Vegetation Biomass, NDVI, and LAI along the Eurasian Arctic Transect

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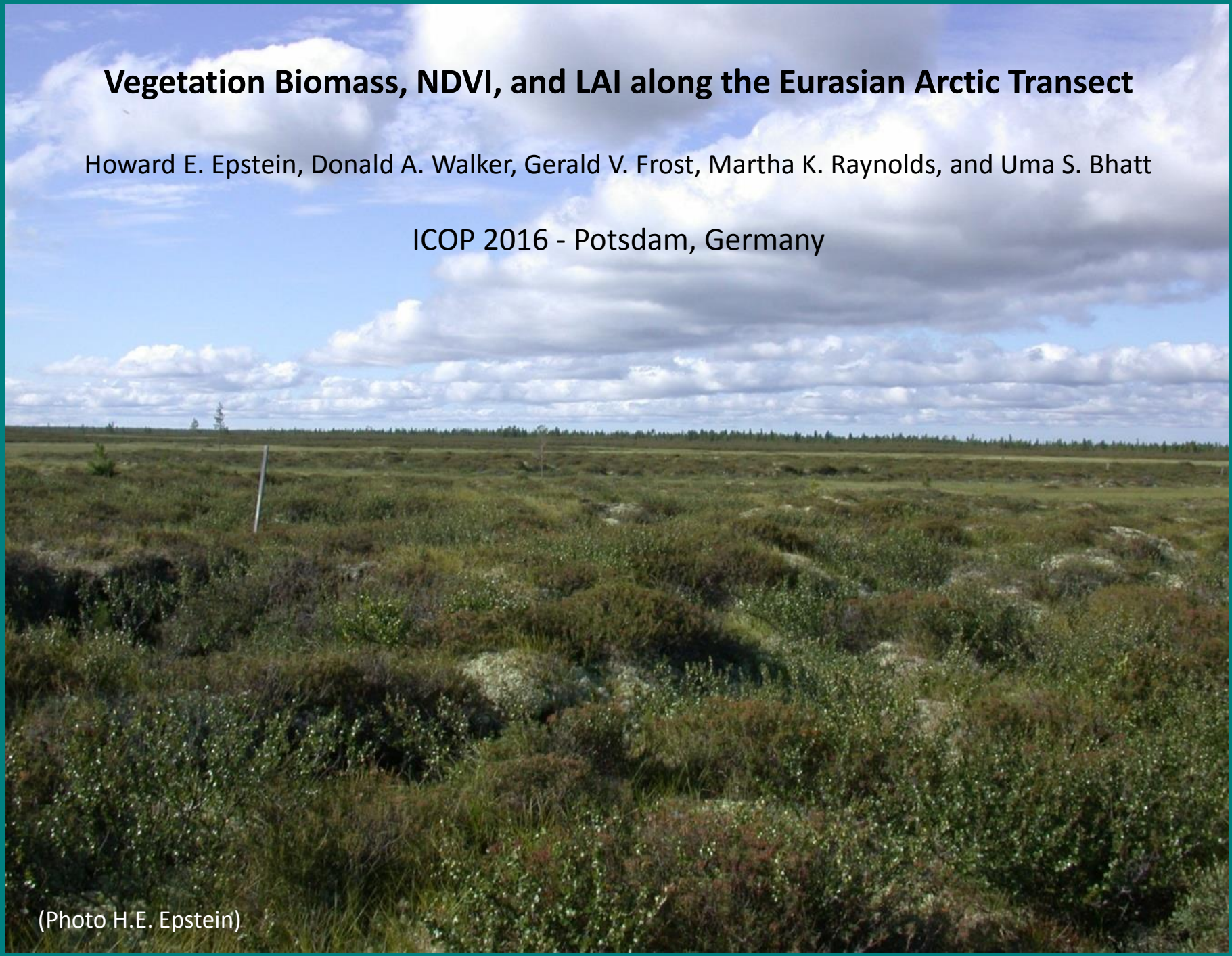
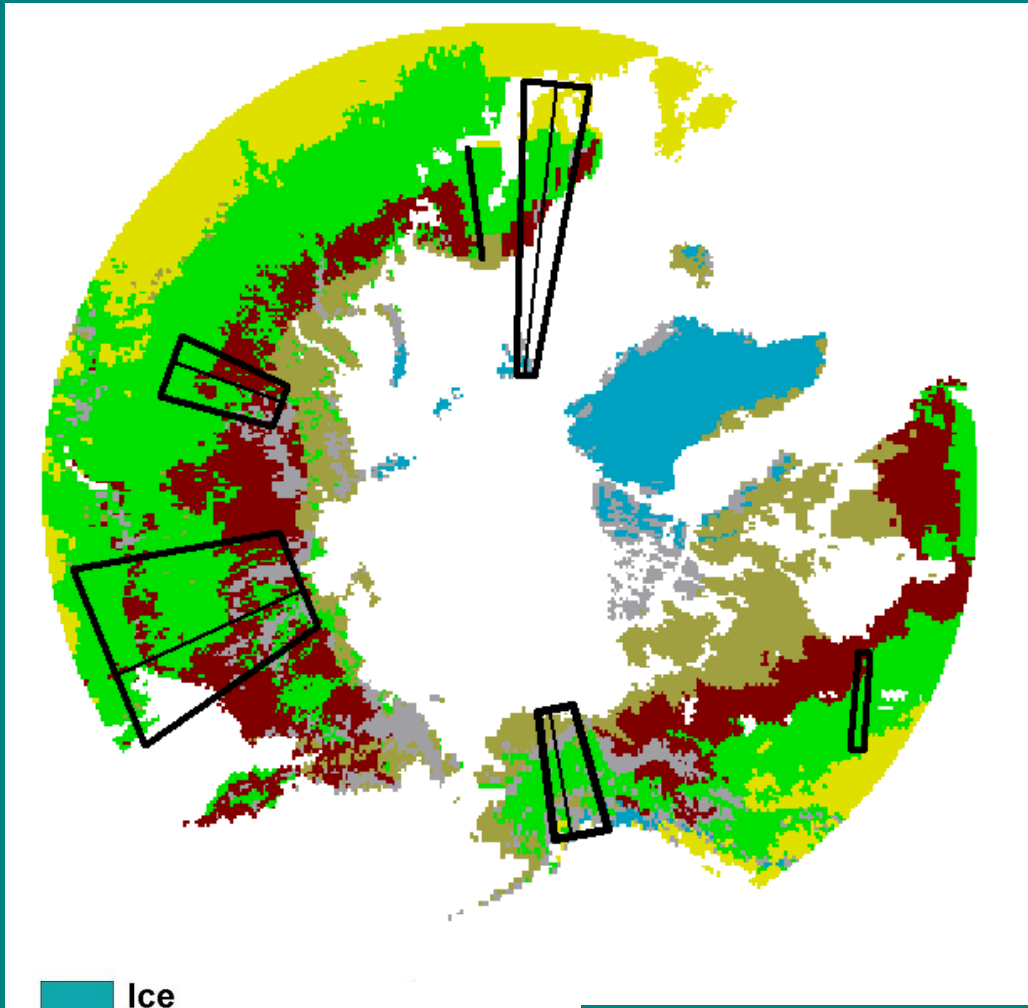
ICOP 2016 - Potsdam, Germany

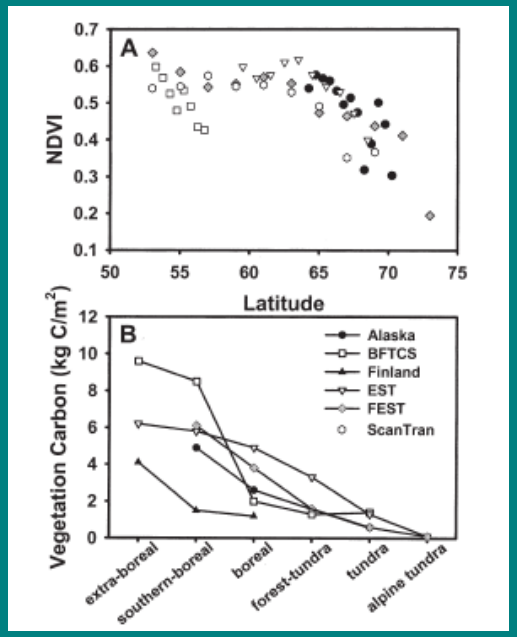


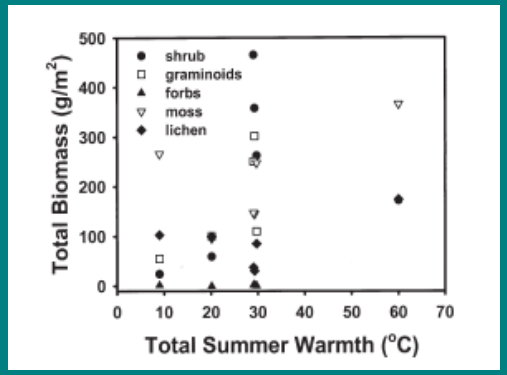
(Photo H.E. Epstein)

Spatial Patterns of Tundra Vegetation



IGBP High-Latitude Transects





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

McGuire et al. 2002 (Journal of Vegetation Science)

