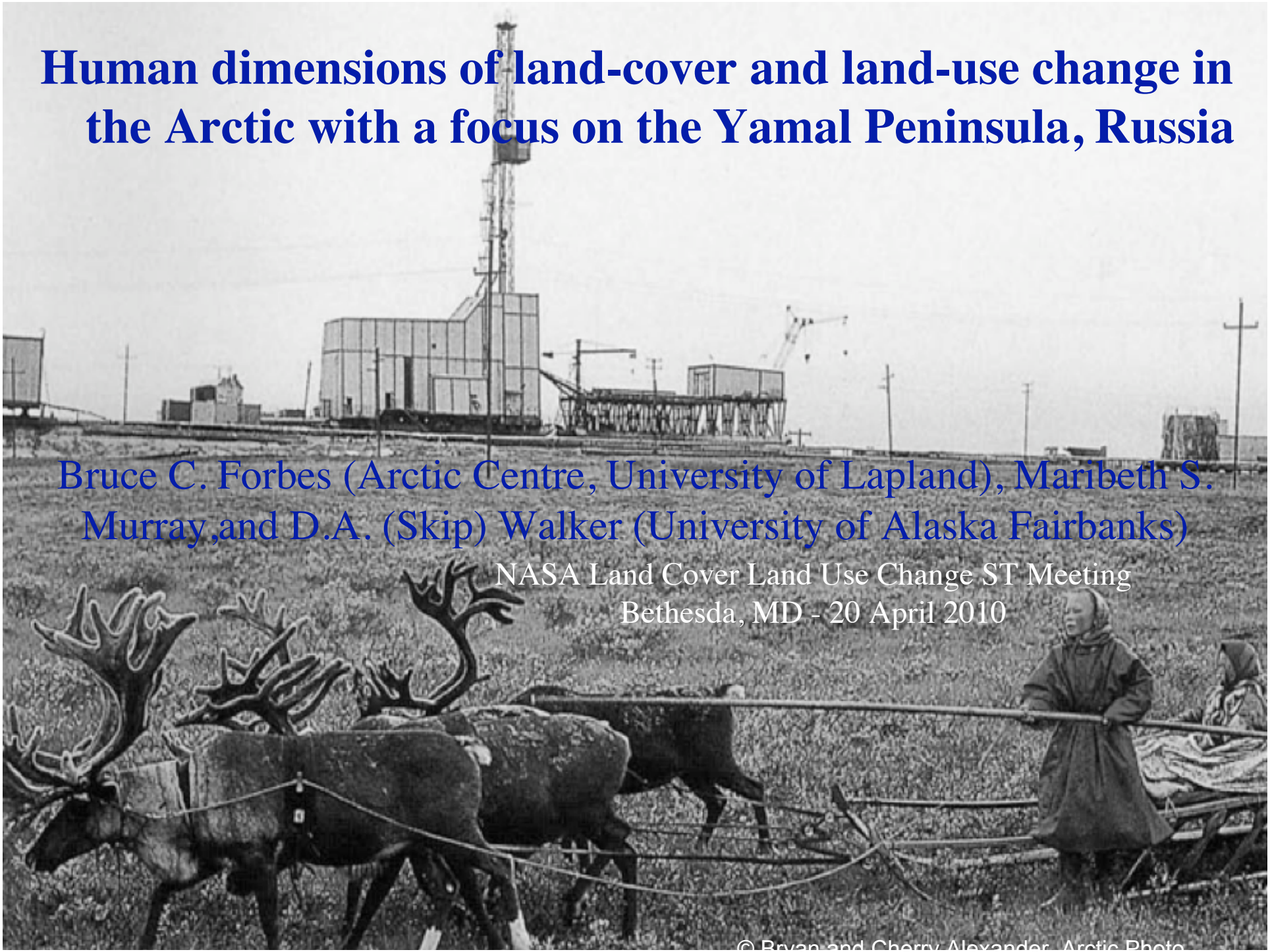
Human dimensions of land-cover and land-use change in the Arctic with a focus on the Yamal Peninsula, Russia



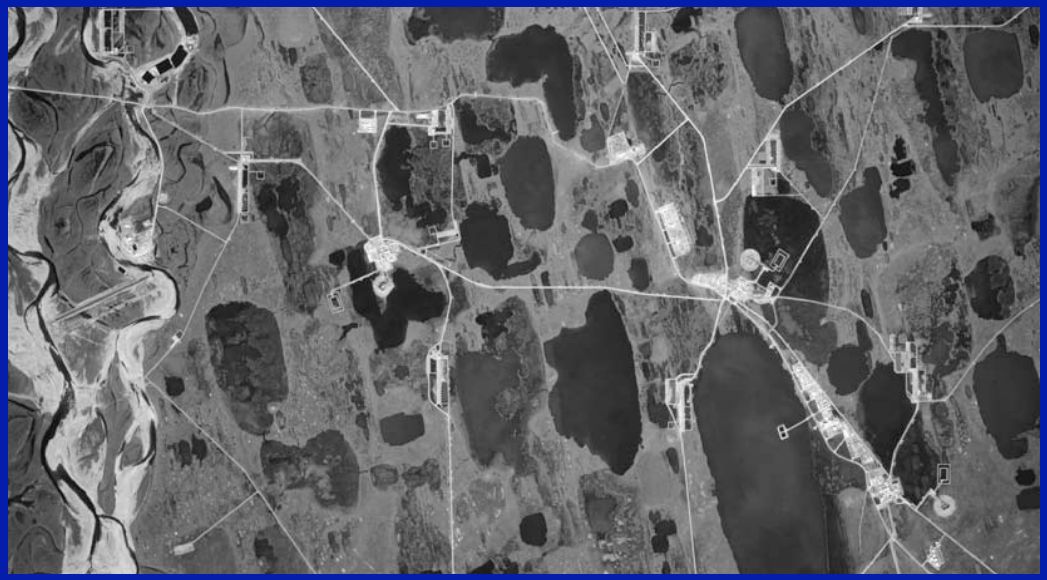
Bruce C. Forbes (Arctic Centre, University of Lapland), Maribeth S. Murray,and D.A. (Skip) Walker (University of Alaska Fairbanks)

NASA Land Cover Land Use Change ST Meeting
Bethesda, MD - 20 April 2010

Scope of the talk

- Overview of socio-ecological change in the Arctic.
- The big issues affecting people in the Arctic.
  - Sea-ice cover changes
  - Land cover changes
  - Land-use changes
- How these changes are being assessed using remote-sensing technology.
- Integrating indigenous views and knowledge into the research agenda: Examples from the Yamal Peninsula, Russia.

Land-use change



Road network at Prudhoe Bay, AK, 1982 CIR Photo NASA.

Land-cover and sea-ice cover change

Landscape patterns on the Yamal & Nentsy herder. Photos: D.A. Walker

Arctic Peoples and Environmental Change

Increasing interest in modes of adaptation and resilience in linked social-ecological systems

ARTICLE

Arctic Environmental Change of the Last Four Centuries

J. Overpeck,* K. Hughen, D. Hardy, R. Bradley, R. Case, M. Douglas, B. Finney, K. Gajewski, G. Jacoby, A. Jennings, S. Lamoureux, A. Lasca, G. MacDonald, J. Moore, M. Retelle, S. Smith, A. Wolfe, G. Zielinski

A compilation of paleoclimate records from lake sediments, trees, glaciers, and marine sediments provides a view of circum-Arctic environmental variability over the last 400 years. From 1840 to the mid-20th century, the Arctic warmed to the highest temperatures in four centuries. This warming ended the Little Ice Age in the Arctic and has caused retreats of glaciers, melting of permafrost and sea ice, and alteration of terrestrial and lake ecosystems. Although warming, particularly after 1920, was likely caused by increases in atmospheric trace gases, the initiation of the warming in the mid-19th century suggests that increased solar irradiance, decreased volcanic activity, and feedbacks internal to the climate system played roles.

and other feedbacks (6, 7).

In this article, we use the paleoenvironmental record to assess the climate events of this century from the perspective of the last four centuries. We build on previous work (8–10) by compiling a variety of complementary paleoenvironmental indicators of climate from around the entire Arctic. This perspective permits the visualization of natural subdecadal to century-scale climate variability in the circum-Arctic region and

Ann. Rev. Anthropol. 1981. 10:1–25

HUMAN ADAPTATION TO ARCTIC ZONES

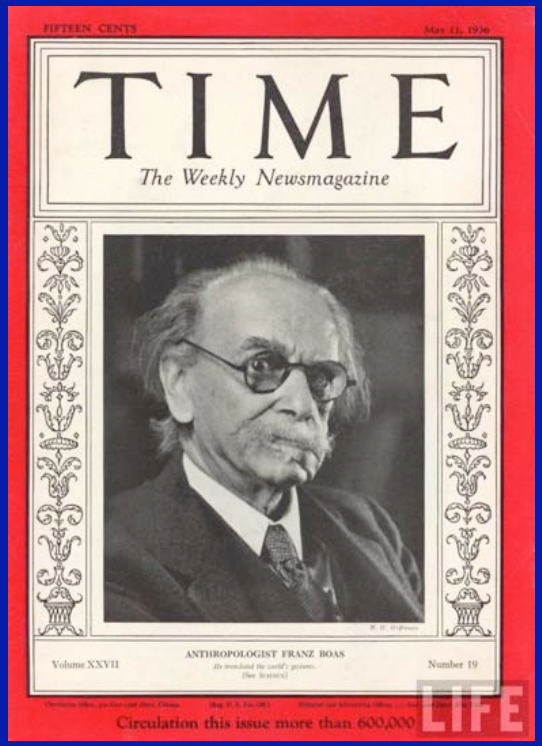
◆9669

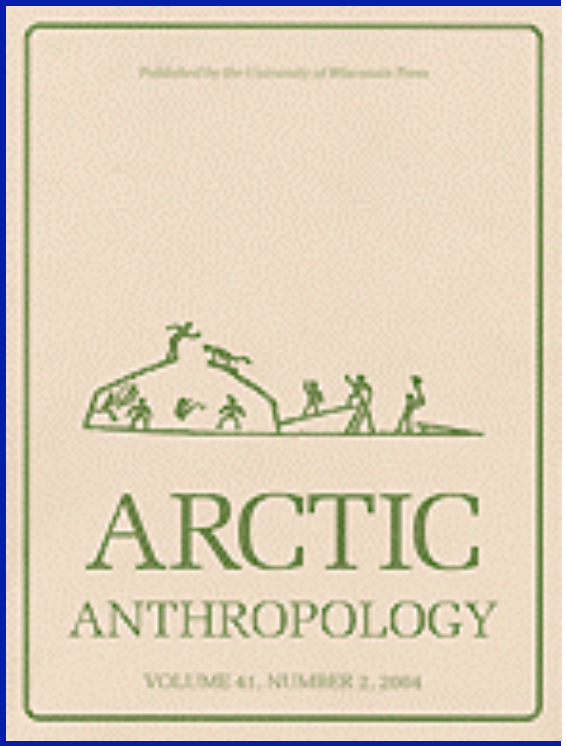
Emilio F. Moran

Department of Anthropology, Indiana University, Bloomington, Indiana 47401

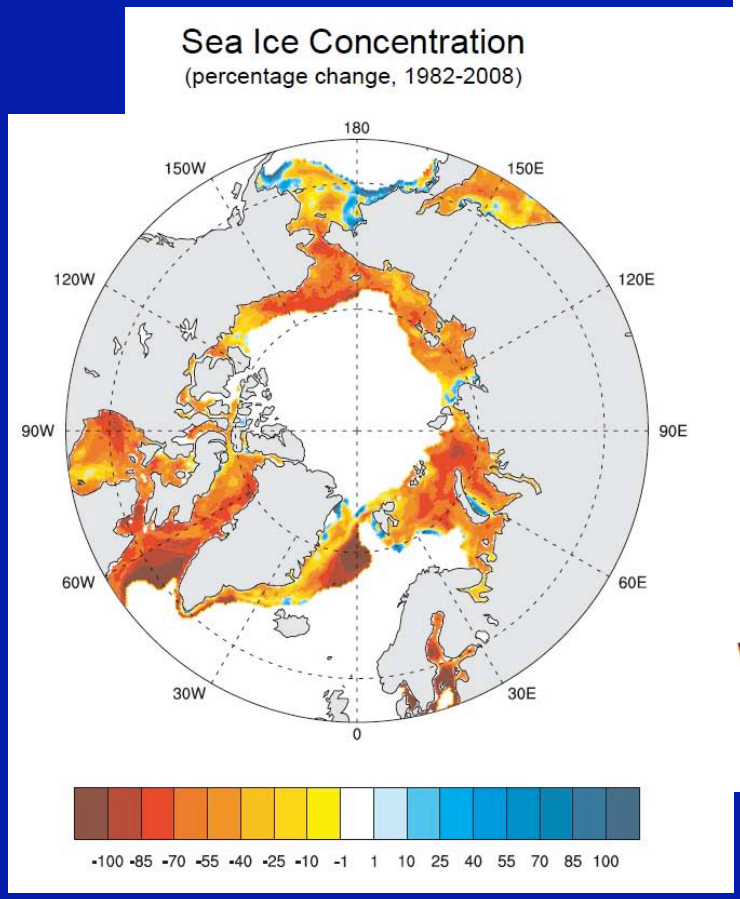
INTRODUCTION

The study of human adaptation to polar areas has engaged scholars in many fields since the late nineteenth century. The first two scientific monographs on the Eskimo were published in 1888 (16,55), and were soon followed by useful reports (2, 39, 99, 110). Since then much work has been undertaken, and efforts at a synthesis are now under way. Tundra ecosystems were recently a focus of research efforts by the International Biological Program (IBP), and students with interest in the human ecology of this region now have a rich and rapidly growing literature. The Swedish component of the IBP/Tundra Biome has published a useful collection of papers on the structure and function of tundra ecosystems (102).

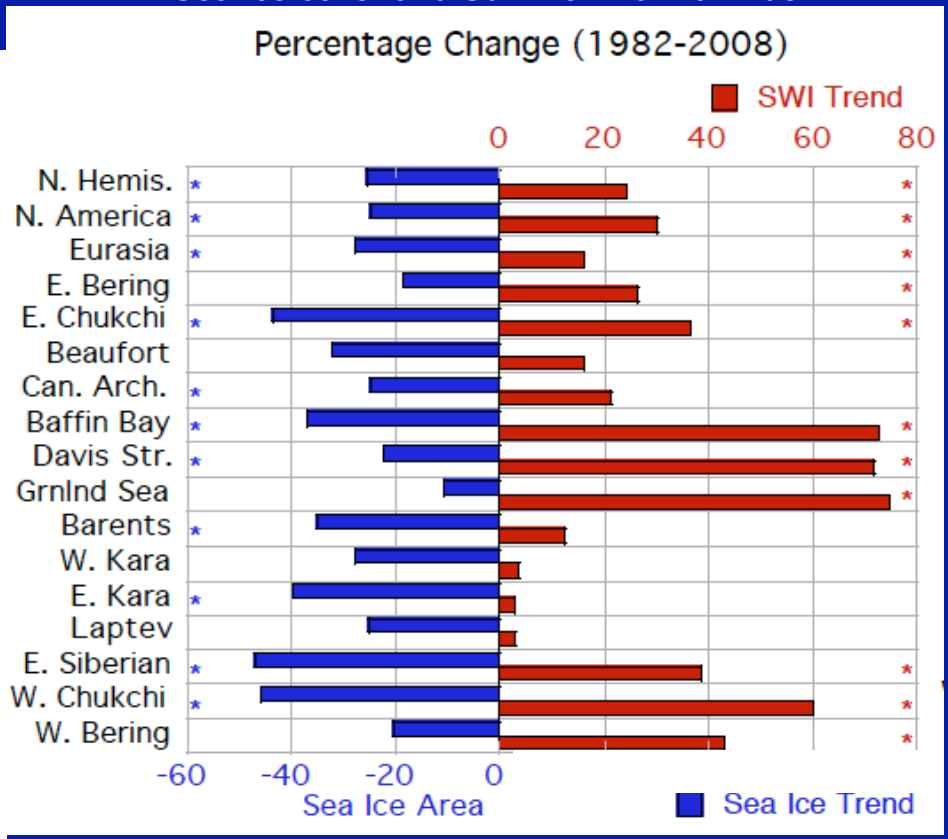




Sea-cover changes: Percentage changes in sea ice and summer land temperatures (1982-2008)



Sea Ice cover and Summer Warmth Index



Bhatt et al. 2010 submitted. *Earth Interactions.*

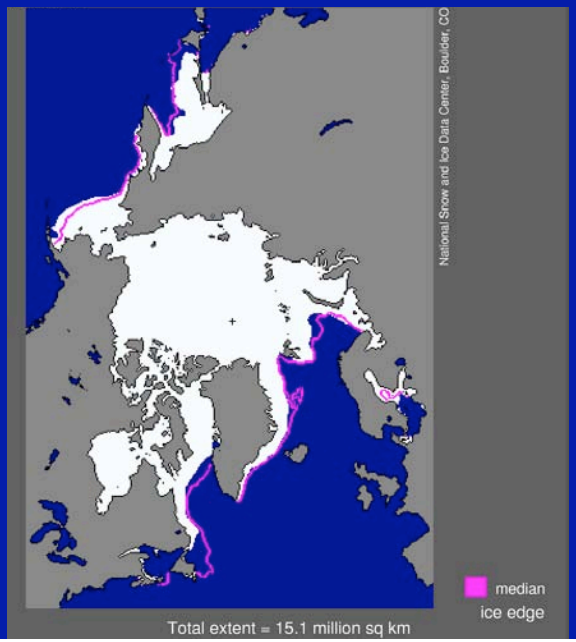
Sea ice within 50-km of coast: -25% for Arctic as a whole: <-44% in E. Siberia to Chukchi seas; some increases in Bering region and other scattered areas.

