Vegetation biomass, leaf area index, and NDVI patterns and relationships along two latitudinal transects in arctic tundra

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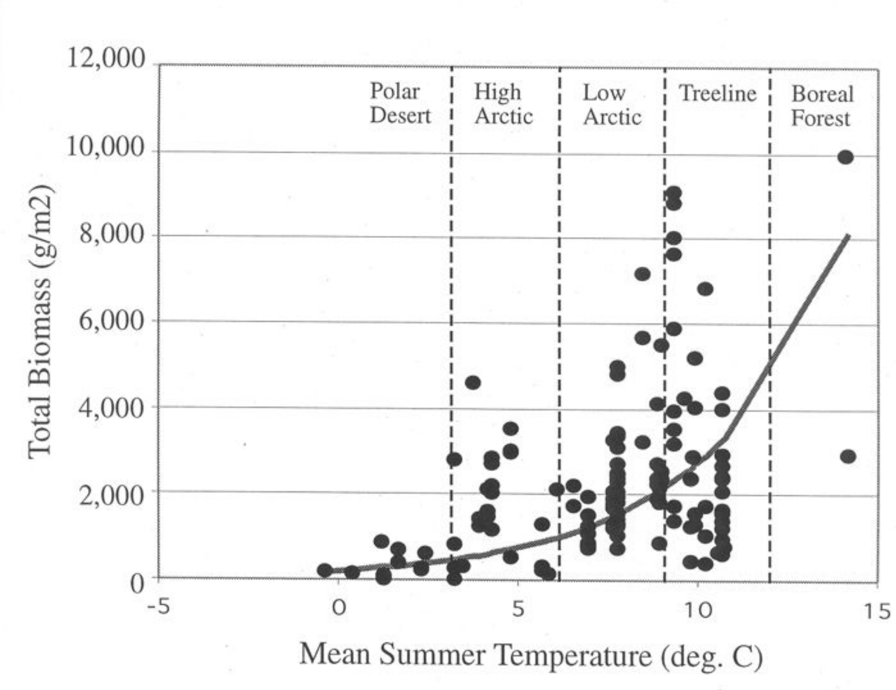
Gilmanov and Oechel (1995)

- first synthetic collection of arctic-subarctic vegetation biomass and NPP
- highly varying methodologies

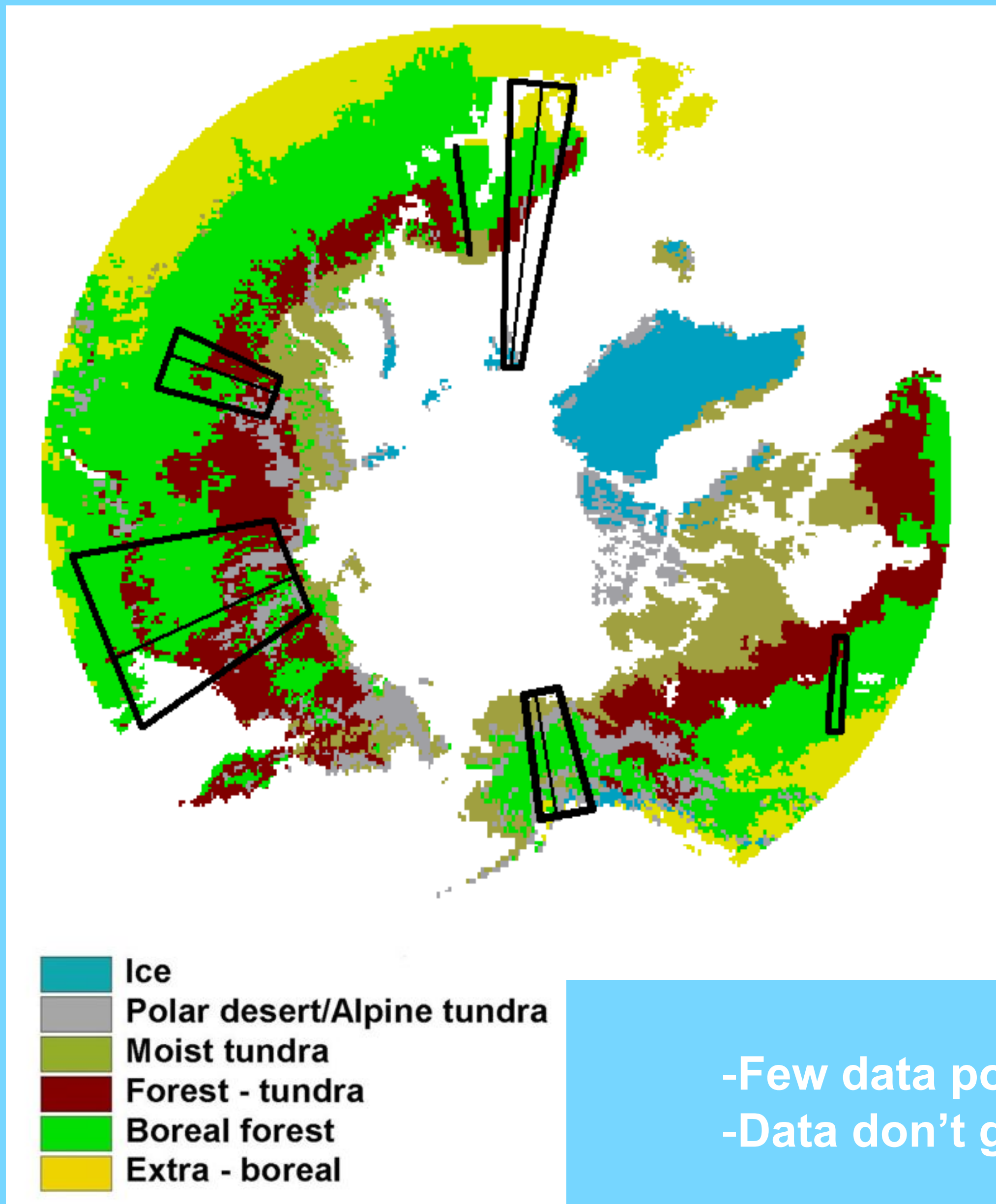
TABLE 2. Geographically referenced phytomass (t/ha) and production (t/ha/yr) estimates for zonal, meadow and Arctic/sub-Arctic ecosystems of North America and Greenland.

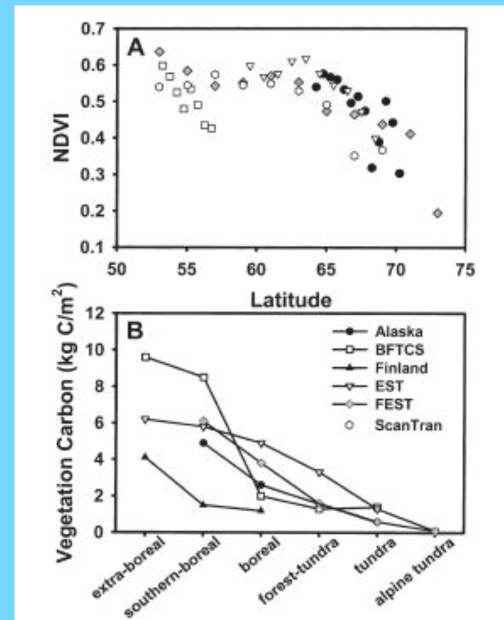
Latitude deg.	Longitude deg	Community	Location	Above-ground phytomass	Above-ground net primary production	Total live phytomass	Net primary production	Author
				Zonal ecosystems				
75.55	−84.67	Moss–herb on plateau	Devon Island	2.47	0.07	2.57	0.08	Bliss, 1975
75.55	−84.67	Cushion plant–moss	Devon Island	7.49	0.49	7.99	0.54	Bliss, 1975
75.55	−84.67	Raised beach	Devon Island	10.67	0.58	28.06	1.83	Bliss & Kerik, 1973
75.07	−91.75	Barrens	Devon Island	0.03	0.006	0.038	0.009	Bliss, Svoboda & Bliss, 1984
75.00	−108.00	Herb–moss	Queen Elizabeth Islands	7.37	0.293	8.486	0.518	Bliss & Svoboda, 1984
75.00	−85.00	Barrens	Devon Island	0.12	0.0008	0.155	0.012	Bliss, Svoboda & Bliss, 1984
74.75	−95.00	Snowflush	Cornwallis Island	0.67	0.014	0.828	0.017	Bliss, Svoboda & Bliss, 1984
74.07	−93.88	Barrens	Somerset Island	0.38	0.0125	0.416	0.015	Bliss, Svoboda & Bliss, 1984
74.07	−93.88	Barrens	Somerset Island	0.02	0.0017	0.03	0.0026	Bliss, Svoboda & Bliss, 1984
74.07	−93.88	Cushion plant	Somerset Island	0.12	0.005	0.393	0.0063	Bliss, Svoboda & Bliss, 1984
71.33	−156.67	Dwarf shrub	Barrow	1.08	0.25	5.79	1.35	P.J. Webber, in Wielgolaski *et al.*, 1981
70.47	−157.40	Dwarf shrub	Atkasook, AK	3.81	0.9	—	—	Komarkova & Webber, 1980
70.47	−157.40	*Eriophorum*–seasonal short grass	Atkasook, AK	4.89	0.99	—	—	Komarkova & Webber, 1980
70.47	−157.40	*Erioph.–Carex*–low cent. polygons	Atkasook, AK	3.14	1.27	—	—	Komarkova & Webber, 1980
70.47	−157.40	Shrub lowland	Atkasook, AK	4.48	1.04	—	—	Komarkova & Webber, 1980
70.25	−148.50	Dry acidic tundra	Prudhoe Bay	2.65	—	—	—	Walker & Everett, 1991
70.25	−148.50	Moist acidic tundra	Prudhoe Bay	2.52	—	—	—	Walker & Everett, 1991
69.45	−133.00	Birch–willow heath	Tuktoyaktuk	2.85	1.25	—	4.9	Haag, 1974; Haag & Bliss, 1974
69.42	−148.67	Tussock tundra	Sagwon	1.62	0.62	—	—	Shaver & Chapin, 1986
69.37	−151.92	Cottongrass–heath	Umiat	0.8	0.8	—	—	Wein & Bliss, 1974
69.30	−148.72	Mesic tussock tundra	Sagwon	1.95	—	4.47	—	Chapin & Shaver, 1981
69.25	−53.50	Cushion plant–lichen	Disko	0.99	0.32			
68.63	−159.57	Tussock tundra	Toolik Lake	7.43	2.05			
68.63	−159.57	Hilltop heath	Toolik Lake	3.19	0.4326			
68.58	−133.75	Tundra in forest–tundra	near Inuvik, NWT	26.65	—			
68.58	−133.75	Tundra in forest–tundra, burned 17 yr	near Inuvik, NWT	8.18	—			
68.50	−133.75	Forest tundra	near Inuvik, NWT	23.16	—			
68.50	−133.75	Forest tundra, burned 17 yr	near Inuvik, NWT	6.75	—			
68.00	−161.00	Sedge–tussock	Noatak River, AK	2	1.05			
66.53	−151.25	Mesic tussock	Fish Creek, Alaska	2.39	—			
66.53	−151.25	Dry tussock tundra	Fish Creek, Alaska	3.24	—			
66.00	−128.00	*Betula papyrifera* forest tundra	N.W. Canada	74.5	2.2			
64.75	−148.25	*Picea mariana* forest tundra	Alaska	16.51	0.78			
62.00	−43.00	*Betula pubescens* forest tundra	Greenland	48.5	1.98			
54.72	−67.70	*Picea–Cladonia* forest tundra, 47 yr	Schefferville, Quebec	9.641	—			
54.72	−67.70	*Picea–Cladonia* forest, 140 yr	Schefferville, Quebec	40.58	—			

