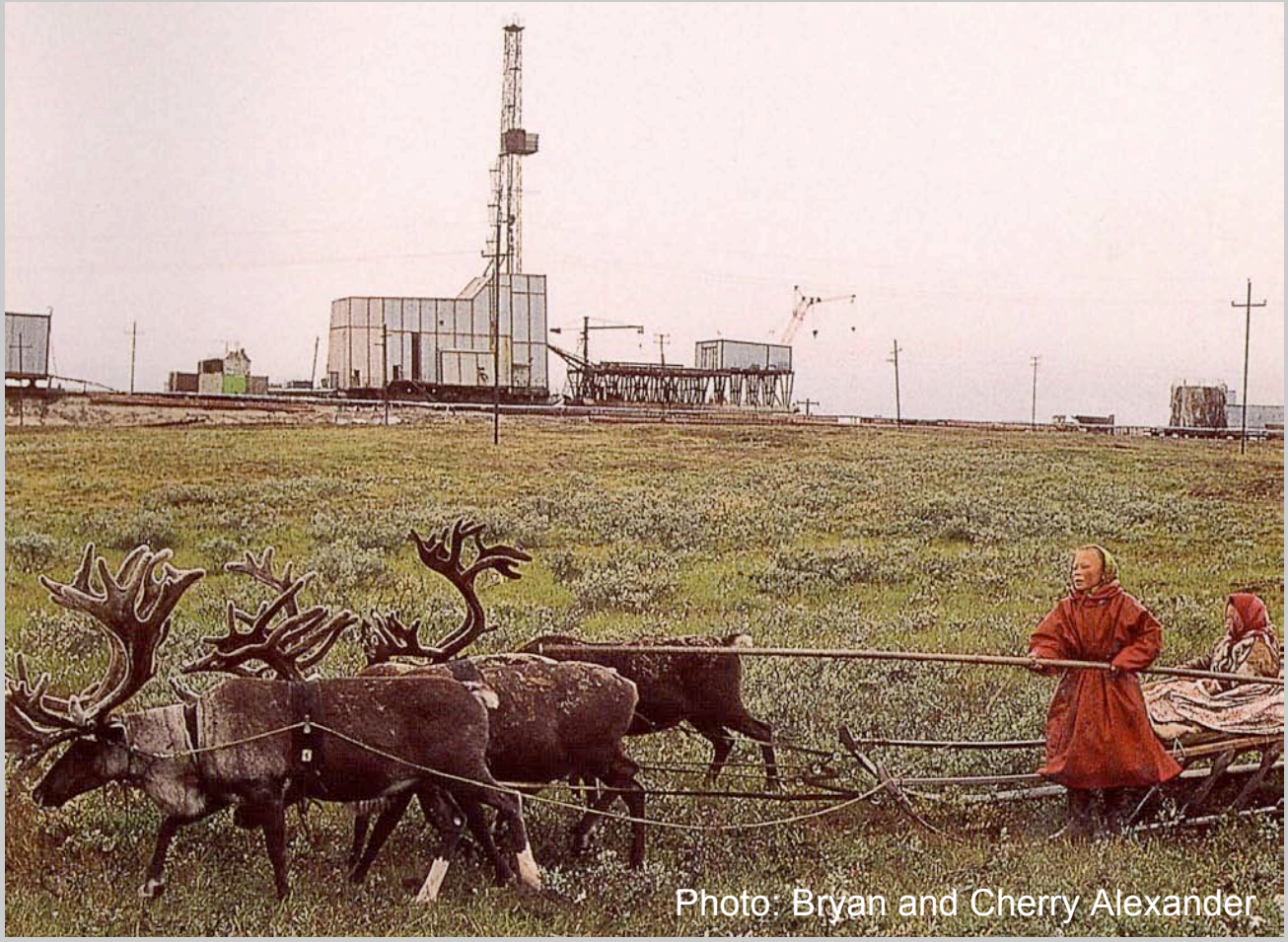
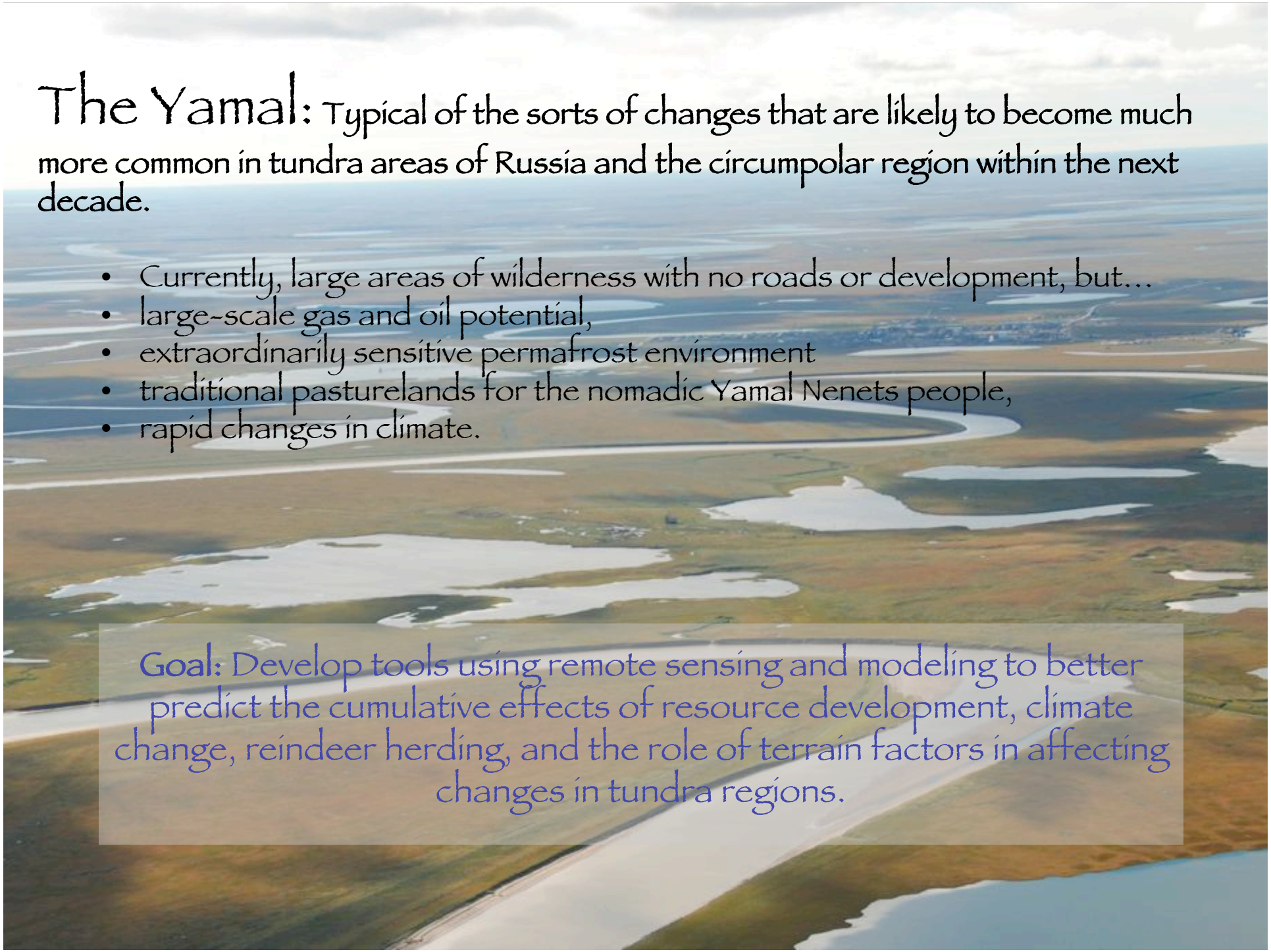
Cumulative effects of resource development, reindeer herding, and climate change on the Yamal Peninsula, Russia