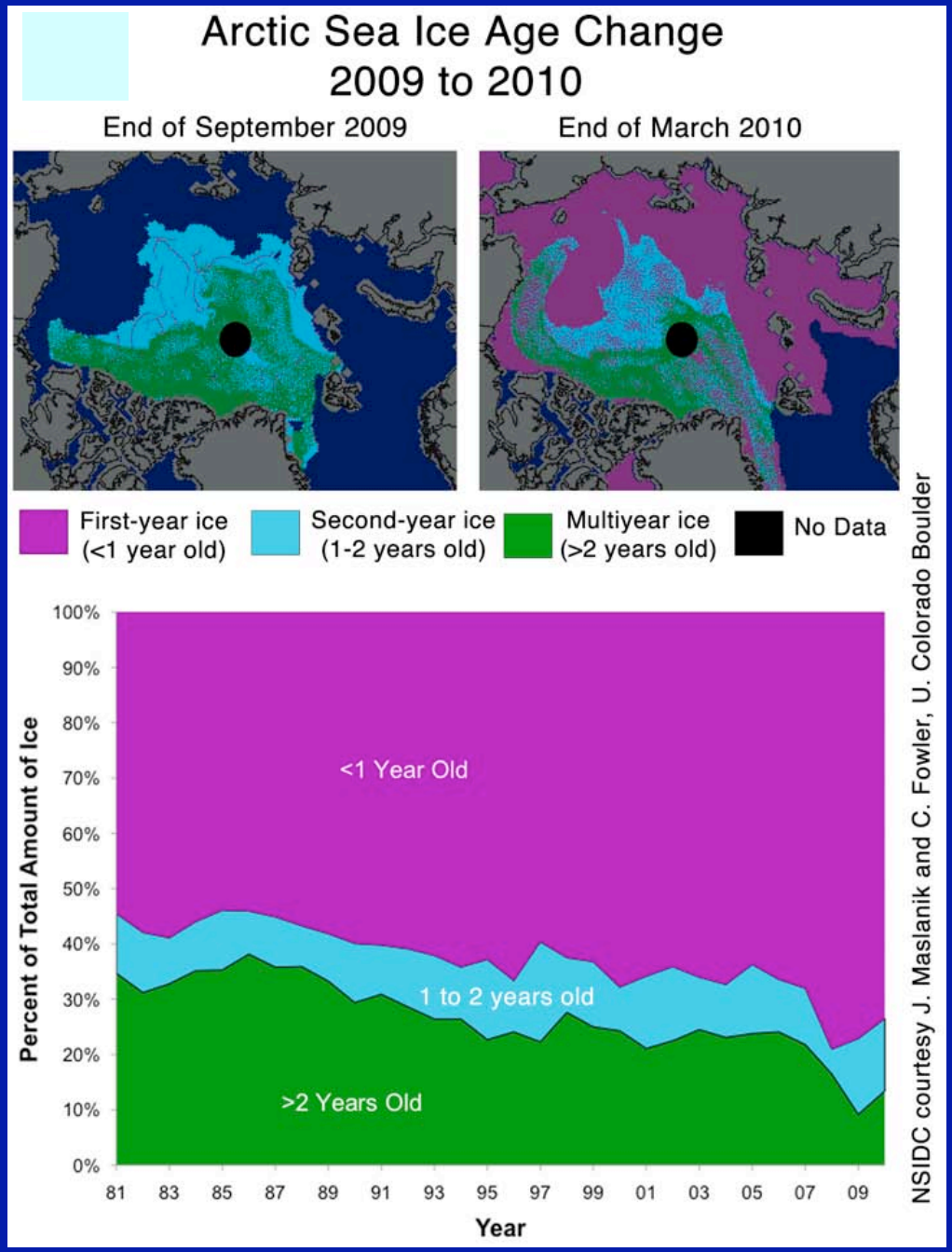
Summer land temperatures (SWI): +24% Arctic as a whole; +30% in North America, +16% Eurasia. Largest increases in Canadian High Arctic and Greenland (>70%).

Importance of multi-year sea ice

- Much of the indigenous use of Arctic Ocean resources is dependent on thick multi-year sea ice.
- This has been declining steadily over the period of the record.
- Even though 2010 revealed a somewhat normal March extent of sea ice, most of this was 1st-year ice and will like melt quickly in summer 2010.

March 2010 sea-ice extent

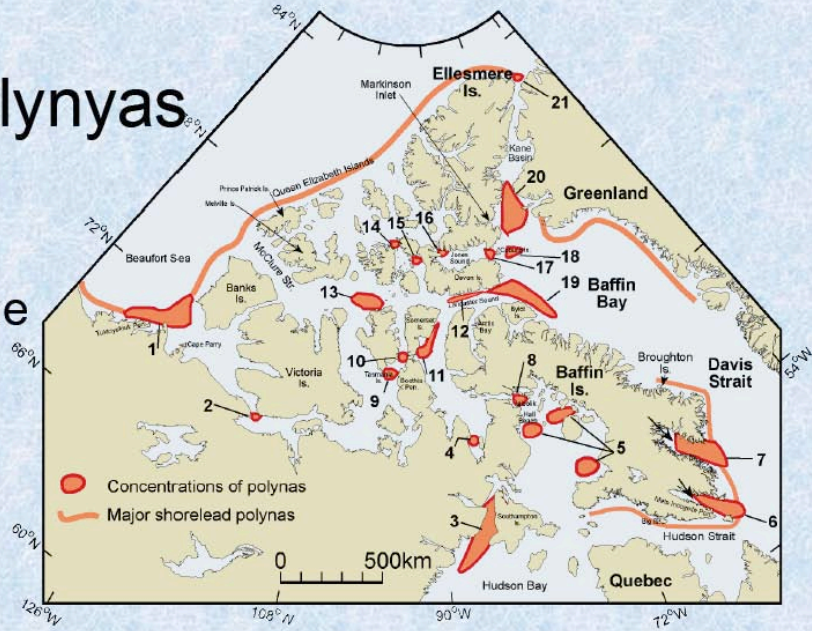




Polynyas in Arctic Canada: Sea-ice provides access to resources

Known Polynyas

An area of ice free water in the midst of ice covered water (some or most of the time)



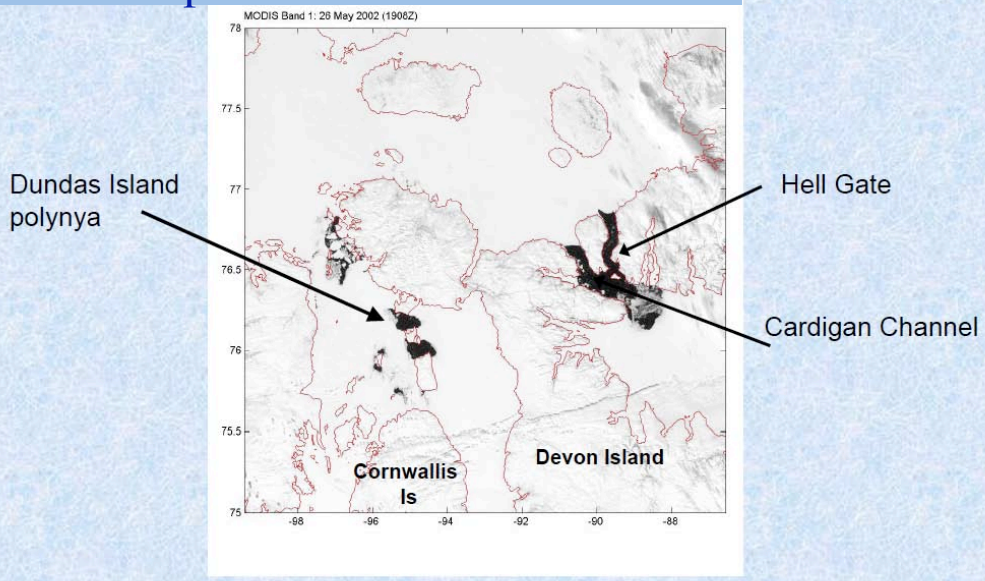
1 Cape Bathurst
2 Lambert Channel
3 Roes Welcome Sound
4 Committee Bay
5 Foxe Basin
6 Frobisher Bay
7 Cumberland Sound
8 Fury and Hecla Strait
9 Franklin Strait
10 Bellot Strait
11 Prince Regent Inlet
12 Lancaster Sound
13 Viscount Melville Sound
14 Queens Channel and Penny Strait
15 Dundas Island
16 Hell Gate - Cardigan Strait
17 Lady Ann Strait
18 Coburg Island
19 Bylot Island
20 NOW (Northwater)
21 Lincoln Sea

Barber and Massom 2007

Polynyas near Devon and Cornwallis islands (26 May 2002):

White is ice, snow and clouds.

Black is open water.



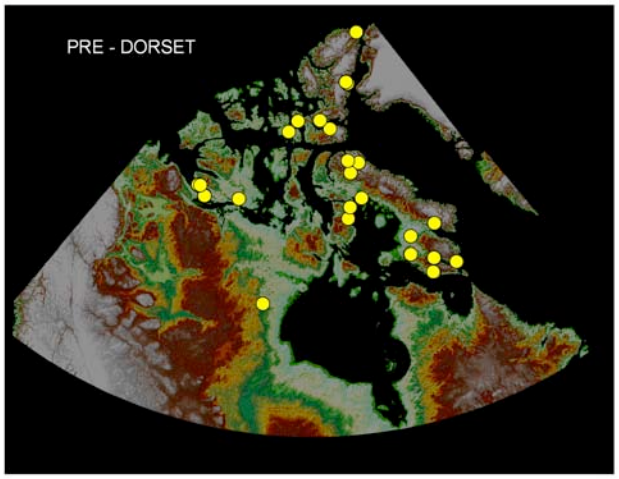
Murray and Hannah 2010. Tidal Mixing, Polynyas, and Human Settlement in the Canadian Arctic Archipelago. State of the Arctic Conference, Miami, Fl

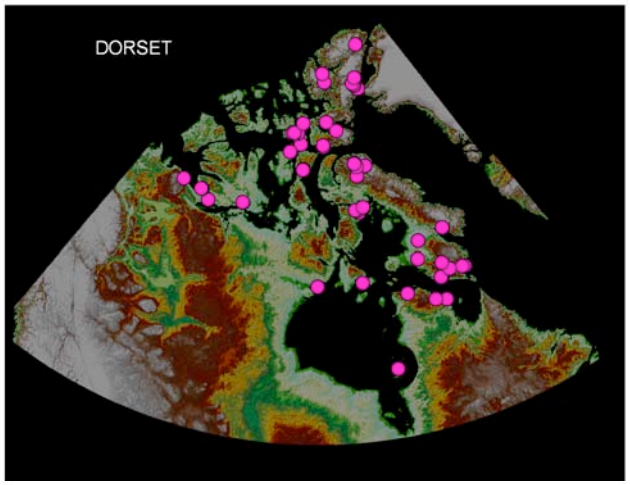
Ecological “hot spots”: Prehistoric settlements in Northern Canada in relationship to polynyas

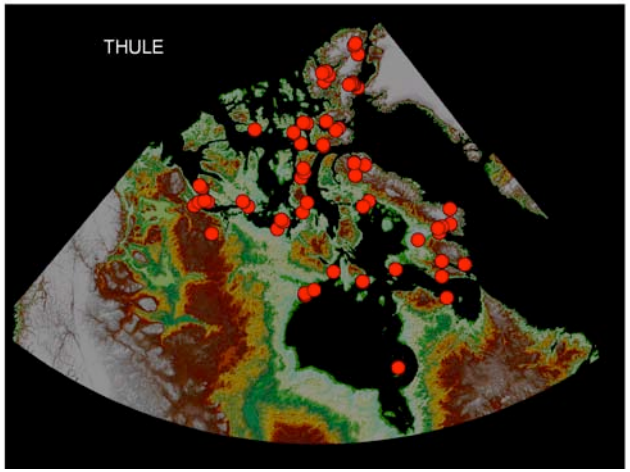
Pre-Dorset (Paleoeskimo), ca. 4500-2300 BP

Dorset (Paleoeskimo), ca. 2300-1000 BP

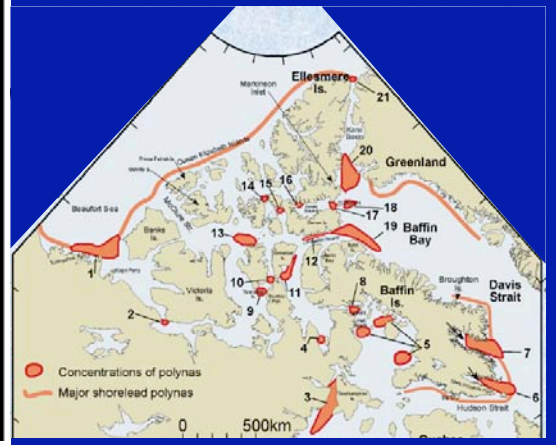
Thule (Ancestral Inuit), ca. 800-200 BP







Ilulissat, Greenland, 2009



Polynyas in Canadian Archipelago.

From: Murray and Hannah 2010.

