Recent dynamics of arctic tundra vegetation: Remote sensing, field observations, and modeling

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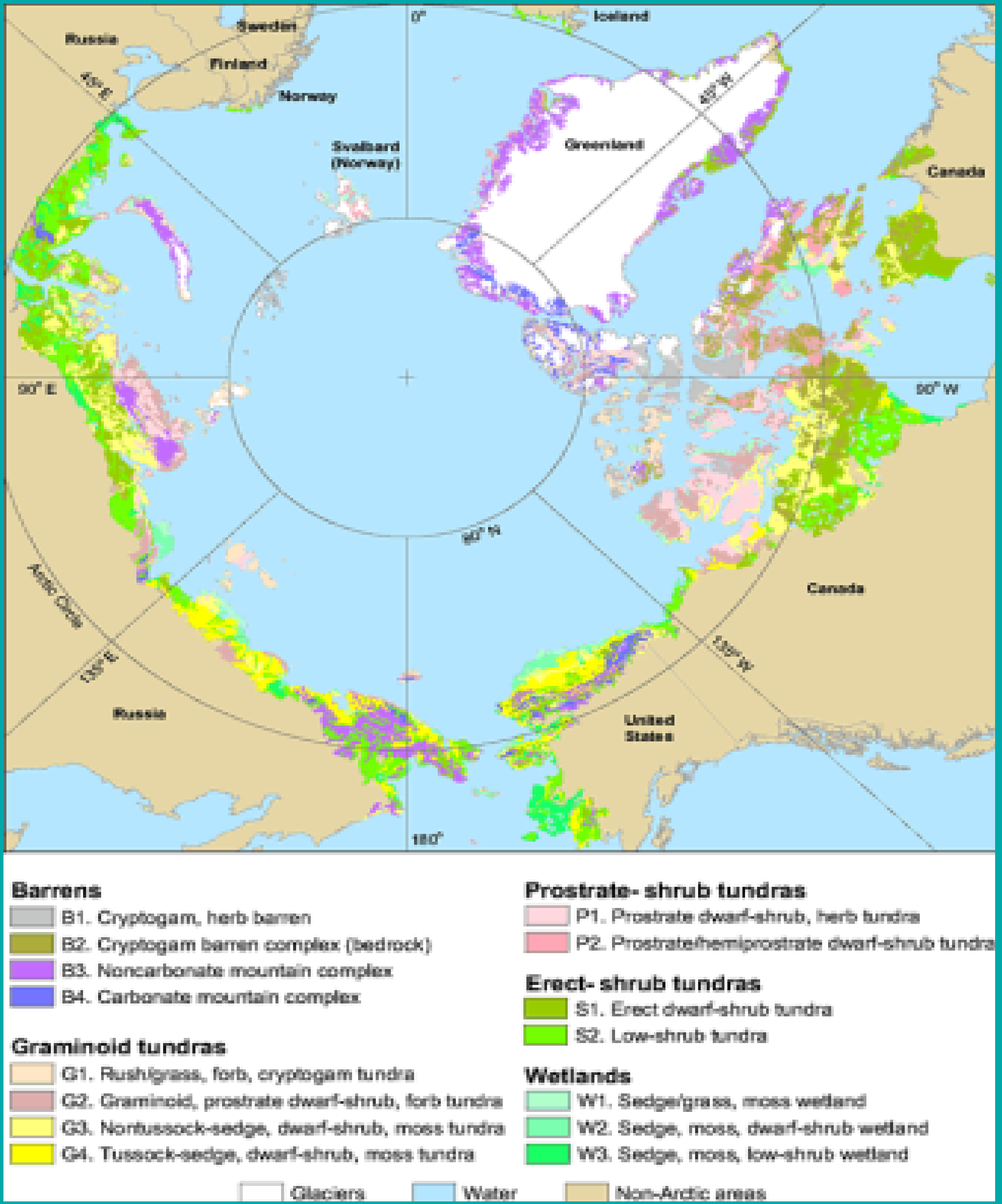
International Polar Year
Montreal, April 2012

(Photo H.E. Epstein)

The Arctic Tundra Biome

- Southern boundary of the mapped area is tree line.
- Tundra is defined as being treeless but not absent of woody plants.
- Largest expanses in Russia and Canada, with some in U.S., Scandinavia, and Greenland.
- Note the close proximity of all parts of the biome to perennially or seasonally frozen seawaters.



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

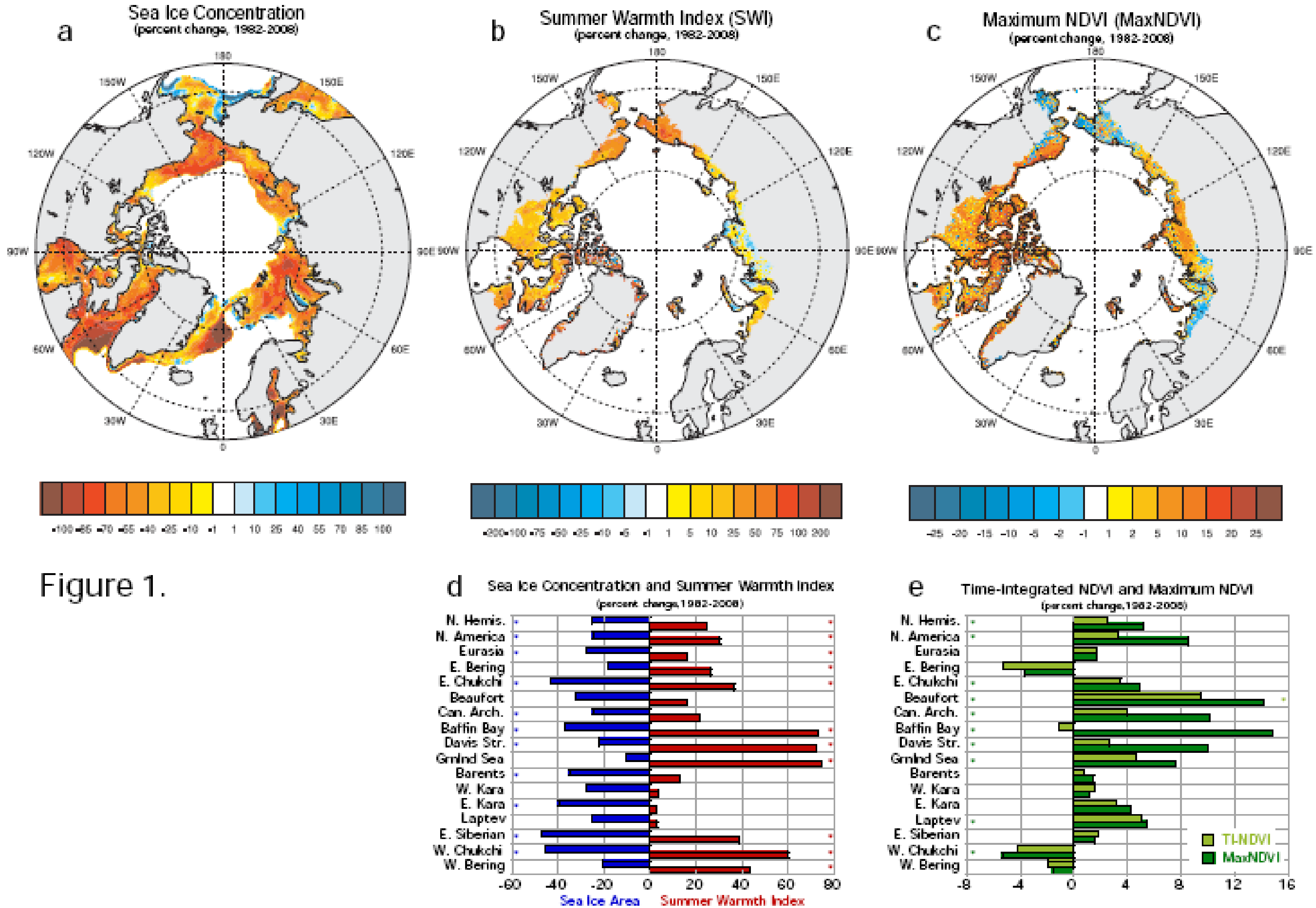
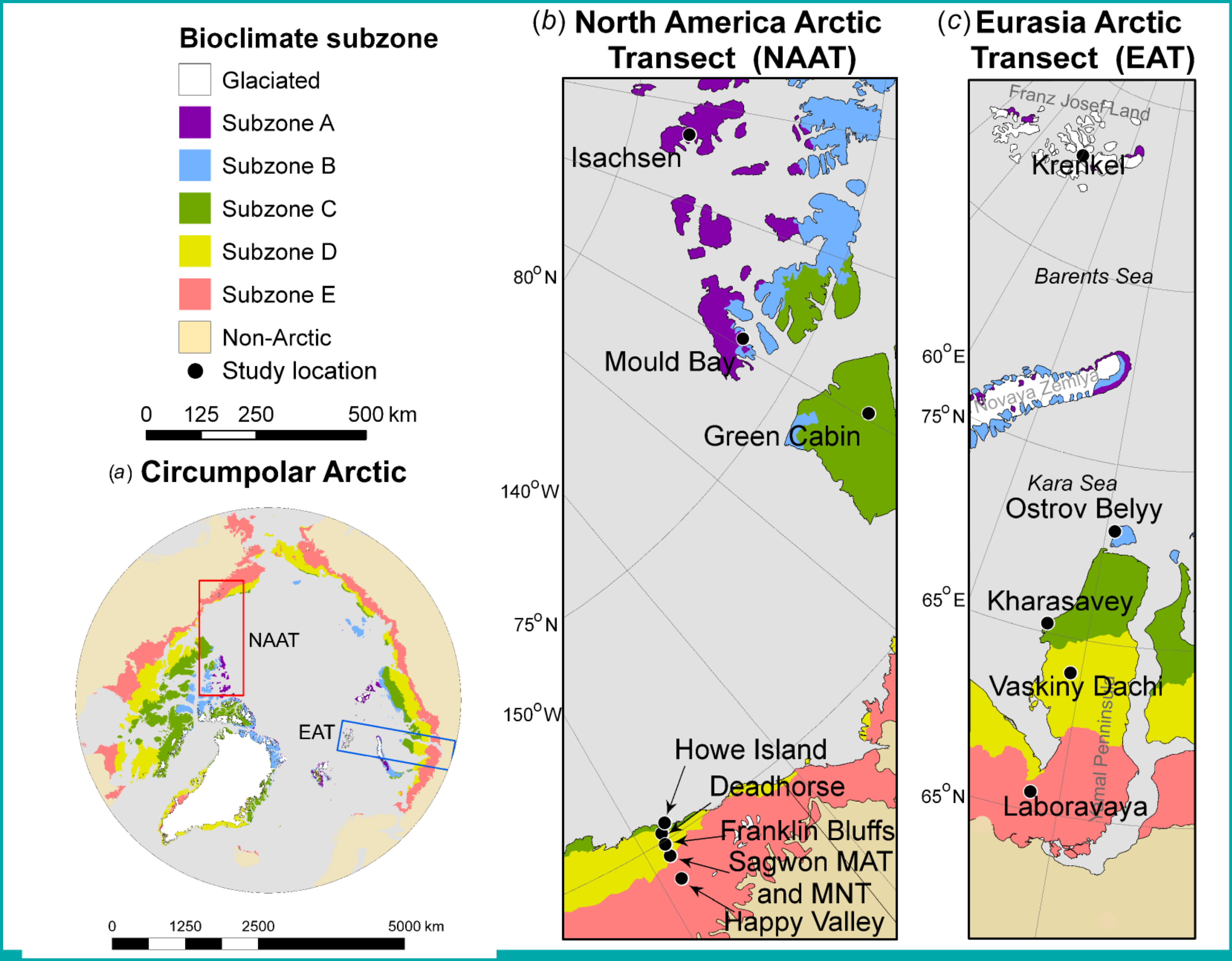


