Climate and grazing influences on circumpolar dynamics of arctic tundra vegetation

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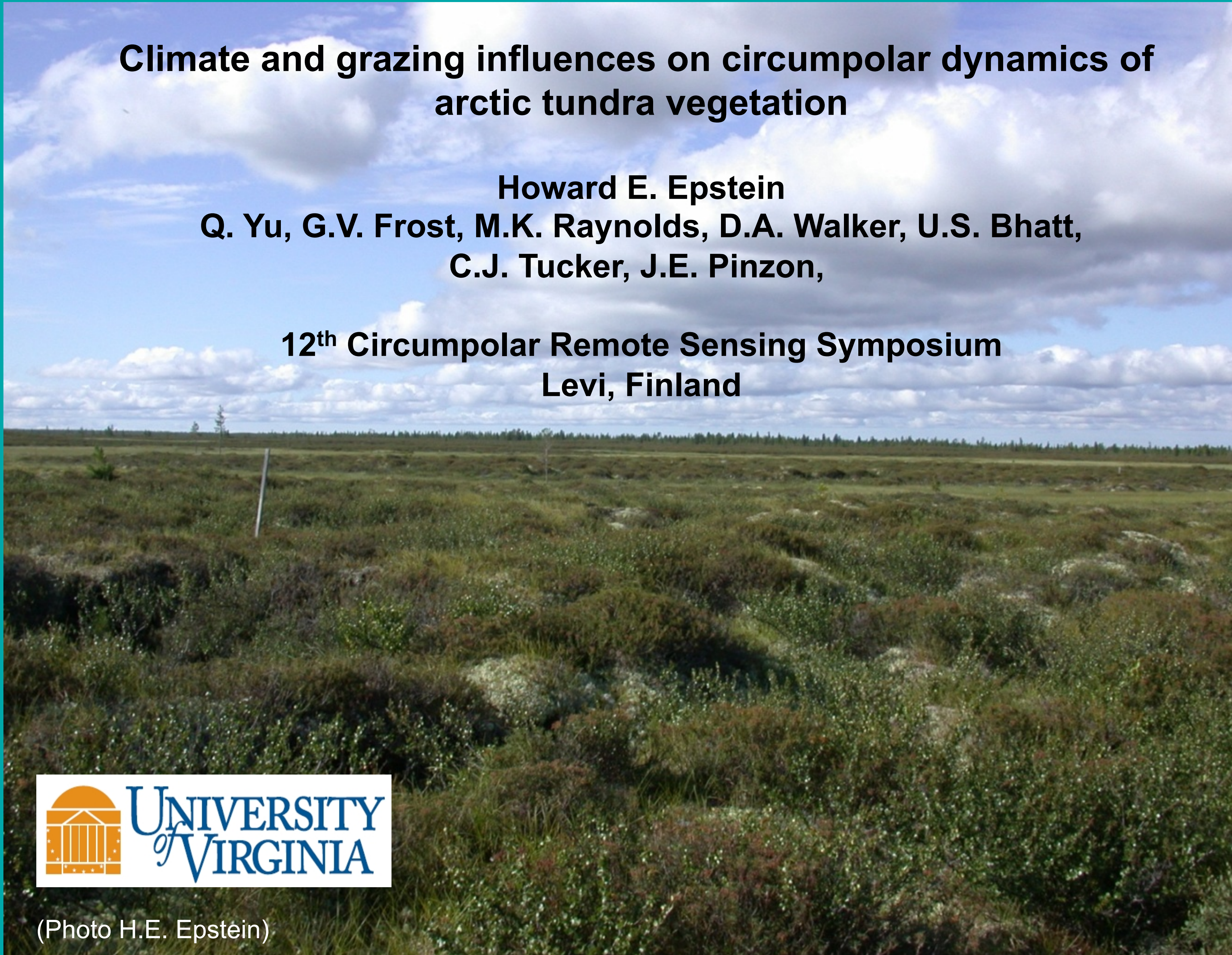
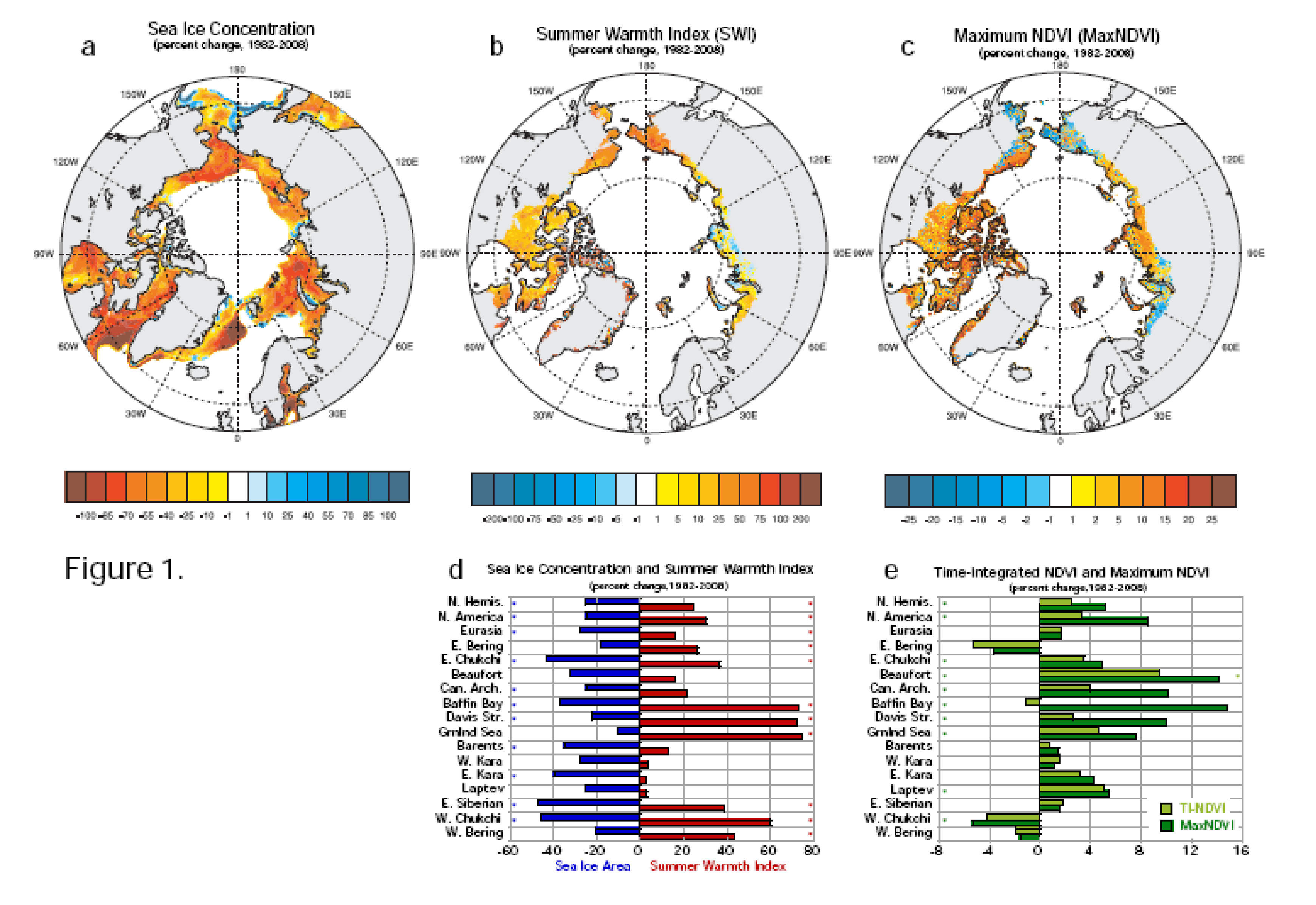
Levi, Finland

UNIVERSITY of VIRGINIA

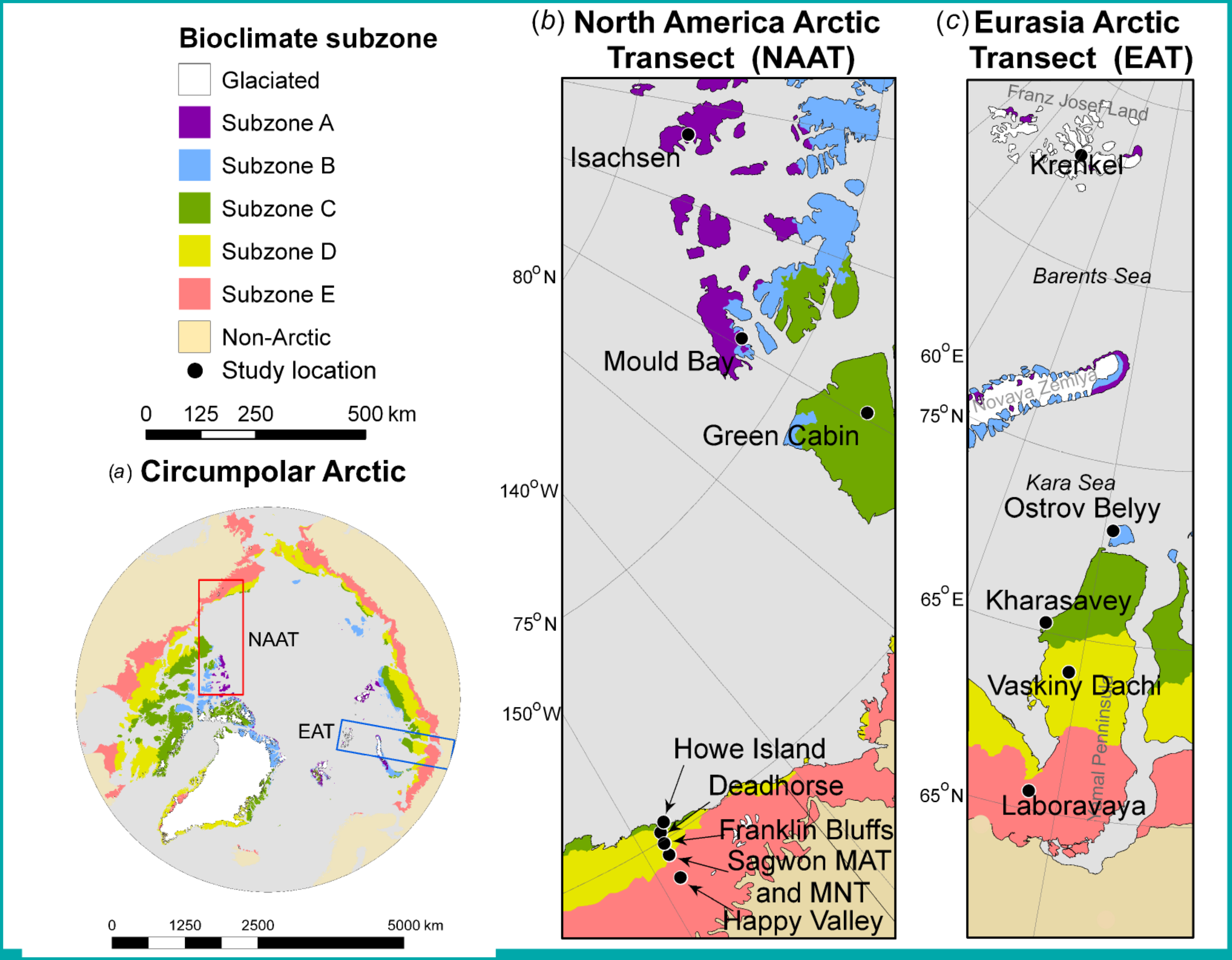


(Photo H.E. Epstein)