D. A. (Skip) Walker, University of Alaska Fairbanks,
and many colleagues

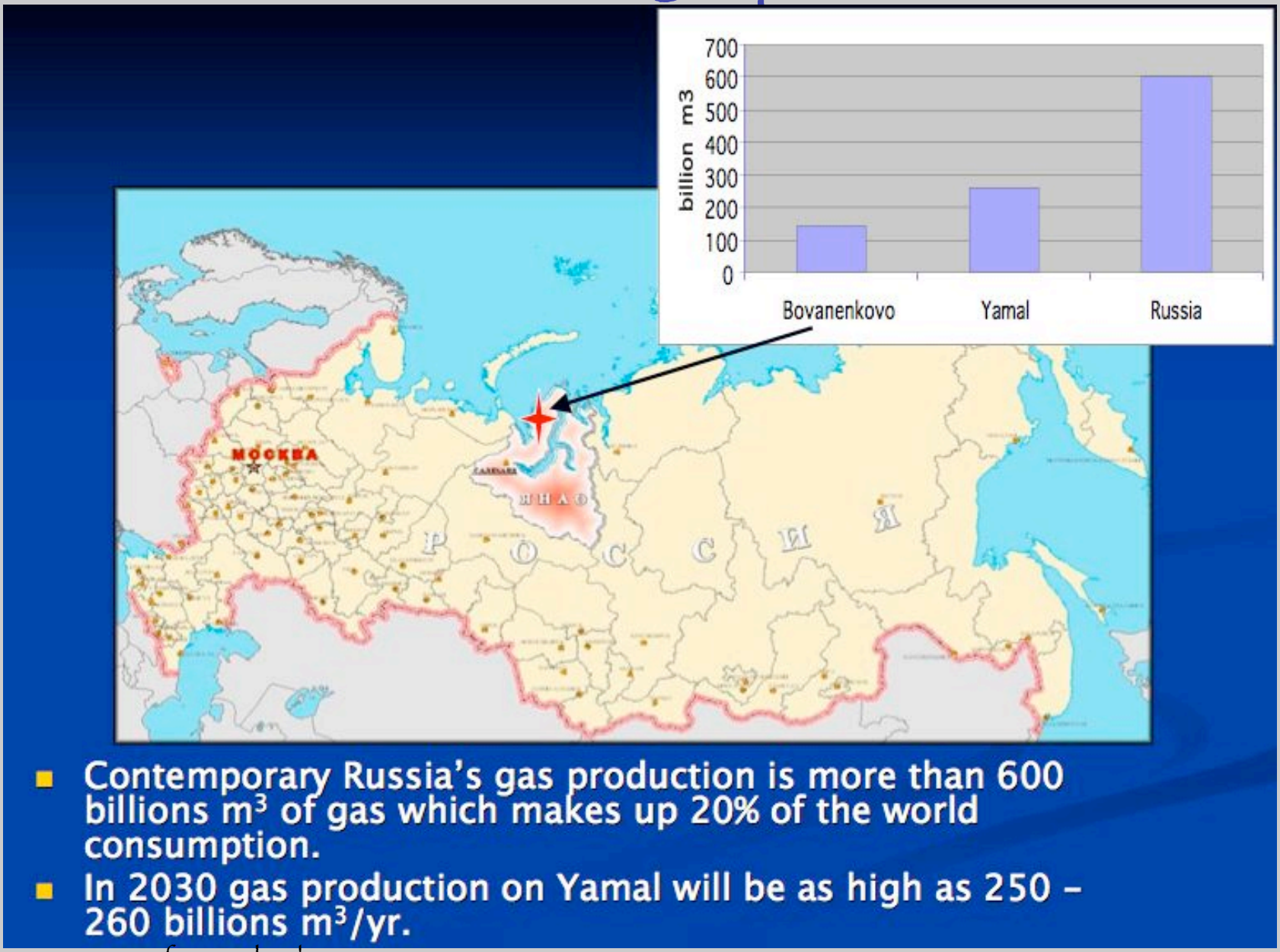


The Yamal: Typical of the sorts of changes that are likely to become much more common in tundra areas of Russia and the circumpolar region within the next decade.

- Currently, large areas of wilderness with no roads or development, but…
- large-scale gas and oil potential,
- extraordinarily sensitive permafrost environment
- traditional pasturelands for the nomadic Yamal Nenets people,
- rapid changes in climate.

Goal: Develop tools using remote sensing and modeling to better predict the cumulative effects of resource development, climate change, reindeer herding, and the role of terrain factors in affecting changes in tundra regions.

Yamal: Center of future gas production in Russia



- Contemporary Russia's gas production is more than 600 billions m^3 of gas which makes up 20% of the world consumption.
- In 2030 gas production on Yamal will be as high as 250 – 260 billions m^3/yr.

Courtesy of A. Gubarkov

Existing and designed pipelines

- "Gazprom" has accepted the Yamal hydrocarbons transportation scheme of main pipeline across the Baidarata Bay of the Kara Sea. Four pipelines will transport 50–60 billions m³ of gas each.

Courtesy of A. Gubarkov

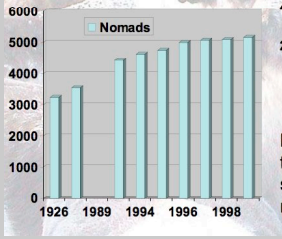
The Nenets people and their reindeer

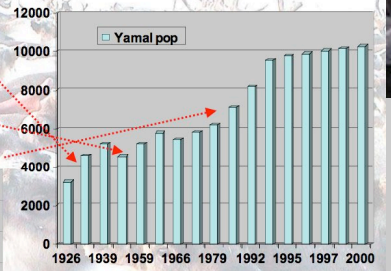
Increase of humans on Yamal

Euro-Nentsy escape to Yamal, early 1930s,

'Dekulakization' and prosecution of shamans under Stalin

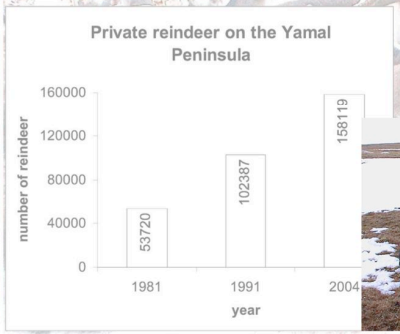
Steady growth after sovkhoz system stabilised





Before 1926: no permanent settlements on the Peninsula. Today: Half of Nentsy settled, plus another 5000 non-indigenous residents

Increase of private reindeer



Where do all these animals graze???

Florian Stammler: Yamal LCLUC Workshop, Moscow, 28-30 Jan 2008.

Terrain factors that make the Yamal region so sensitive to terrain disturbance

Sandy nutrient poor soils:

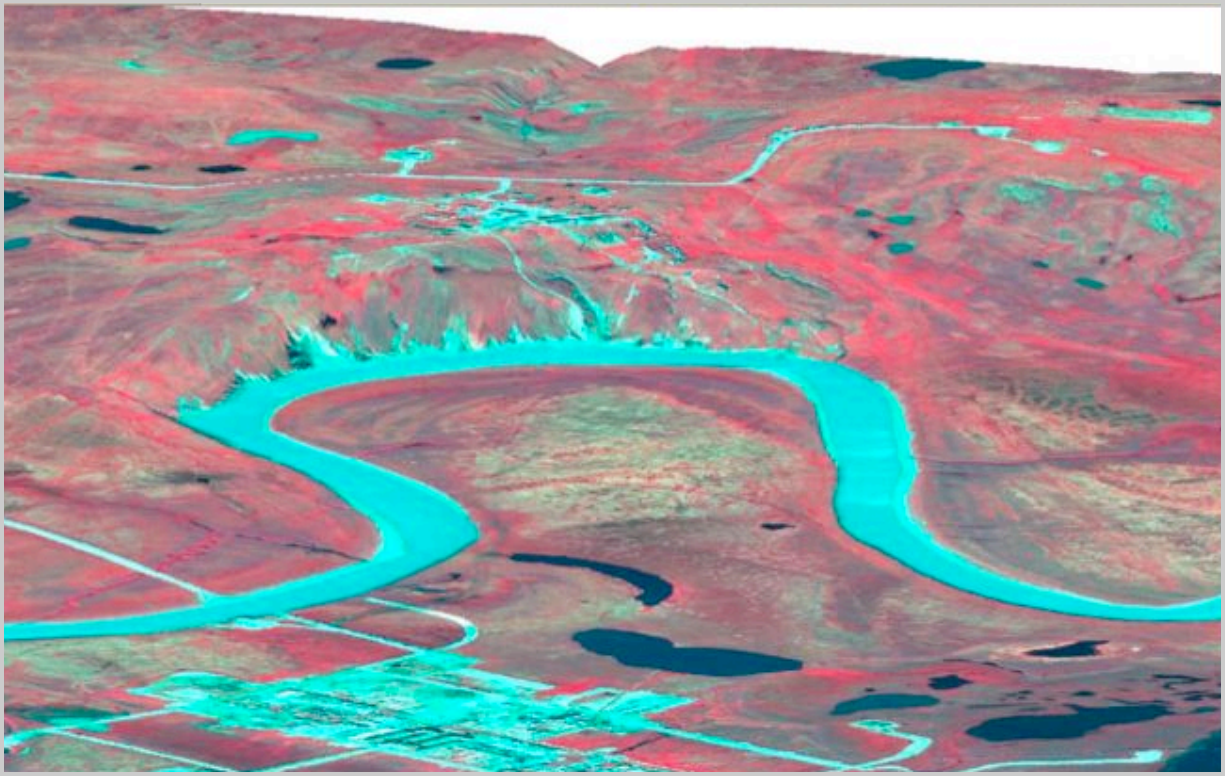
- Highly susceptible to wind erosion.
- Poor plant production, low plant diversity, slow recovery.

T. Kumpula: Yamal LCLUC Workshop, Moscow, 28-30 Jan 2008.

Extreme ground-ice conditions:

- Extreme ice-rich permafrost makes the region very susceptible to thermal erosion and landslides.

Effects of resource extraction:



- Use of remote sensing and GIS to inventory direct and indirect effects of the Bovanenkovo Gas Field.

T. Kumpula: Yamal LCLUC Workshop, Moscow, 28-30 Jan 2008.

Detectability of impacts with different sensors

- Quickbird best available sensor for most gas field impacts.
- Better than ground surveys for detecting off-road vehicle trails.

