

# Cumulative effects of rapid climate and land-use changes on the Yamal Peninsula, Russia

*D.A. Walker, M.O. Leibman, B.C. Forbes, H.E. Epstein*  
*AGU Meeting, 15-19 Dec 2008*



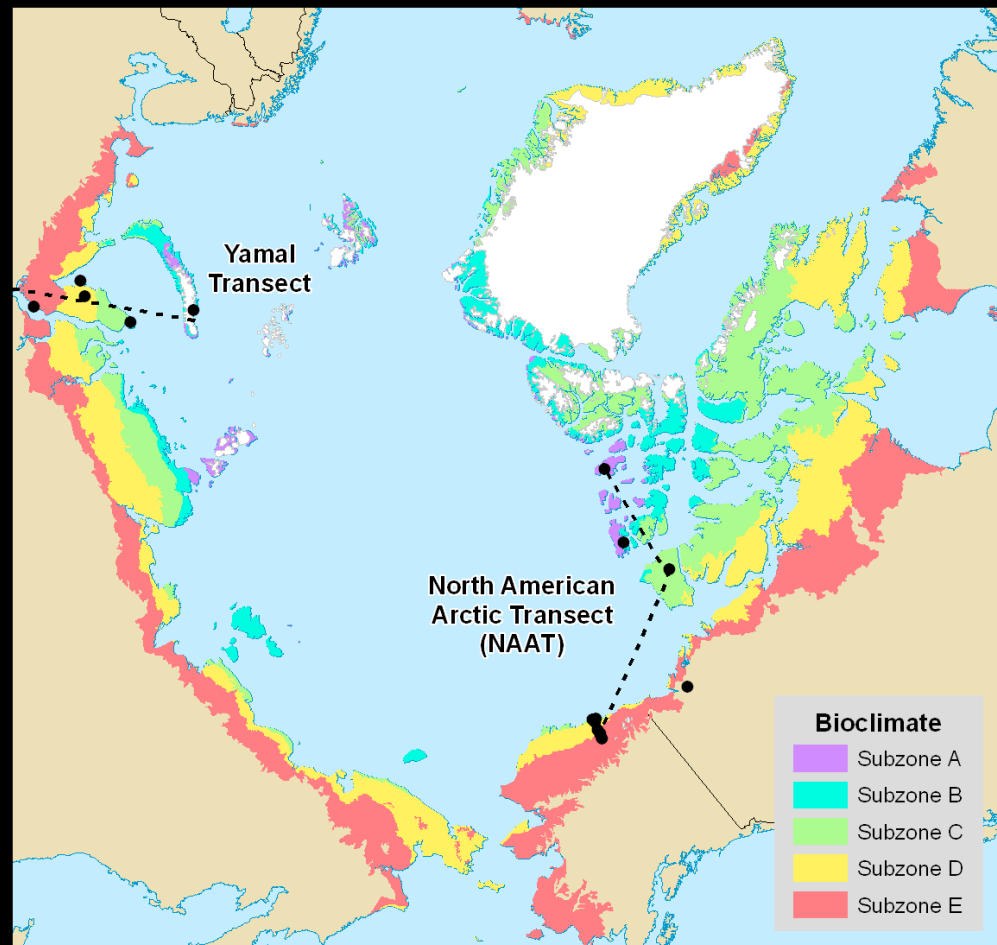
Photos: D.A. Walker

# The Greening of the Arctic Project: Two Arctic Transects

- North America Arctic Transect: Alaska-Canada.
- Eurasia Transect: Yamal Peninsula.
- Through all 5 Arctic bioclimate subzones.



Isachsen Grid, Subzone A  
Photo D.A. Walker



Base map: Walker 2005, *Journal of Vegetation Science*, 16: 267-282.  
Photo: Subzone A, Isachsen, D.A. Walker.

# Yamal Transect

## 2007

- Nadym
- Laborovaya
- Vaskiny Dachi

## 2008

- Kharasavey

## 2010 (proposed)

- Ostrov Belyy
- Russkaya Gavan (or Franz Josef Land)
- Marresale (or site in N. Yamal)





# Collaborators

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Bruce Forbes, Florian Stammer, Timo Kumpula,  
Elina Karlejaärvi: *Arctic Centre, Rovaniemi, Finland*

Howie Epstein: *University of Virginia*

Jiong Jia: *REC-TEA, Chinese Academy of Science*

Joey Comiso: *NASA Goddard*

NASA: Land Cover Land-Use Change program

- Funding NASA LCLUC program.
- NEESPI (CLPN) project.

