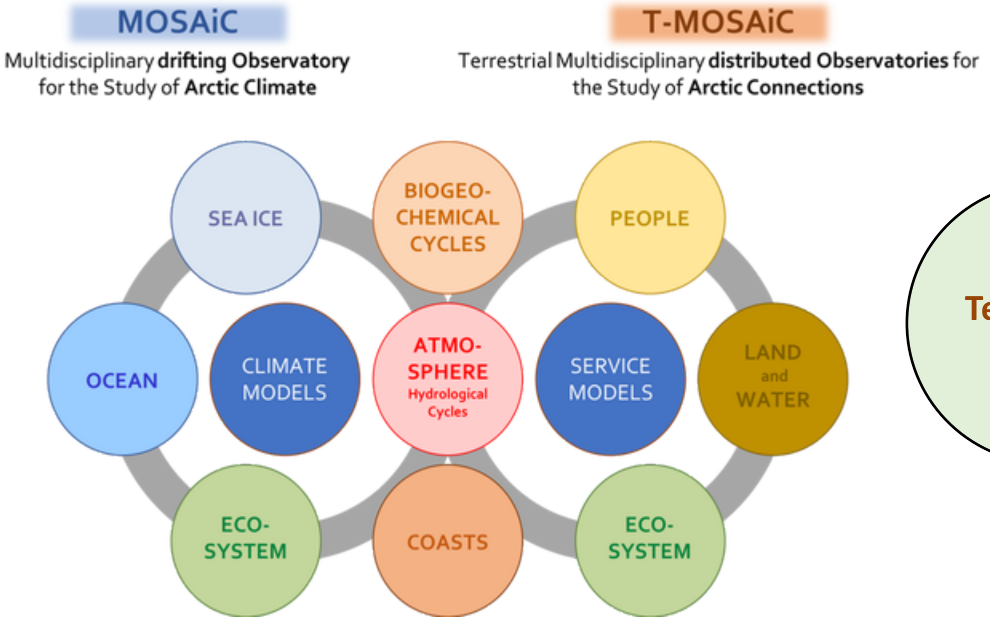
T-MOSAiC

NSF: Navigating the New Arctic (NNA)

- One of NSFs 10 Big Ideas
- Major foci:
  - Establishment of observational research sites, observational platforms, or networks of sites to document key aspects of the changing Arctic.
  - Studies to understand and forecast changes in the biogeochemical, geophysical, ecological and social processes occurring in the new Arctic.
  - Studies of feedbacks between the design and engineering of urban and rural civil infrastructure and changes in natural ecosystems such as thawing permafrost and sea ice retreat and social systems such as increasing marine commerce.
  - Studies that advance STEM education through Arctic research activities.

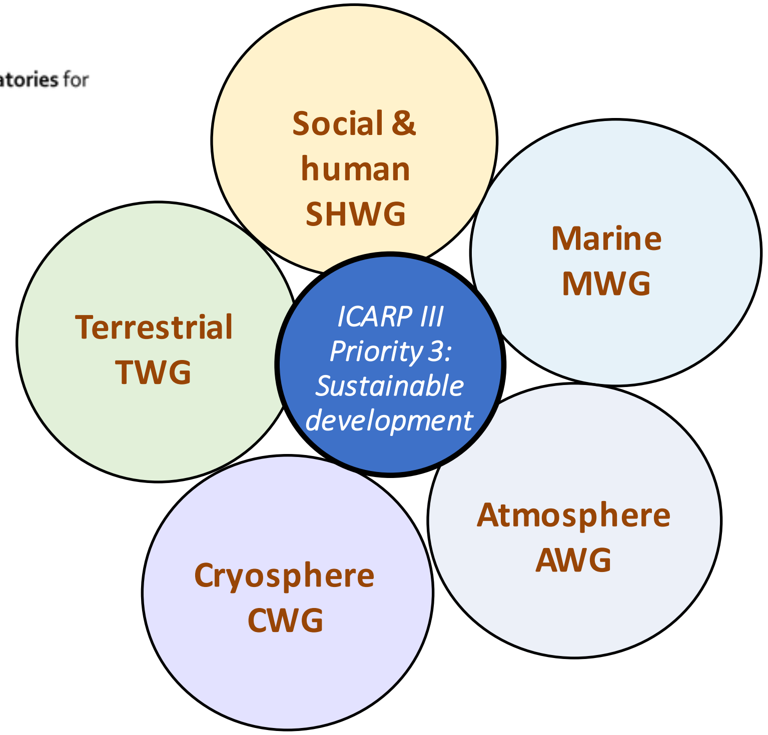
Conceptual thematic diagrams

T-MOSAiC–**MOSAiC** linkages



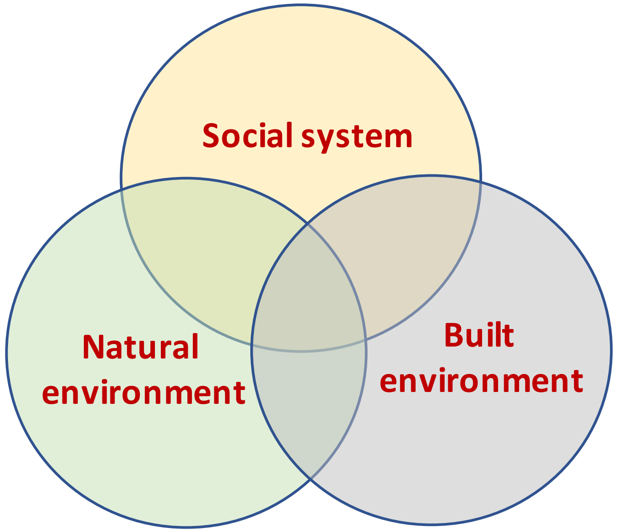
Major area of overlap is coastal environment
Focus on modeling connections.