Detectivity / Impact	Field survey	Quickbird-2 Panchromatic	Quickbird-2 Multispectral	ASTER TERRA VNIR	Landsat TM	Landsat MSS
Soil contamination, oil & chemicals	x	–	–	–	–	–
Removal of top soil and vegetation	xxx	xxx	xxx	xx	x	x
Quarries	xxx	xxx	xxx	xxx	xx	x
Garbage						
- metal	xx	–	–	–	–	–
- glass	x	–	–	–	–	–
- concrete	xxx	x	x	–	–	–
- wood	xxx	x	–	–	–	–
Pipelines	xxx	xx	x	–	–	–
Powerlines	xxx	xx	x	–	–	–
Roads	xxx	xxx	xxx	xxx	x	x
Offroad tracks	xx	xxx	xx	xx	x	x
Winter roads	xx	xx	xx	xx	x	–
Drill towers	xxx	xxx	xx	x	–	–
Barracks	xxx	xxx	xx	x	–	–
Trucks/Vehicles	xxx	xx	x	–	–	–
Changes in hydrology	xxx	xxx	xx	xx	x	x

T. Kumpula: Yamal LCLUC Workshop, Moscow, 28-30 Jan 2008.

GIS and remote sensing approach to catalog impacts

Bovanenko gas field

Petroleum exploration related activity

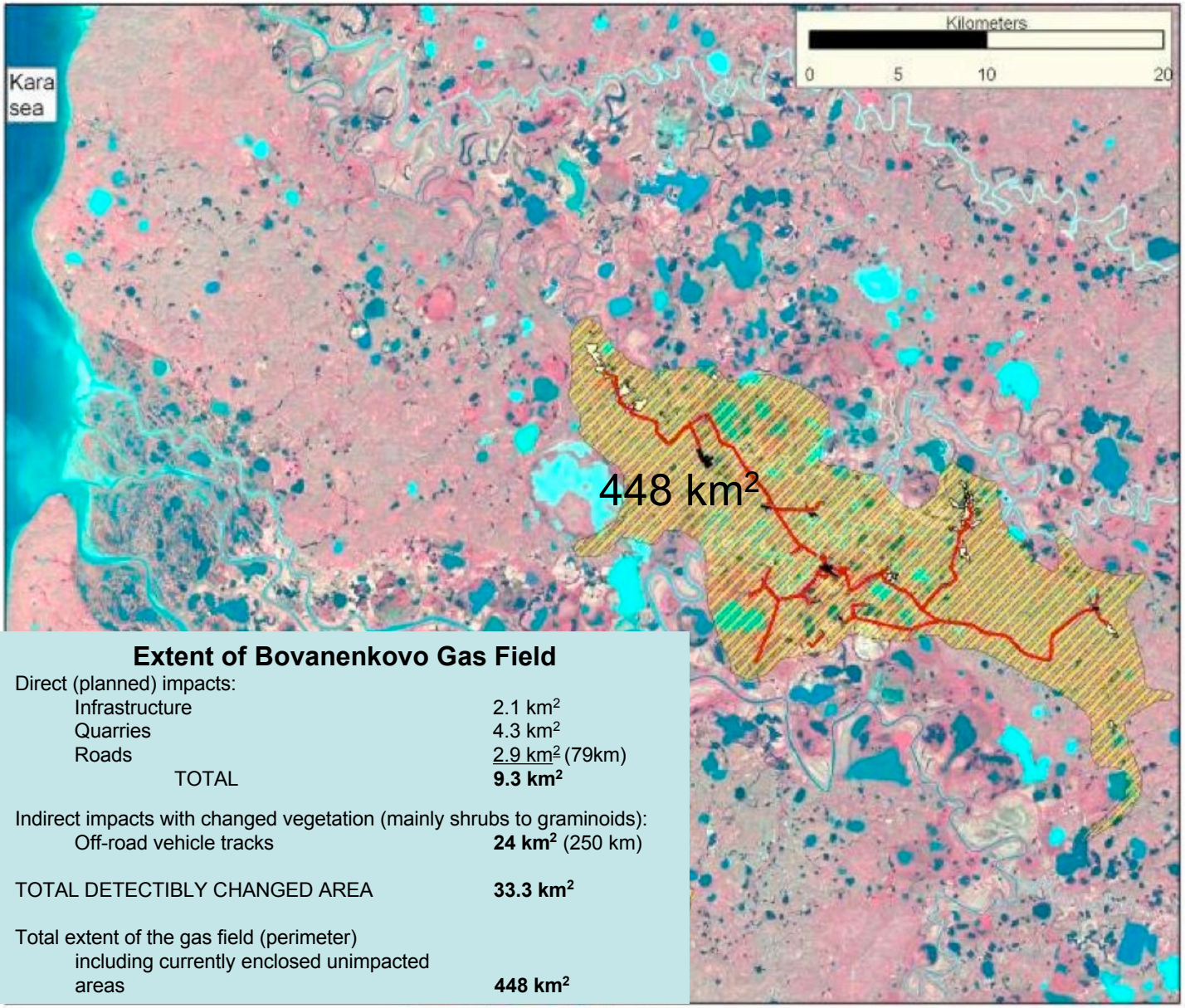
- Main road network
- Zone of effected area
- Sand quarries
- Active infrastructure

GIS database collection

- **Visual interpretation of impacts**
- **Develop digital elevation model from 1:100,000 maps**
- **Digitize boundaries**
  - **Roads**
  - **Pipeline network**
  - **Off-road vehicle trails**
  - **Infrastructure**
  - **Quarries**

Digitized from:
Quickbird-2 image 15.7.2004 (2.4 m resolution)
Aster Terra VNIR image 21.7.2001 (15 m resolution)

Background image:
Landsat TM 07.08.1988



Extent of Bovanenkovo Gas Field

Direct (planned) impacts:	
Infrastructure	2.1 km²
Quarries	4.3 km²
Roads	2.9 km² (79km)
TOTAL	**9.3 km²**
Indirect impacts with changed vegetation (mainly shrubs to graminoids):	
Off-road vehicle tracks	**24 km²** (250 km)
TOTAL DETECTIBLY CHANGED AREA	**33.3 km²**
Total extent of the gas field (perimeter) including currently enclosed unimpacted areas	**448 km²**

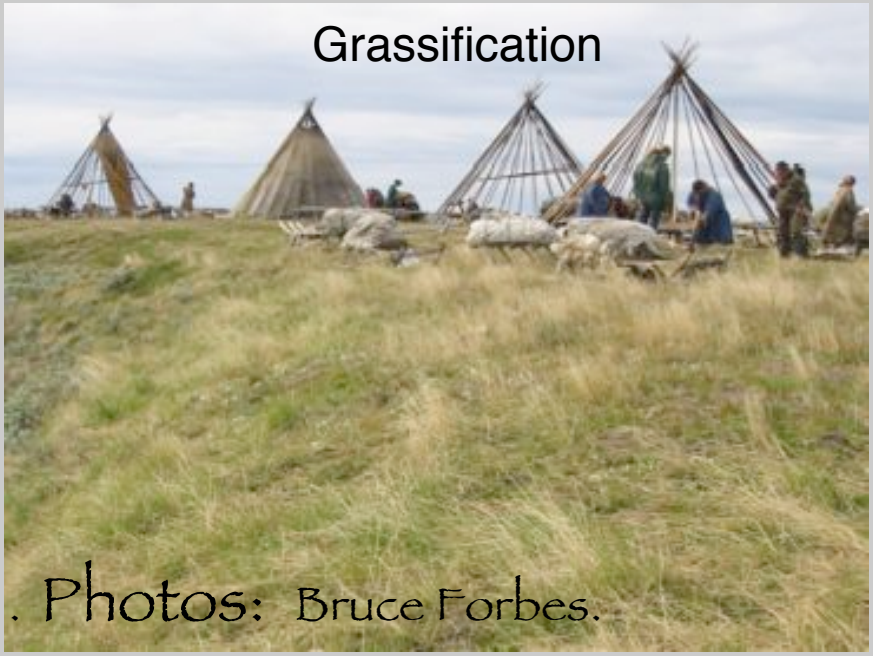
T. Kumpula: Yamal LCLUC Workshop, Moscow, 28-30 Jan 2008.

Effects of reindeer herding

Overgrazing

Trampling

Grassification



. Photos: Bruce Forbes.

