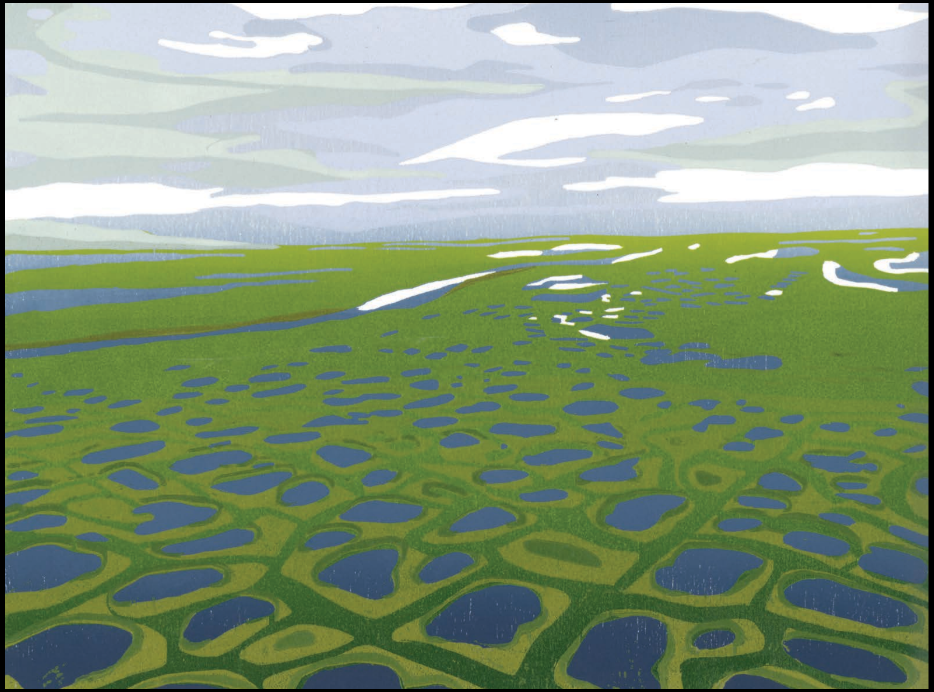
Landscape evolution and adapting to change in ice-rich permafrost systems (NNA-IRPS)

D. A. "Skip" Walker,

Institute of Arctic Biology and Department of Biology and Wildlife,
University of Alaska Fairbanks (UAF), Seminar 11 Oct 2019



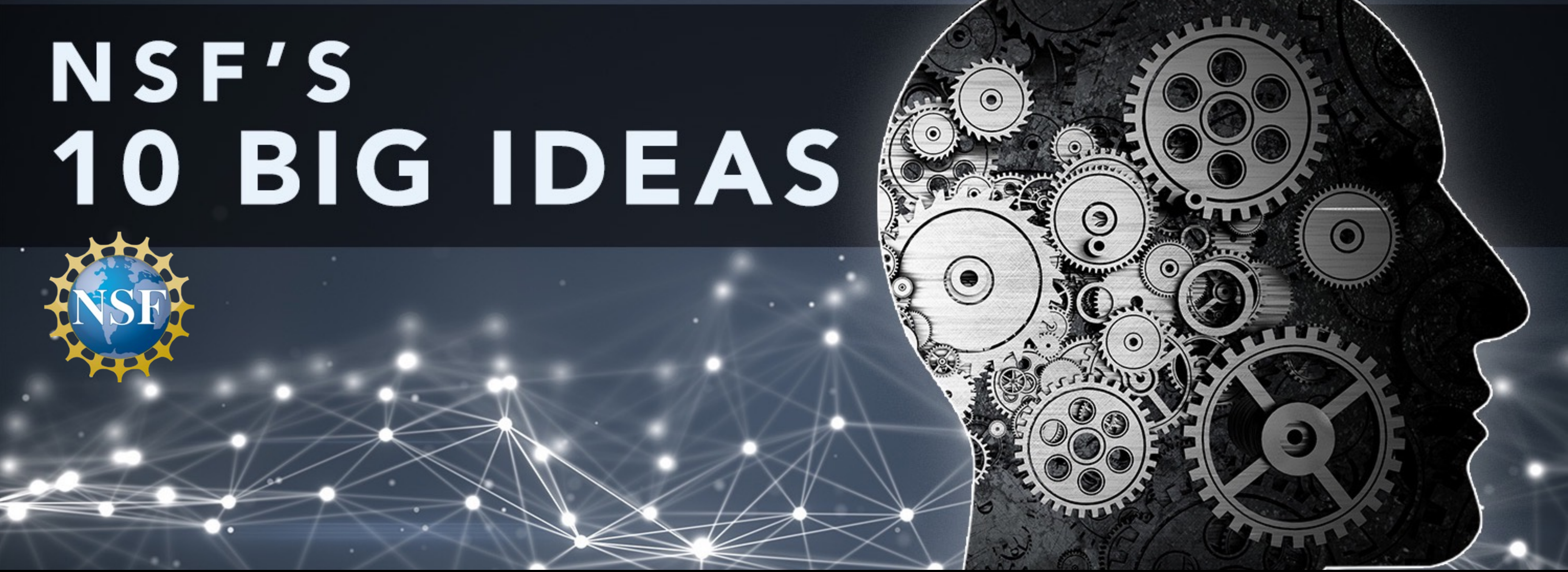
Evolution of low-centered polygons into high-centered polygons under the influence of a warming climate. **Wood cuts by Ina Timling.**

Structure of the talk

- NSF NNA Concept
- Ice-rich permafrost systems (IRPS), some background
- How IRPSs are changing
  - **Climate change**
  - **Infrastructure**
- History of change at Prudhoe Bay and Point Lay
- IRPS Observatories
- Adaptive housing at Point Lay
- RATIC and T-MOSAiC initiatives

Ina Timling

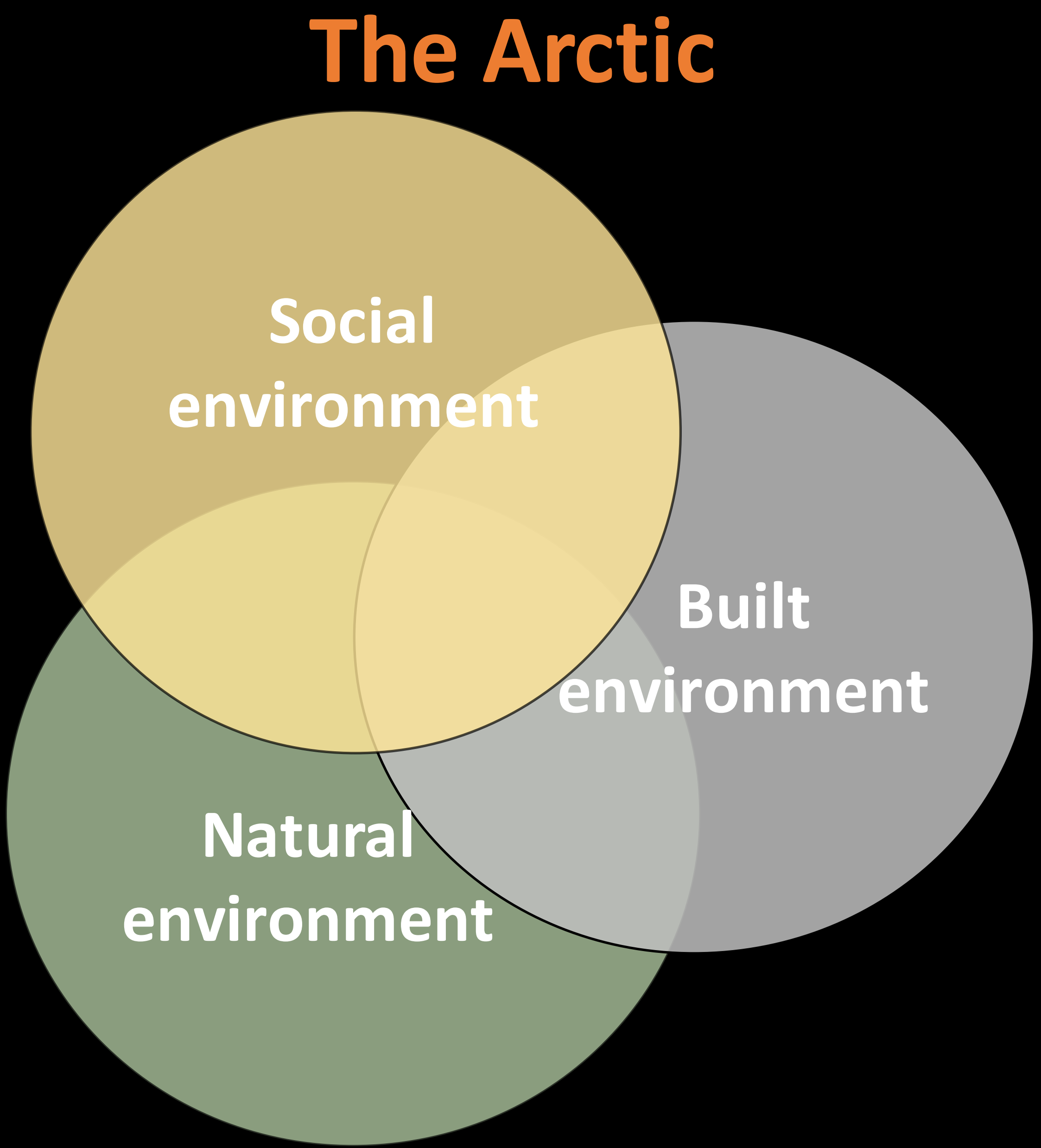
Navigating the New Arctic (NNA): one of



NSF is investing $30 million in each Big Idea to identify and support emerging opportunities for U.S. leadership in Big Ideas that serve the Nation's future.

Major goals of NNA

- Improved ***understanding of Arctic change***, its local and global effects, and its effects on the natural, social, and built environments.
- Development of ***new research communities*** at the intersections of the natural, social, and built environments.
- Research that inform U.S. security, and economic development needs and enables resilient ***sustainable Arctic communities***.
- Studies of ***feedbacks between the infrastructure and changes in natural ecosystems***.
- Studies that advance ***STEM education*** through Arctic research activities.



“To heal the planet we first need to understand it.”

Mark Hansen
Maine seaweed harvester

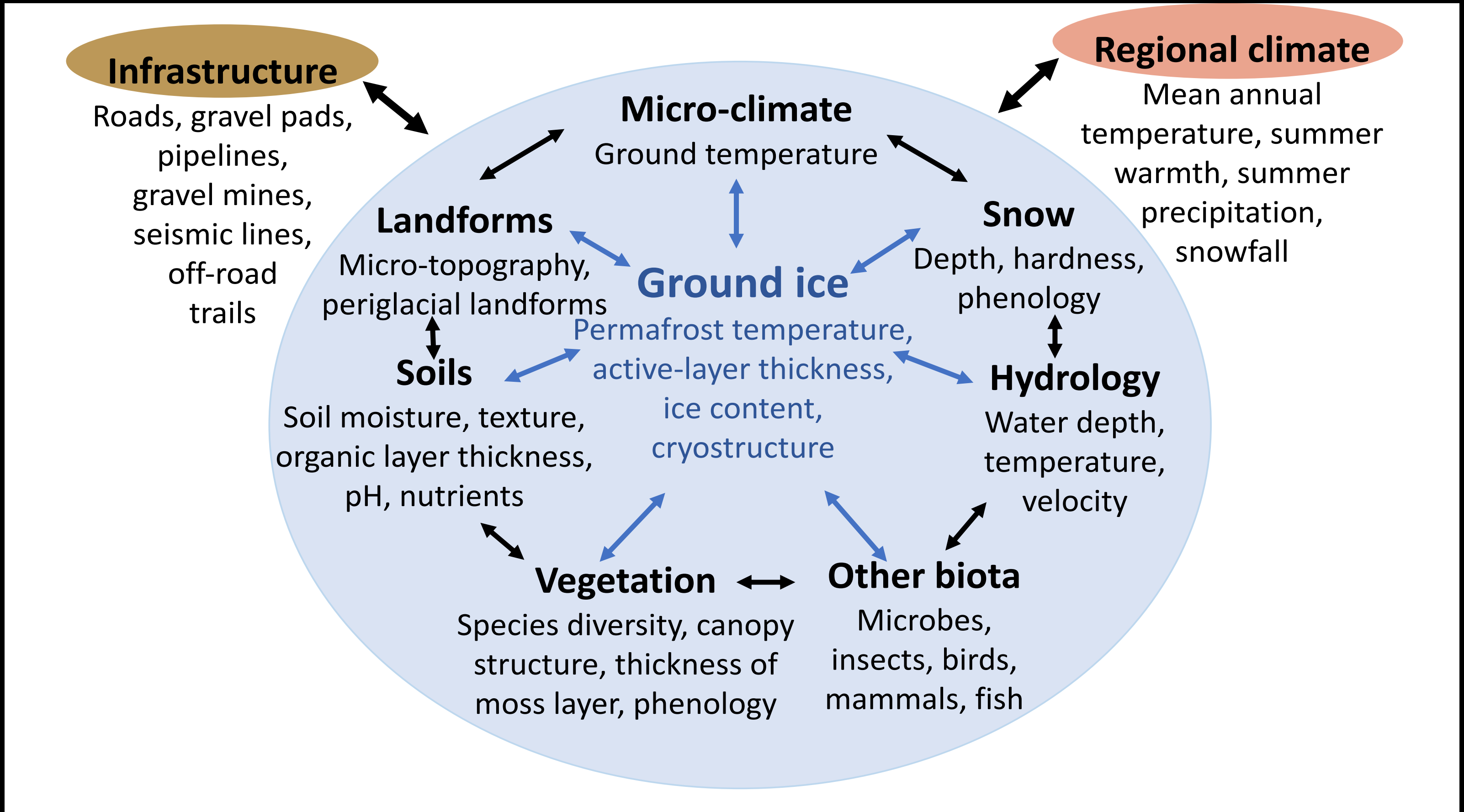
The mission of our NNA project

To understand the structure, processes, evolution, and degradation of ice-rich permafrost (IRPS) in relationship to Arctic ecosystems, the people of the North, and the built environment.

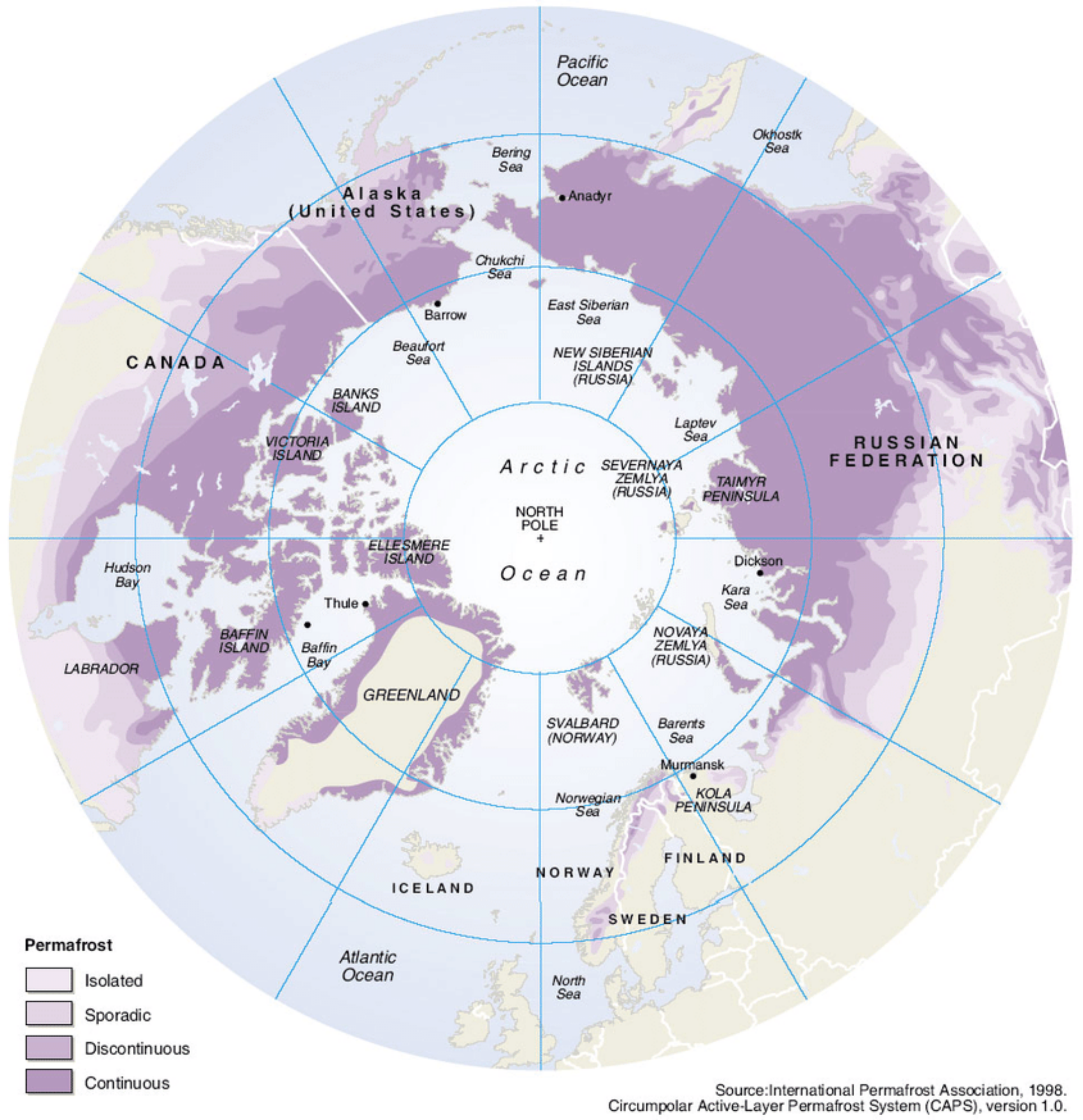
To convey to students, government institutions and the public the role of IRPS and its function in Arctic and global social-ecological systems.

To use the acquired knowledge to promote better living conditions, methods of construction, and land-use policies in the North.

Focus: Ice-rich permafrost system



Conceptual model places ice-rich permafrost at the center of a web of changing Arctic system component — **similar to a keystone biological species** — if IRP is removed or drastically reduced, the system is totally transformed.



