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

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The Arctic Tundra Biome

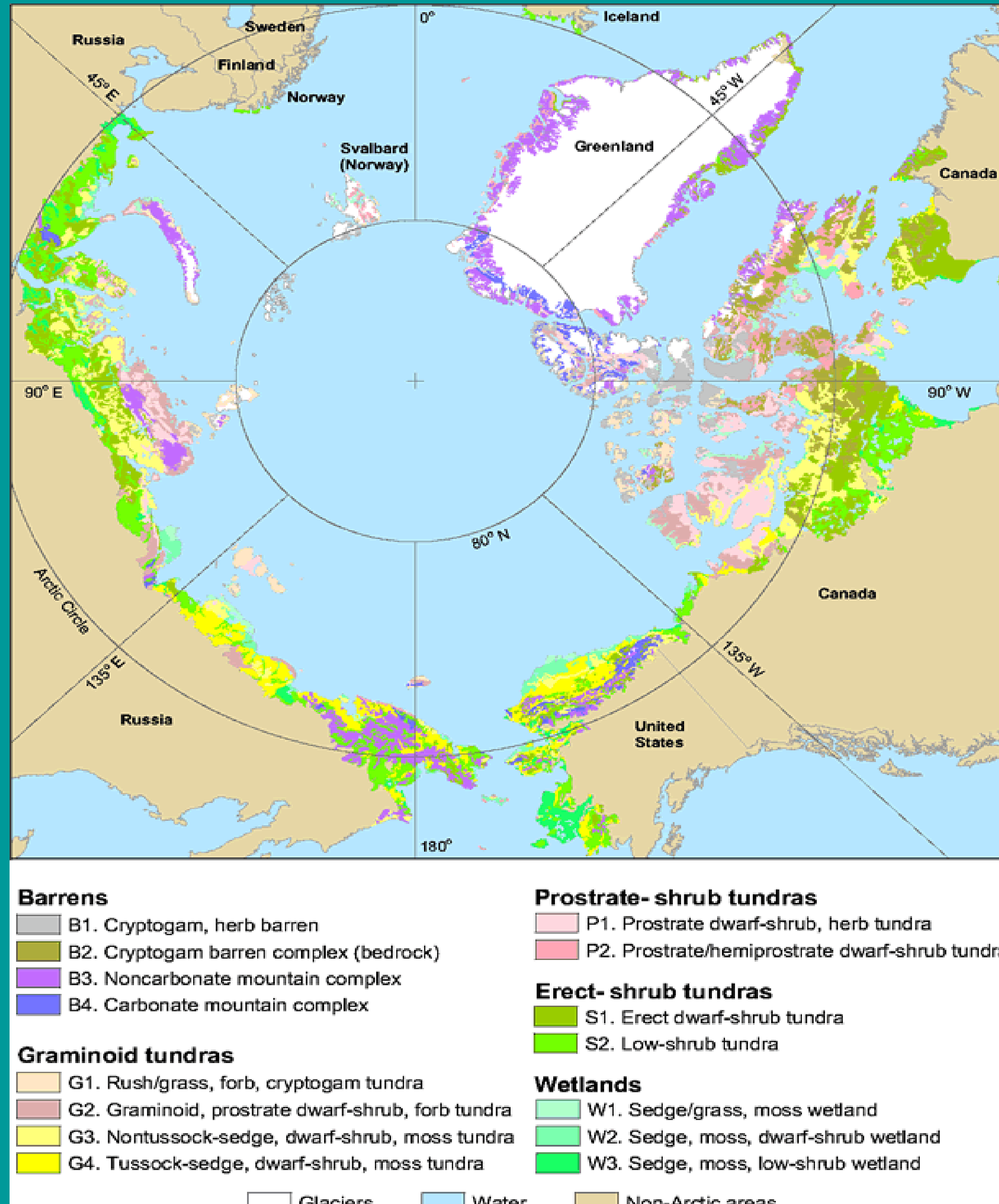
Arctic tundra vegetation has been undergoing substantive changes recently, at least since the mid 20th century.

These changes have been rather heterogeneous from a circumpolar perspective.