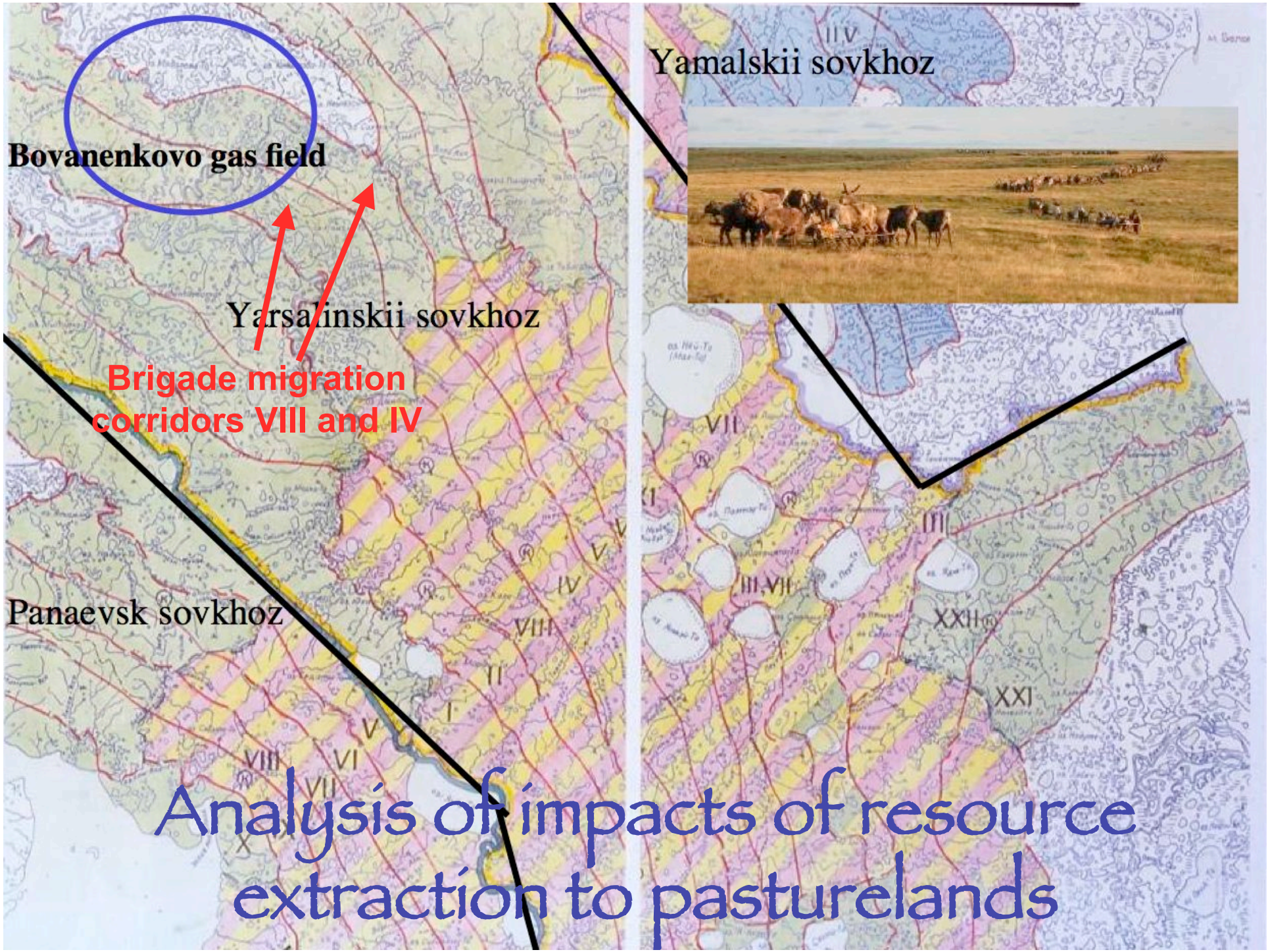
Wind erosion

Working with sociologists:

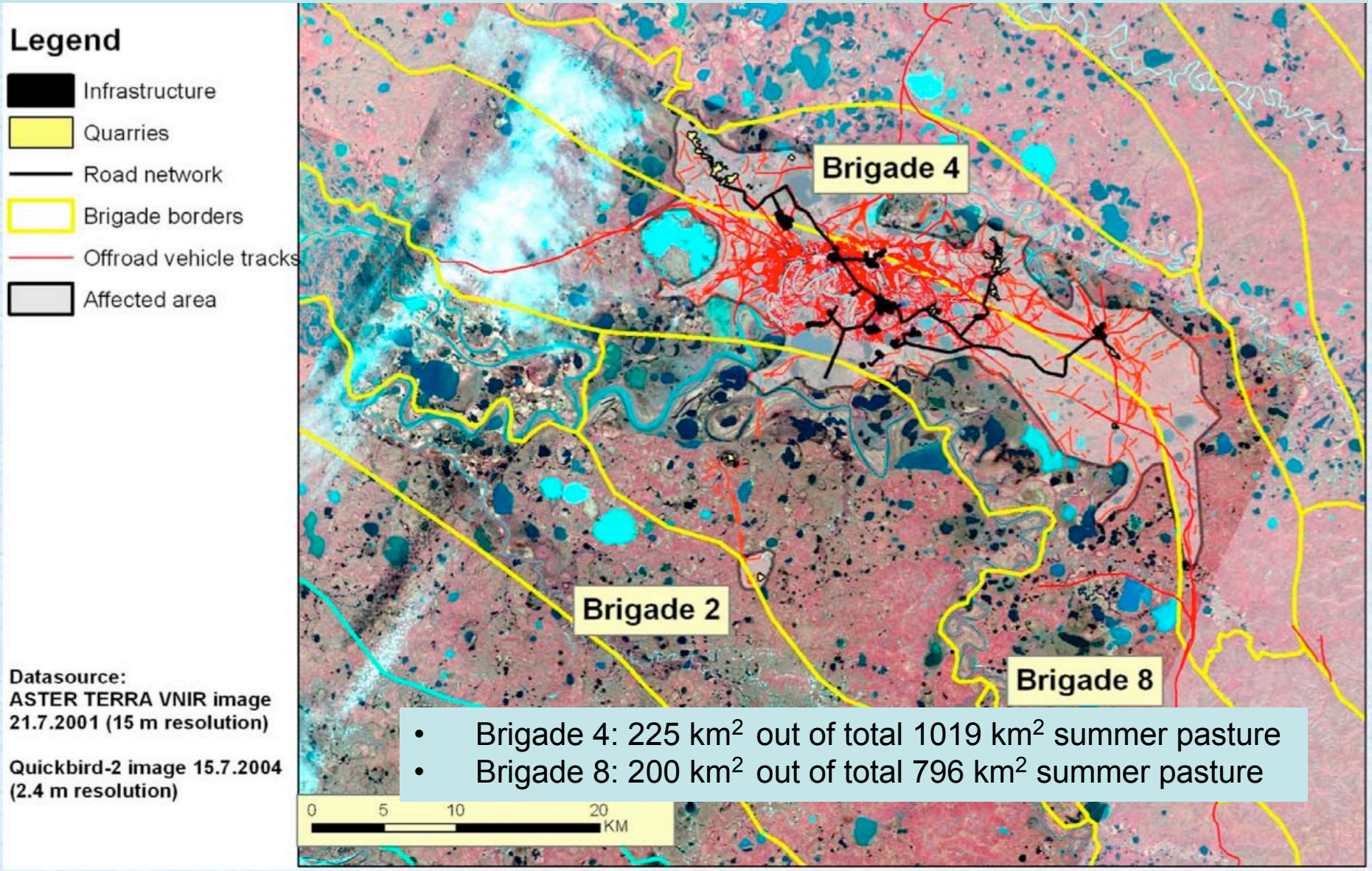
Combining remote sensing and traditional knowledge

Florian Stammler interviewing members of Nenets brigade.

Photo: Bruce Forbes


Bovanenkovo gas field
Yarsalinskii sovkhoz
Brigade migration corridors VIII and IV
Panaevsk sovkhoz
Yamalskii sovkhoz
Analysis of impacts of resource extraction to pasturelands

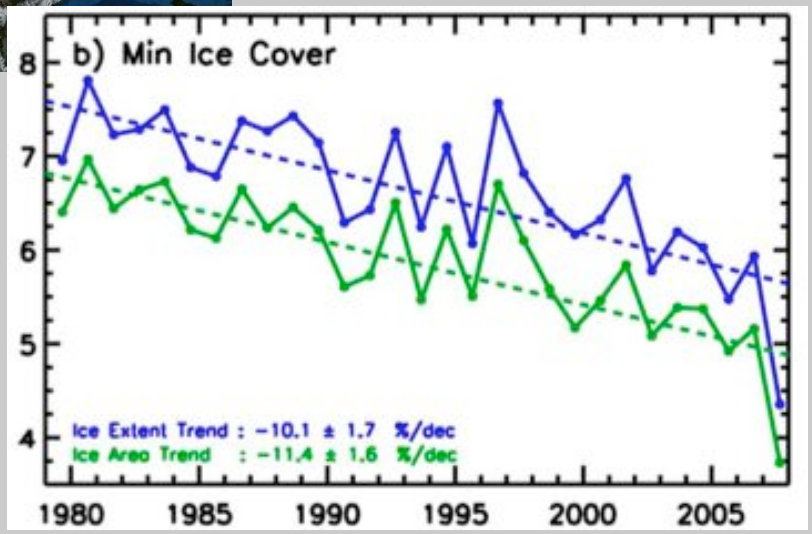
Impacts of Bovanenkovo gas field to summer pasture of Brigades 4 and 8



Effects of climate change:
Analysis of sea-ice, land surface temperature and NDVI trends

Is the trend in sea-ice affecting Arctic vegetation ?

Since 1980, perennial sea ice extent in the Arctic has declined at the rate of 10.1% per decade.