RATIC-IASC Working Group linkages



Linkages are strongest between TWG, SHWG, and CWG

NSF Navigating the New Arctic (NNA) major foci



Infrastructure and sustainable development important

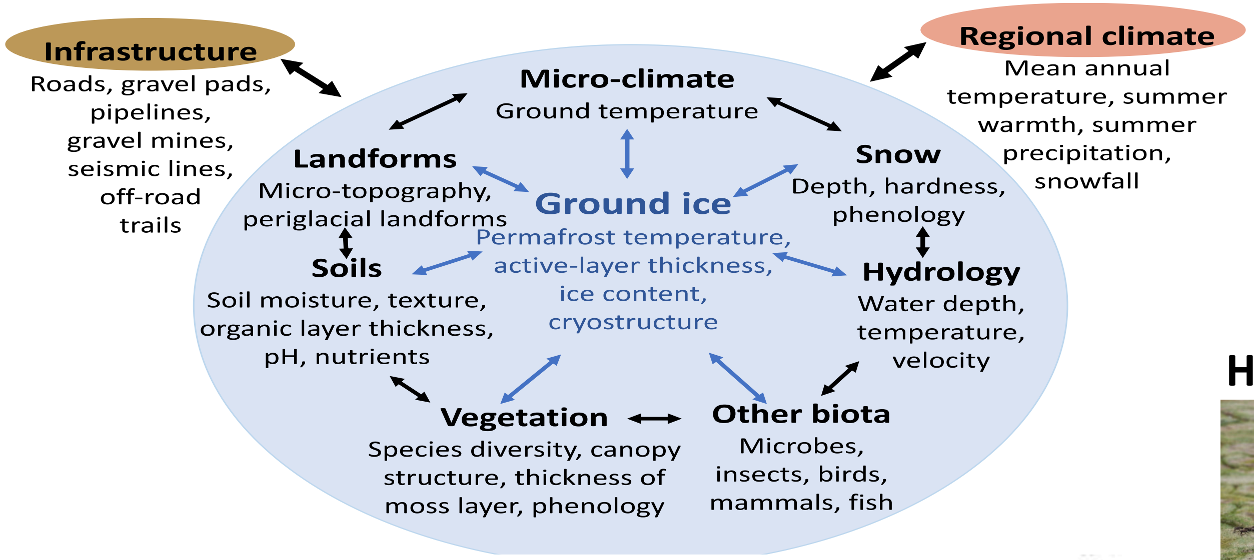
Our NNA proposal

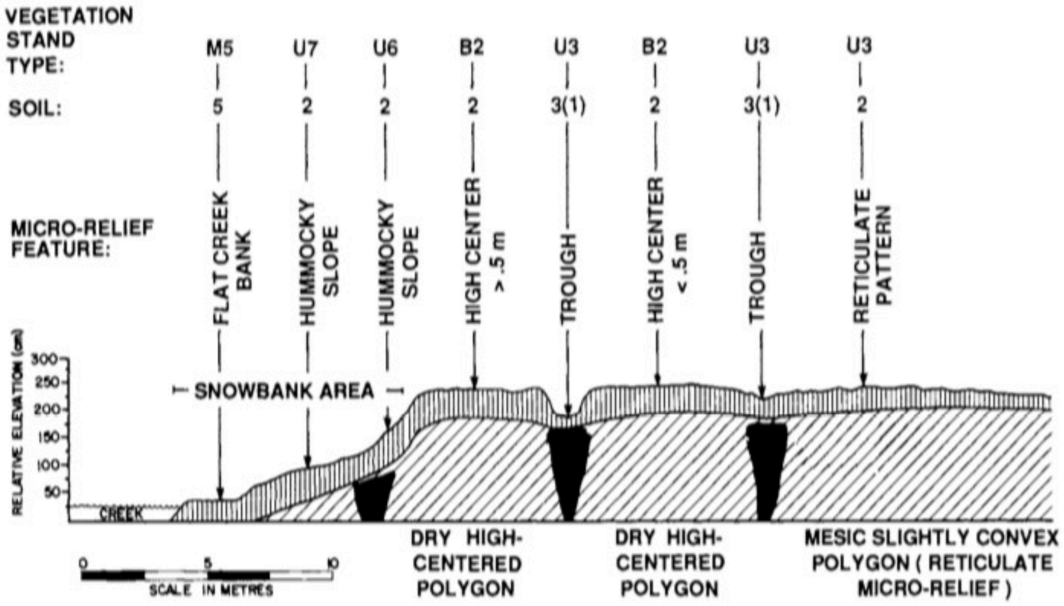
- **Key questions**
  - Where, why, and how is ground ice accumulated?
  - How have IRPS evolved and how are they currently changing?
  - How can people and their infrastructure adapt to the changes?
- **How differences in vegetation, water, and time influence the accumulation and degradation of ground ice in IRP landscapes.**
- **How the loss of ground ice can radically change these systems and their components.**
- **Two major components of the research:**
  - Ice-rich permafrost systems and landscape evolution
  - Adaptations to change
- **Transformative element:**
  - A new conceptual model of permafrost evolution that places ice-rich permafrost at the center of a web of changing Arctic system components. We will show that IRP has a role similar to a keystone biological species and if removed or drastically reduced, totally transforms the system.

Ice-rich-permafrost systems (IRPS)

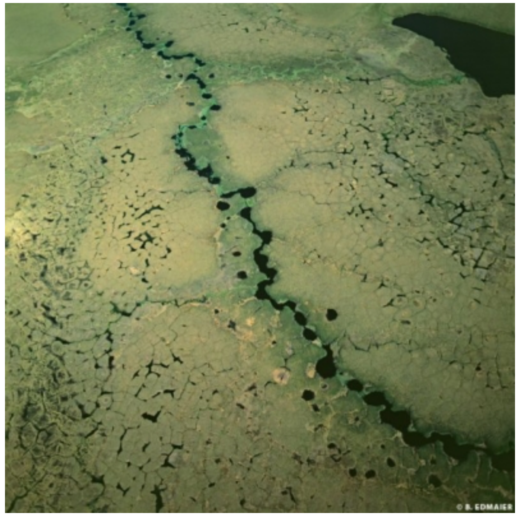
Cryostratigraphy

Patterned ground





Walker & Everett. 1991. *Ecological Monographs*.