Figure 1.

Bhatt et al. (2010)



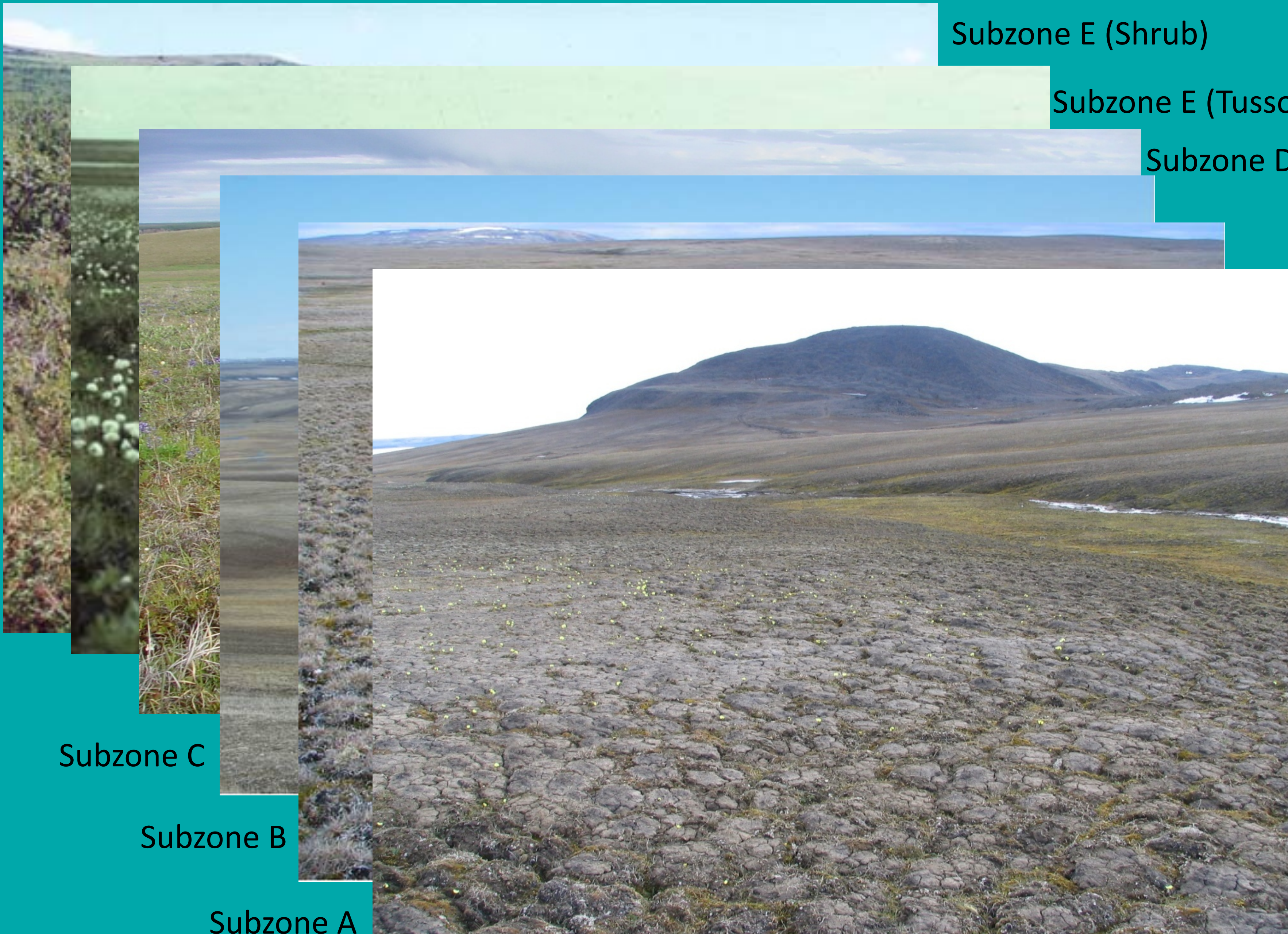
From Raynolds et al. 2012

North American Arctic Transect

Subzone E (Shrub)

Subzone E (Tussock)

Subzone D



Subzone C

Subzone B

Subzone A

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

Yamal Arctic Transect

Forest Tundra (Forest)

Forest Tundra (Tundra)