Photo: D.A. Walker







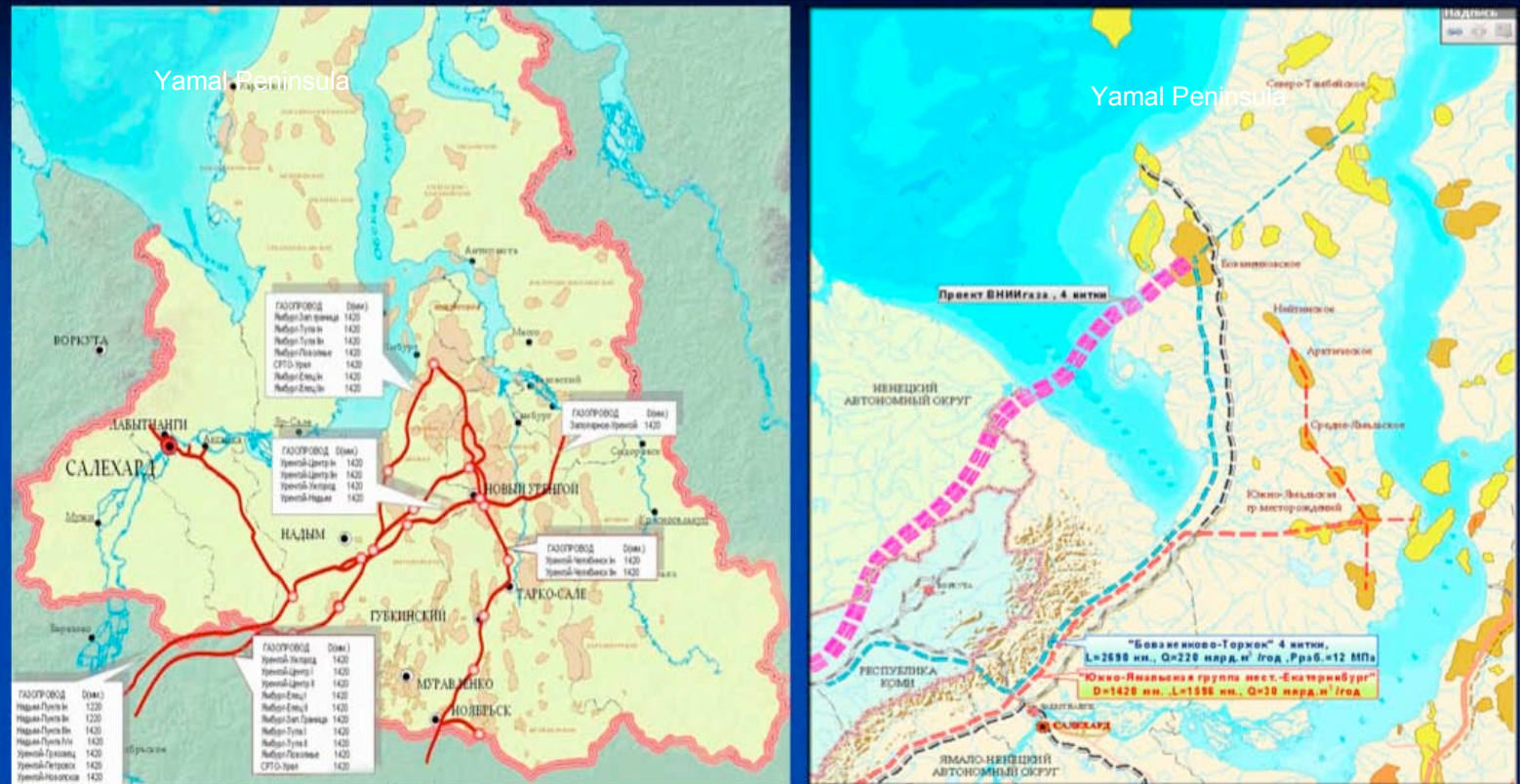
## The Yamal

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.

Large-scale development will occur once road, railroad and pipeline links to the south are built.