Immediate and cumulative effects of 2007 sea-ice minimum on coastal communities in Alaska

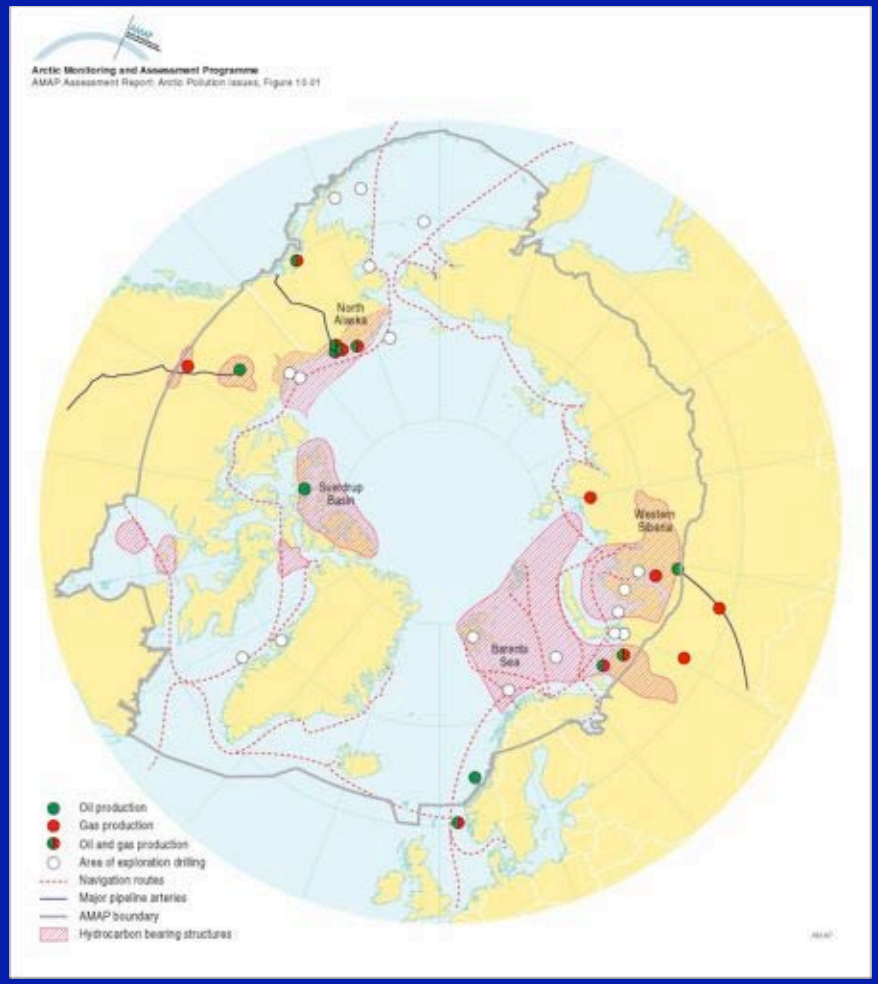
Butchering seals on the ice at Shishmaref, Alaska. Photo: K. Stenek

Feedbacks from changing environmental conditions and global processes:

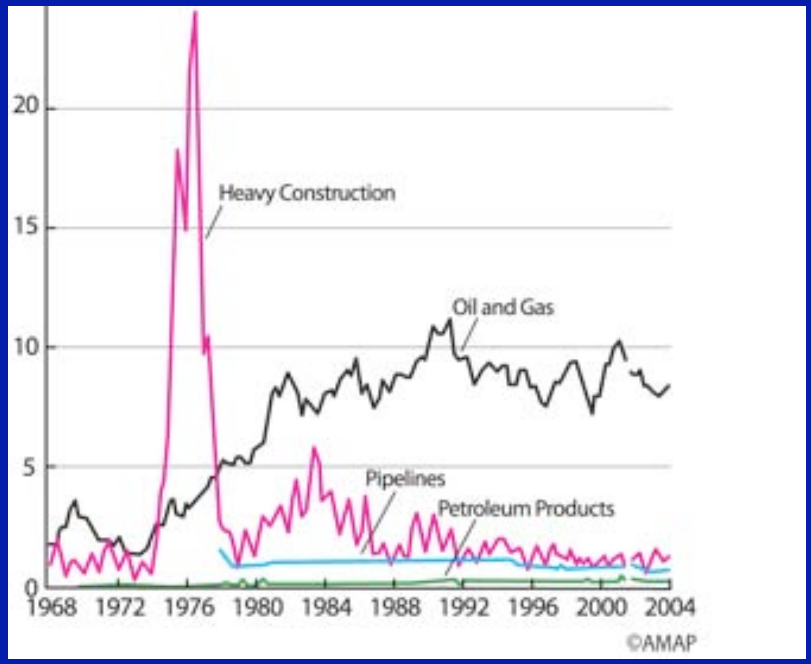
- Greater distances traveled
- Higher cost of fuel
- Lower success of harvest
- Higher cost of purchased goods
- Needs for wage labour
- Out migration to cities
- Impacts on health

Land-use changes: Effects of development

Major oil and gas resources in the Arctic



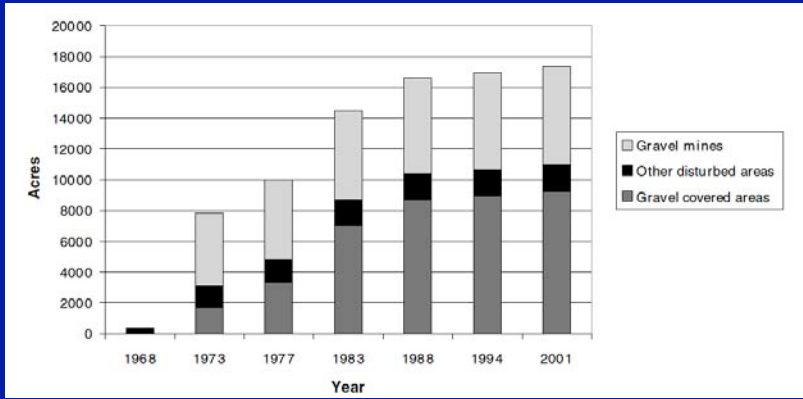
Employment in thousands



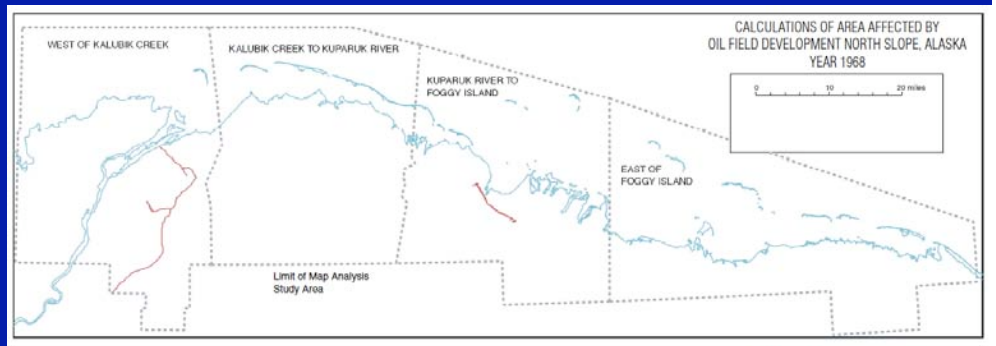
Land-use changes: Growth of Prudhoe Bay infrastructure, 1968-2001

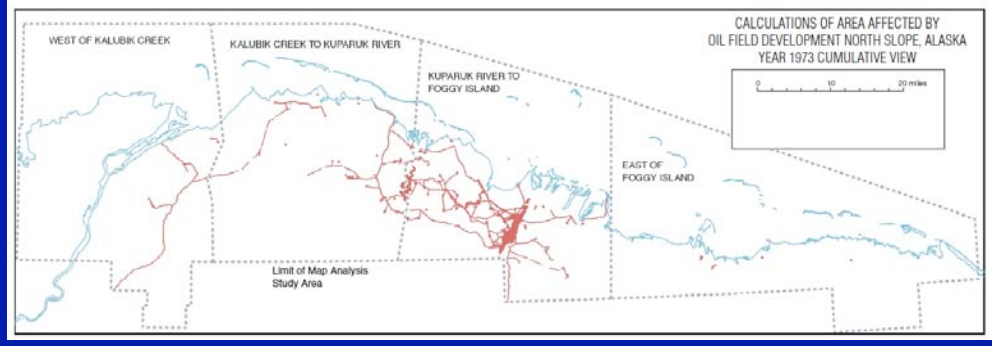
Direct impacts in 2001:

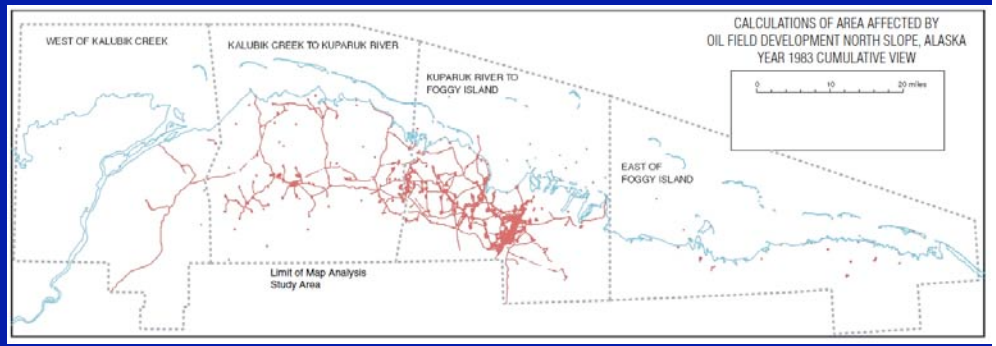
Gravel roads (km)	400
Pipelines (km)	450
Powerlines (km)	219
Production pads	115
Airstrips	4
Culverts	1395
Bridges	17
Gravel area (km^2)	37.5
Gravel mines	25.7
Off-shore gravel	0.6
Other impacted areas	7.1
Total directly impacted area:	**70.2 km^2**

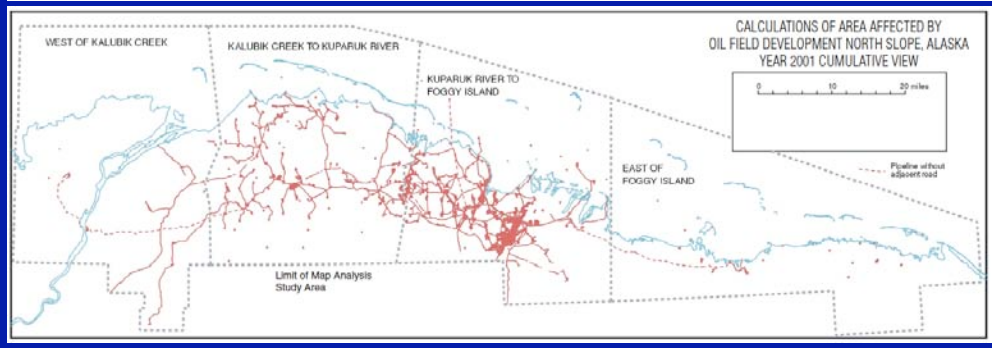


National Research Council 2003

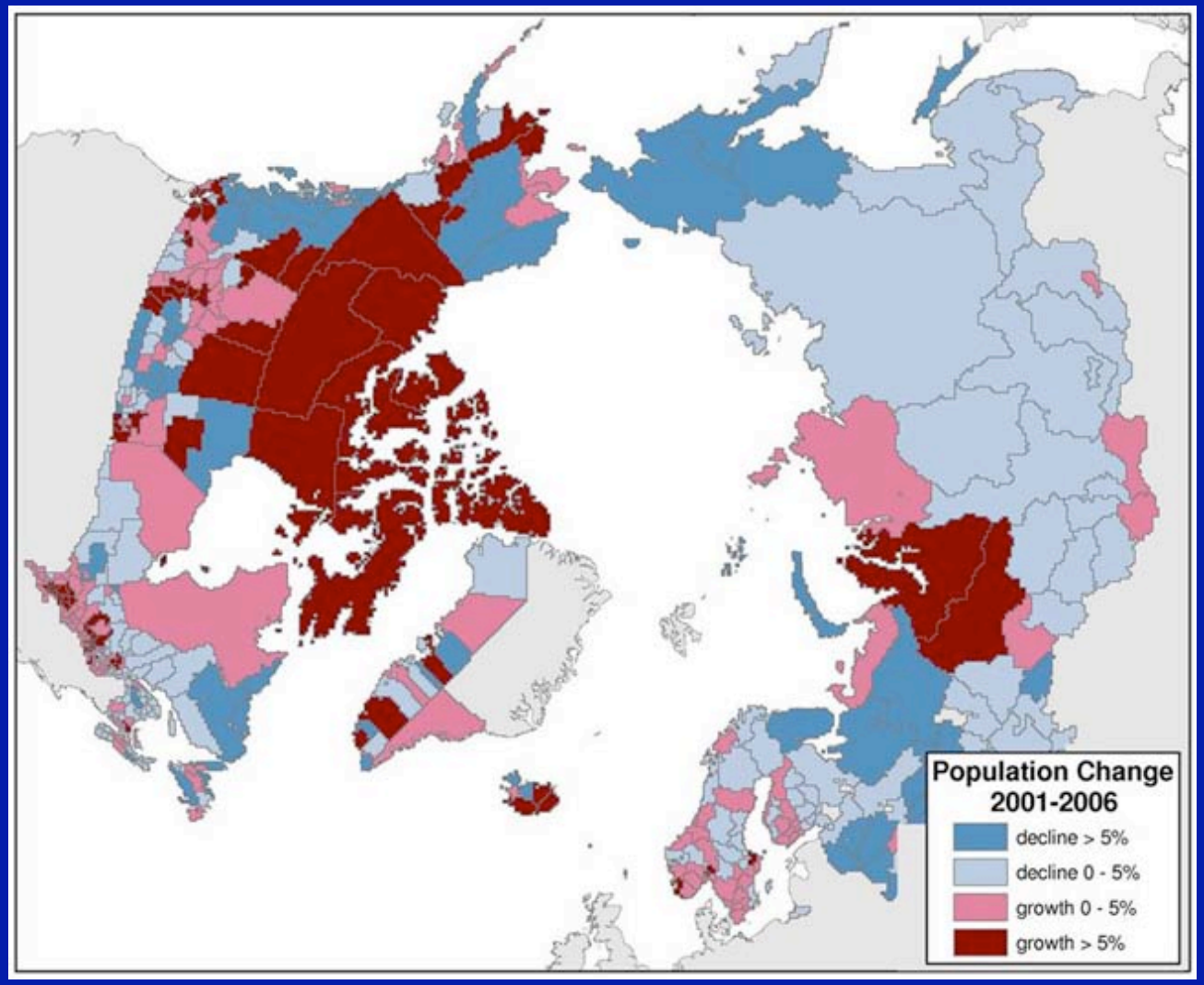




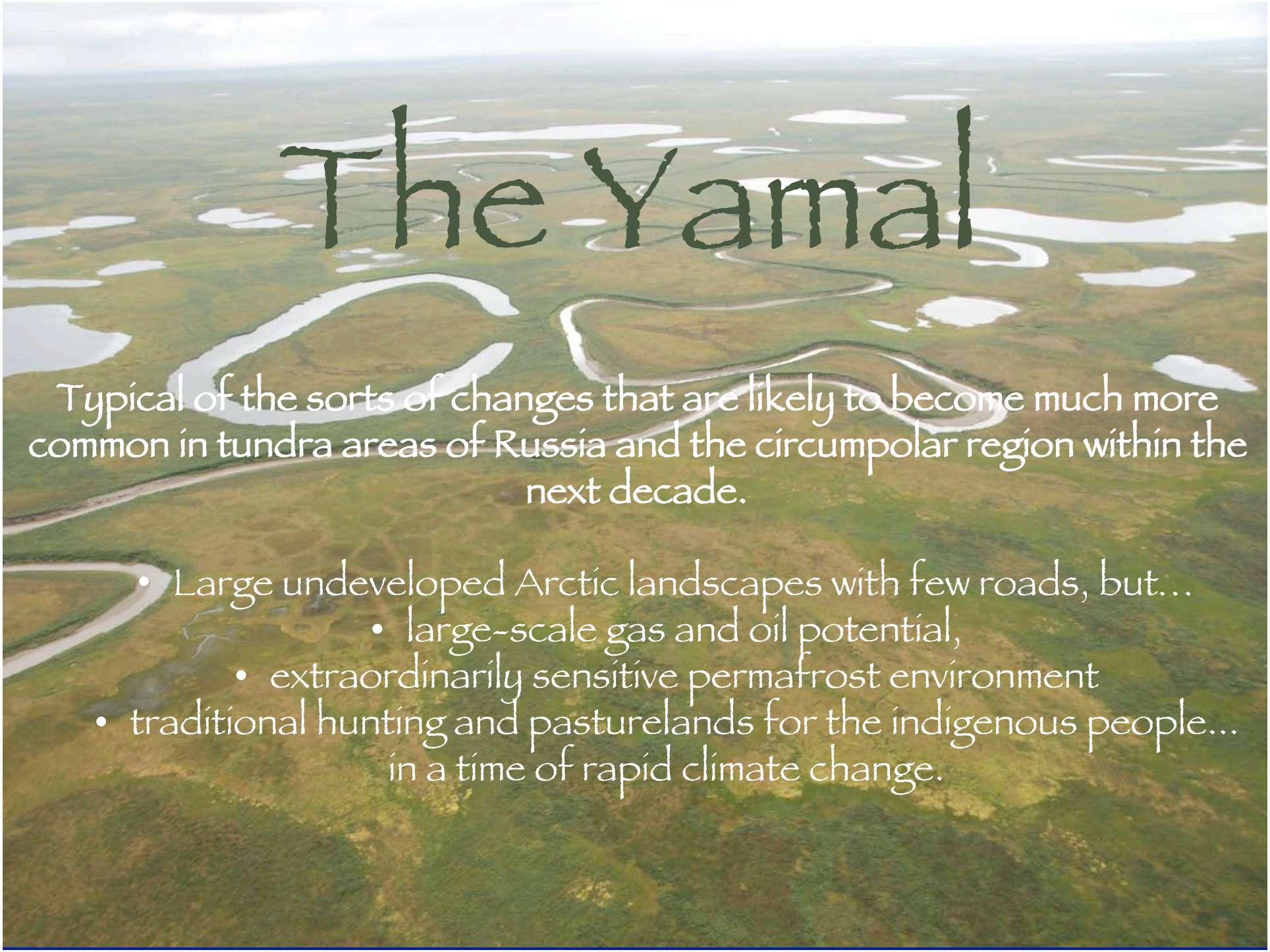




Arctic Demographics



From Hamilton 2009, http://carseyinstitute.unh.edu/alaska-indicators-northern.html



The Yamal

Typical of the sorts of changes that are likely to become much more common in tundra areas of Russia and the circumpolar region within the next decade.