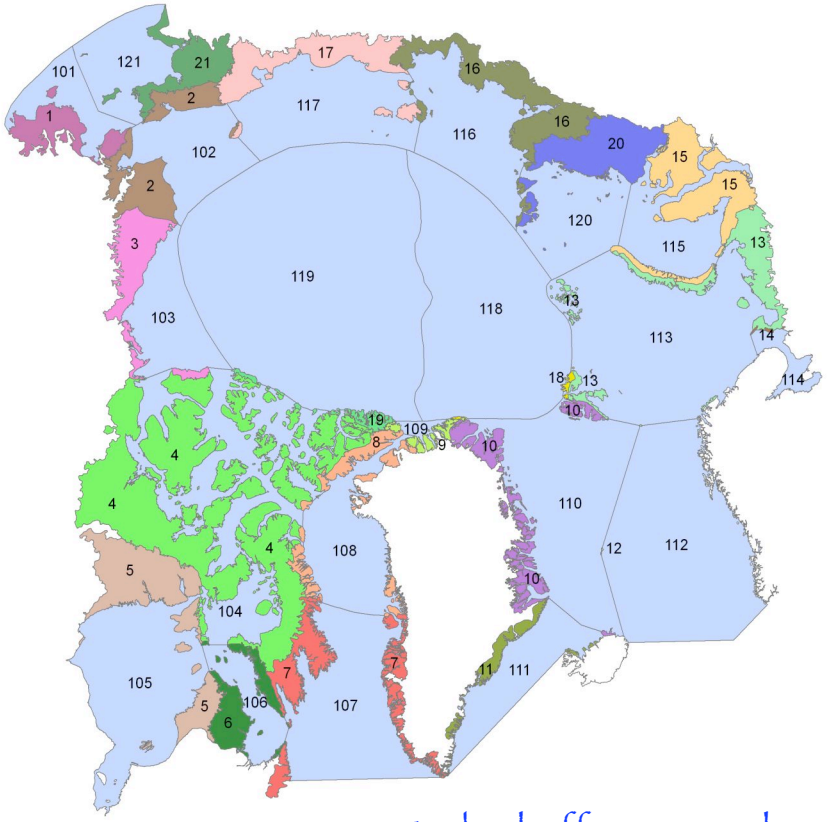


Comiso et al.: 2008, *Geophysical Research Letters*, 35: L01703.

Pan-Arctic variability of sea-ice concentration, land-surface temperatures, and vegetation greenness.

Division of Arctic Ocean and associated land masses according to Russian Arctic Atlas and Circumpolar Arctic Vegetation Map

101 & 1* East Bering Sea
102 & 2 Chukchi Sea
103 & 3 Beaufort Sea
104 & 4 Canadian Arch. Straits
105 & 5 Hudson Bay
106 & 6 Hudson Strait
107 & 7 Davis Strait
108 & 8 Baffin Sea
109 & 9 Lincoln Sea
110 & 10 Greenland Sea
111 & 11 Denmark Strait
112 & 12 Norwegian Sea
113 & 13 Barents Sea
114 & 14 White Sea
115 & 15* West Kara Sea
116 & 16 Laptev Sea
117 & 17 East Siberian Sea
118 & 18 Russian Arctic Basin
119 & 19 American Arctic Basin
120 & 20* East Kara Sea
121 & 21* West Bering Sea
*Treshnikov basin divided for purposes of this study



50-km buffer seaward and landward of coastline in each sea

Polar stereographic projection (J. Comiso)
Map by M. Raynolds, March 2008

Bhatt et al.: Yamal LCLUC Workshop, Moscow, 28-30 Jan 2008.

AVHRR 1980-2007 Trends

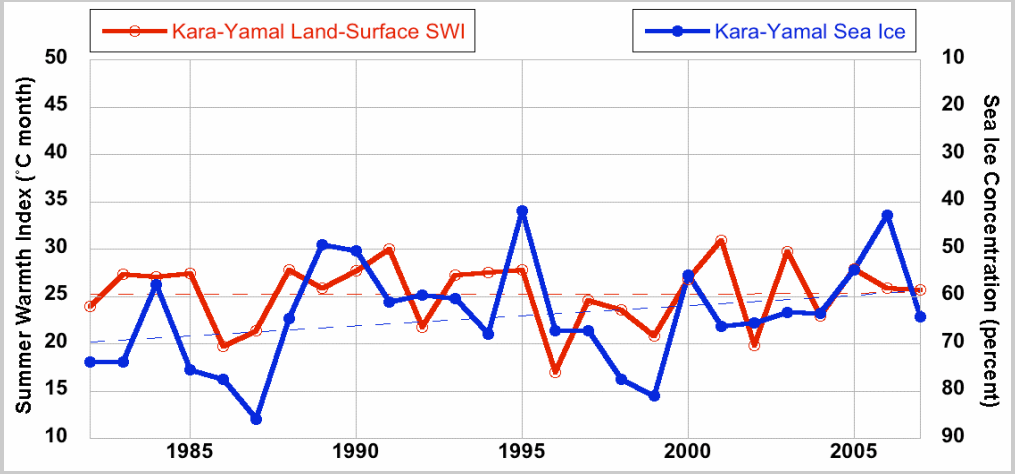
- Mid July Sea Ice percentage cover
- Summer warmth index (SWI)
- Max NDVI
- Integrated NDVI

Bhatt, Walker, Raynolds, Comiso: Yamal LCLUC Workshop, Moscow, 28-30 Jan 2008, and EGU 2008.

Sea-ice and temperature trends in Kara/Yamal region of Russia and Beaufort Sea

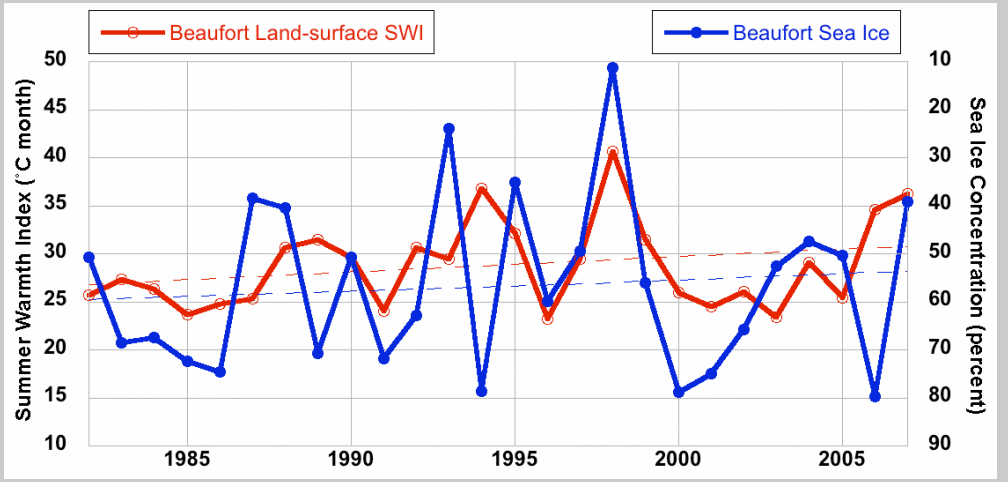
Kara/Yamal

- Negative sea-ice trend but nearly flat temperature trend



Beaufort

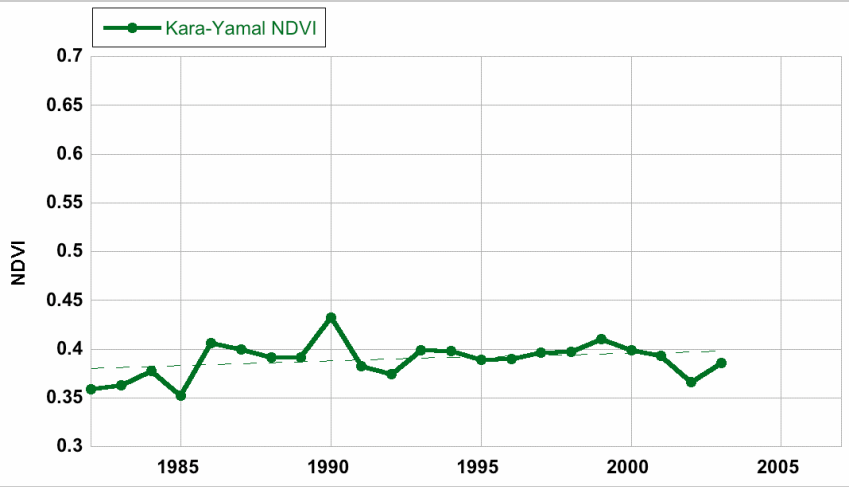
- High year-to-year variability
- Negative sea-ice trend correlated with positive temperature trend



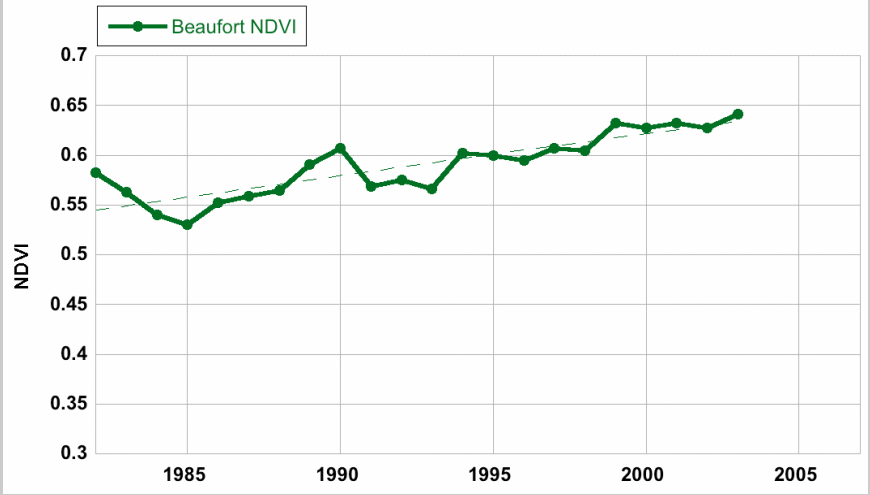
Bhatt et al.: NASA LCLUC Workshop, 2008.