Arctic tundra "greening"

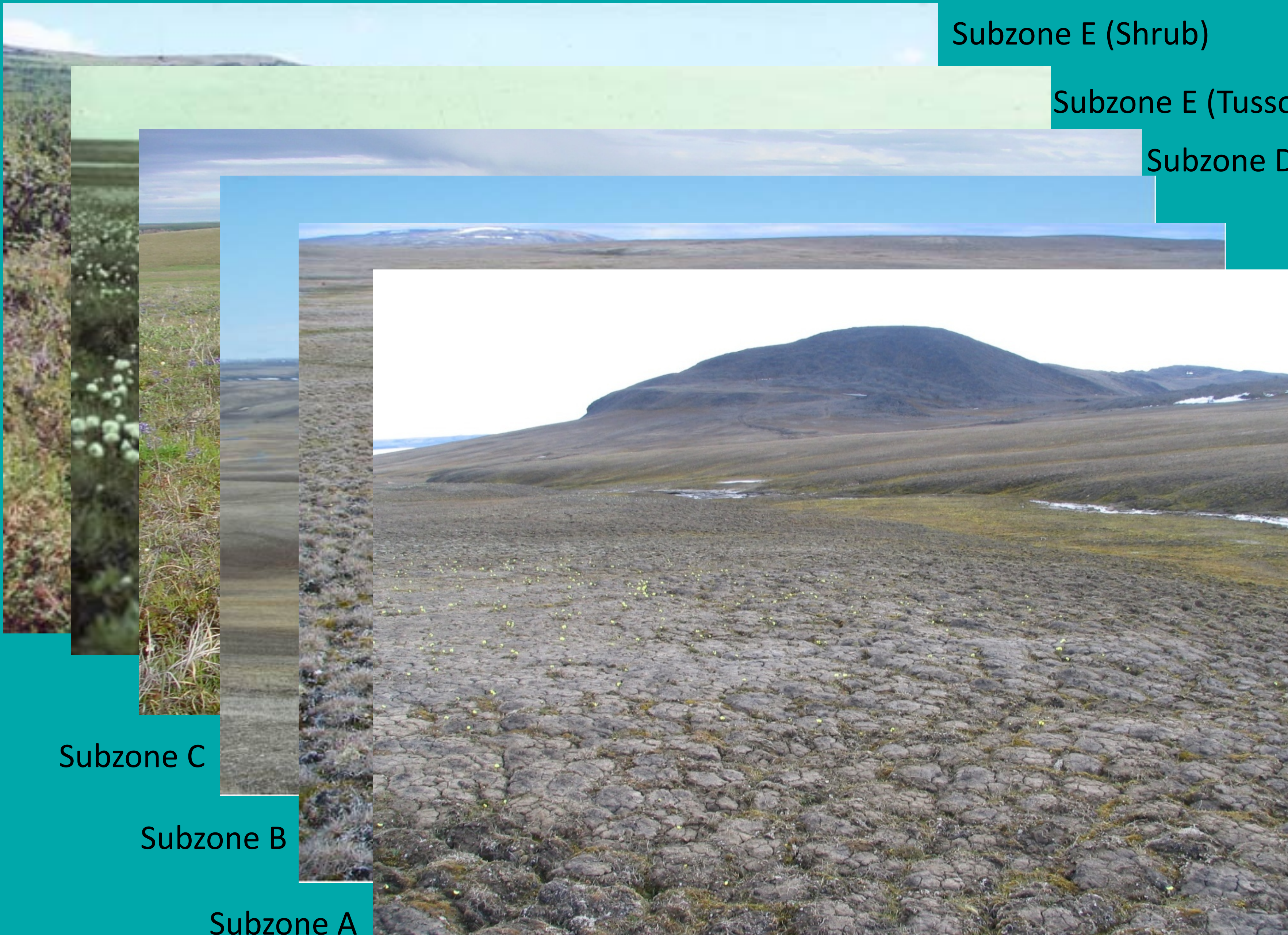


Bhatt et al. (2010)