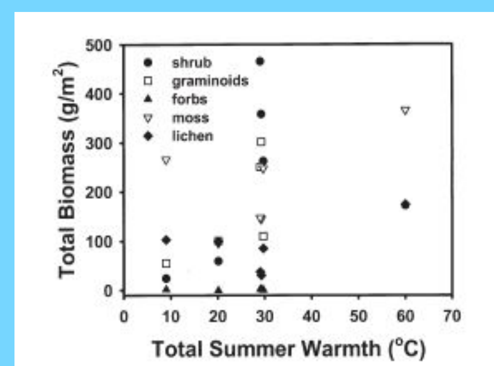


Epstein (unpublished)

IGBP High-Latitude Transects







-Few data points
-Data don't go very "high"

McGuire et al. 2002 (Journal of Vegetation Science)

Series of *at least* five projects with some common investigators and a focus on arctic tundra vegetation properties across climate gradients

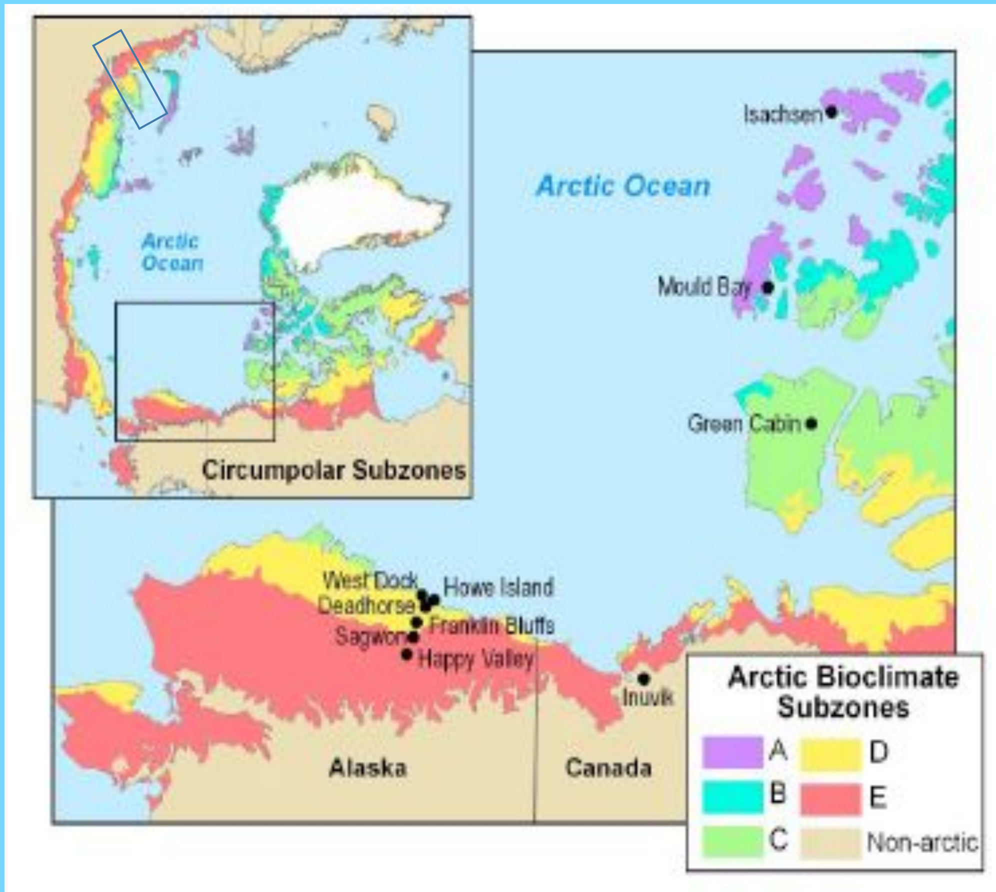
Arctic vegetation: Climate-substrate interactions. 1999-2003. National Science Foundation, Office of Polar Programs, Arctic System Science, Land-Atmosphere-Ice Interactions, ATLAS (Arctic Transitions in the Land-Atmosphere System)

Biocomplexity associated with biogeochemical cycles in arctic frost-boil ecosystems. 2002-2007. National Science Foundation, Biocomplexity in the Environment.

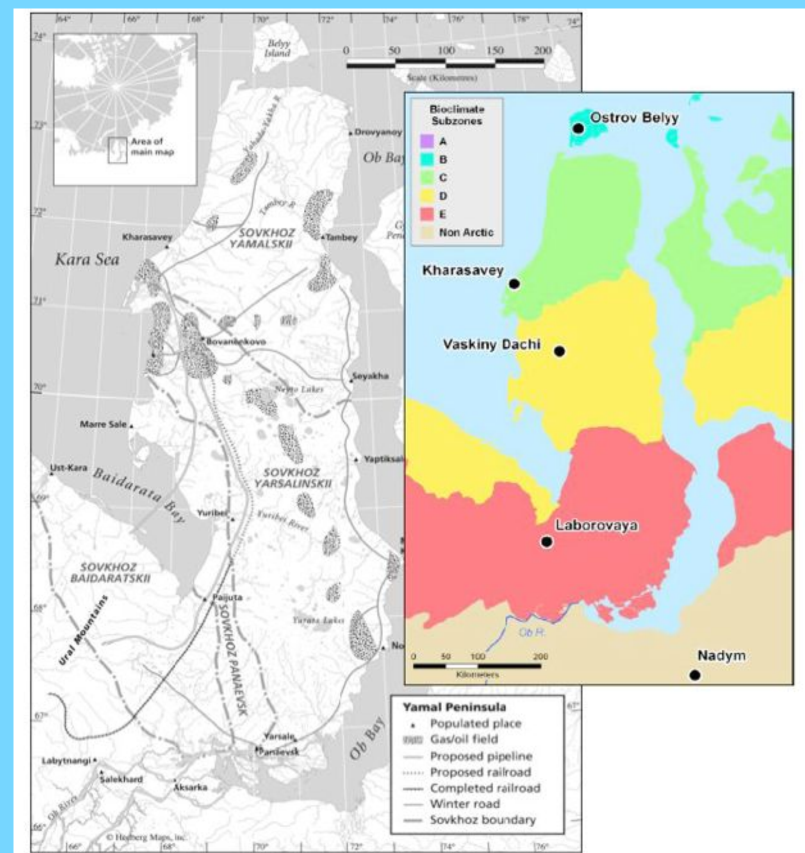
Collaborative research: Greening of the Arctic – Synthesis of models to examine the effects of climate, sea-ice, and terrain on circumpolar vegetation change. 2005-2008. National Science Foundation, Office of Polar Programs, Arctic System Sciences, SASS (Synthesis of Arctic System Science)

Application of space-based technologies and models to address land cover / land use change problems on the Yamal Peninsula, Russia 2006-2009. NASA LCLUC (Land Cover Land Use Change), NEESPI (Northern Eurasia Earth Science Partnership Initiative)

Adaptation to rapid land-use and climate changes on the Yamal Peninsula, Russia: Remote sensing and models for analyzing cumulative effects. 2009-2011. NASA LCLUC, NEESPI

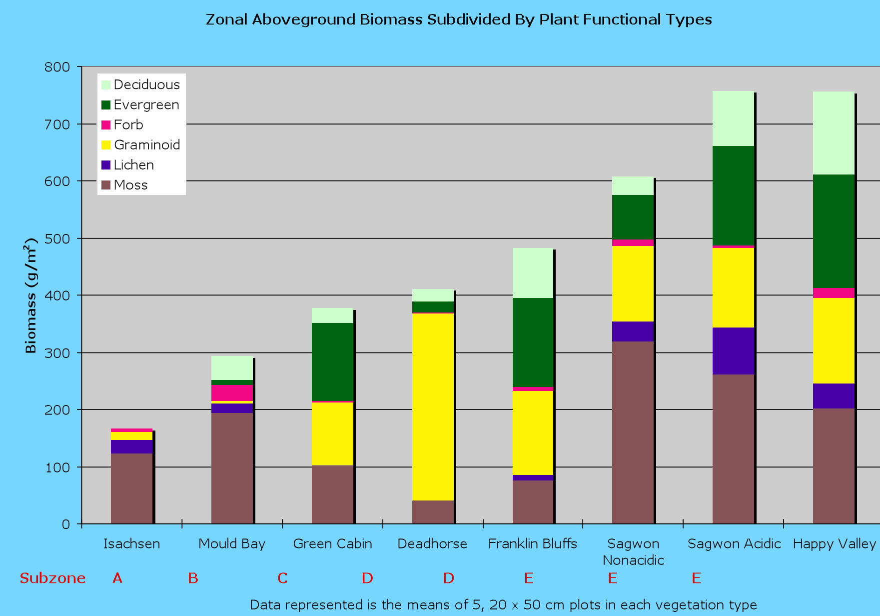


North American Arctic Transect (NAAT)

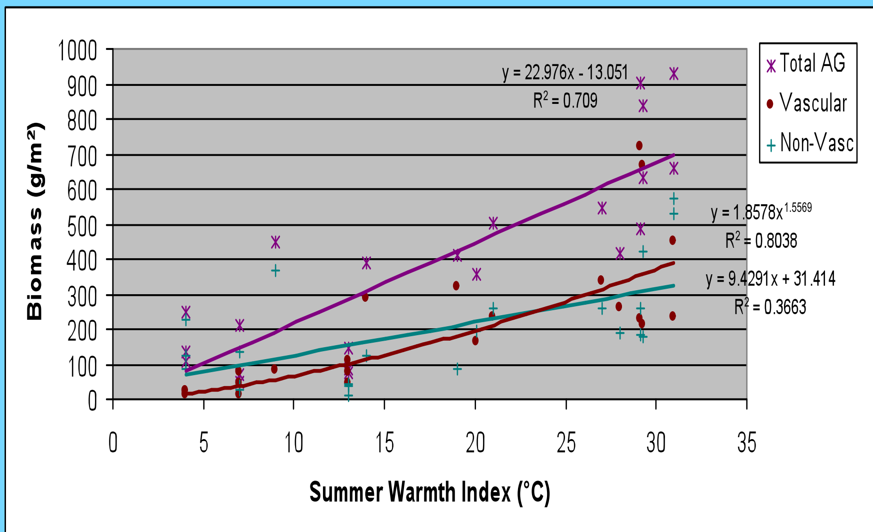


Yamal Arctic Transect (YAT)

Walker et al. (2008)