NDVI trends in Kara/Yamal region of Russia and Beaufort Sea

Kara/Yamal



Beaufort



- Much lower NDVI on the Yamal is likely due to sandy wind-blown nutrient-poor soils, and grazing by reindeer.
- Greater change in Beaufort Region most likely due to more positive trend in ground surface temperatures in the Beaufort region during the period of record.

Bhatt et al.: EGU, Vienna, Proceedings, 2008.

Correlations between climate indices SWI, sea ice, & integrated NDVI

50-km zones with climate indices during preceding winter (DJFM)

Showing bold values with significance at 90% level or greater

Correlation	Sea Ice			Summer Warmth			Integrated NDVI		
	NAO	AO	PDO	NAO	AO	PDO	NAO	AO	PDO
Barents	-0.38	-0.34	0.26	**0.45**	0.28		0.16		-0.15
Kara-Yamal	**-0.41**	-0.31	0.32	0.28	0.11		0.11		-0.22
Laptev	**-0.52**			0.38	0.23	-0.30	**0.56**	**0.47**	**-.52**
E.Siberian	**-0.50**	**-0.59**	**0.42**	0.37	0.38	-0.36		**0.49**	**-.60**
Beaufort		-0.14	-0.28	**0.52**	**0.33**				-0.15

Throughout the Arctic including the Yamal, the general trend is positive summer warmth and NDVI with positive phases of the North Atlantic Oscillation and Arctic Oscillation, and negative correlations with positive phases of the Pacific Decadal Oscillation.

Bhatt et al.: EGU, Vienna, Proceedings, 2008.

Cumulative effects in the Yamal

Resource development:

- Indirect (unplanned) impacts are greater than the direct (planned) impacts.
- Roads and pipelines: serious barriers to migration corridors.
- Effects will increase as new field are developed.

Landscape factors and terrain sensitivity:

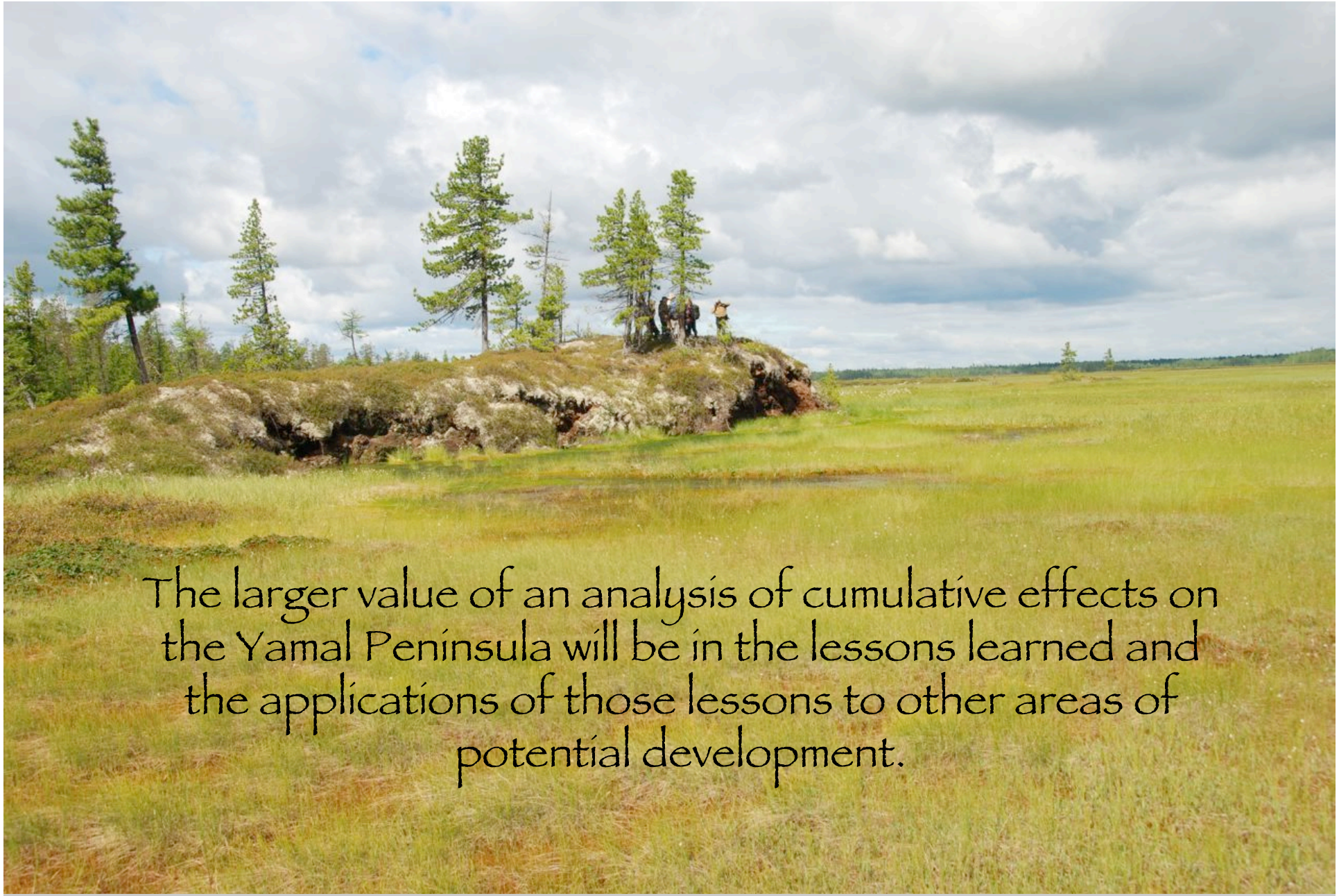
- High potential for extensive landscape effects due to unstable sandy soils, and extremely ice-rich permafrost near the surface.

Reindeer herding:

- Land withdrawals by industry, increasing Nenets population, and larger reindeer herds are all increasing pressure on the rangelands.
- Herders view: Threats from industrial development much greater than threats from climate change.
- They generally view the gas development positively because of increased economic opportunities.

Climate change:

- Satellite data suggest that there has been only modest summer land-surface warming and only slight greening changes across the Yamal during the past 24 years. (Trend is much stronger in other parts of the Arctic, e.g. Beaufort Sea.)
- Kara-Yamal: negative sea ice, positive summer warmth and positive NDVI are correlated with positive phases of the North Atlantic Oscillation and Arctic Oscillation.


The larger value of an analysis of cumulative effects on the Yamal Peninsula will be in the lessons learned and the applications of those lessons to other areas of potential development.

2007 Expedition to Yamal Peninsula Region, Russia

Members of the Expedition:

Nadym

Laborovaya and Vaskiny Dachi

Logistics:

Data collected:

Soils

Plant Cover

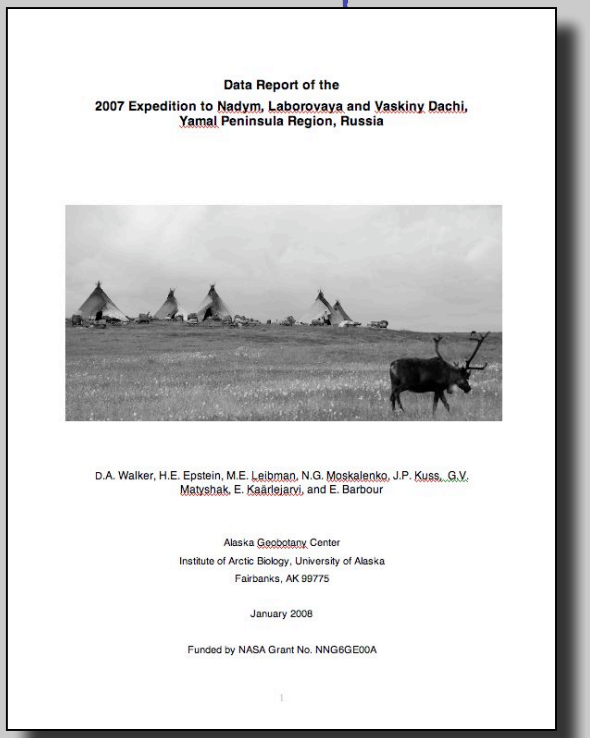
NDVI & LAI

Ground temperatures

Active layer

Plant Biomass

Data Report



Data Report of the
2007 Expedition to Nadym, Laborovaya and Vaskiny Dachi,
Yamal Peninsula Region, Russia

D.A. Walker, H.E. Epstein, M.E. Leibman, N.G. Moskalenko, J.P. Kuss, G.V. Matyshak, E. Kaärlejarvi, and E. Barbour