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

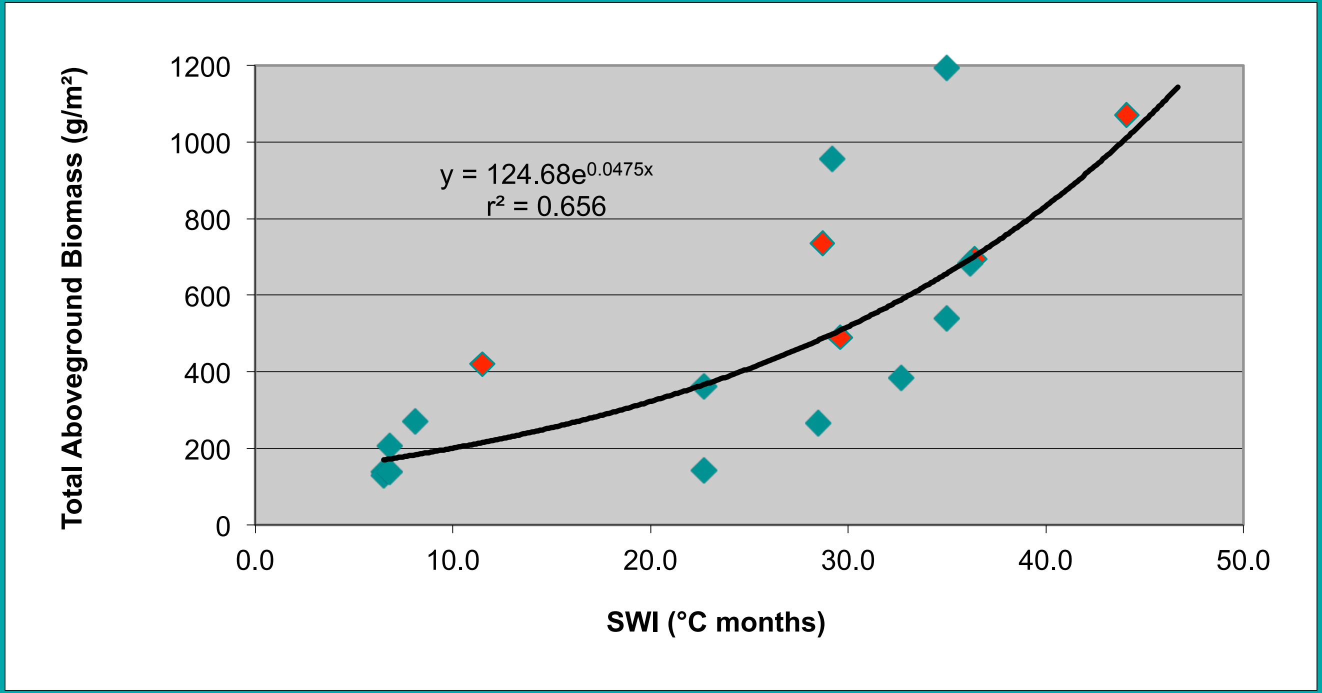
Subzone C

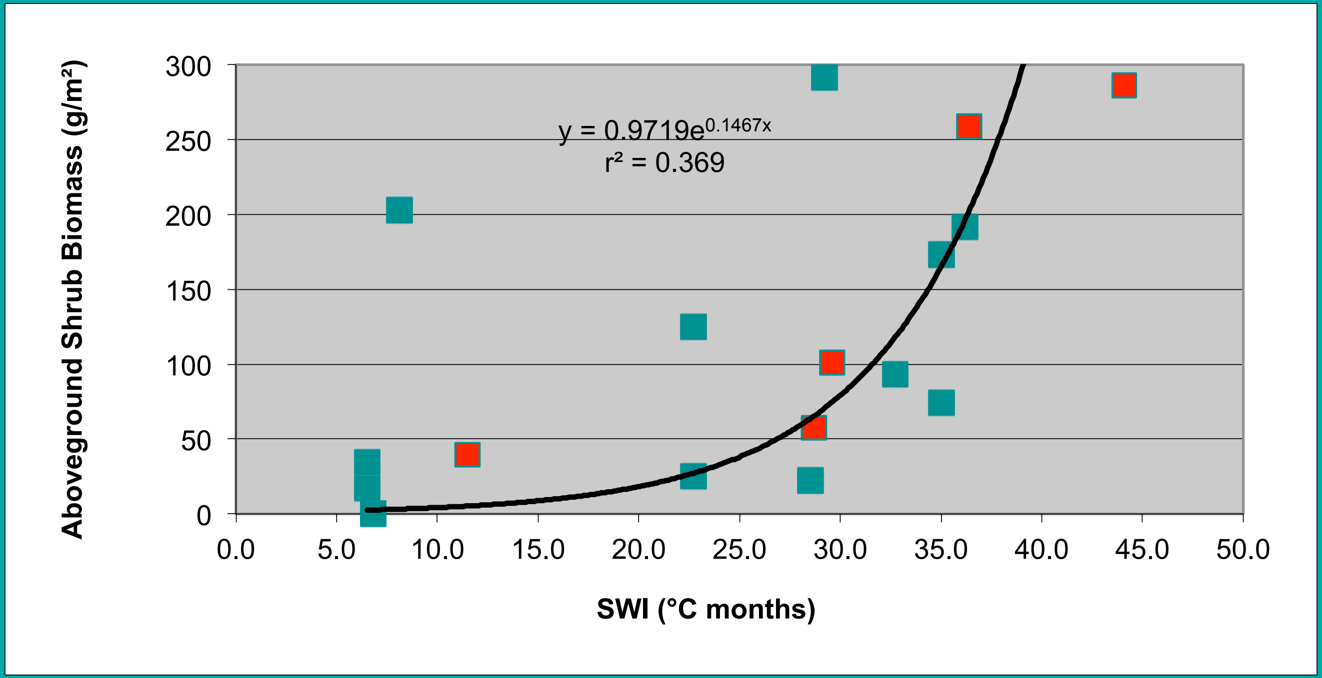
Subzone B

Subzone A

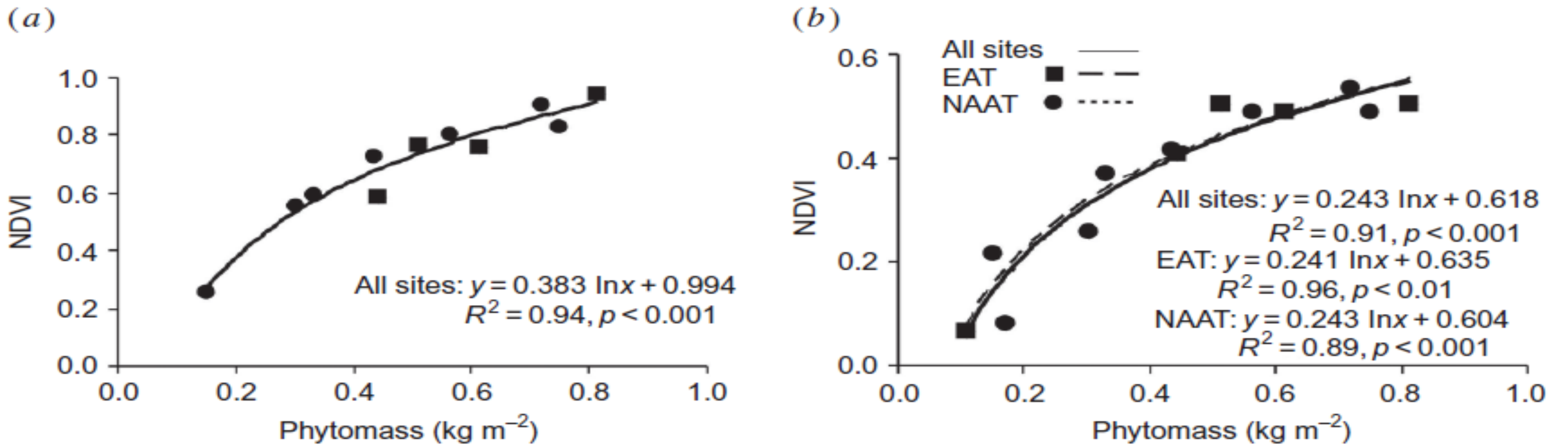
(photos by D.A. Walker and H.E. Epstein)

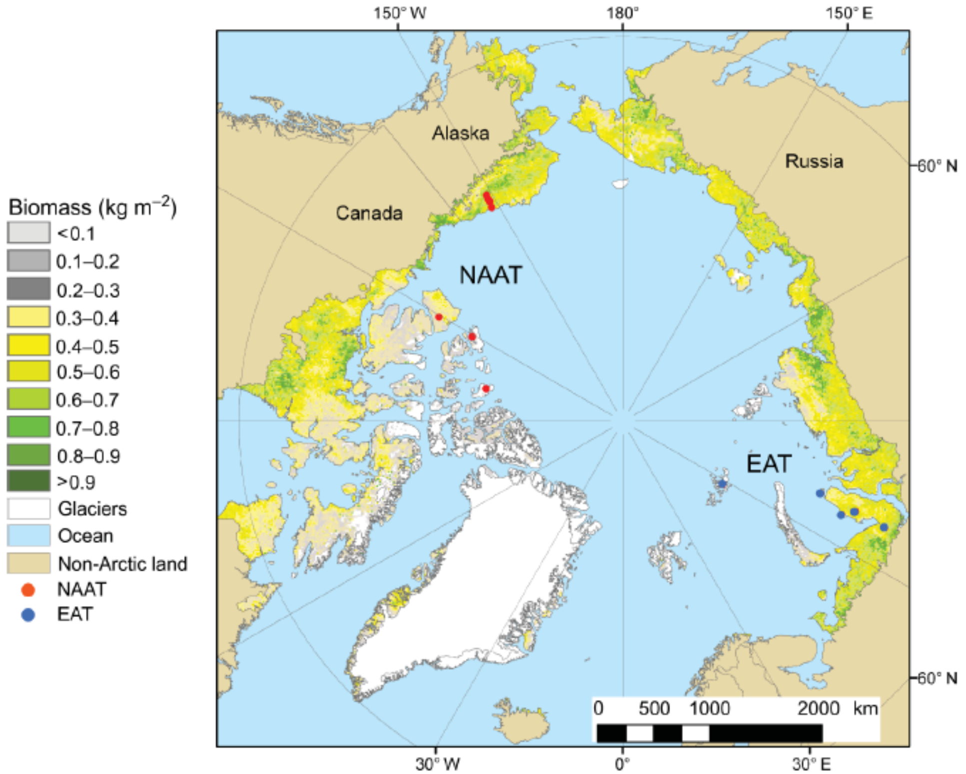
Aboveground Total and Shrub Biomass along both transects



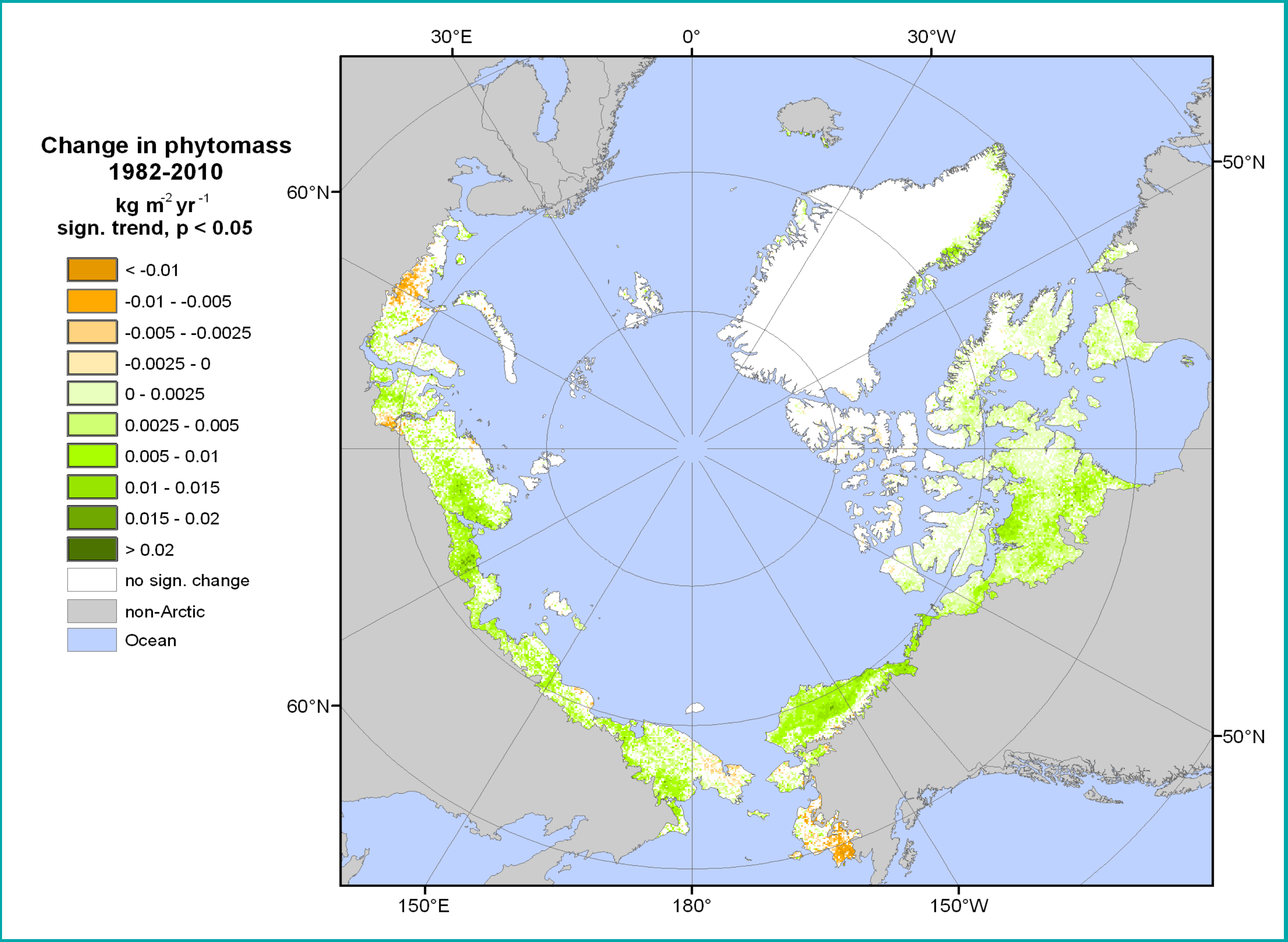


YAMAL
(EAT)

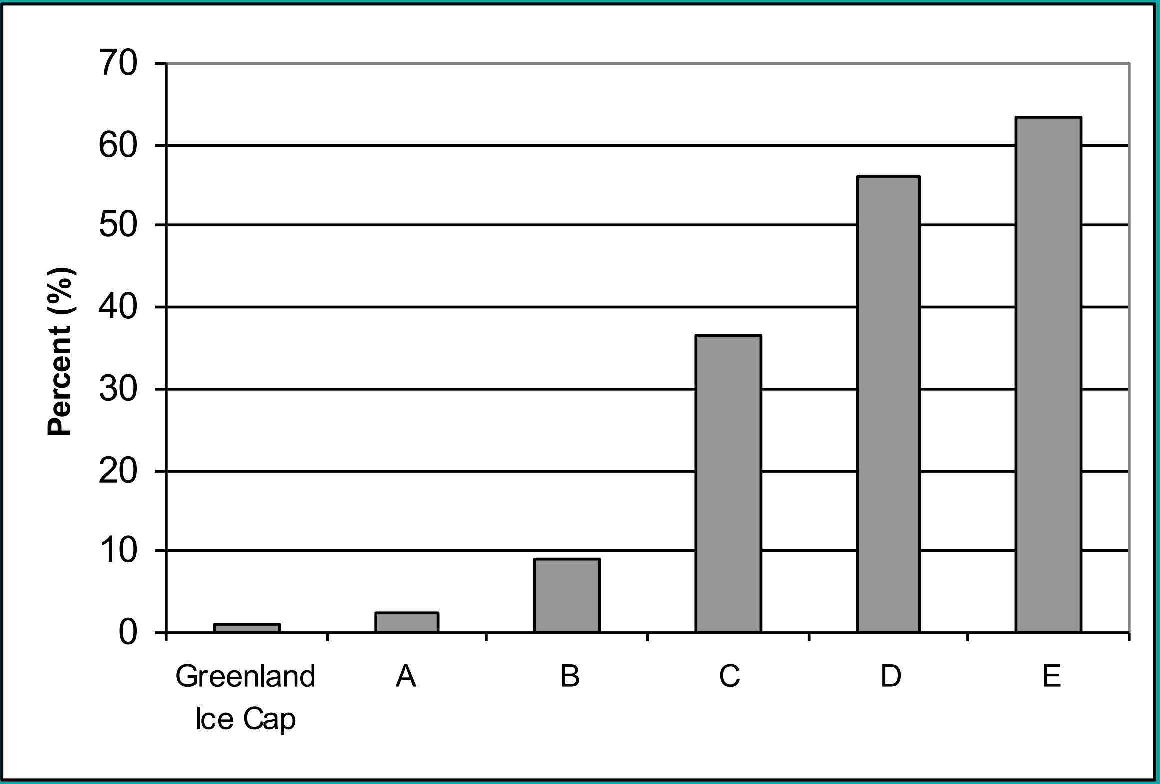




(Raynolds et al. 2012)



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.