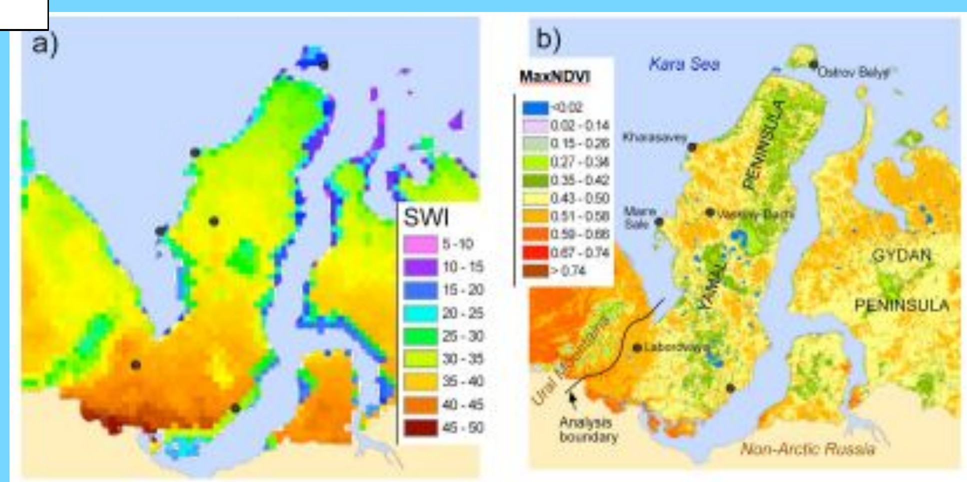


NORTH AMERICA



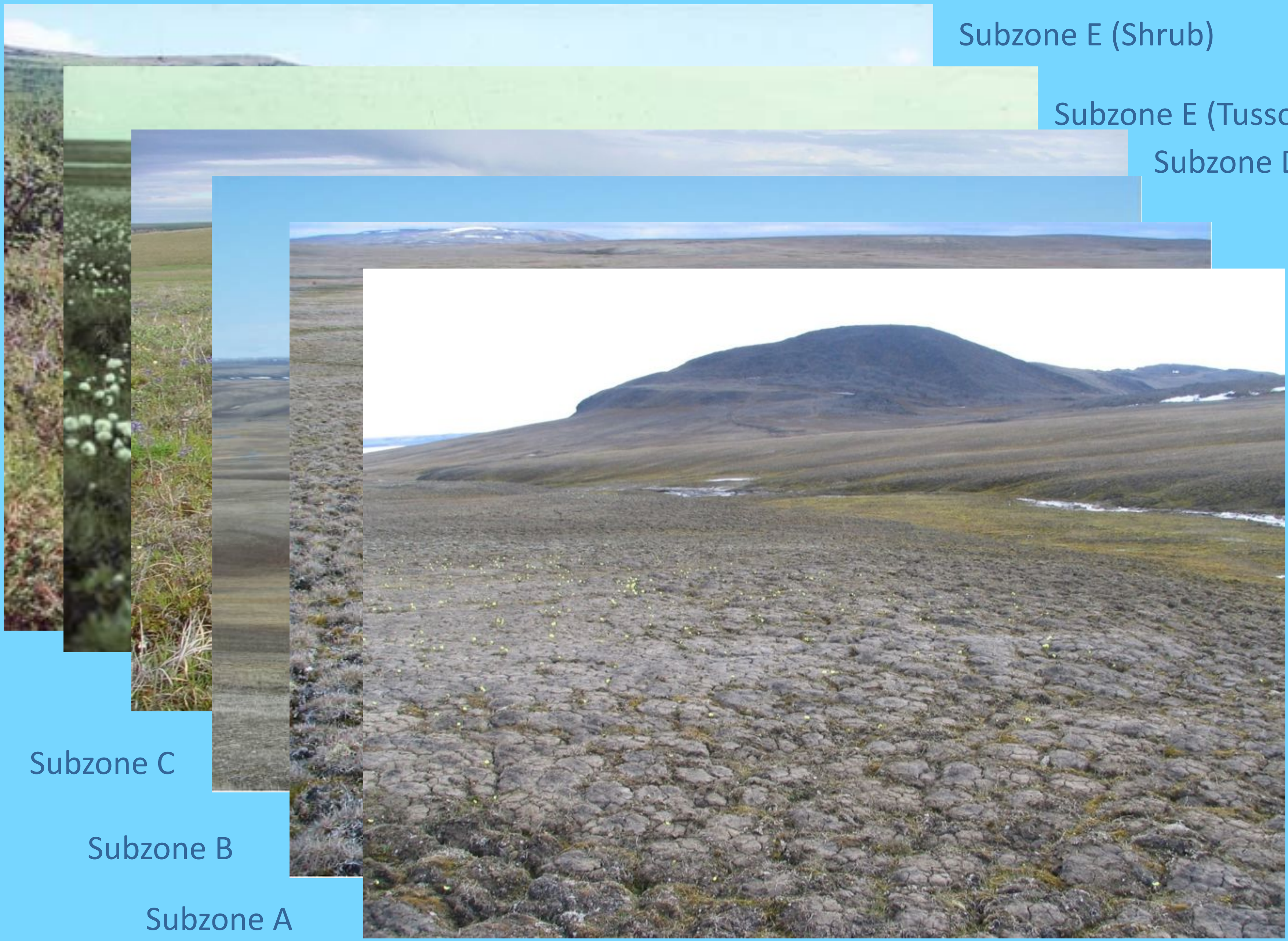
Epstein et al. (2008)

YAMAL, RUSSIA



Walker et al. (2009)

North American Arctic Transect



Subzone E (Shrub)

Subzone E (Tussock)

Subzone D

Subzone C

Subzone B

Subzone A

(photos by D.A. Walker and H.E. Epstein)

Yamal Arctic Transect

Forest Tundra (Forest)

Forest Tundra (Tundra)

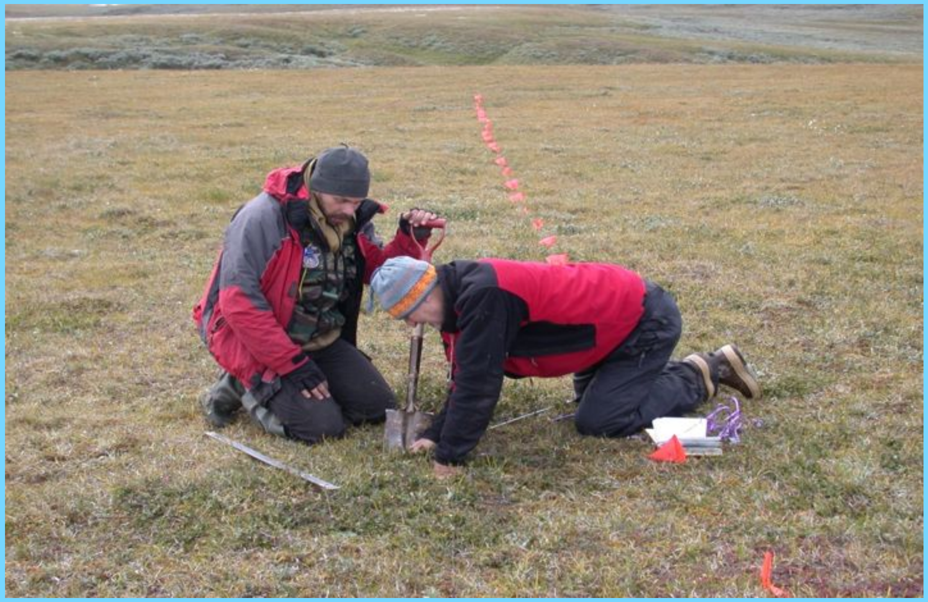
Subzone E

Subzone D

Subzone C

Subzone B

(photos by D.A. Walker and H.E. Epstein)

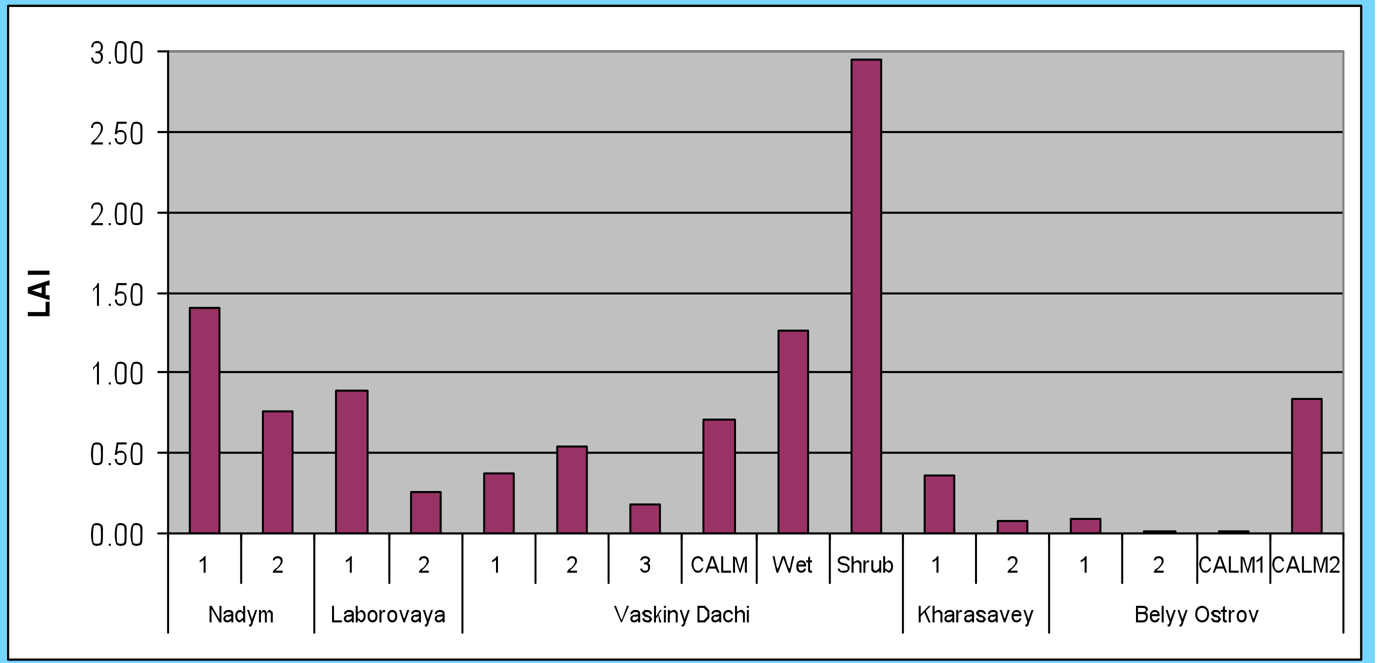


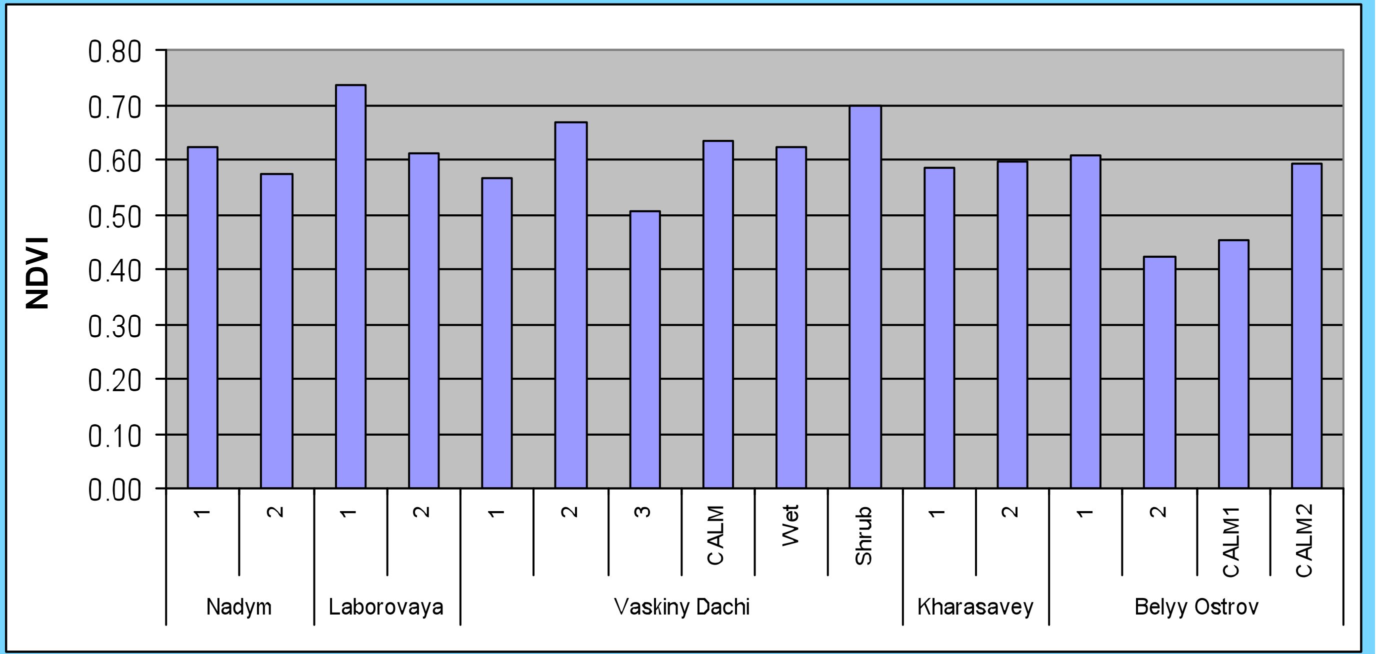
Remote Sensing
- maximum NDVI
- Land Surface Temperatures (LST)