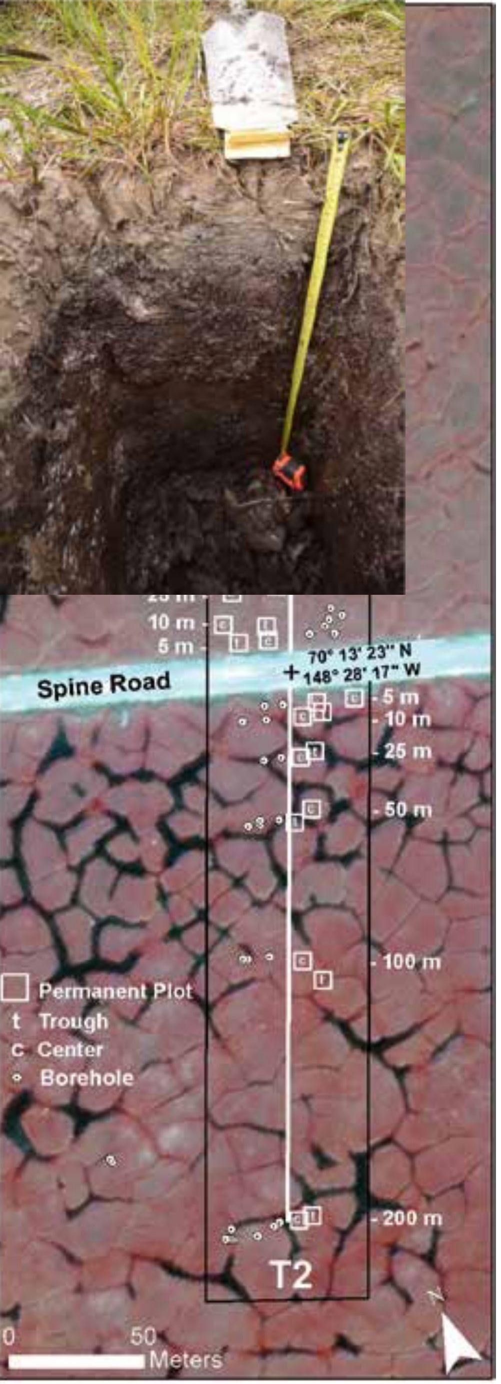


Hydrological connections

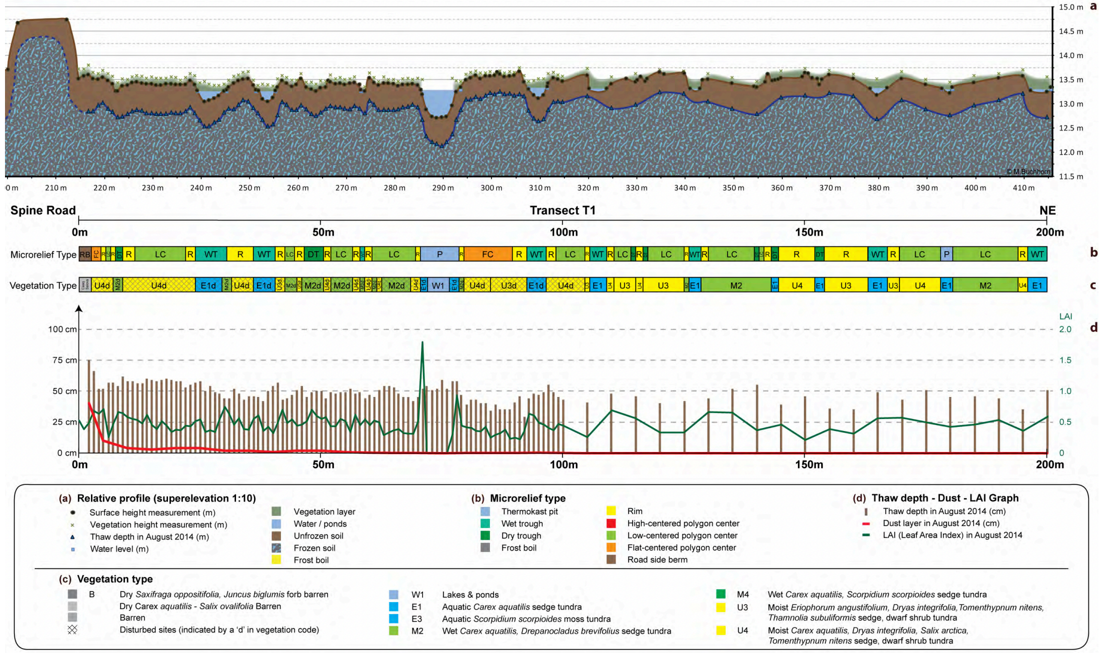
Fish and Wildlife connections

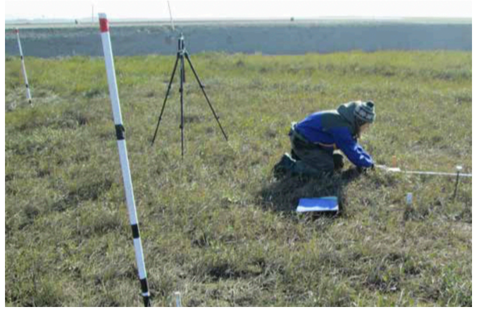
Thermokarst and social connections

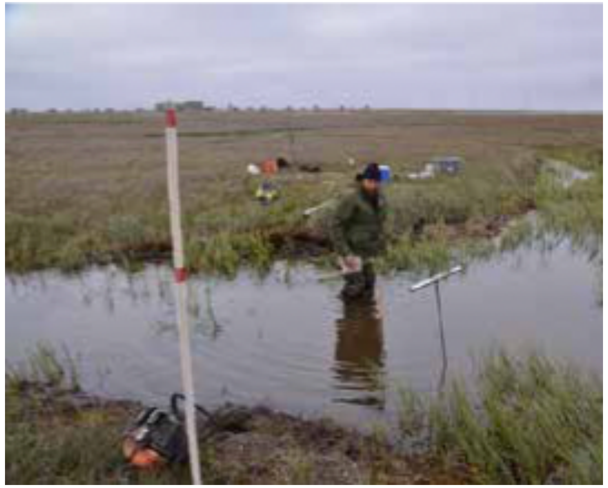
Roadside observatories



- Aerial photo time series
- Transect surveys
  - Micro-topography
  - Permafrost cores
  - Active layer
- Vegetation
- Soil
- Snow
- Dust
- Flooding