Subzone E

Subzone D

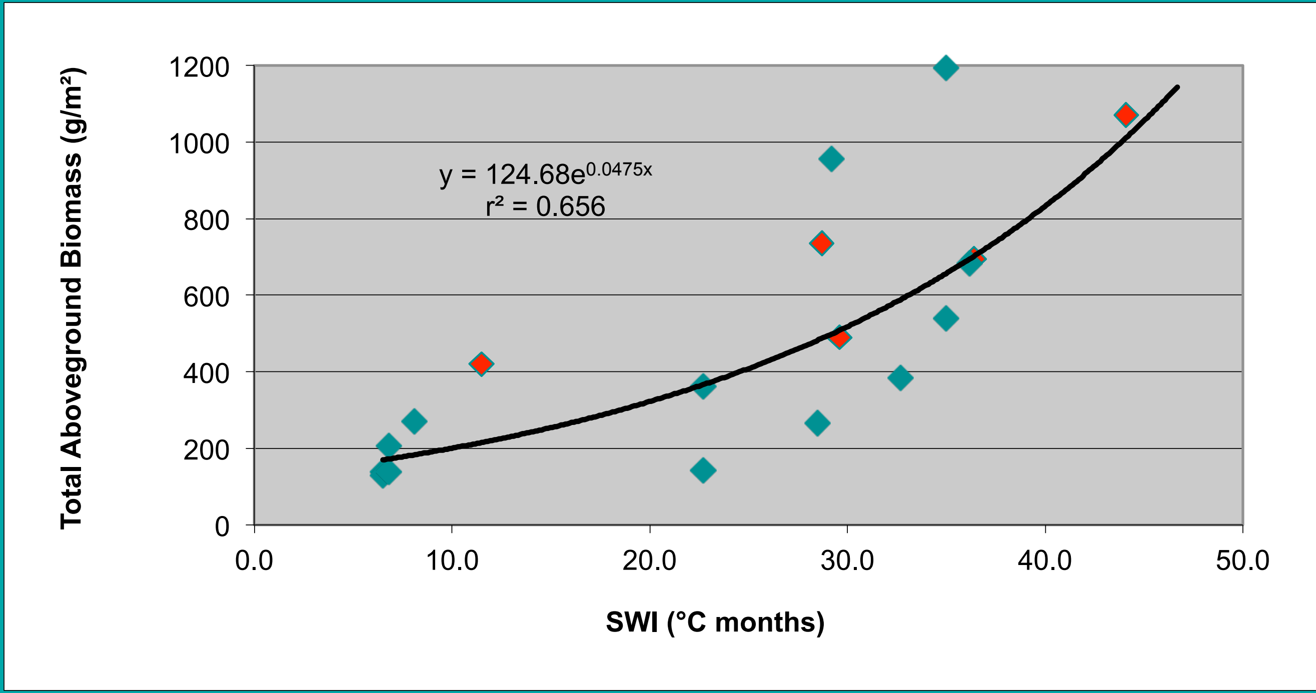
Subzone C

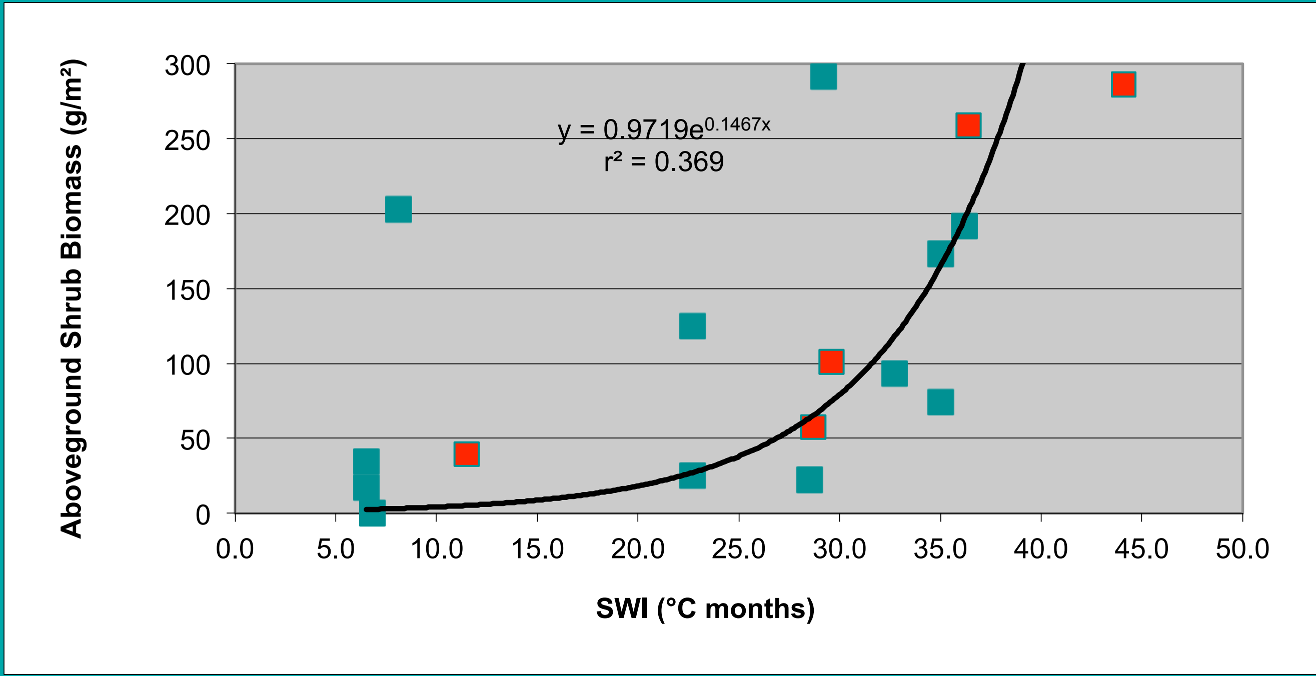
Subzone B

Subzone A

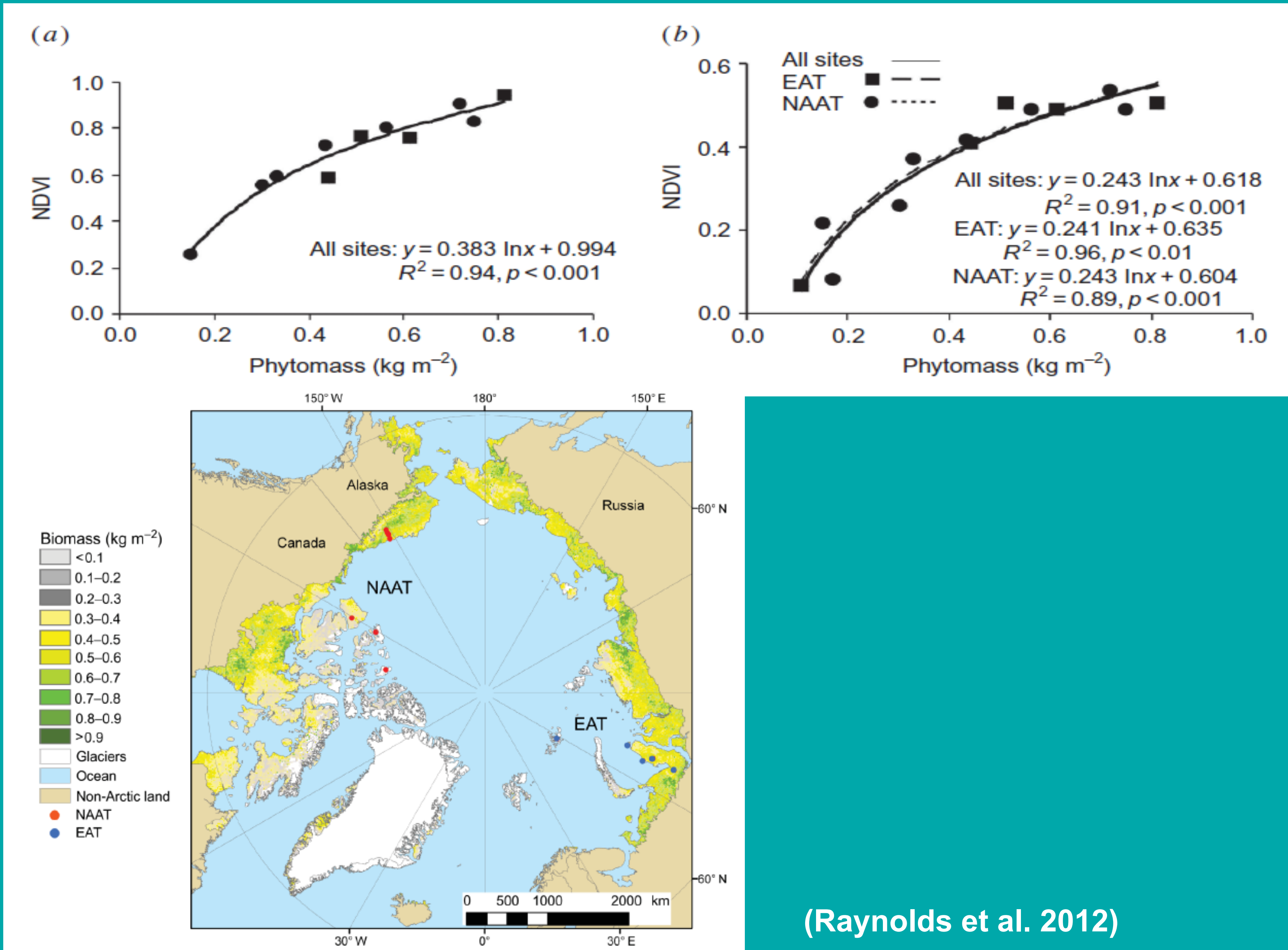
(photos by D.A. Walker and H.E. Epstein)