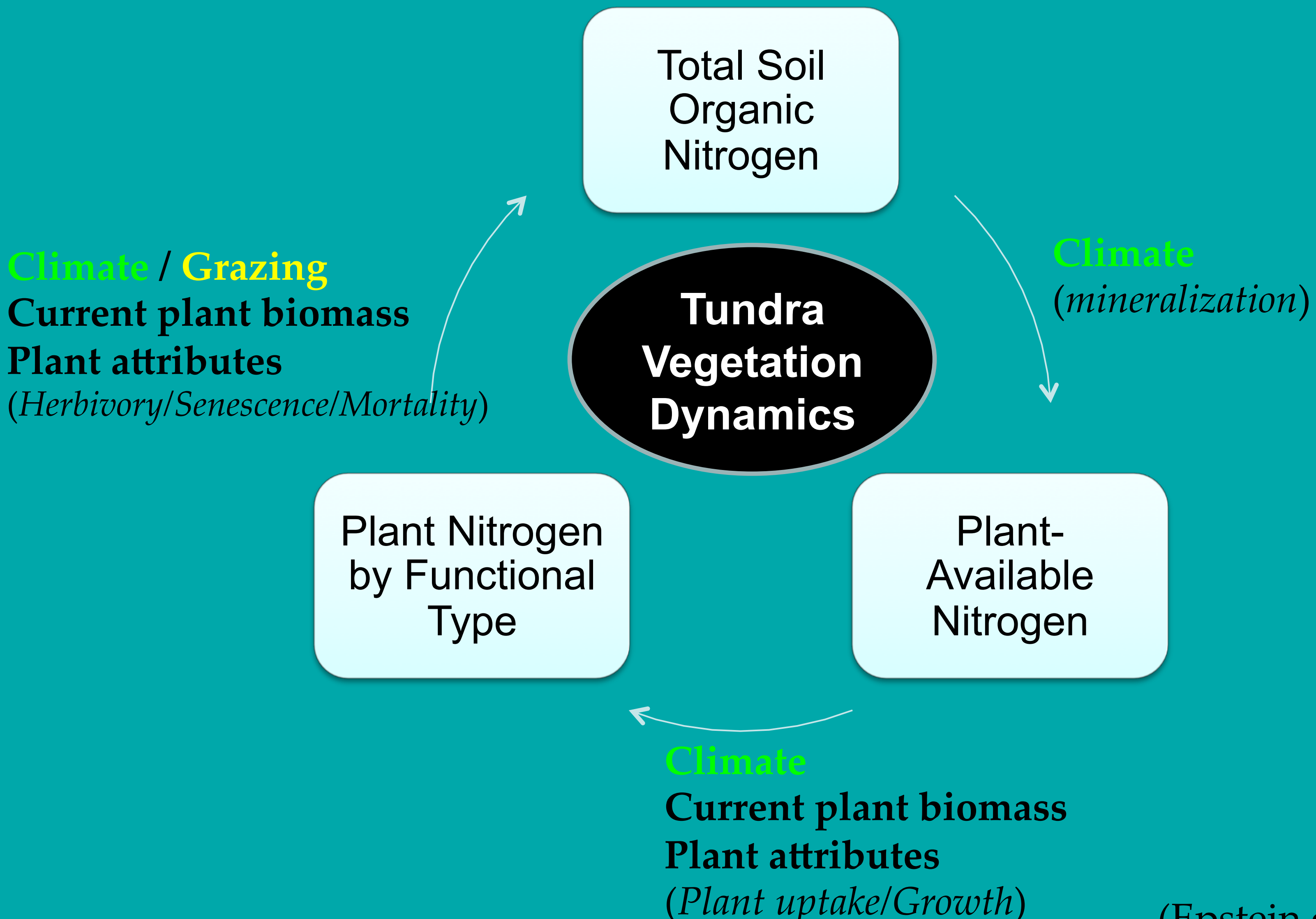


Percent of pixels with significant change in biomass

Bioclimate Subzone	Area (km²)	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	140.7	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

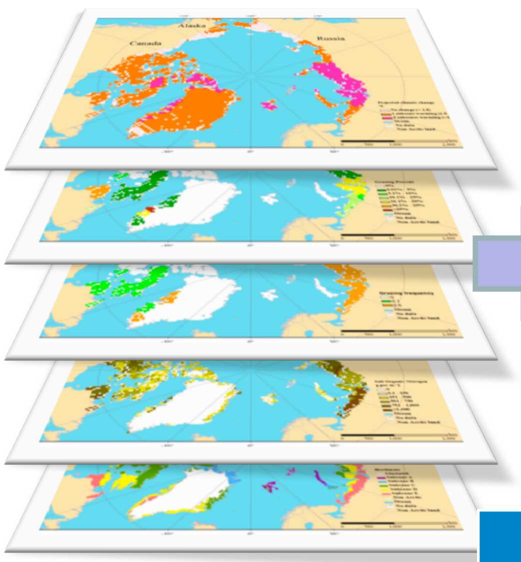
NDVI increase is a combination of all factors

ArcVeg – Arctic tundra vegetation dynamics model



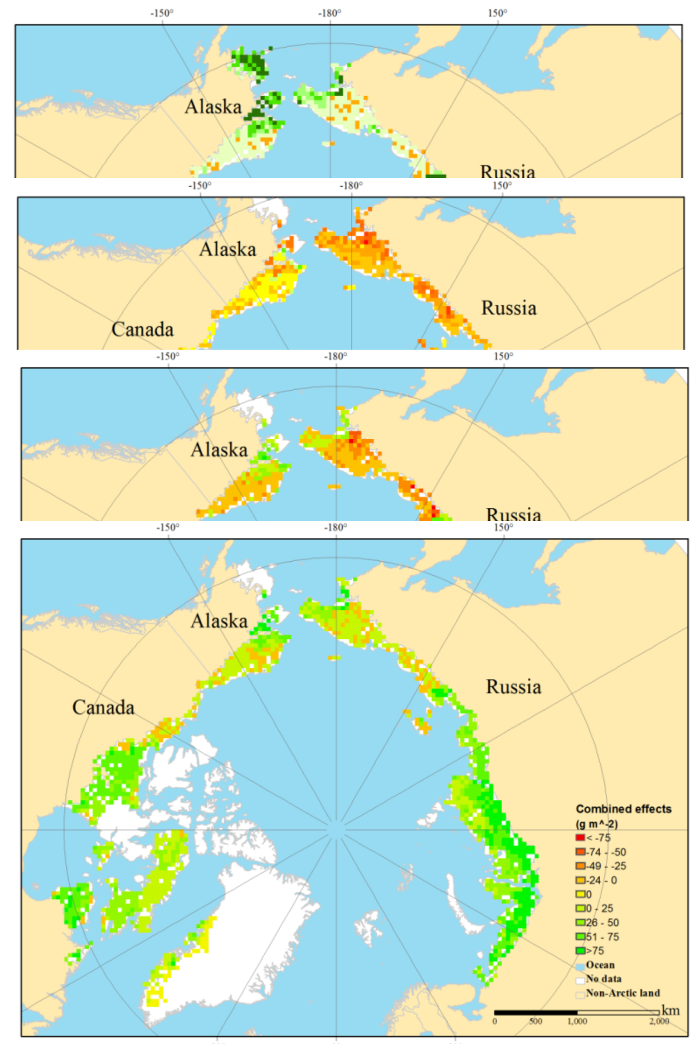
(Epstein et al. 2000)

CIRCUMPOLAR ARCTIC TUNDRA RESPONSES TO GRAZING PRESSURE AND PROJECTED CLIMATE CHANGE



ArcVeg → **Above-ground biomass** / **NPP**

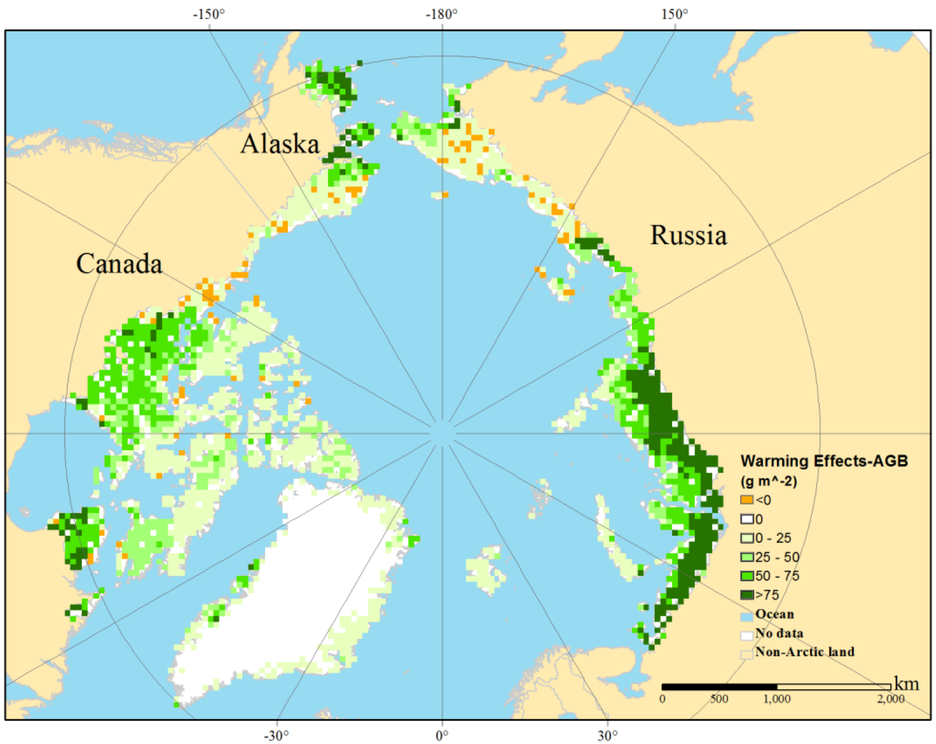
Simulation scenario
Control
Grazing only
Warming only
Combined effects