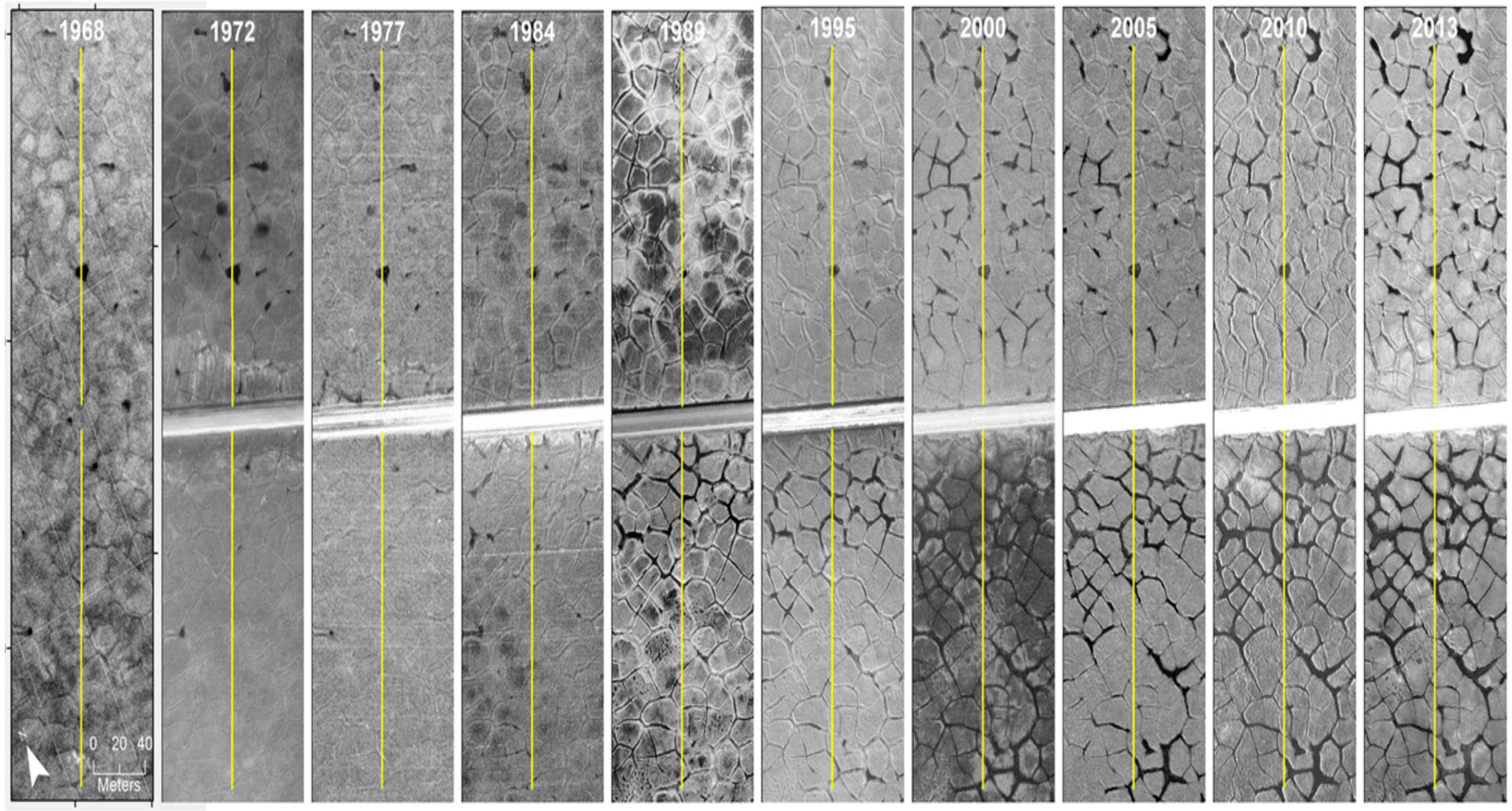




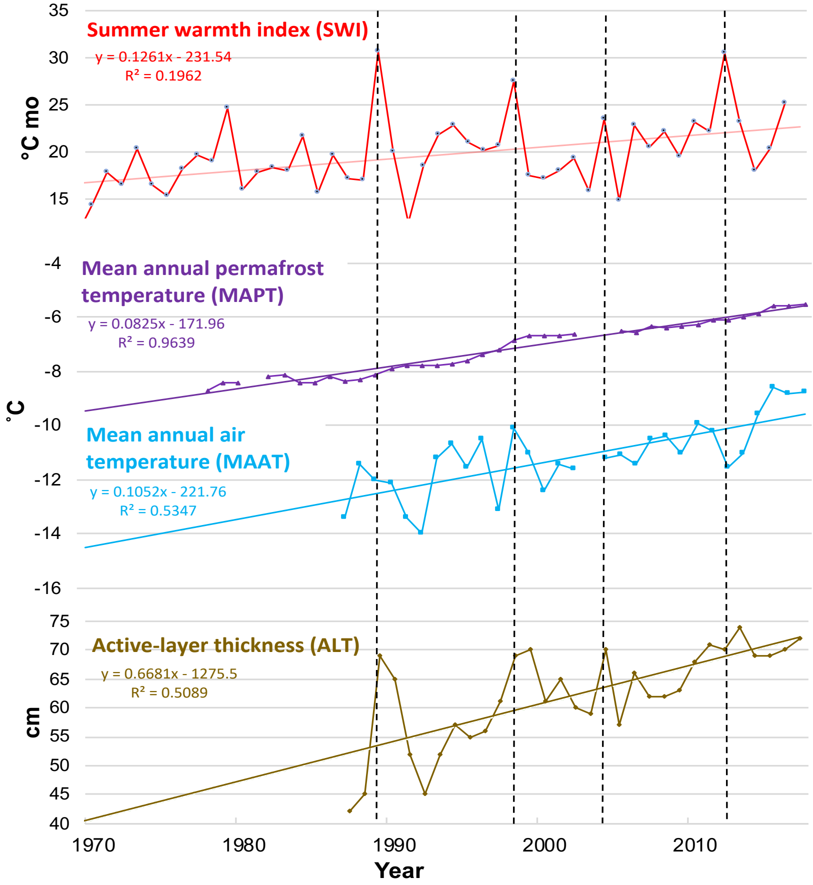


Abrupt thermokarst expansion in the Prudhoe Bay oilfield

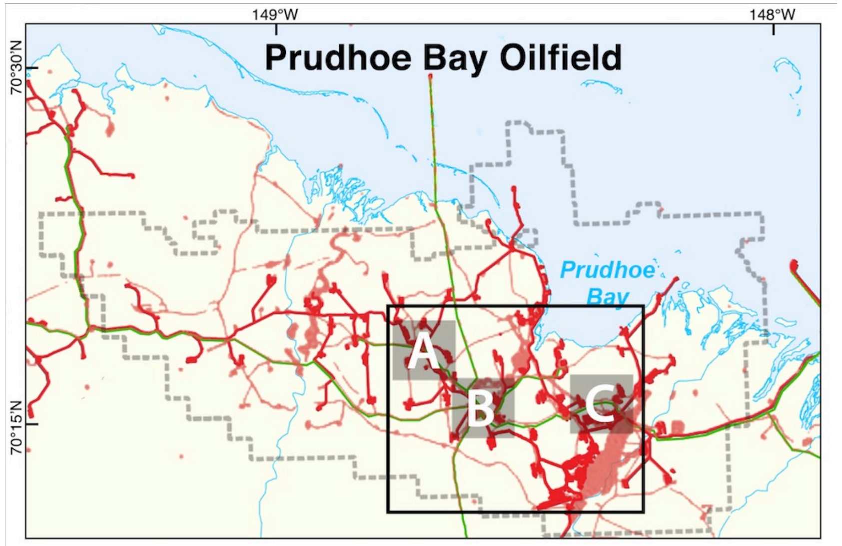
Time-series of thermokarst along main Spine Road