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

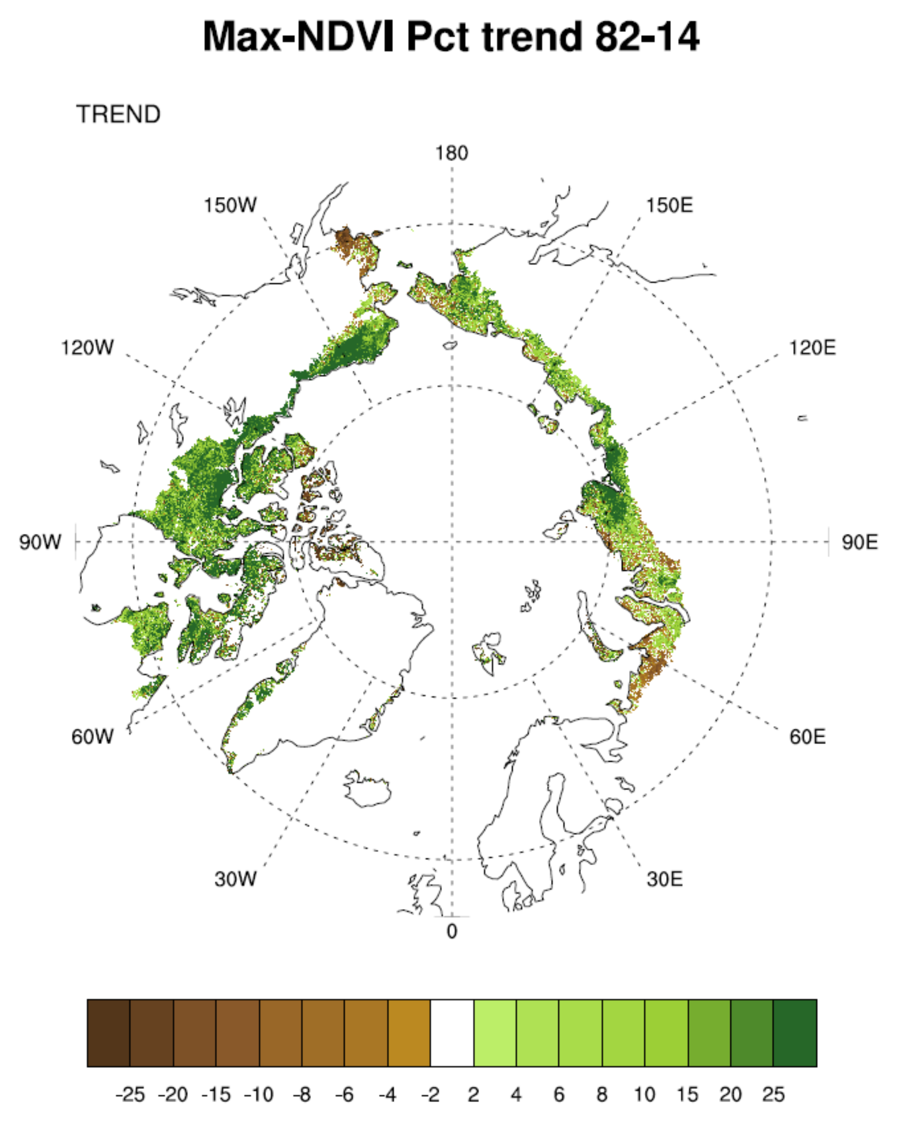
2) ***How does interannual variability in temperature relate to interannual variability in vegetation?***

