Temporal dynamics of circumpolar arctic tundra vegetation in response to temperature changes

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The Arctic Tundra Biome

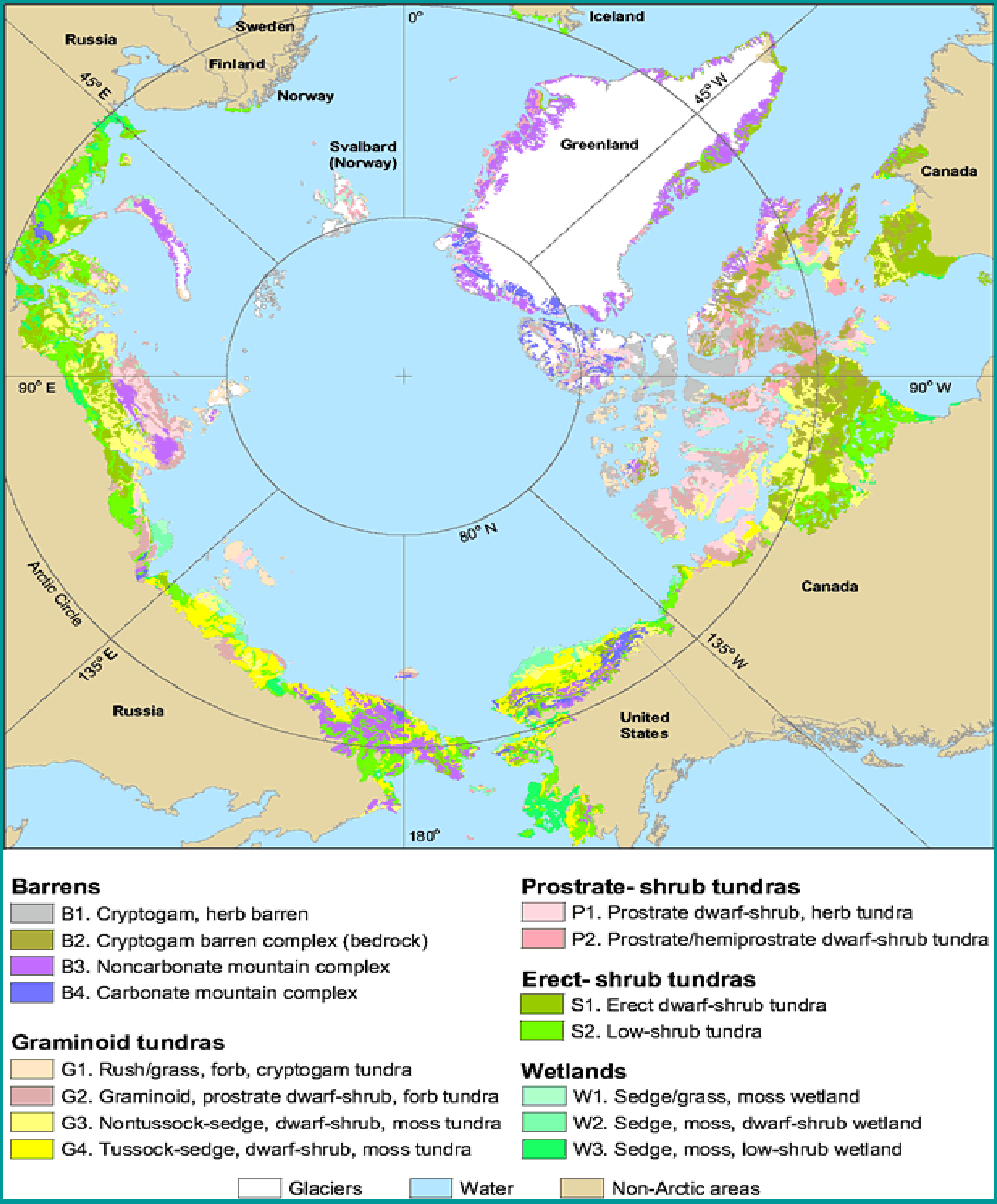
Arctic tundra vegetation has been undergoing substantive changes recently, at least since the mid 20th century.

These changes have been rather heterogeneous from a circumpolar perspective.

1) ***How strongly do temperature changes predict vegetation dynamics?***

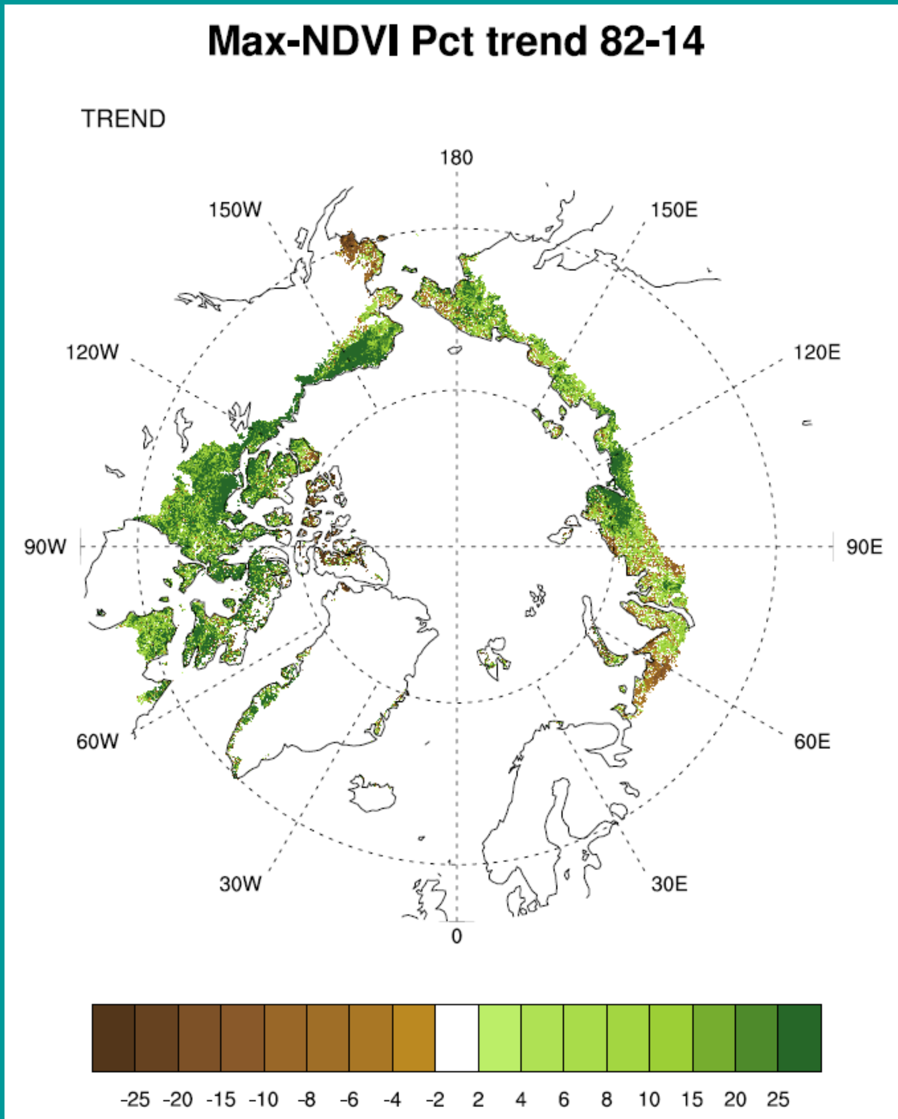
2) ***How does interannual variability in temperature relate to interannual variability in vegetation?***

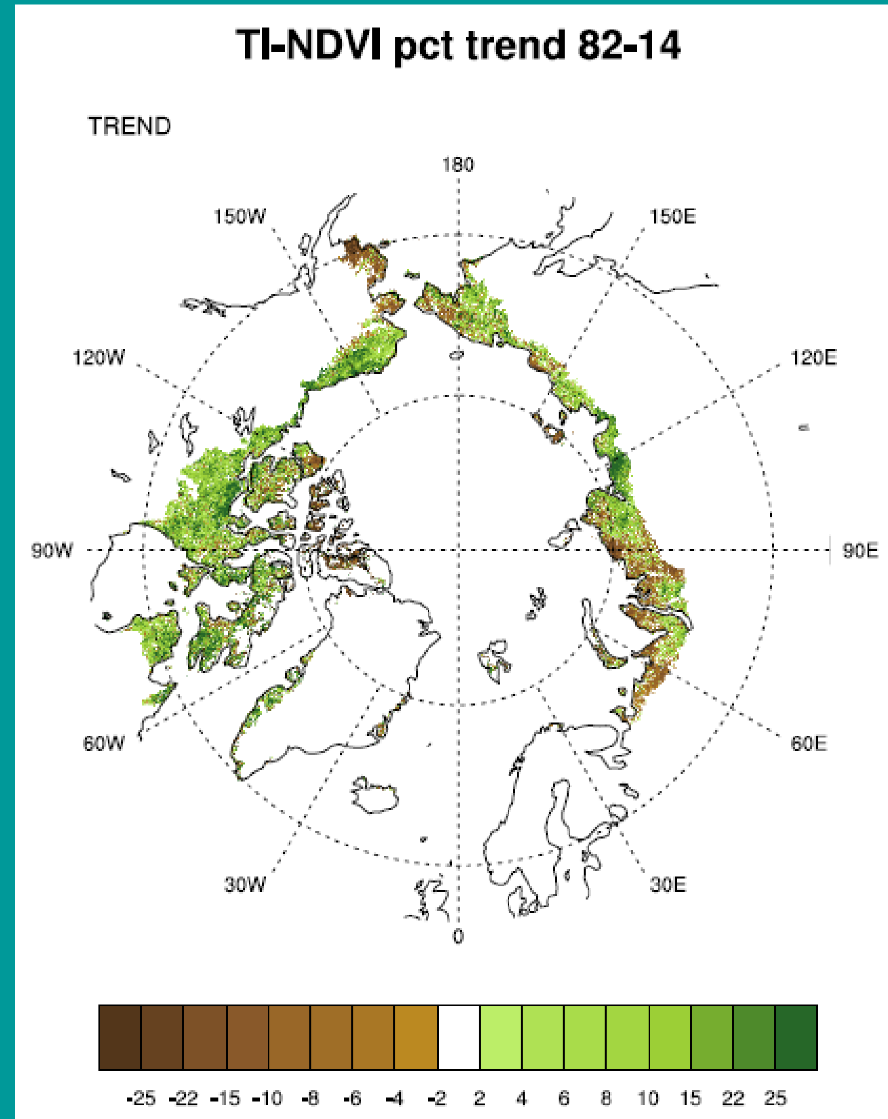
3) ***How do these relationships vary across continents and tundra subzones?***