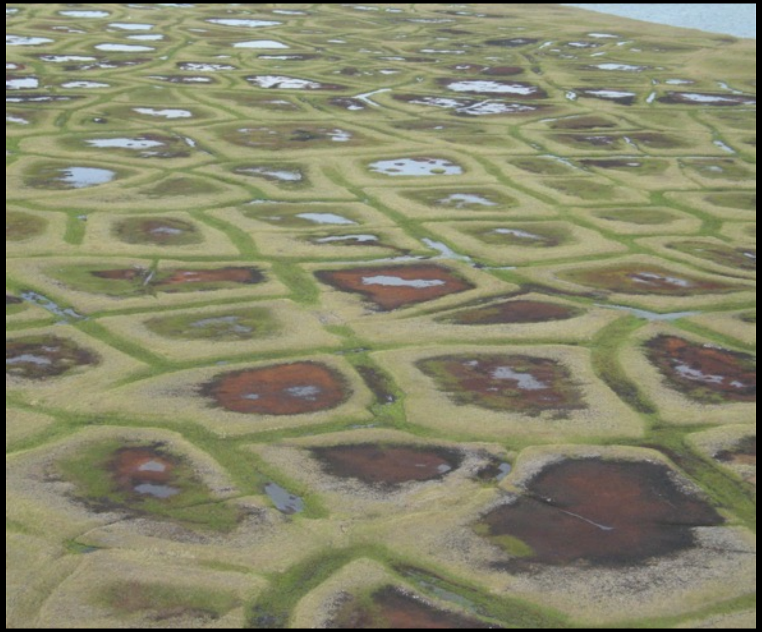
Permafrost

- Ground that remains below 0 ˚C for two or more years.
- Occurs beneath approximately 20% of the Earth's surface.
- Estimated to contain twice as much water as all lakes and rivers on Earth (0.022% vs. 0.011%).
- Most landscapes with continuous and discontinuous permafrost (darker purple areas in this figure) are extraordinarily sensitive to climate change.

Ice-Rich Permafrost

Ice wedge, Misha Kanevskiy

Coastal erosion of Ice wedges, USGS



Low-centered and high-centered ice-wedge polygon, Misha Kanevskiy

- IRP is permafrost with *excess ice* (ice that exceeds the volume of the pore spaces in the soil).
- Nearly 50% of the Arctic is underlain by ice-rich permafrost.
- Includes ice-wedges, tabular ice, lens ice, pingo ice.
- Many arctic landforms, such as ice-wedge polygons, tabular ice, and pingos are the result of various forms of massive ground ice.

Thermokarst ponds: Matt Nolan

Thaw lakes: Ann Blasubramaniam:

Thermal erosion gully: Polar Field Services.

Themocirque and gully: https://www.21stcentech.com

IRP is the most susceptible element of Arctic systems to disturbance and climate change. If the ice in IRP melts. the soil becomes liquid and collapses!

Thermokarst

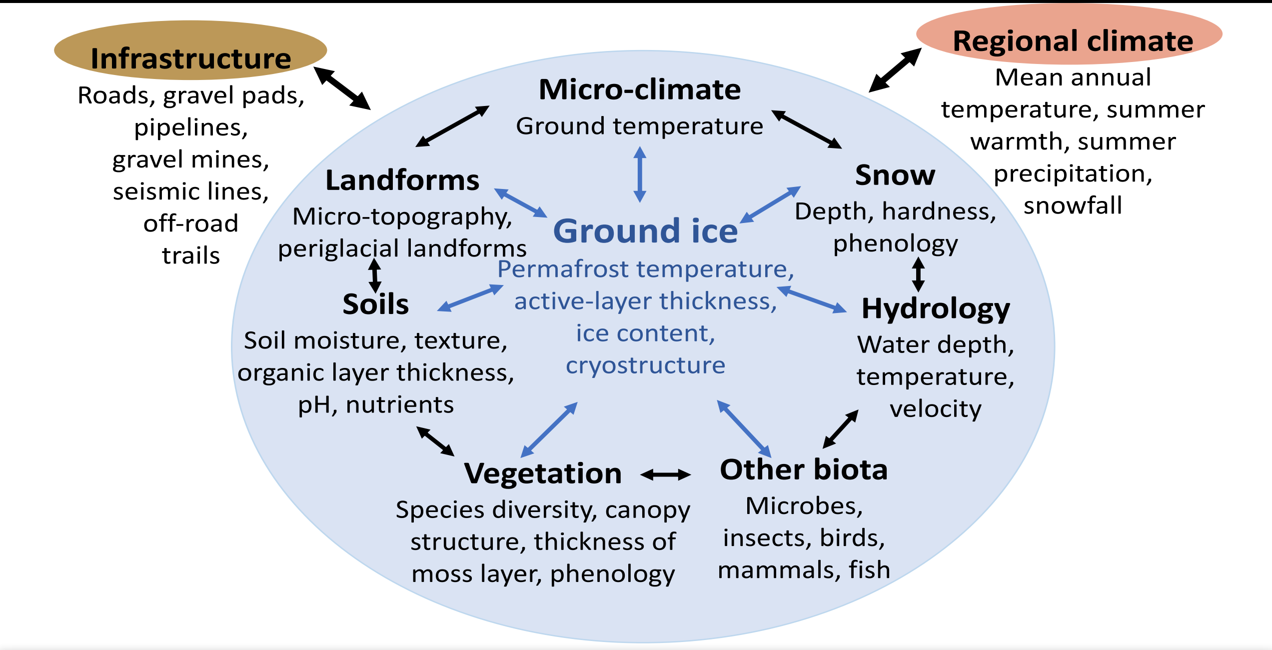
- The process caused by melting ground ice that results in subsidence of the ground surface and characteristic landforms such as thaw ponds, irregular surfaces, and thaw lakes.
- Common forms include thermokarst ponds, and thaw lakes.

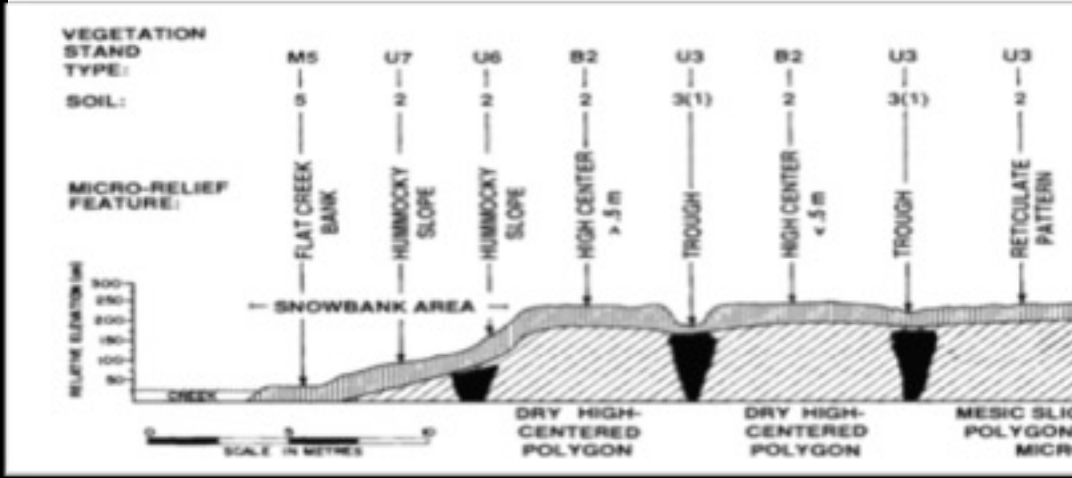
Thermal erosion

- Refers to the erosion of the land surface by thermal and mechanical processes.
- Common forms include thermal erosion gullys

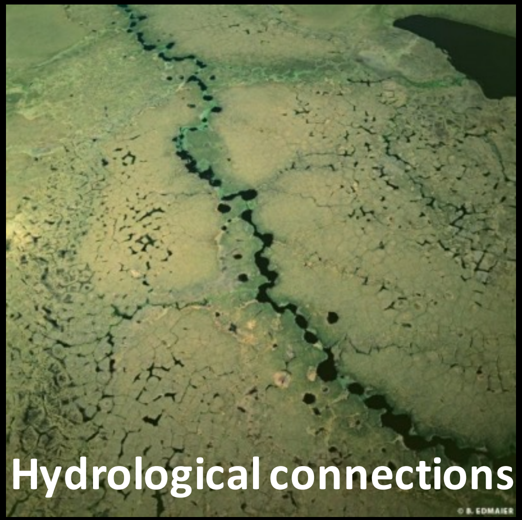
Ice-rich-permafrost systems (IRPS)

Ground ice is at the center of a web of ecosystem properties and processes



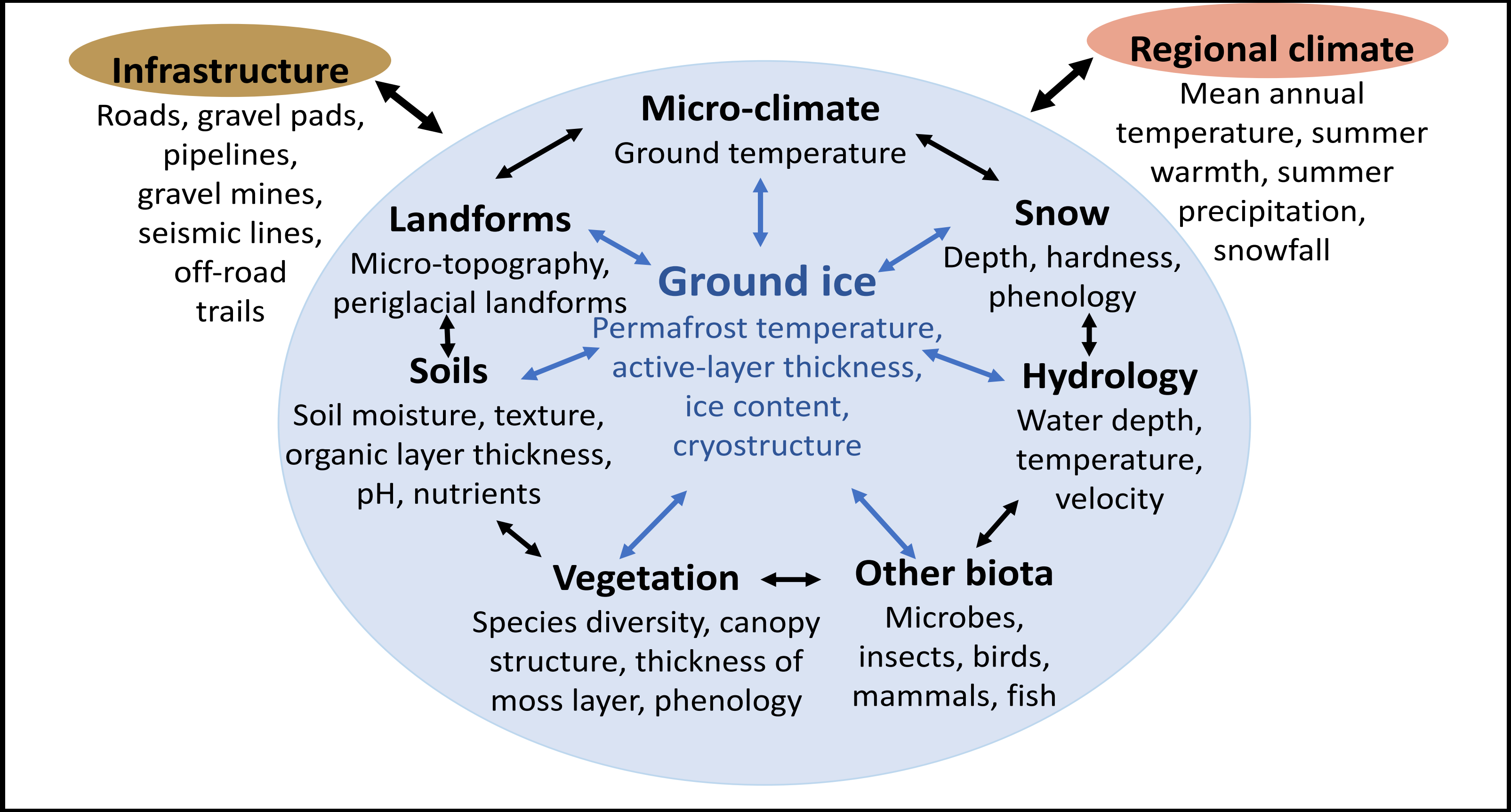


Walker & Everett. 1991. *Ecological Monographs*.



Key Questions

- Where, why, and how is ground ice accumulated in IRPS?
- How do IRPS evolve and how are they currently changing?
    - How do differences in vegetation, water, and time influence the accumulation and degradation of ground ice in IRP landscapes?
    - How does the loss of ground ice change these systems and their components?
- How can people and their infrastructure adapt to the changes?



Variety of ice-wedge polygon forms

Poorly developed low-centered polygons with <0.5 m relief in drained lake basin

Poorly developed low-centered polygons with <0.5 m relief

Well developed low-centered polygons with >0.5 m relief

Well developed low-centered polygons with <0.5 m relief

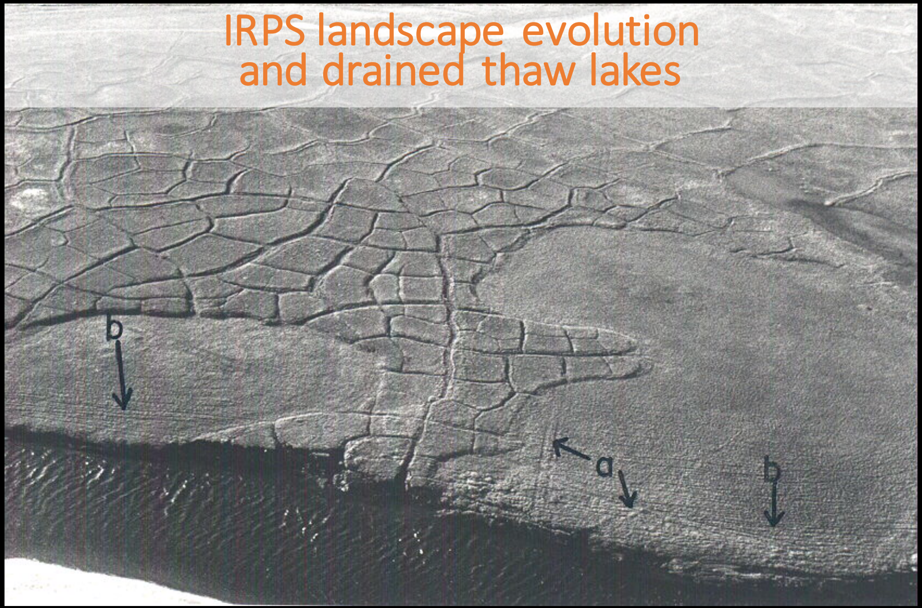
Well developed low-centered polygons with <0.5 m relief and thermokarst pits

Mixed low- and high-centered polygons with >0.5 m relief

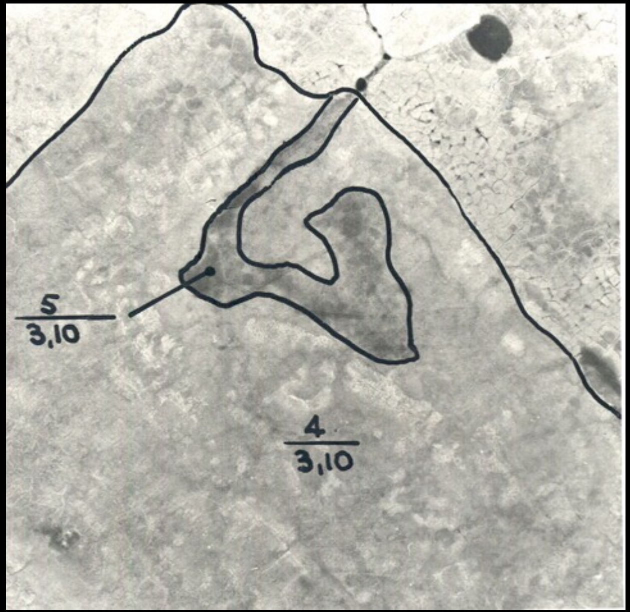
Well developed high-centered polygons with >0.5 m relief

Well developed high-centered polygons with >0.5 m relief

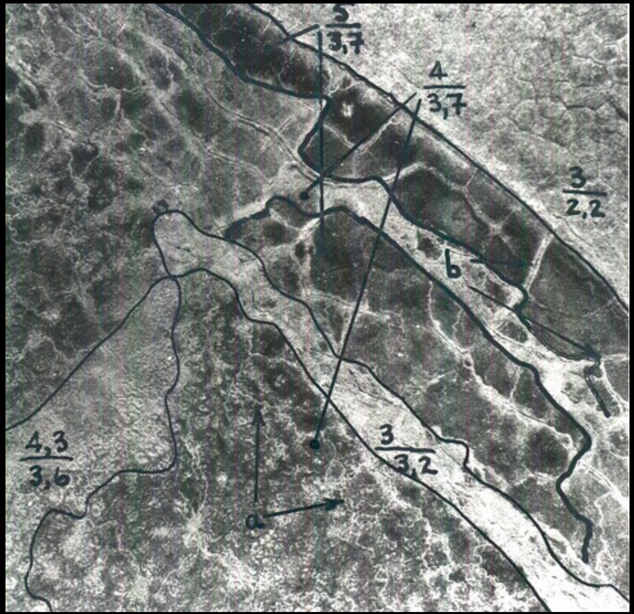
IRPS landscape evolution and drained thaw lakes



Old residual surface with two recent drained thaw lakes

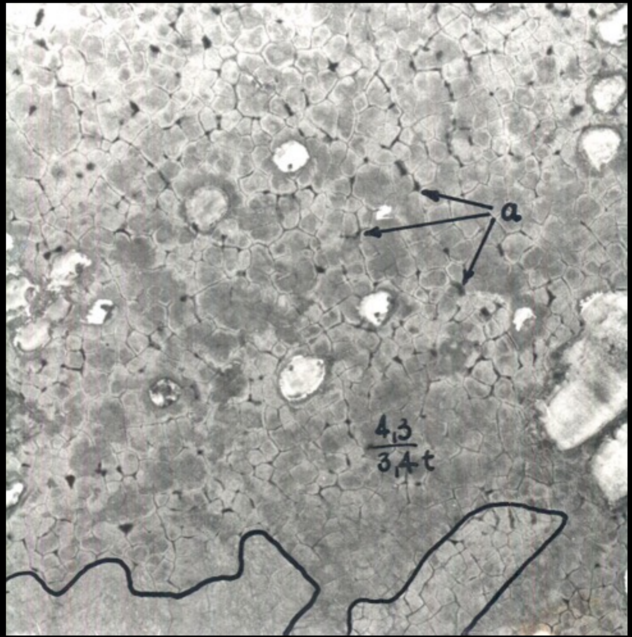


Recent drained lake, no ice wedges

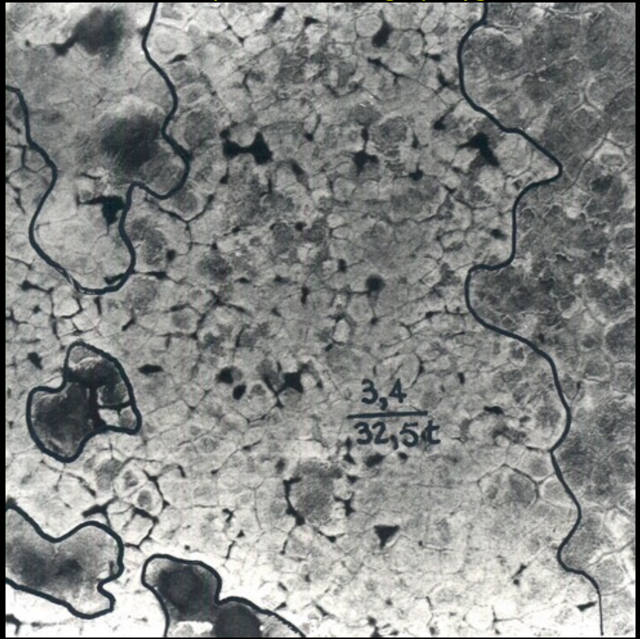


Older drained lake surfaces with weakly developed ice-wedge polygons

Residual surface, well developed low-centered polygons



Residual surface, well developed low-centered polygons & thermokarst pits



Degrading residual surface

Photos:
Walker, 1980
and Air Photo Tech, Inc. 1973

Recent abrupt changes in thermokarst

GEOPHYSICAL RESEARCH LETTERS, VOL. 33, L02503, doi:10.1029/2005GL024960, 2006

Abrupt increase in permafrost degradation in Arctic Alaska

M. Torre Jorgenson,[1] Yuri L. Shur,[2] and Erik R. Pullman[1]

Received 14 October 2005; revised 28 November 2005; accepted 5 December 2005; published 24 January 2006.