Presentation Topics

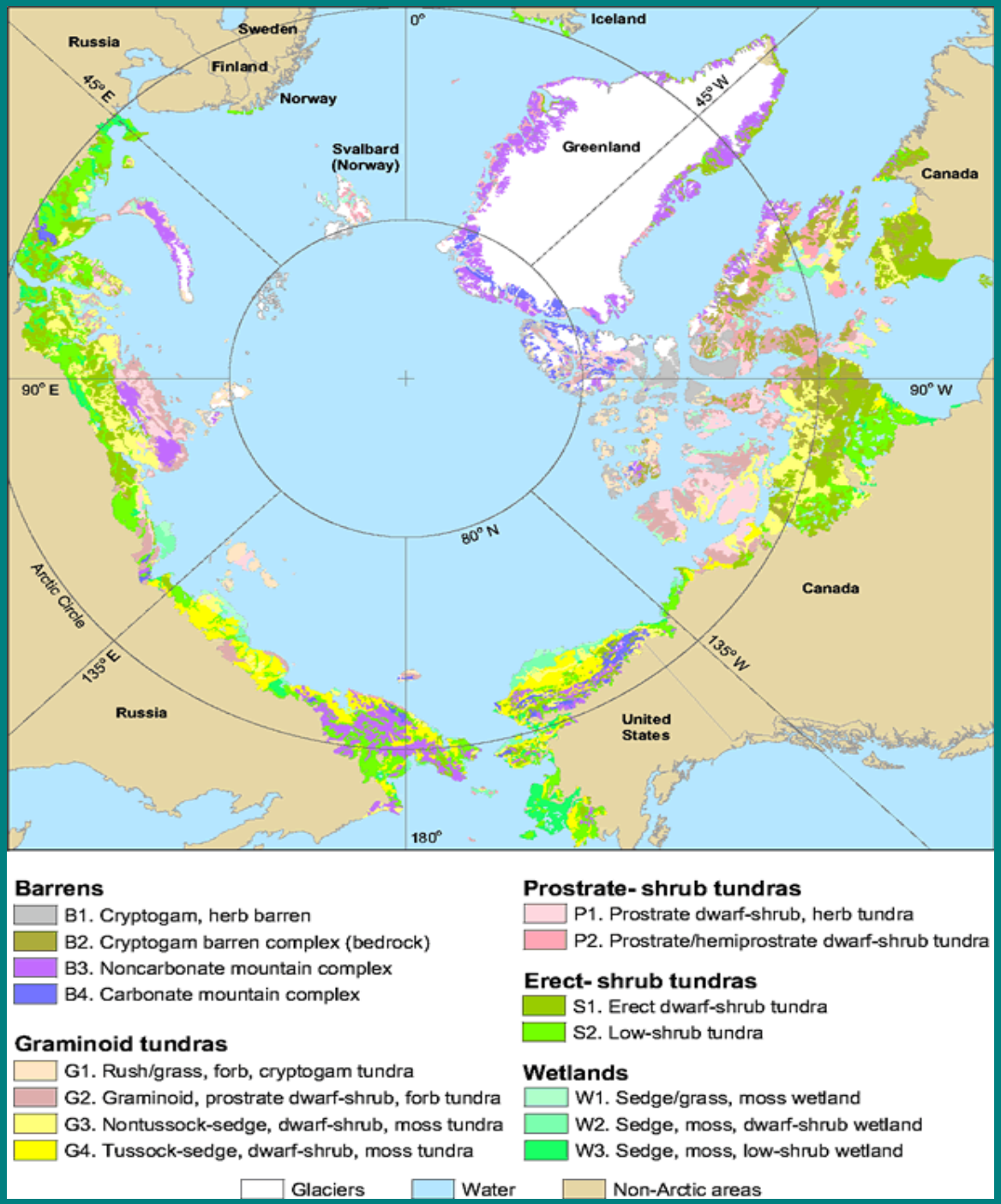
1) Field observations of vegetation biomass, NDVI, and LAI along the Yamal Peninsula, Siberia and beyond (the EAT)

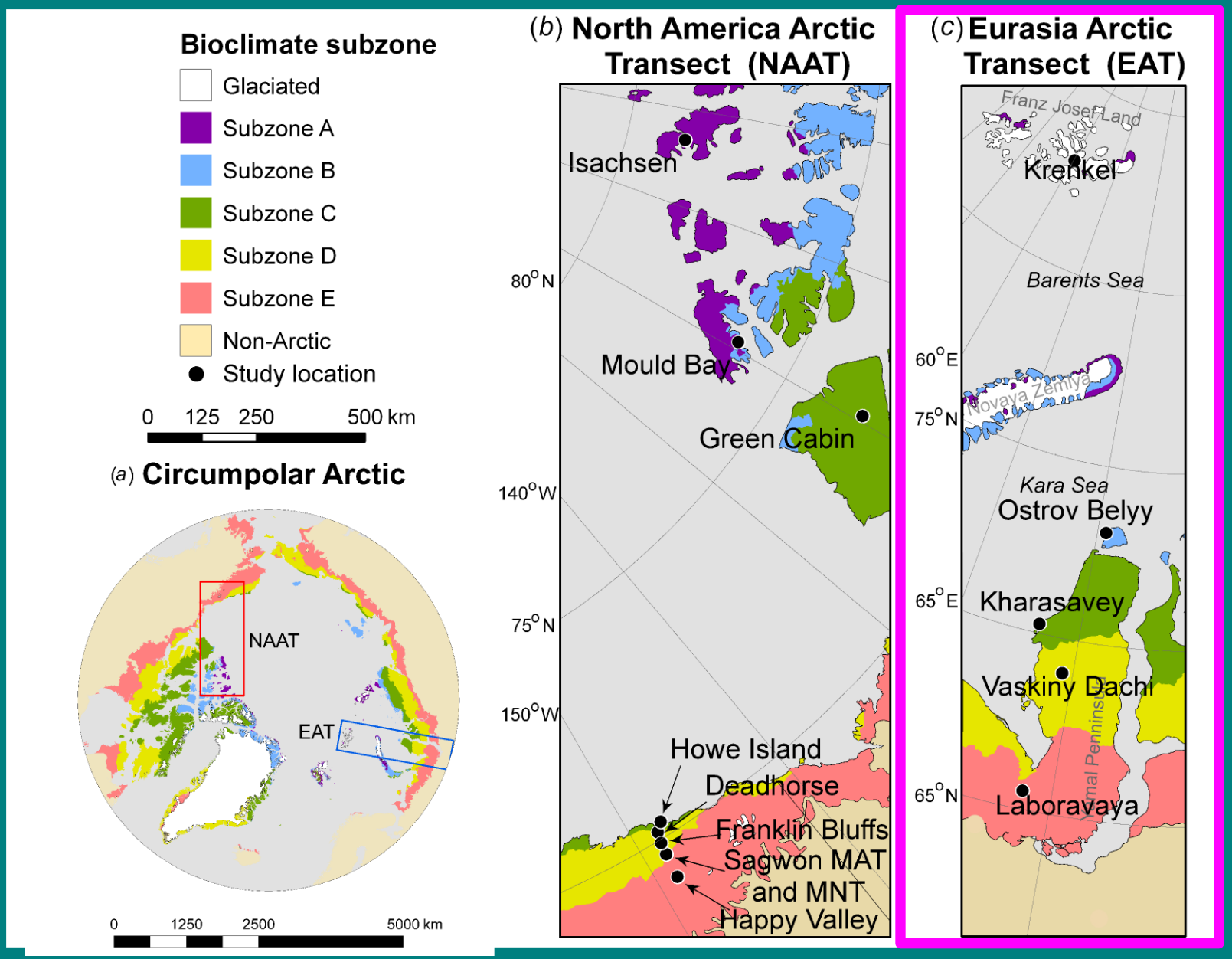
2) Satellite remote sensing of vegetation trends along the EAT

3) Satellite remote sensing of vegetation trends throughout Eurasia

The Arctic Tundra Biome

Walker, D. A., 2005. The Circumpolar Arctic Vegetation Map. Journal of Vegetation Science.





Raynolds et al. (2012), Walker et al. (2012)

Eurasian Arctic Transect

Subzone A

Subzone B

Subzone C

Subzone D

Subzone E

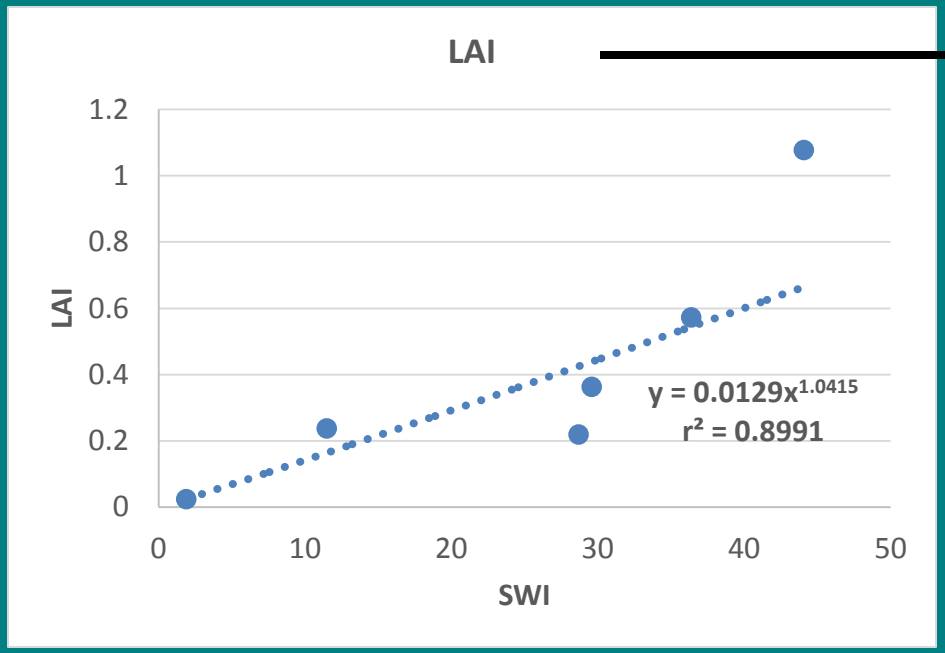
(Photos D.A. Walker and H.E. Epstein)