Aboveground Total and Shrub Biomass along both transects

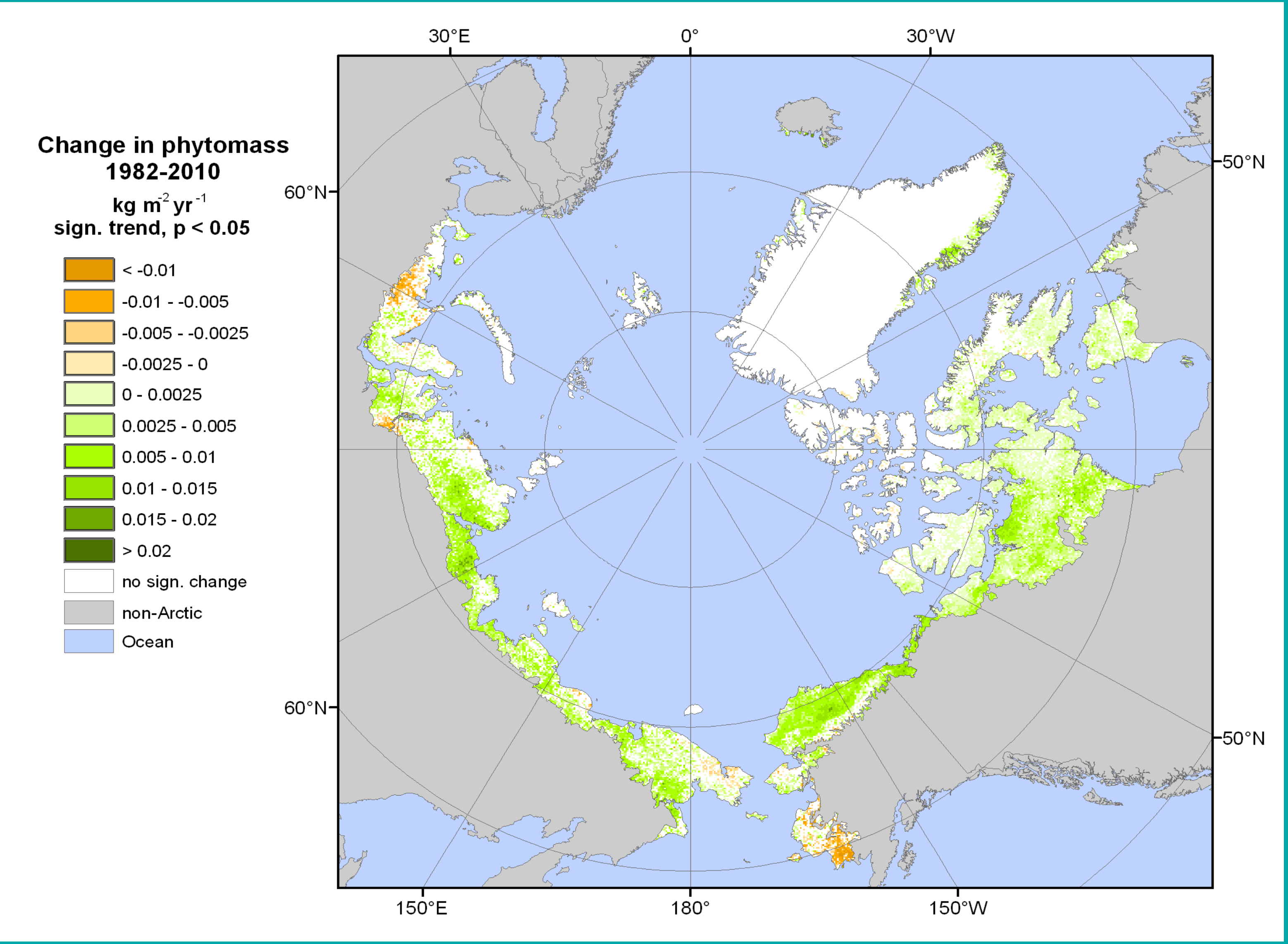




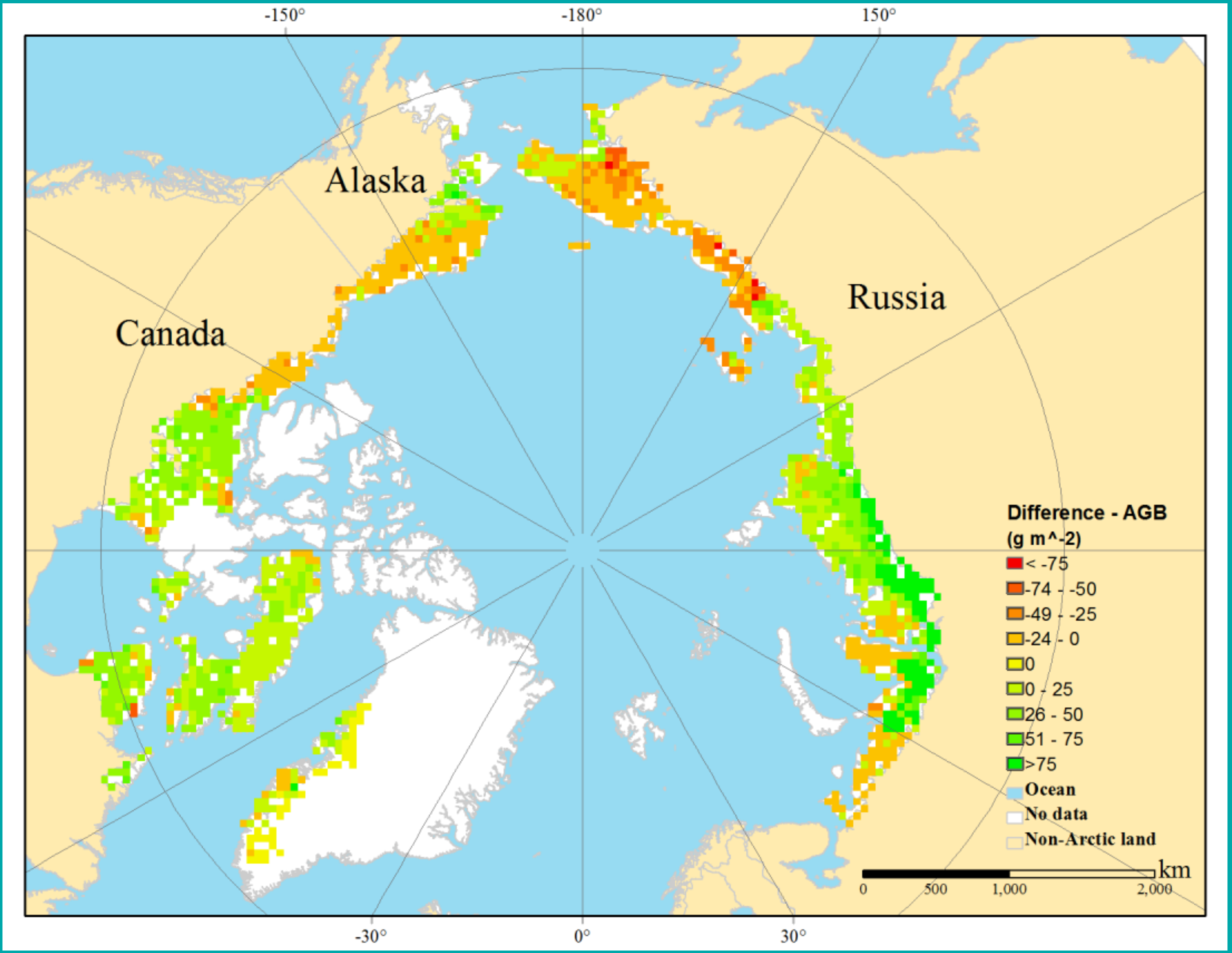
YAMAL



(Raynolds et al. 2012)