Field Data Collection
- sampling grids and transects
- aboveground biomass harvests
- NDVI (ASD PSII)
- LAI (Li-Cor LAI-2000)
- soil analyses (top 10 cm)

Data Analysis
- Best-fit regressions (within reason)
- Each data point represents a great deal of field data (2-4 sampling grids, each with 5+ 0.1-m^2 biomass harvests and 250+ LAI, NDVI measurements)

Regional and landscape scale variability in LAI NDVI for the Yamal Region





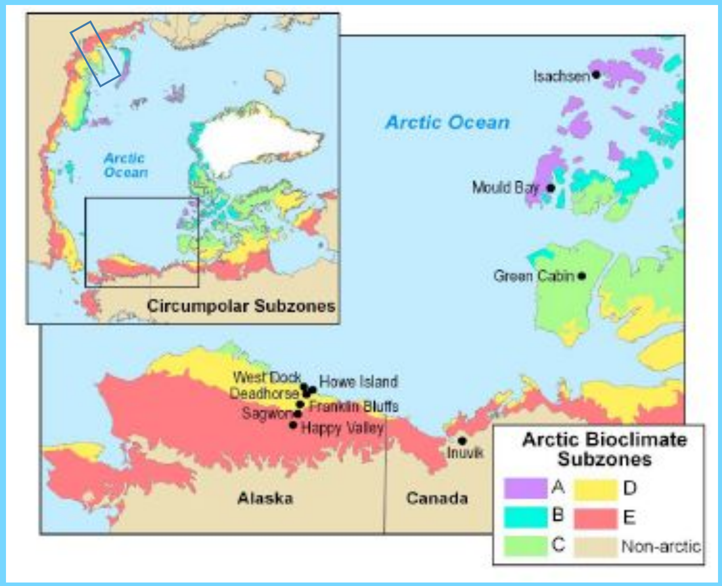
RESEARCH QUESTIONS

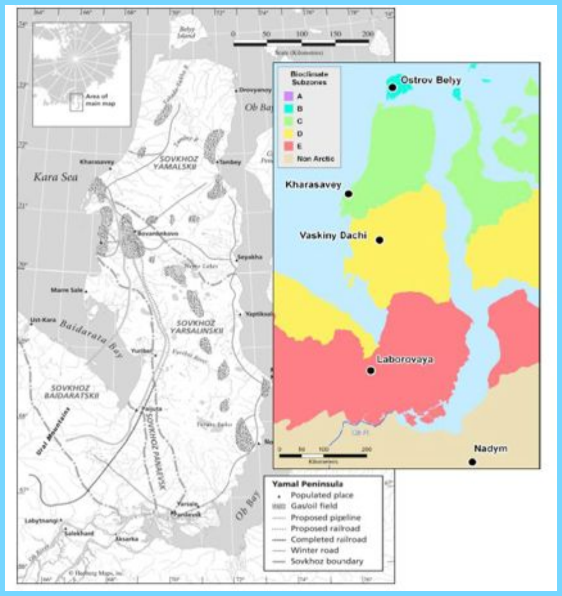
1) How do vegetation properties, such as aboveground biomass, Normalized Difference Vegetation Index (NDVI), and Leaf Area Index (LAI) vary along two latitudinal temperature gradients in arctic tundra?

2) How do soil properties vary along these arctic latitudinal gradients?

3) How do these relationships differ between the North American Arctic Transect (NAAT) and the Yamal Arctic Transect (YAT – northwestern Siberia)?

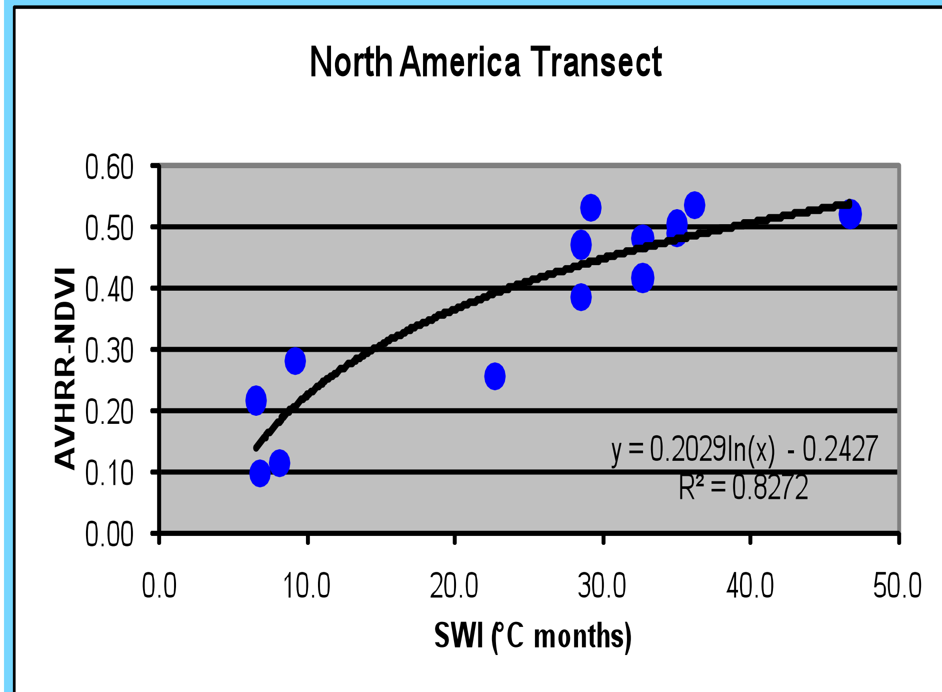
4) What are the potential causal mechanisms for any differences?

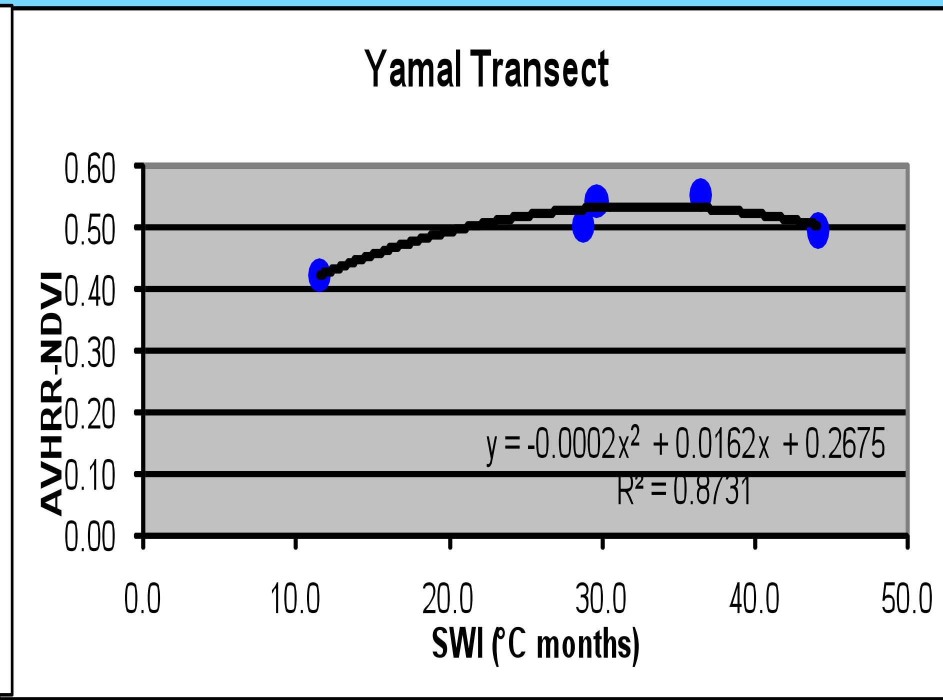




Regional scale (sites) relationship between temperature and NDVI for each transect

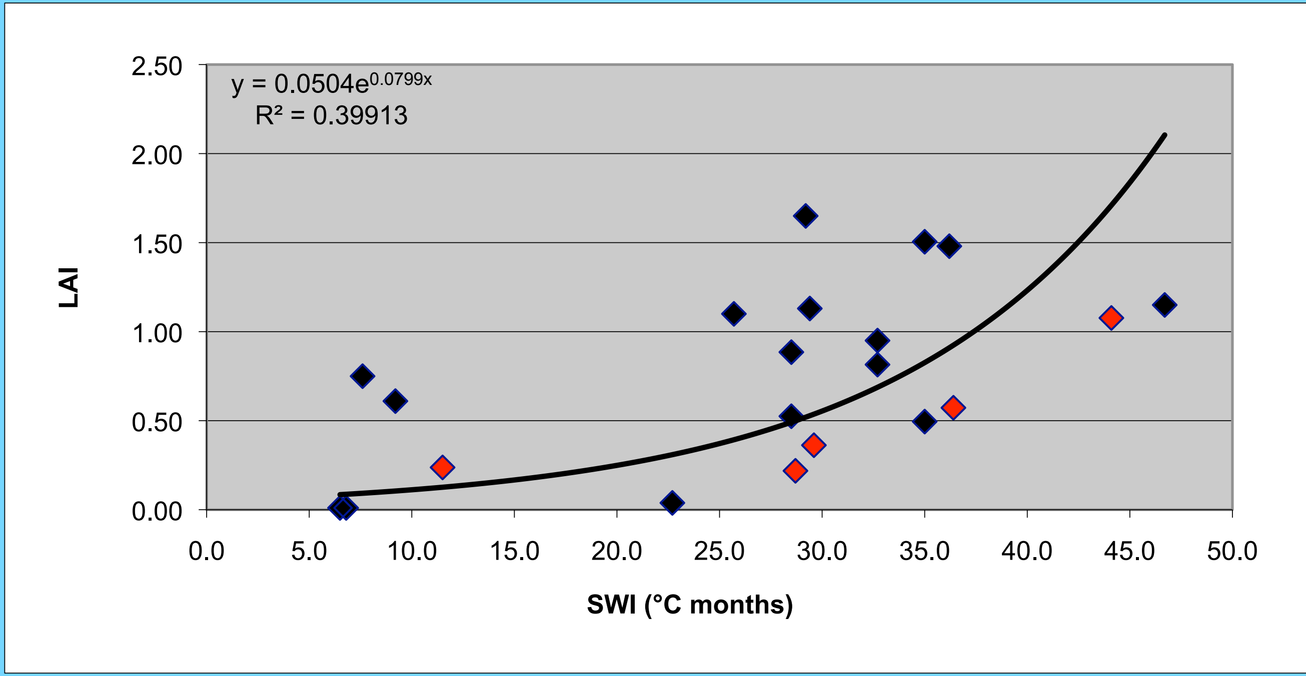
- Max AVHRR NDVI (1km² encompassing each site) 1993-1995
- Summer Warmth Index (SWI – mean monthly temperatures > 0°C) estimated from AVHRR Land Surface Temperatures (12.5km) 1982-2003