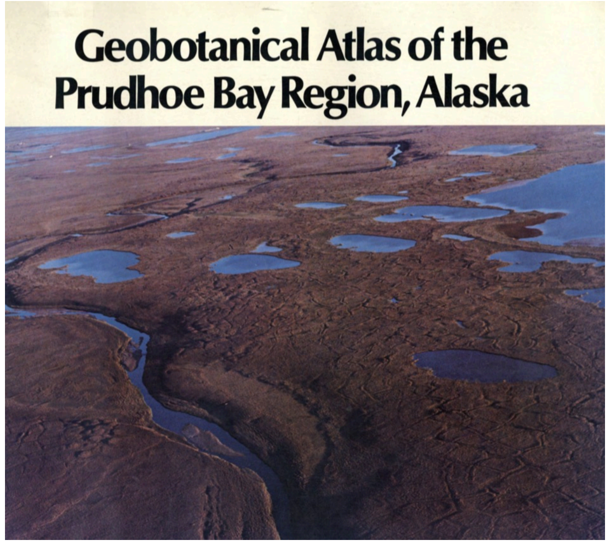


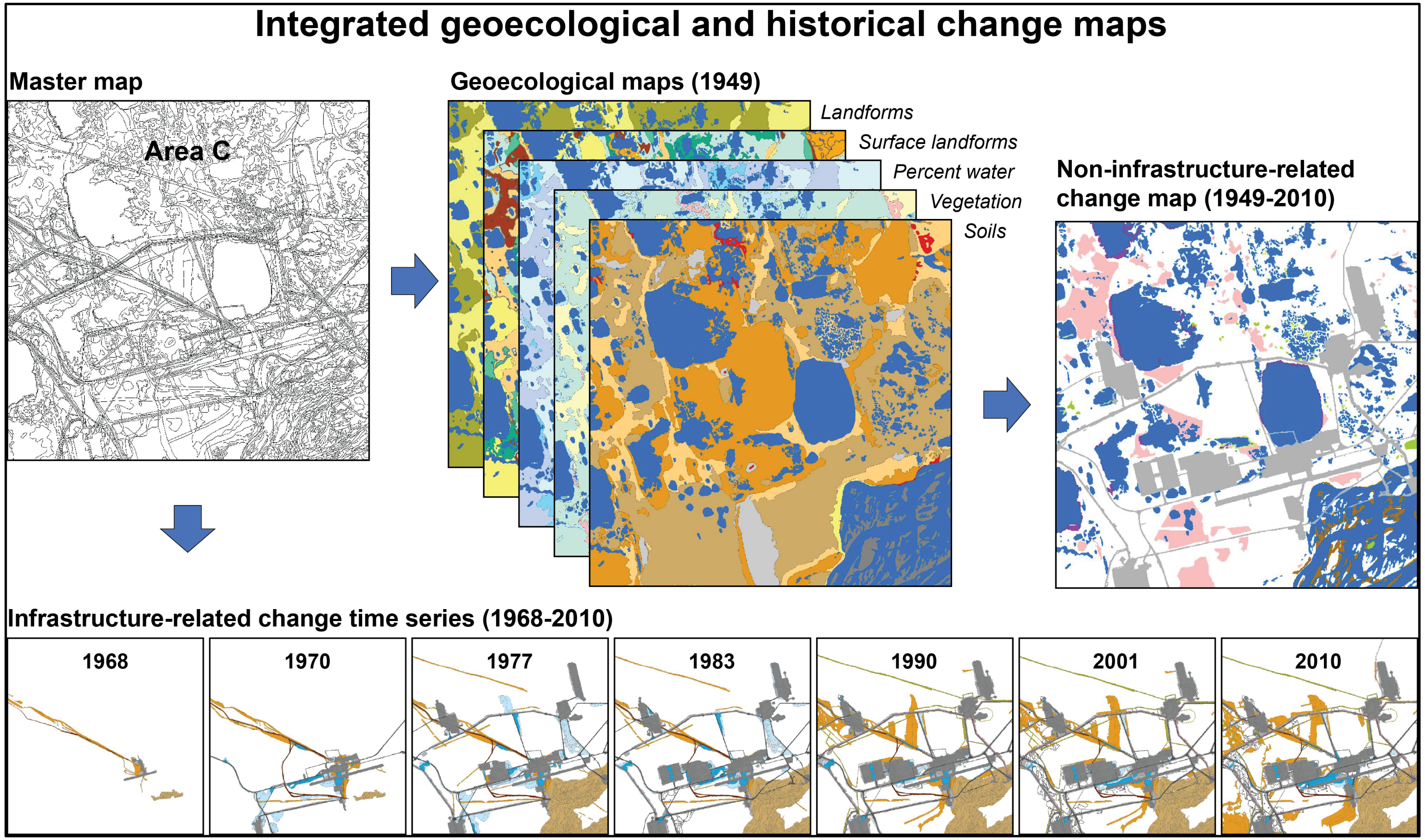
Time-series of summer temperature, permafrost temperatures, and active-layer thickness



IRPS-observatories, historical mapping





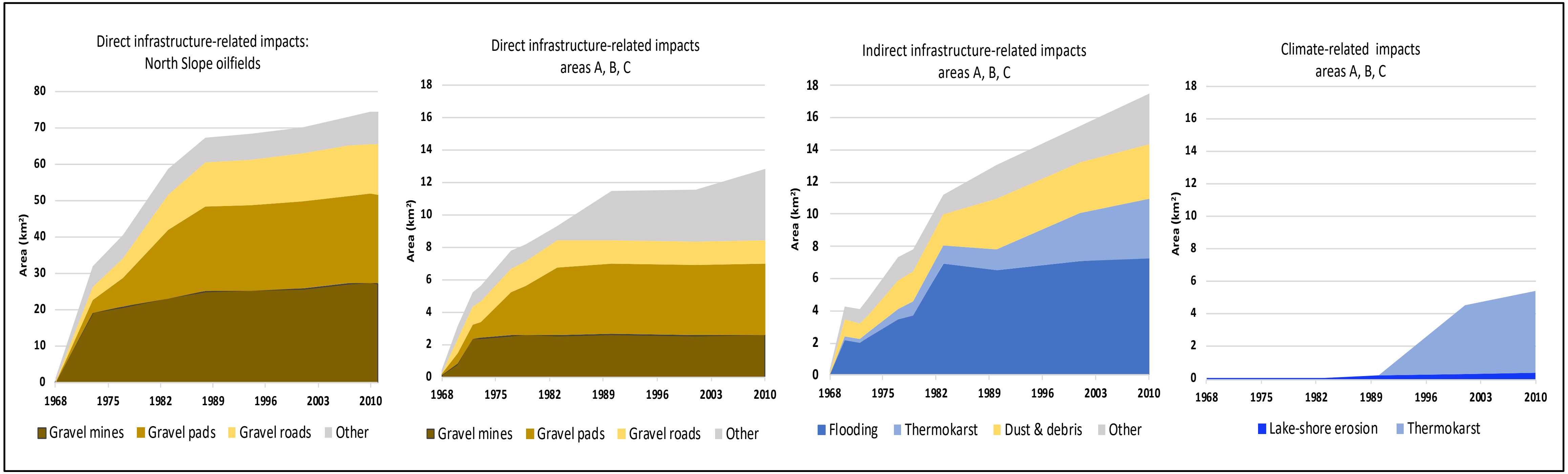


1968 Baseline: Walker, D. A., Everett, K. R., Webber, P. J., & Brown, J. (1980). *Geobotanical atlas of the Prudhoe Bay region, Alaska. CRREL Report 80-14.*