- Large undeveloped Arctic landscapes with few roads, but…
  - large-scale gas and oil potential,
  - extraordinarily sensitive permafrost environment
  - traditional hunting and pasturelands for the indigenous people…

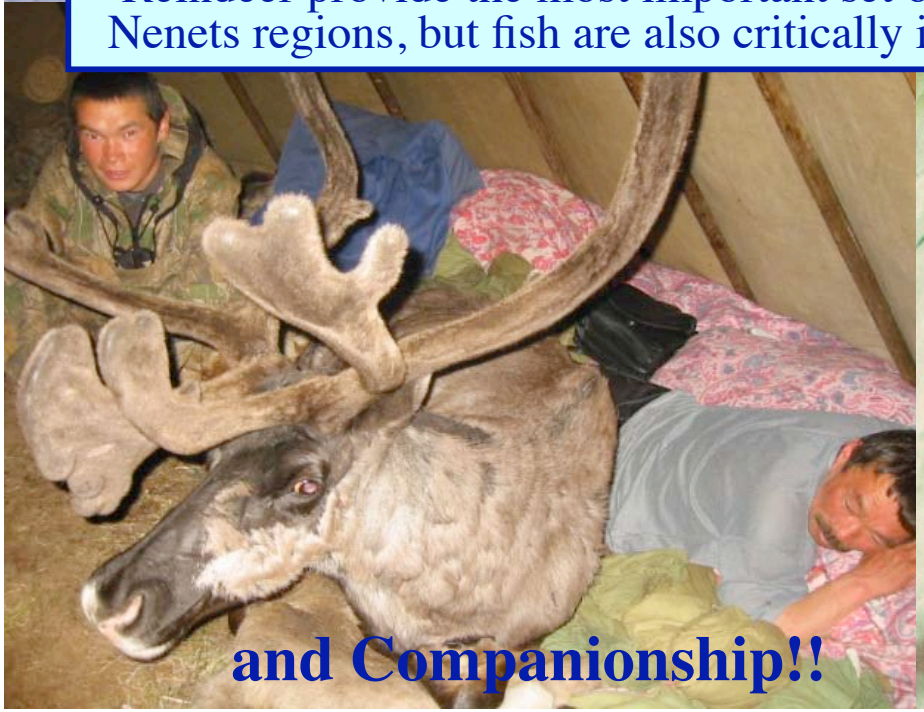
in a time of rapid climate change.

Primary Russian oil & gas pipelines supplying Europe

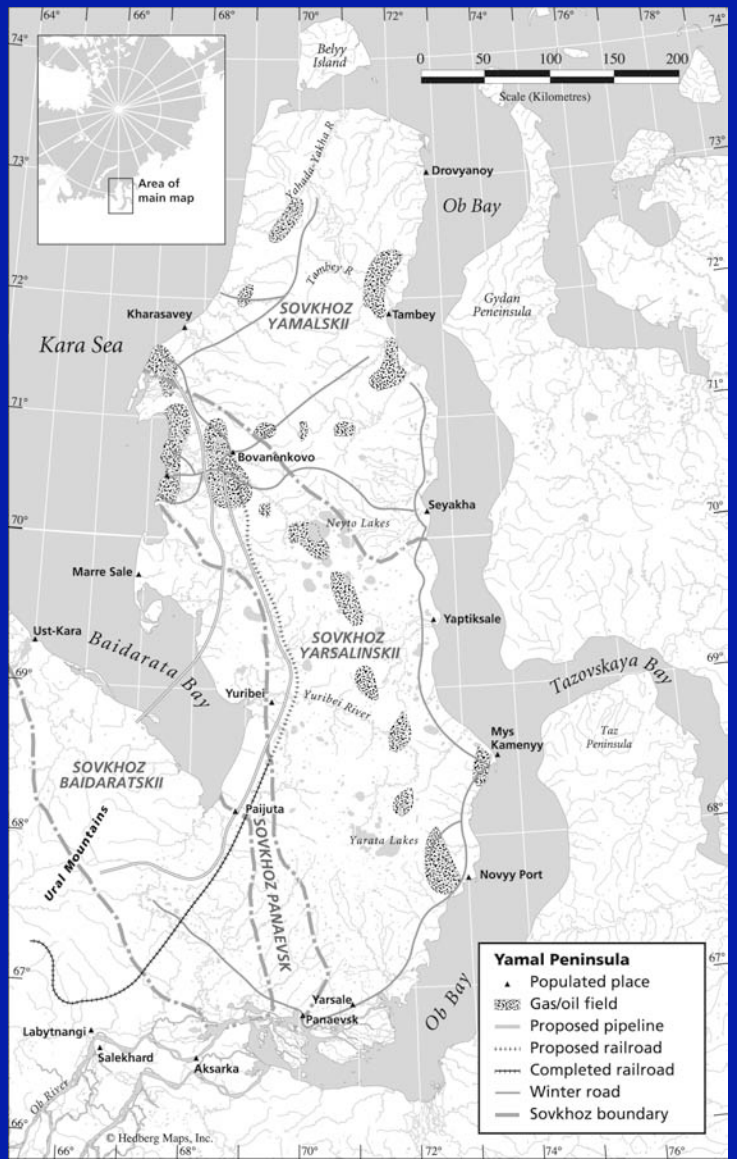
The new Baltic 'Nord Stream' gas pipeline will be supplied in large part with gas from the Yamal Peninsula, West Siberia.

Besides extensive oil & gas development, the Yamal has experienced profound pressures in the past 20-30 years from the Soviet Union's collapse and extreme weather scientists attribute to climate warming.

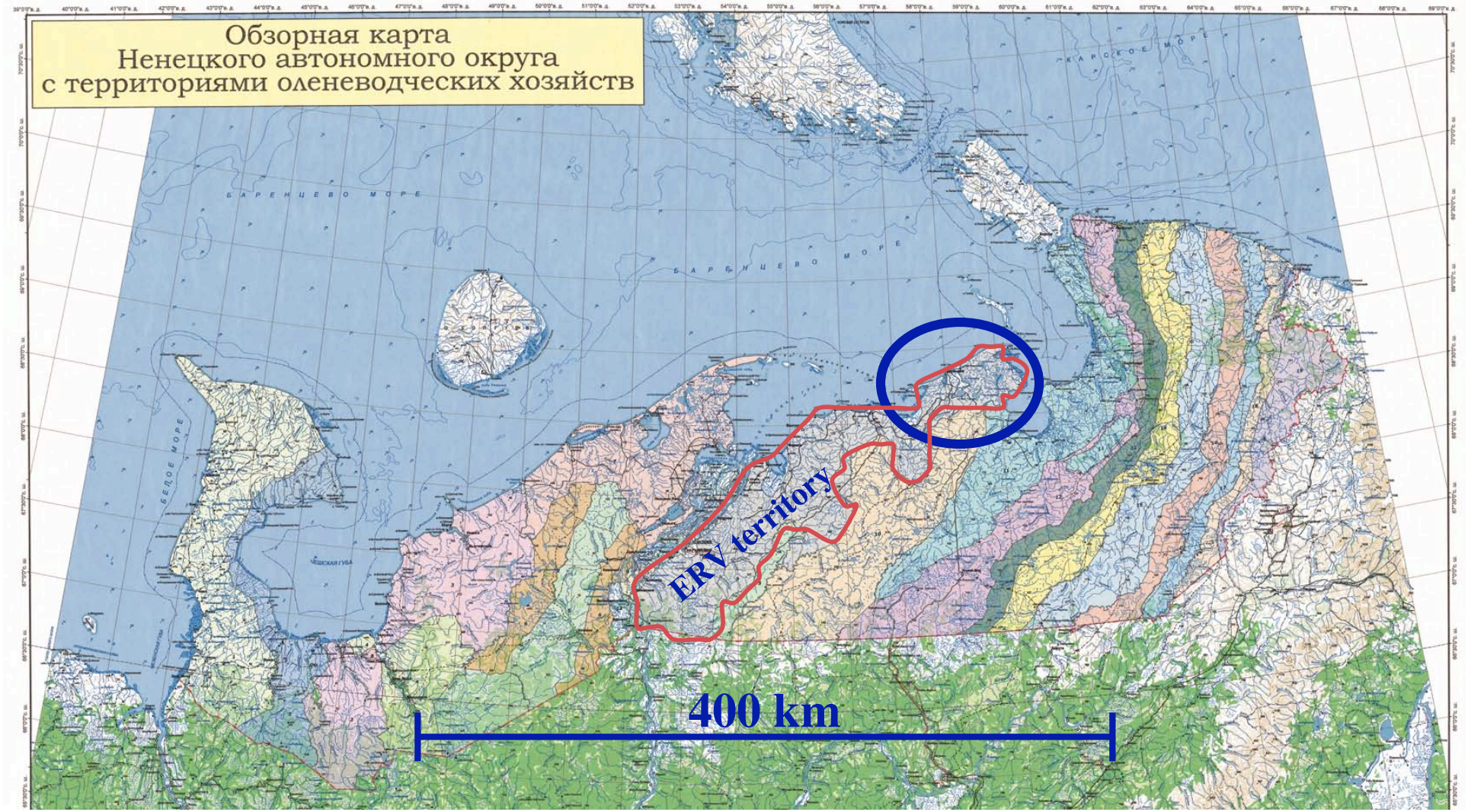
Reindeer provide the most important set of provisional ecosystem services in the tundra Nenets regions, but fish are also critically important, especially during summer migration



Yamal Peninsula, West Siberia: Gas & oil deposits overlap with the territories of nomadic Nenets reindeer herders. Therefore our research efforts have directly involved herders to understand resilience at the level of the entire social-ecological system. We began in 2004 with funding from the Finnish Academy and since 2007 have continued with support from NASA and NSF. Dr. Florian Stammler is the social anthropologist who led the participant observation efforts.



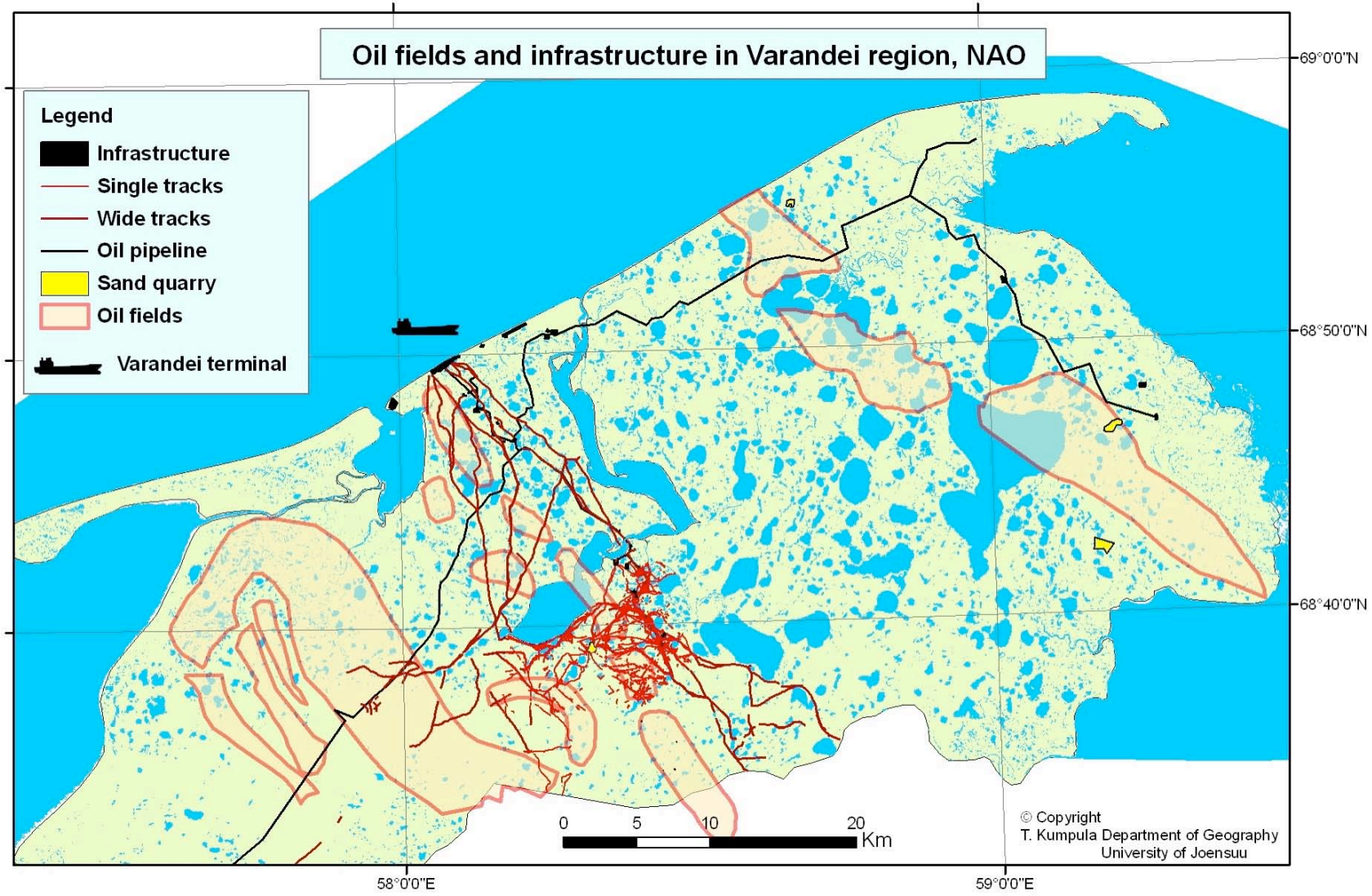
Reindeer herding management units (sovkhozi, etc.) of the Nenets Autonomous Okrug (NAO). Some of these also overlap directly with major hydrocarbon fields. Even without additional sea ice retreat, this is a fairly accessible portion of the Northern Sea Route and most export will be by tanker.



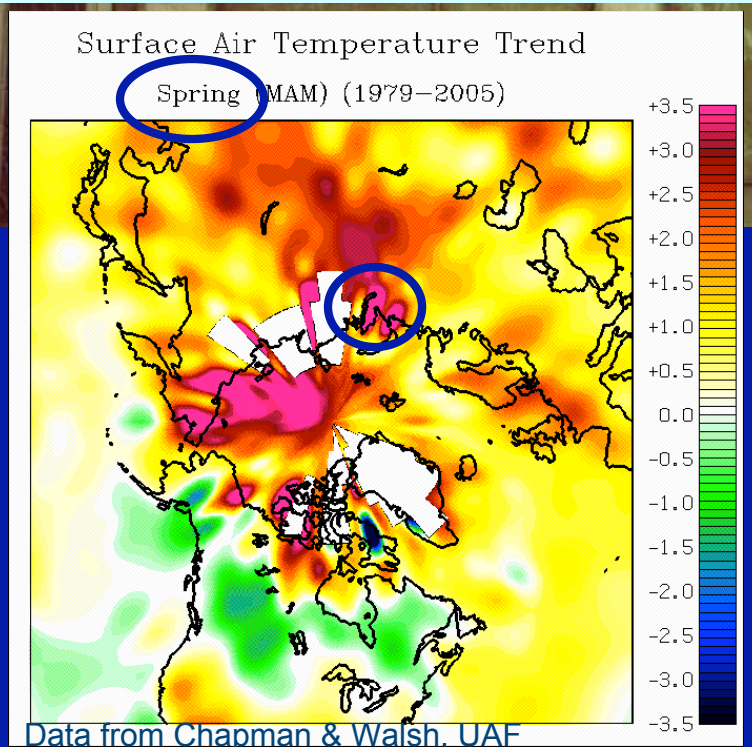
Rapid changes in land use in Nenets regions

In NAO and YNAO gas and oil fields and infrastructure are increasing both onshore and offshore. The terrestrial territories have been used extensively by reindeer herders for centuries.