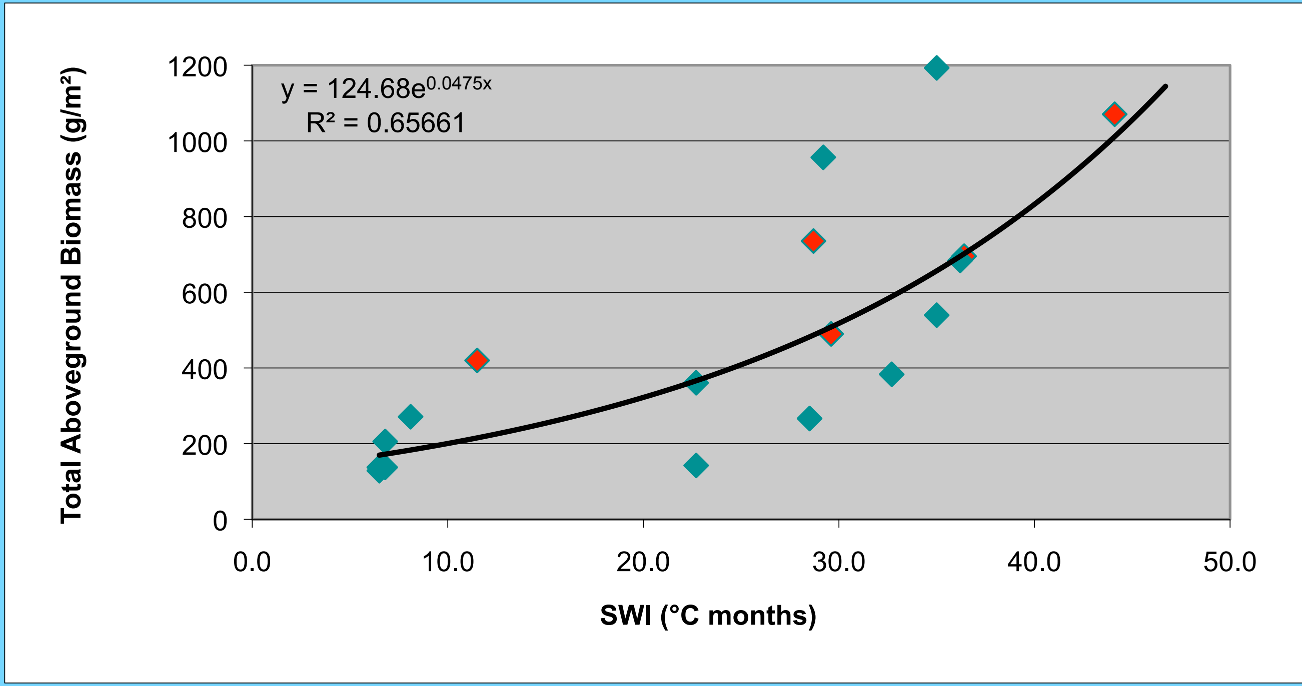




- -For similar SWI, AVHRR-NDVI is greater for the Yamal than for the NAAT, particularly at the colder climates
- -Differences are likely related to glacial history and resulting soil substrates glaciation vs. marine transgressions

LAI and Total Aboveground Biomass along both transects



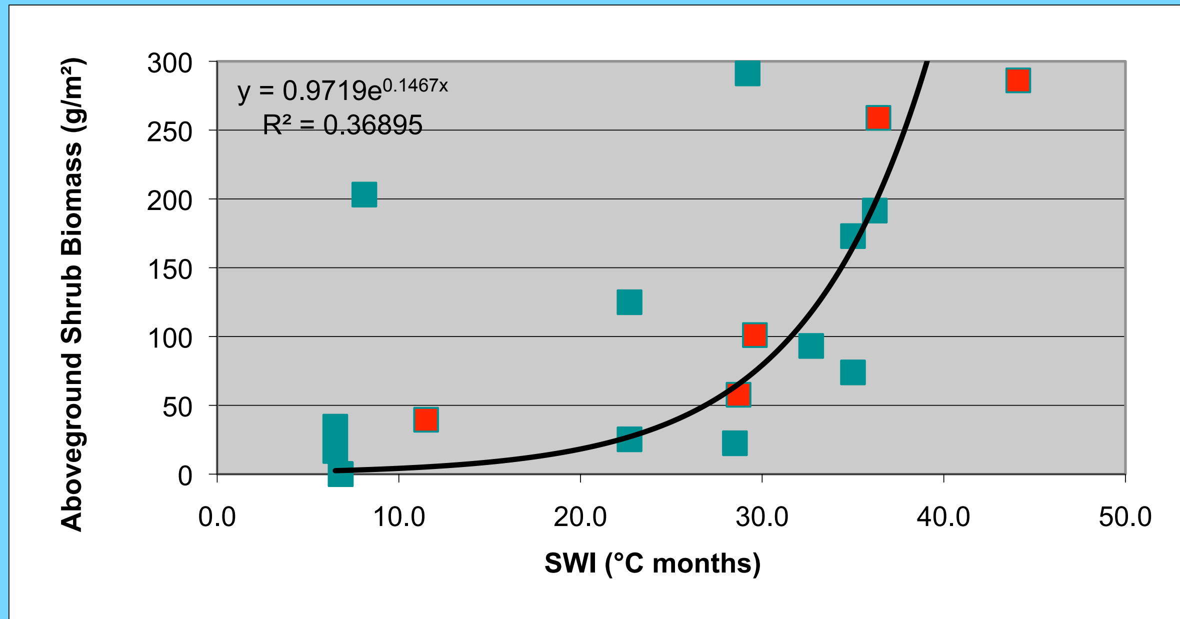


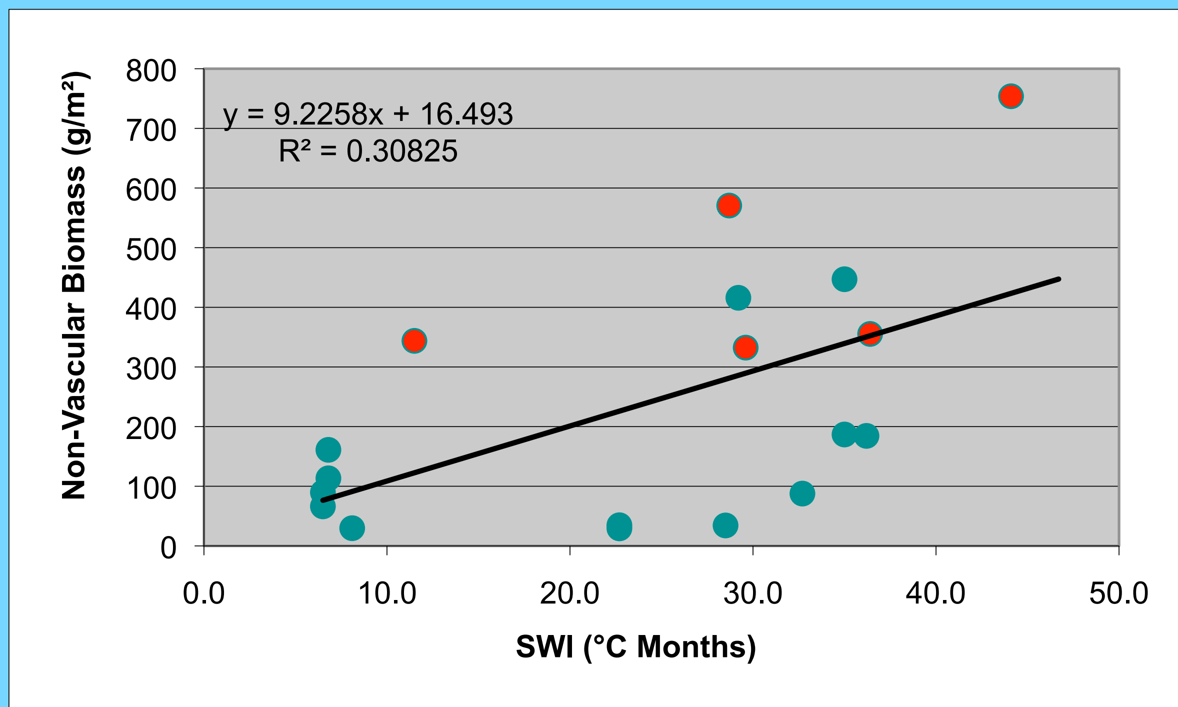
YAMAL

-Lower LAI

-Greater Total Aboveground Biomass

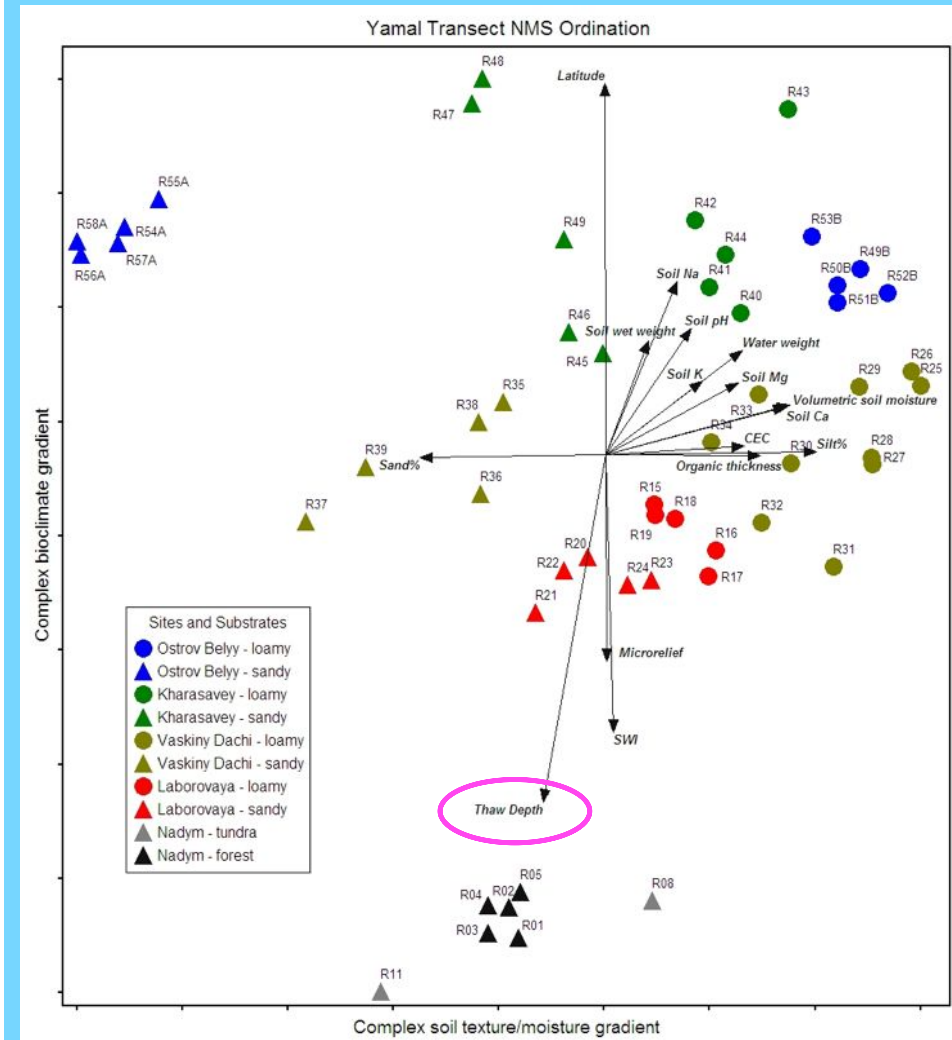
Shrub and Non-Vascular Biomass along both transects