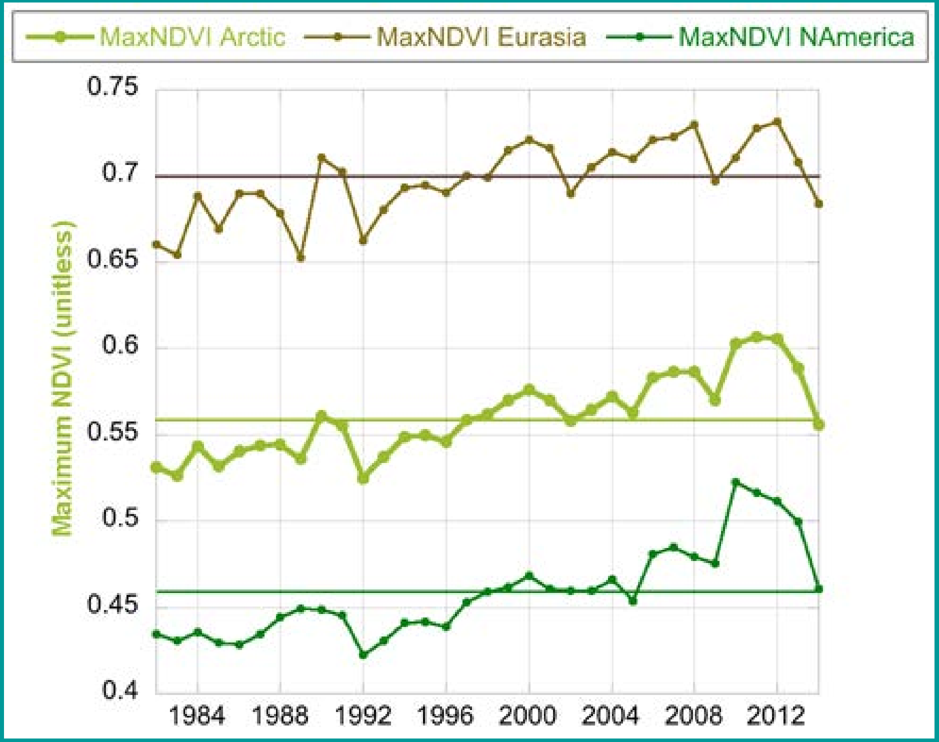
Walker, D. A., 2005. The Circumpolar Arctic Vegetation Map. Journal of Vegetation Science.

Heterogeneous Arctic "Greening" and "Browning"





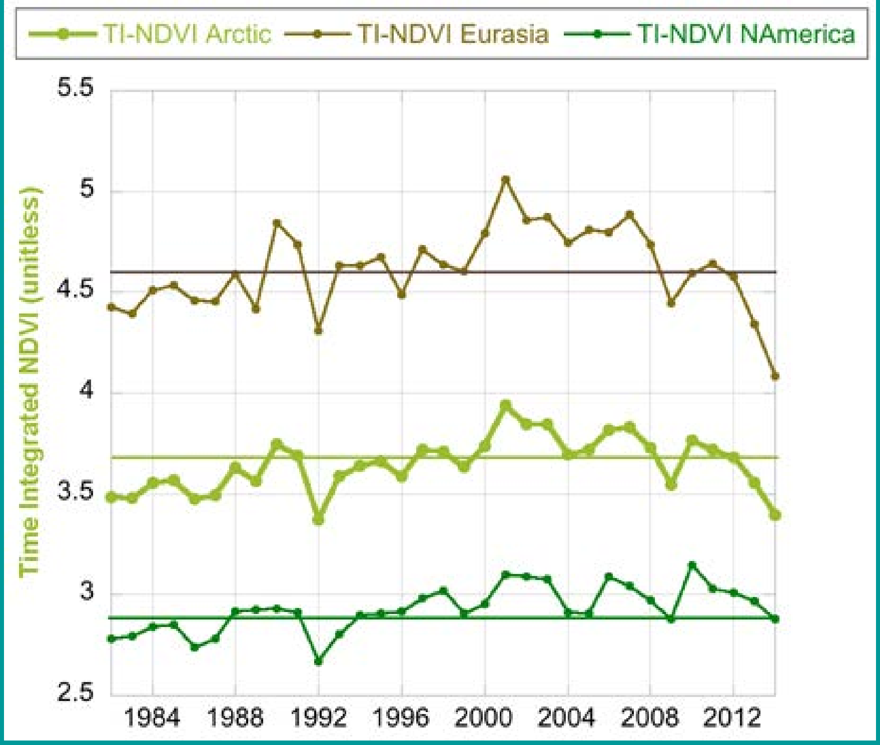
Bhatt et al. (2013), Epstein et al. (NOAA Arctic Report Card 2015)



MaxNDVI
(peak greenness)

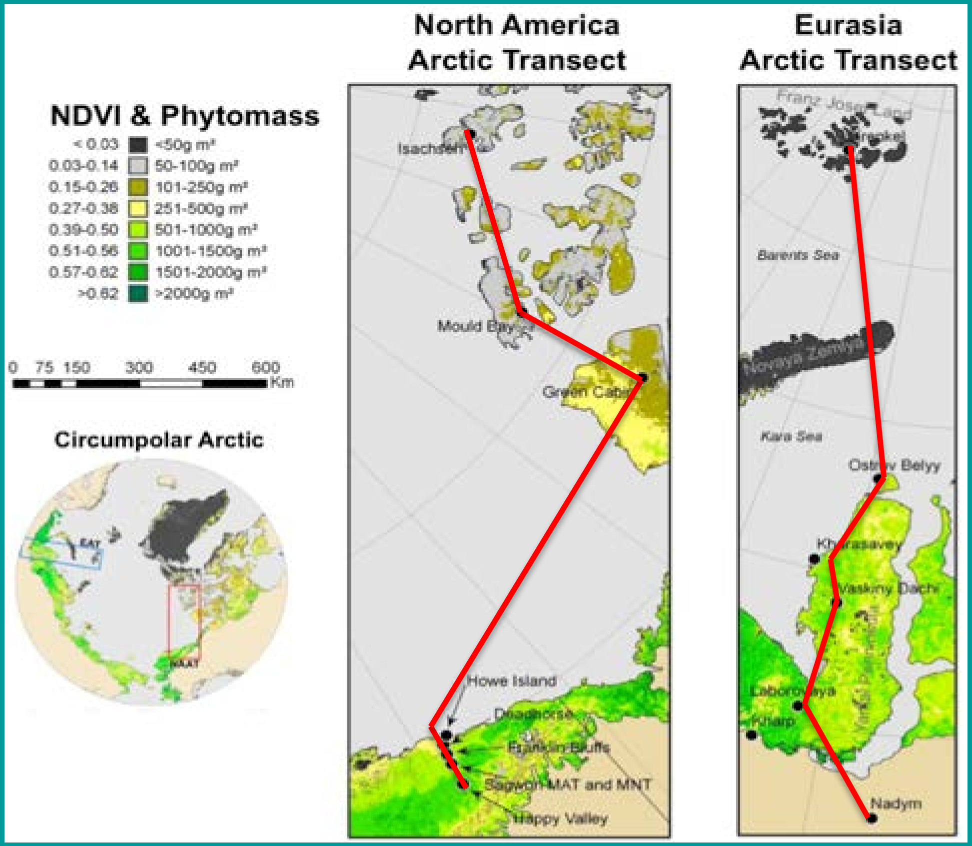
Trends are changing, particularly for TI-NDVI, indicative of a shorter growing season (possibly longer snow cover duration)

TI-NDVI
(temporally integrated greenness)

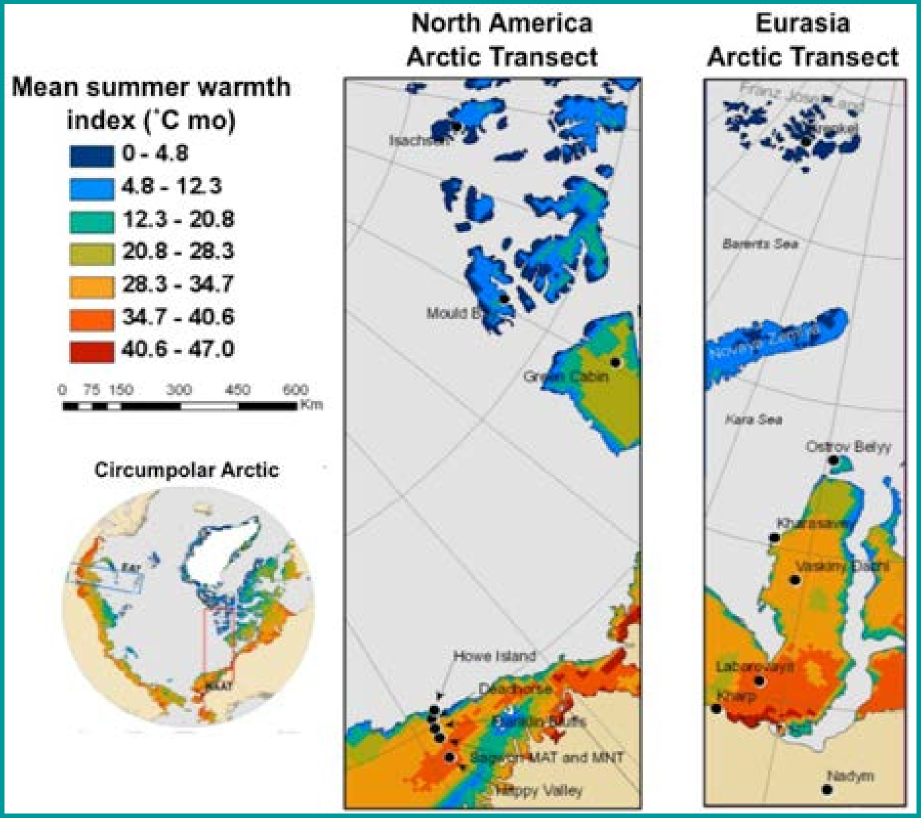


Bhatt et al. (2013)
Bieniek et al. (2015)
Epstein et al. (NOAA Arctic Report Card 2015)