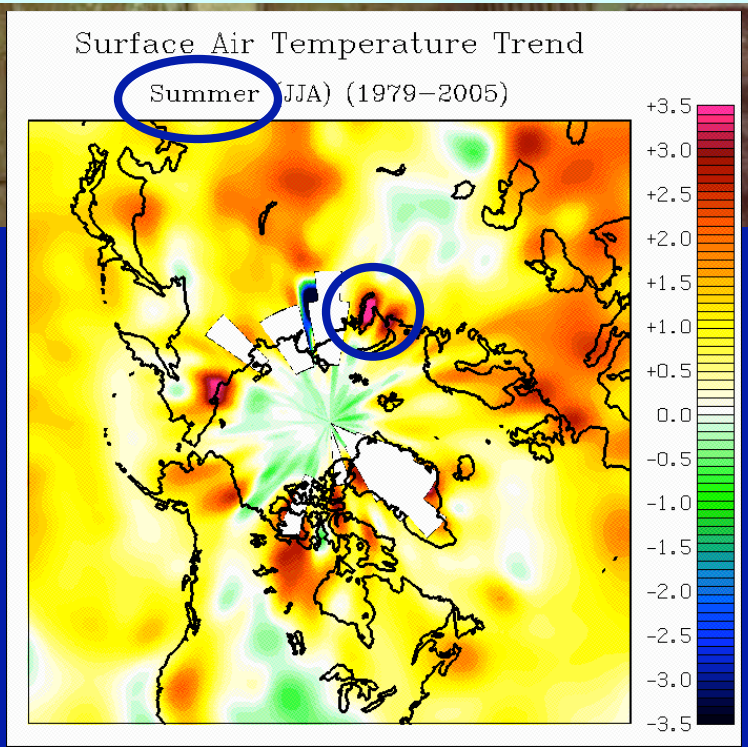
First ice-class tanker was loaded in June 2008 and sailed for Canada

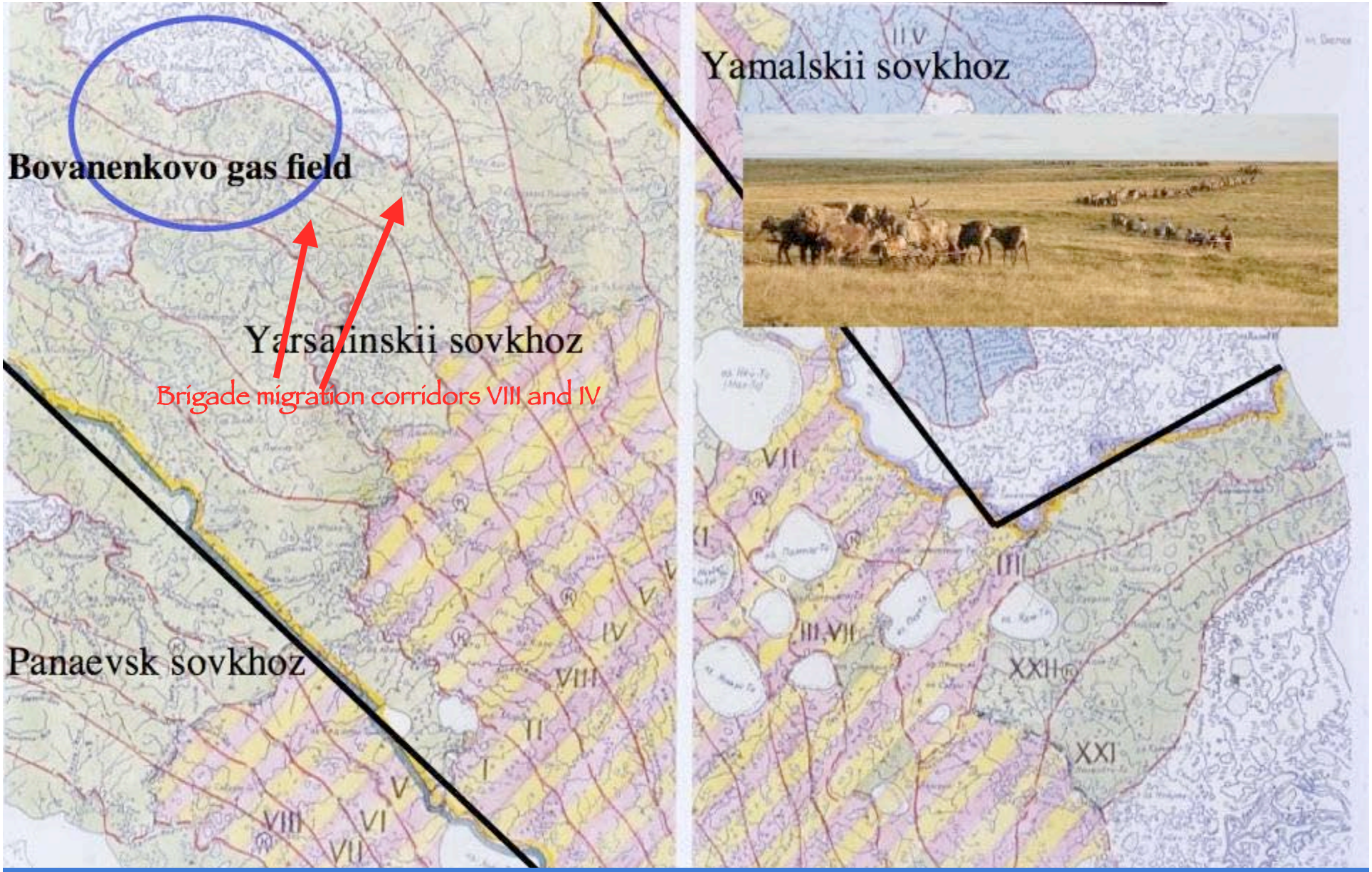


Our recent projects were designed to consider primarily oil & gas activities because these were what herders themselves cited as the most important factors affecting them. However, spring and summer air temperatures in YNAO and NAO have warmed over the past 25 to 30 years some 2 to 3°C. This has major implications for both oil & gas infrastructure and the future of reindeer herding since it means that people and reindeer are potentially exposed to multiple stressors.



Data from Chapman & Walsh, UAF

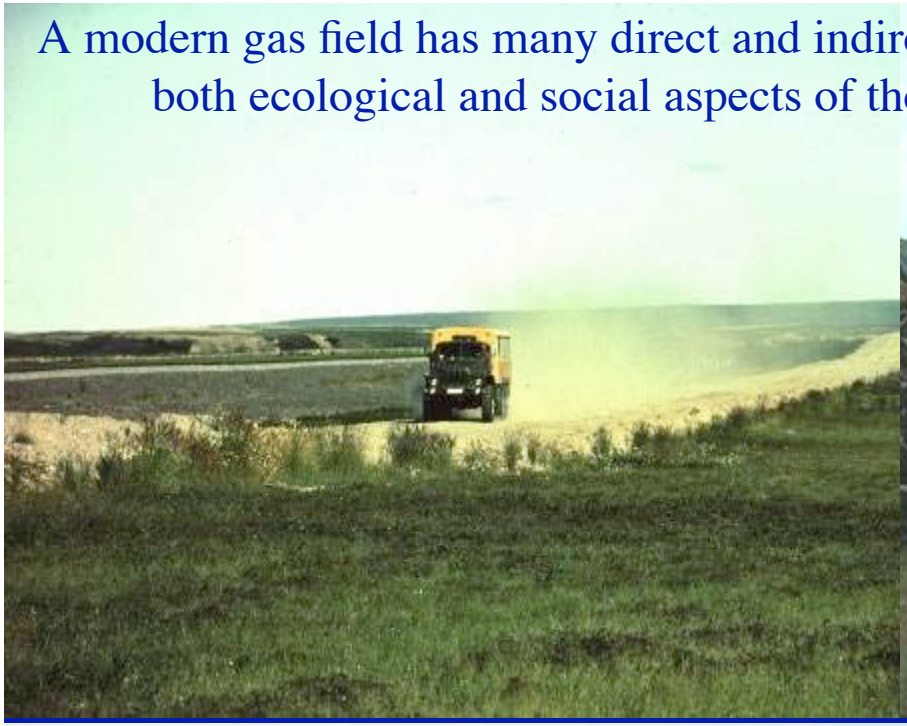


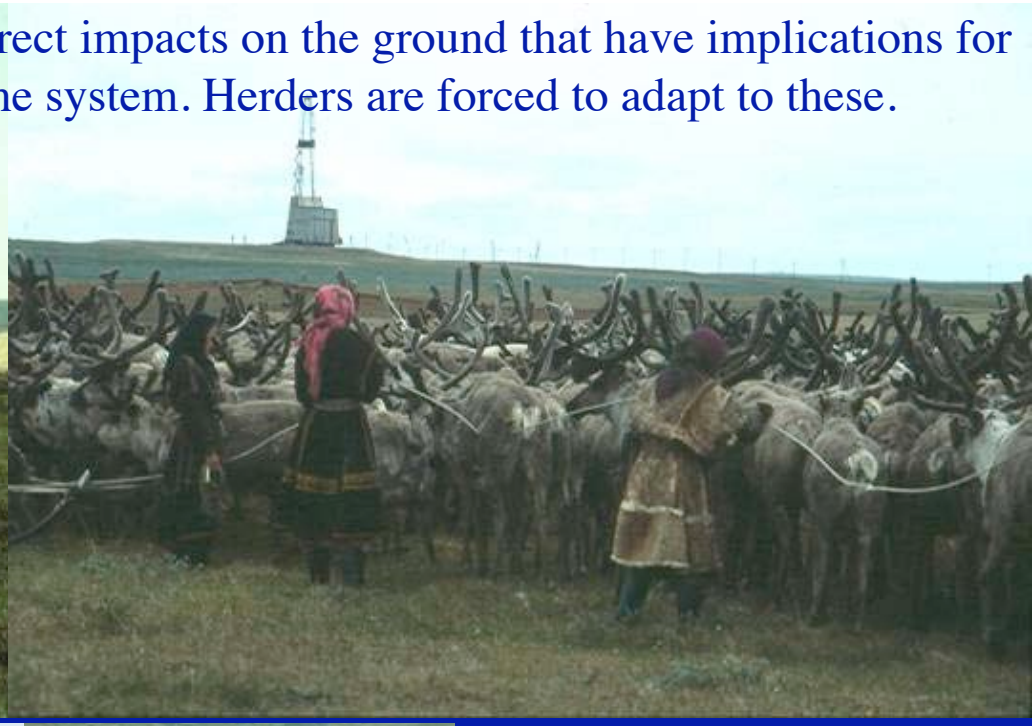


A mixture of private and state owned animals share lands, rivers and lakes that are divided according to different sovkhoz units and migration corridors, none of which are fenced. The territory of Yamal Peninsula seems large, but all available pastures are under seasonal exploitation. Still, the system remains flexible enough to handle many different pressures which arise, such as 'rain-on-snow' or icing events. However, fixed infrastructure - such as new pipelines, roads and railways - and associated pasture and lake/river degradation presents challenges specific to certain migratory '**brigades**'.

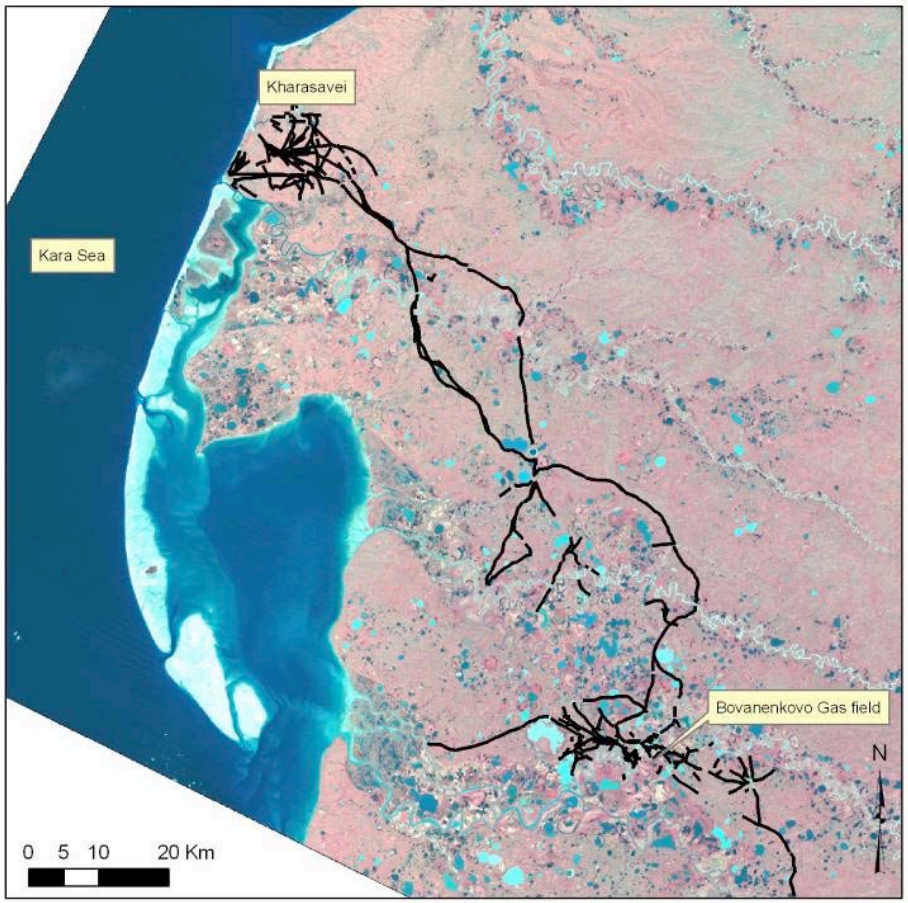
Migration along fixed brigade corridor in summer - herds tend to move onto neighbouring corridors only if there is a serious problem, such as heavily crusted snow in winter

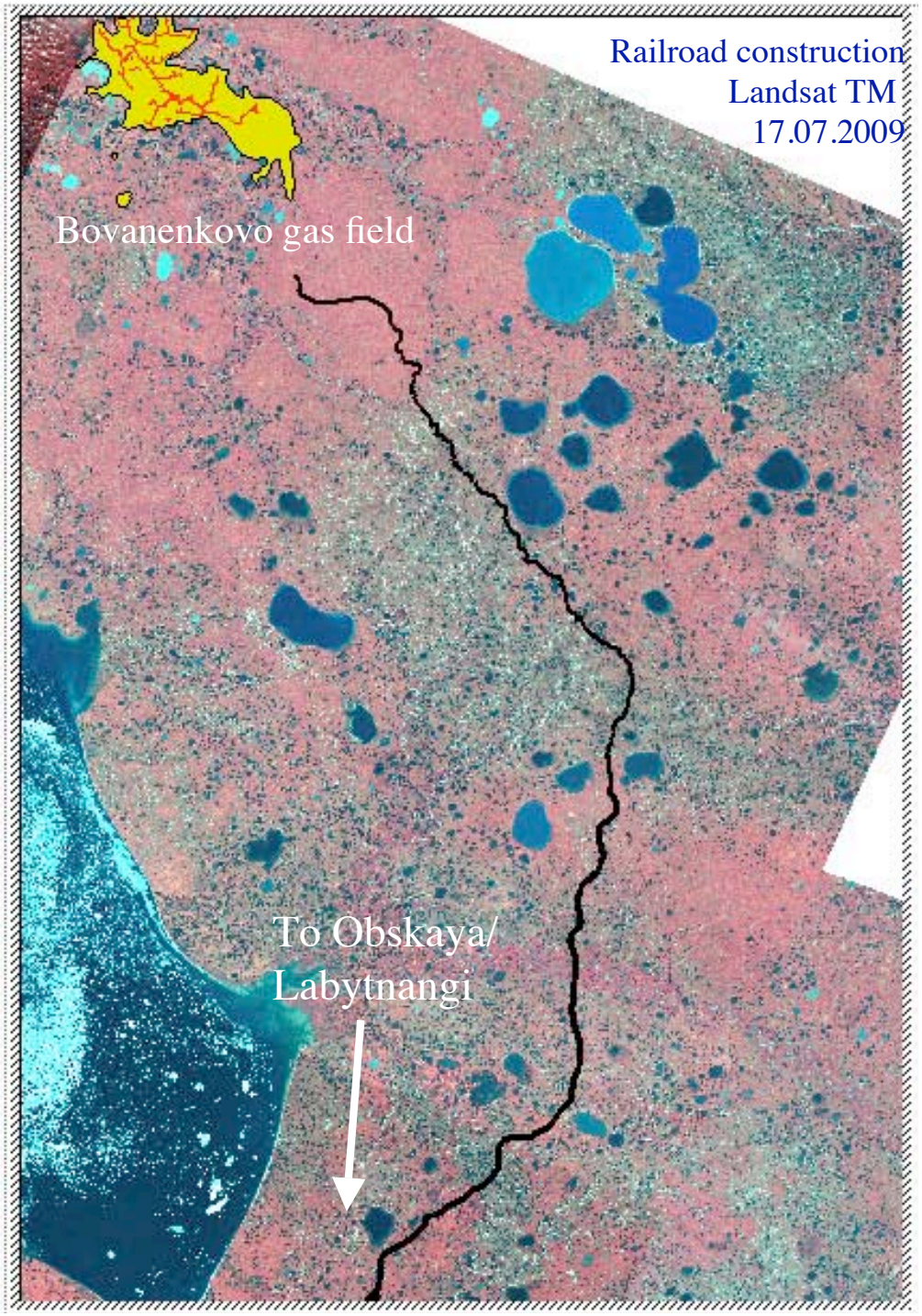
A modern gas field has many direct and indirect impacts on the ground that have implications for both ecological and social aspects of the system. Herders are forced to adapt to these.