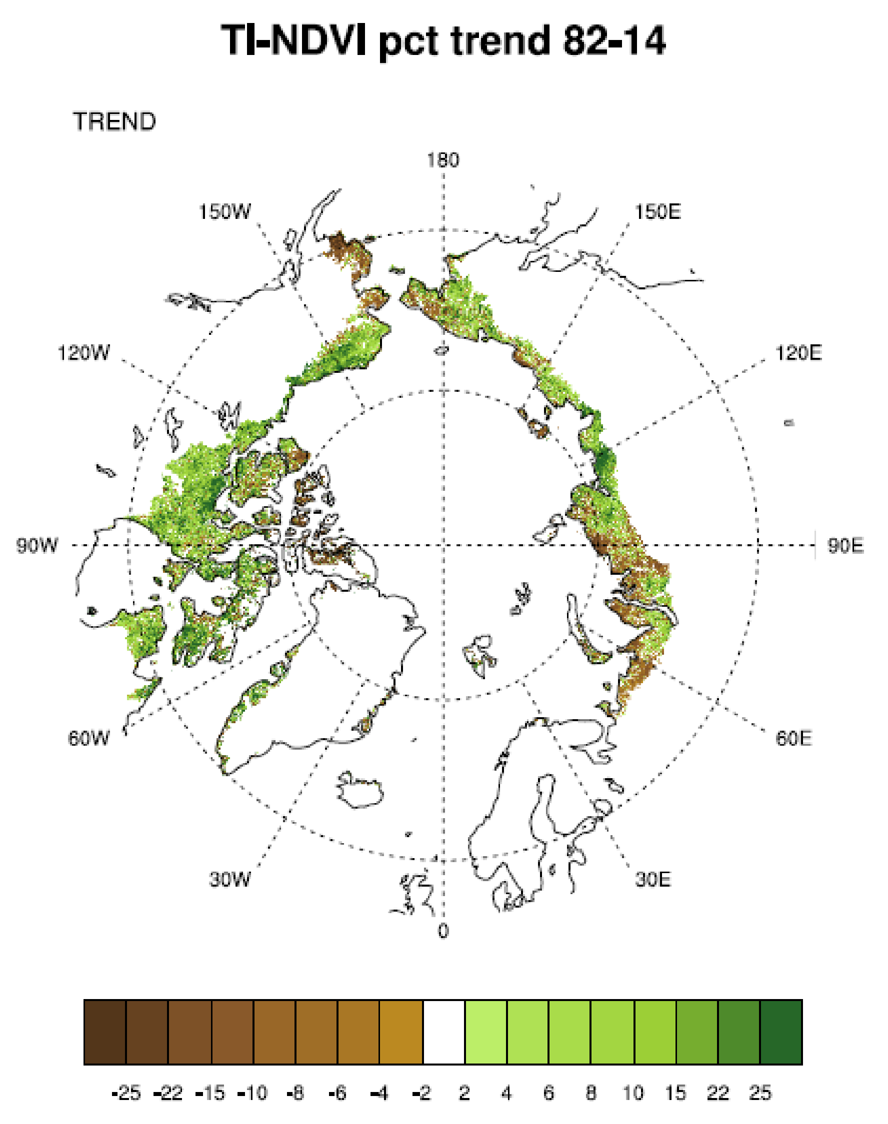
3) ***How do these relationships vary across continents and tundra subzones?***