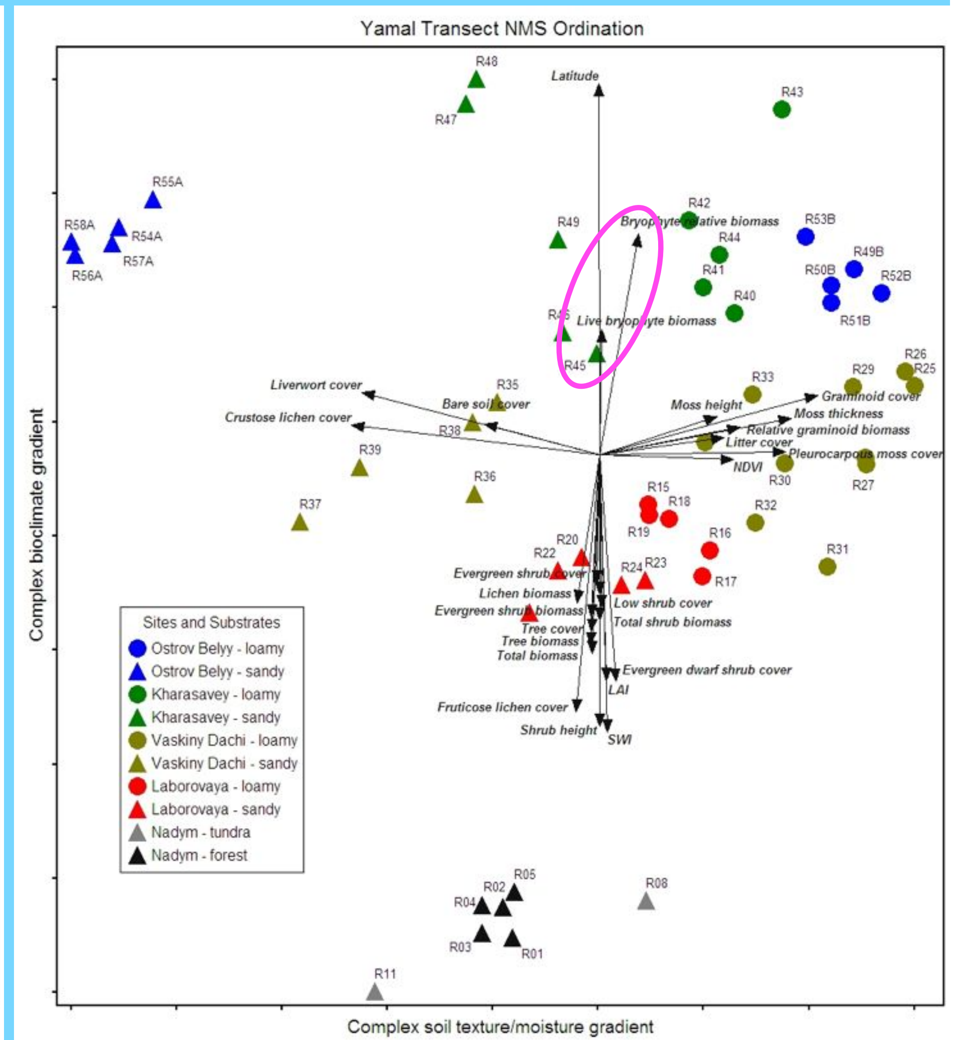




YAMAL

-Similar Shrub Biomass
-Greater Non-Vascular Biomass

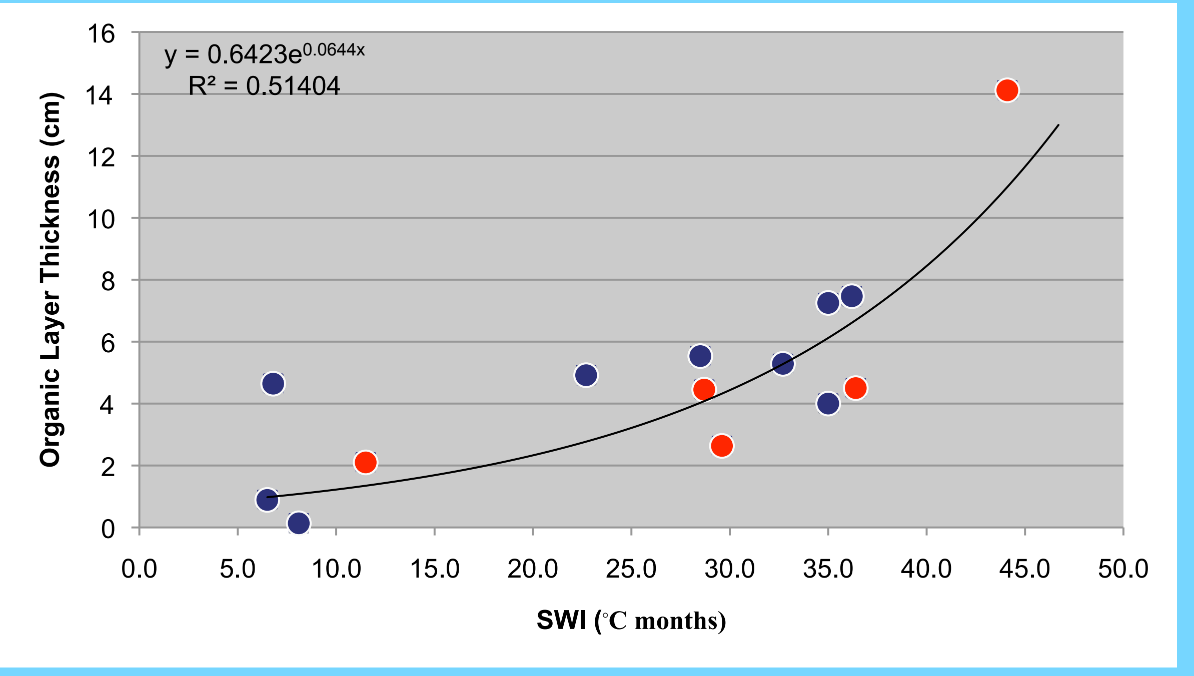


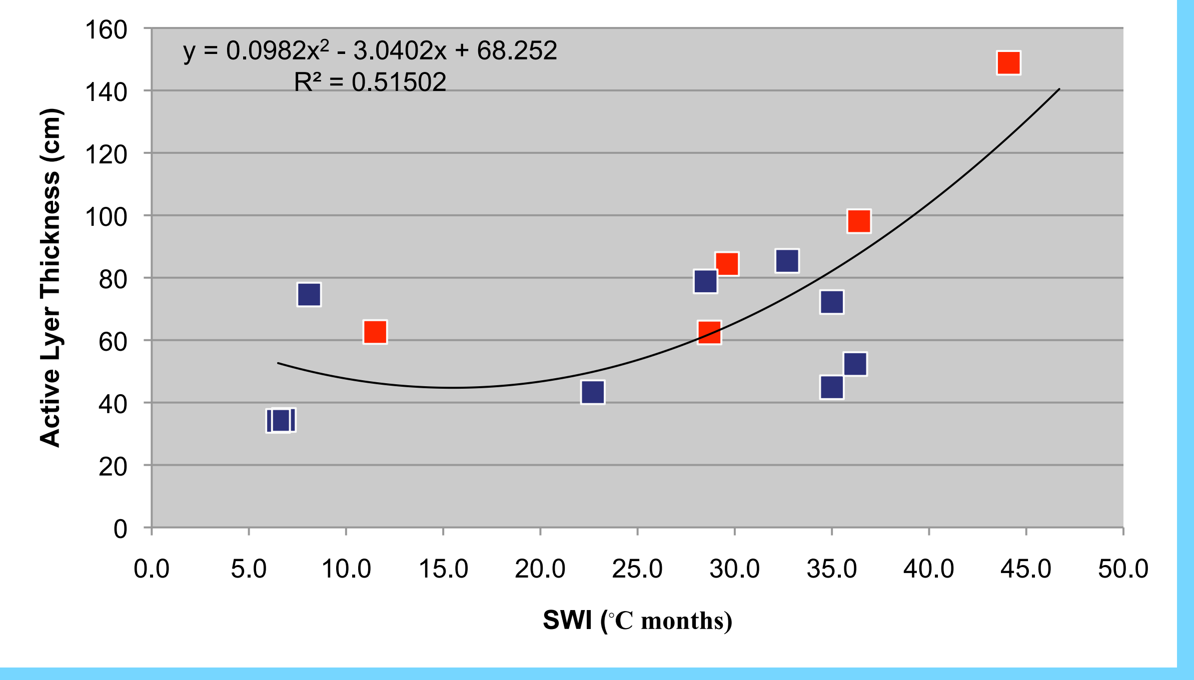


- Ordination of data from releves on the Yamal Peninsula

(Frost et al. in prep)