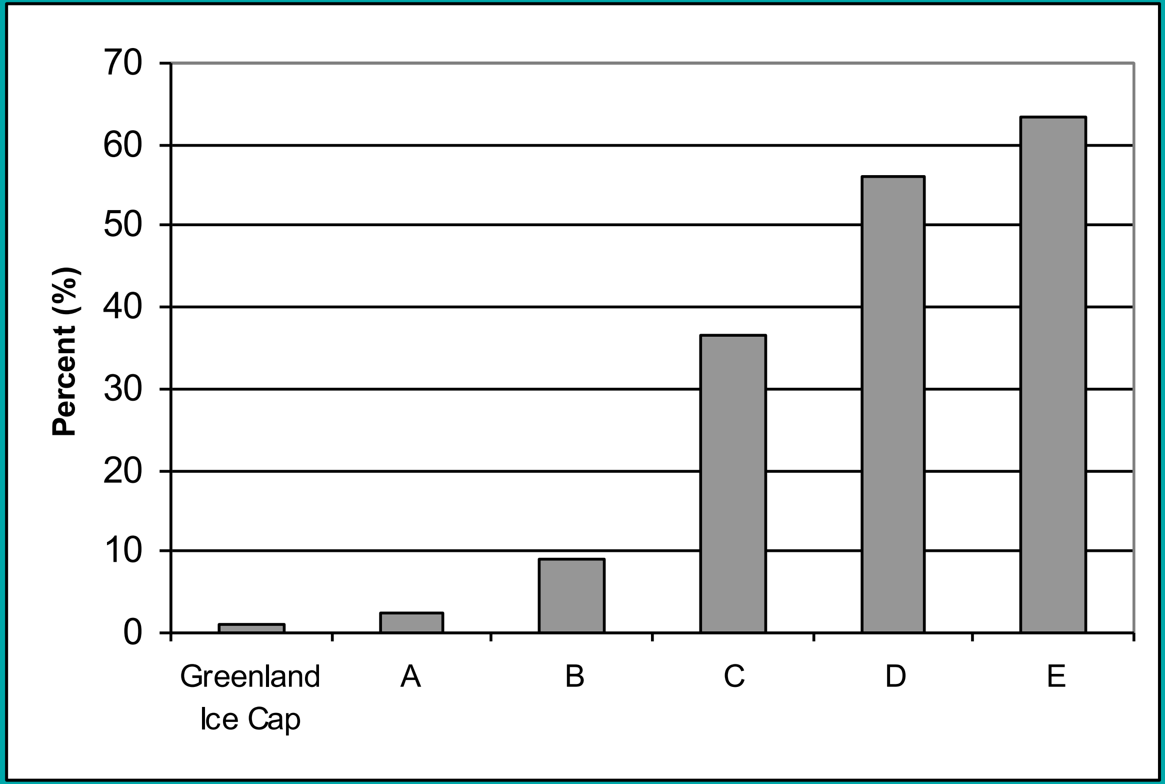


Total ~0.40 Pg C increase in tundra vegetation over 28-year period Epstein et al. (2012) – up to ~0.2 Pg C sequestered per year.



Climate warming (+) and grazing (-) effects on aboveground biomass as simulated by the ArcVeg tundra vegetation dynamics model

Yu et al. (in prep. – presentation 1600, this session)



Percent of pixels with significant change in biomass

Bioclimate Subzone	Area (km^2)	1982	SD	2010	SD	Change in mean biomass ($g\ m^{-2}$)	Rate of change ($g\ m^{-2}\ y^{-1}$)	1982	2010	Change	% change	Rate of change (% y^{-1})
Greenland Ice Cap	1,795,920	83.8	14.0	84.4	18.0	0.6	0.02	0.15	0.15	0.0011	0.70	0.025
A	200,964	98.3	39.2	100.3	53.4	2.0	0.07	0.02	0.02	0.0004	2.05	0.073
B	530,780	142.7	100.9	151.8	118.4	9.1	0.33	0.08	0.08	0.0048	6.39	0.228
C	1,380,760	199.6	116.6	241.2	148.7	41.6	1.49	0.28	0.33	0.0575	20.85	0.745
D	1,708,430	319.8	145.6	401.5	195.2	81.7	2.92	0.55	0.69	0.1396	25.56	0.913
E	2,027,020	467.5	142.5	563.6	153.1	96.1	3.43	0.95	1.14	0.1948	20.55	0.734