## 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  $m^3$  of gas each.



# Relaxed Regulatory Environment



Photos: D.A. Walker

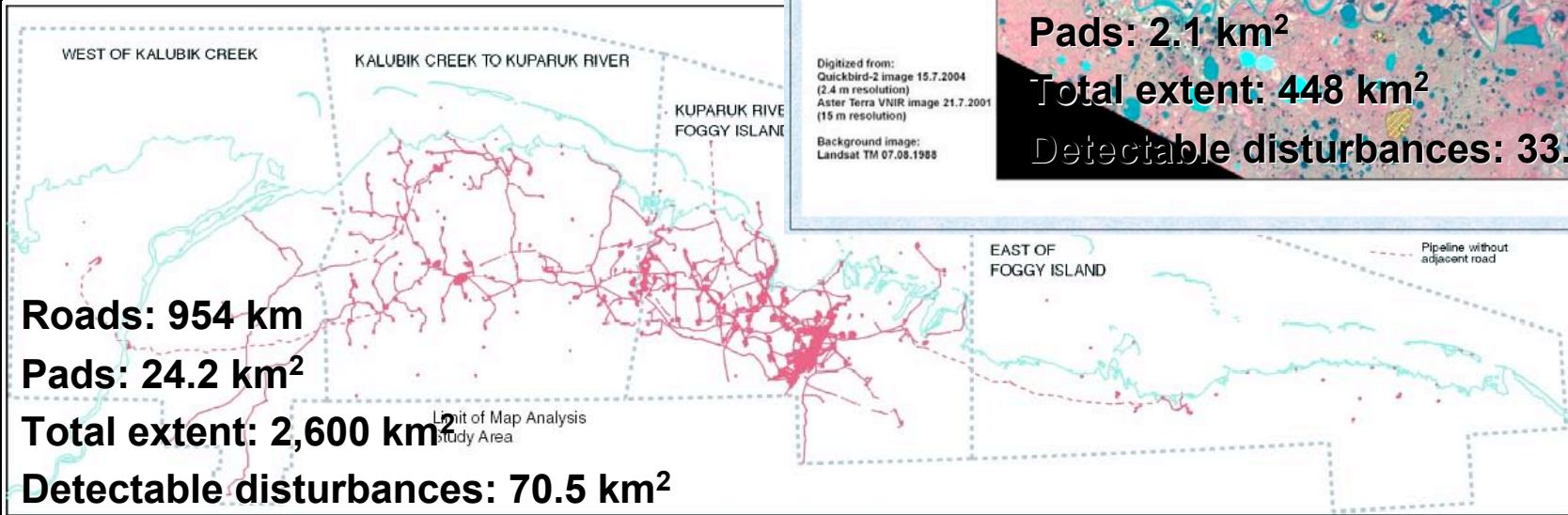


# Extent of infrastructure of Bovanenkova Field compared to Prudhoe Bay

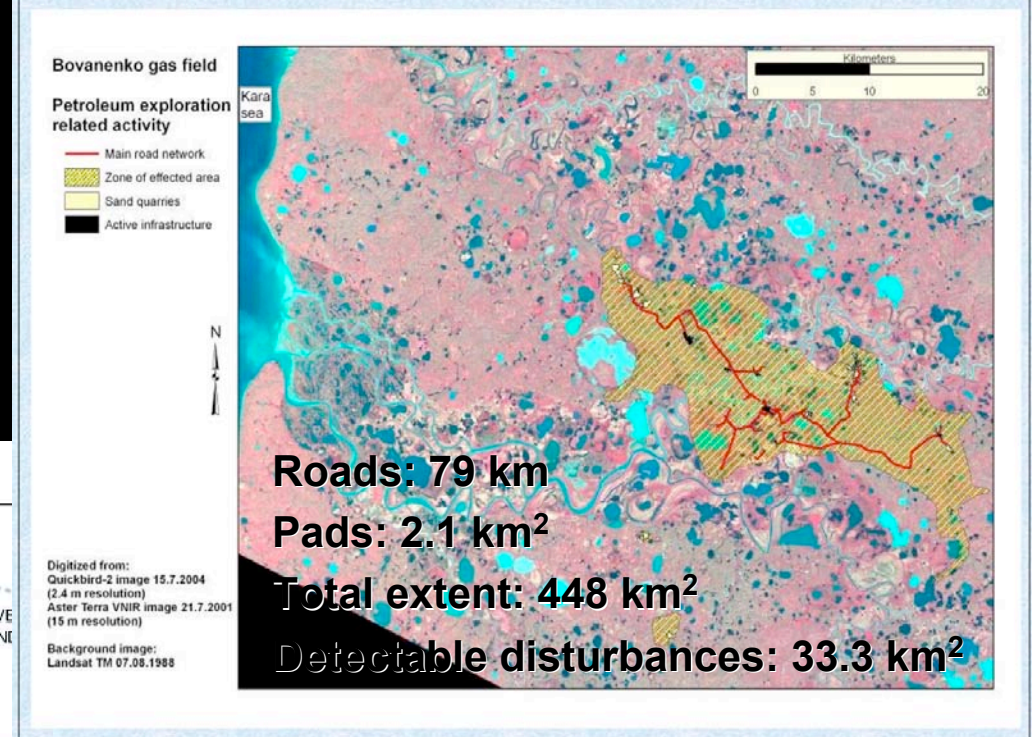
Currently, about 1/10 the roads and pads, 1/5 the area of Prudhoe Bay and about 1/2 the detectable impact.