Latitudinal (subzonal) and continental patterns of vegetation (NDVI) and temperature (SWI)



Two full latitudinal arctic gradients, with research sites in all five bioclimatic subzones



Remotely sensed indices:

SWI – summer warmth index (sum of mean monthly temps > 0°C)

MaxNDVI and TI-NDVI – vegetation greenness

(Raynolds et al. 2012)

North American Arctic Transect

Subzone A

Subzone B

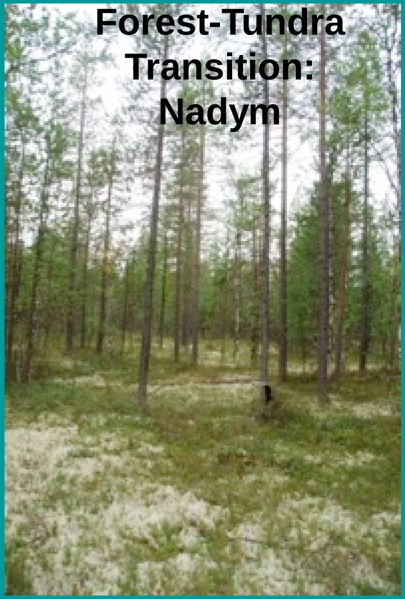
Subzone C

Subzone D

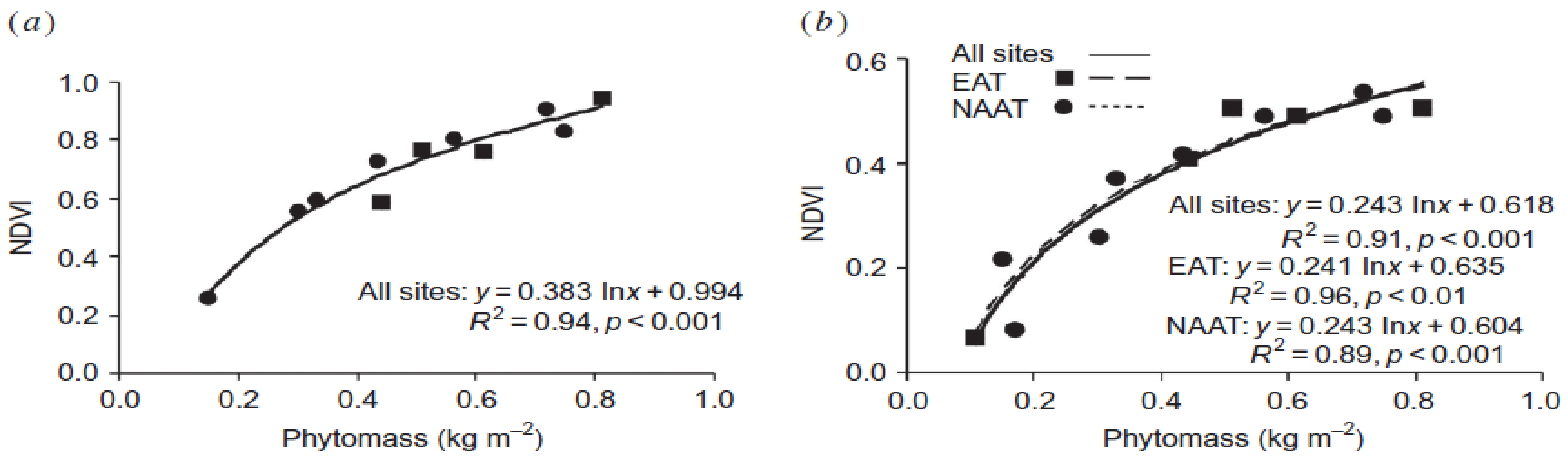
Subzone E

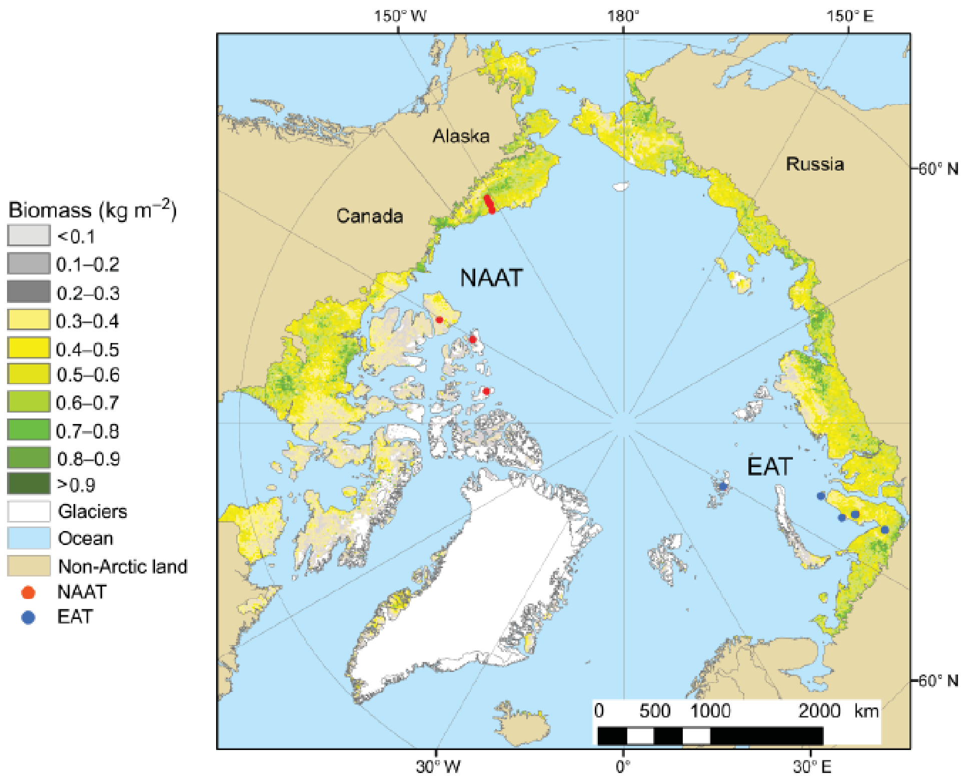
(Photos D.A. Walker and H.E. Epstein)

Eurasian Arctic Transect



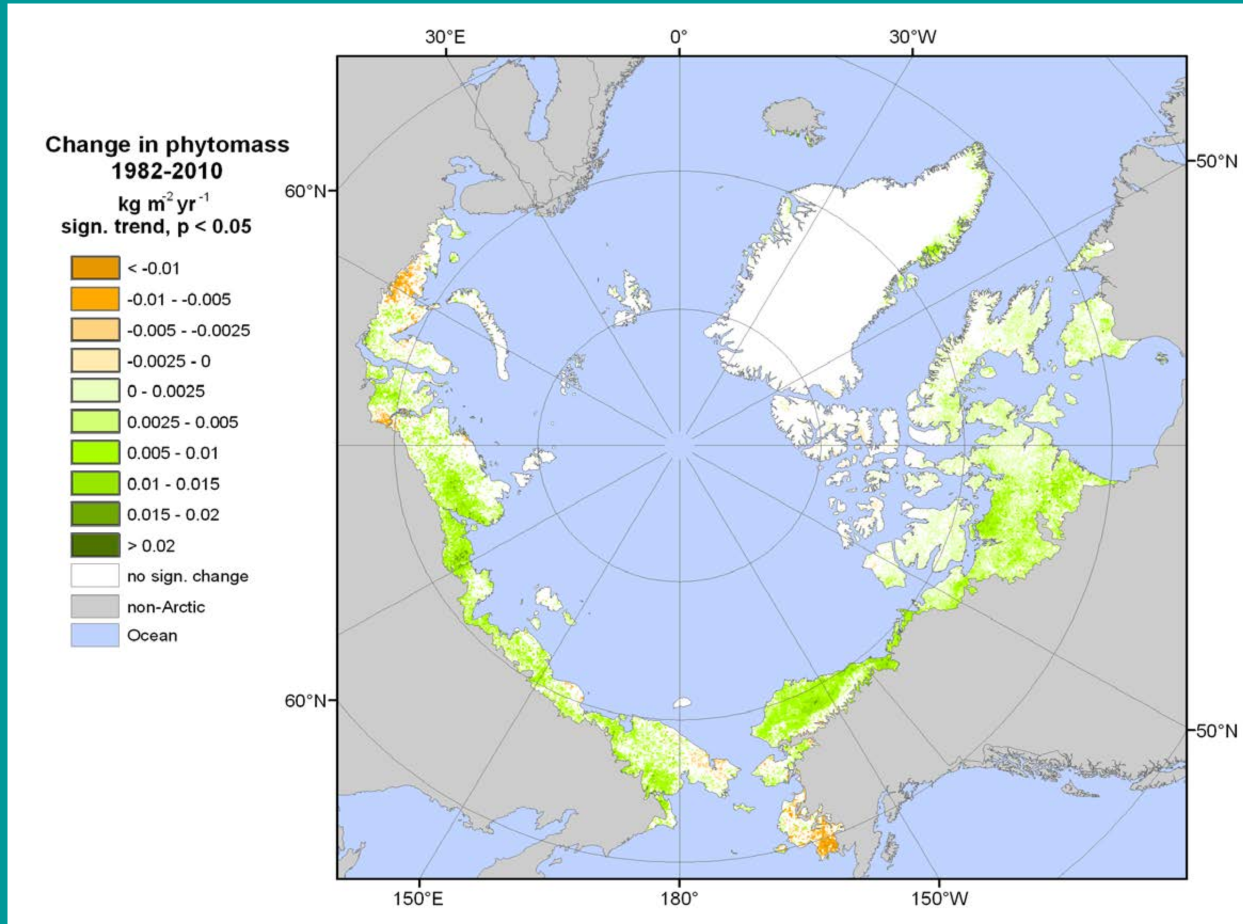
(photos D.A. Walker)





Spatial relationship between NDVI and field-measured total aboveground biomass

(Raynolds et al. 2012)