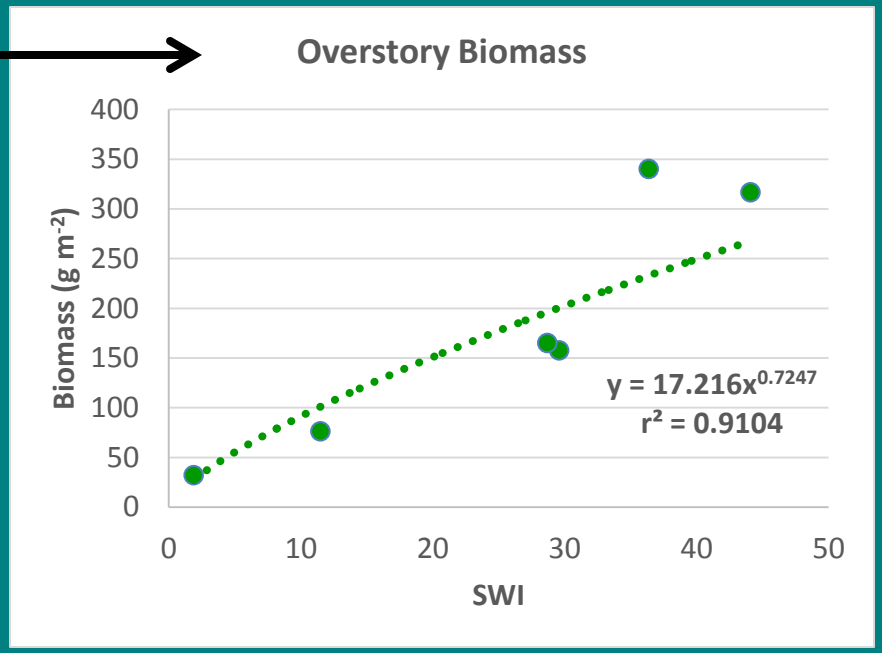
Eurasian Arctic Transect Location Data

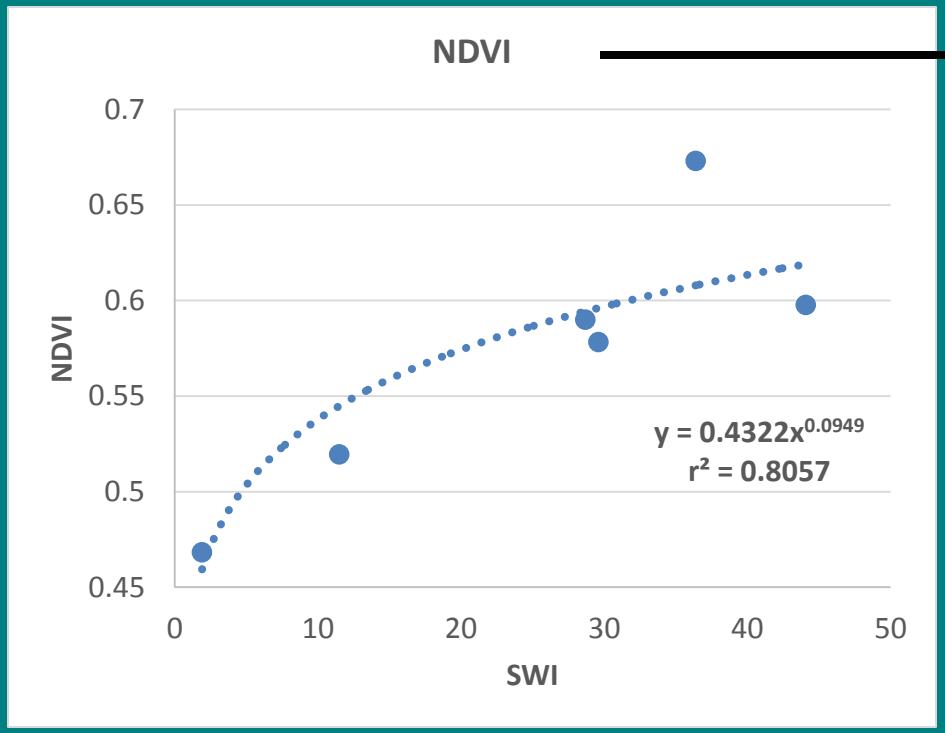
Location	Longitude, latitude	Bioclimate subzone	Summer Warmth Index (˚C mo)	Mean annual temperature (˚C)	Geological setting, slope, elevation (m), parent material, surface geomorphology of zonal site	Soil texture, pH	Dominant vegetation
Nadym	65.19° N, 72.53° E	Forest-Tundra	40	-6.5	Fluvial terrace II, Karga-age, (about 20-40 kya), alluvial sands	Sand 3.25	Lichen woodland: *Pinus sylvestris-Ledum palustre-Cladonia stellaris* (Walker et al. 2008a)
Laborovaya	67.71˚ N, 67.99˚ E	E	38	-7	Hill slope, 2˚ slope SW, 80 m, hillslope colluviun over glacial till (Ermakovsky-age, about 50-110 kya), no patterned ground.	Clay loam, 4.6	Sedge, dwarf-shrub, moss tundra: *Carex bigelowii-Betula nana-Aulacomnium palustre* (Walker et al. 2008b).
Vaskiny Dachi	70.28˚ N, 68.89˚ E	D	22	-8.1	Stable hill crest in strongly eroded section of coastal plain with many landslides, flat, 45 m, marine terrace IV (Kazantsevskaya-age, about 130-117 kya), no patterned ground.	Silt loam, 4.5	Sedge, dwarf-shrub, moss tundra: *Carex bigelowii-Vaccinium vitis idaea-Hylocomium splendens* (Walker et al. 2008b).
Kharasavey	71.18˚ N, 66.98˚ E	C	15.5	-9.7	Coastal plain, marine terrace, flat, 16 m, alluvial-marine sediments, Marine terrace II, Karginsky-age, (about 20-40 kya), no patterned ground.	Silt loam, 4.5	Graminoid, prostrate dwarf-shrub, moss tundra: *Carex bigelowii-Calamagrostis holmii-Salix polaris-Dicranum elongatum-Cladonia* spp. (Walker et al. 2009a)
Ostrov Belyy	73.33˚ N, 70.08˚ E	B	11.5	-10.3	Coastal plain, gentle slope of marine terrace, 2˚ NE, 2 m, alluvial-marine sediments, marine terrace II (Upper Pleistocene to Holocene age), non-sorted circles (0.5-0.7 m diameter).	Loam, 4.6	Nonsorted circle complex: (Inter-circle areas) Graminoid, prostrate dwarf-shrub, moss tundra: *Carex bigelowii-Calamagrostis holmii-Salix polaris-Hylocomiuim splendens.* (Nonsorted circles) Prostrate dwarf-shrub, crustose-lichen barren: *Dryas integrifolia-Arctagrostis latifolia-Racomitrium lanuginosum-Ochrolechia frigida* (Walker et al. 2009b).
Krenkel	80.58˚ N, 57.90˚ E	A	1	-13.3	Hill backslope, 4˚ W, 30 m, hillslope colluvium derived from unconsolidated calcareous sandstone deposits (Mesozoic age), small nonsorted polygons (10-15 cm diameter).	Sandy loam, 6.2	Cushion-forb, lichen, moss tundra: *Papaver dahlianum* spp. *polare-Stellaria edwardsii-Cetrariella delisei-Ditrichum flexicaule*-black soil crust (Walker et al. 2011).

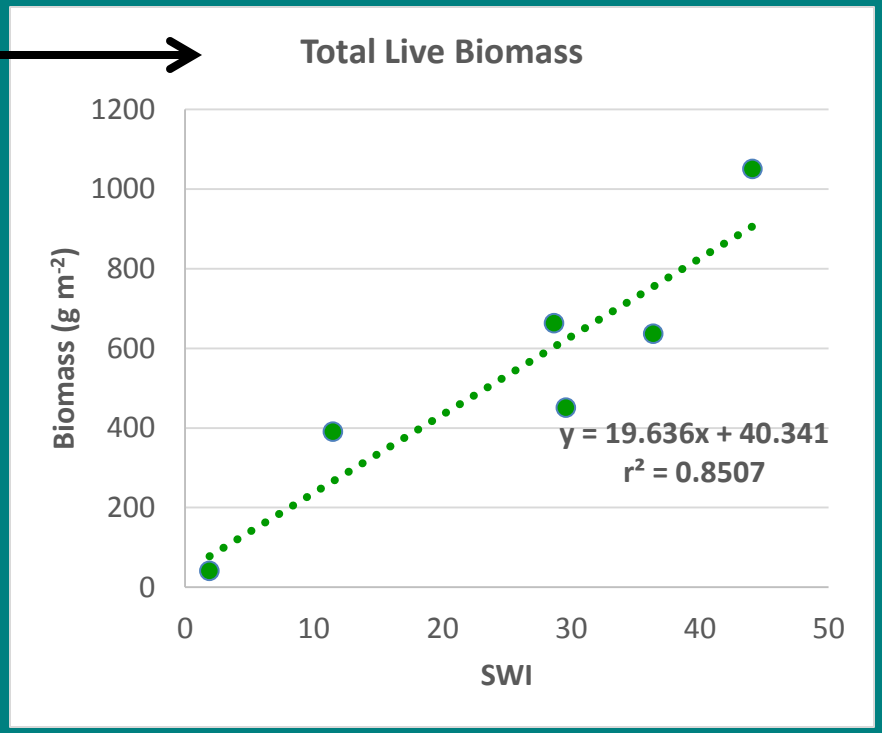
Field Data Collection

- six locations, with 2-3 sites at each location with varying soil textures
- 50 x 50 m sampling grid and five 50 m transects at each site
- NDVI (ASD PSII) at 1-m intervals along the transects
- LAI (Li-Cor LAI-2000) at 1-m intervals along the transects
- five aboveground biomass harvests
- five soil samples (top 10 cm)