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

## Extent of the North Slope, AK development (2001)



## Extent of Bovanenkovo Gas Field (2001)



NRC, 2003. *Cumulative Environmental Effects of the Oil and Gas Development on the Alaska North Slope.*

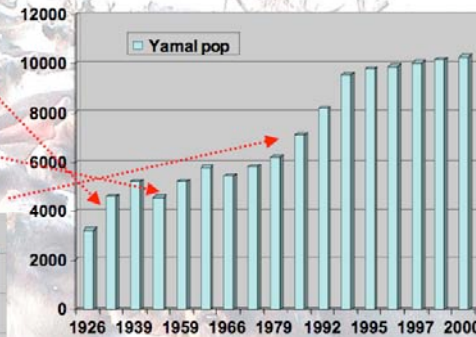
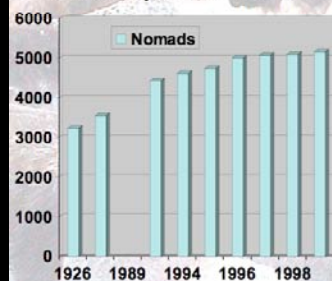




## The Nentsy and their reindeer

### Increase of humans on Yamal

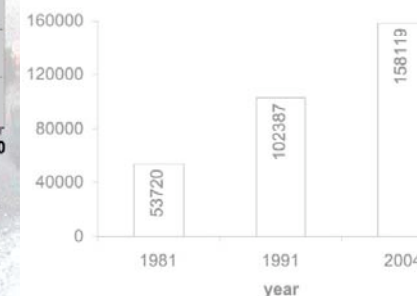
Euro-Nentsy escape to Yamal, early 1930s,  
'Dekulakization' and prosecution of shamans under Stalin  
Steady growth after sovkhos system stabilised



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

### Increase of private reindeer

#### Private reindeer on the Yamal Peninsula



Where do all these animals graze???



Graphics: Florian Stammner: Yamal LCLUC Workshop, Moscow, 28-30 Jan 2008.  
Photos: D.A. Walker



# The Nentsy use the entire Yamal Peninsula.



Photos: D.A. Walker



## The herders view:



Photo: D.A. Walker

- Threats from industrial development are much greater than threats from climate change.
- However, they currently generally view the gas development positively because of increased economic opportunities (e.g. markets for reindeer, some perks from the industry).
- Moderate demands:
  1. Complete and timely reclamation of lands used during the technical work that are not industrial and have no facilities on them.
  2. Establishing and protecting corridors for movement between camps by people and reindeer herders.

(Zen'ko 2004, Stammier 2005).

Stammier, F. 2005. Reindeer Nomads Meet the Market: Culture, Property and Globalisation at the End of the Land. Litverlag-Halle Studies in the Anthropology of Eurasia, Muenster.

Zen'ko, M. A. 2004. Contemporary Yamal: ethnoecological and ethnosocial problems. Anthropology & Archeology of Eurasia 42:7-63.

However, there is a lack of equity in discussions regarding land-use.



Pavel Orekhov and Nenets herder.