Increased length of the growing season

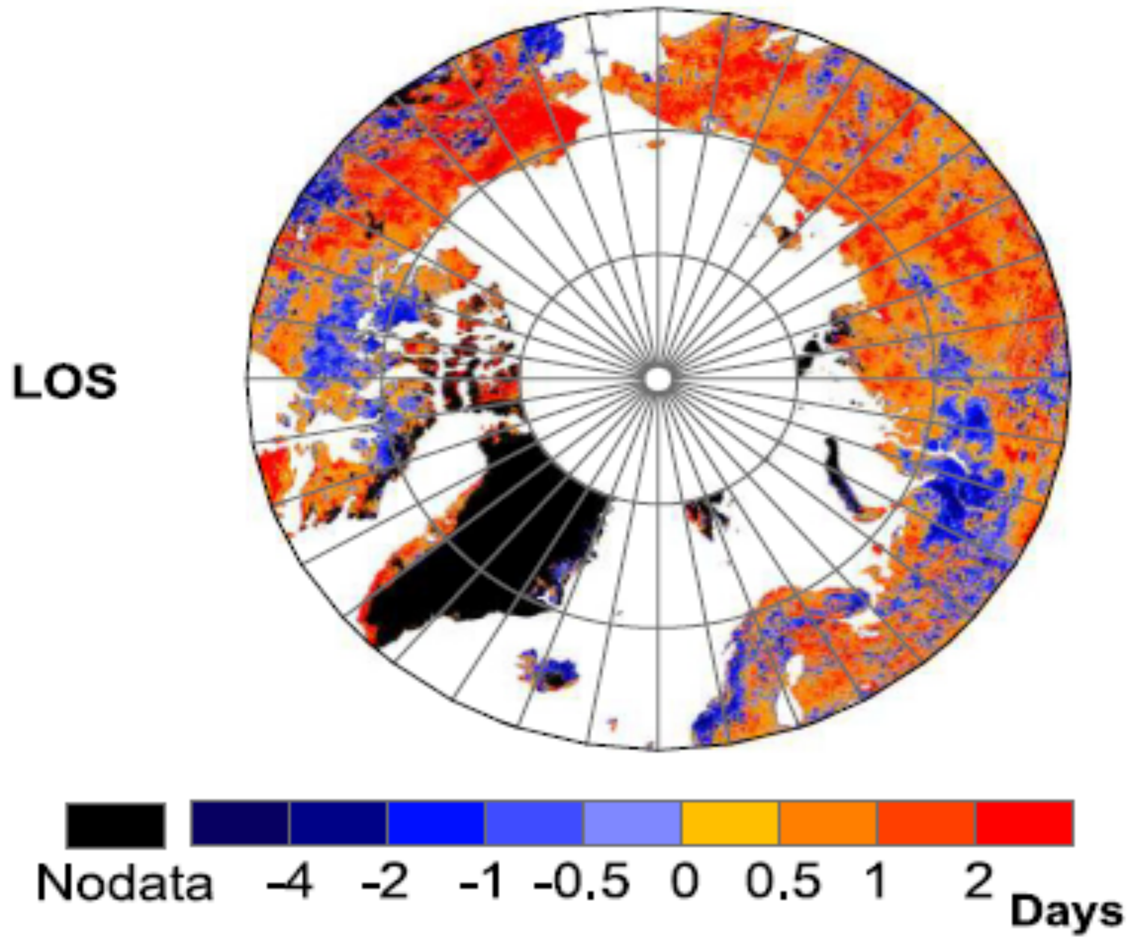
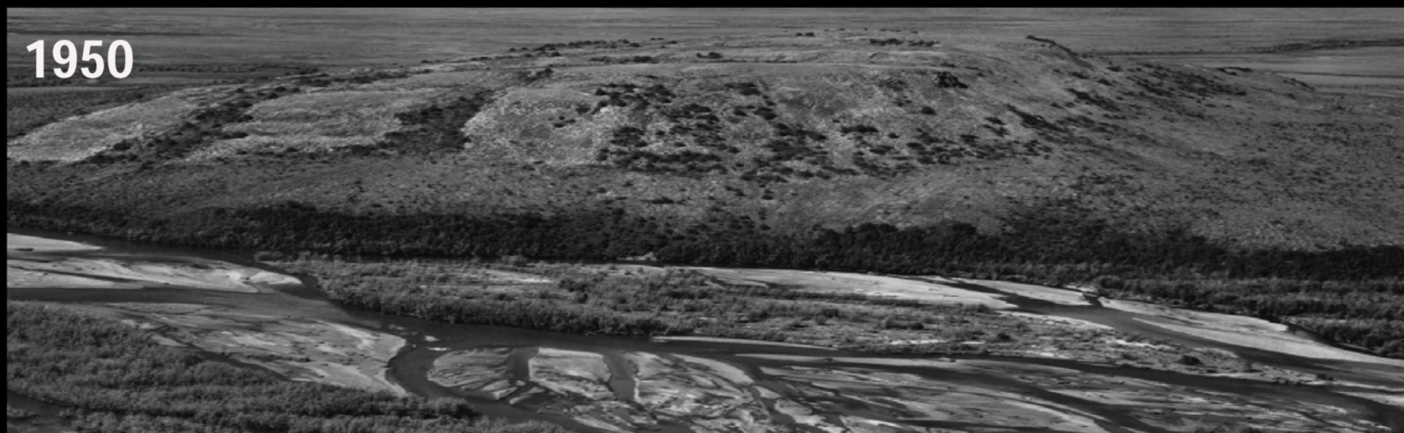


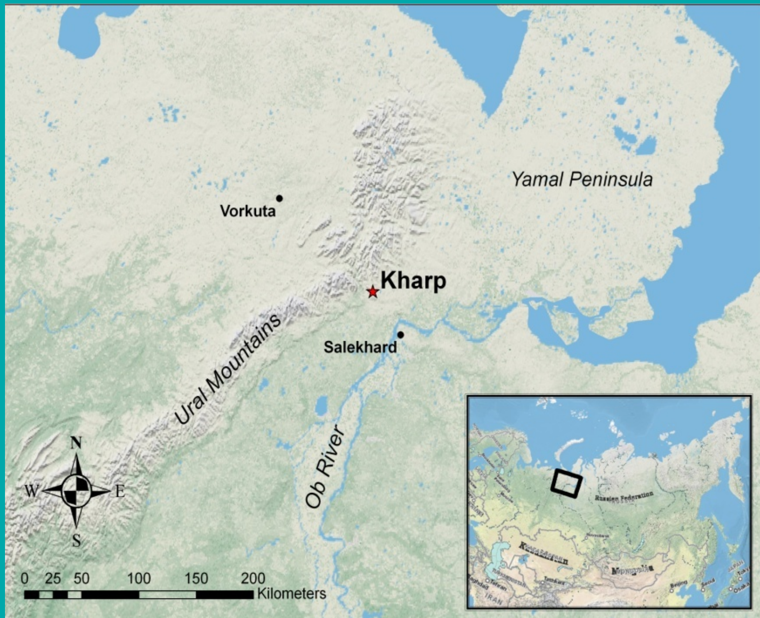
Figure 2. Spatial patterns of the linear trends in SOS, EOS and LOS from 2000 to 2010 based on MODIS data. Positive values (warm colors) indicate later onset (SOS), later finish (EOS) and longer duration (LOS) of the growing season.

Zeng et al. (2011)

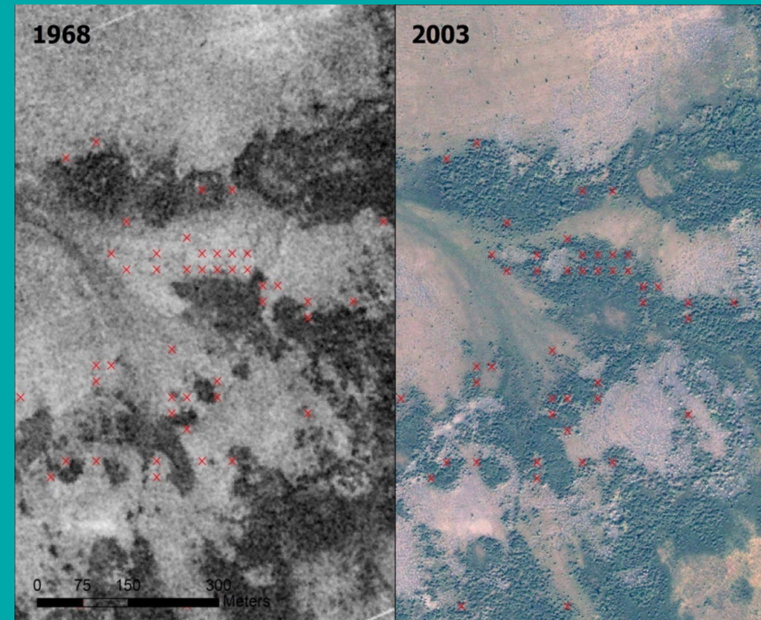
Changes in shrub cover, northern Alaska 1950-2003



Sturm, M., C. Racine, and K. Tape. 2001. Increasing shrub abundance in Arctic. Nature **411**:547-548.



Map showing southern Yamal region and location of Kharp study site in northwest Siberia.



Comparison of 1968 (Corona) and 2003 (QuickBird) showing area of recent alder expansion. Areas with new shrub cover are marked in red.

Kharp landcover change summary

- Changes in alder cover are readily detected using Corona imagery as baseline
- Alder cover increased by 8% (52 ha) during 1968-2003

Frost et al. (in prep.)