[1] Even though the arctic zone of continuous permafrost has relatively cold mean annual air temperatures, we found an abrupt, large increase in the extent of permafrost degradation in northern Alaska since 1982, associated with record warm temperatures during 1989–1998. Our field studies revealed that the recent degradation has mainly occurred to massive wedges of ice that previously had been stable for 1000s of years. Analysis of airphotos from 1945, 1982, and 2001 revealed large increases in the area (0.5%, 0.6%, and 4.4% of area, respectively) and density (88, 128, and 1336 pits/km^2) of degrading ice wedges in two study areas on the arctic coastal plain. Spectral analysis across a broader landscape found that newly degraded, water-filled pits covered 3.8% of the land area. These results indicate that thermokarst potentially can affect 10–30% of arctic lowland landscapes and severely alter tundra ecosystems even under scenarios of modest climate warming. **Citation:** Jorgenson, M. T., Y. L. Shur, and E. R. Pullman (2006), Abrupt increase in permafrost degradation in Arctic Alaska, *Geophys. Res. Lett.*, *33*, L02503, doi:10.1029/2005GL024960.

1. Introduction

[2] Although thawing and settling of ice-rich terrain (thermokarst) is widespread in the subarctic zone where permanently frozen ground (permafrost) is discontinuous [*Jorgenson et al.*, 2001; *Halsey et al.*, 1995], the ground in the arctic zone of continuous permafrost has been considered stable because of much lower mean annual air temperatures (annual means −6 to −12°C). The risk for thaw subsidence in arctic lowlands is substantial, however, because of the high volume of ground ice at the top of the permafrost [*Nelson et al.*, 2001]. Under the cold climatic conditions in the Arctic, a polygonal network of wedge-shaped ice bodies form beneath a thin layer of seasonally thawed soil due to contraction cracking caused by large fluctuations in winter temperature [*Leffingwell*, 1919; *Lachenbruch*, 1962; *Mackay*, 1990]. Between the active layer and the ice wedges is a very thin transient layer [*Shur*, 1977] of usually frozen soil that adjusts in thickness to vides only limited protection, and thermokarst due to human disturbance frequently has been observed in the Arctic, even at cold temperatures. Here we report an abrupt increase in natural degradation of ice-wedges during a period of an unprecedented 2–5°C increase in mean annual ground temperatures (MAGT) in northern Alaska since the 1980s [*Osterkamp*, 2003; *Clow*, 2003].

2. Methods

[3] We evaluated the degradation of ice wedges in northern Alaska at three spatial scales that included: (1) field surveys within two small, intensive sites (0.6-km^2); (2) photo-interpretation of a time-series of aerial photography within the two intensive sites; and (3) image processing of the spectral characteristics of aerial photography for two larger areas (14.5-km^2). During field surveys in Aug. 2003 and 2004, we sampled 43 plots in the two intensive areas (C1 and C2) 10–40 km west of the Colville River and 20 km south of the coast to assess changes in vegetation, microtopography, and soils associated with ice-wedge degradation evident on the ground. For vegetation, the cover of dominant live and dead species was visually estimated to evaluate patterns of plant mortality and recovery. For microtopography, relative elevations of the ground and water surfaces were surveyed with an auto-level. The stratigraphy of soil plugs from the active layer and shallow 1-m cores from the underlying permafrost was described using standard soil methods with special emphasis in differentiating fibrous peat comprised of varying plant remains. Thaw depths were determined with a metal tile probe.

[4] For the photo-interpretation of ice-wedge degradation over time, we delineated and classified thermokarst pits on photography from 4 July 1945 (1:45,000 scale, B&W), July 1982 (1:63,000 scale CIR), and 14–15 July 2001 (1:18,000 scale, color orthophoto mosaic by Aeromap, Inc., Anchorage, Alaska) to assess temporal changes in various stages of thermokarst within the two intensive sites. To compensate for differences in visibility of pits due to the

Jorgenson et al., 2006:
Abrupt ice-wedge degradation in northern Alaska

Global Change Biology

Global Change Biology (2014), doi: 10.1111/gcb.12500

Cumulative geoecological effects of 62 years of infrastructure and climate change in ice-rich permafrost landscapes, Prudhoe Bay Oilfield, Alaska

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Abstract

Many areas of the Arctic are simultaneously affected by rapid climate change and rapid industrial development. These areas are likely to increase in number and size as sea ice melts and abundant Arctic natural resources become more accessible. Documenting the changes that have already occurred is essential to inform management approaches to minimize the impacts of future activities. Here, we determine the cumulative geoecological effects of 62 years (1949–2011) of infrastructure- and climate-related changes in the Prudhoe Bay Oilfield, the oldest and most extensive industrial complex in the Arctic, and an area with extensive ice-rich permafrost that is extraordinarily sensitive to climate change. We demonstrate that thermokarst has recently affected broad areas of the entire region, and that a sudden increase in the area affected began shortly after 1990 corresponding to a rapid rise in regional summer air temperatures and related permafrost temperatures. We also present a conceptual model that describes how infrastructure-related factors, including road dust and roadside flooding are contributing to more extensive thermokarst in areas adjacent to roads and gravel pads. We mapped the historical infrastructure changes for the Alaska North Slope oilfields for 10 dates from the initial oil discovery in 1968–2011. By 2010, over 34% of the intensively mapped area was affected by oil development. In addition, between 1990 and 2001, coincident with strong atmospheric warming during the 1990s, 19% of the remaining natural landscapes (excluding areas covered by infrastructure, lakes and river floodplains) exhibited expansion of thermokarst features resulting in more abundant small ponds, greater microrelief, more active lakeshore erosion and increased landscape and habitat heterogeneity. This transition to a new geoecological regime will have impacts to wildlife habitat, local residents and industry.

Keywords: Arctic, climate change, cumulative impacts, geoecological mapping, ice-rich permafrost, ice-wedge polygons, infrastructure, photo-interpretation, thermokarst, tundra

Received 18 September 2013 and accepted 8 November 2013

Raynolds et al. 2014:
Abrupt ice-wedge degradation due to infrastructure and climate change at Prudhoe Bay

nature geoscience

ARTICLES

PUBLISHED ONLINE: 14 MARCH 2016 | DOI: 10.1038/NGEO2674

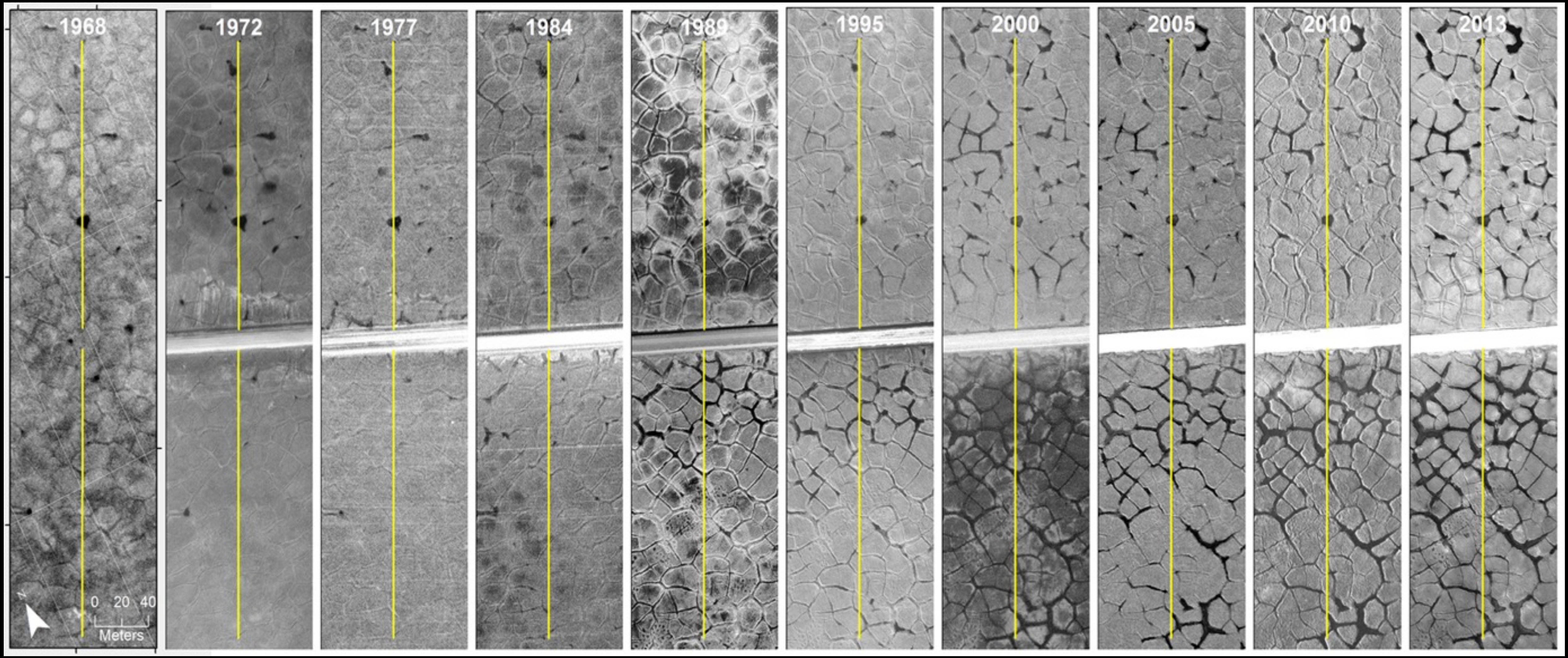
Pan-Arctic ice-wedge degradation in warming permafrost and its influence on tundra hydrology

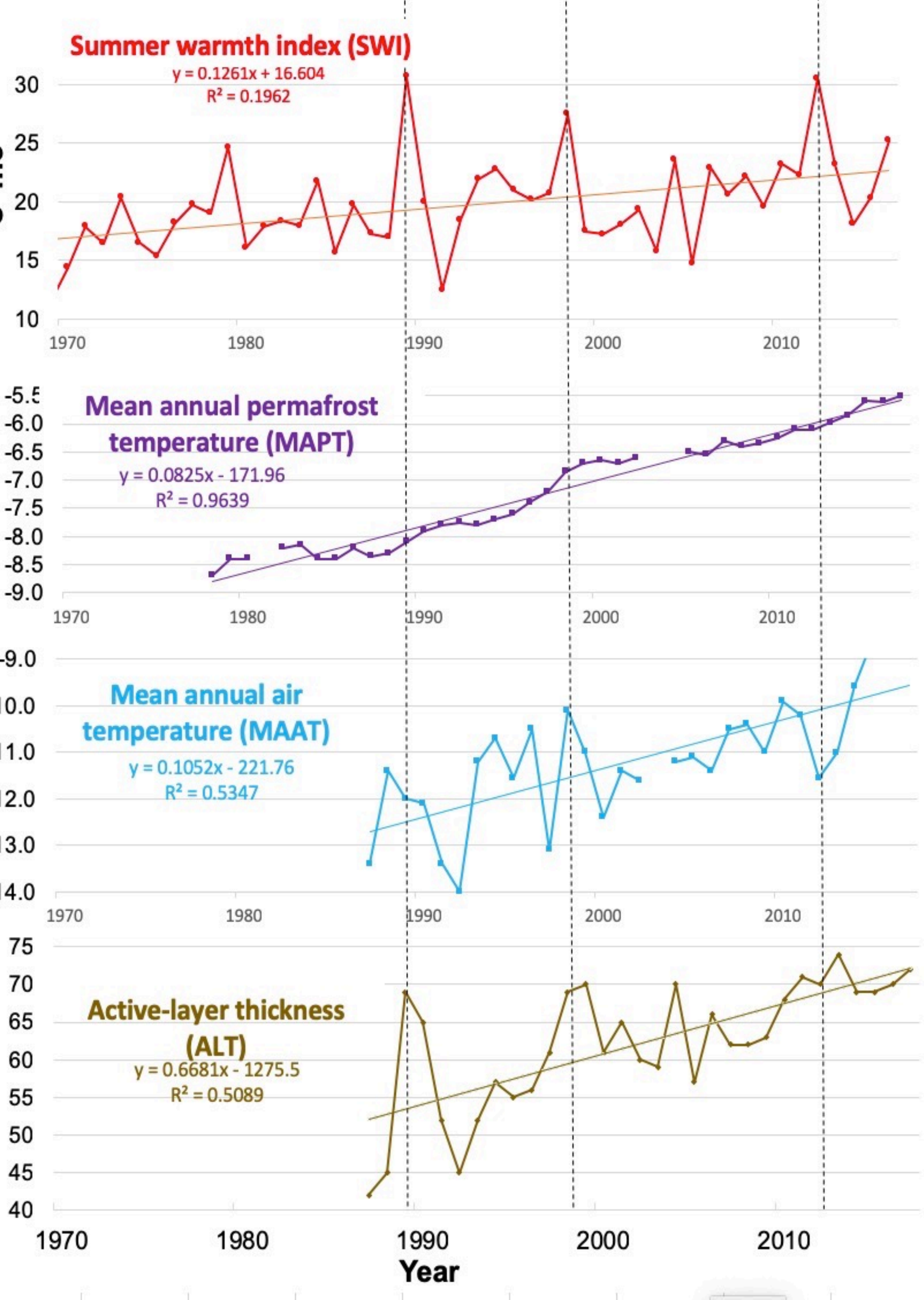
Anna K. Liljedahl[1]*, Julia Boike[2], Ronald P. Daanen[3], Alexander N. Fedorov[4], Gerald V. Frost[5], Guido Grosse[6], Larry D. Hinzman[7], Yoshihiro Iijma[8], Janet C. Jorgenson[9], Nadya Matveyeva[10], Marius Necsoiu[11], Martha K. Raynolds[12], Vladimir E. Romanovsky[13,14], Jörg Schulla[15], Ken D. Tape[1], Donald A. Walker[12], Cathy J. Wilson[16], Hironori Yabuki[17] and Donatella Zona[18,19]

Ice wedges are common features of the subsurface in permafrost regions. They develop by repeated frost cracking and ice vein growth over hundreds to thousands of years. Ice-wedge formation causes the archetypal polygonal patterns seen in tundra across the Arctic landscape. Here we use field and remote sensing observations to document polygon succession due to ice-wedge degradation and trough development in ten Arctic localities over sub-decadal timescales. Initial thaw drains polygon centres and forms disconnected troughs that hold isolated ponds. Continued ice-wedge melting leads to increased trough connectivity and an overall draining of the landscape. We find that melting at the tops of ice wedges over recent decades and subsequent decimetre-scale ground subsidence is a widespread Arctic phenomenon. Although permafrost temperatures have been increasing gradually, we find that ice-wedge degradation is occurring on sub-decadal timescales. Our hydrological model simulations show that advanced ice-wedge degradation can significantly alter the water balance of lowland tundra by reducing inundation and increasing runoff, in particular due to changes in snow distribution as troughs form. We predict that ice-wedge degradation and the hydrological changes associated with the resulting differential ground subsidence will expand and amplify in rapidly warming permafrost regions.

Liljedahl et al. 2016:
Ice-wedge degradation is occurring widely across the whole Arctic:

Lake Colleen observatory:
Abrupt thermokarst expansion, Prudhoe Bay Spine Road





Climate change at Prudhoe Bay

Time-series of temperature and thaw depth

SWI: ⬆5 ˚C mo in 47 years

MAPT: ⬆3.7 ˚C in 39 years

MAAT: ⬆3.1 ˚C in 29 years

ALT: ⬆20 cm in 30 years

Data:
SWI: ARCO (1969–1989) & Deadhorse (NWS, 1990–2016)
MAPT, MAAT, & ALT: Romanovsky, Deadhorse station

Thermokarst collapse due to flooding along the Dalton Highway

Underground thermal erosion of ice wedges

Dalton Highway near Deadhorse, May 25, 2015.

Shur et al. 2016. TICOP and in prep.

Photos: Courtesy of AKDOT & PF.

Flooding & thermokarst are major issues 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.
- Serious flooding also occurred in 2016 and 2018.