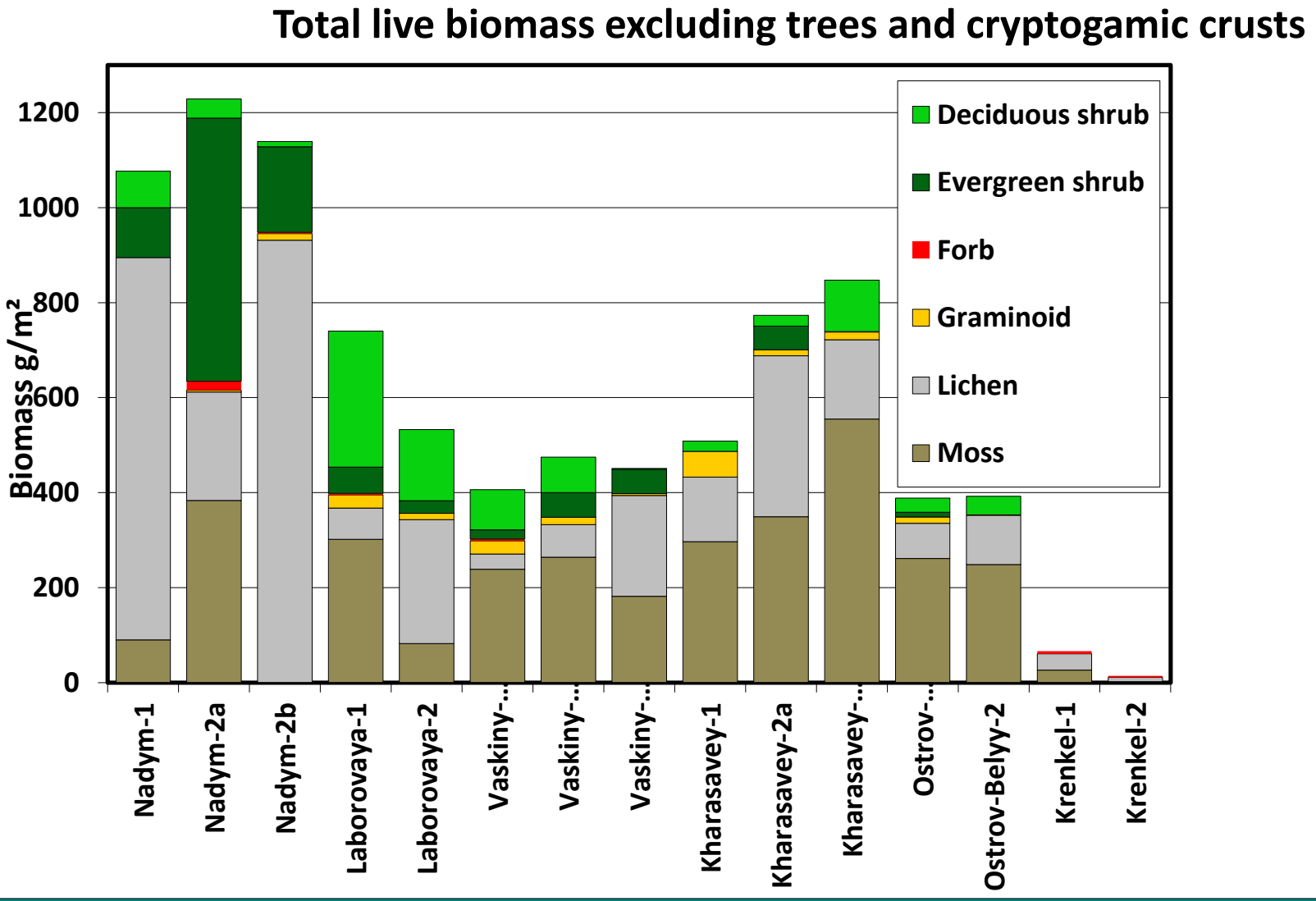

LAI
LAI
SWI
y = 0.0129x^1.0415
r² = 0.8991


Overstory Biomass
Biomass (g m-2)
SWI
y = 17.216x^0.7247
r² = 0.9104

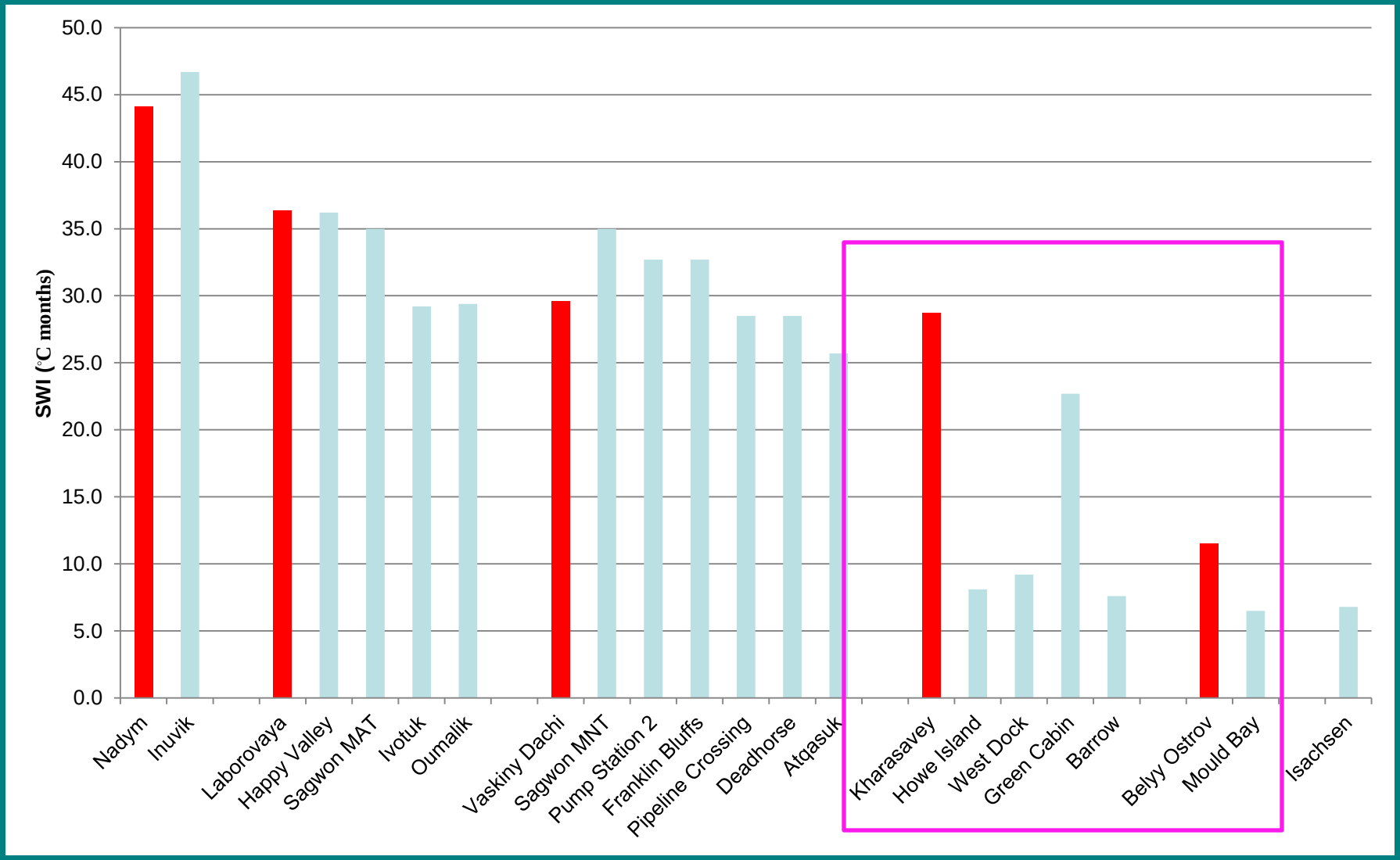

NDVI
NDVI
SWI
y = 0.4322x^0.0949
r² = 0.8057


Total Live Biomass
Biomass (g m-2)
SWI
y = 19.636x + 40.341
r² = 0.8507

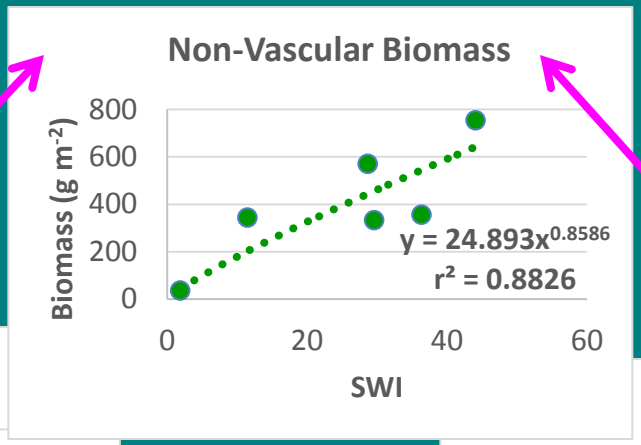
Aboveground biomass by plant functional type (Walker et al. 2012)