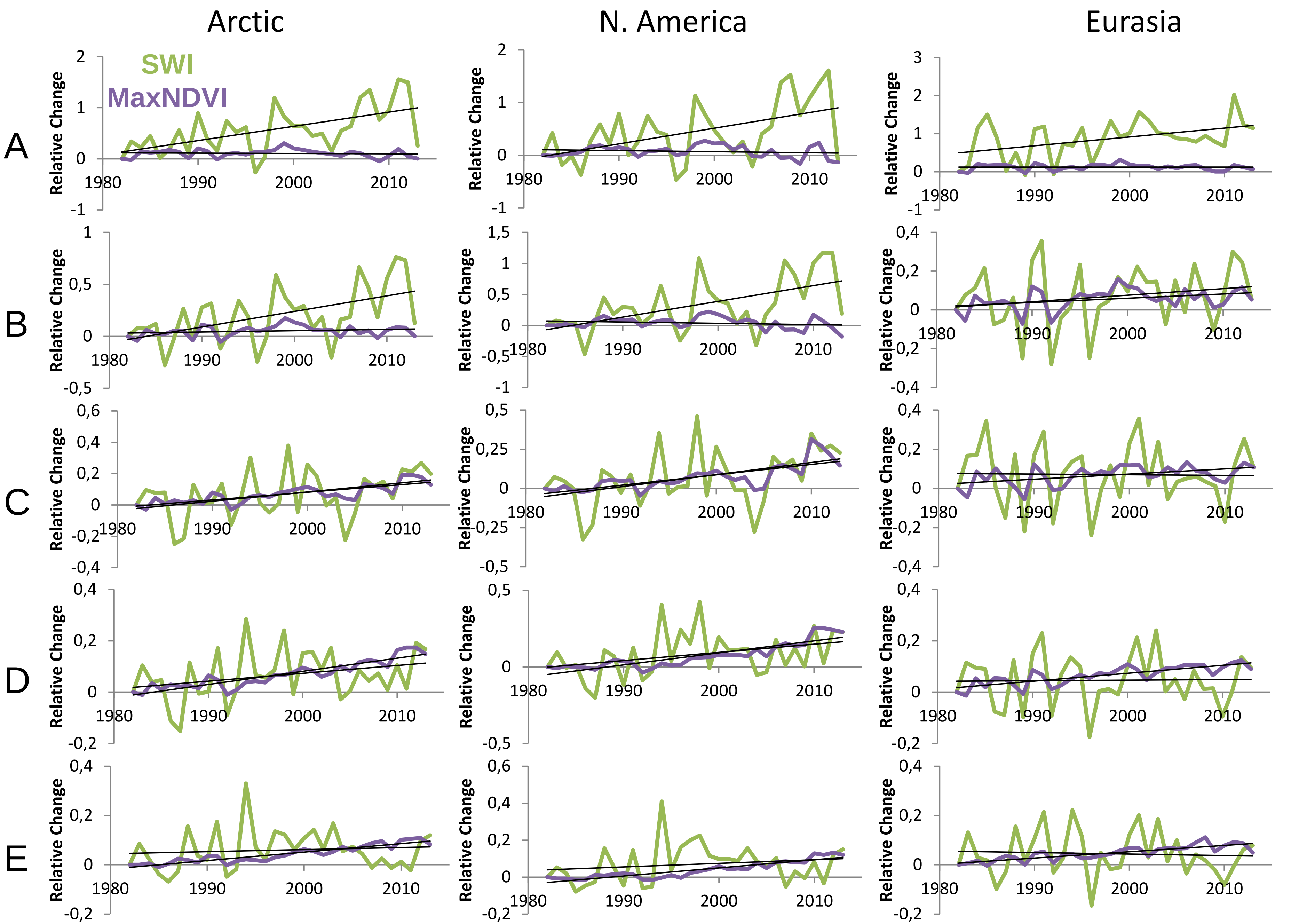


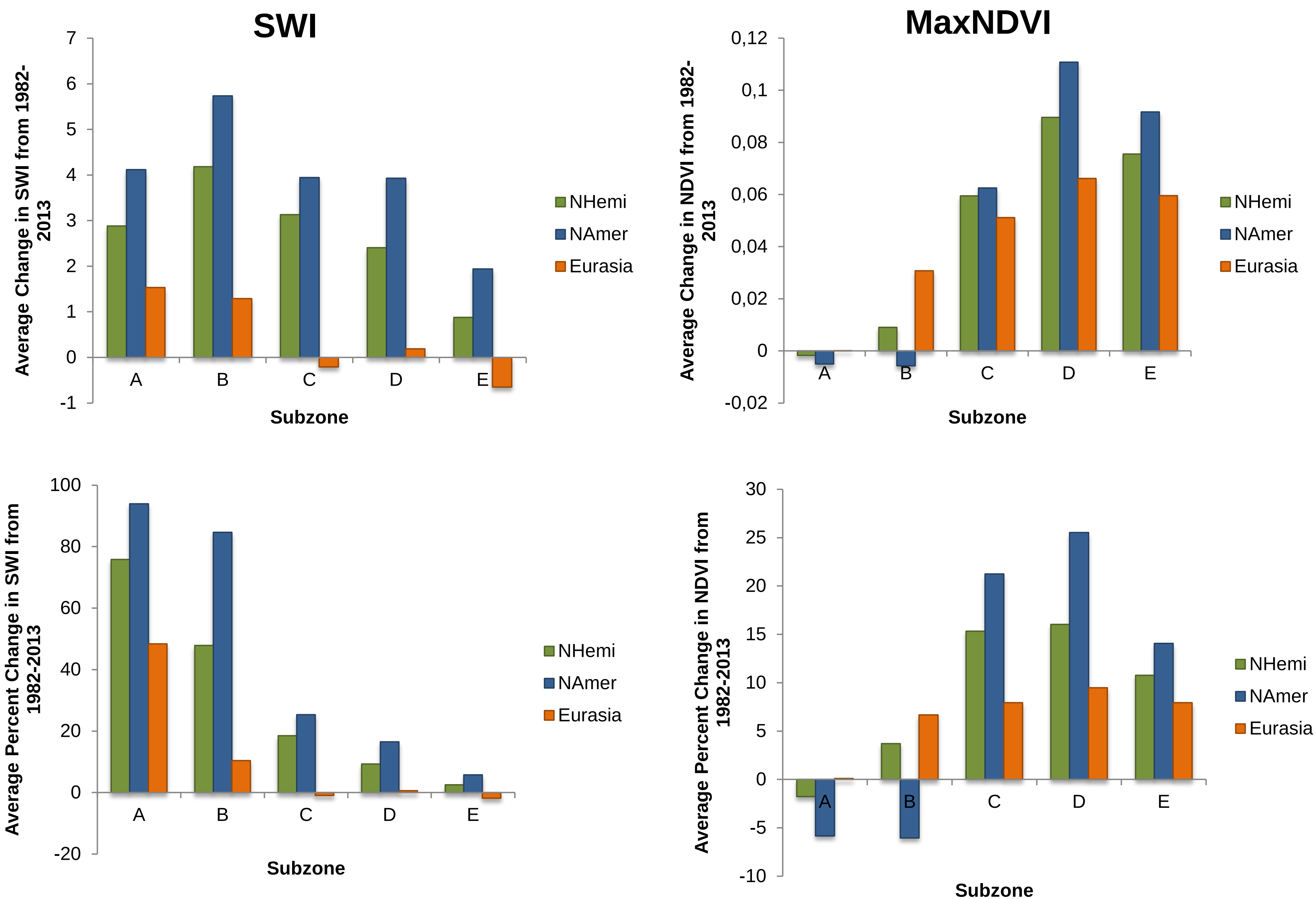
Bioclimate Subzone	Area (km²)	1982	SD	2010	SD	Change in mean biomass (g m⁻²)	Rate of change (g m⁻² y⁻¹)	1982	2010	Change	% change	Rate of change (% y⁻¹)
Greenland Ice Cap	1,795,920	83.8	14.0	84.4	18.0	0.6	0.02	0.15	0.15	0.0011	0.70	0.025
A	200,964	98.3	39.2	100.3	53.4	2.0	0.07	0.02	0.02	0.0004	2.05	0.073
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	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

Aboveground biomass increases since 1982 have been particularly strong in the mid- to Low-Arctic (20-26%), compared the High Arctic (2-7%).

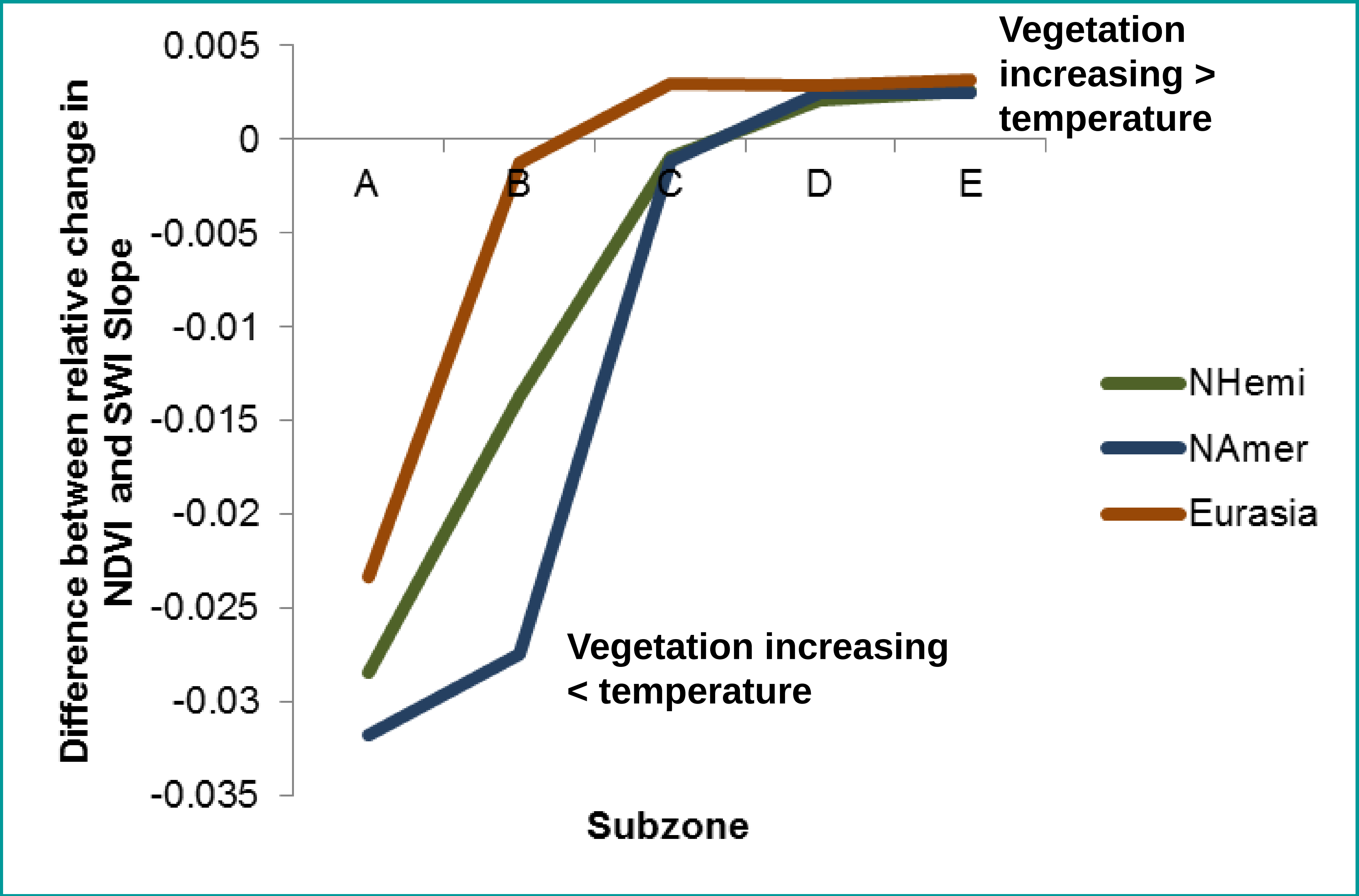
Epstein et al. (2012)