Some impacts accumulate in space & time, e.g. vehicle tracks, road dust & hydrological changes. Many comprise essentially permanent additions to the landscape. To date, however, people and animals have adapted remarkably well via a variety of strategies.





Transport networks are expanding rapidly to connect Bovanenkovo gas field to the northwest coast at Kharasavei (via off-road vehicles, above) and to the Ob delta in south (via railway, right). Direct and cumulative impacts are social and ecological. Nenets cite both positive and negative socio-economic impacts and herders are mostly in favor of development.

Exposed saline clay from off-road vehicle traffic

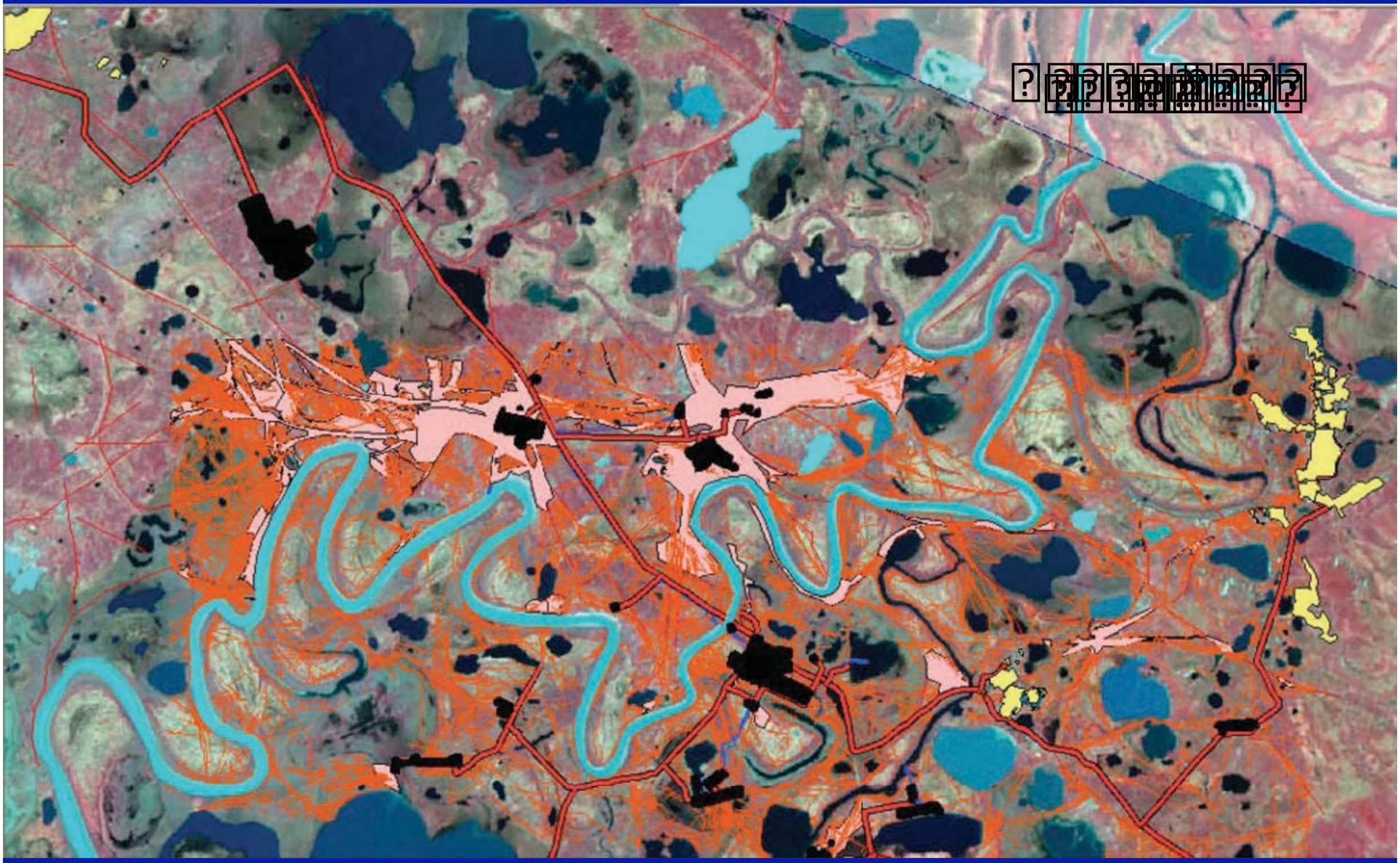
Within active oil & gas fields, time series imagery at different scales is used for change detection, in this case tracking the development of infrastructure and calculating the amount of habitat destroyed or visibly altered.

Thawing permafrost

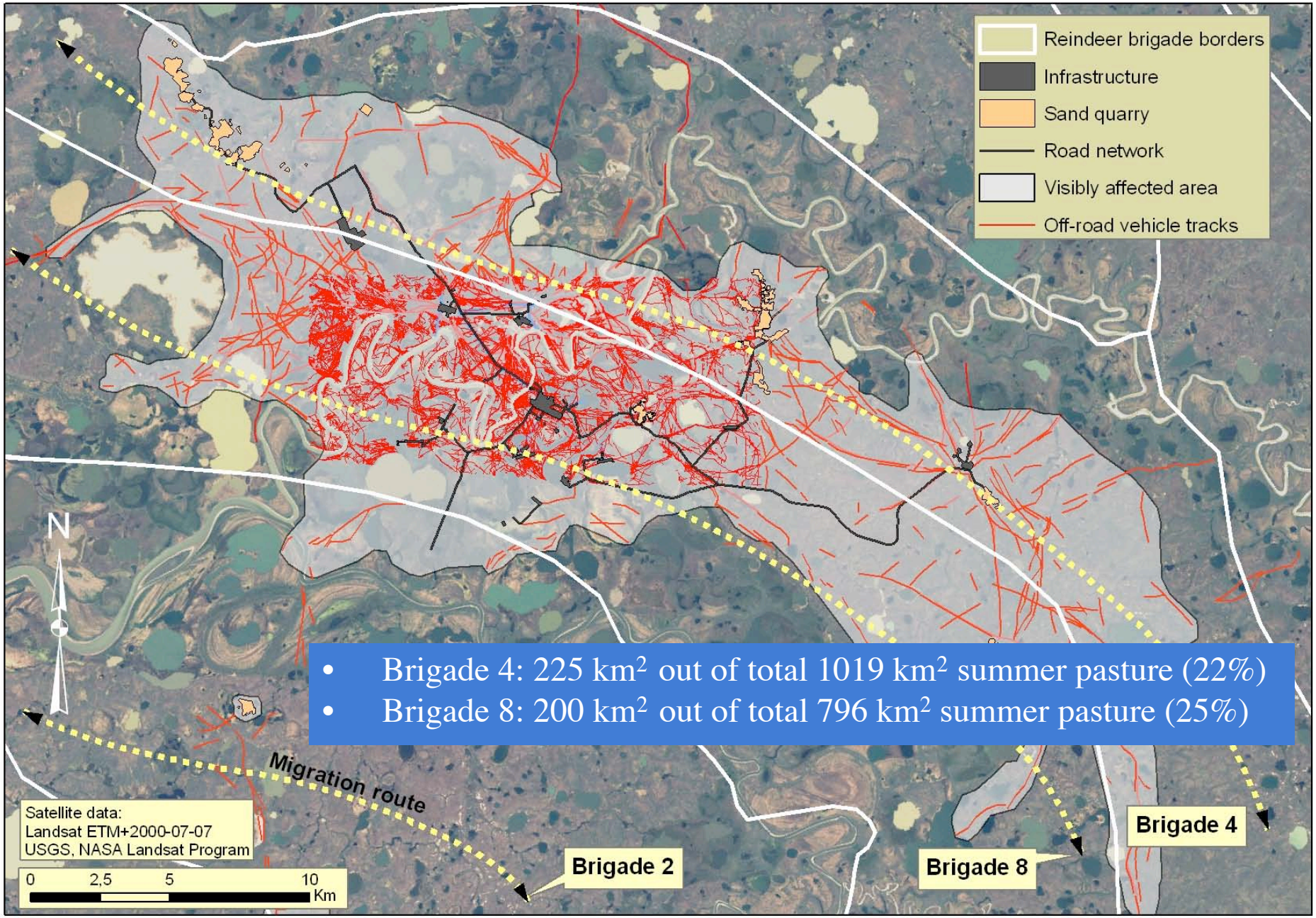
Top: SPOT panchromatic image, 9.0 m resolution, Bovanenkovo gas field Yamal, September 1990

One important trend appears to be the amount of terrain that has switched from shrub-dominated to graminoid-dominated. Mechanical disturbance can lead either to erosion, on sandy substrates, or to highly productive swards on more organic soils.

Right: Quickbird infrared (false colour) image of Bovanenkovo, Yamal, 2.4 m resolution, July 2004

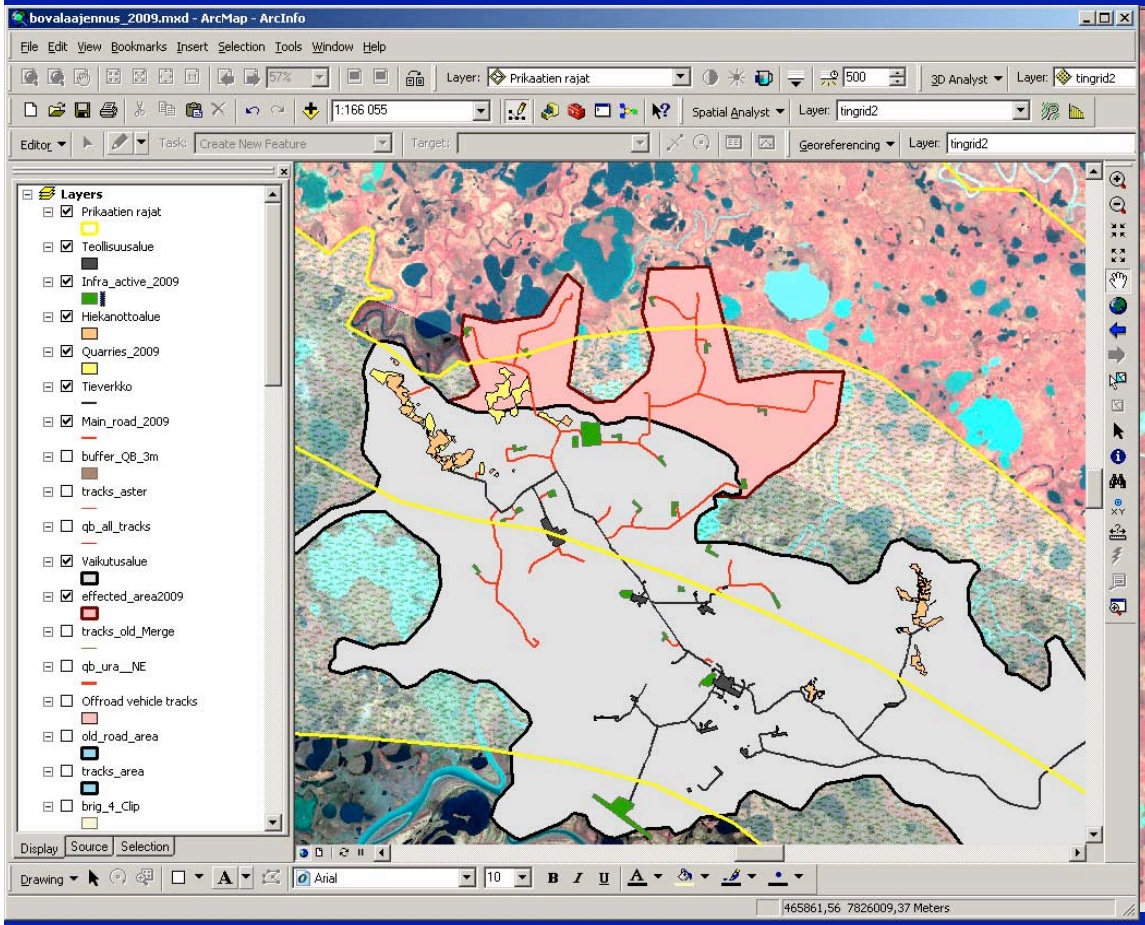


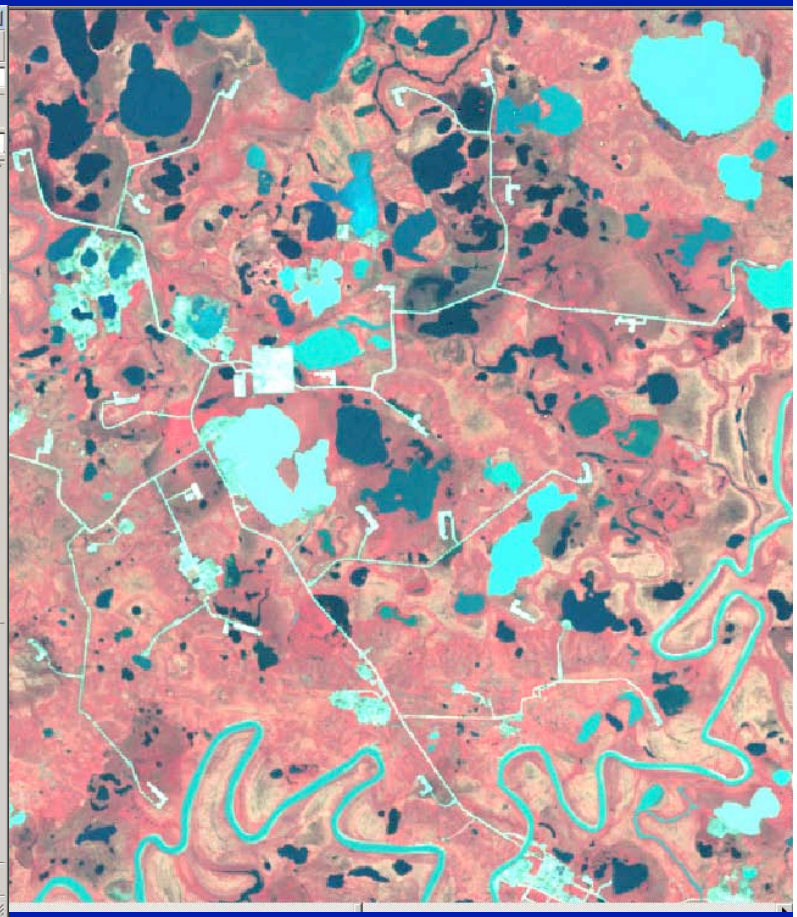
Visible impacts of Bovanenkovo gas field on summer pastures as of 2005