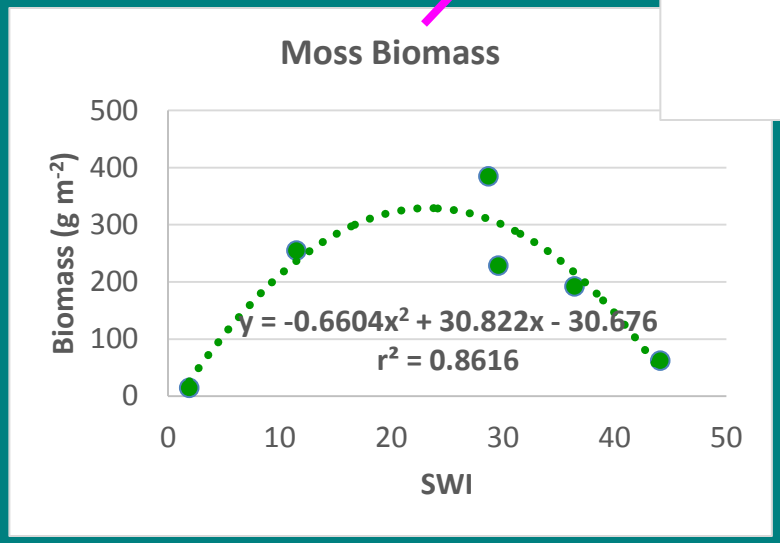


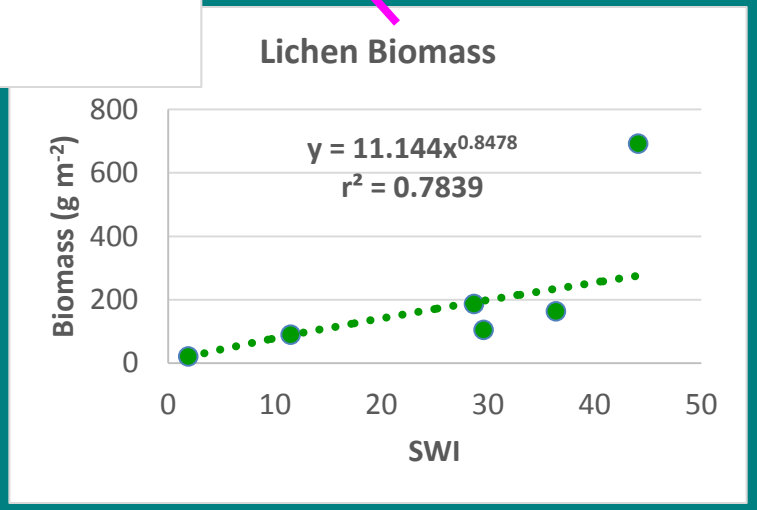
SOUTH → NORTH

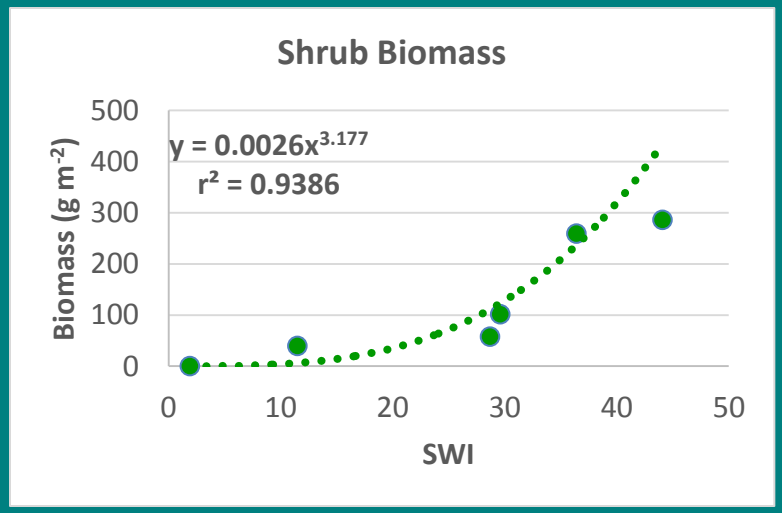


- **High Arctic (Subzones C and B) sites on the Yamal are warmer than comparable subzonal sites in North America**

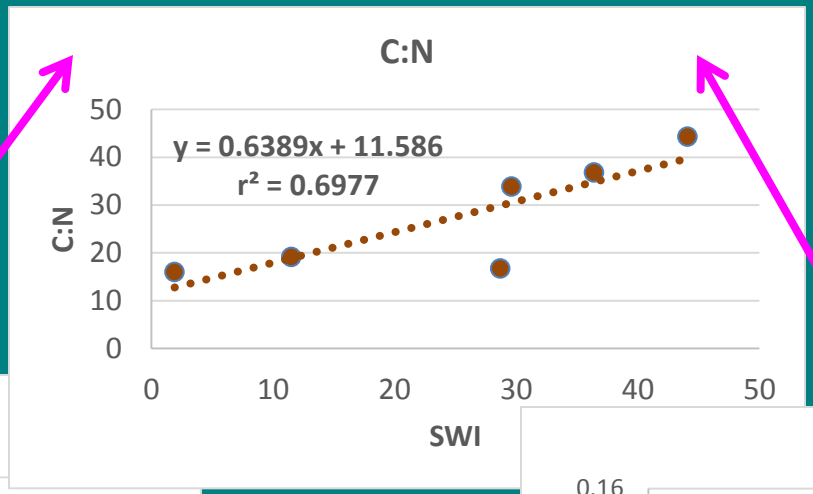

Non-Vascular Biomass
Biomass (g m-2)
800
600
400
200
0
0
20
40
60
SWI
y = 24.893x0.8586
r² = 0.8826

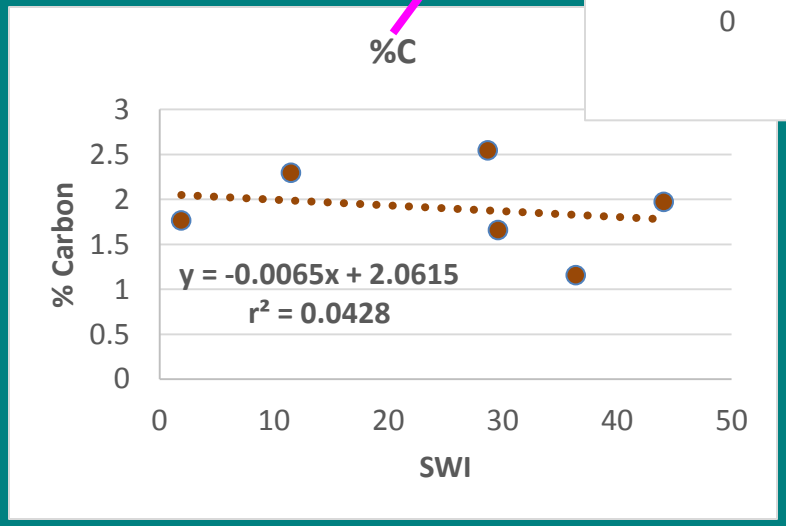

Moss Biomass
Biomass (g m-2)
500
400
300
200
100
0
0
10
20
30
40
50
SWI
y = -0.6604x² + 30.822x - 30.676
r² = 0.8616

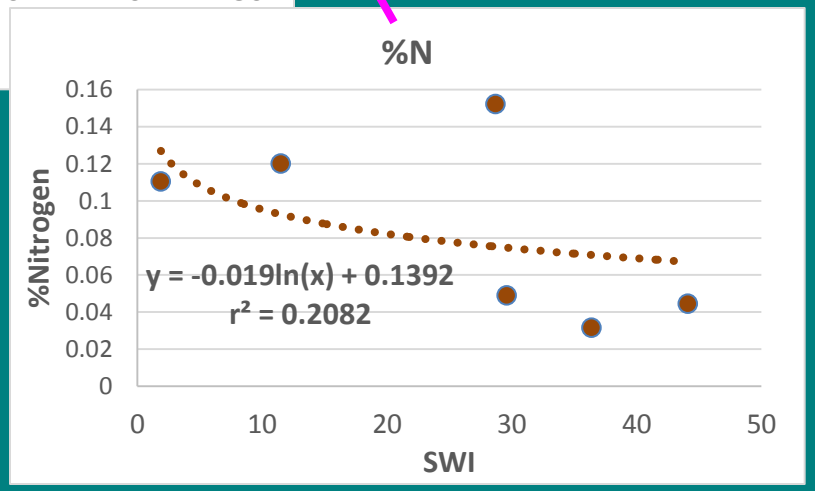

Lichen Biomass
Biomass (g m-2)
800
600
400
200
0
0
10
20
30
40
50
SWI
y = 11.144x0.8478
r² = 0.7839

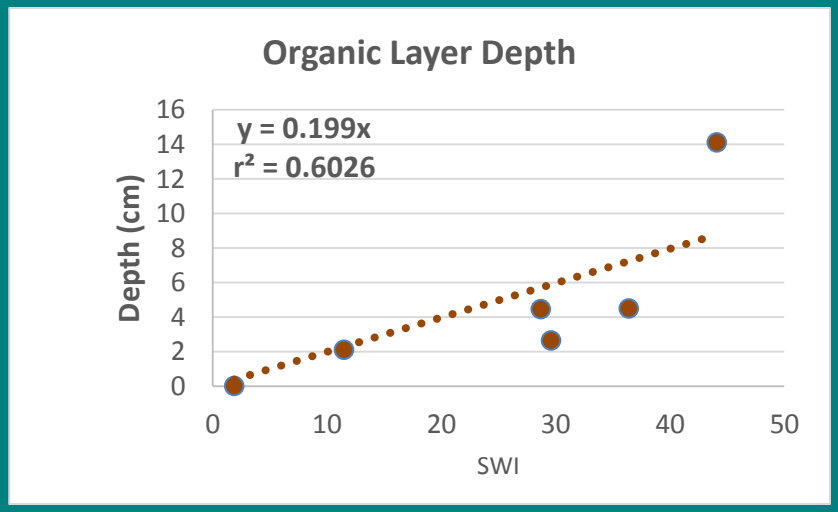

Shrub Biomass
Biomass (g m-2)
500
400
300
200
100
0
0
10
20
30
40
50
SWI
y = 0.0026x3.177
r² = 0.9386