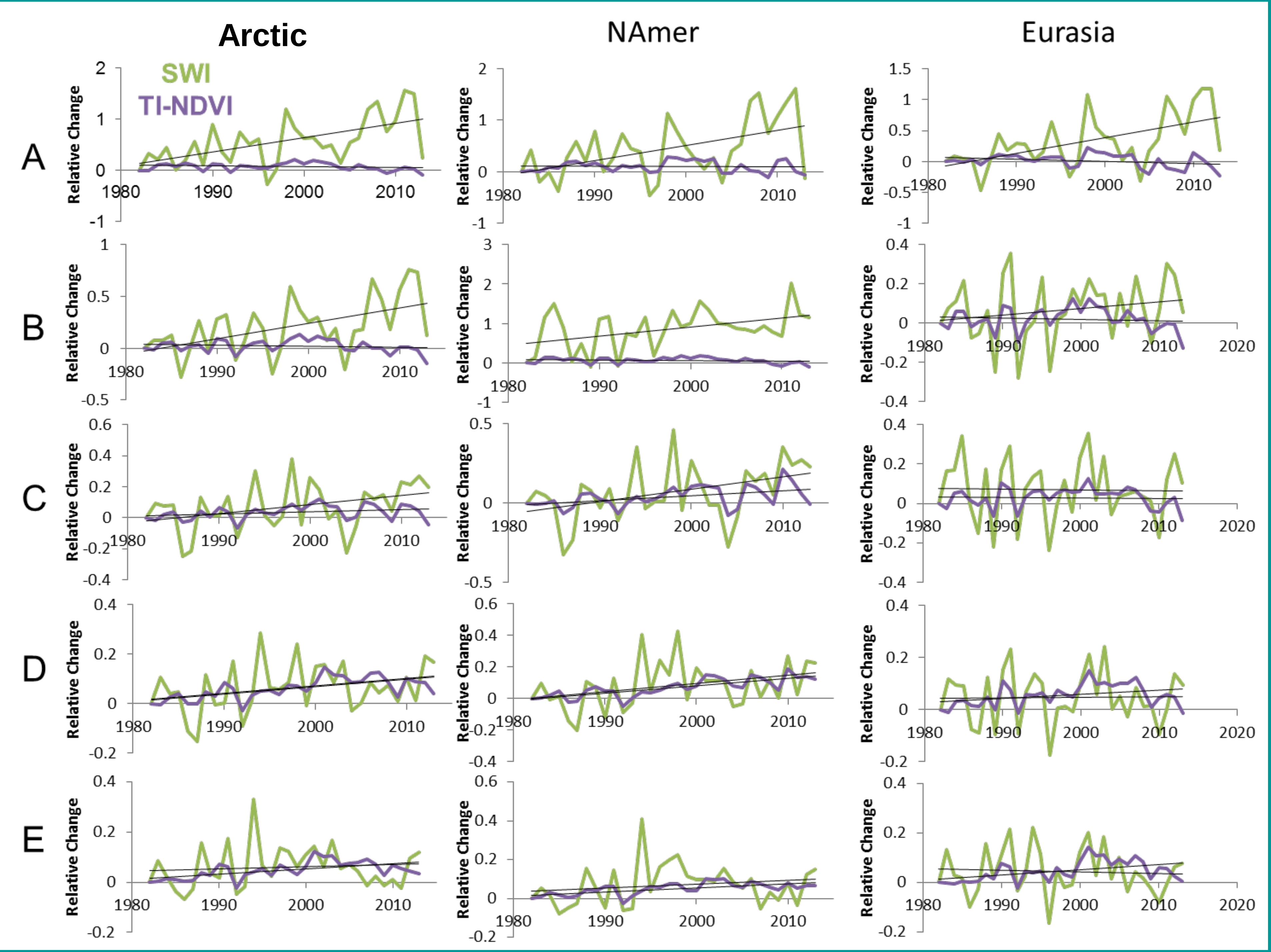
How do vegetation dynamics relate to temperature changes?




SWI
MaxNDVI
Average Change in SWI from 1982-2013
Average Change in NDVI from 1982-2013
Average Percent Change in SWI from 1982-2013
Average Percent Change in NDVI from 1982-2013
Subzone
A
B
C
D
E
NHemi
NAmer
Eurasia

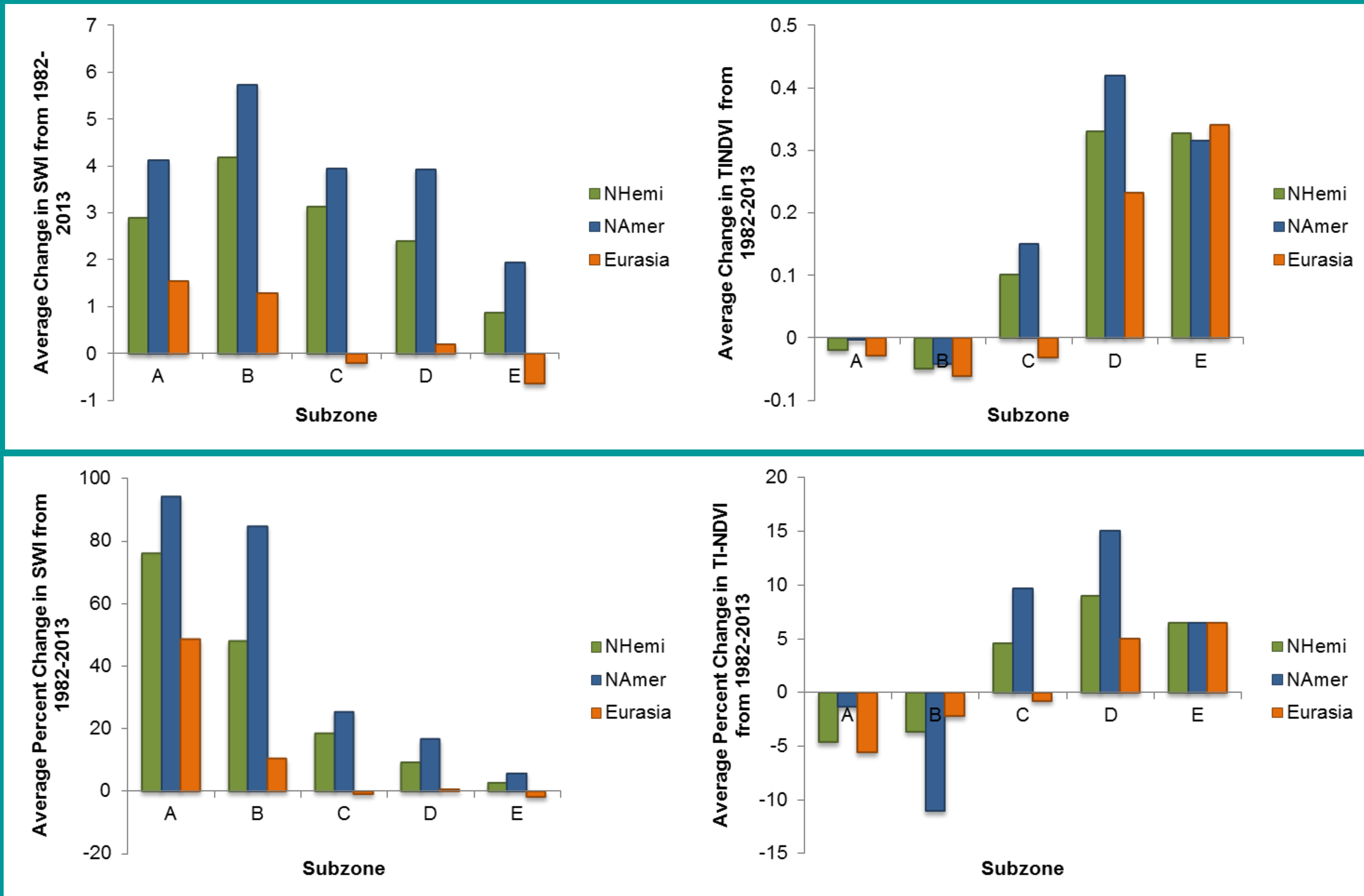
Difference between Vegetation (MaxNDVI) and Temperature Slopes