- Brigade 4: 225 km^2 out of total 1019 km^2 summer pasture (22%)
- Brigade 8: 200 km^2 out of total 796 km^2 summer pasture (25%)

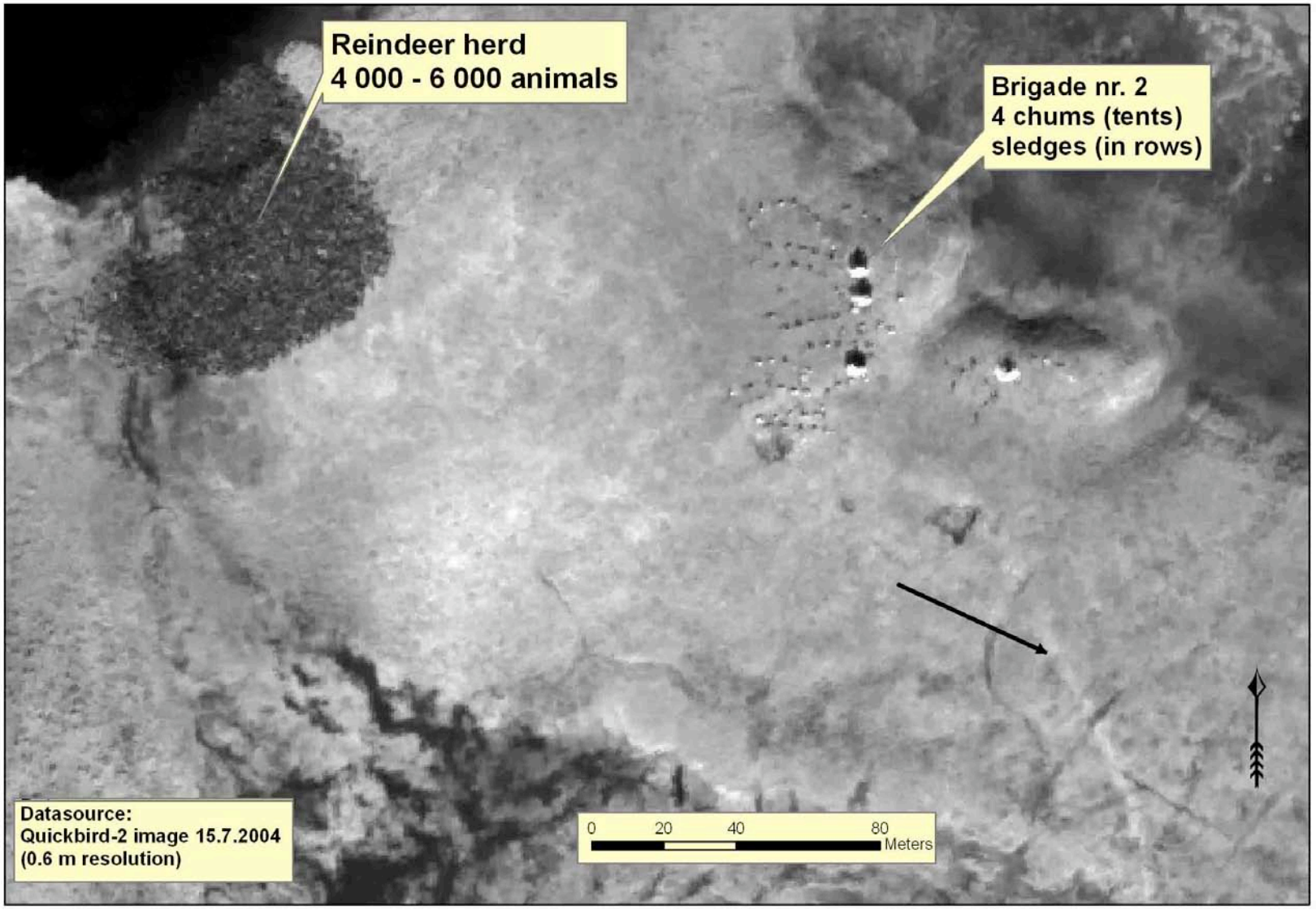
ASTER images (15 m pixel) from the northern portion of Bovanenkovo gas field in 2001 (left) and 2009 (right)



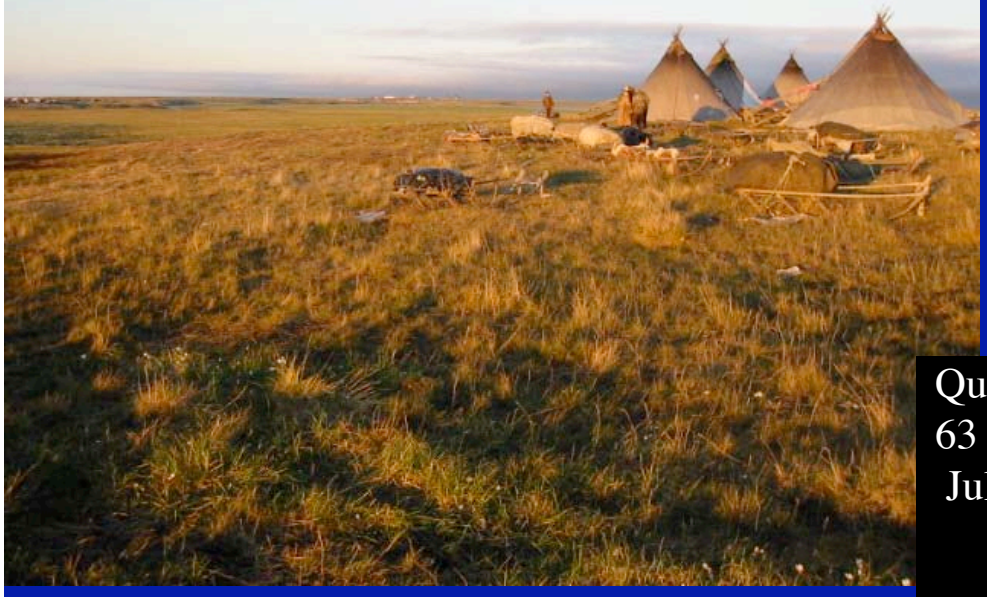


The infrastructure is expanding to the north and east and now overlaps with the summer pastures of brigade 5, which had until recently avoided significant direct impacts on its territory

Very high-resolution imagery (Quickbird-2) aids in discussions of spatial aspects of change as informants were able to recognize virtually all locations on the ground. Social as well as ecological matters raised.

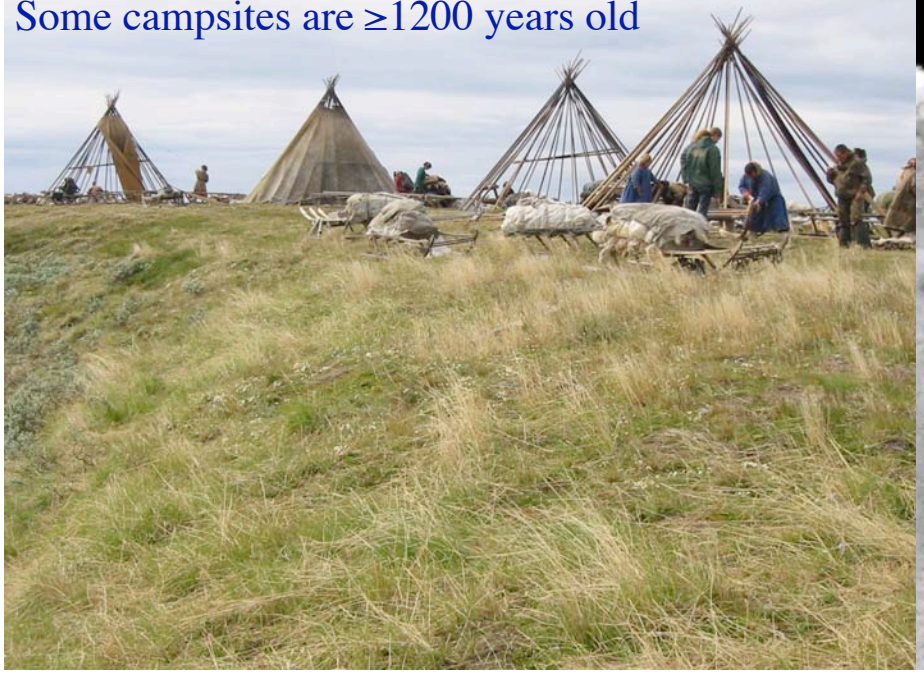


Nenets brigade camps with grassy steppe-like vegetation near Bovanenkovo, Yamal Peninsula



As with the coastal sites in the Canadian Arctic, many Nenets campsites have been occupied seasonally for millennia. The various trends and drivers on land have to be well understood if we are to properly interpret the growing amount of remotely sensed data telling us that the Arctic is 'greening'. Grazing & trampling must be accounted for at local and regional scales.

Some campsites are ≥1200 years old

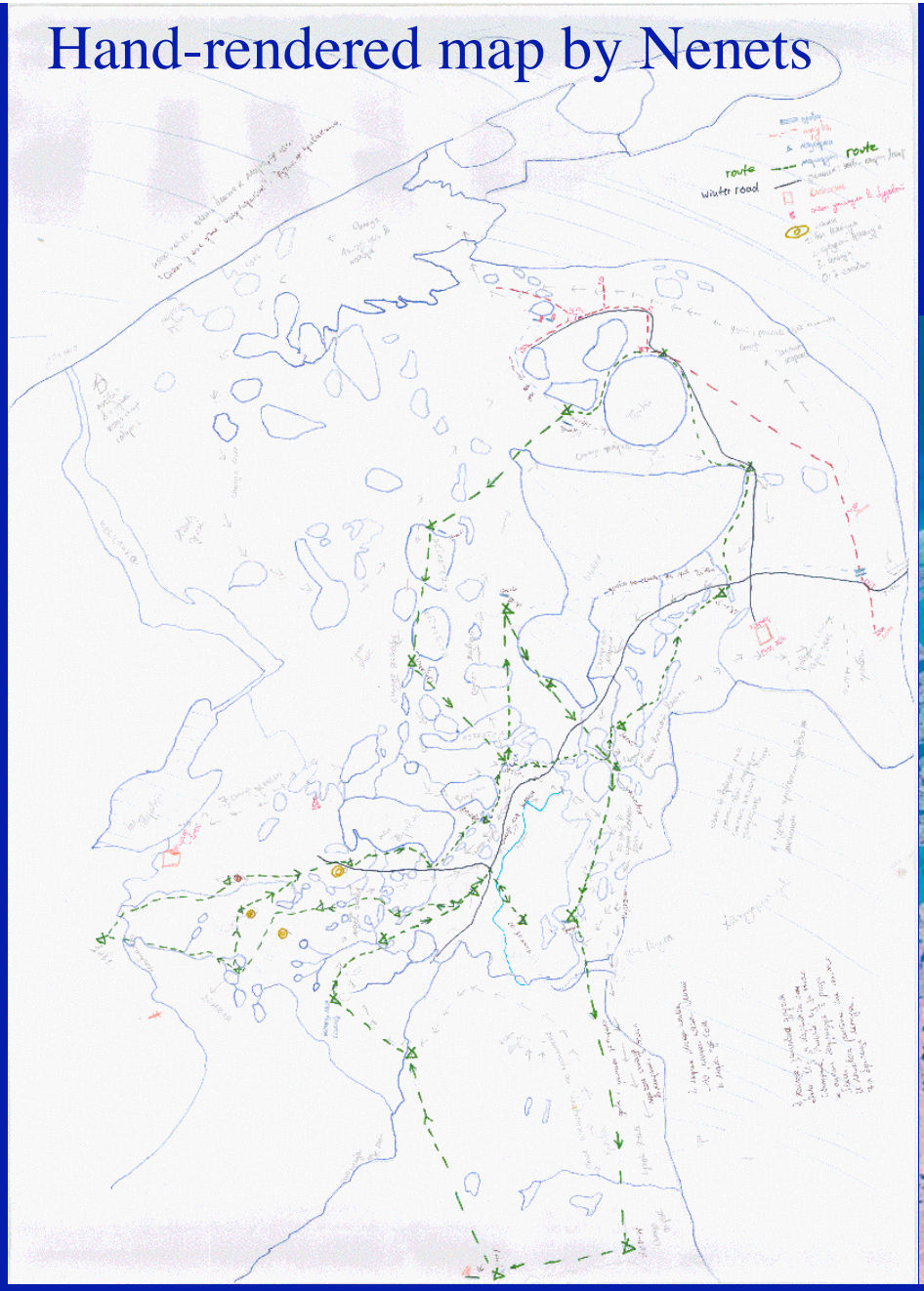


Quickbird B/W image
63 cm pixel size,
July 2004

Reindeer herd clustered together on lake shore

Reindeer sledges and chums, Yarsalinski sovkhoz, northern Yamal Peninsula

Hand-rendered map by Nenets

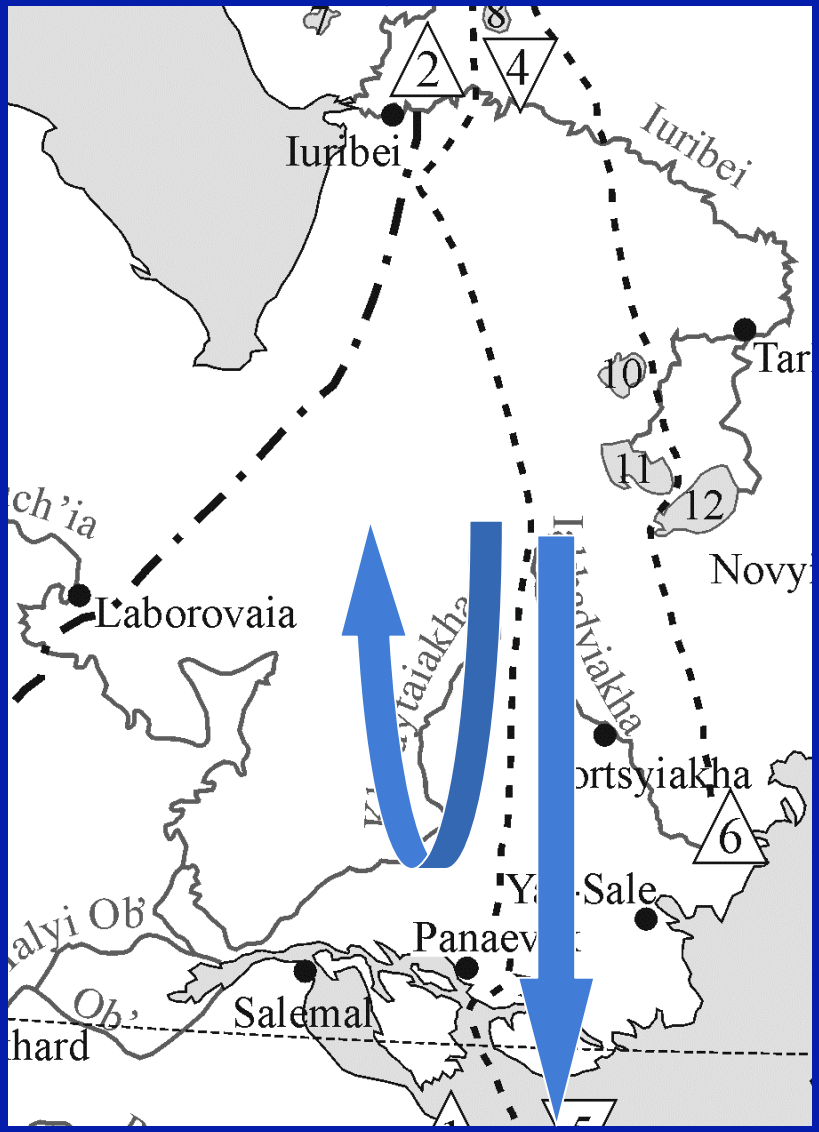


Examples of maps co-produced with reindeer herders in 2006. Herders migrate through active oil fields and discuss positive & negative aspects of development in real time. This step is necessary to understand patterns detected by satellite imagery, as well many not detected.