Example of unpredictable cumulative effects:

2015-2016 Quintillion fiber-optic cable

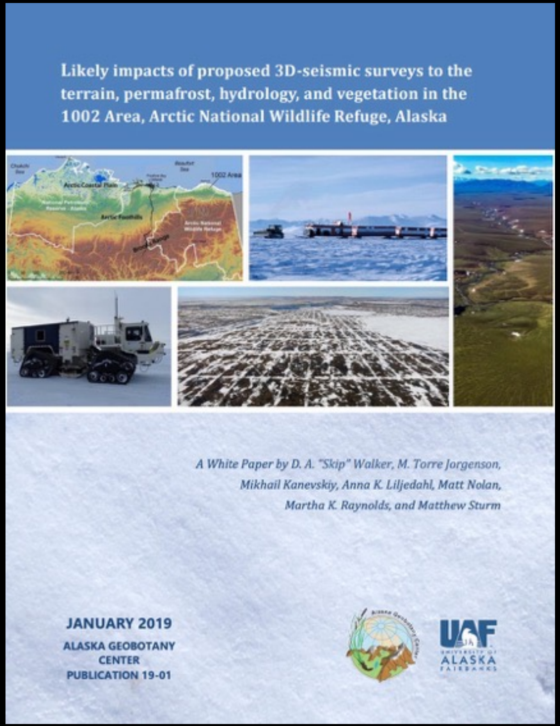
- Cable to deliver high-speed telecommunication services.
- The cable was buried in a trench, much of which was dug in summer with extensive damage to the vegetation and permafrost.
- Especially visible in tundra of North Slope parallel to the Dalton Highway.
- Cable trench provided a pathway for flood 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.

3D-seismic surveys

Seemingly minor initial impacts cover large areas but with unknown long-term consequences to hydrology, vegetation, and permafrost regimes

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

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



3D-seismic white paper

https://www.geobotany.uaf.edu/library/pubs/WalkerDA2019_seismic_exploration_whitepaper.pdf

Change at Point Lay:

- Rapidly changing ice-wedge polygons
- Eroding coastal bluffs
- Changing drainage systems
- Loss of water source
- Unstable housing
- Compromised utilities

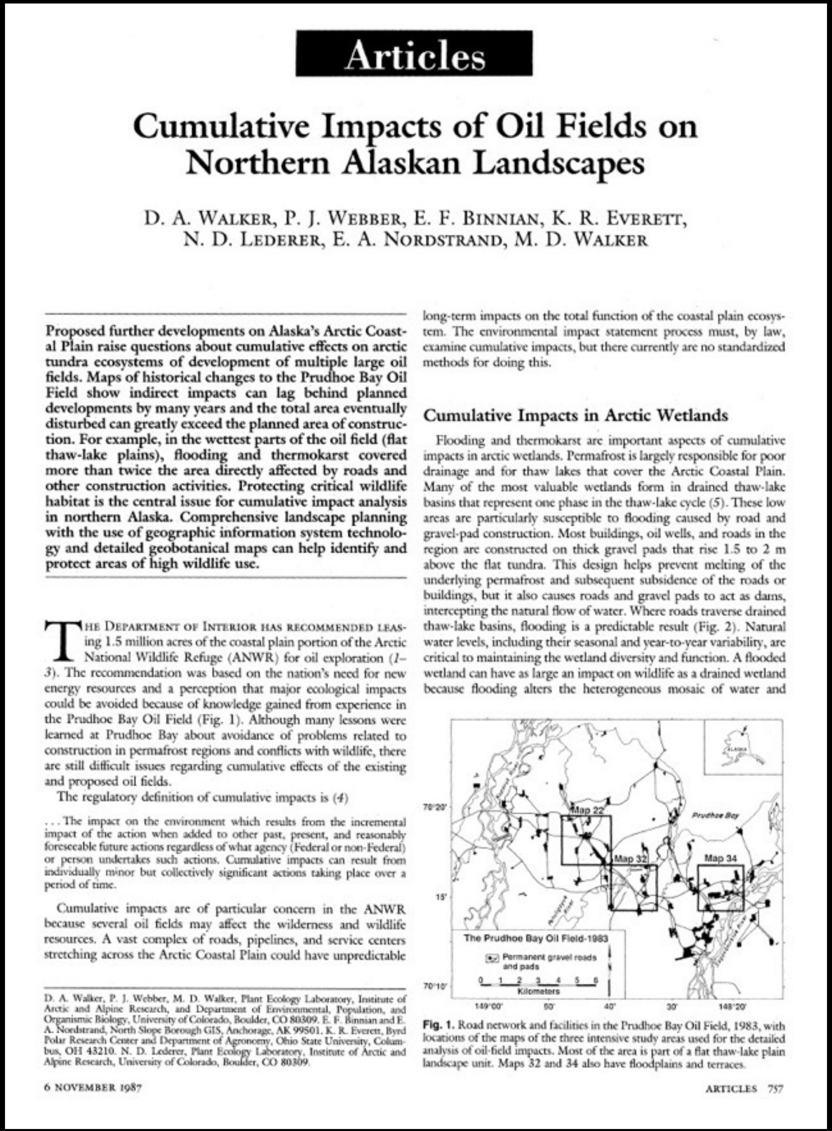
Major impacts to housing due to ground subsidence at Point Lay, Alaska

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

Photo: Courtesy of CCHRC.

Cumulative impact analyses of oil and gas activities

1987: Prudhoe Bay: Walker et al., Science



Articles

Cumulative Impacts of Oil Fields on Northern Alaskan Landscapes

D. A. WALKER, P. J. WEBBER, E. F. BINNIAN, K. R. EVERETT, N. D. LEDERER, E. A. NORDSTRAND, M. D. WALKER

Proposed further developments on Alaska's Arctic Coastal Plain raise questions about cumulative effects on arctic tundra ecosystems of development of multiple large oil fields. Maps of historical changes to the Prudhoe Bay Oil Field show indirect impacts can lag behind planned developments by many years and the total area eventually disturbed can greatly exceed the planned area of construction. For example, in the wettest parts of the oil field (flat thaw-lake plains), flooding and thermokarst covered more than twice the area directly affected by roads and other construction activities. Protecting critical wildlife habitat is the central issue for cumulative impact analysis in northern Alaska. Comprehensive landscape planning with the use of geographic information system technology and detailed geobotanical maps can help identify and protect areas of high wildlife use.

THE DEPARTMENT OF INTERIOR HAS RECOMMENDED LEASing 1.5 million acres of the coastal plain portion of the Arctic National Wildlife Refuge (ANWR) for oil exploration (*1–3*). The recommendation was based on the nation's need for new energy resources and a perception that major ecological impacts could be avoided because of knowledge gained from experience in the Prudhoe Bay Oil Field (Fig. 1). Although many lessons were learned at Prudhoe Bay about avoidance of problems related to construction in permafrost regions and conflicts with wildlife, there are still difficult issues regarding cumulative effects of the existing and proposed oil fields.

The regulatory definition of cumulative impacts is (*4*)

. . . The impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time.

Cumulative impacts are of particular concern in the ANWR because several oil fields may affect the wilderness and wildlife resources. A vast complex of roads, pipelines, and service centers stretching across the Arctic Coastal Plain could have unpredictable long-term impacts on the total function of the coastal plain ecosystem. The environmental impact statement process must, by law, examine cumulative impacts, but there currently are no standardized methods for doing this.

Cumulative Impacts in Arctic Wetlands

Flooding and thermokarst are important aspects of cumulative impacts in arctic wetlands. Permafrost is largely responsible for poor drainage and for thaw lakes that cover the Arctic Coastal Plain. Many of the most valuable wetlands form in drained thaw-lake basins that represent one phase in the thaw-lake cycle (*5*). These low areas are particularly susceptible to flooding caused by road and gravel-pad construction. Most buildings, oil wells, and roads in the region are constructed on thick gravel pads that rise 1.5 to 2 m above the flat tundra. This design helps prevent melting of the underlying permafrost and subsequent subsidence of the roads or buildings, but it also causes roads and gravel pads to act as dams, intercepting the natural flow of water. Where roads traverse drained thaw-lake basins, flooding is a predictable result (Fig. 2). Natural water levels, including their seasonal and year-to-year variability, are critical to maintaining the wetland diversity and function. A flooded wetland can have as large an impact on wildlife as a drained wetland because flooding alters the heterogeneous mosaic of water and

Fig. 1. Road network and facilities in the Prudhoe Bay Oil Field, 1983, with locations of the maps of the three intensive study areas used for the detailed analysis of oil-field impacts. Most of the area is part of a flat thaw-lake plain landscape unit. Maps 32 and 34 also have floodplains and terraces.

D. A. Walker, P. J. Webber, M. D. Walker, Plant Ecology Laboratory, Institute of Arctic and Alpine Research, and Department of Environmental, Population, and Organismic Biology, University of Colorado, Boulder, CO 80309. E. F. Binnian and E. A. Nordstrand, North Slope Borough GIS, Anchorage, AK 99501. K. R. Everett, Byrd Polar Research Center and Department of Agronomy, Ohio State University, Columbus, OH 43210. N. D. Lederer, Plant Ecology Laboratory, Institute of Arctic and Alpine Research, University of Colorado, Boulder, CO 80309.

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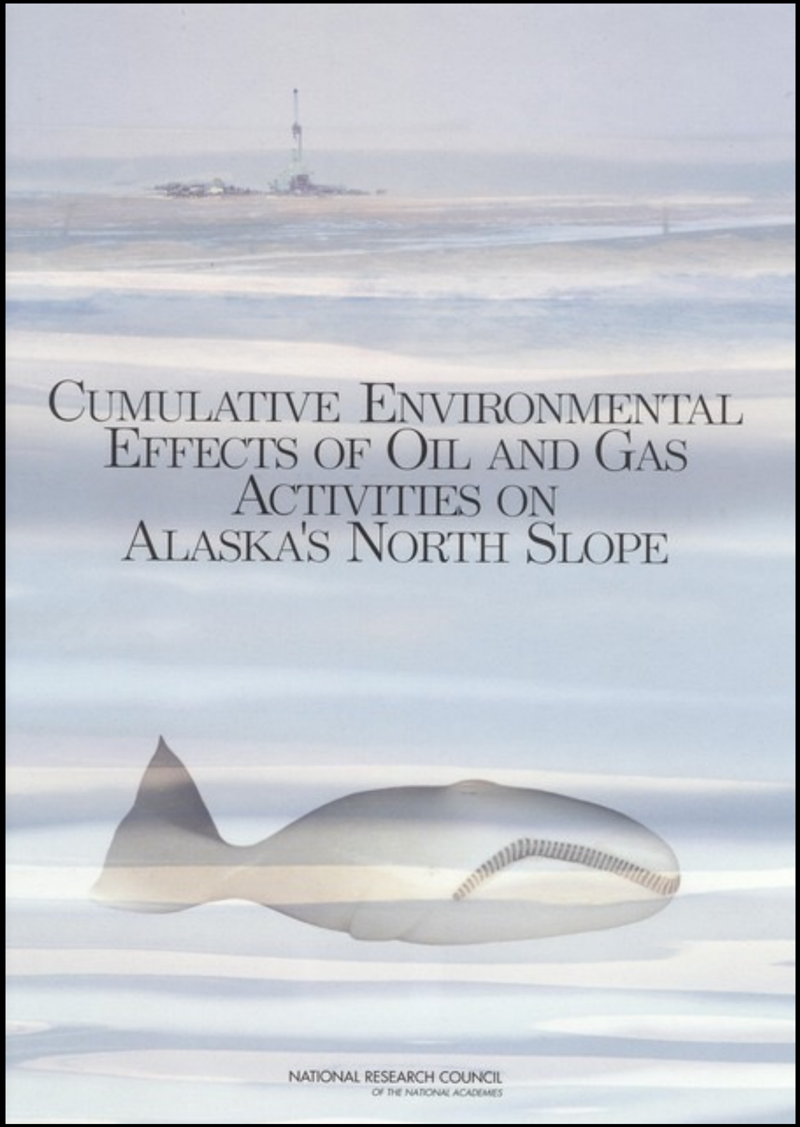
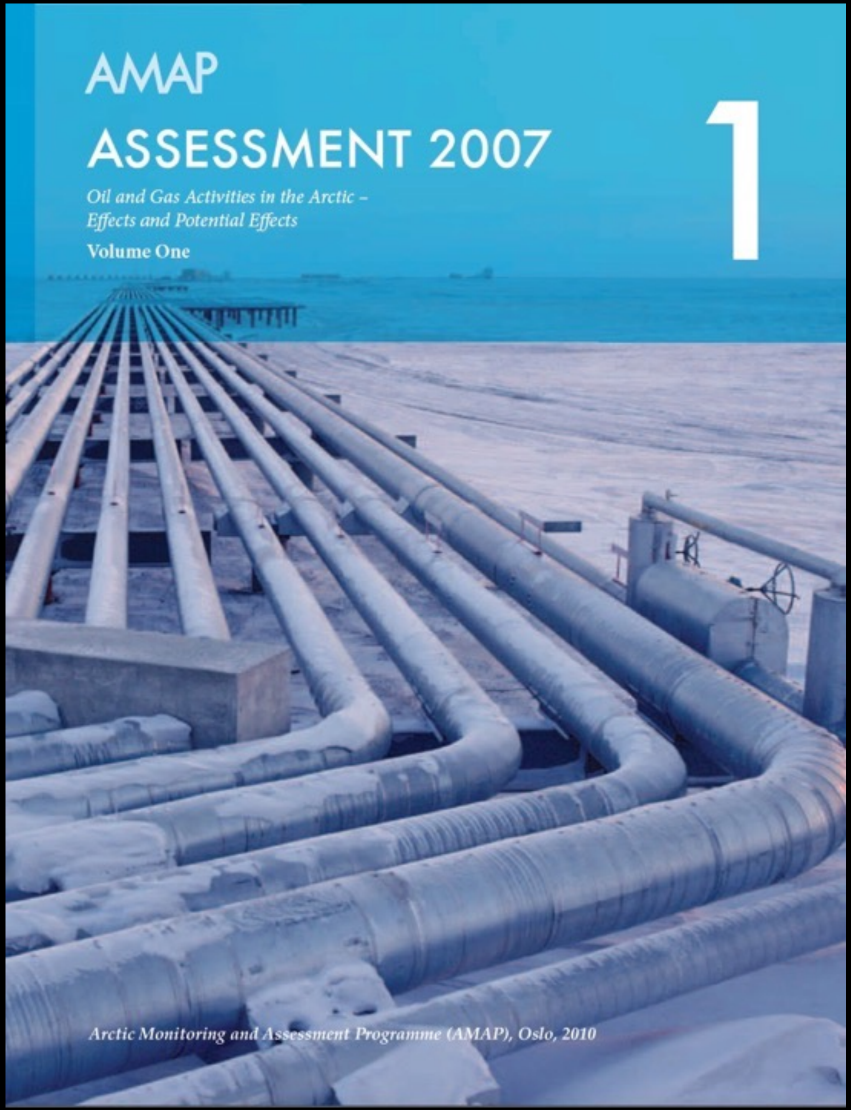
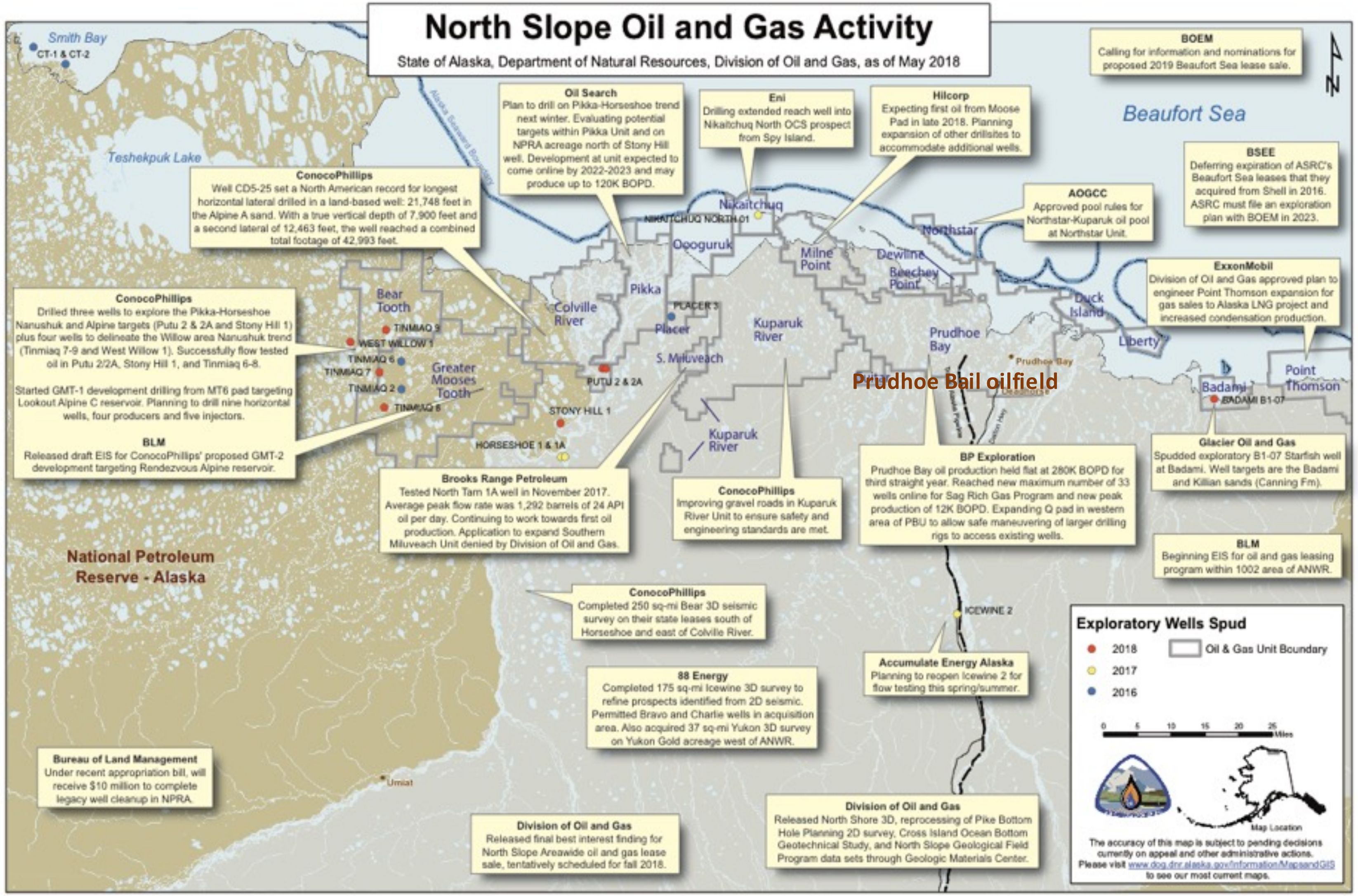
2003: North Slope, 2003 NRC report