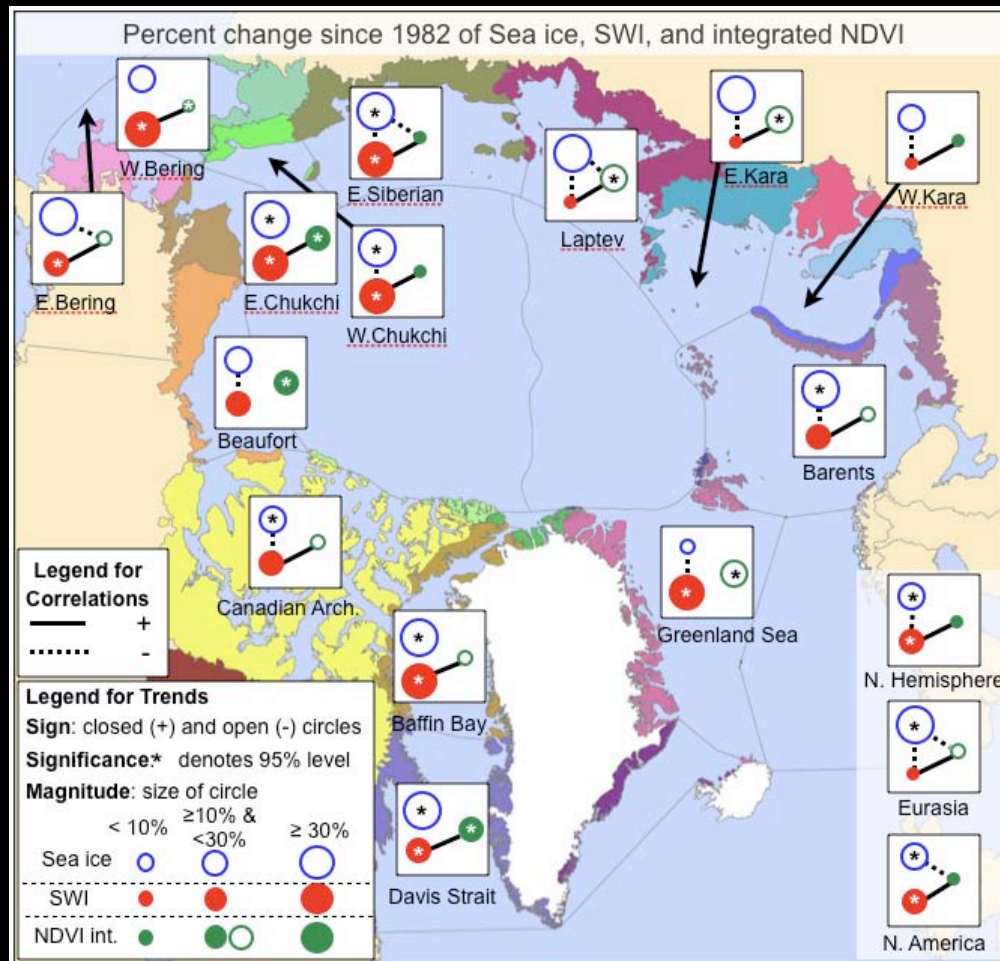
Photo: D.A. Walker

- Despite an amazing ability to adapt to past climate, social, economic, and political upheavals in Russia, the Nentsy face difficult challenges with respect to adapting to industrial change because they lack title to their land.
- In Alaska and Canada, indigenous groups gained legal land claims. No such legal land rights exist for the Nentsy.

Bruce Forbes. 2008. Equity, vulnerability and resilience in social-ecological systems: A contemporary example from the Russian Arctic. *Research in Social Problems and Public Policy*, 15: 203-236.



# Analysis of sea-ice, land surface temperature and NDVI trends



- 50-km buffers seaward and landward along each sea coast.
- 1982-2007 AVHRR data to analyze trends in sea ice concentration, LST, and NDVI.

Bhatt et al., in progress, 2008.

# Sea-ice, temperature and greening trends in Kara/Yamal region of Russia, 1982-2007

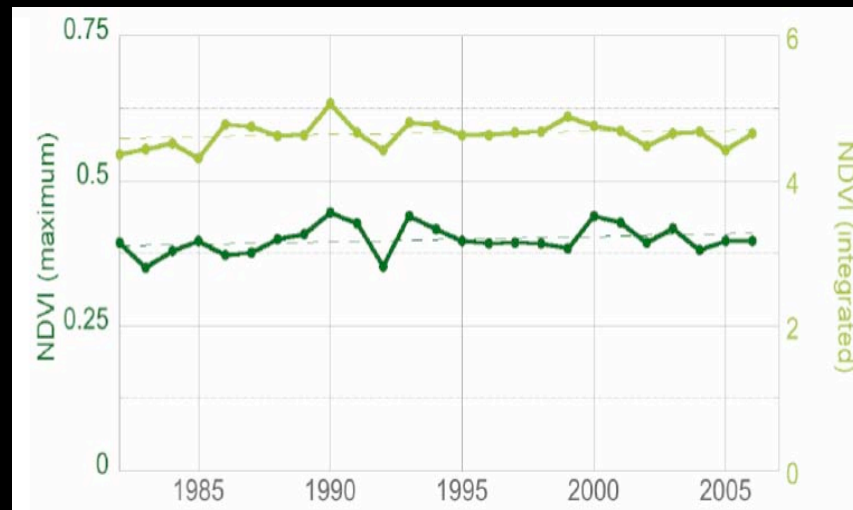
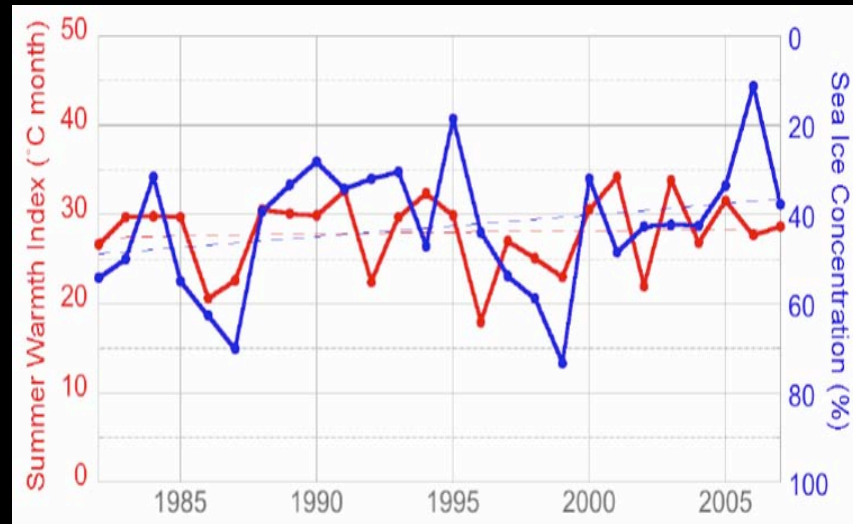
Sea ice: -25%)

Summer surface  
temperature: +4%

Maximum NDVI: +3%

None of the trends are significant at  $p = 0.05$  because of high interannual variability.