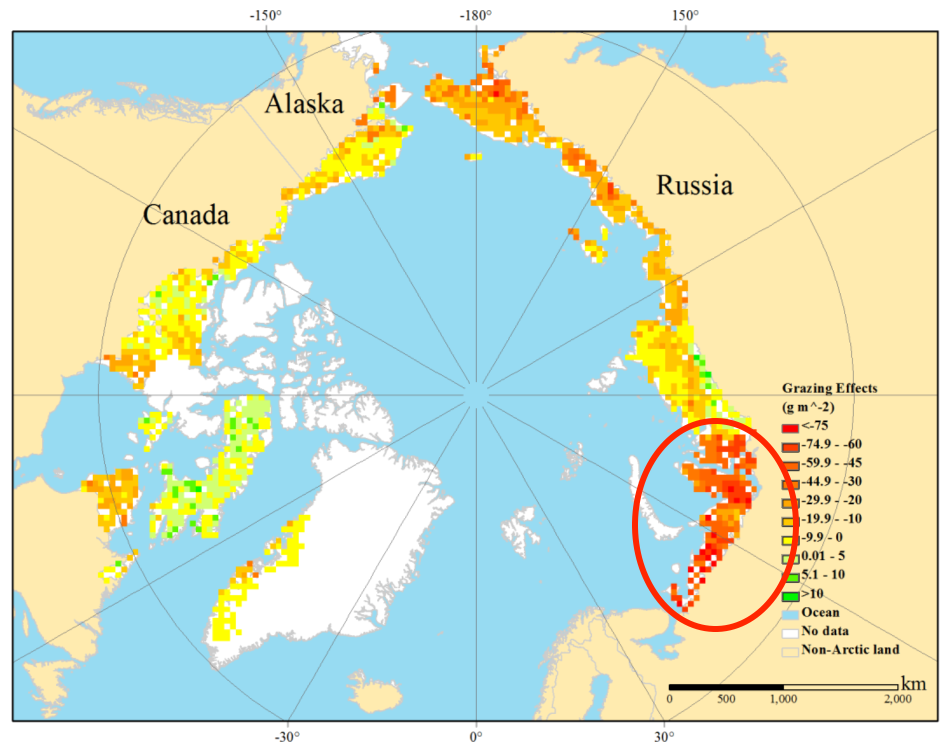
Yu et al. (in prep)

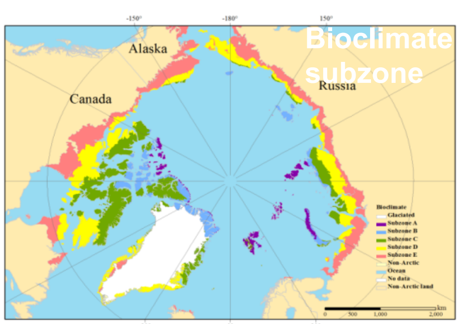
CIRCUMPOLAR ARCTIC TUNDRA RESPONSES TO GRAZING PRESSURE AND PROJECTED CLIMATE CHANGE

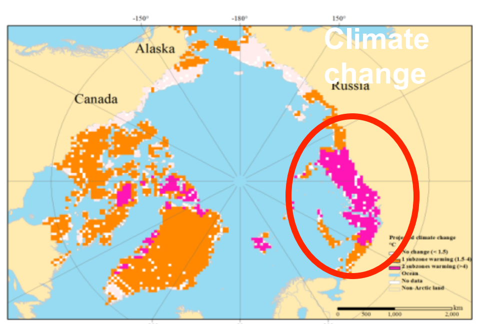
Projected Temperature caused change

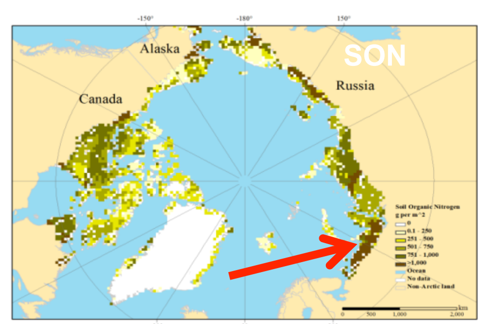


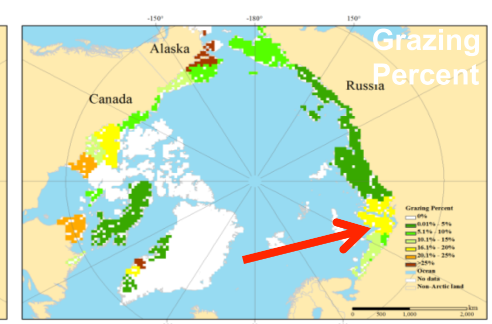
Reindeer/caribou grazing caused change





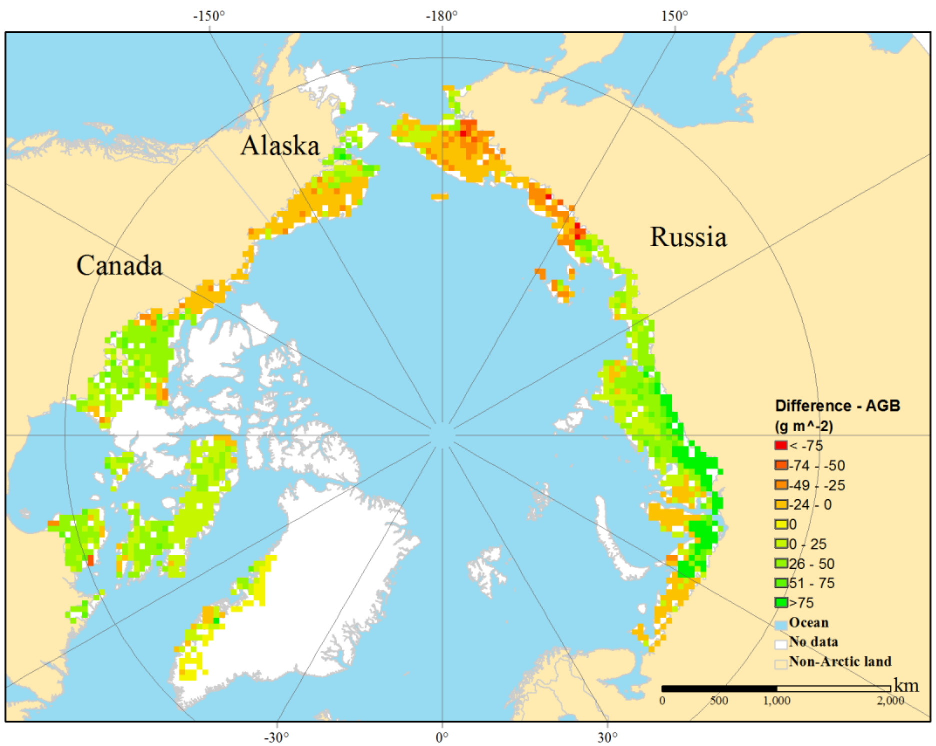


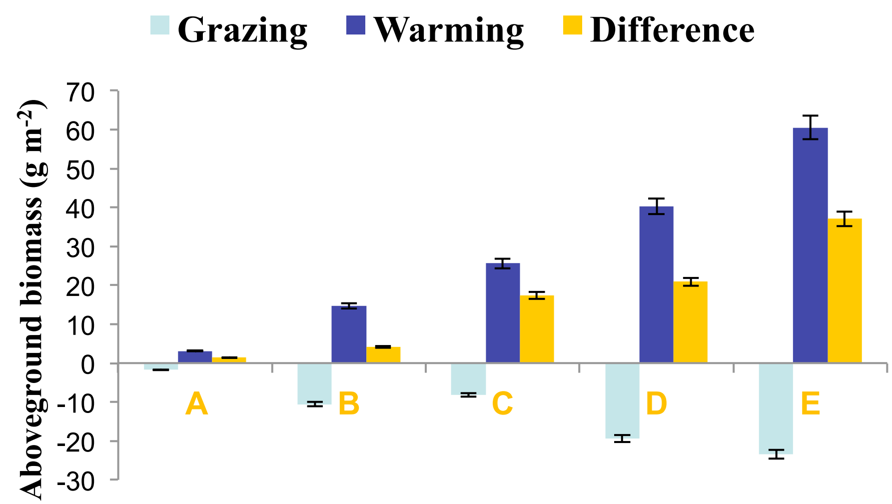




DIFFERENCE IN INDIVIDUAL EFFECTS

Simple difference between climate change and grazing caused biomass change





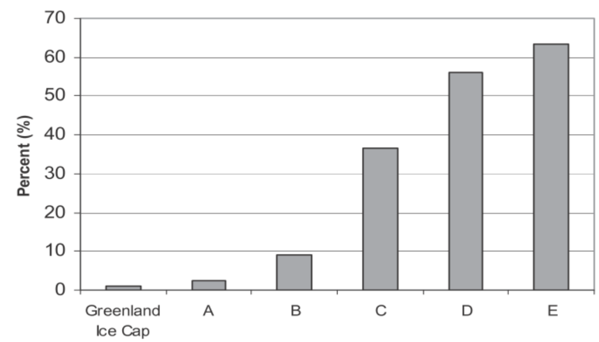


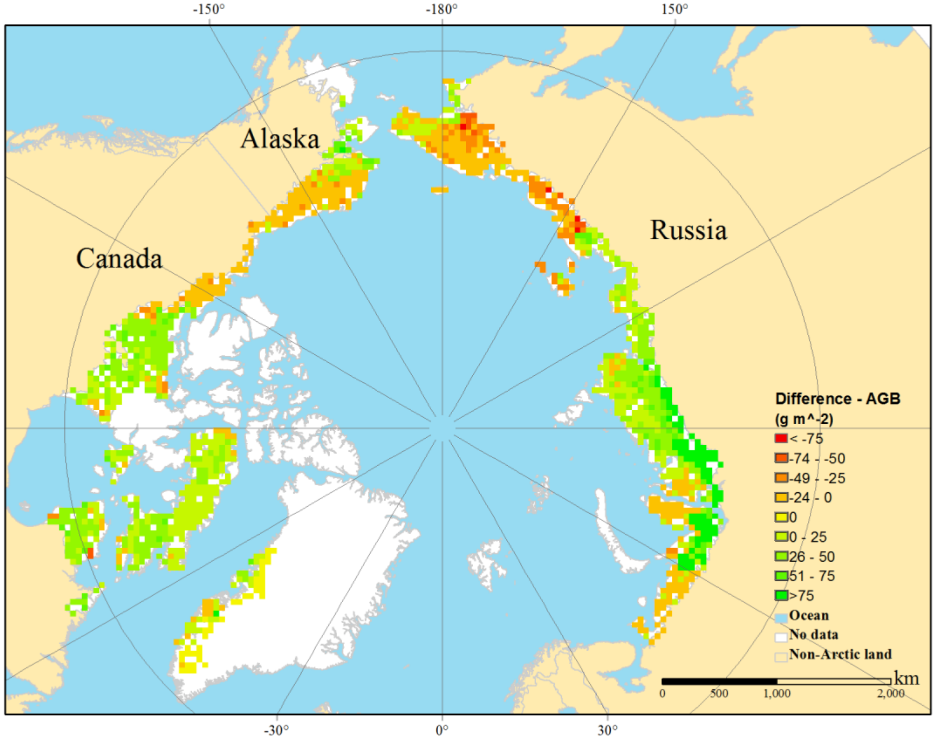
Figure 4. Per cent of subzone pixels with significant ($p < 0.05$) positive trend.