2008: Arctic wide, AMAP report

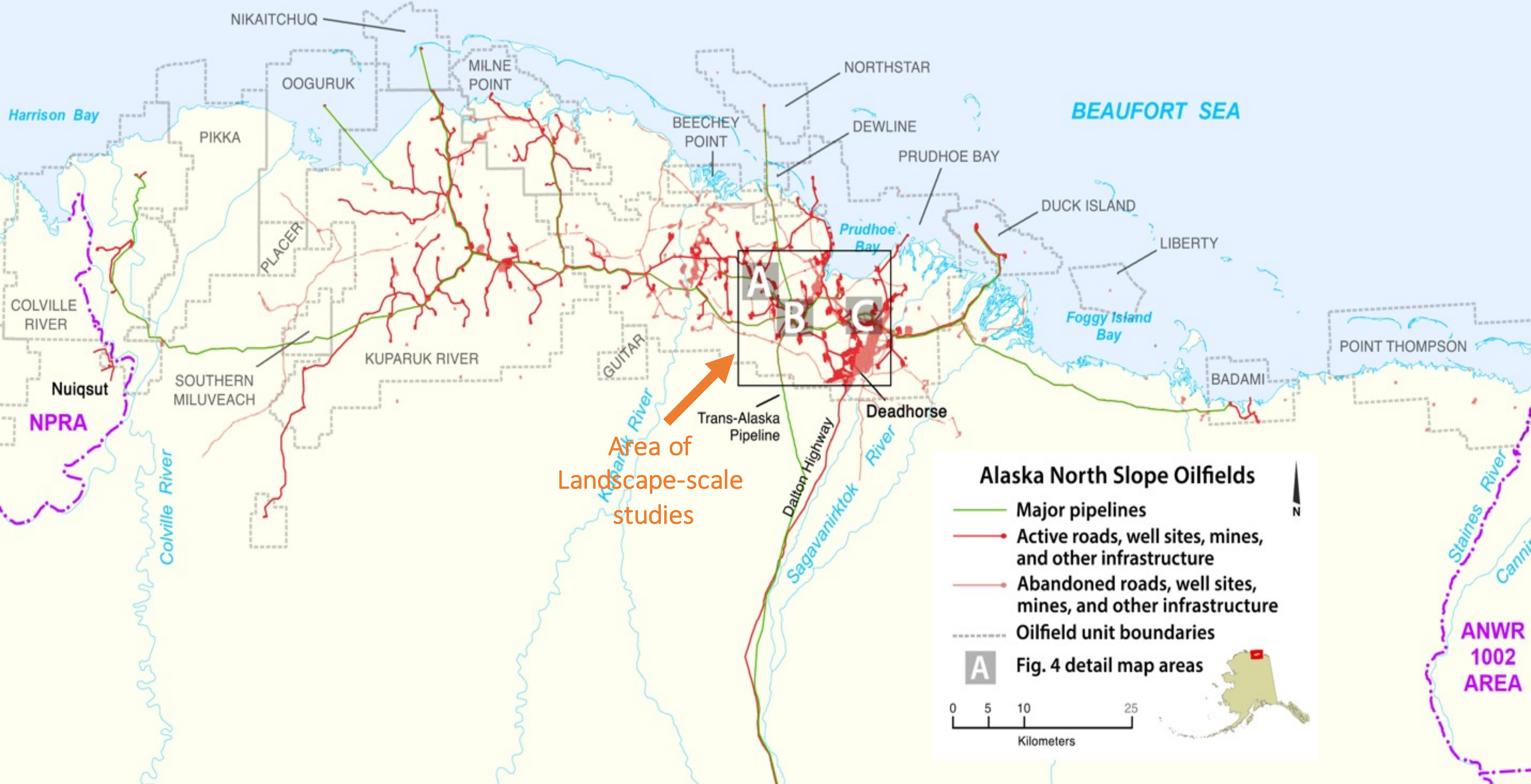


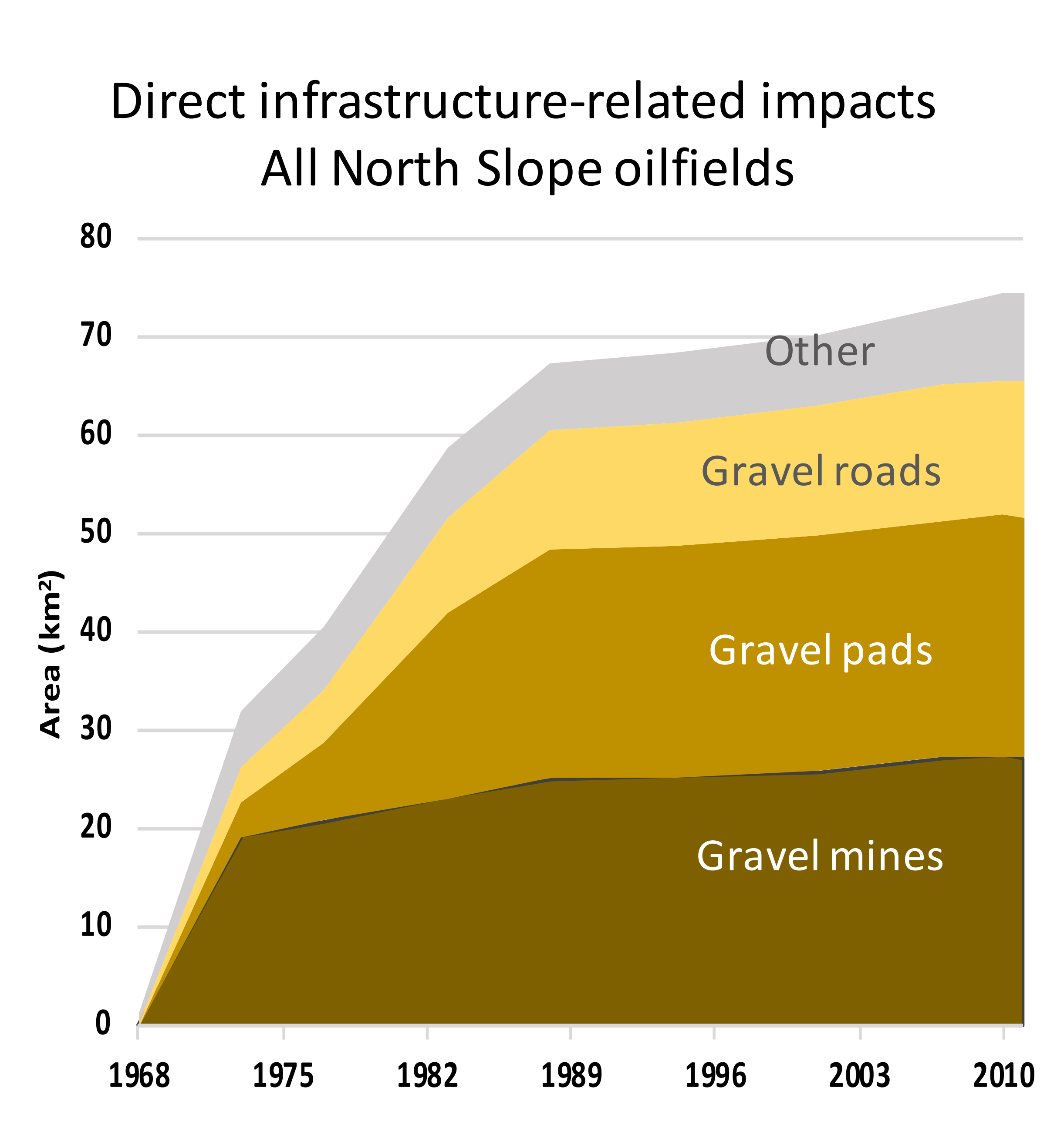
Current areas of active development, northern Alaska, 2018



Map courtesy of Alaska Division of Oil and Gas, Showing 2018 activity in yellow boxes.

Area of regional-, landscape--scale studies





Trends at regional-scale direct impacts (footprint)

Area impacted

- 27.4 km^2 gravel mines
- 23.5 km^2 gravel drill sites & construction pads
- 12.6 km^2 gravel roads
- 10.8 km^2 other (airstrips, off-shore drilling islands, peat roads, etc.)

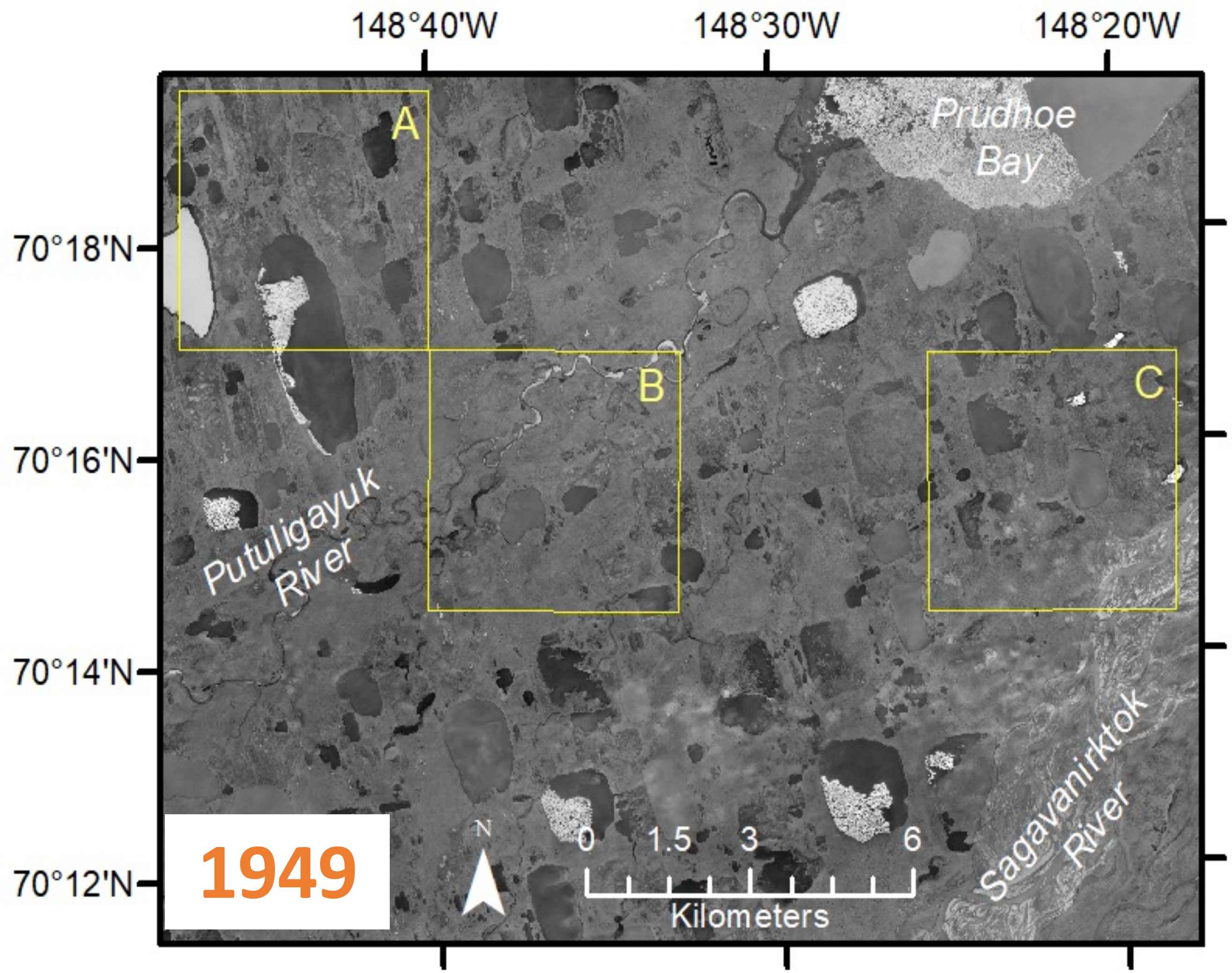
74.3 km^2 total footprint

Rate of increase

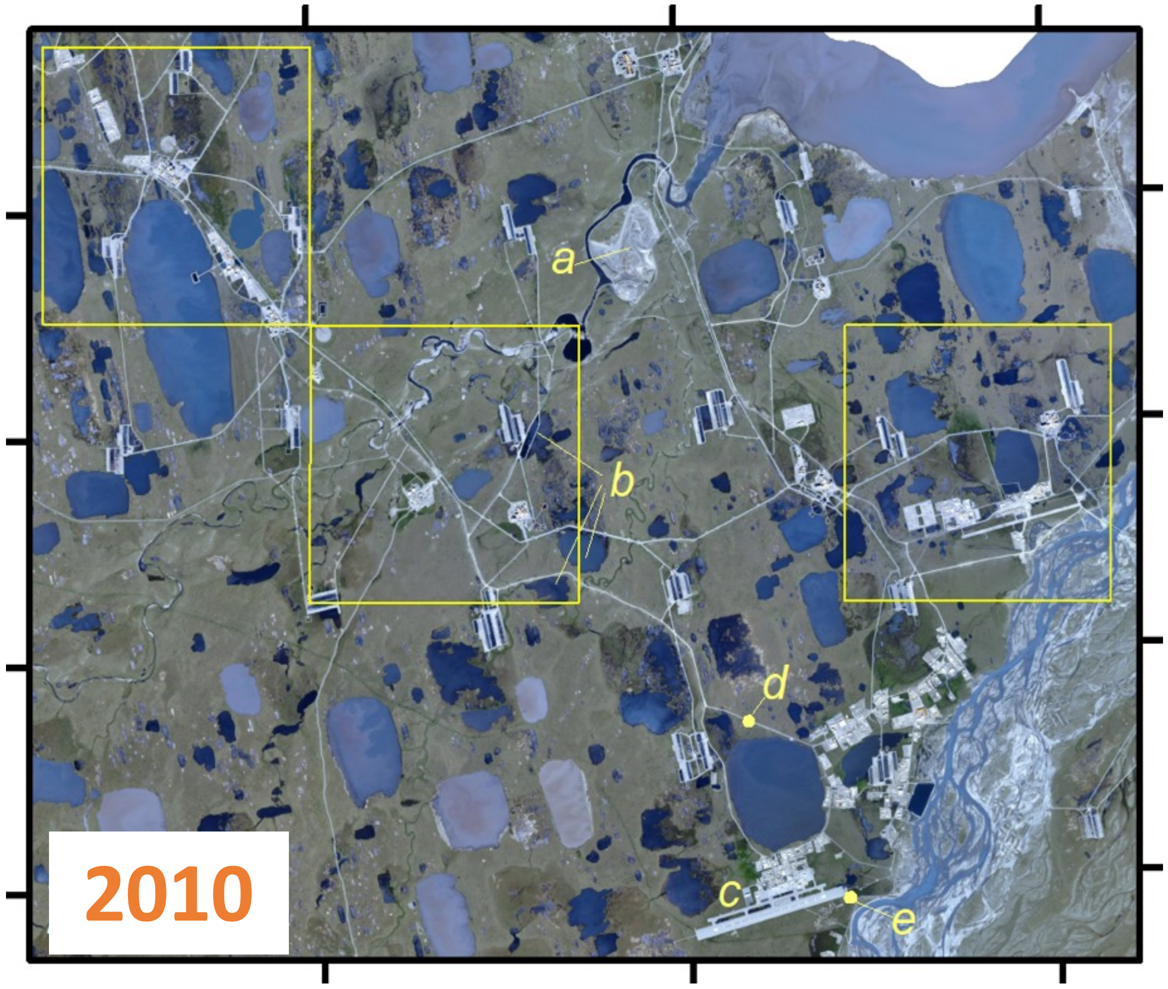
- Very rapid during main development phase 1968–1989.
- Reduced rate during production phase to 2010.

62 years of IRPS landscape evolution

Studies of natural and developed landscapes prior to and after development

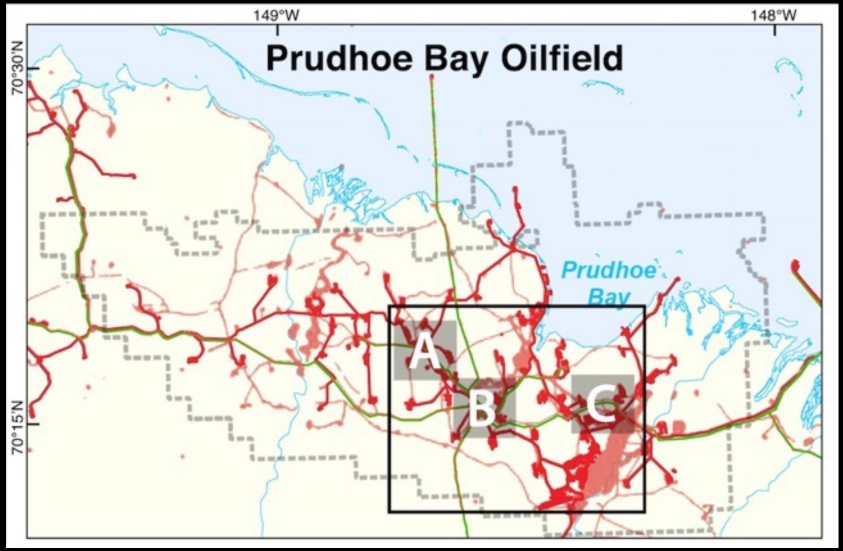


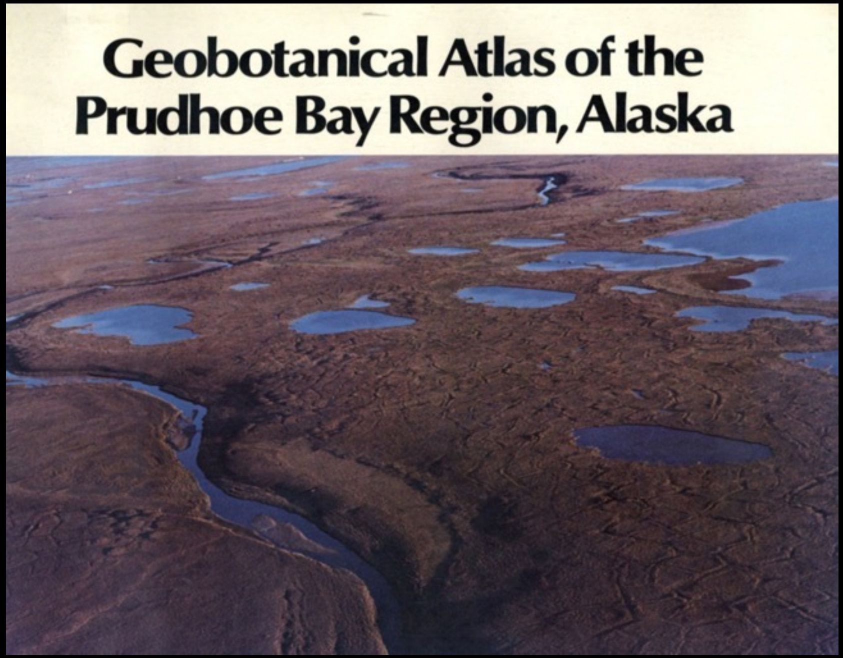
U.S. Navy BAR photograph mosaic, 1:50,000 scale.