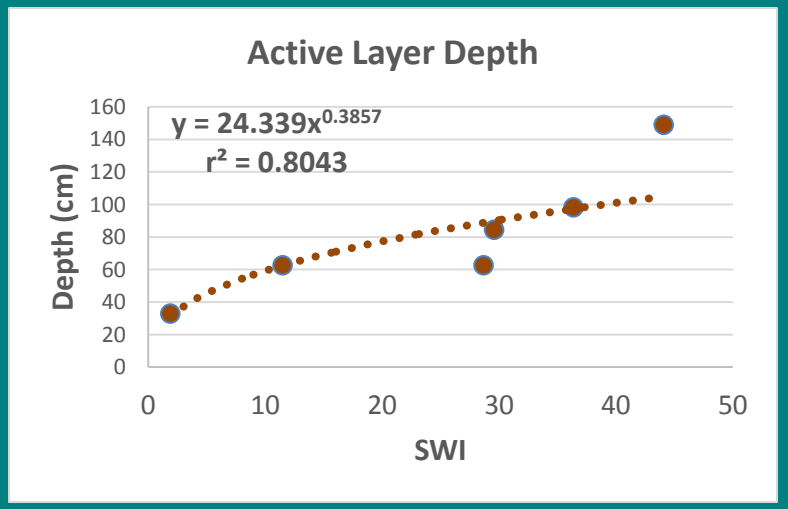
SOILS


C:N
y = 0.6389x + 11.586
r² = 0.6977
C:N
SWI

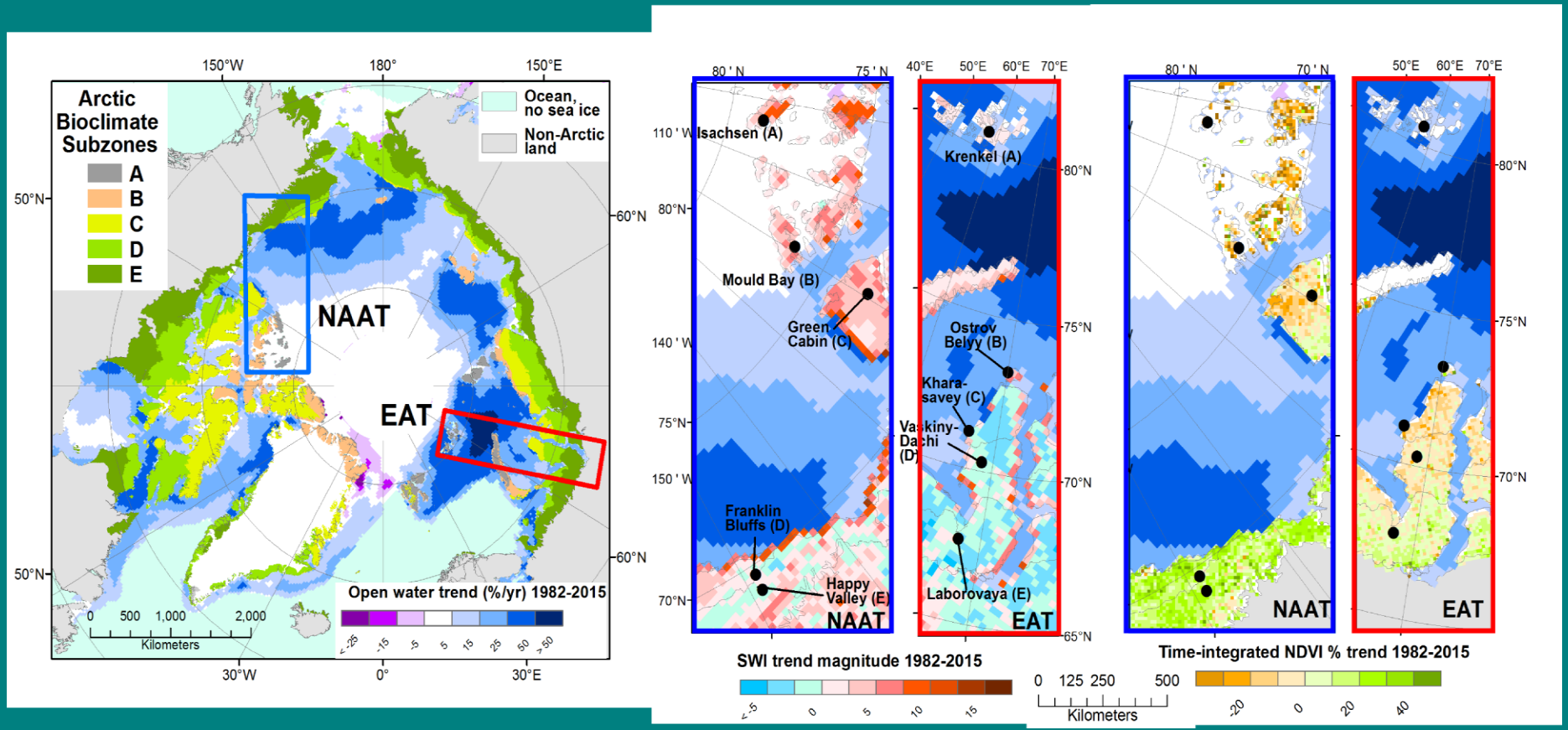

%C
y = -0.0065x + 2.0615
r² = 0.0428
% Carbon
SWI


%N
y = -0.019ln(x) + 0.1392
r² = 0.2082
%Nitrogen
SWI


Organic Layer Depth
y = 0.199x
r² = 0.6026
Depth (cm)
SWI


Active Layer Depth
y = 24.339x^0.3857
r² = 0.8043
Depth (cm)
SWI

Temporal Dynamics of Temperature (SWI) and NDVI for the Eurasian Arctic Transect

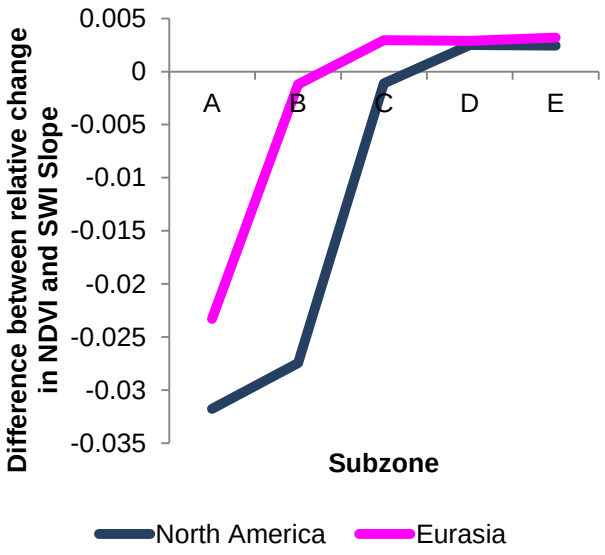


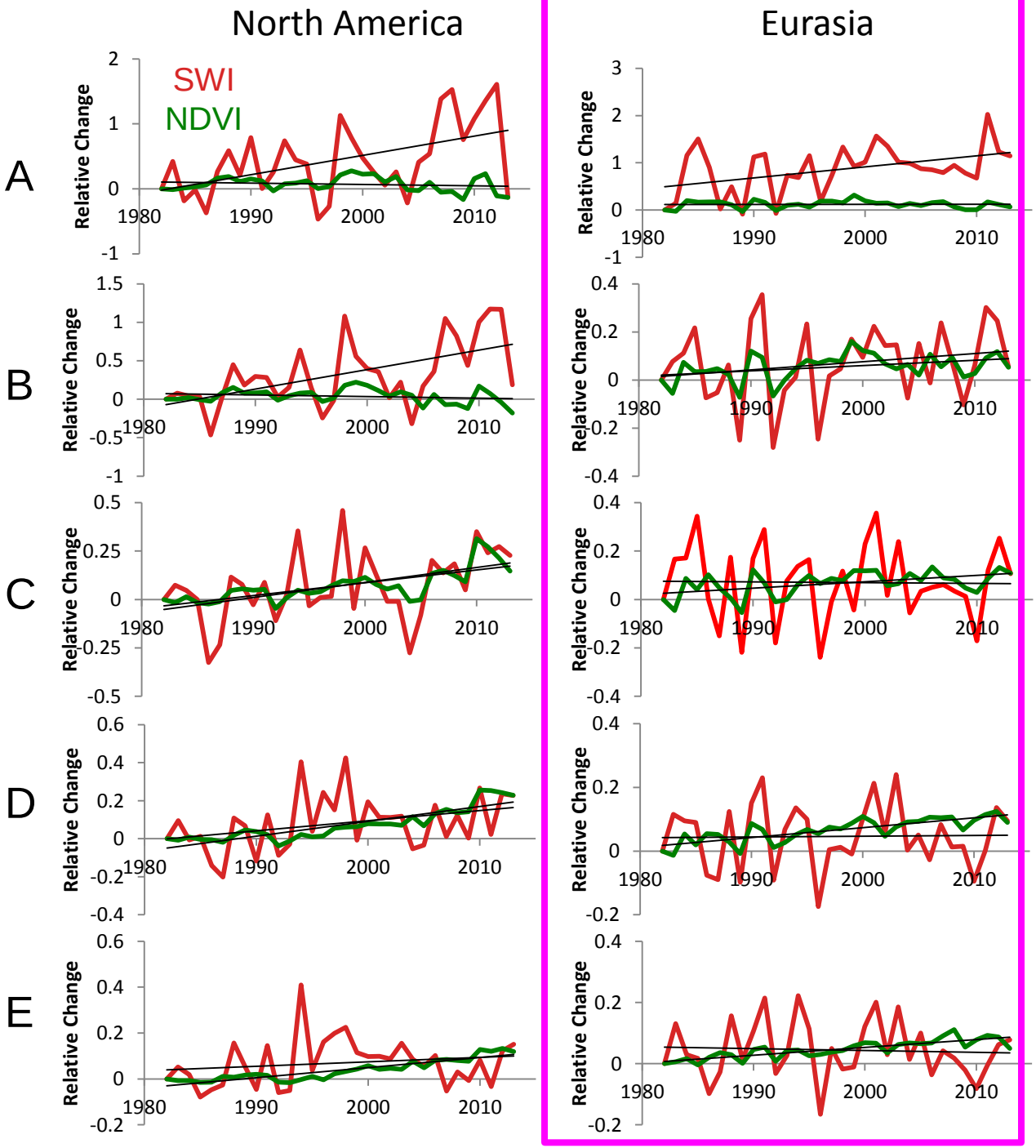
- TI (temporally integrated) –NDVI is an indicator of cumulative growing season productivity
- The Eurasian Arctic Transect has experienced substantive warming further north and generally slight cooling on the Yamal Peninsula from 1982-2015
- The Eurasian Arctic Transect has exhibited slight “greening” in the southern part of the Yamal Peninsula and “browning” in the northern part of the Peninsula