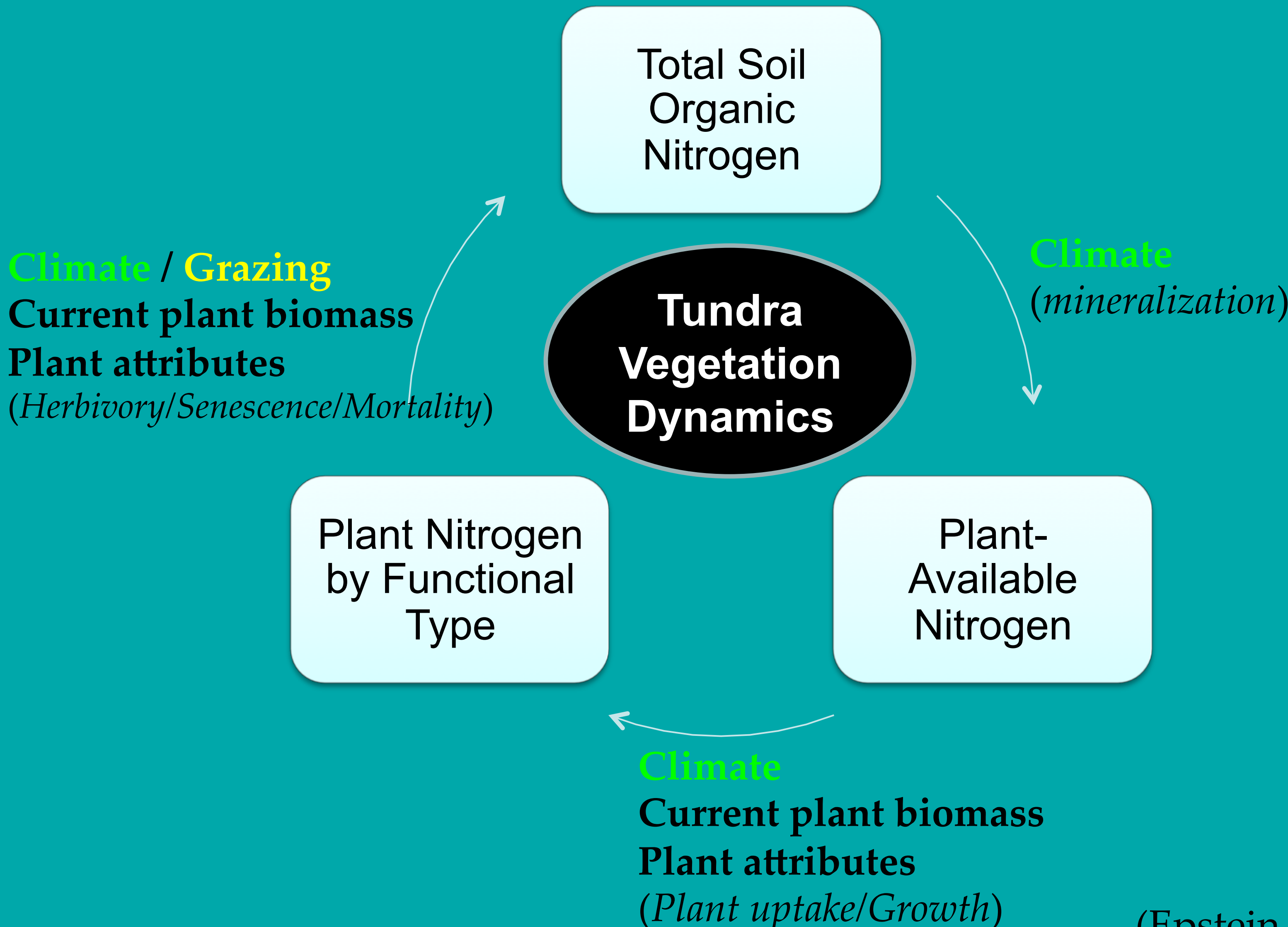
Feedbacks between shrubland development and permafrost in the northwest Siberian Low Arctic

Gerald V. Frost

Friday, 10:15 AM Room 520A

Session 2.2.8 – Environmental Consequences of Change

ArcVeg – Arctic tundra vegetation dynamics model



(Epstein et al. 2000)

Model setting

ArcVeg simulations were conducted with field collected parameters:

- **Bioclimate subzones**
- **Soil nutrients – soil organic nitrogen**
- **Grazing:** (0.1, 25%), (0.1, 50%), (0.5, 25%), (0.5, 50%)
- **Climate warming:** 2°c transient warming and equilibrium warming

Subzone	sites	N%	%Sand	Active Layer Depth(cm)	SON (g/m^2)
A	KR-1	0.11	60.08	33.60	449
A	KR-2	0.10	81.40	32.80	277
B	BO-1	0.03	36.50	49.98	227
B	BO-2	0.01	83.76	77.60	145
C	KH-1	0.06	24.47	56.33	844
C	KH-2	0.07	65.60	75.50	599
D	VD-1	0.03	28.90	71.75	271
D	VD-2	0.04	38.28	68.60	202
D	VD-3	0.05	92.80	113.80	135
E	LV-1	0.06	18.00	81.20	570
E	LV-2	0.01	93.60	114.60	148

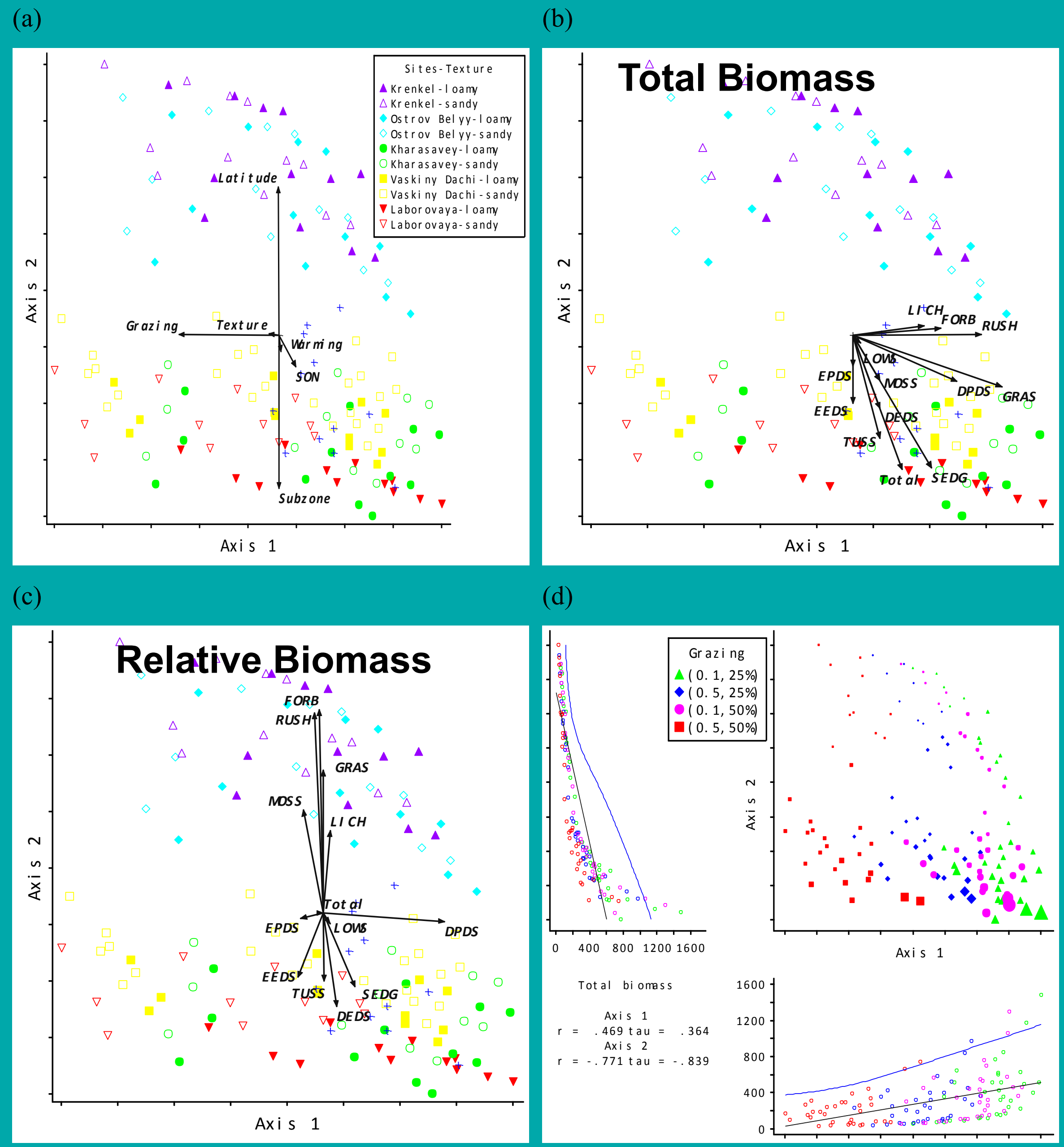
Table 1. Field collected data for model input

Yamal Peninsula, northwestern Siberia, Russia

Nenets reindeer herders

132 model simulations

Five climate zones, with grazing intensity and climate change scenarios – each point is a multivariate vegetation community