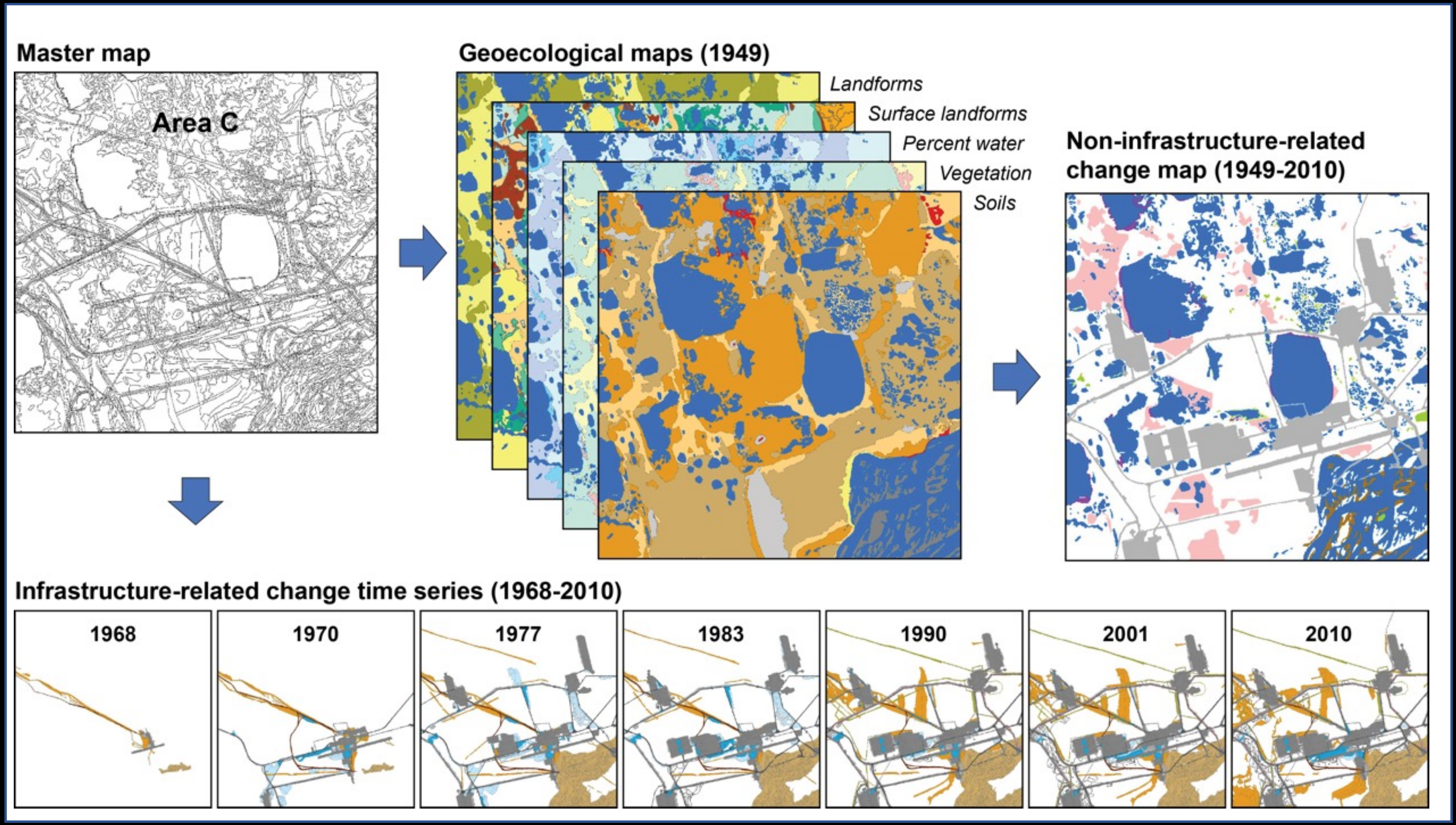


SPOT satellite image, 1.5-m pixel resolution.

Integrated geoecological and historical-change mapping

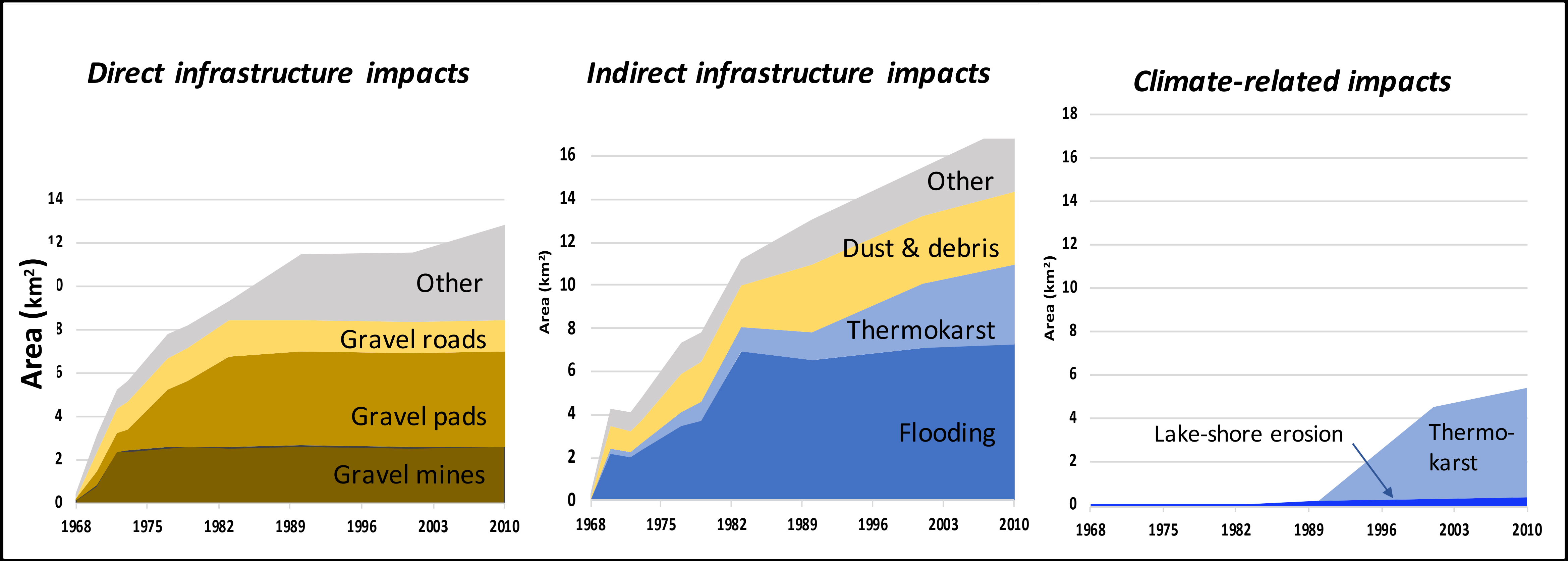






- **Baseline**: 1949 Navy BAR aerial photographs and Walker, D. A., Everett, K. R., Webber, P. J., & Brown, J. (1980). *Geobotanical atlas of the Prudhoe Bay region, Alaska. CRREL Report 80-14*.
- **2010 Historical change analysis**: Raynolds et al. (2014) *Global Change Biology*, 20: 1211–1224

Comparison of direct, indirect infrastructure- and climate-related impacts in Areas A, B, C



- Area of indirect impacts exceeded area of direct impacts after 1982.
- Anthropogenic direct impacts slowed rate of increase after about 1983.
- Indirect impacts slowed in 1983 but continued to increase.
- Climate-related thermokarst started to occur in 1983 and increased dramatically after 1990.

Plot-level monitoring

IRPS observatories

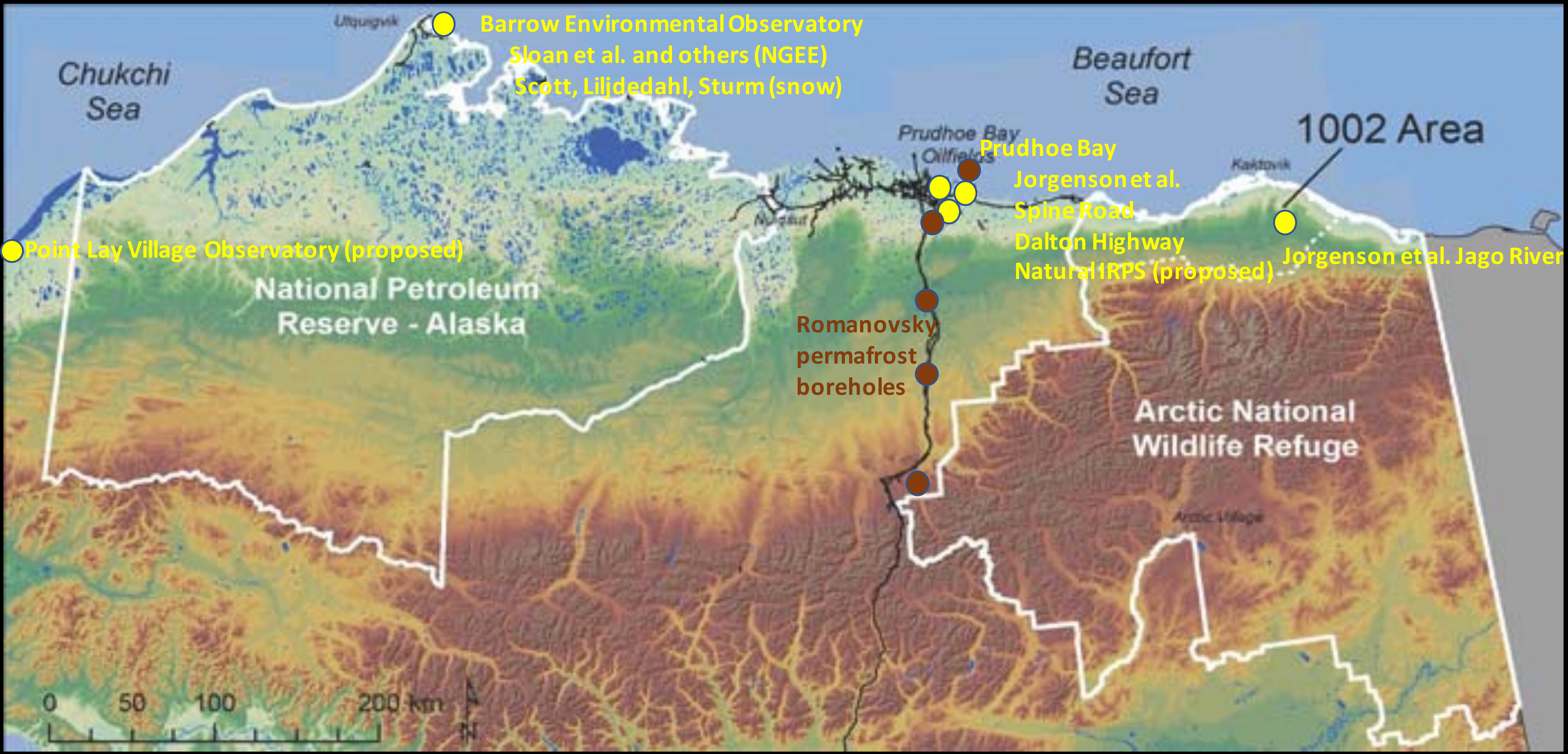
Node: Prudhoe Bay Oilfield	Corridor: Dalton Highway	Village Housing: Point Lay