2010 Analysis: Raynolds et al. (2014) *Global Change Biology,* 20: 1211–1224

IRPS-observatories, historical mapping

Area of infrastructure-related impacts (1968–2010)

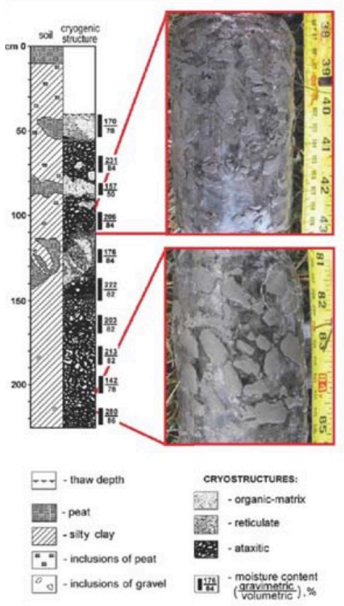


ANTHROPOGENIC DIRECT IMPACTS DECREASED IN RATE OF INCREASE AFTER ABOUT 1983 WITHIN THE STUDY AREAS . INDIRECT IMPACTS CONTINUED TO INCREASE.

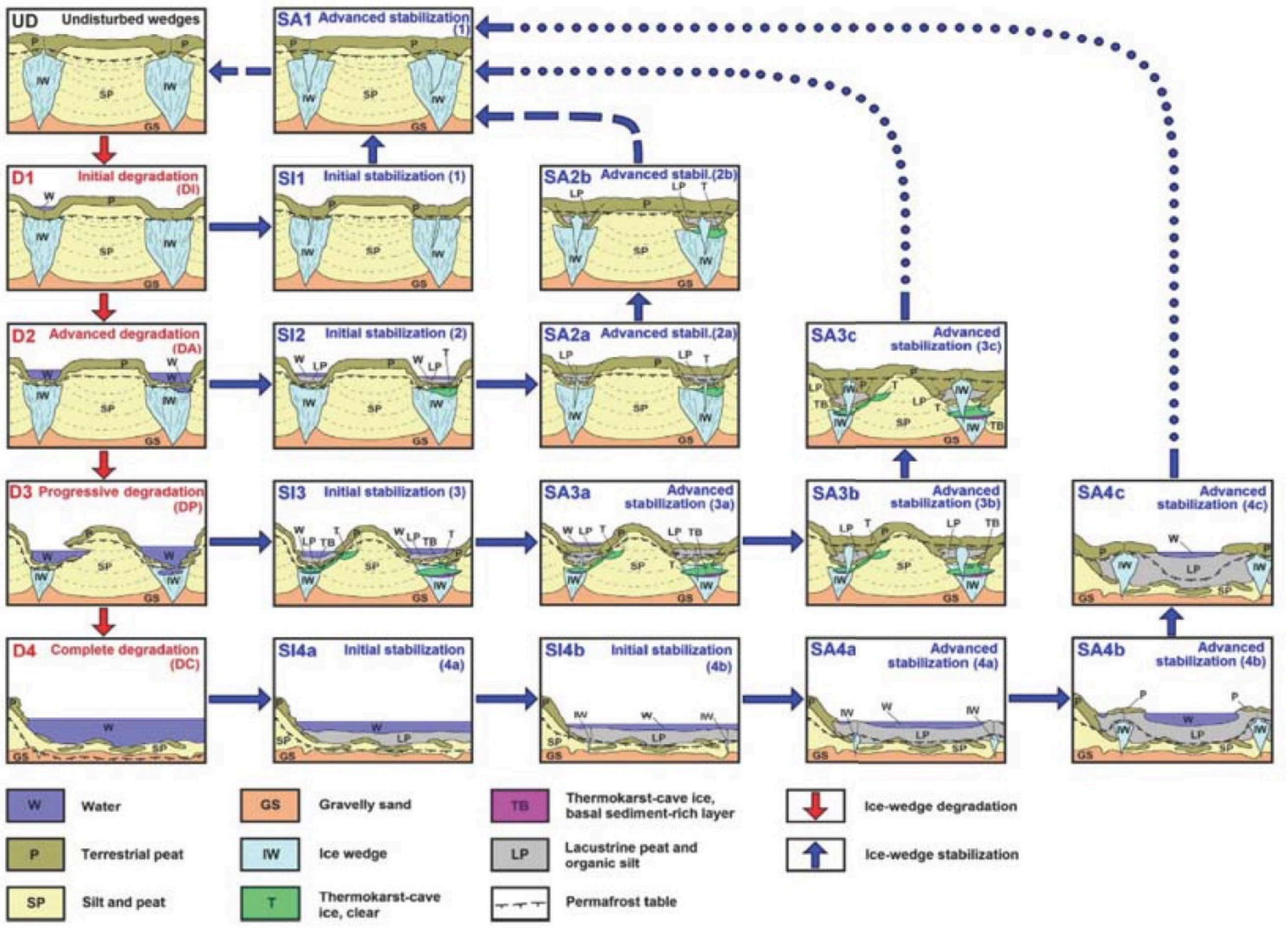
CLIMATE RELATED IMPACTS STARTED TO APPEAR IN 1983 AND INCREASED DRAMATICALLY AFTER 1990.