Epstein et al. 2012

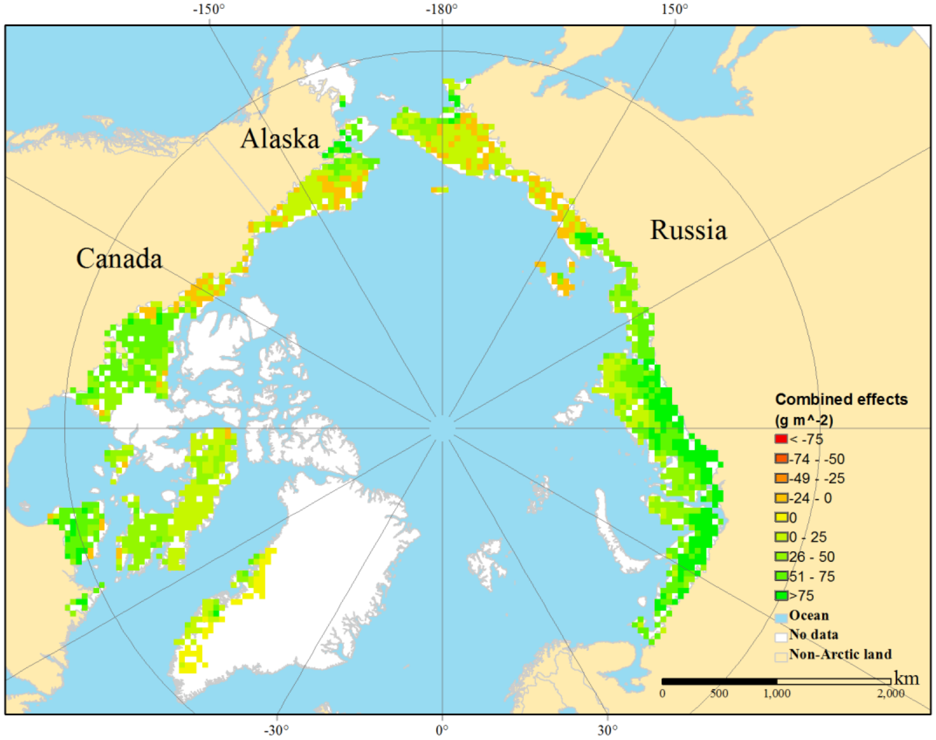
- **Most of the biomass changes in the three southernmost subzones**
- **very little change in subzones A (2.1%) and B (6.4%)**

INDIVIDUAL EFFECTS VS. COMBINED EFFECTS

Simple difference between climate change and grazing caused biomass change



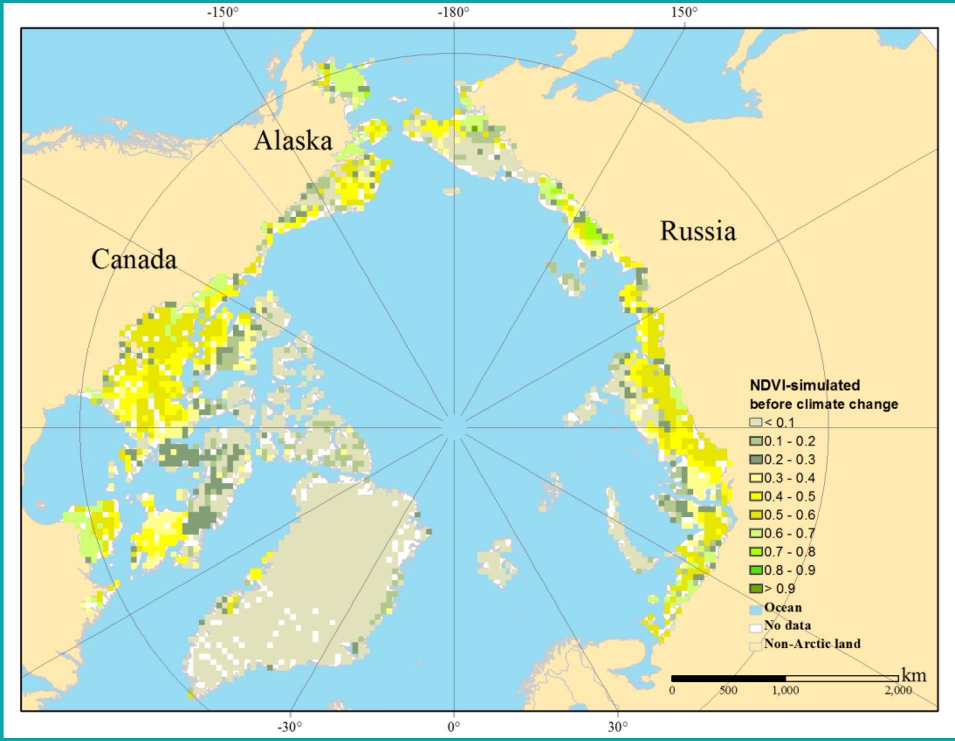
Combined effects of climate change and reindeer/caribou grazing caused change



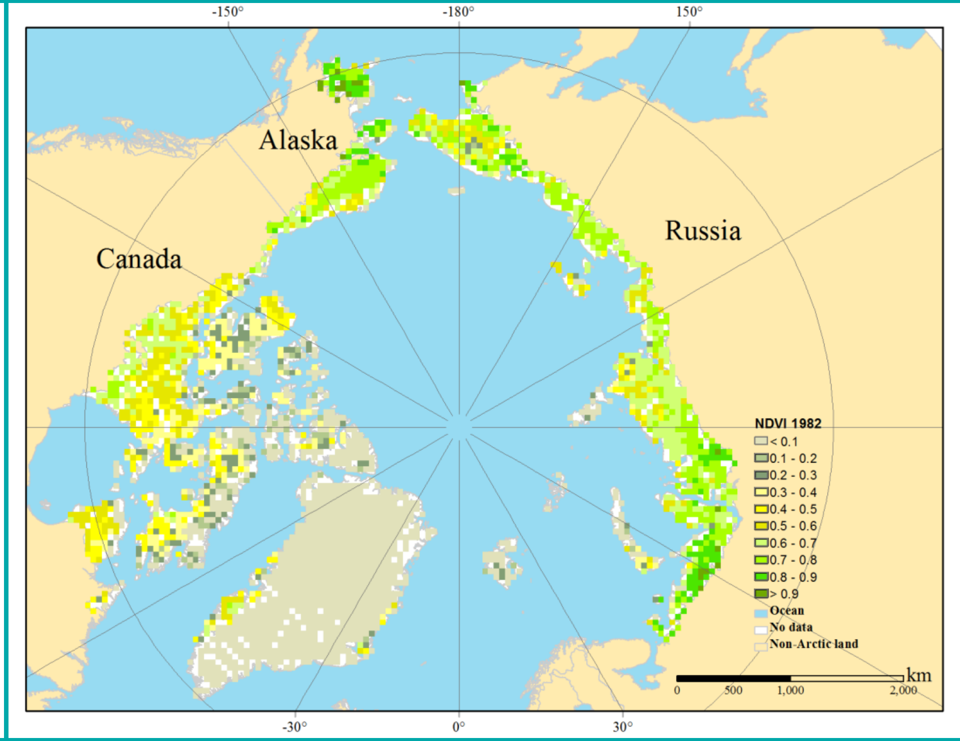
Interaction effect is positive for aboveground biomass

Comparison of simulated NDVI and satellite NDVI

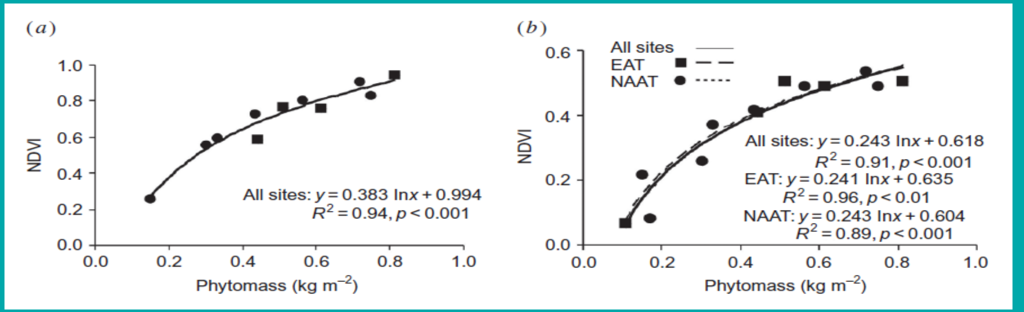
NDVI based on simulated aboveground biomass before climate change