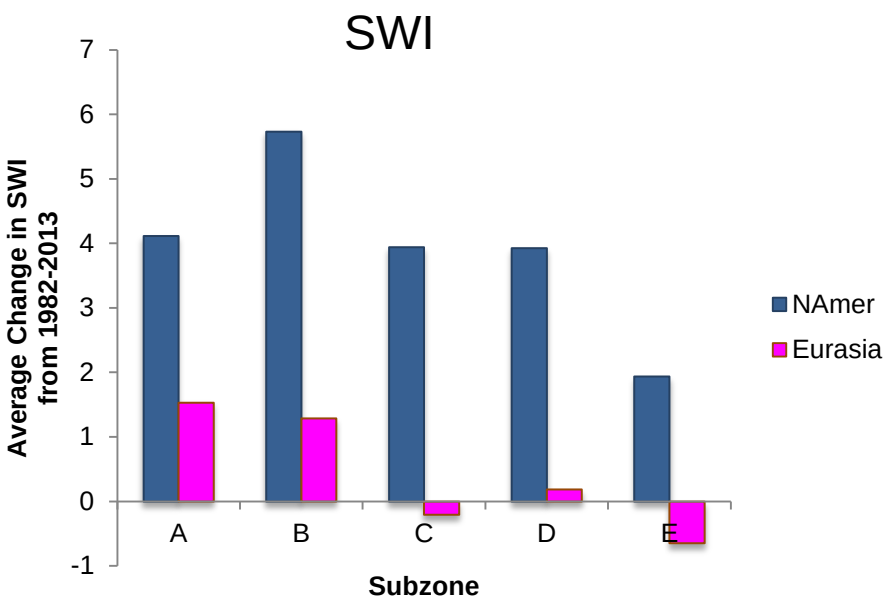
Bioclimate subzone	NAAT				EAT			
	SWI		TI-NDVI		SWI		TI-NDVI	
	Subzone	Study location	Subzone	Study location	Subzone	Study location	Subzone	Study location
A	**73% (3.7)**	Isachsen: **174% (6.7)**	-6.3% (0.0)	Isachsen: NA	**175% (3.6)**	Krenkel: **NM (0.83)**	8.6% (0.02)	Krenkel: NA
B	**74% (5.2)**	Mould Bay: *49% (5.0)*	**-17% (-0.22)**	Mould Bay: **-47% (-0.25**	**38% (3.2)**	Belyy Ostrov: **NM (13.0)**	3.8% (0.09)	Belyy Ostrov: 5.3% (0.15)
C	*20% (3.8)*	Green Cabin 11.8% (3.1)	-5% (-0.14)	Green Cabin: 4.5% (0.14)	-1.9% (-0.50)	Kharasavey: **154% (9.4)**	**-7.8% (-0.37)**	Kharasavey: **8.6% (0.37)**
D	11% (3.1)	Franklin Bluffs: 1.7% (0.65)	**21% (0.91)**	Franklin Bluffs: **17% (0.74)**	-2.3% (-0.72)	Vaskiny Dachi: 1.6% (0.51)	-2.7% (-0.14)	Vaskiny Dachi: -8.6% (-0.45)
E	3.5% (1.3)	Happy Valley: 1.7% (0.69)	**18% (1.0)**	Happy Valley **25% (1.4)**	-3.7% (-1.5)	Laborovaya: -1.9% (-0.78)	**6.1% (0.32)**	Laborovaya: **6.7% (0.39)**
Total	11% (2.4)		**10% (0.33)**		-4.4% (-1.3)		0% (0)	

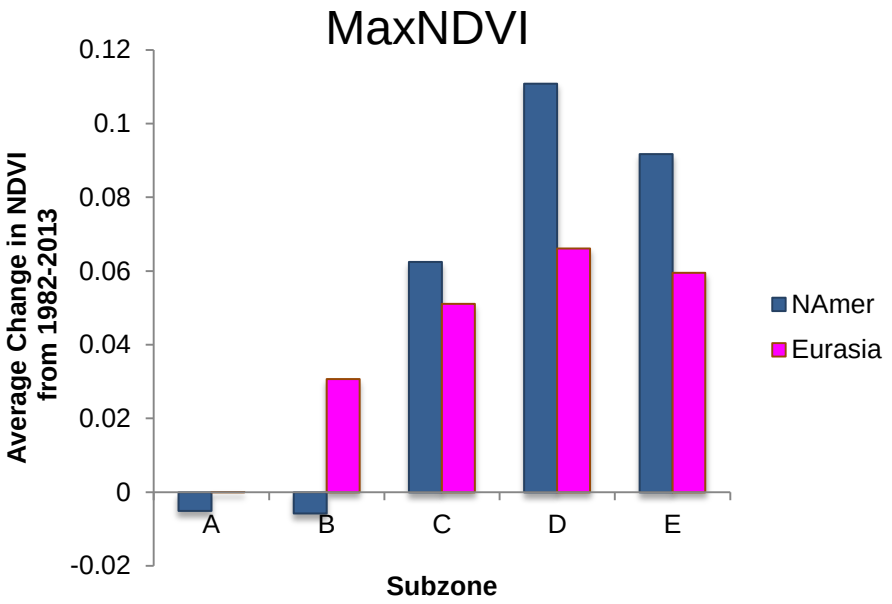
- Again, substantive warming in Subzones A and B with slight cooling in Subzones C-E on the Yamal Peninsula from 1982-2015
- Field sites within each subzone do not always exhibit the same trends compared to the subzone as a whole (e.g. Kharasavey)

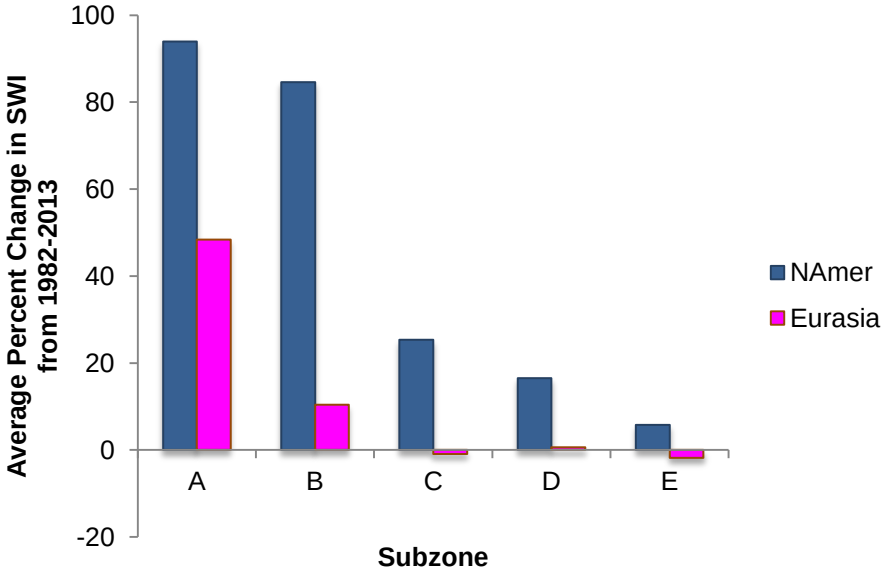
Temporal Dynamics of Temperature (SWI) and MaxNDVI (peak season) for Eurasia

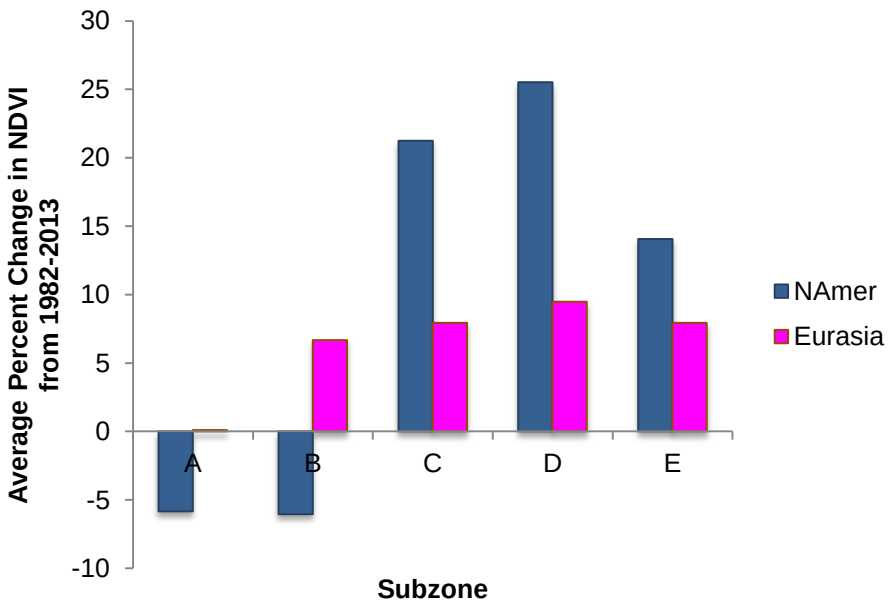




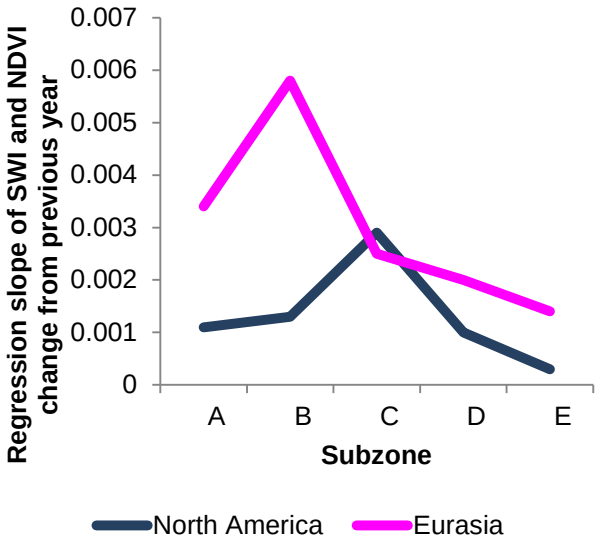

SWI
Average Change in SWI from 1982-2013
7
6
5
4
3
2
1
0
-1
A
B
C
D
E
Subzone
NAmer
Eurasia