Compared to other areas of the Arctic, the Yamal has shown comparable levels of sea-ice retreat, but less increase in temperature, and NDVI.

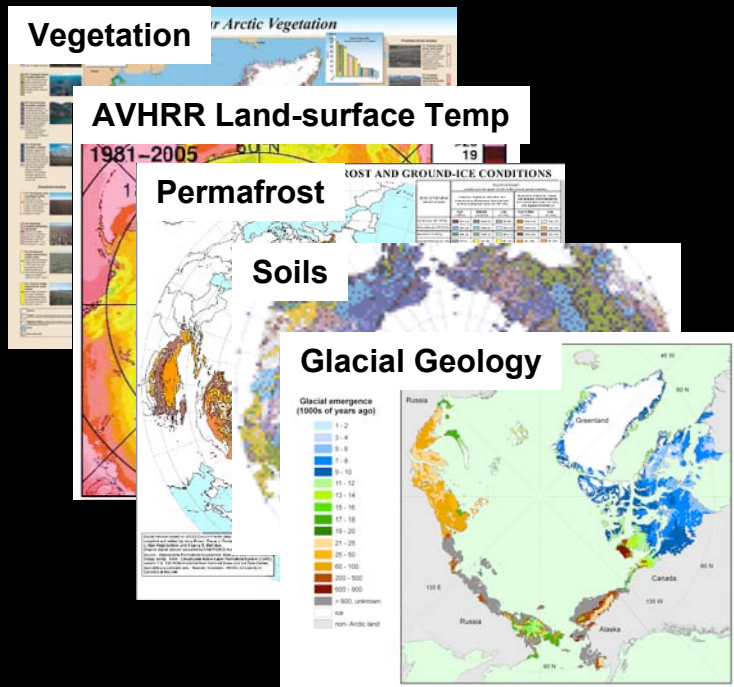


Bhatt et al.: NASA LCLUC Workshop, 2008.

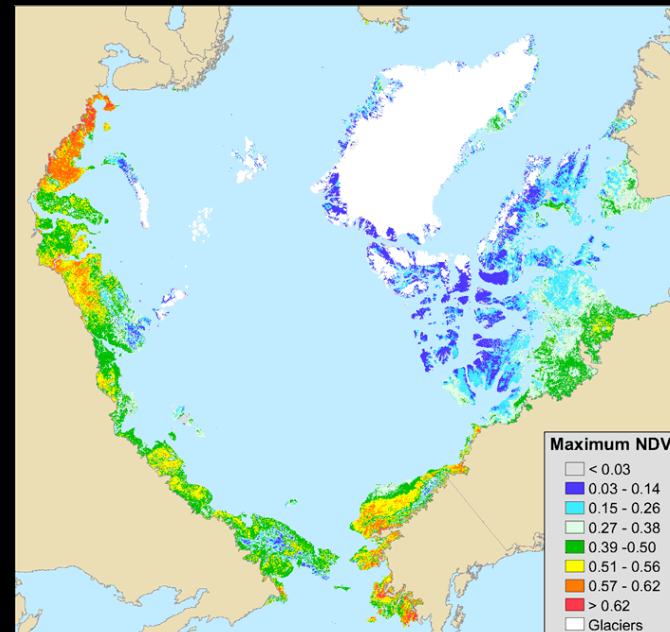


# Circumpolar Analysis of NDVI patterns

## Circumpolar Data Sets



## NDVI



Primary controls at pan-Arctic scale:

- Summer temp
- Lake cover
- Glacial history
- Soil type

Raynolds, M.K., D. A. Walker and H. A. Maier. 2006. NDVI patterns and phytomass distribution in the circumpolar Arctic. *Remote Sensing of Environment* 102:271-28 .

Raynolds, M. K., J. C. Comiso, D. A. Walker, D. Verbyla. 2008. Relationship between satellite-derived land surface temperatures, arctic vegetation types, and NDVI. *Remote Sensing of Environment* 112:1884-1894.