NDVI in year 1982 from AVHRR GIMMS-3g

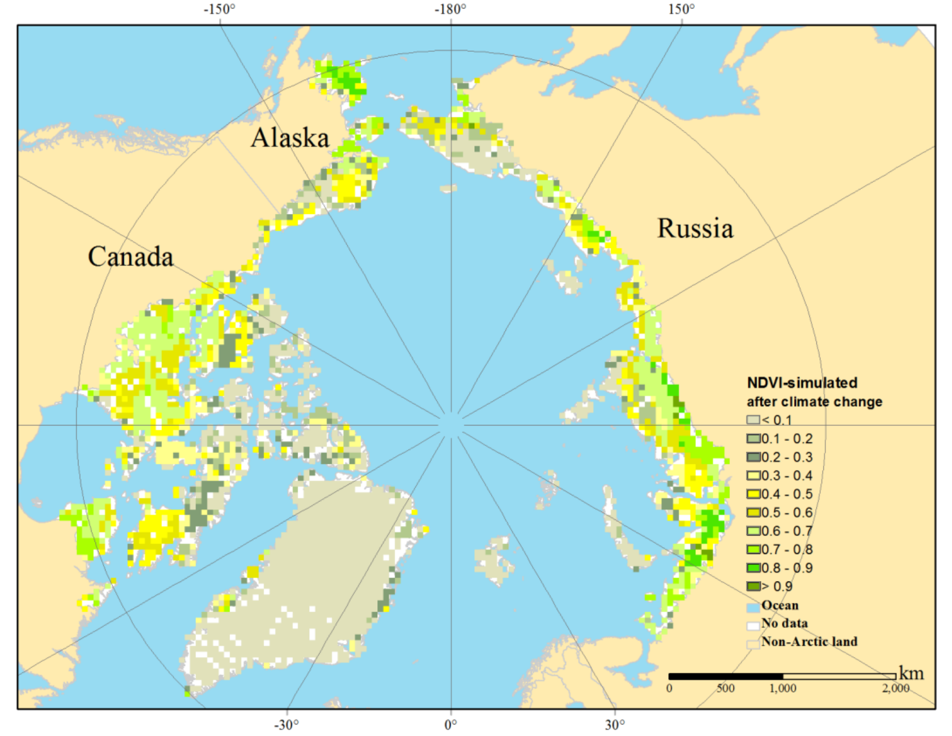


NDVI calculated based on Raynolds et al. 2012_Remote Sensing Letters

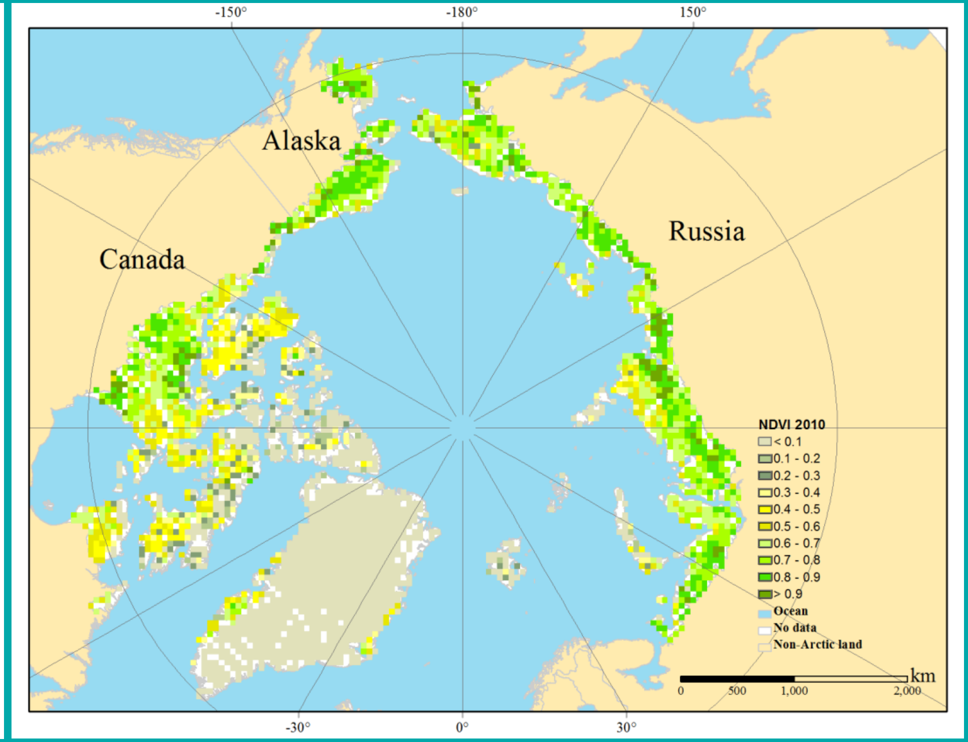


Comparison of simulated NDVI and satellite NDVI

NDVI based on simulated aboveground biomass after climate change



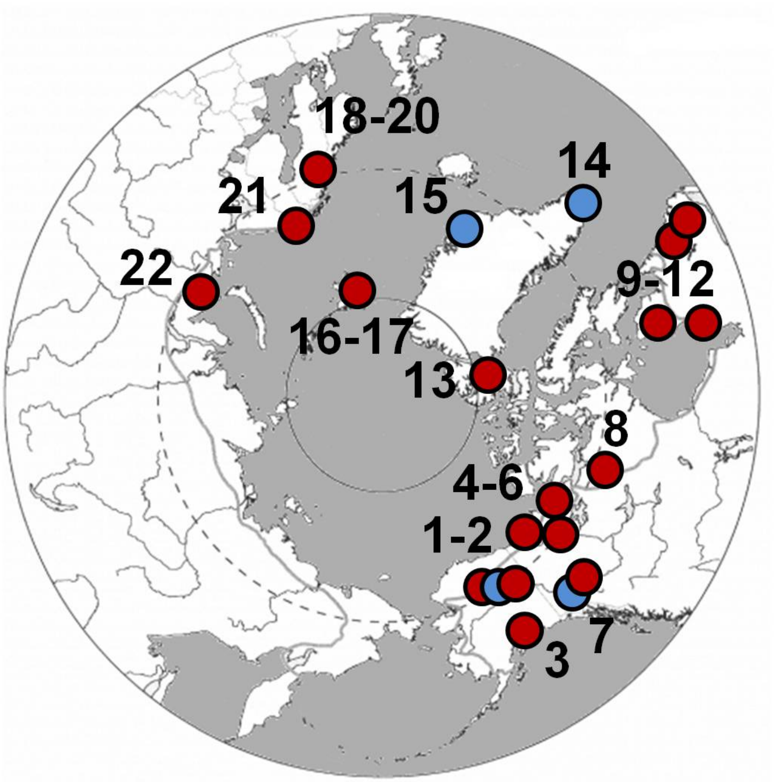
NDVI in year 2010 from AVHRR GIMMS-3g



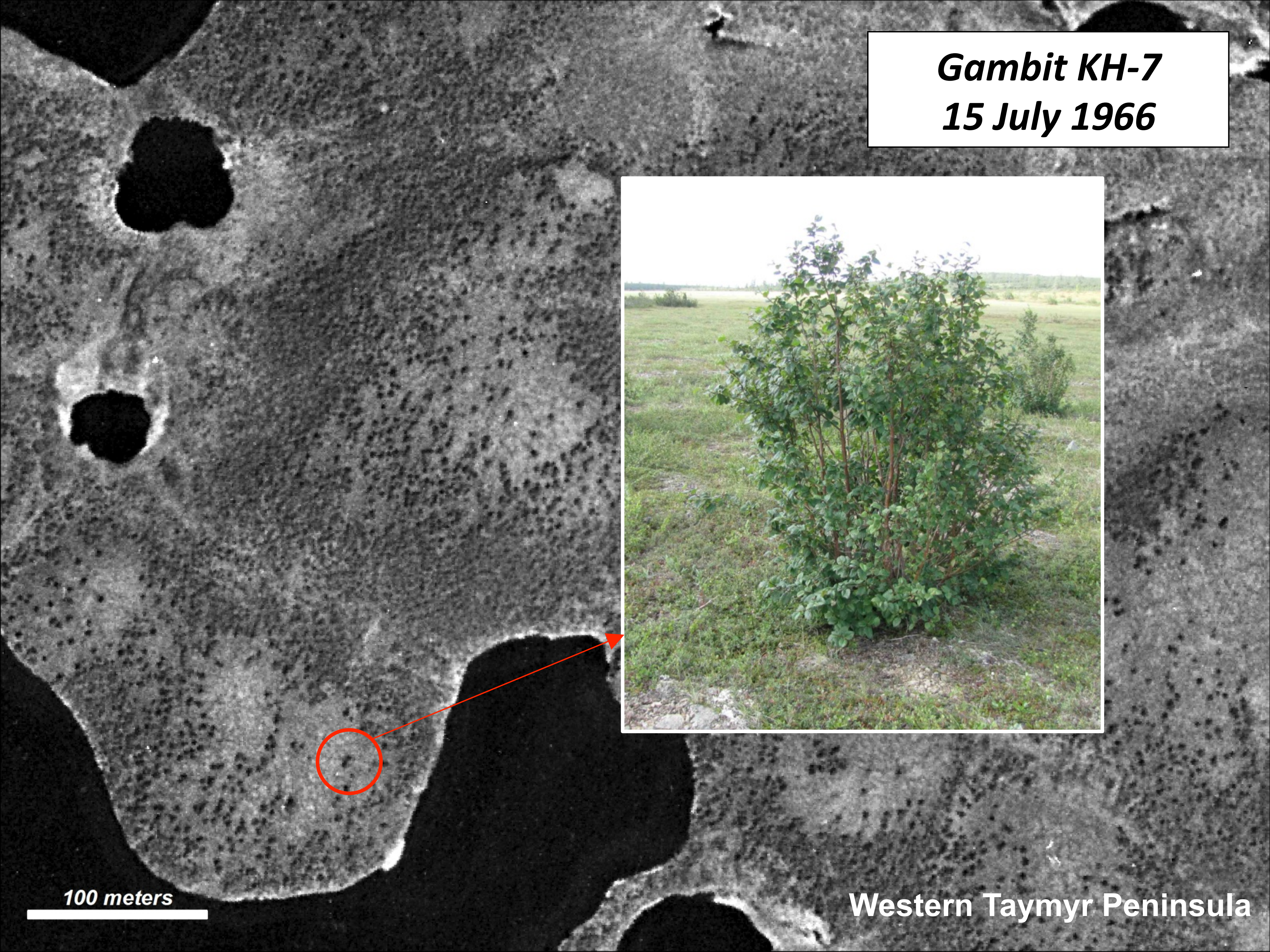
Changes in shrub cover, northern Alaska
1950-2003

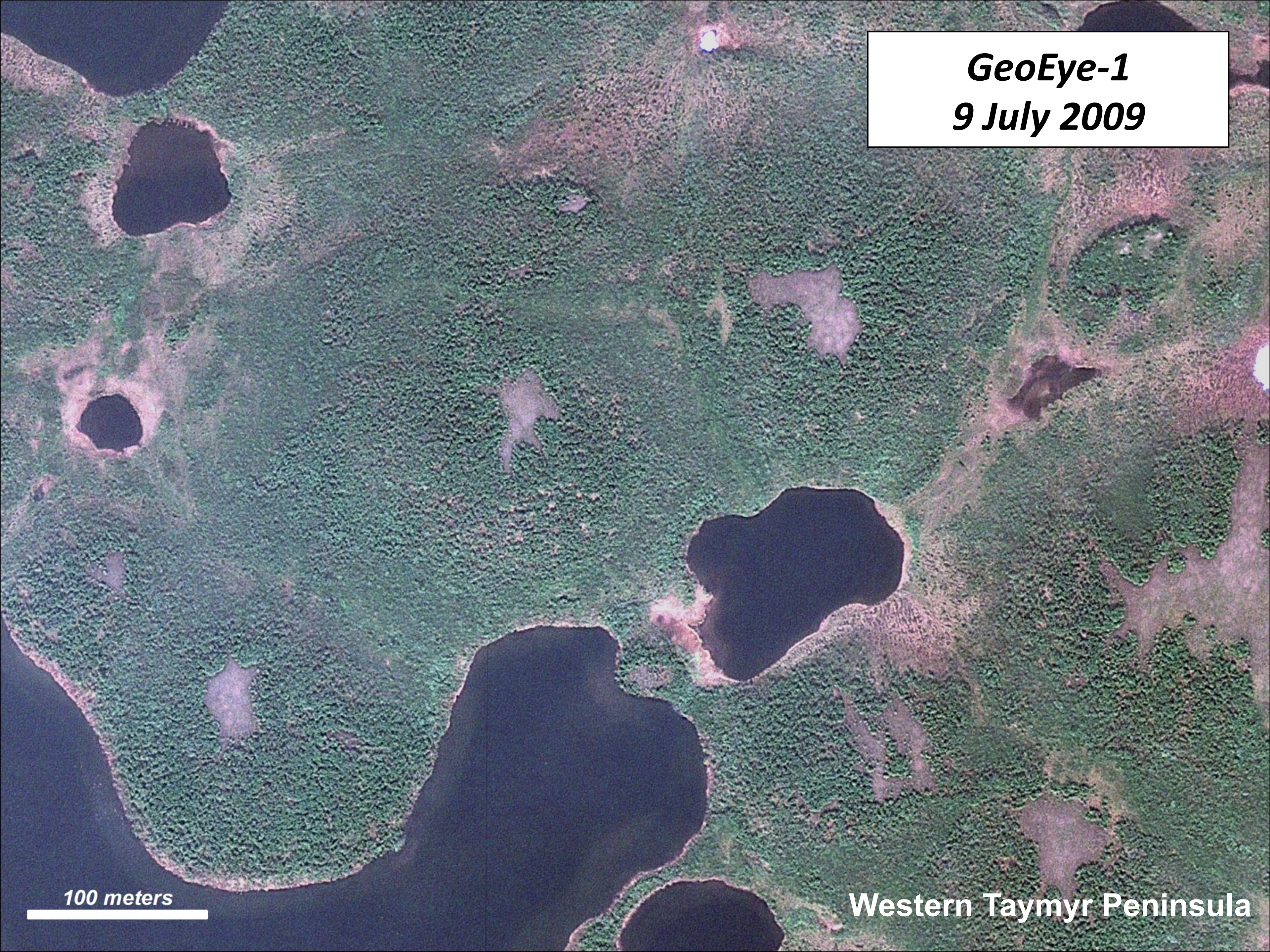
Sturm, M., C. Racine, and K. Tape. 2001. Increasing shrub abundance in Arctic. Nature **411**:547-548.