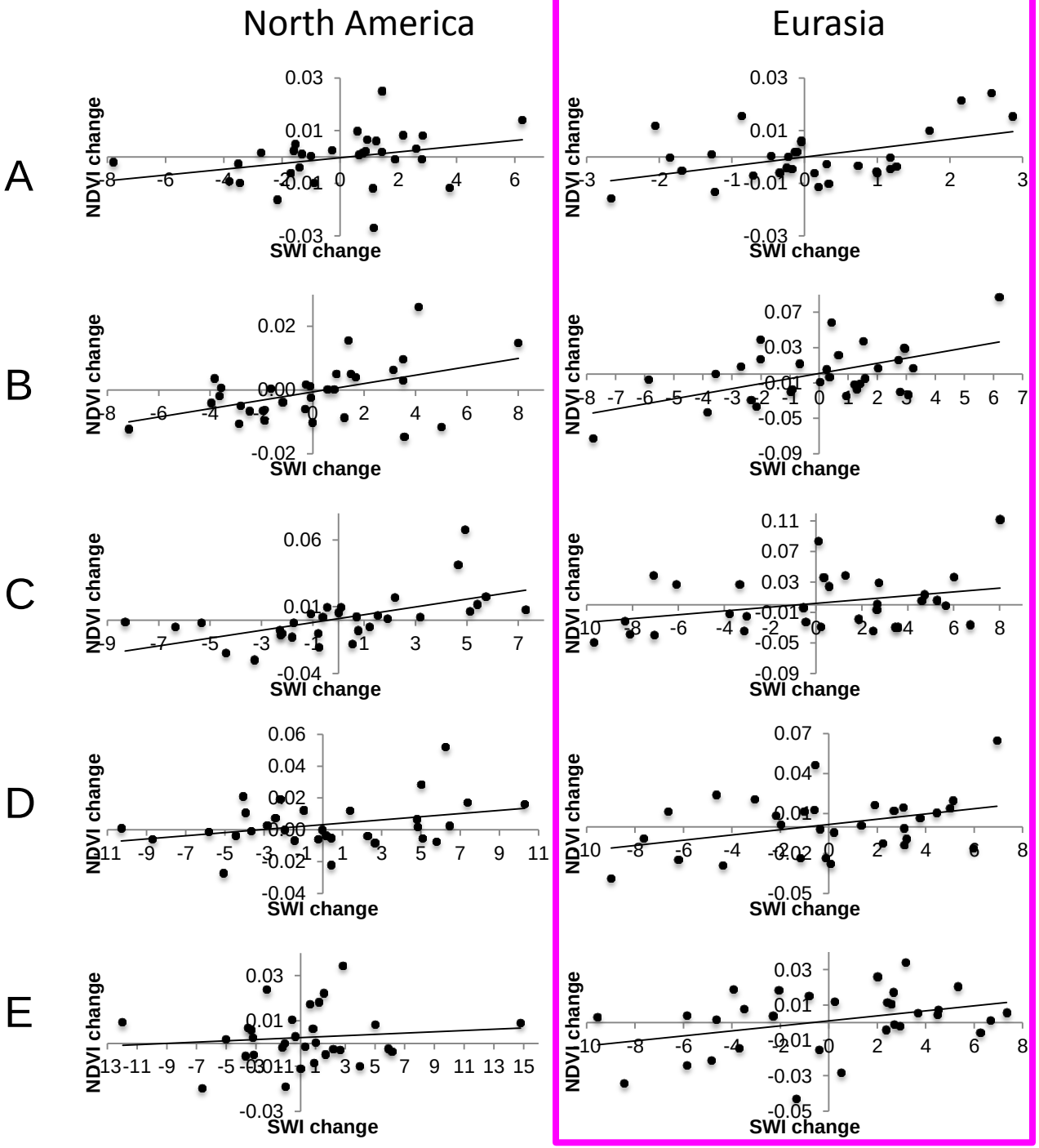

MaxNDVI
Average Change in NDVI from 1982-2013
0.12
0.1
0.08
0.06
0.04
0.02
0
-0.02
A
B
C
D
E
Subzone
NAmer
Eurasia

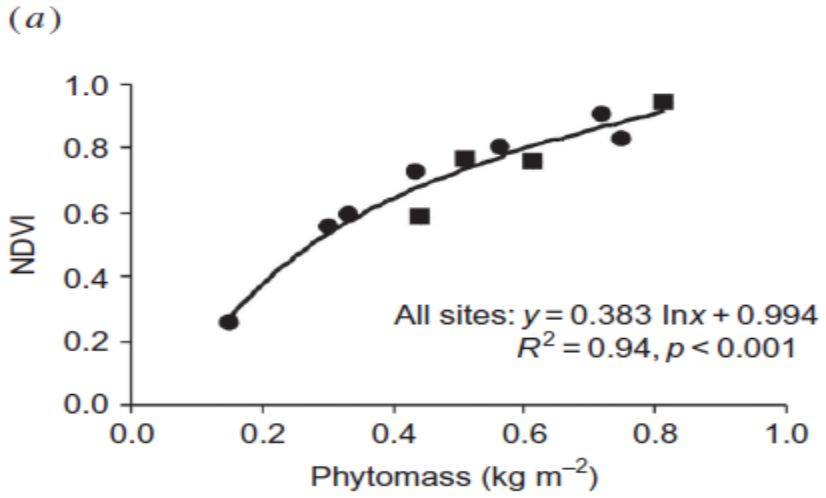

Average Percent Change in SWI from 1982-2013
100
80
60
40
20
0
-20
A
B
C
D
E
Subzone
NAmer
Eurasia

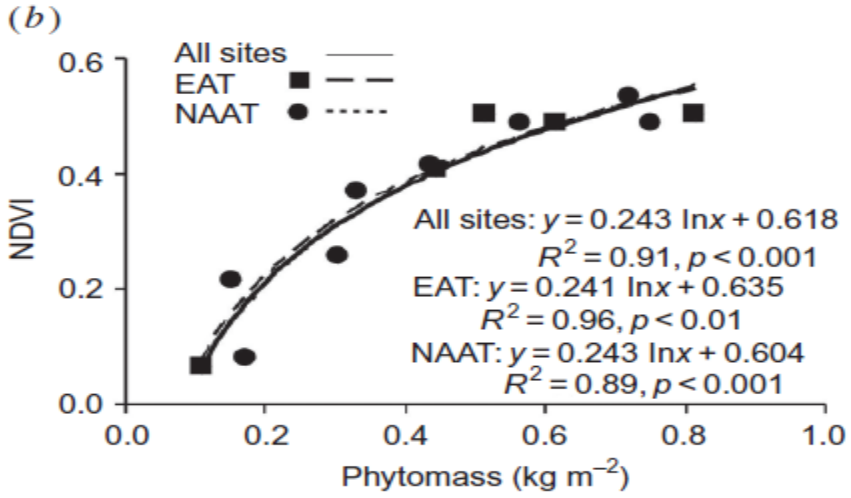

Average Percent Change in NDVI from 1982-2013
30
25
20
15
10
5
0
-5
-10
A
B
C
D
E
Subzone
NAmer
Eurasia

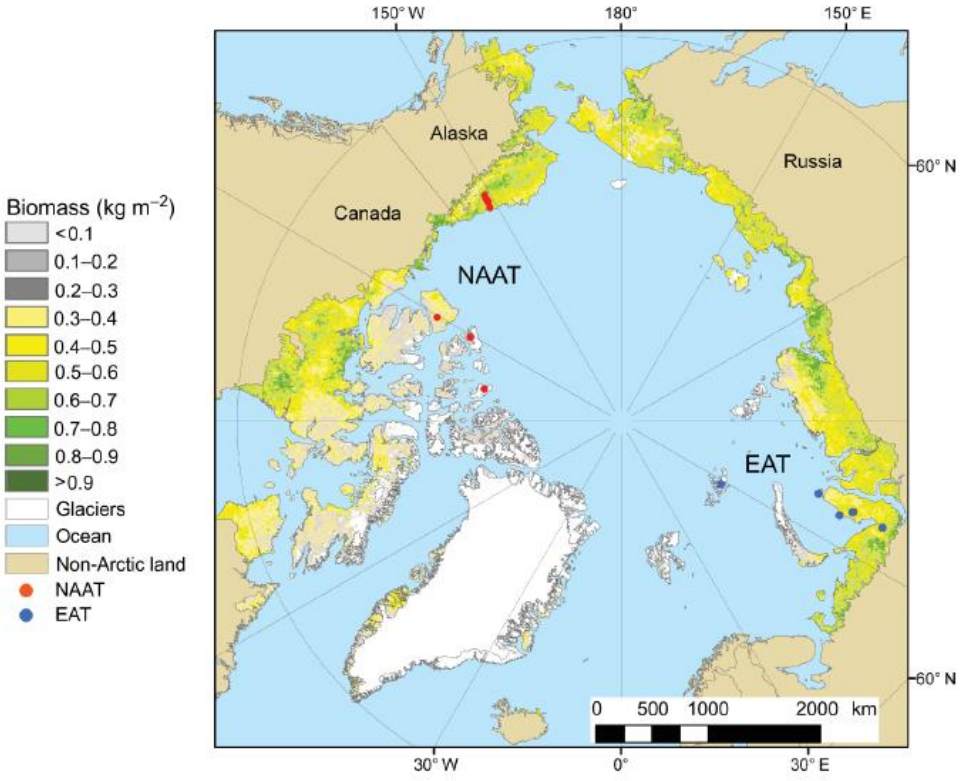
Inter-annual Changes in Temperature (SWI) and MaxNDVI (peak season) for Eurasia











Integration of field and remote sensing data still presents a major challenge

- *Inherent differences in resolutions and extents of the data*
- *Landscape heterogeneity vs. field sampling scheme (e.g. zonal vegetation)*

Raynolds et al. (2012)

Conclusions

- A collection of field locations along a latitudinal gradient in northwestern Siberia, Russia (EAT) was used to evaluate the spatial patterns of vegetation and soils properties along a summer warmth index (SWI) gradient

- NDVI, LAI, total biomass, shrub biomass, and total non-vascular biomass all increased with increasing SWI; mosses had their greatest biomass at intermediate values of SWI

- C:N ratio (mineral soil), organic layer thickness, and active layer thickness all increased with increasing SWI

- With regard to temporal dynamics, the Higher Arctic of the EAT has warmed substantively since 1982, where the mainland Yamal Peninsula has experience a general slight cooling; the northern Yamal has showed “browning” trends, whereas the southern Yamal has “greened”

- The northernmost subzones in Eurasia have shown substantial warming with minimal vegetation response, whereas the southernmost areas have show the greatest vegetation increases with essentially no warming

- Vegetation in Subzone B (along the EAT) is the most response with regard to inter-annual variability in SWI

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