subhankarbanerjee.org

motorcycle-usa.com

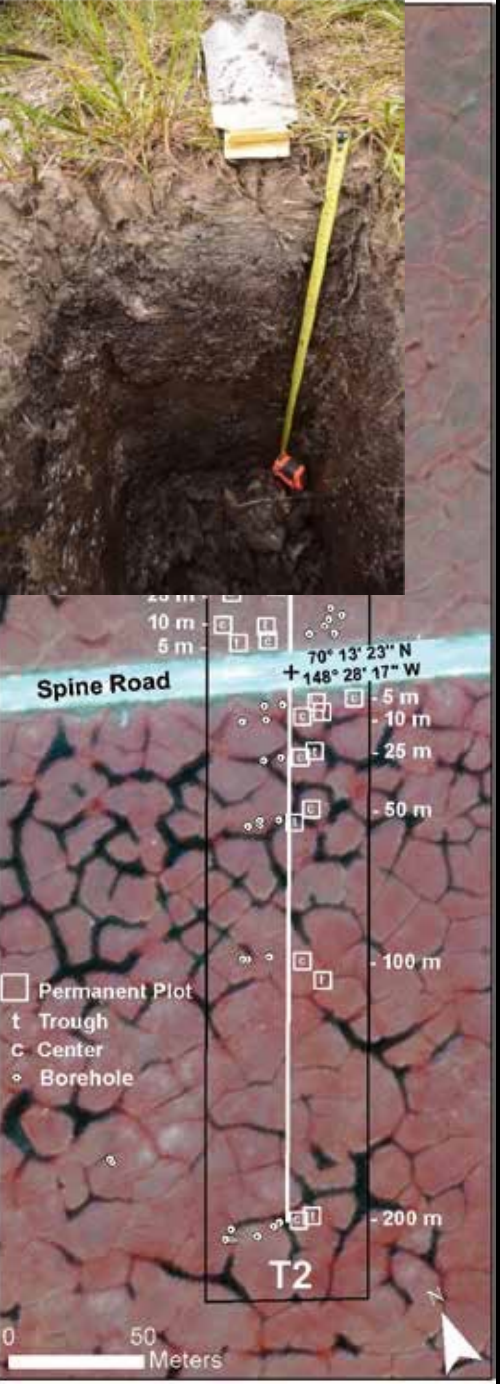
AlaskaTeenMedia

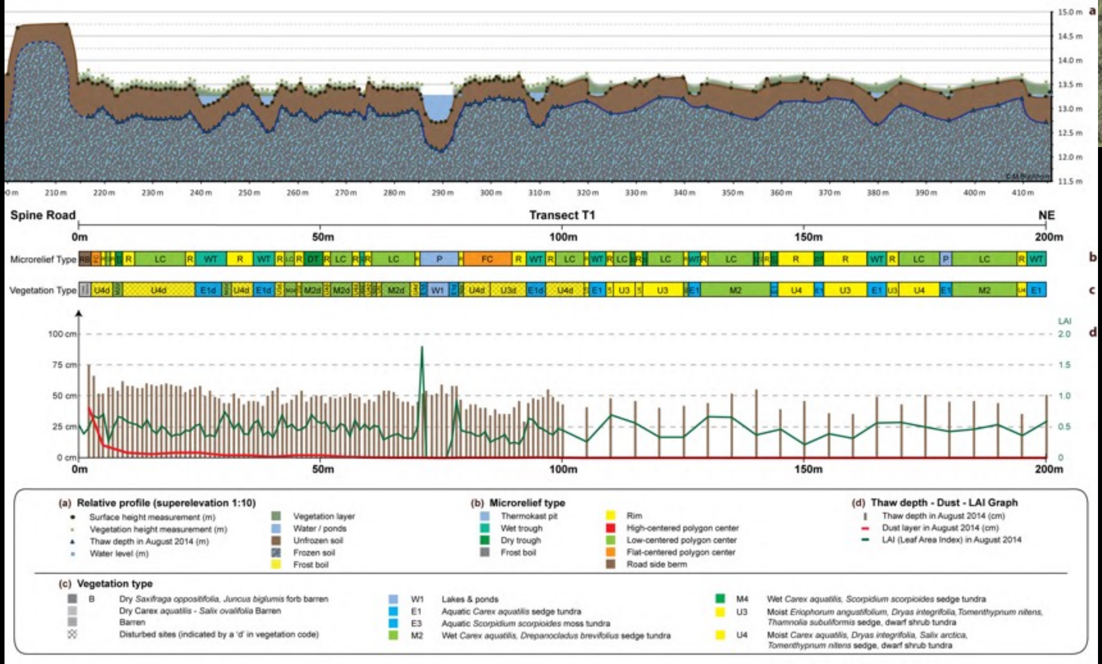
Network of NNA-IRPS observatories

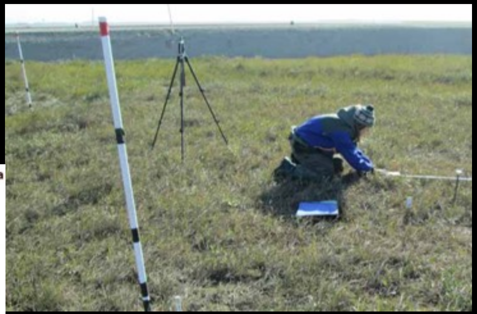


Plot-level monitoring:
IRPS roadside observatory, Prudhoe Bay

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

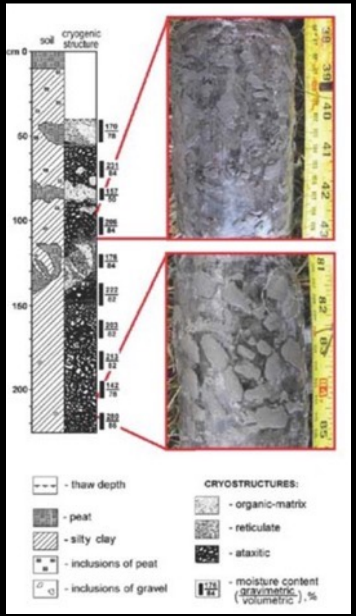




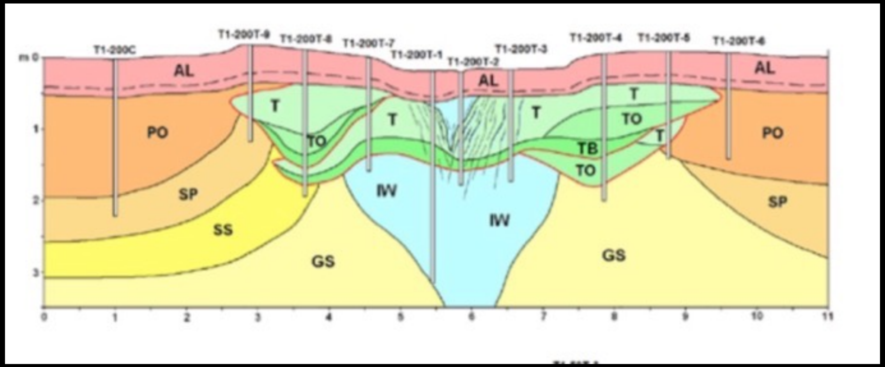


Ground-ice characterization and evolution

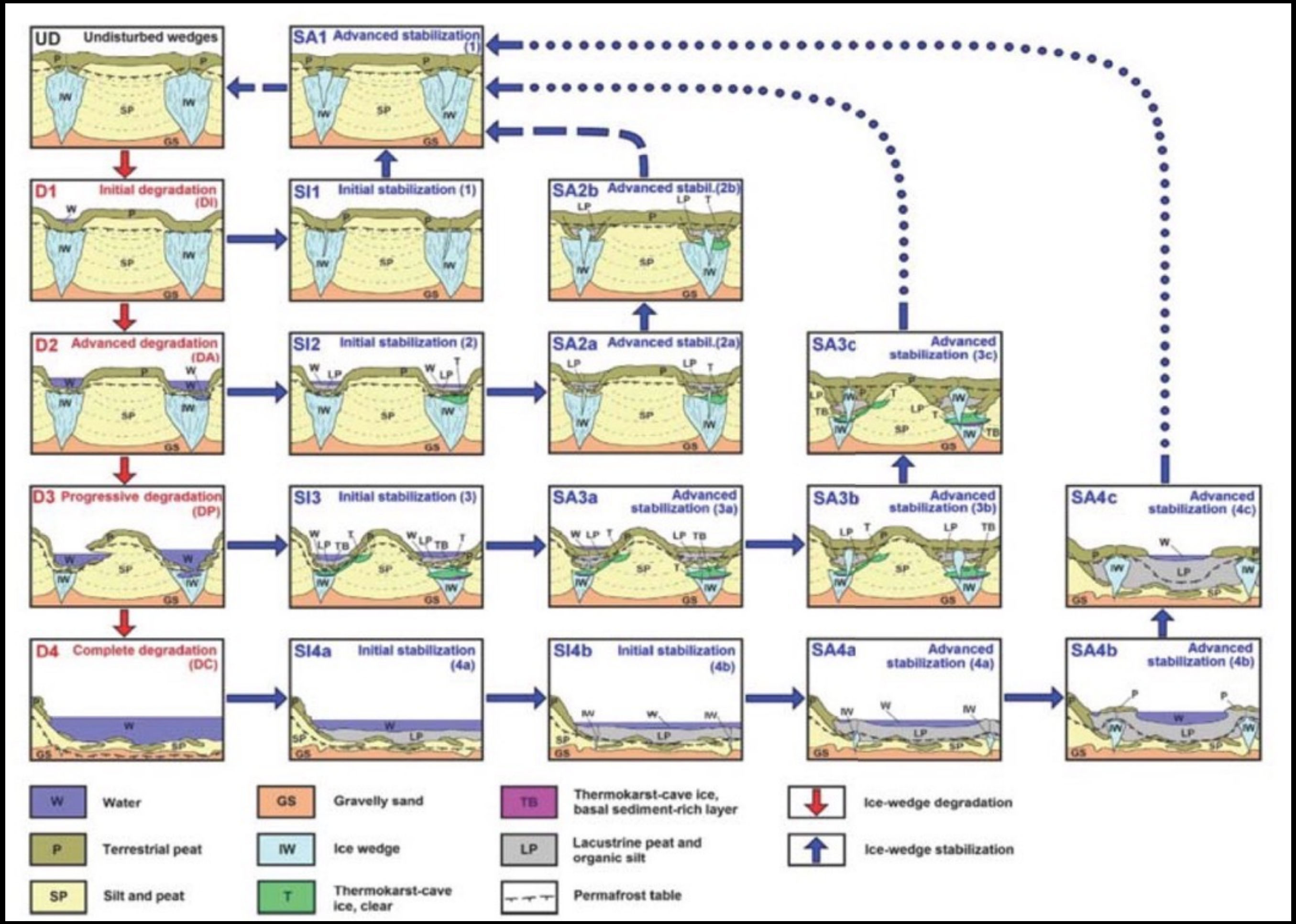
Boreholes



Profiles



Scenarios of IRP change



Adapting to change at Point Lay:

Cold Climate Housing Research Center (CCHRC)

Working with village stakeholders, the school, and the IRPS research team to:

Develop solutions to address infrastructure issues pertaining to changing subsurface conditions.

- Drill and place subsurface monitoring instrumentation.
- Work with the Point Lay School to develop material for the education of students and local residents.
- Develop permafrost outreach materials for homeowners and contractors, including video on permafrost foundations.
- Best practices guidelines to build new and retrofit existing foundations.

CCHRC housing prototypes

Anaktuvuk Pass prototype: Super insulated home with thermal-raft foundation

Atmautluak prototype: Integrated truss house, adjustable piling foundation

Buckland prototype: Thermal raft foundation, integrated truss house with single-piece, floor, walls, roof adjustable piling foundation

Quinhagak octagon prototype

Point Lay, thermal raft piles

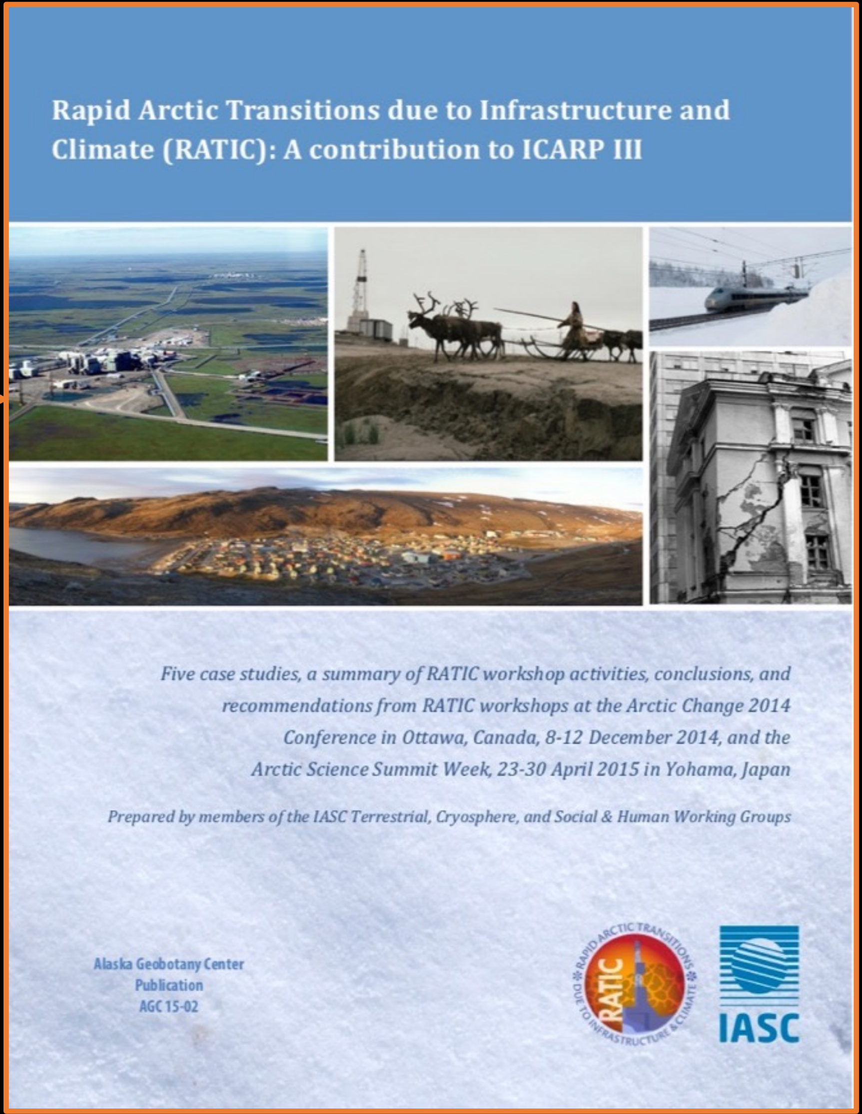
Photos courtesy of the Cold Climate Housing Research Center

International collaboration: RATIC

Rapid Arctic Transitions due to Infrastructure and Climate

- IASC-sponsored forum for developing and sharing new ideas and methods regarding sustainable development in the face of rapid arctic change

- White paper


Rapid Arctic Transitions due to Infrastructure and Climate (RATIC): A contribution to ICARP III

Five case studies, a summary of RATIC workshop activities, conclusions, and recommendations from RATIC workshops at the Arctic Change 2014 Conference in Ottawa, Canada, 8-12 December 2014, and the Arctic Science Summit Week, 23-30 April 2015 in Yohama, Japan

Prepared by members of the IASC Terrestrial, Cryosphere, and Social & Human Working Groups

Alaska Geobotany Center Publication AGC 15-02

IASC

https://www.geobotany.uaf.edu/library/pubs/WalkerDAed2015RATICWhitePaper-ICARPIII.pdf

RATIC white paper:

Five international case studies of infrastructure impacts to social systems

Road & pad impacts
Prudhoe Bay oil field, AK

Nenets subsistance
Bovanenkovo gas field , RU

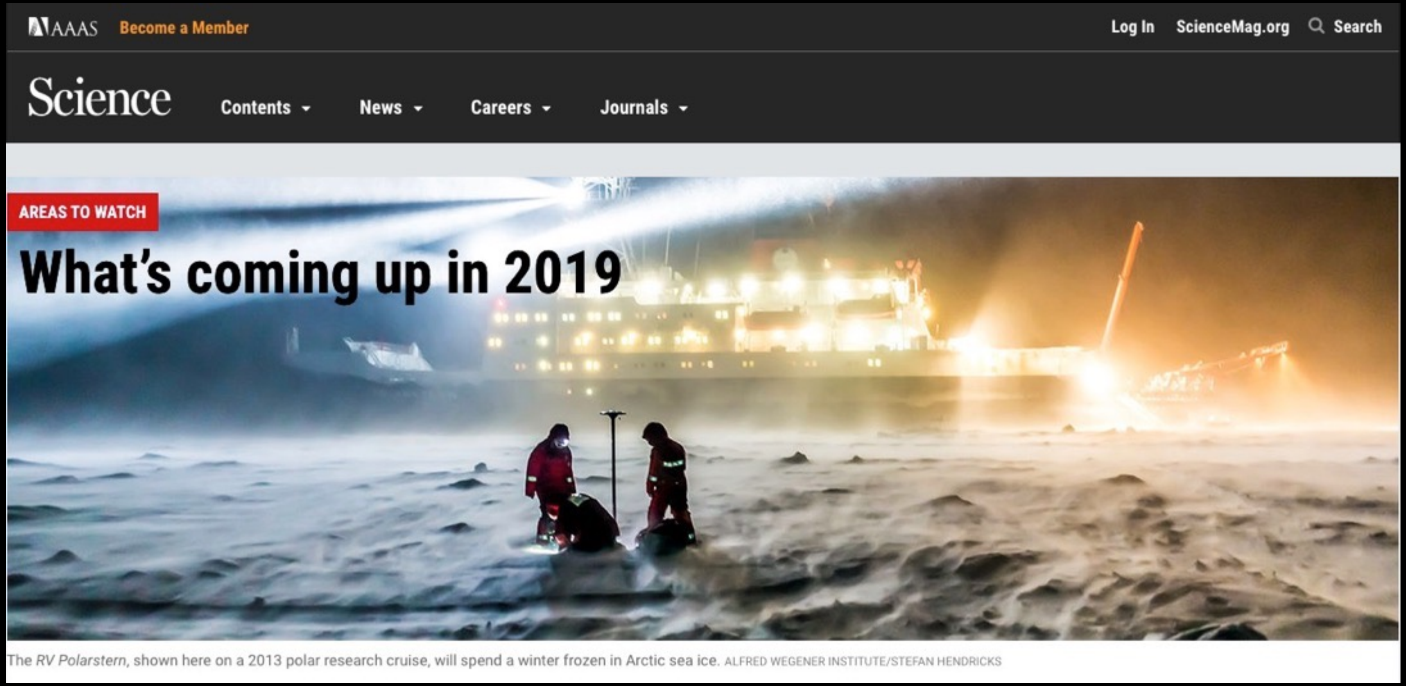
Roads & airstrip stability,
arctic villages, CA

Rail corridors, NO

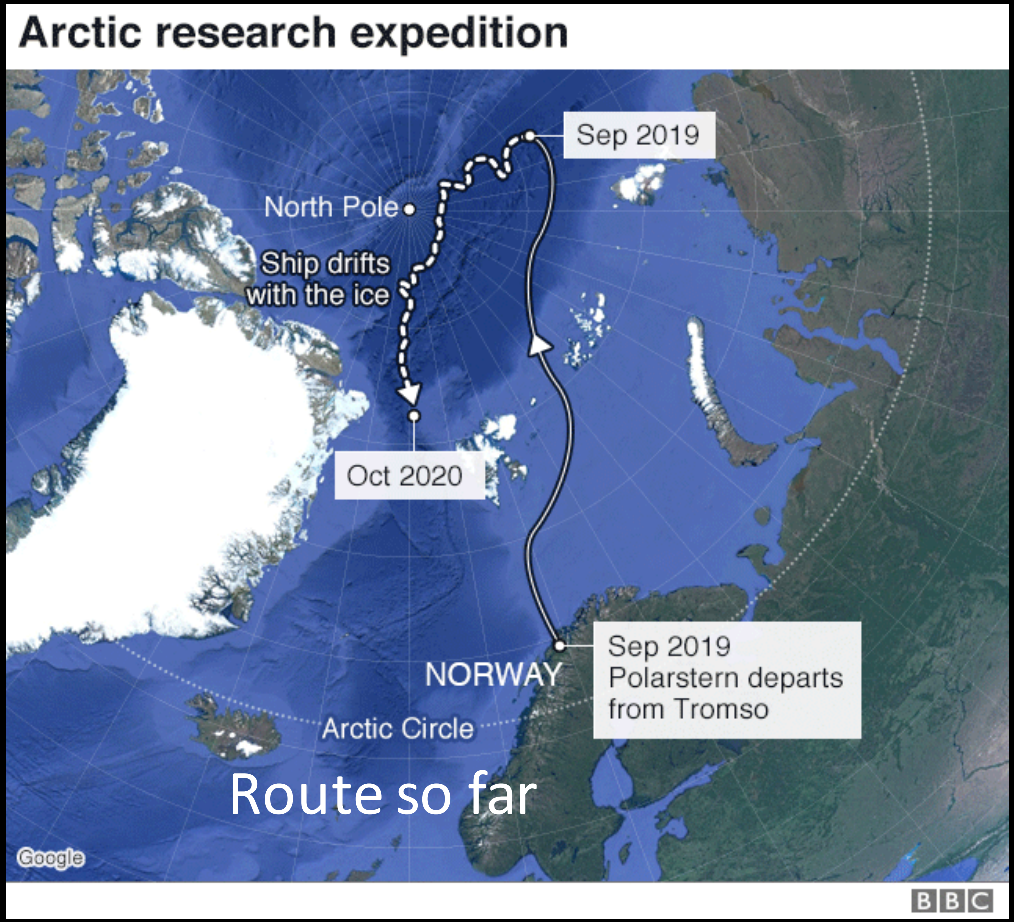
Urban
infrastructure,
RU

MOSAiC

International Arctic Drift Expedition



MOASAiC: One of *Science* magazine's 10 stories likely to make headlines in 2019



Current position of the *Polarstern*

RATIC is the Infrastructure Action Group of T-MOSAiC

Terrestrial Multidisciplinary distributed Observatories for the Study of Arctic Connections

T-MOSAiC

Objective: Coordinate complementary activities that aid and benefit from MOSAiC by extending the work to the lands surrounding the Arctic Ocean and to the northern communities who live on those lands.