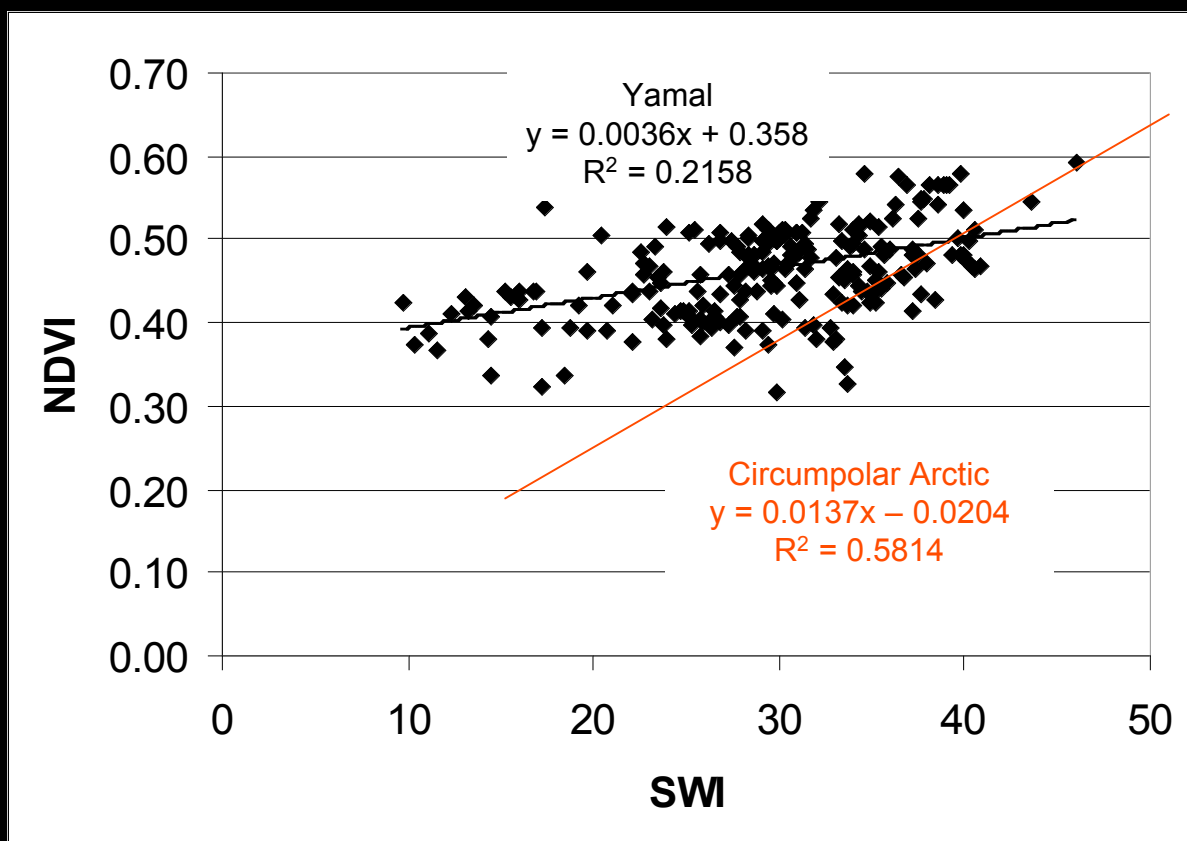
Raynolds, M. K. and Walker, D. A. 2008. Relationship of permafrost characteristics, NDVI, and arctic vegetation types. *Proceedings of the Ninth International Conference on Permafrost*: 1469-1474.

Raynolds, M. K. and Walker, D. A. 2008 (submitted): The effects of deglaciation on circumpolar distribution of arctic vegetation. *Canadian Journal of Remote Sensing*.

Raynolds, M.K. 2009 in prep. Synthesis of circumpolar controls on NDVI.