Organic Layer Thickness and Active Layer Thickness

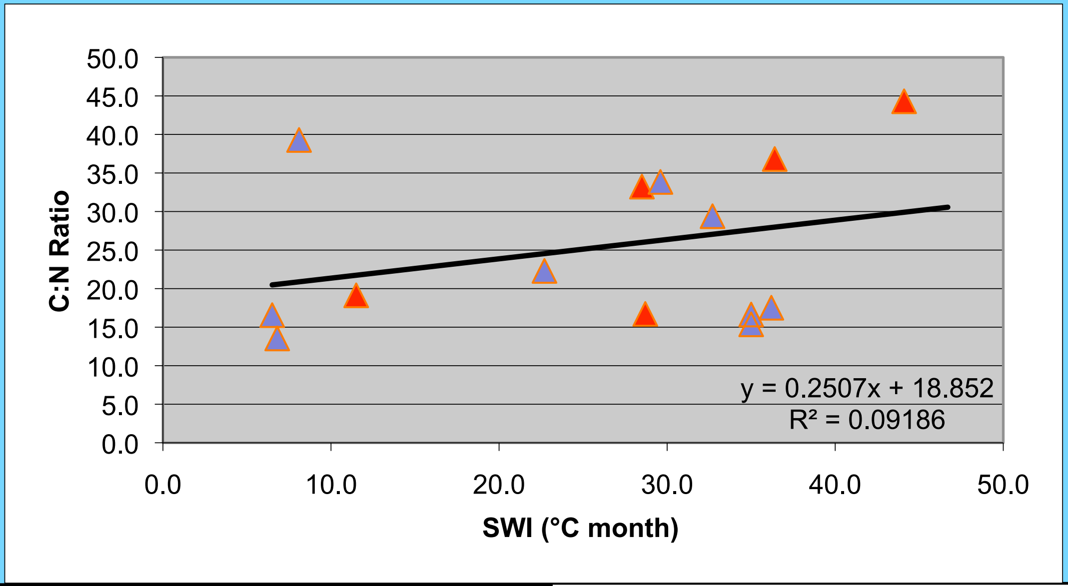


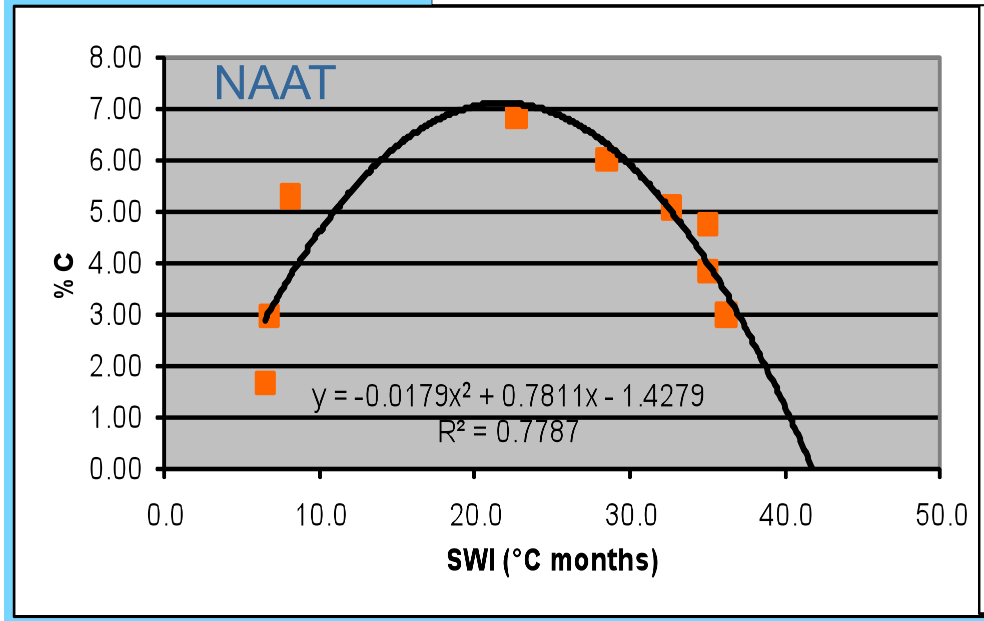


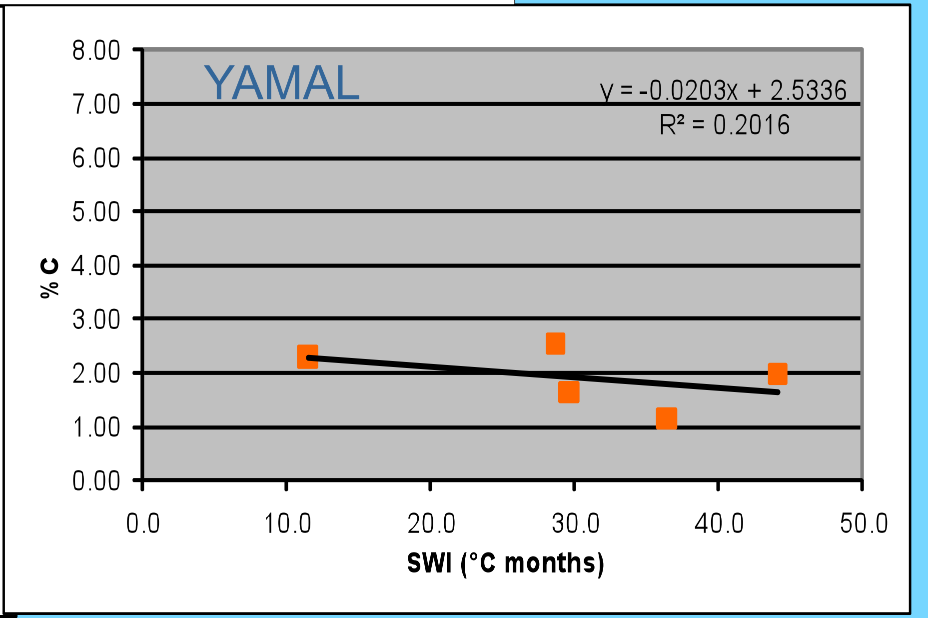
YAMAL

-Similar Organic Layer Thickness
-Greater Active Layer Thickness

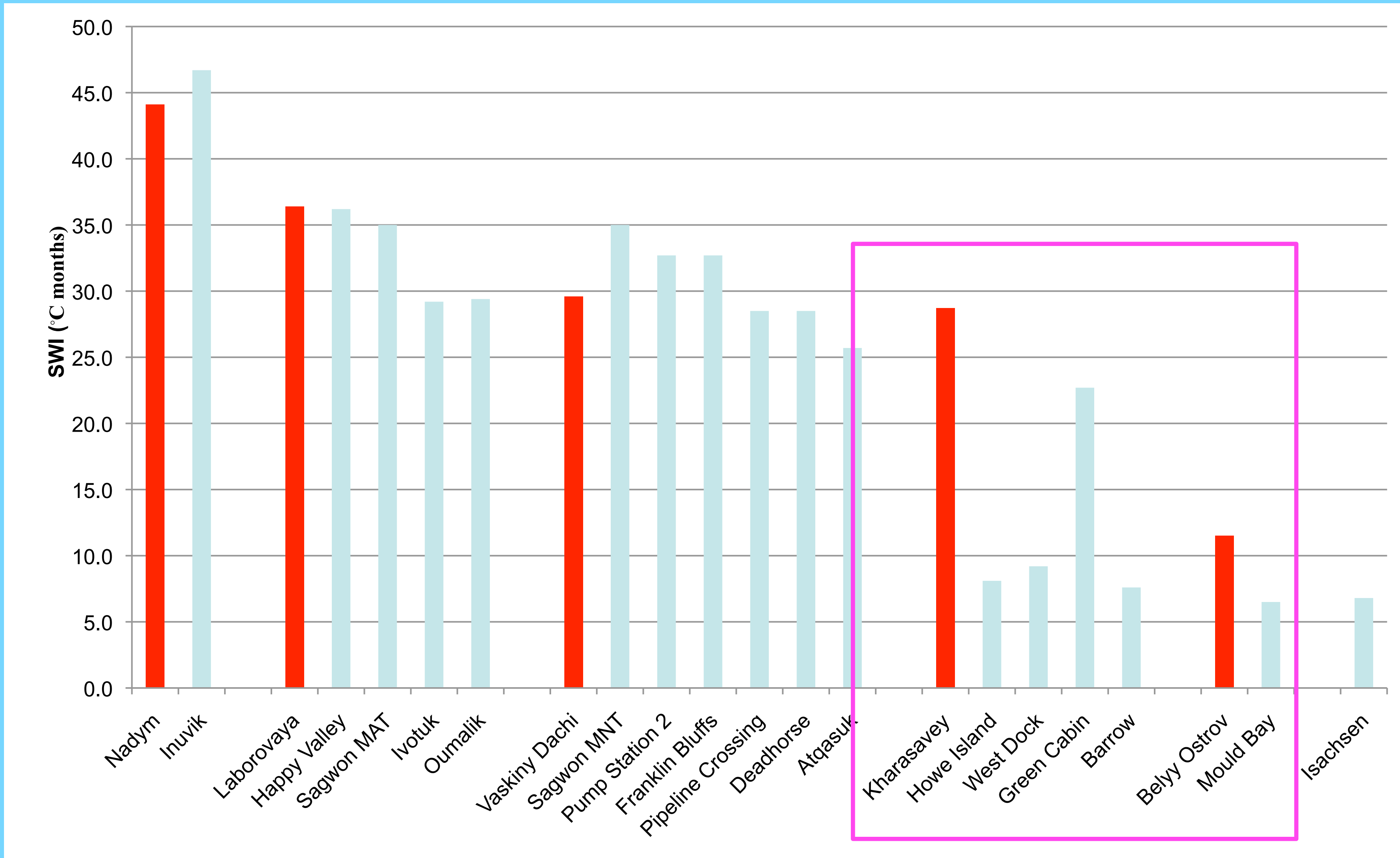
Mineral Soil C and N







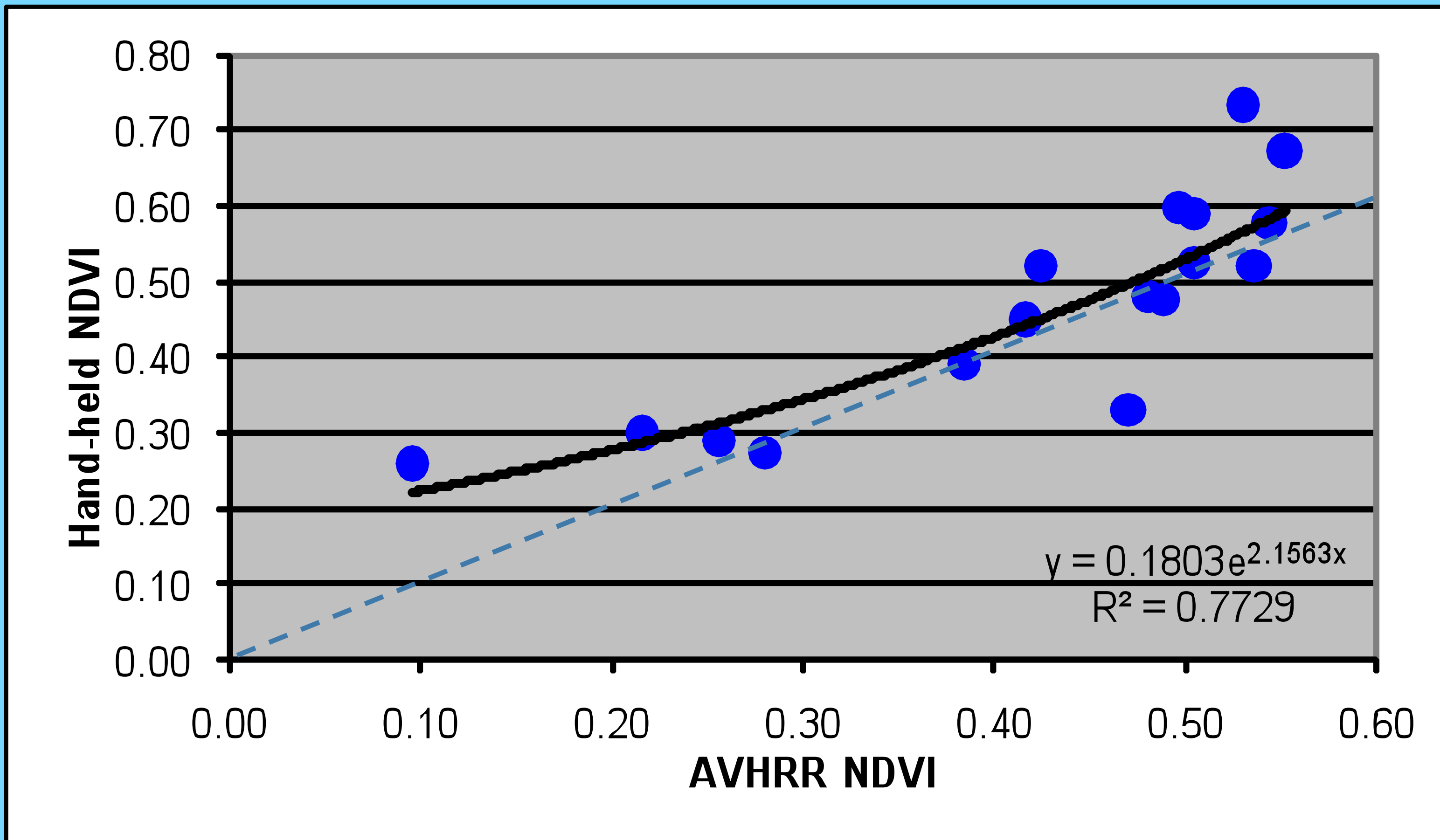
-Parabolic relationships of %C with SWI for the NAAT
-Low %C across the Yamal
-Possibly faster nutrient cycling on the Yamal