Previous arctic shrub studies



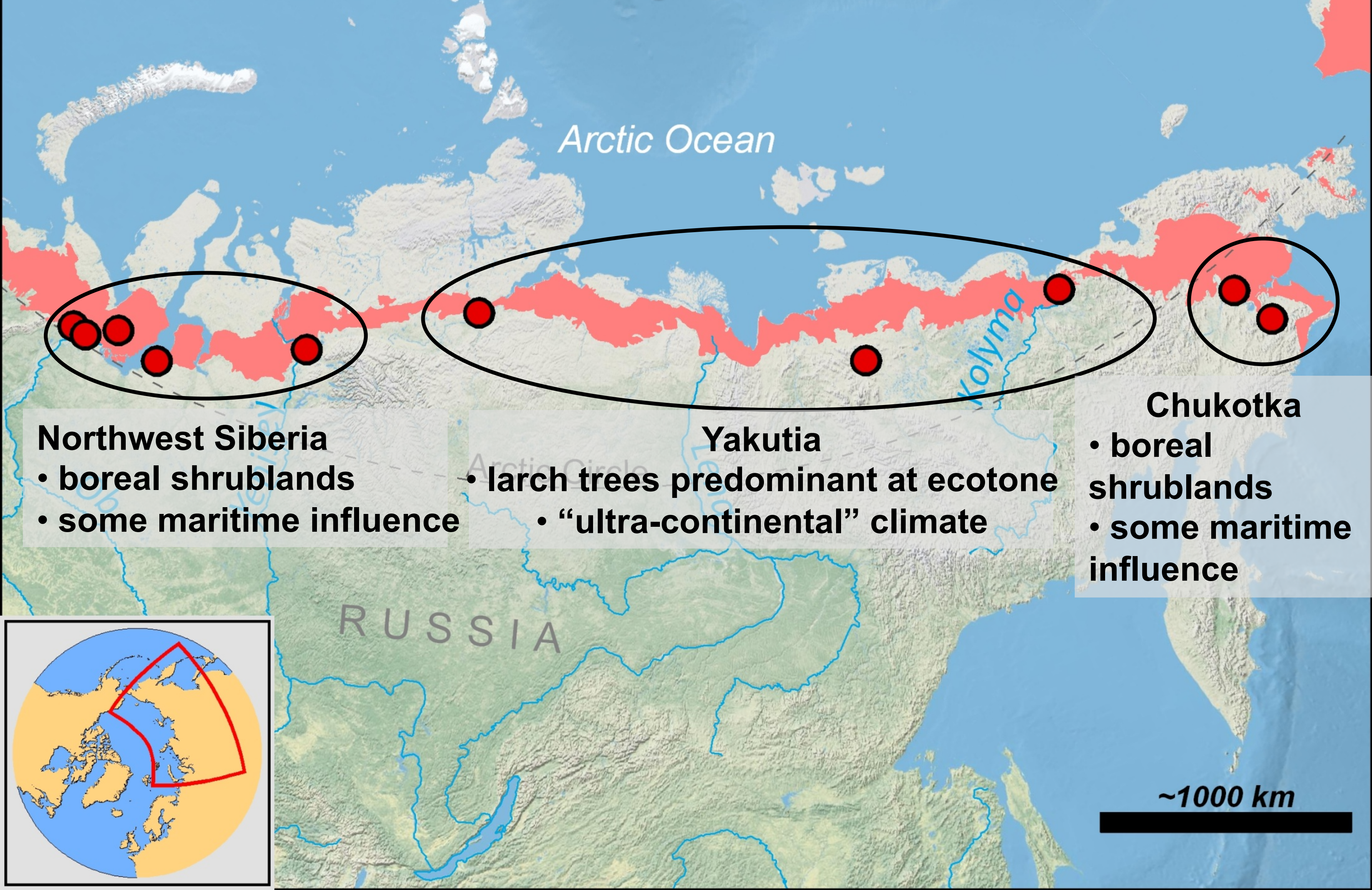
Myers-Smith *et al.* 2011, ERL


Gambit KH-7
15 July 1966
100 meters
Western Taymyr Peninsula

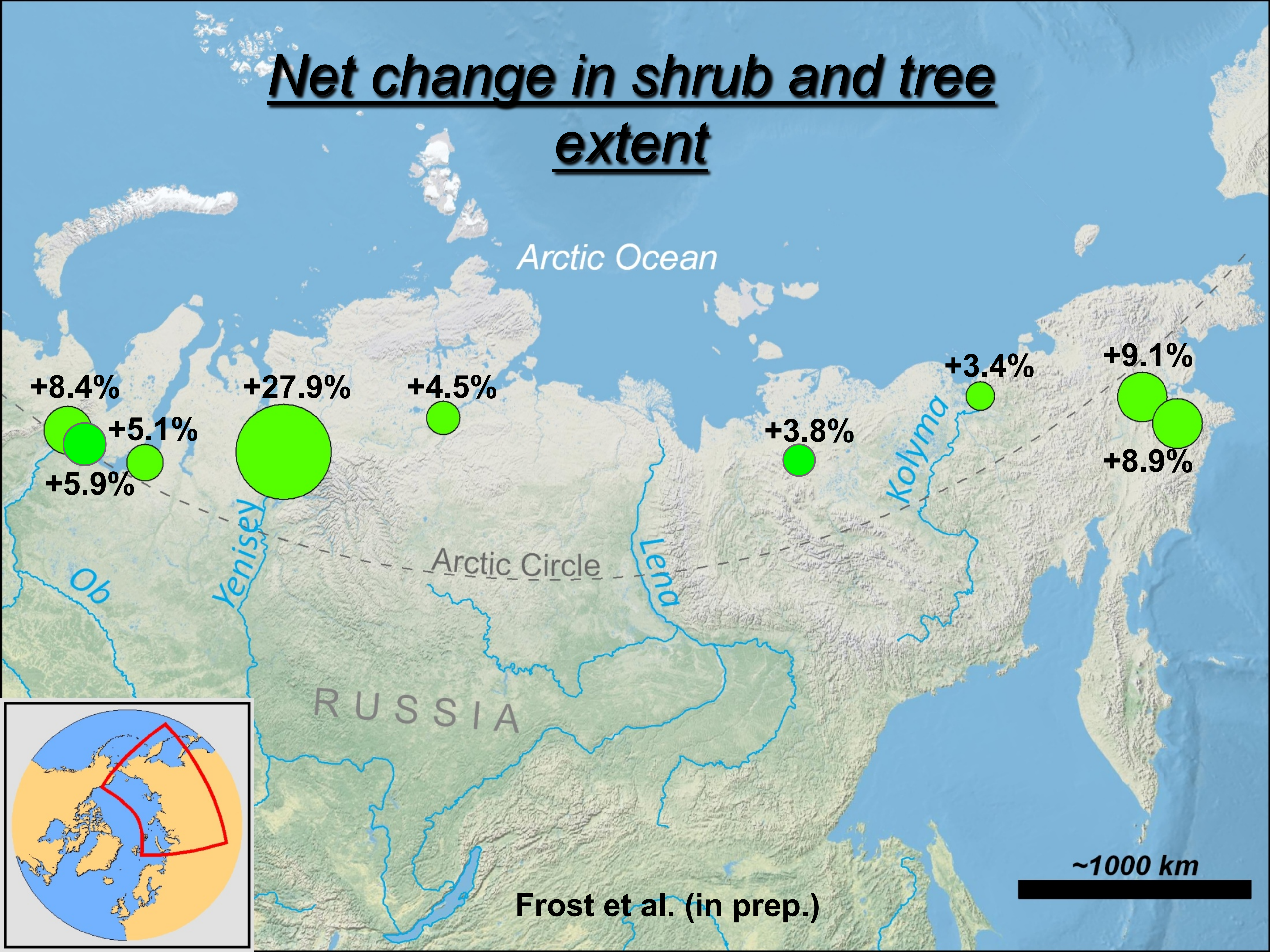

GeoEye-1
9 July 2009
100 meters
Western Taymyr Peninsula


Young alders growing in patterned-ground, Kharp
Strong facilitation of alder expansion by patterned ground
Photo (Gerald V. Frost)

Study sites


Arctic Ocean
Kolyma
Lena
Yenisei
Ob
Arctic Circle
RUSSIA
Northwest Siberia
• boreal shrublands
• some maritime influence
Yakutia
• larch trees predominant at ecotone
• “ultra-continental” climate
Chukotka
• boreal shrublands
• some maritime influence
~1000 km

Net change in shrub and tree extent



Frost et al. (in prep.)

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.
- Grazing may buffer the responses of vegetation to warming, and the remotely sensed NDVI dynamics are the combined result of these two opposing processes.
- Shrub expansion appears to be accounting for a substantive fraction of the greening circumpolarly, particularly in the southern tundra. Shrub extent is increasing, in some places dramatically, and at least some of this is facilitated by patterned ground features.

Acknowledgments

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➢ Department of Environmental Sciences, Univ. of Virginia