RAPID ARCTIC TRANSITIONS DUE TO INFRASTRUCTURE & CLIMATE

RATIC

The Infrastructure Action Group of T-MOSAiC

NNA-IRPS 2020 Summer Field Course

2019 Brooks Range & Beyond

Student photos of 2018 BIOL 495/695 Student Expedition

- 17-day expedition along the Dalton Highway
- Instructors: Members of the NNA-IRPS team.
- Focused on ice-rich permafrost systems, infrastructure, landscape evolution, arctic ecosystems, arctic plants

Co-investigators and collaborators

University of Alaska Fairbanks (* co-PI):

Geophysical Institute

Dmitri Nicolsky

*Vlad Romanovsky

Institute of Arctic Biology

Lisa Druckenmiller

Anja Kade

*Gary Kofinas

Jana Peirce

Marth Raynolds

* Skip Walker

Institute of Northern Engineering

Billy Connor

Misha Kanevskiy

*Yuri Shur

International Arctic Research Center

Amy Breen

Water and Environmental Research Center

Ben Jones

*Anna Liljedahl

Cold Climate Housing Research Center

Robbin Garber-Slaght

Jack Hébert

Vanessa Stevens

Alaska Division of Geological and Geophysical Surveys

Ronnie Daanen

Native Village of Point Lay

Kali School

Taġiuġmiullu Nunamiullu Housing Authority (TNHA)

NSB Department of Planning and Community Services

BP Alaska (now Hillcorp)

International collaborators

Jozef Šibik, Slovak Republic

Helga Bültmann, Germany

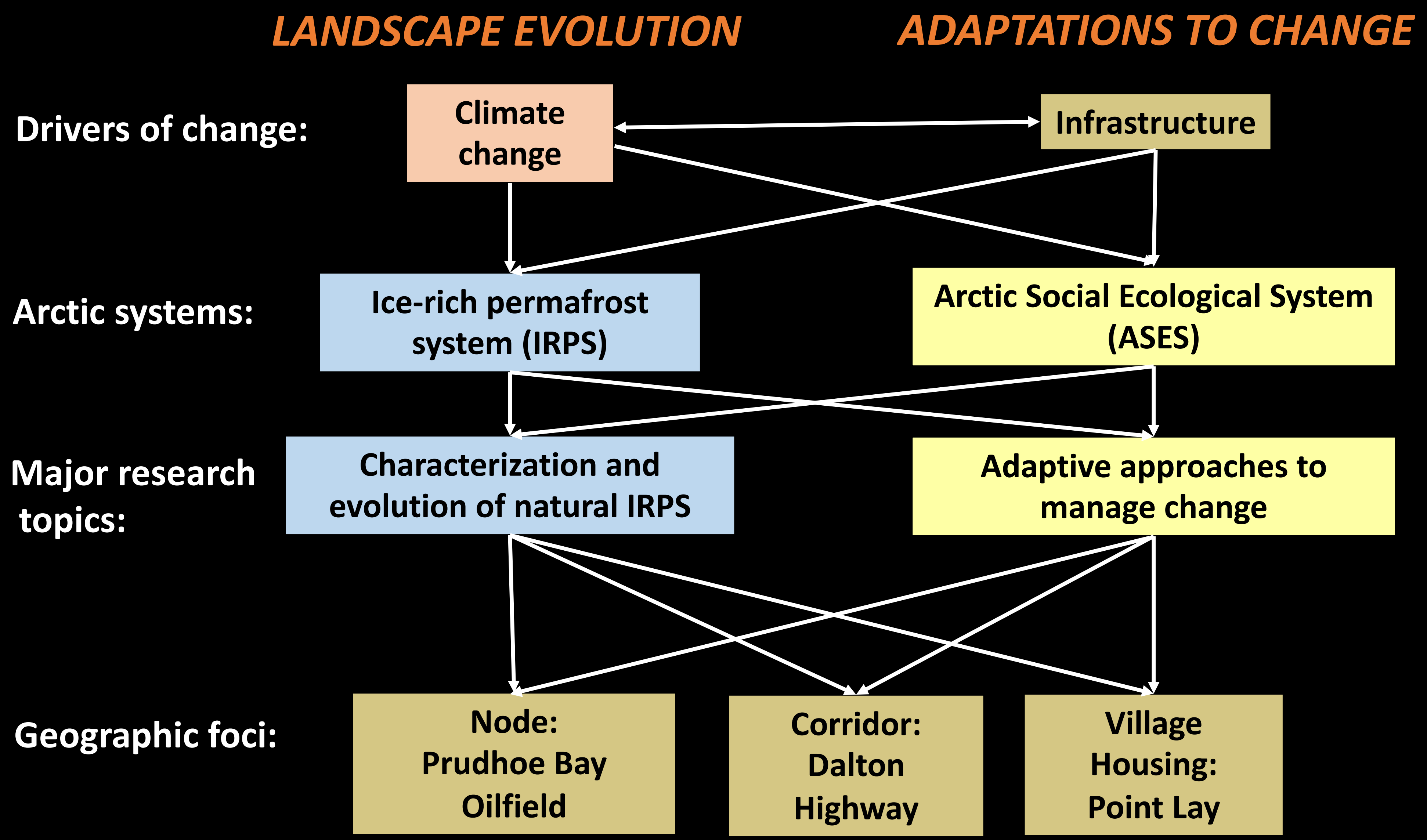
Warwick Vincent, Canada

NNA-IRPS proposal:

www.geobotany.uaf.edu/library/pubs/NNA-IRPSproposal2019.pdf

Ina Timling

Our NNA-IRPS proposal
Major themes and linkages



Thermokarst on Banks Island

remote sensing

MDPI

Article

Climate Sensitivity of High Arctic Permafrost Terrain Demonstrated by Widespread Ice-Wedge Thermokarst on Banks Island

Robert H. Fraser [1,*], Steven V. Kokelj [2], Trevor C. Lantz [3], Morgan McFarlane-Winchester [1], Ian Olthof [1] and Denis Lacelle [4]

1 Canada Centre for Mapping and Earth Observation, Natural Resources Canada, Ottawa, ON K1A 0E4, Canada; morgan.mcfarlane-winchester@canada.ca (M.M.-W.); ian.olthof@canada.ca (I.O.)
2 Northwest Territories Geological Survey, Government of Northwest Territories, Yellowknife, NT X1A 2L9, Canada; steve_kokelj@gov.nt.ca
3 School of Environmental Studies, University of Victoria, Victoria, BC V8P 5C2, Canada; tlantz@uvic.ca
4 Department of Geography, University of Ottawa, Ottawa, ON K1N 6N5, Canada; dlacelle@uOttawa.ca
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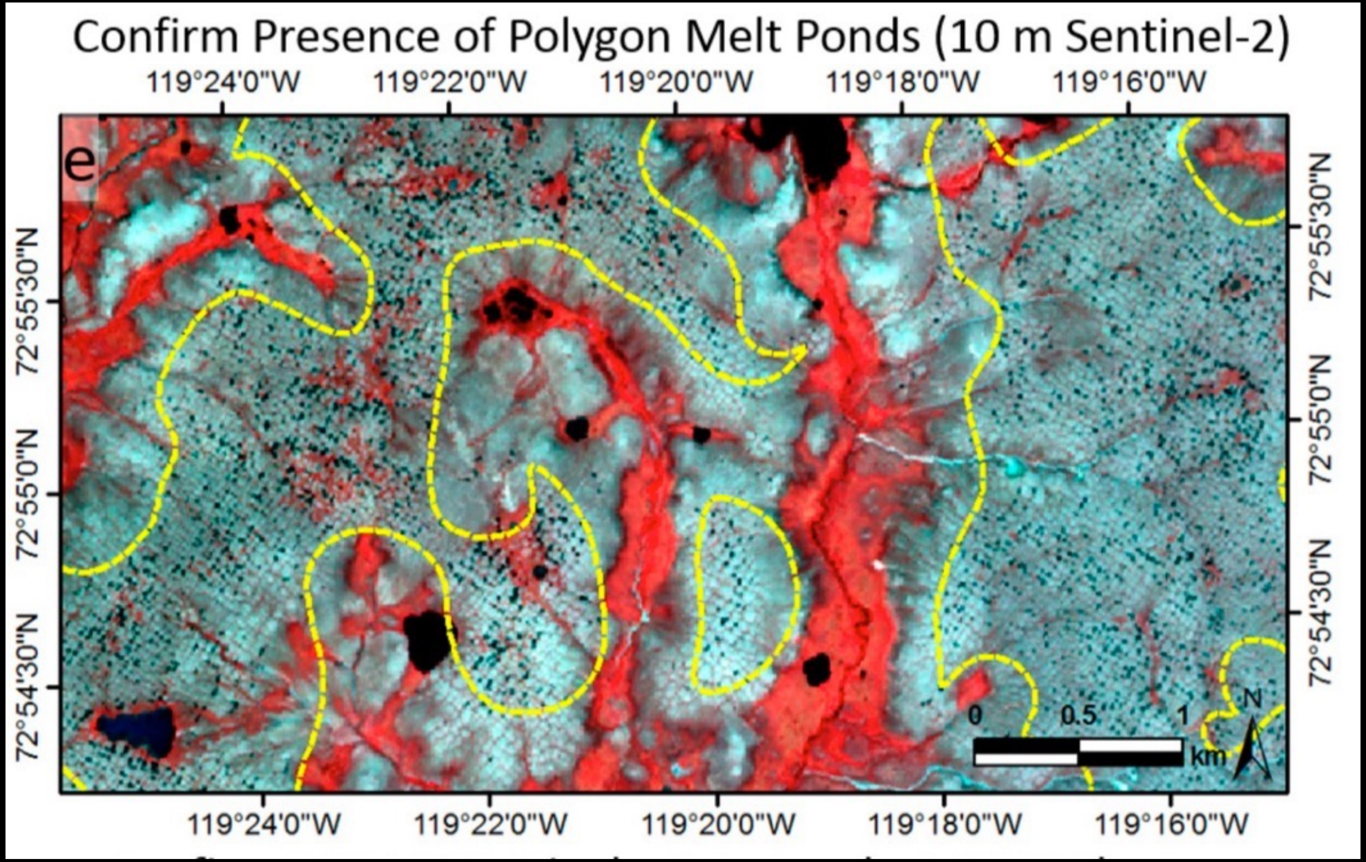
Received: 29 March 2018; Accepted: 12 June 2018; Published: 15 June 2018

check for updates

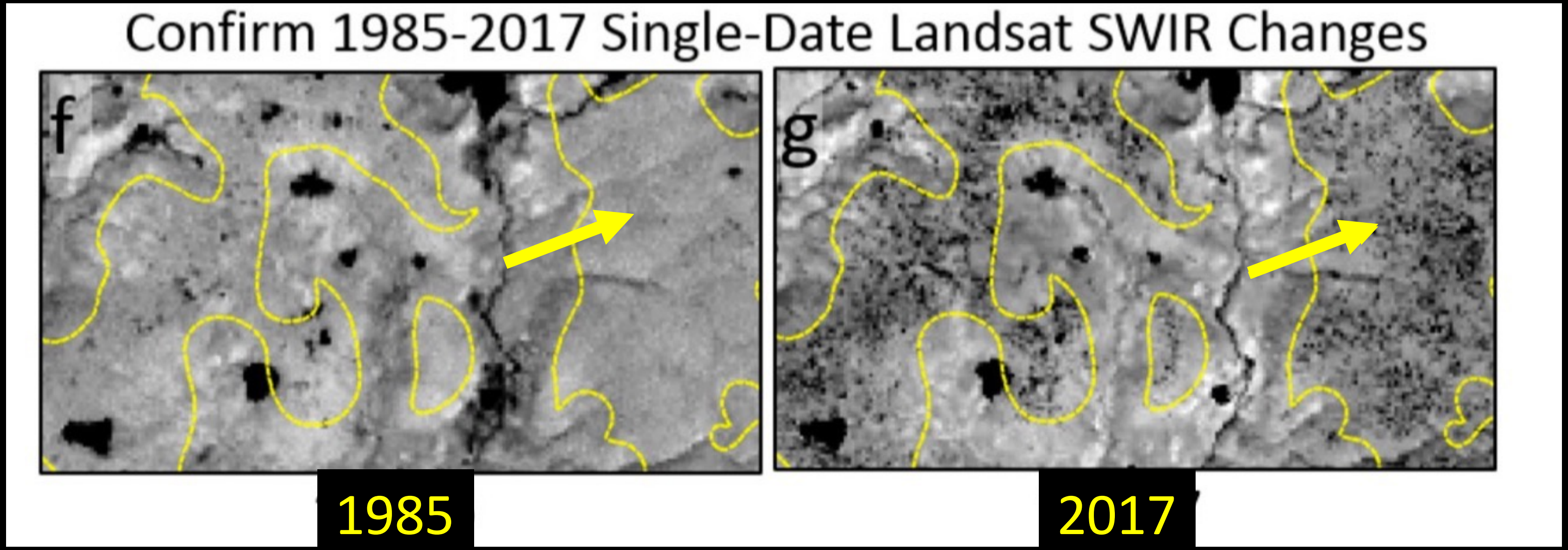
Abstract: Ice-wedge networks underlie polygonal terrain and comprise the most widespread form of massive ground ice in continuous permafrost. Here, we show that climate-driven thaw of hilltop ice-wedge networks is rapidly transforming uplands across Banks Island in the Canadian Arctic Archipelago. Change detection using high-resolution WorldView images and historical air photos, coupled with 32-year Landsat reflectance trends, indicate broad-scale increases in ponding from ice-wedge thaw on hilltops, which has significantly affected at least 1500 km^2 of Banks Island and over 3.5% of the total upland area. Trajectories of change associated with this upland ice-wedge thermokarst include increased micro-relief, development of high-centred polygons, and, in areas of poor drainage, ponding and potential initiation of thaw lakes. Millennia of cooling climate have favoured ice-wedge growth, and an absence of ecosystem disturbance combined with surface denudation by solifluction has produced high Arctic uplands and slopes underlain by ice-wedge networks truncated at the permafrost table. The thin veneer of thermally-conductive mineral soils strongly links Arctic upland active-layer responses to summer warming. For these reasons, widespread and intense ice-wedge thermokarst on Arctic hilltops and slopes contrast more muted responses to warming reported in low and subarctic environments. Increasing field evidence of thermokarst highlights the inherent climate sensitivity of the Arctic permafrost terrain and the need for integrated approaches to monitor change and investigate the cascade of environmental consequences.

Keywords: permafrost; climate change; ice-wedge polygons; Landsat; Banks Island; Arctic; terrain sensitivity



R.H. Fraser et al. 2018, *Remote Sensing. 10:* 984.

Thermokarst on Banks Island

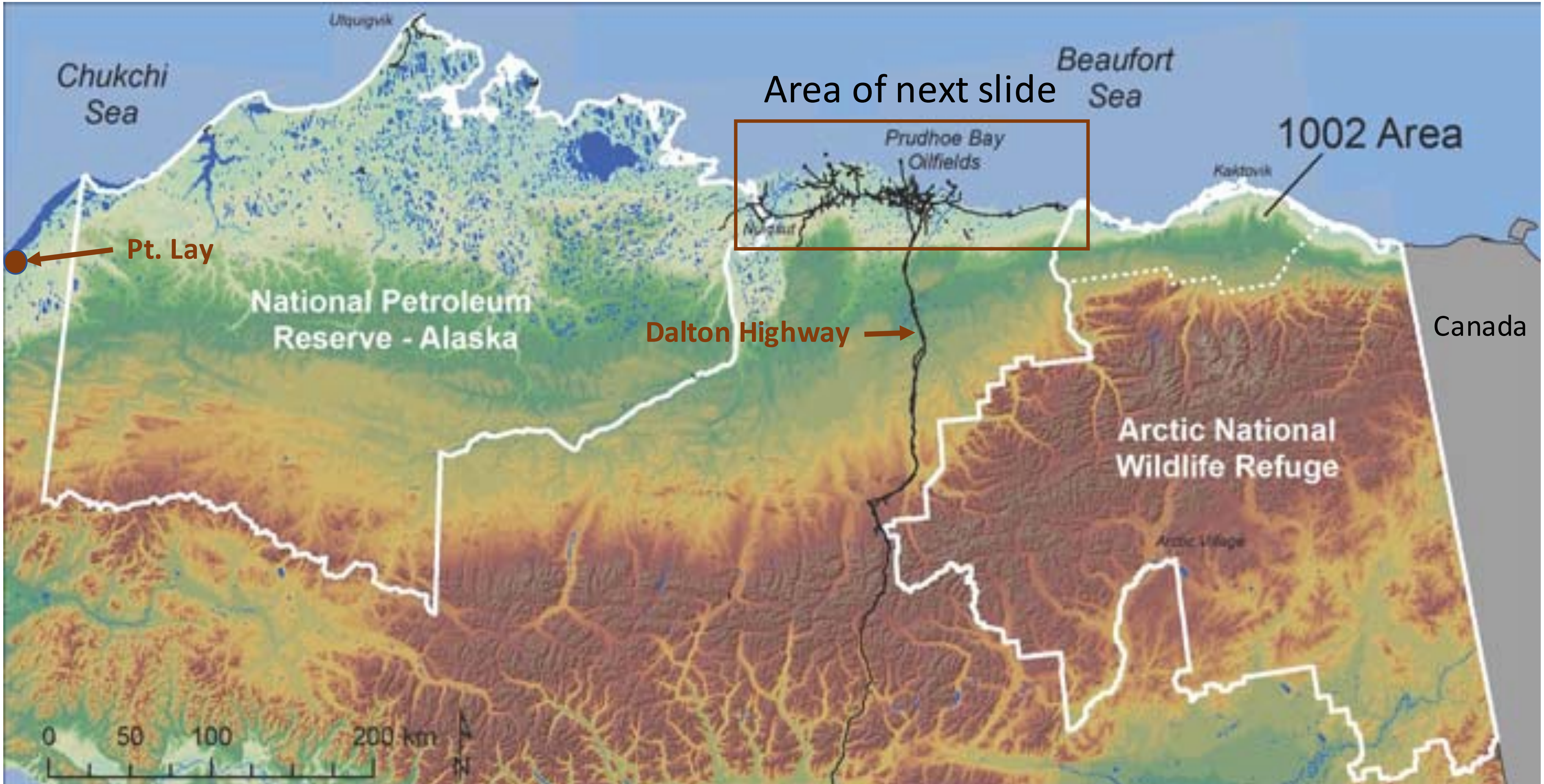


R.H. Fraser et al. 2018, *Remote Sensing. 10:* 984.

Extensive ponding at top of ice-wedges in previously barren sparsely vegetated upland terrain with large ice-wedge polygons.

Banks Island, high-centered polygons. Aerial photos taken enroute to Mould Bay, 2002.

Northern Alaska oilfields, Dalton Highway & Point Lay



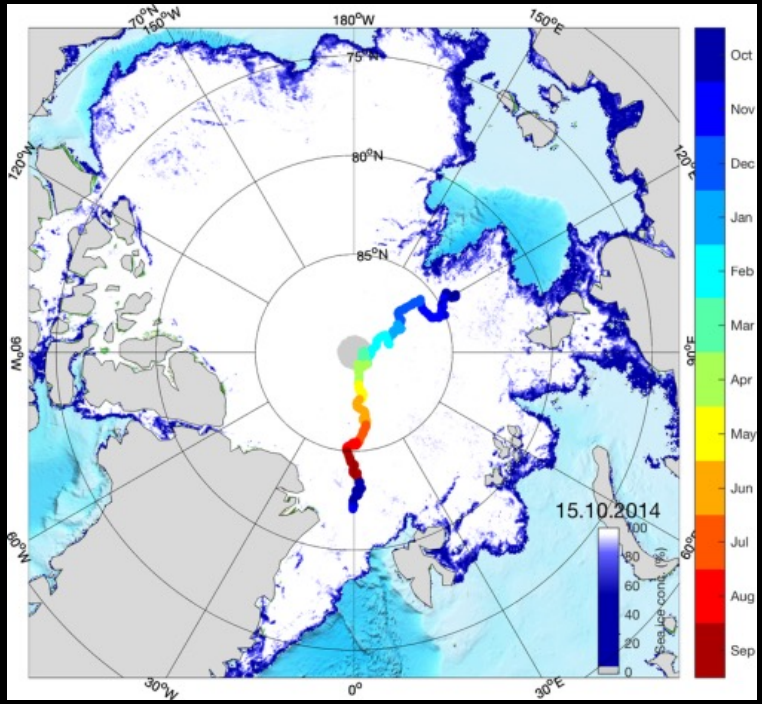
Another Point Lay climate change story

MOSAiC
International Arctic Drift Expedition

MOSAiC

International
Arctic Drift
Expedition

International Collaboration



Route

Polarstern

Modern (2019-2020) repeat of Nansen’s (1893–1896) Fram Expedition

Science observations

Bringing the arts and humanity into NNA

Organizers – UVa:

Matthew Burtner: Dept. Music

Howard Epstein: Dept. Env. Sci.

Leena Cho & Matthew Jull: Dept. Architecture

Sponsors:

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- Institute for Humanities and Global Cultures,
- Center for Global Inquiry and Innovation
- Environmental Resilience Institute (ERI)