-High Arctic (Subzones C and B) sites on the Yamal are warmer than comparable subzonal sites in North America

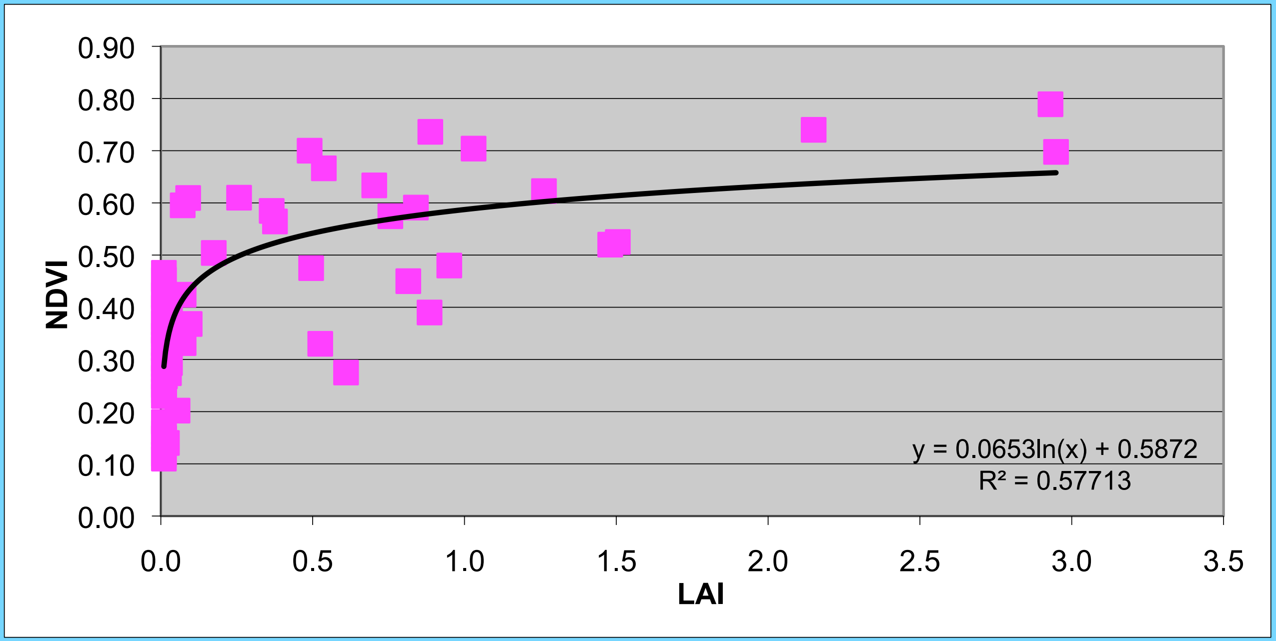
How well does the AVHRR data estimate what is on the ground?

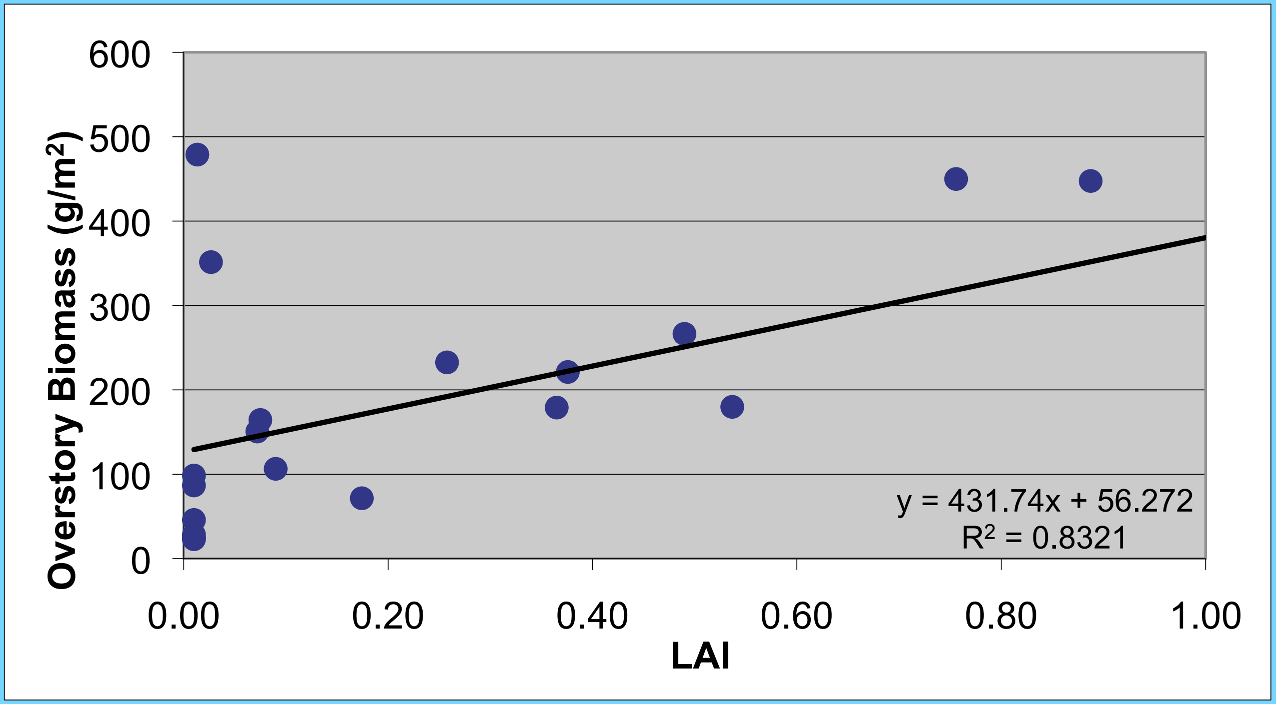
- AVHRR 1km² vs. hand-held NDVI



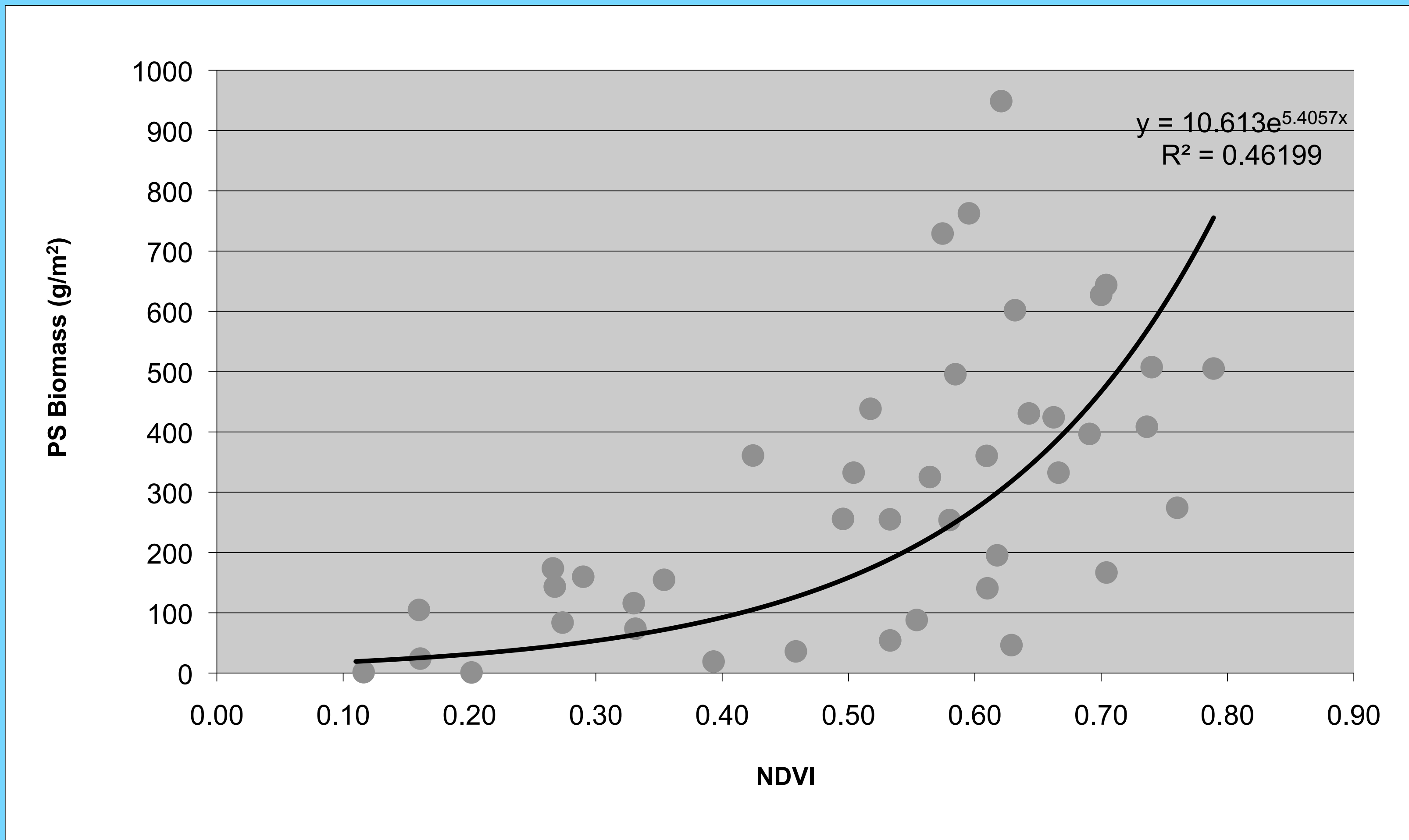
-Coarse-scale NDVI underestimates the fine-scale (makes sense)

Finer-scale data (within sites – grids and transects)





Hand-held NDVI vs. total photosynthetic biomass



CONCLUSIONS

-Development of a comprehensive, synthetic dataset of field vegetation and soil properties along two full arctic tundra temperature transects.

-Regional-scale positive relationships between summer warmth and NDVI, LAI, and aboveground biomass components.

-Regional-scale positive relationships between summer warmth and organic layer thickness, mineral soil C:N, and parabolic relationships with mineral soil %C and active layer thickness.

-Yamal (Russia) transect has higher NDVI, lower LAI, higher total aboveground biomass, and higher non-vascular (essentially moss) biomass than North America

-Yamal has lower mineral soil %C and greater active layer thickness than North America (possible differences in nutrient cycling rates).

-Comparable High Arctic subzones (B and C) on the Yamal have greater summer warmth than the North American sites.

[redacted]