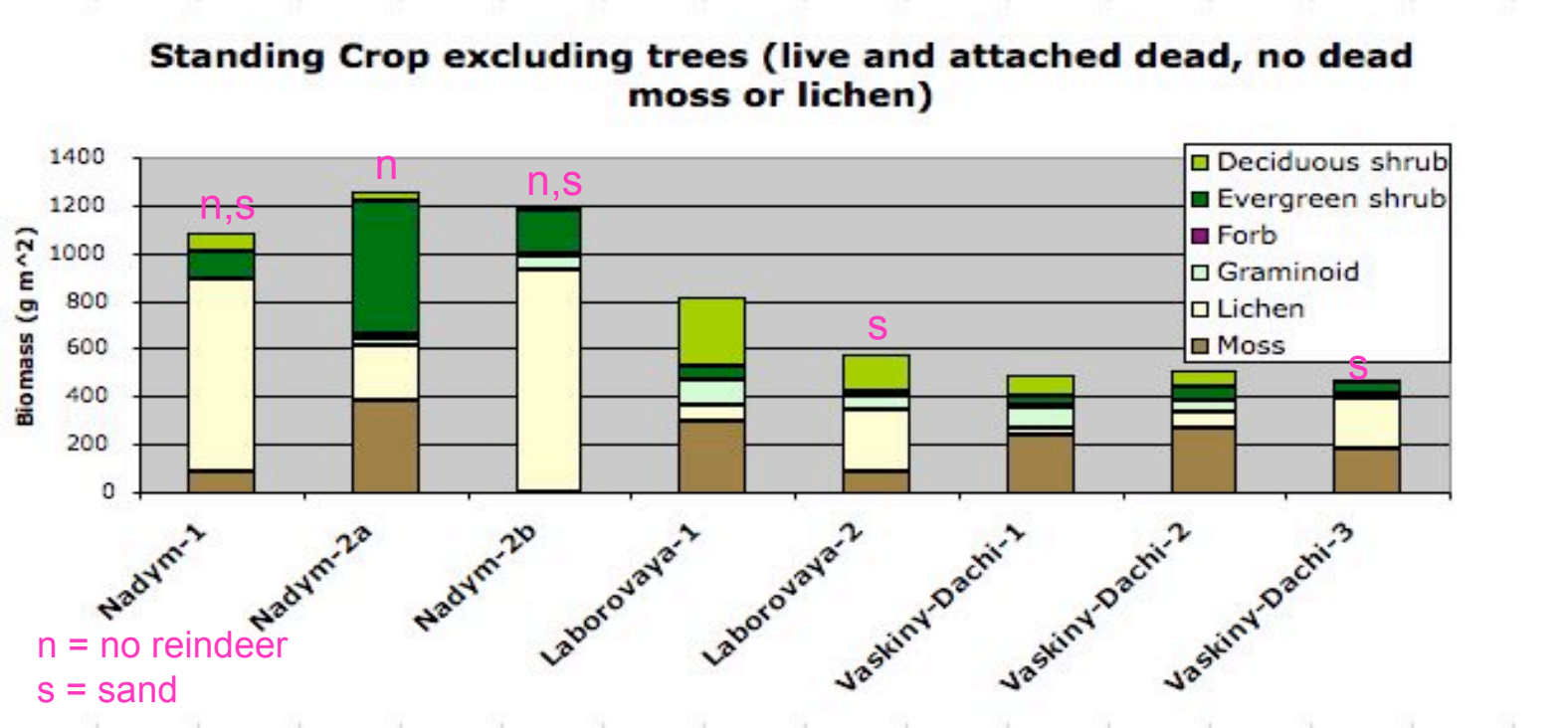
Alaska Geobotany Center
Institute of Arctic Biology, University of Alaska
Fairbanks, AK 99775

January 2008

Funded by NASA Grant No. NNG6GE00A

http://www.geobotany.uaf.edu/yamal/documents/yamal_2007_dr080211

Biomass along the Yamal transect

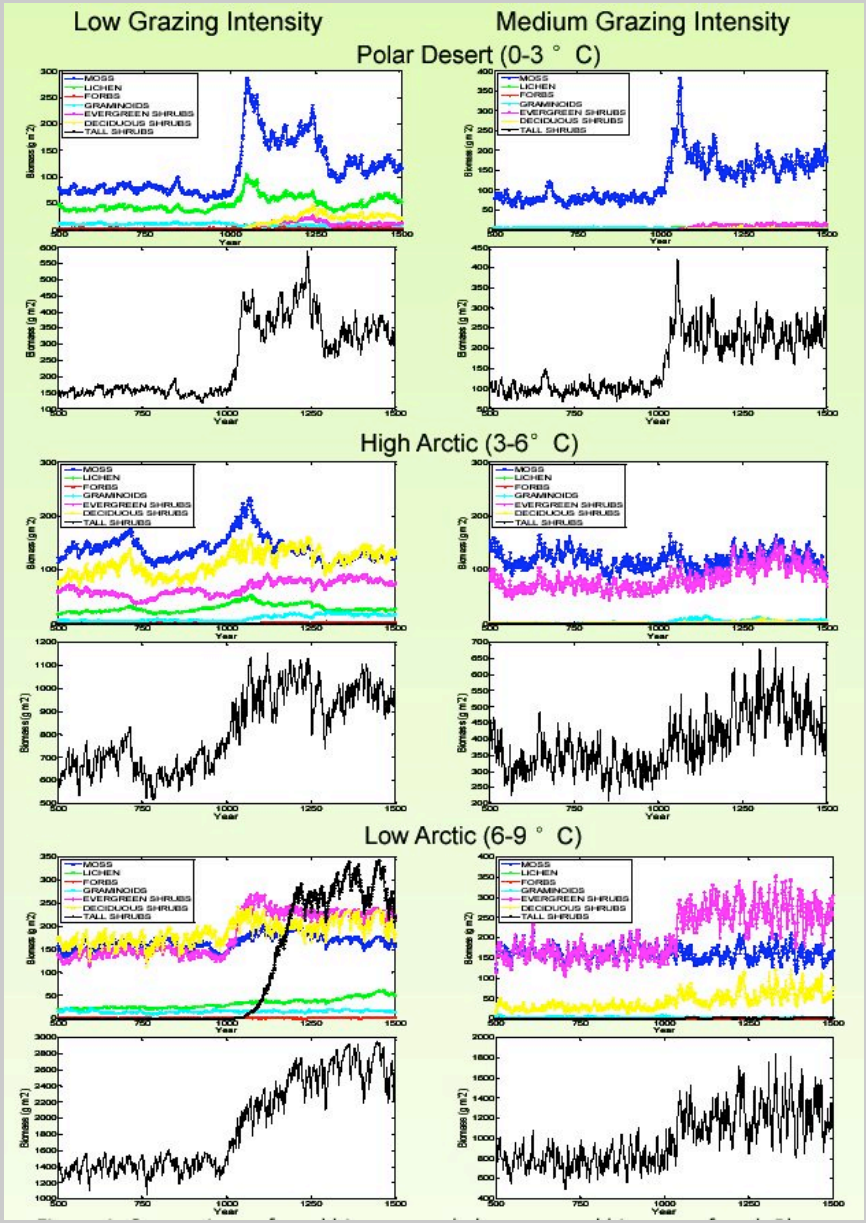


Climate trend:
2000-2300 g m^{-2} at Nadym to about 1000-1300 g m^{-2} at Vaskiny Dachi.

Epstein et al: NASALCLUC meeting 2008.

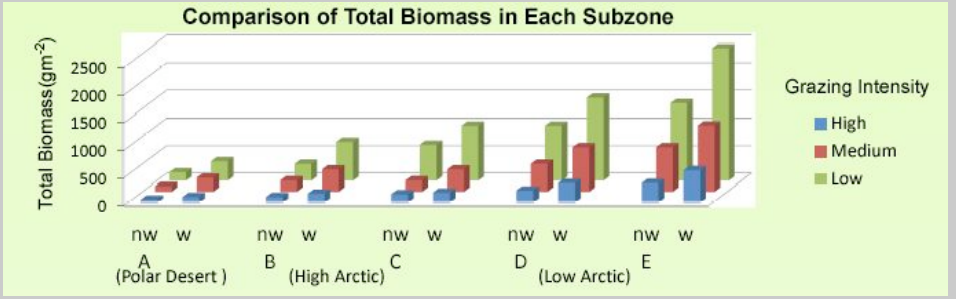
Effect of sandy soils:
- Sandy soils have 250-350 g m^{-2} less biomass than comparable clayey sites
- Much more lichen biomass and less mosses and graminoids.

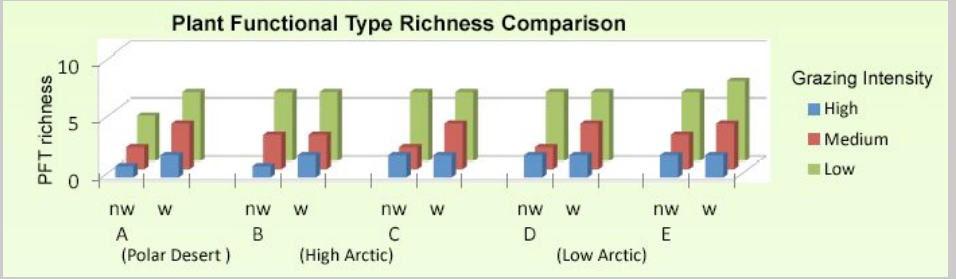
Effect of reindeer:
- Ungrazed sandy areas near Nadym – over 1000 g m^{-2}
- Less than 250 g m^{-2} in sandy areas where reindeer grazing has occurred annually.