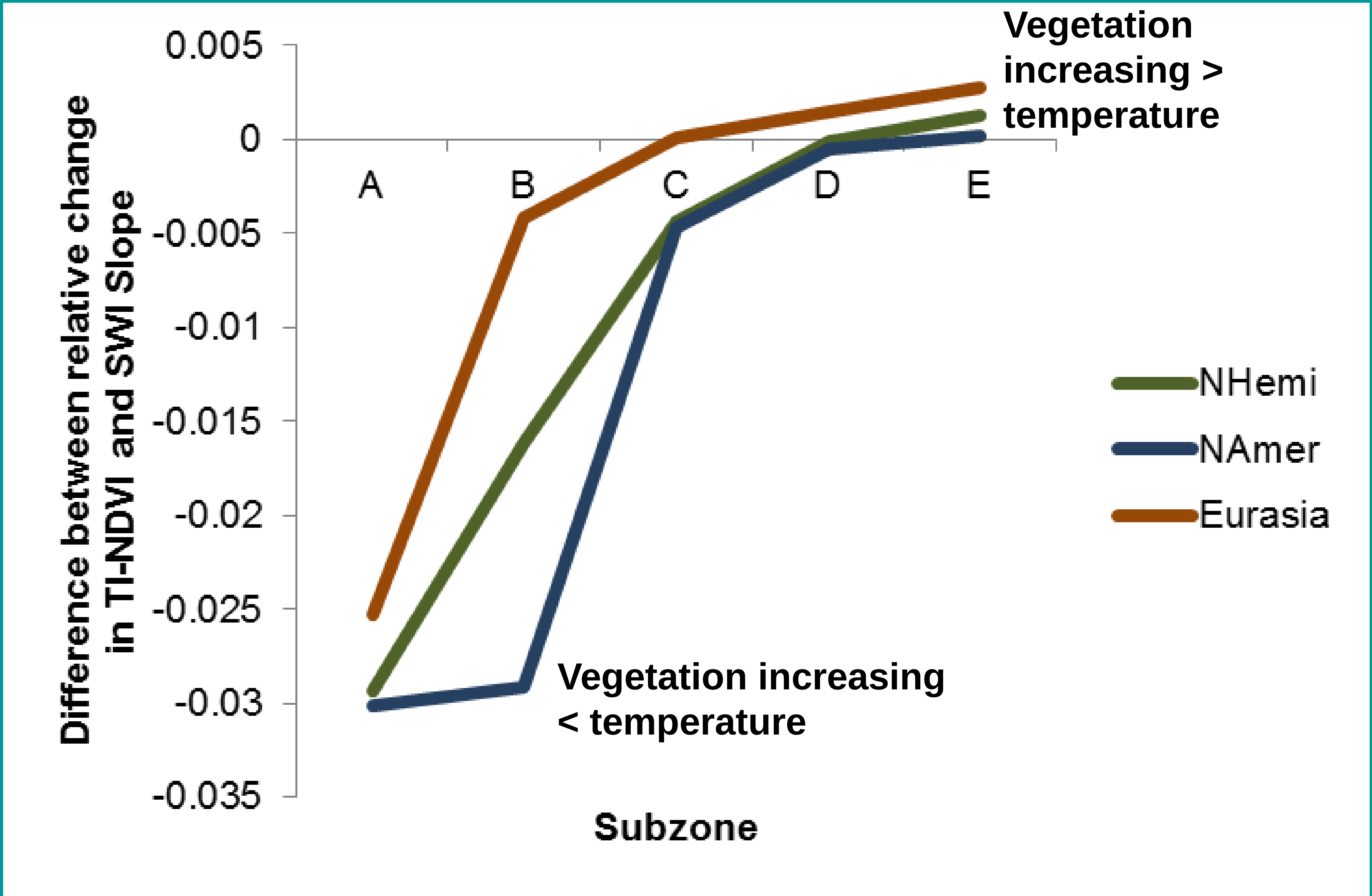
Arctic
NAmer
Eurasia
SWI
TI-NDVI
A
B
C
D
E
Relative Change
1980
1990
2000
2010
2020

SWI TI-NDVI

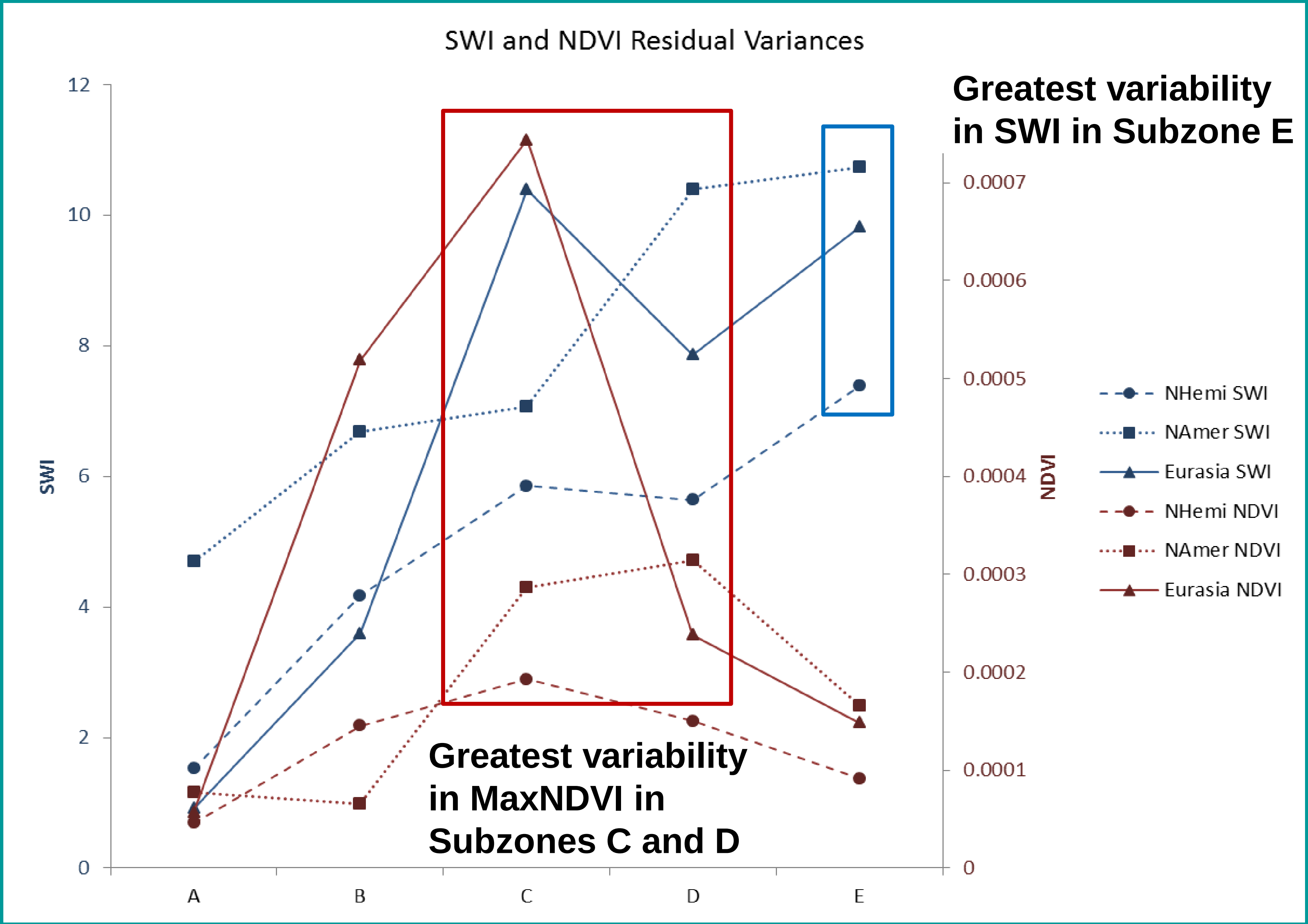


Average Change in SWI from 1982-2013
Subzone
NHemi
NAmer
Eurasia
Average Change in TINDVI from 1982-2013
Subzone
Average Percent Change in SWI from 1982-2013
Average Percent Change in TI-NDVI from 1982-2013
A
B
C
D
E

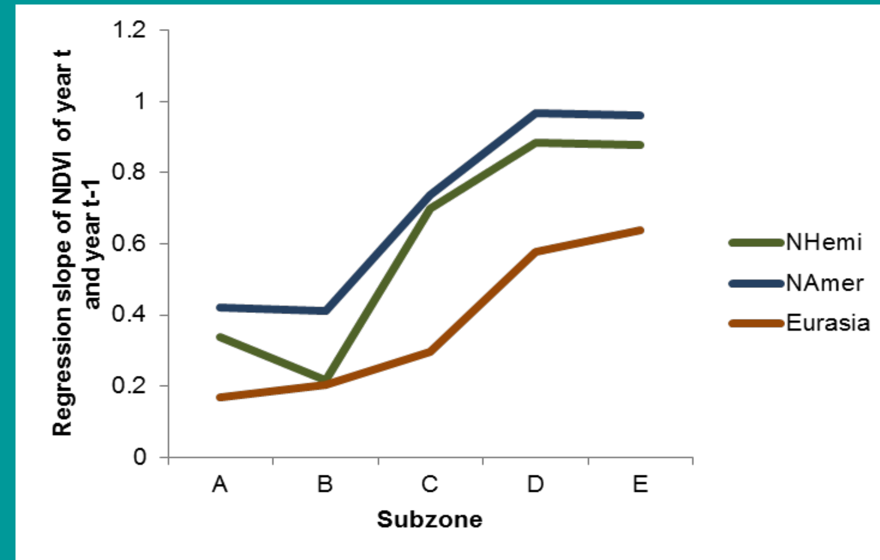
Difference between Vegetation (TI-NDVI) and Temperature Slopes