:Martha Raynolds Ph.D. thesis

## NDVI vs. Summer Warmth on the Yamal compared to the Circumpolar Arctic

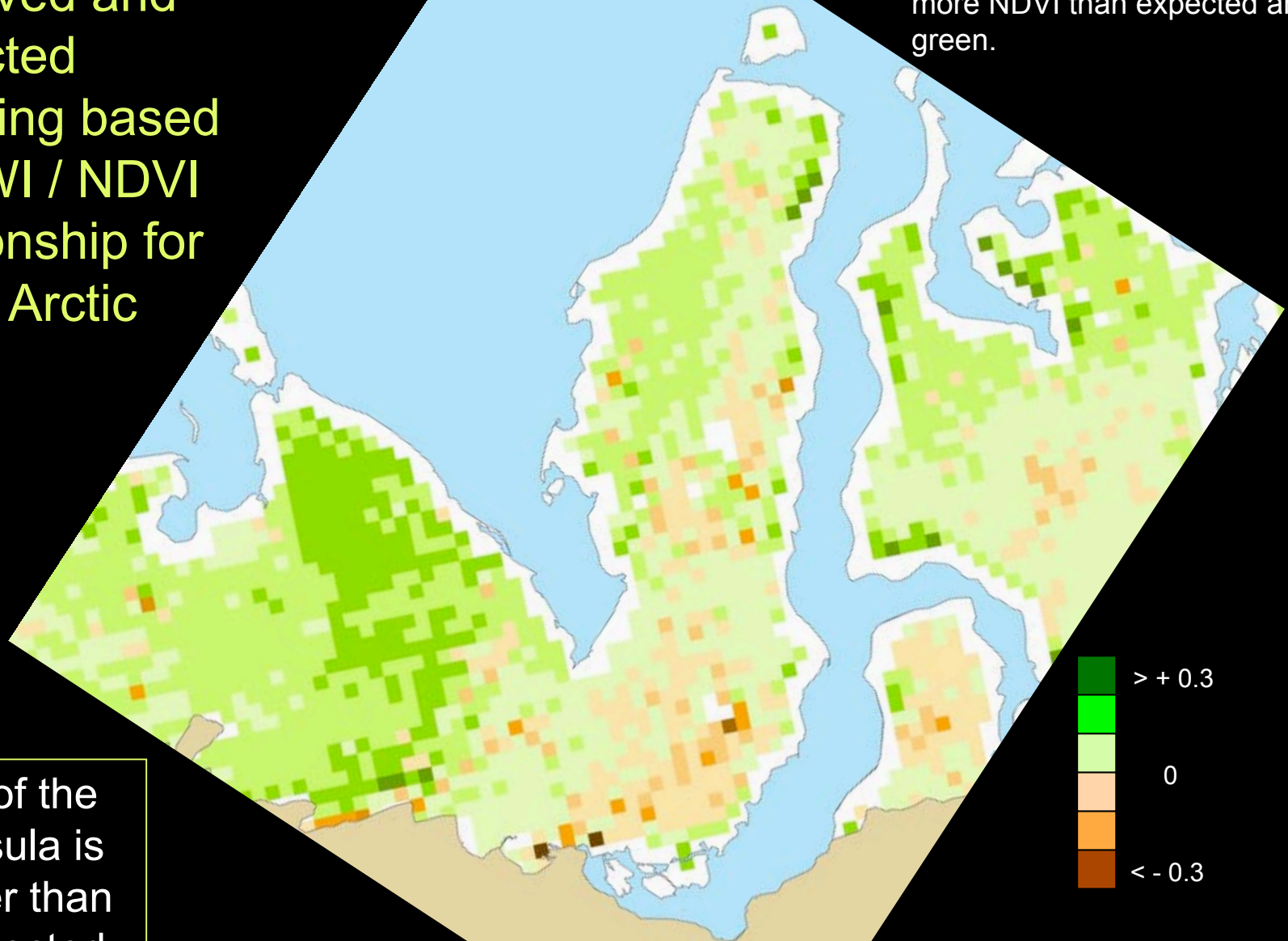


- Arctic as a whole has much stronger correlations between NDVI and SWI.



# Comparison of observed and predicted greening based on SWI / NDVI relationship for entire Arctic

Areas with less NDVI than  
expected are brown, areas with  
more NDVI than expected are  
green.



Most of the  
peninsula is  
greener than  
we expected.

# Effects of climate change: Analysis of biomass and NDVI trends across the climate gradient

Field data collected:





# High-ice Permafrost Landscapes and extraordinarily high natural disturbance regimes

Extensive nutrient-poor  
surface sands with  
lichens that are easily  
overgrazed by reindeer.

Underlain by permafrost  
with massive pure ice.

Extensive landslides are  
rapidly eroding the  
landscape.

Photos: D.A. Walker  
and M. Liebman (upper right)







## Extensive willow shrublands due to landslide disturbances

- Landslides expose salt-rich and nutrient-rich clays.
  - 
  - Complex vegetation succession process result in willow-shrub tundra in the interior parts of the peninsula.
- Natural disturbances are the largest control of vegetation change on the Yamal.
  - Anthropogenic disturbances and climate change locally replicate and exacerbate these changes.



# Cumulative effects on the Yamal

## Resource development:

- Indirect (unplanned) impacts (such as ORV trails, flooding from roads) are greater than the direct (planned) impacts (infrastructure).
- 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. Big concern is lack of power during negotiations.
- They currently 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.

# Working with permafrost experts, sociologists, biologists, and soil scientists with long experience on the Yamal Peninsula



Photo: D. A. Walker

Earth Cryosphere Institute, Russian Academy of Science, Moscow organized the expeditions. Led by Marina Liebman and Nataliya Moskalenko.

Elina Karlejaärvi (Arctic Centre, graduate student, botanist), Nataliya Moskalenko (ECI, ecologist), Howie Epstein (U Va Co-PI, ecosystem ecologist), Marina Leibman (ECI, Permafrost, geomorphologist), Patrick Kuss (UAF, Post Doc, botanist), Anatoly Gubarkov (ECI, graduate student, permafrost, industrial impacts), Artem Khumotov (ECI, graduate student, GIS), George Mateyshak (MSU, Soil Scientist), D.A. Walker (Project PI, geobotanist)

Photo: D.A. Walker



# Environmental and Social Impacts of Industrial Development in Northern Russia (ENSINOR)



Bruce Forbes,  
Arctic Centre,  
Rovaniemi, PI of  
the ENSINOR  
Project.



Florian Stammer interviewing members of a Nenets brigade.  
Combining remote sensing and traditional knowledge.

Photo: Bruce Forbes