Annotated Landsat image

Neighboring migratory units face very different futures based on development plans

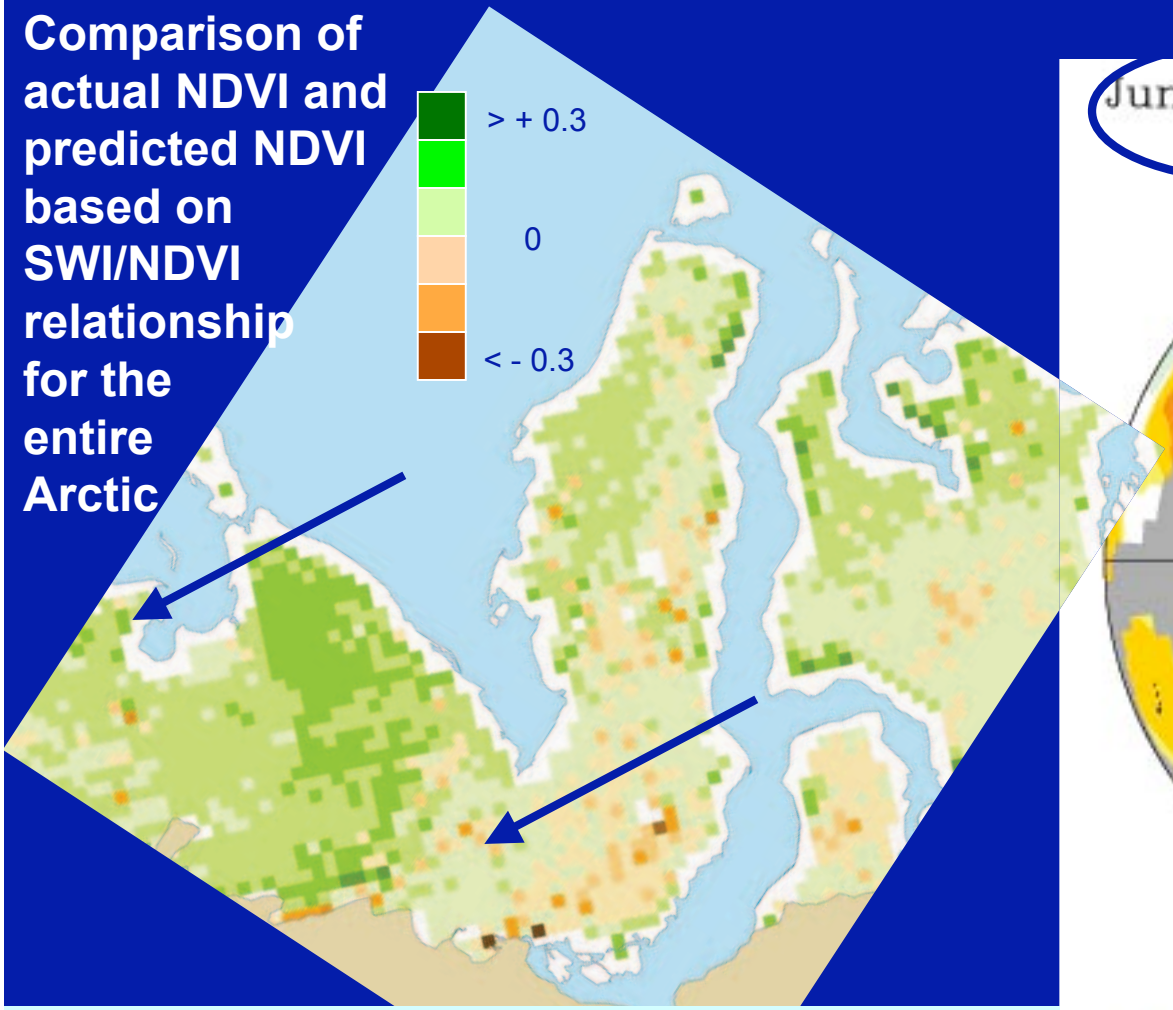
Another factor is warmer winters, with an increase in the frequency and severity of 'rain-on-snow' events as detected by QuikSCAT (Bartsch et al. *Ecological Applications*, in press)



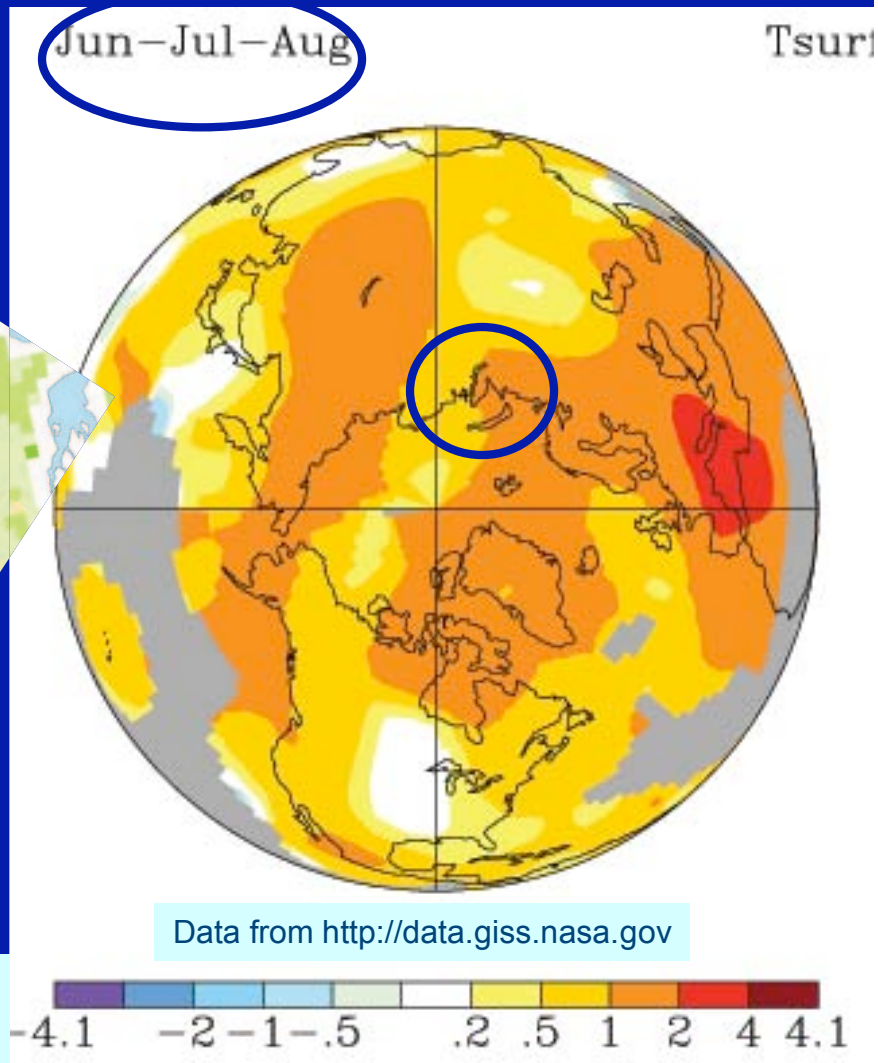
The relatively free use of space according to herders' own needs is a critical factor at present. However, if too much oil & gas infrastructure encroaches on their migration routes, this adaptive capacity will be greatly reduced. Responses so far appear dynamic and non-linear. Mid-winter events used to be extremely rare.

Much of the Russian Arctic is warming during the growing season, but it is not warming evenly. Deciduous shrub growth is increasing (Forbes et al. 2009, *Global Change Biology*), but the increase is greater in the Nenets Autonomous Okrug than on southern Yamal. Our analysis in process indicates that this is likely to be due to differences in substrates, in particular organic content (Forbes et al. unpublished).

Comparison of actual NDVI and predicted NDVI based on SWI/NDVI relationship for the entire Arctic



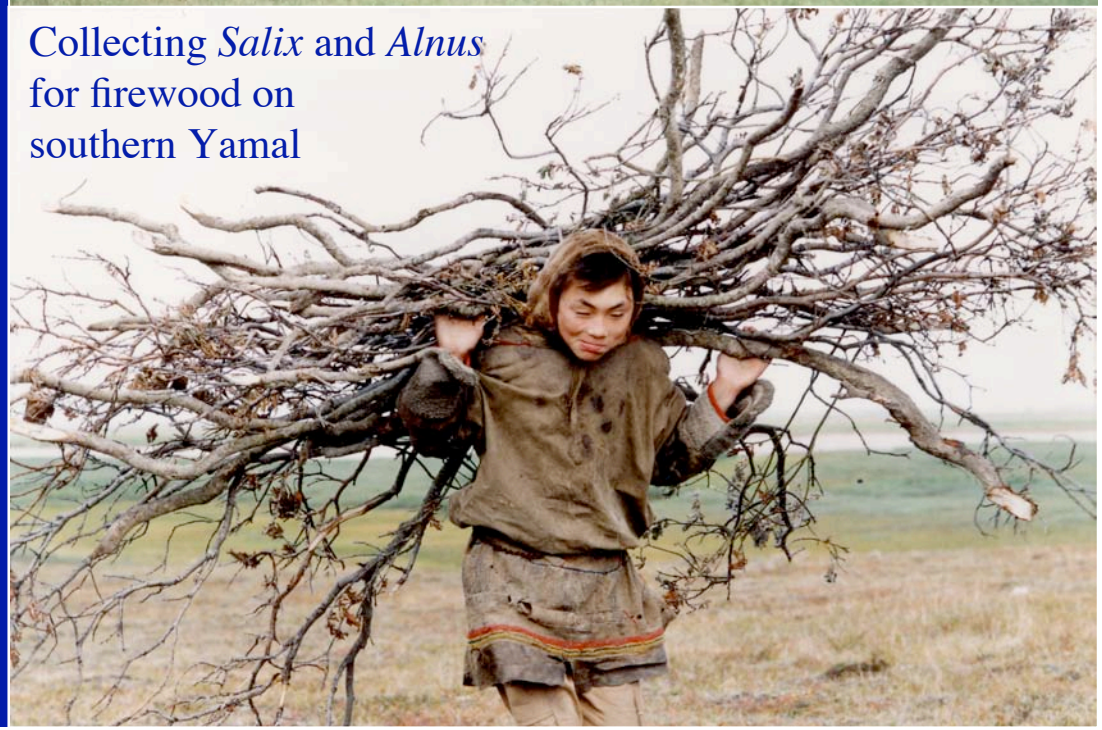
Areas with less NDVI than expected are brown, areas with more NDVI than expected are green (Raynolds et al. 2008).



Data from http://data.giss.nasa.gov

The growth trend agrees with qualitative observations by nomadic Nenets reindeer herders of increases in shrub size in the region

Stems from *Salix lanata*, Nenets Okrug



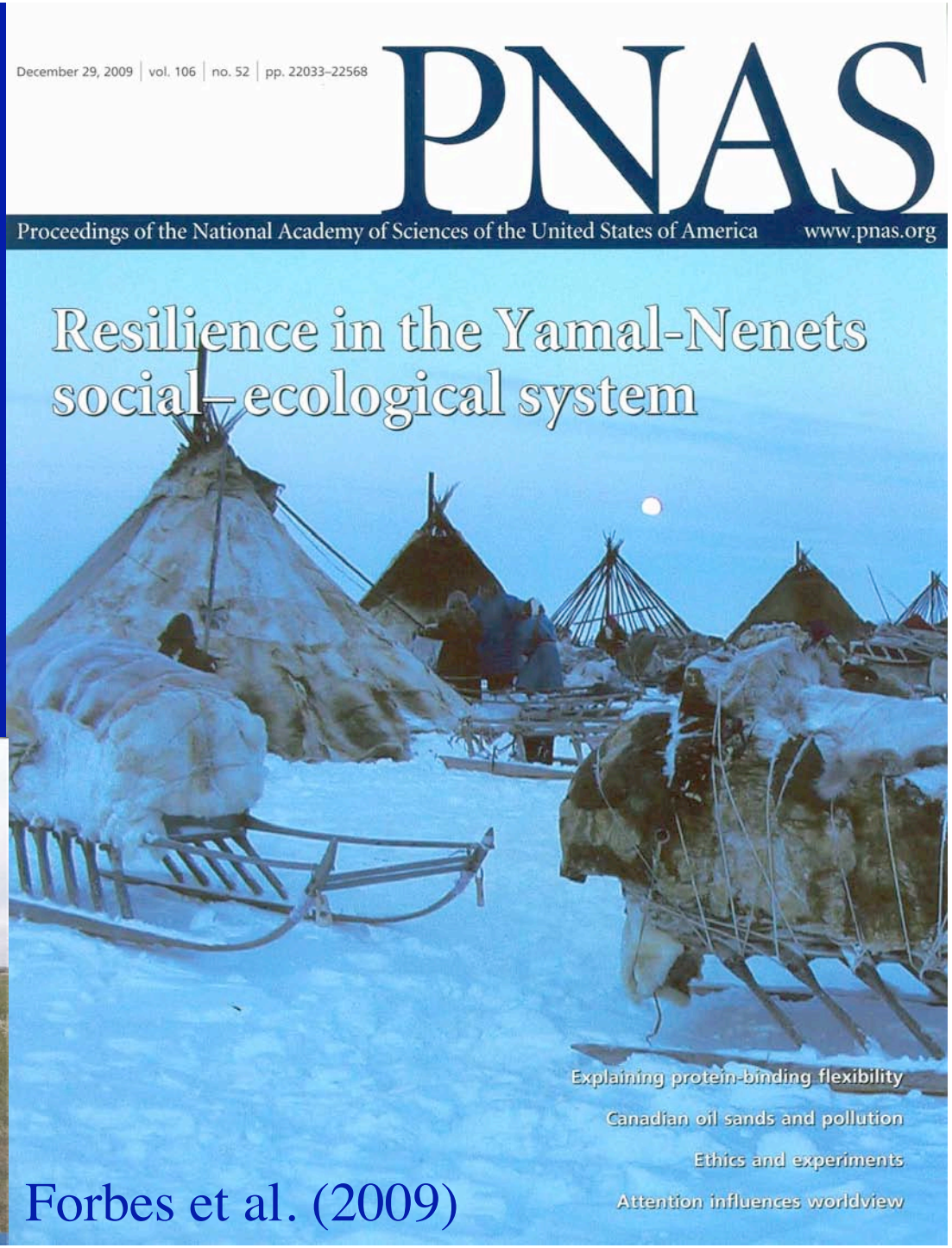
Collecting *Salix* and *Alnus* for firewood on southern Yamal

Two more aspects of a warmer climate are: (1) earlier thawing of rivers in spring, and (2) later freeze-up autumn. Crossing the Seyakha River in the Bovanenkovo Gas Field, July 2005, about 2 weeks earlier than average. People and animals must migrate faster!

Many, but not all, of these trends and responses for Yamal were synthesized in a recent paper appearing in the Sustainability Science section of *PNAS*.

Nenets themselves see oil & gas development as a greater threat than climate change, but feel they can mutually coexist as long as industry keeps to its agreements that exist on paper

Stammler et al. (2009)



Forbes et al. (2009)

Conclusions

- The patterns and processes of changes in sea ice, land use and land cover relevant to human dimensions are variable across the Arctic
- In North America, sea ice reduction has profound impacts on some aspects of human access to marine mammals, yet polynyas and ecological 'hot spots' remain remarkably consistent across millennia
- In the circumpolar North, sustained retreat of sea ice has profound implications for air temps and vegetation cover in tundra regions
- Increases in deciduous shrubs are pronounced for the western portion of the Russian Arctic and clearly linked to observed trend in NDVI
- The Yamal-Nenets social ecological system has successfully reorganized in response to recent shocks: anthropogenic fragmentation of a large proportion of the environment, socio-economic upheaval, and pronounced warming in summer and winter
- Institutional constraints and cultural factors and drivers were clearly as important as the documented ecological changes, so even the highest resolution satellite imagery only gets us so far
- Particularly crucial to success is the unfettered movement of people and animals in space and time. Future institutional arrangements must specifically target mutual coexistence and make use of latest data.

http://www.geobotany.uaf.edu/yamal/