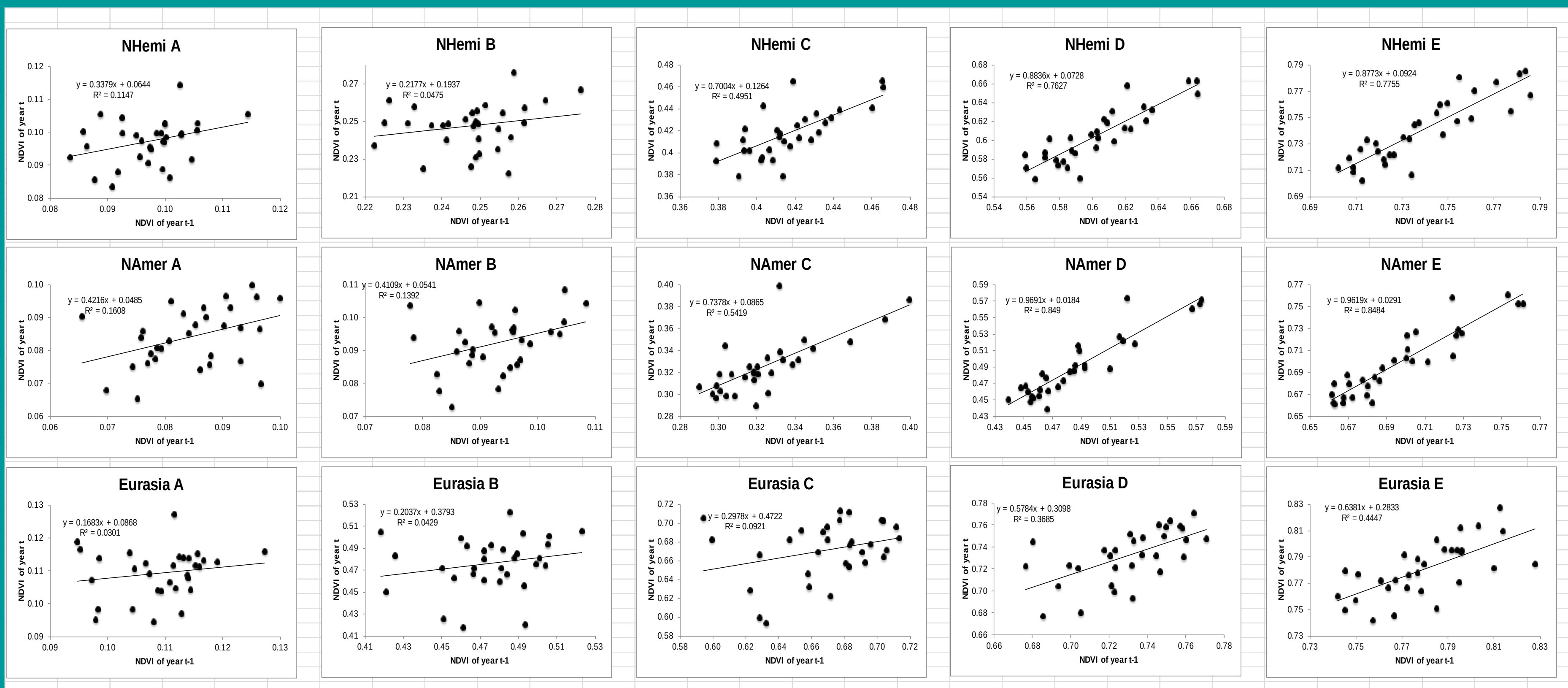


Inter-annual variability in SWI and Max-NDVI

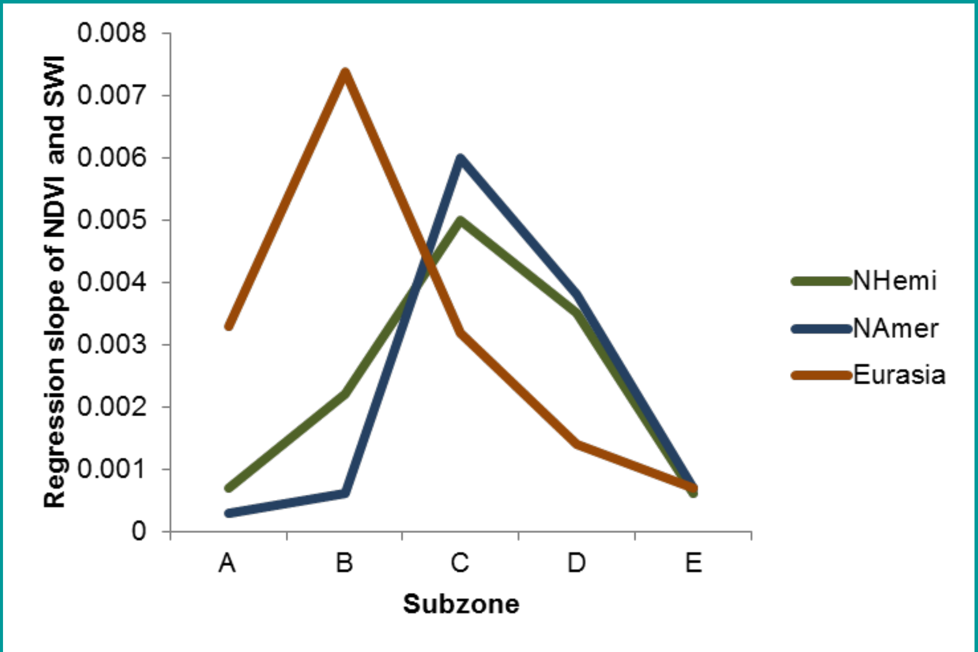


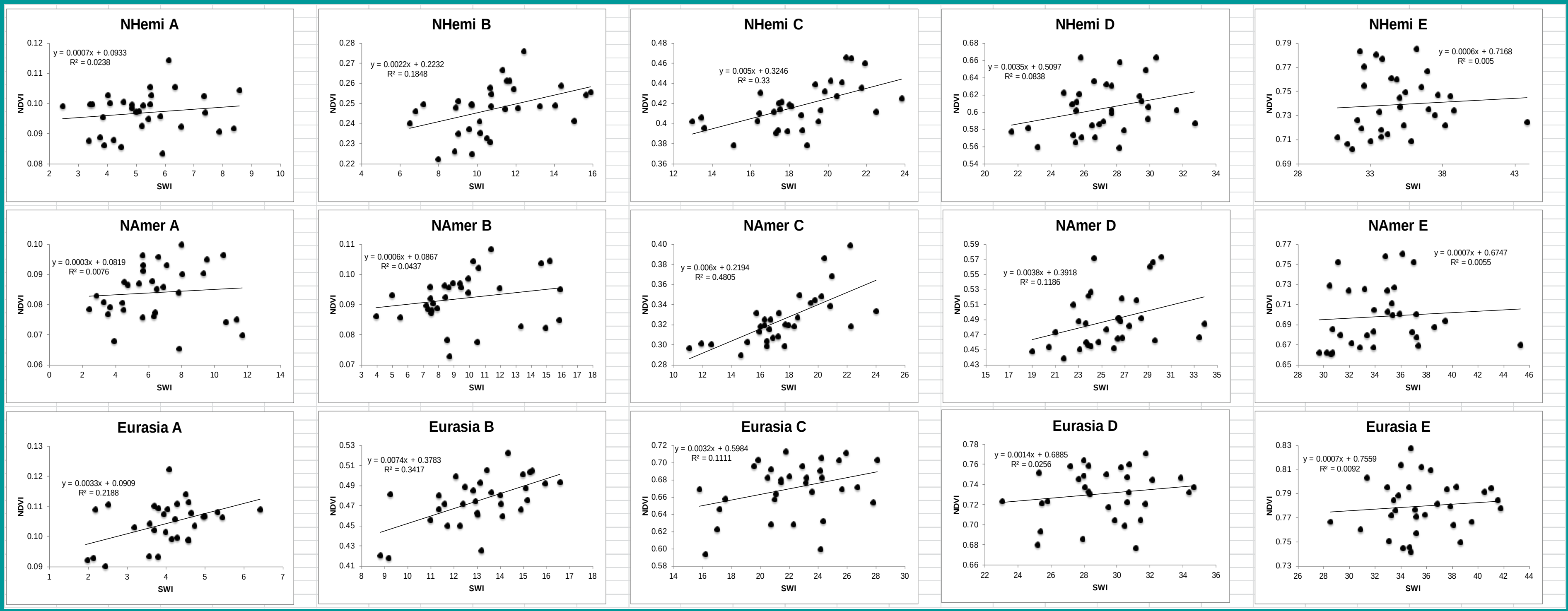
Relationships between MaxNDVI and MaxNDVI in the prior year increases from north to south





Relationship between MaxNDVI and SWI is greatest toward the center of the latitudinal gradient (Subzones B and C)



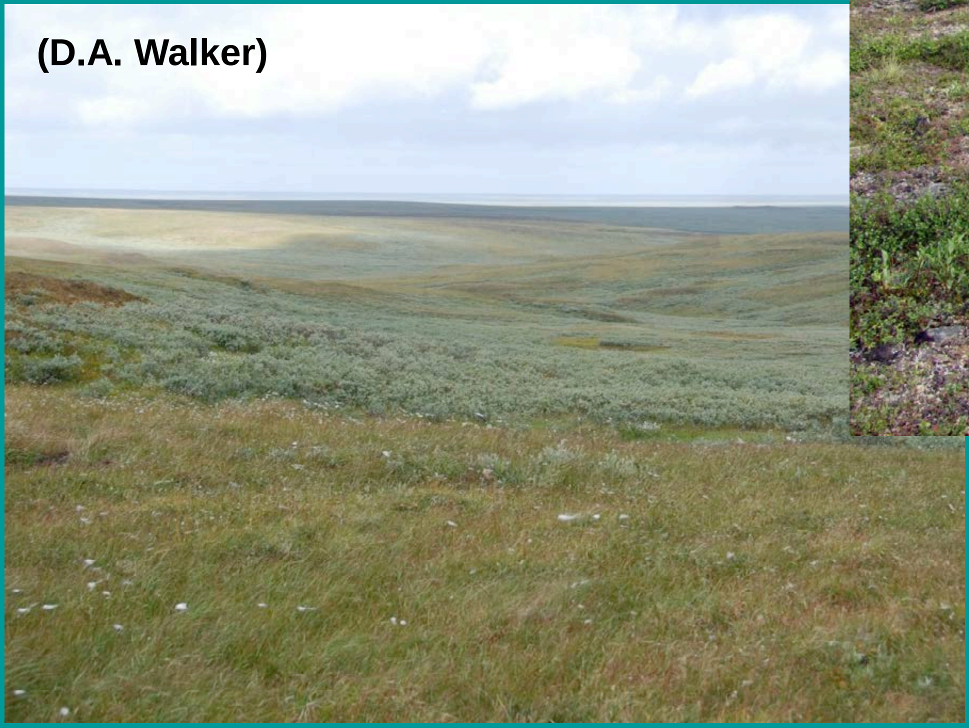


Discussion – Long-Term Trends

Greater responses in more southern subzones could be due to:

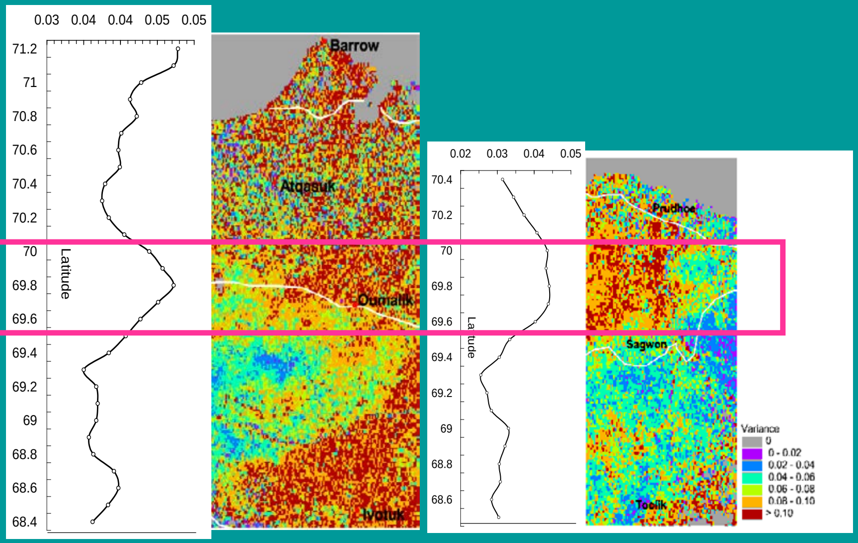
- disturbances such as fire, landslides, cryoturbation
- dispersal and availability of seed bank for low/tall shrubs
- interactions with precipitation

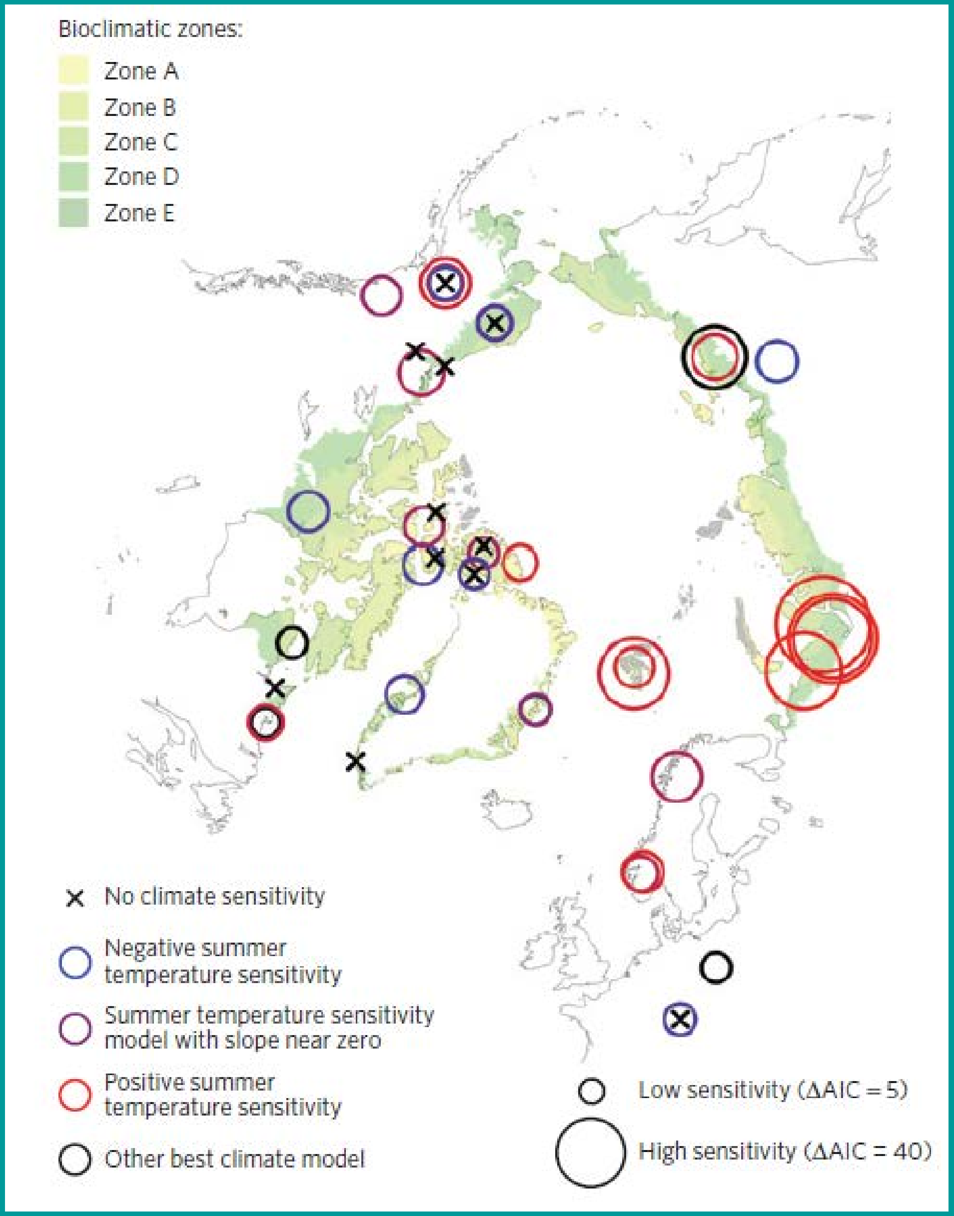
(G.V. Frost)



(D.A. Walker)

Discussion – Interannual Variability





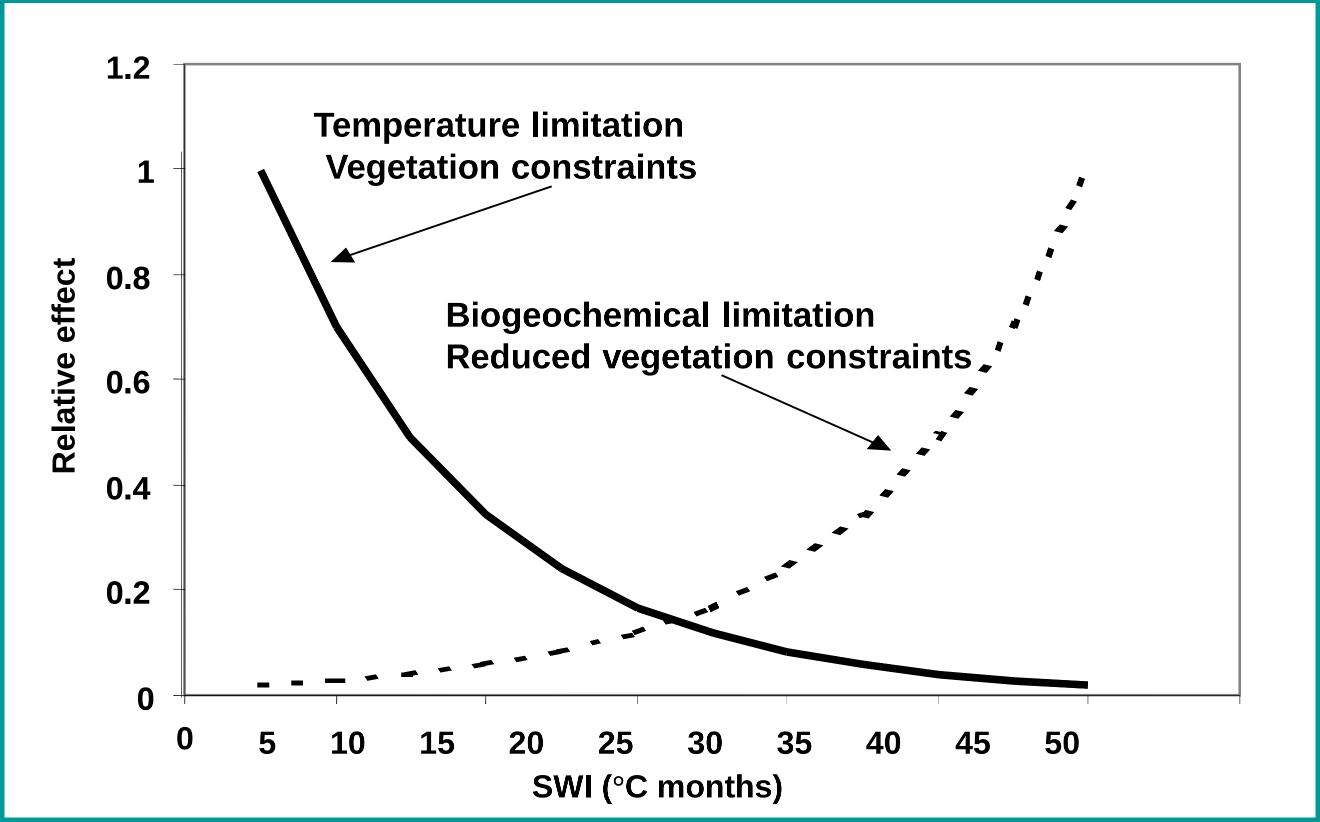
Greatest inter-annual variability in NDVI within Subzone D on the North Slope of Alaska (Jia et al. 2006)

Greatest sensitivity of shrub growth to temperature at the transition between the Low and High Arctic (Myers-Smith et al. 2015)

Conclusions

1) Vegetation has increased to a greater degree than temperature in the more southern Subzones (C, D and E), potentially due to interactions with disturbances, precipitation and other factors. Also, the relationship between NDVI and NDVI in the prior year increases from north to south.

2) Interannual variability and responses to temperature are greatest in Subzones B, C, and D (mid-transect), potentially due to intermediate levels of vegetation and nutrient constraints, as well as a mix of High and Low Arctic plant types.



This work was funded by the NASA Land-Cover Land-Use Change (LCLUC) program, Grant Nos. NNG6GE00A, NNX09AK56G, NNX14AD90G, and NNX13AM20G, and NSF Grant Nos. ARC-0531180 (part of the Synthesis of Arctic System Science initiative - Greening of the Arctic) and ARC-0902152 (part of the Changing Seasonality of Arctic Systems initiative)