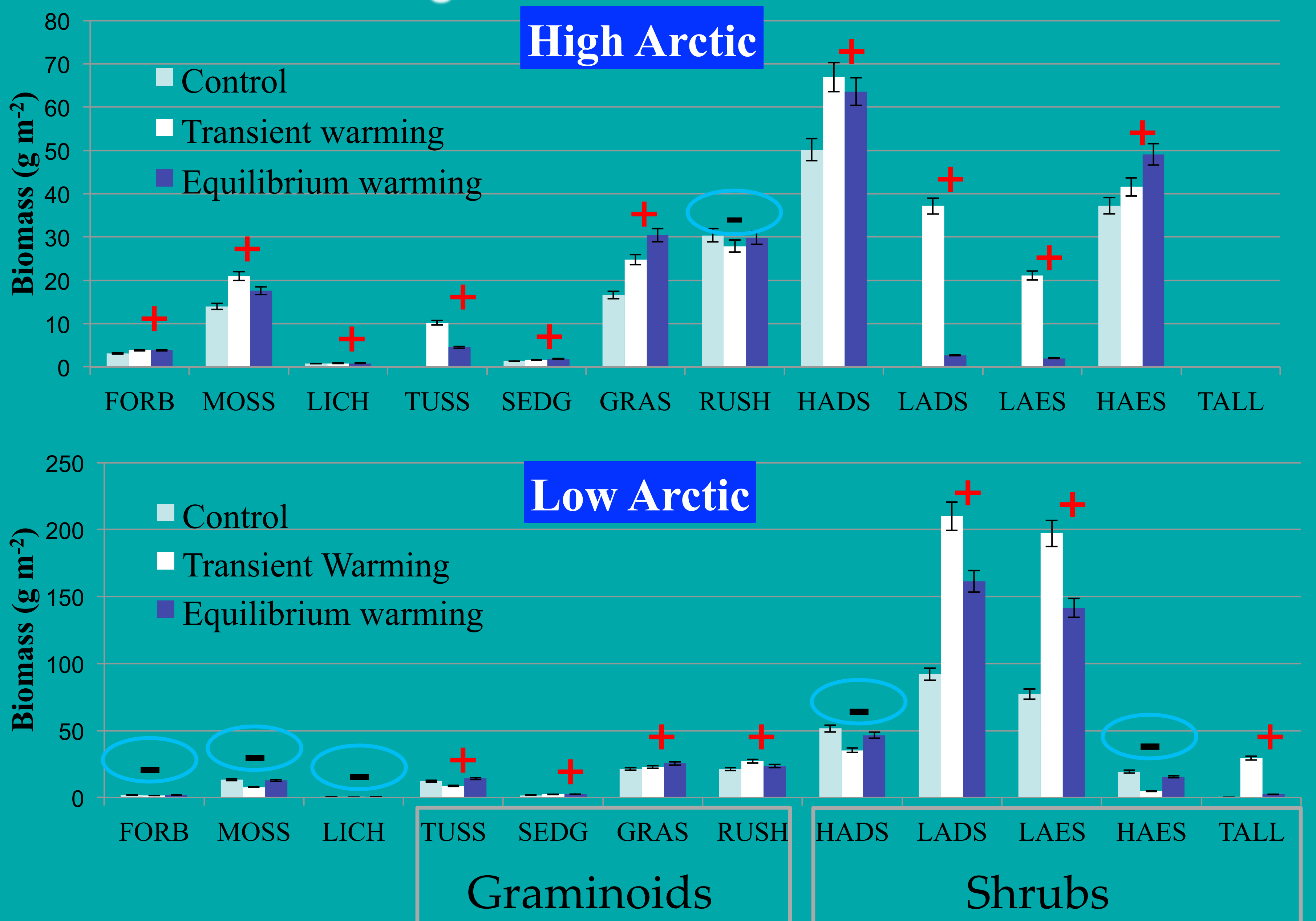
Temperature

Grazing

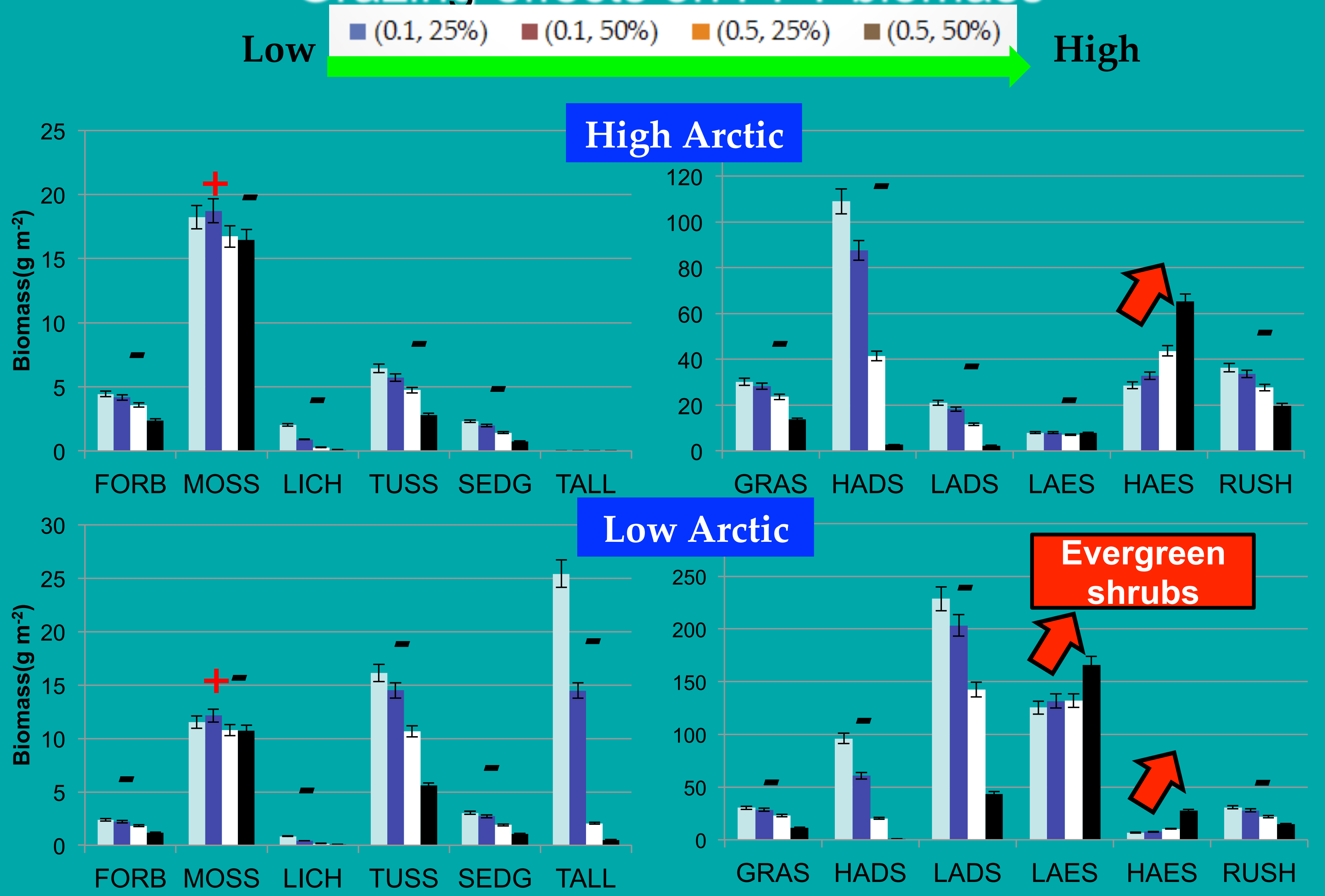
Grazing explains 13% of the variability in plant community structure, buffers positive responses to warming, and alters plant community composition

Yu et al. (2011)

Warming effects on PFT biomass



Grazing effects on PFT biomass



Conclusions

- General widespread greening of arctic tundra, but greater increases in vegetation seen in southern tundra subzones.
- Approximately 0.40 Pg C difference in vegetation over past 28 years.
- Shrub expansion appears to be accounting for a substantive fraction of the greening circumpolarly, particularly in the southern tundra .
- Grazing may buffer the responses of vegetation to warming, and interactions among grazing and warming are likely to alter plant community composition in tundra.

Acknowledgments

- **Funding sources**
  - NASA/NEESPI Land Cover Land Use Change Initiative, Grant No. NNG6GE00A
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