Ground-ice characterization and evolution

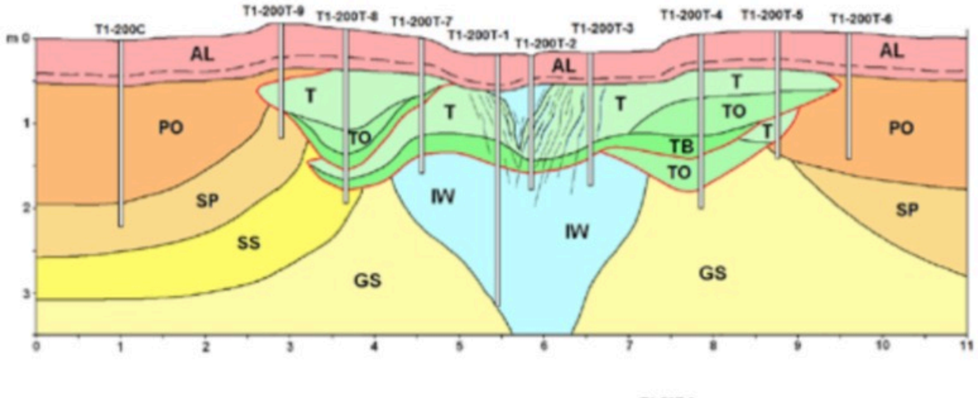
Boreholes



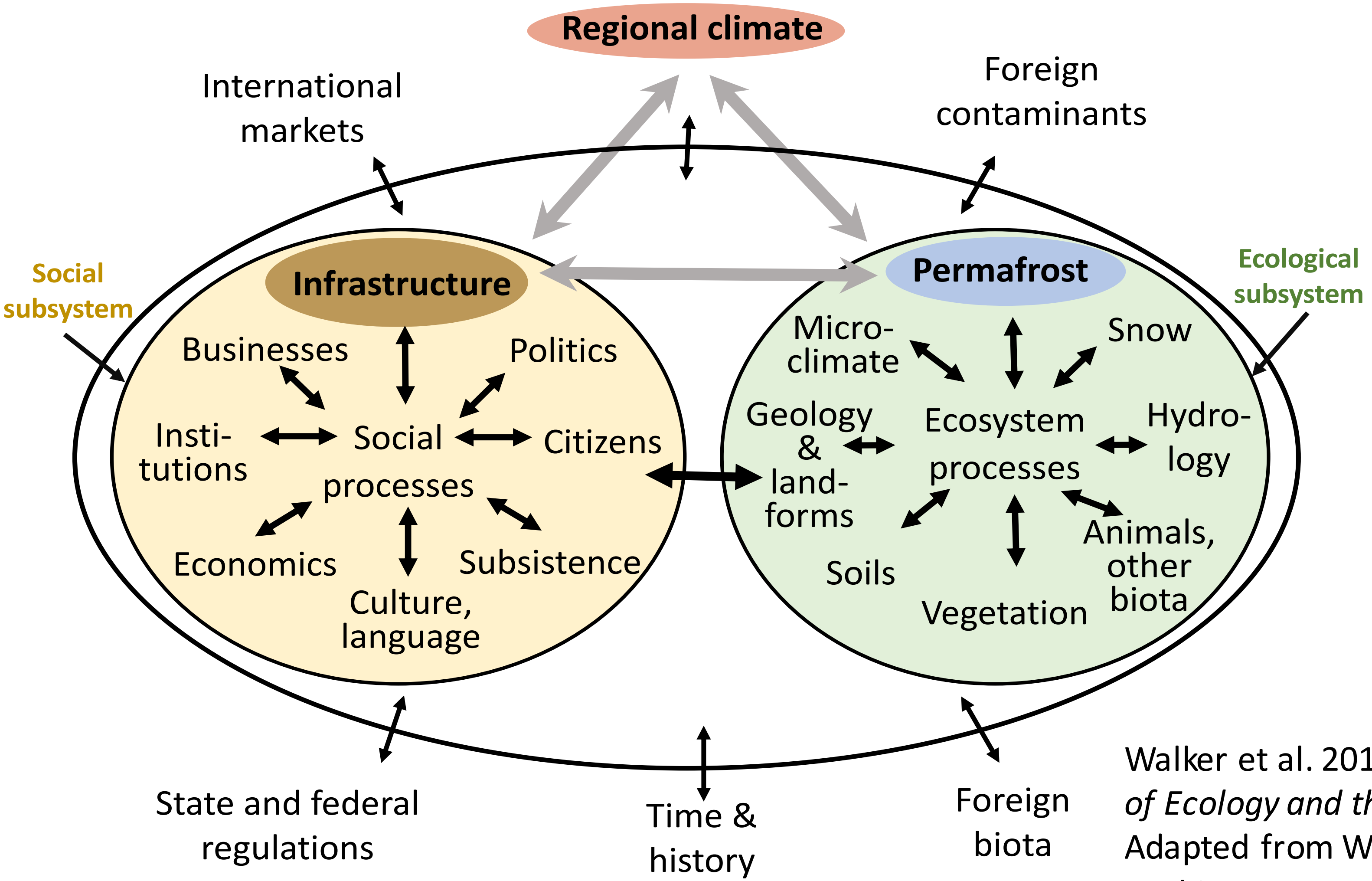
Scenarios of IRP change



Profiles



Cumulative impacts of infrastructure and climate change in Arctic social-ecological systems (ASES)



Walker et al. 2019 (in review). *Frontiers of Ecology and the Environment.* Adapted from Whiteman et al. 2004. *Ambio*.

3D-seismic surveys:

Seemingly minor impacts over large areas but with unknown consequences in view of climate change effects to snow, hydrology, vegetation, and permafrost regimes

New natural thermokarst,
Arctic National Wildlife Refuge, Alaska
Photo: Matt Nolan

2D-seismic trail from 1960s.
Photo: Matt Nolan

3D-seismic grid south of Prudhoe Bay.
Photo: Heather Buelow

Walker, D. A., M. T. Jorgenson, M. Kanevskiy, A. K. Liljedahl, M. Nolan, M. K. Raynolds, and M. Sturm. 2019. Likely impacts of proposed 3D-seismic surveys to the terrain, permafrost, hydrology, and vegetation in the 1002 Area, Arctic National Wildlife Refuge, Alaska. Alaska Geobotany Center Publication AGC 19-01..
https://www.geobotany.uaf.edu/library/pubs/WalkerDA2019_seismic_exploration_whitepaper.pdf

3D-seismic white paper

Thermokarst collapse due to flooding Dalton Highway near Deadhorse Airport

Dalton Highway near Deadhorse, May 25, 2015.

Shur et al. 2016. TICOP and in prep.

Underground thermal erosion of ice wedges

Photos: Courtesy of AKDOT & PF.

Example of unpredictable cumulative effects:

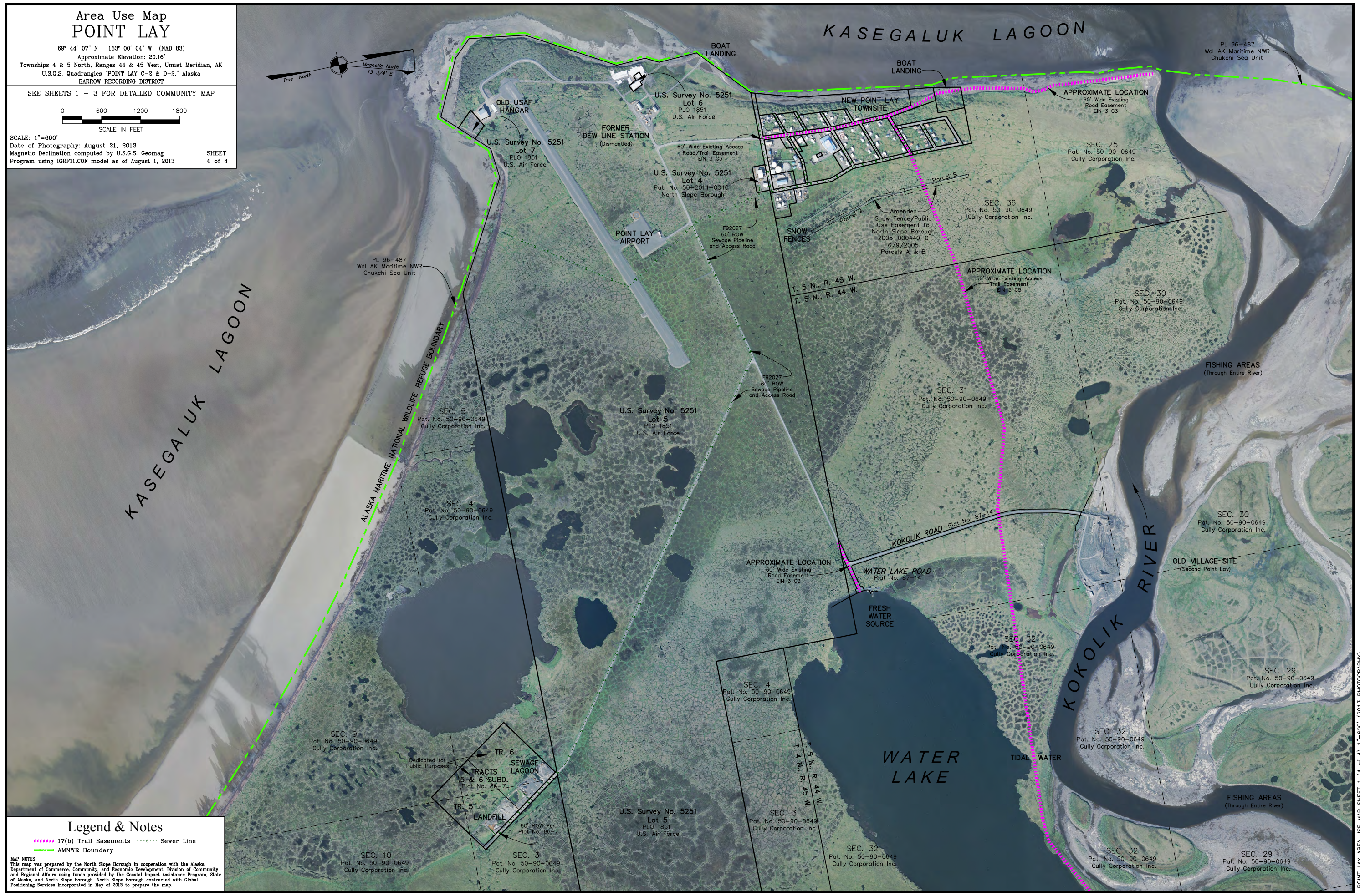
2015-2016 Quintillion fiber-optic cable

- Cable to deliver high-speed telecommunication services.
- The cable was buried in trench, much of which was dug in summer with extensive damage to the vegetation and permafrost.
- Especially visible in tundra of North Slope parallel to the Dalton Highway.
- Cable trench provided a pathway for flood waters to penetrate to the base of ice-wedge facilitating very rapid thermal erosion.
- Decision letter by AK-DNR permitted the project without a thorough environmental review.

Flooding is becoming a major issue for oilfield operation

- 2015 aufeis and flooding disrupted road traffic and communication for over 3 weeks in April and May.
- Alaska Governor declared a disaster twice.
- Major economic impacts.
- National security issue.
- Flooding was repeated in 2016 and 2018.

Adapting to change at Point Lay:
Major impacts to housing due to coastal erosion and ground subsidence



Point Lay infrastructure amidst rapidly changing ice-wedge polygons and eroding coastal bluffs. Courtesy of North Slope Borough.

Subsiding ice-wedges: Base of steps was at ground level and there was no thermokarst when house was built in late 1980s.

Housing adaptations to change at Point Lay

Photos courtesy of the Cold Climate Housing Research Center, Fairbanks

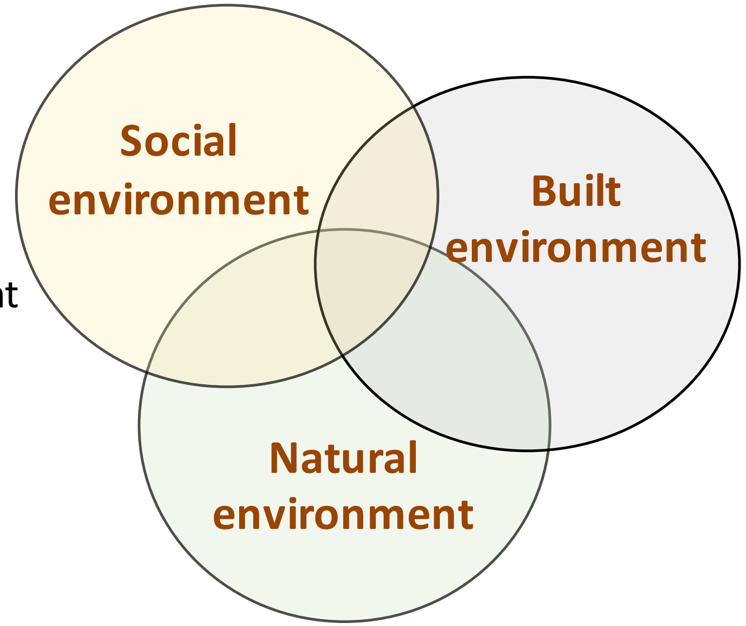
Navigating the New Arctic (NSF)

https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=505594

Possible scientific questions for T-MOSAiC-RATIC collaboration

Social environment

- What are the historical indigenous housing adaptations to climate change and can these aid in finding modern solutions?
- How do the adaptive responses of ice-rich permafrost vary in different ASES?
- What are the social, economic, political & technological drivers of IRPS change in different ASES?
- How can scientists, industry, and local communities collaborate to develop adaptive approaches to sustainable development?



Built environment

- Can we improve engineering solutions for IRPS problems related to urban nodes, remote villages, and transportation corridors?
- How are roads in IRPS affecting intensity flooding events? And jhow can we reduce the intensity?
- Can we develop adaptive engineering solutions that include consideration of local culture, and indigenous knowledge?
- Can we develop circumpolar remote-sensing tools to document infrastructure expansion and consequences to engineering and the environment at multiple scales?

Natural environment

- How do natural IRPS responses to climate and infrastructure changes vary along N-S bioclimate gradients?
- How are these changes linked to observed changes in sea-ice and the marine environment?
- Can we develop standardized monitoring protocols for terrestrial ecosystem responses? at multiple scales using remote sensing and ground observations?
- What are the circumpolar impacts to IRPS of historical changes in air temperatures and flooding?
- What are the total ecosystem consequences pf the documented abrupt thermokarst changes?
- What are the ecosystem consequences of widespread 3D-seismic exploration?