Modeled productivity of PFTs on the Yamal

- ArcVeg model (Epstein et al. 2002)
- Examines succession of biomass for seven Arctic plant functional types.
- Five climate scenarios.
- Warming vs. non-warming treatments.
- Three grazing intensities.
- Next steps will incorporate soil type and disturbance regimes (dust and complete removal of vegetation), relate to NDVI and develop regional extrapolations.

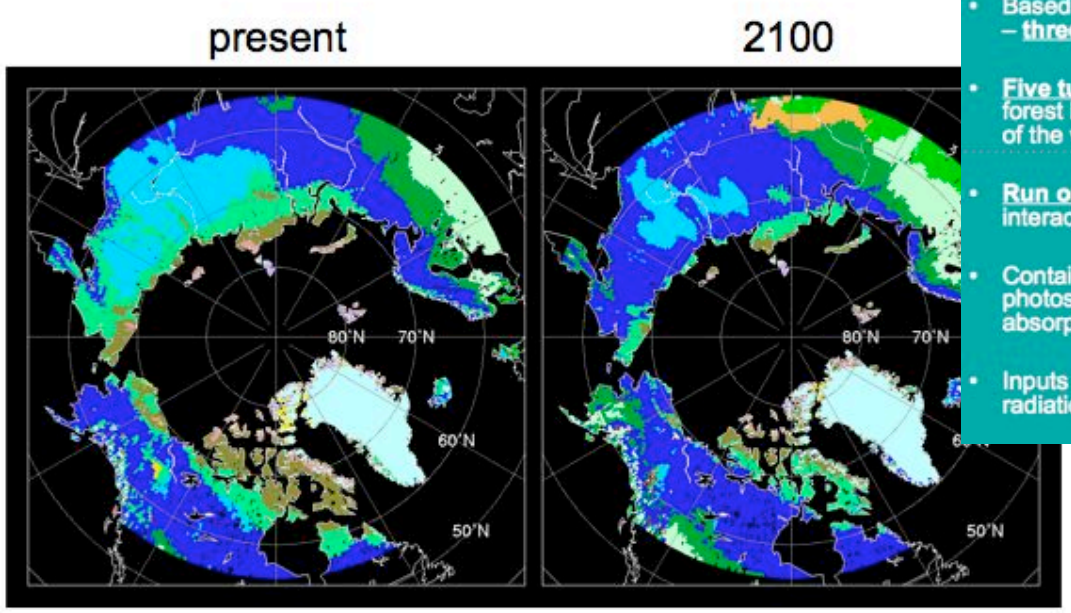




Yu and Epstein: 2008, NASA LCLUC conference.

BIOME4/LPJ model

- IPCC IS92a scenario

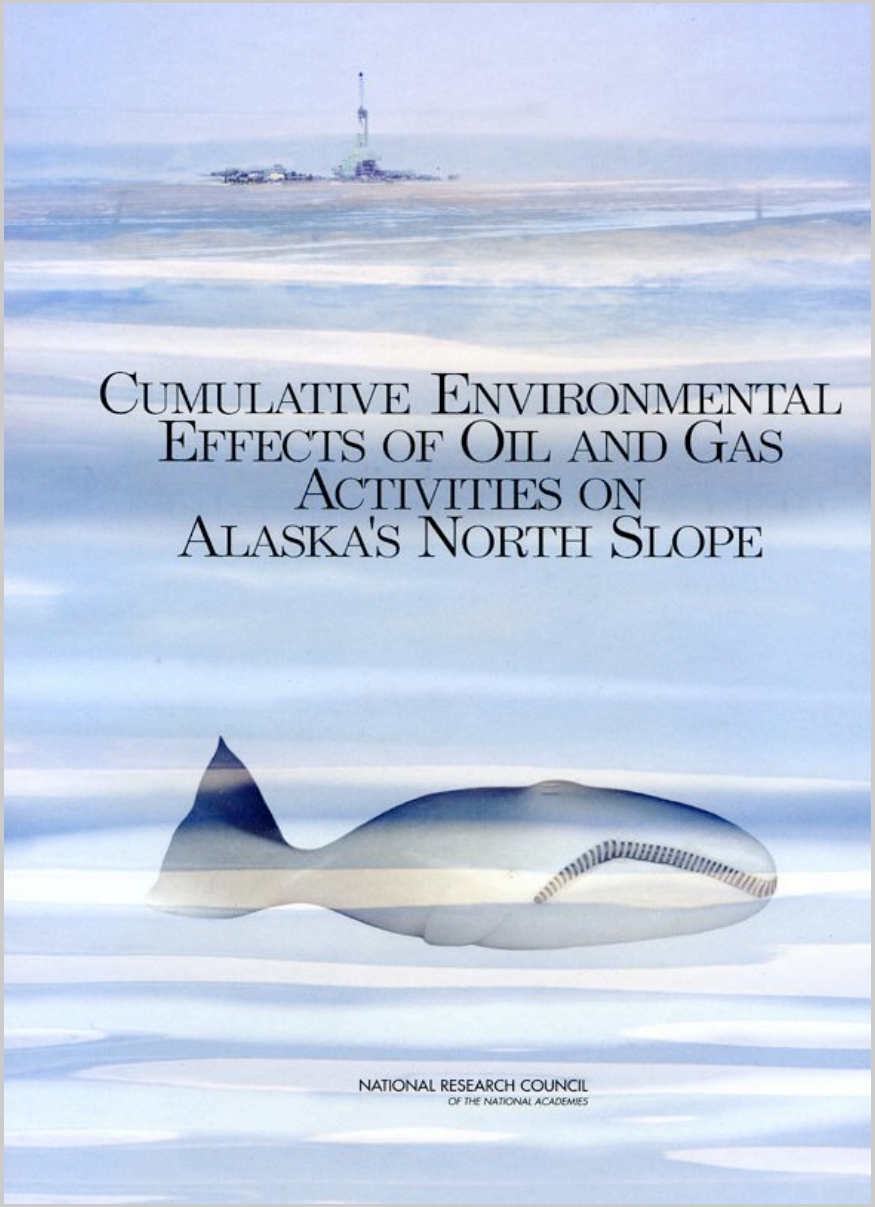


BIOME4 – Vegetation Type Biogeography Model

- Based on the plant functional type concept (rather than species) – **three tundra PFTs** in BIOME4
- **Five tundra biomes**, a cold parkland biome, and two boreal forest biomes are simulated, based on the resultant composition of the various PFTs.
- **Run on a spatial grid (0.5° x 0.5°),** but does not simulate interactions among grid cells
- Contains basic **ecophysiological equations** for photosynthesis, respiration, soil hydrology, and sunlight absorption
- Inputs include **monthly temperatures and precipitation**, solar radiation, soil texture and atmospheric CO2 concentrations

Using the terrain, soil, and vegetation data to improve BIOME4 global vegetation change model.

Kaplan, J.: Yamal LCLUC Workshop, Moscow, 28-30 Jan 2008.



National Research Council 2003

Comparative study with Alaska oil and gas development

Comparison of Cumulative Effects as detected using remote sensing in Alaska and Yamal:

- Resource development
- Traditional land-use
- Climate change

Develop predictive change models

- Based on field data from both areas,
- Apply to new areas of development

Walker et al.: in progress, in Gutman et al. LCLUC book.

Greening of the Arctic
An IPY Initiative

Authors

D.A. Walker, U.S. Bhatt, V.E. Romanovsky, G.P. Kofinas, M.K. Raynolds, University of Alaska, Fairbanks, AK, USA,
H.E. Epstein, Q. Yu: Department of Environmental Sciences, University of Virginia, USA,
B.C. Forbes, F. Stammler, E. Karlejäarvi: Arctic Centre, Rovaneimi, Finland,
M. Leibma, N. Moskalenko, A. Gubarkov, A. Khomutov: Earth, Cryosphere Institute, Moscow, Russia,
T. Kumpula: Department of Geography, University of Joensuu, Finland
J.C. Comiso: NASA Goddard, USA,
J.P. Kuss: Institute of Plant Science, University of Bern, Switzerland
G.J. Jia: REC-TEA, Chinese Academy of Science, Beijing, China,
J.O. Kaplan: Swiss Federal Institute for Forest, Snow &. Landscape Research, Lausanne, Switzerland
G. Matyshak: Faculty of Pedology, Moscow State University,Russia

Funding:

NASA Land Cover Land Use Change Initiative, Grant No. NNG6GE00A
NSF Grant No. ARC-0531180, part of the Synthesis of Arctic System Science initiative.
Finnish participation came from the Russia in Flux program of the Academy of Finland (Decision #208147).

The project is part of the Greening of the Arctic project of the International Polar Year and the Northern Eurasia Earth Science Partnership Initiative (NEESPI).