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

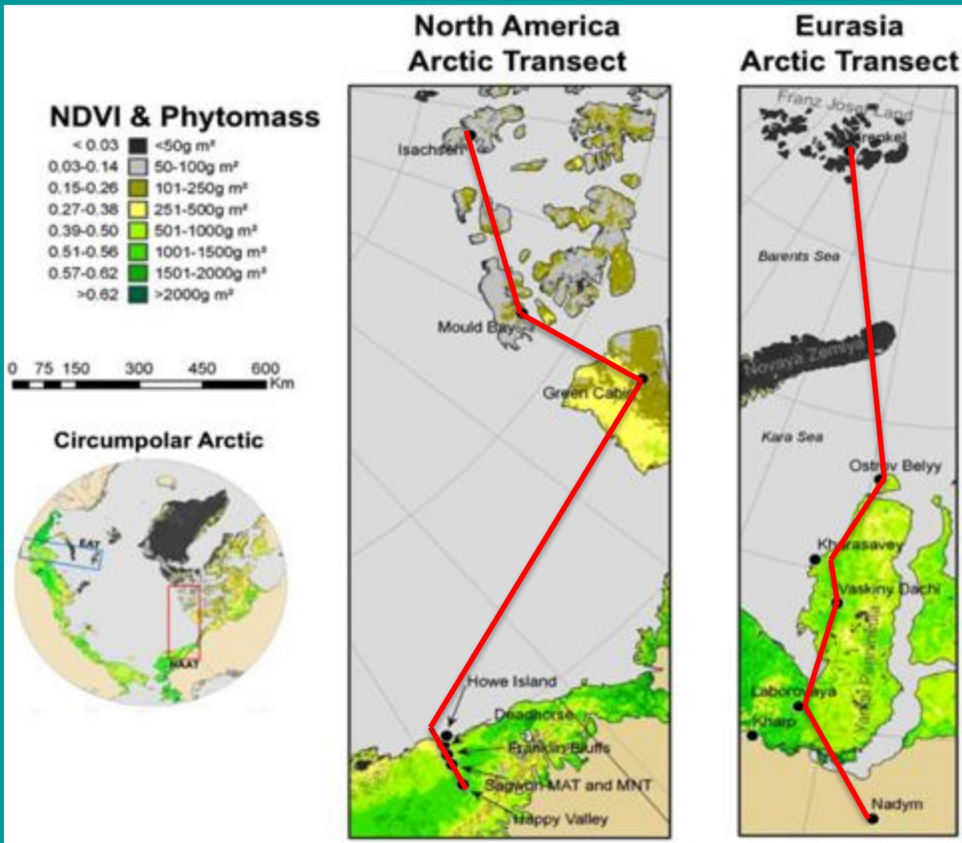
Heterogeneous Arctic "Greening" and "Browning"



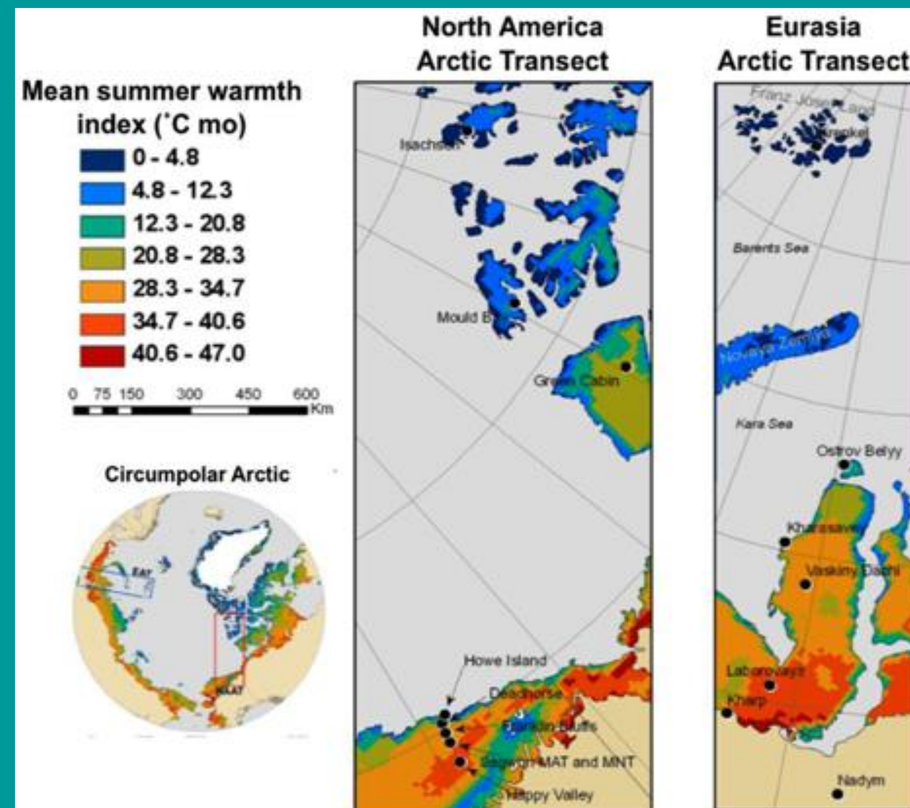


Bhatt et al. (2013), Epstein et al. (NOAA Arctic Report Card 2015)

Latitudinal (subzonal) and continental variation in 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)

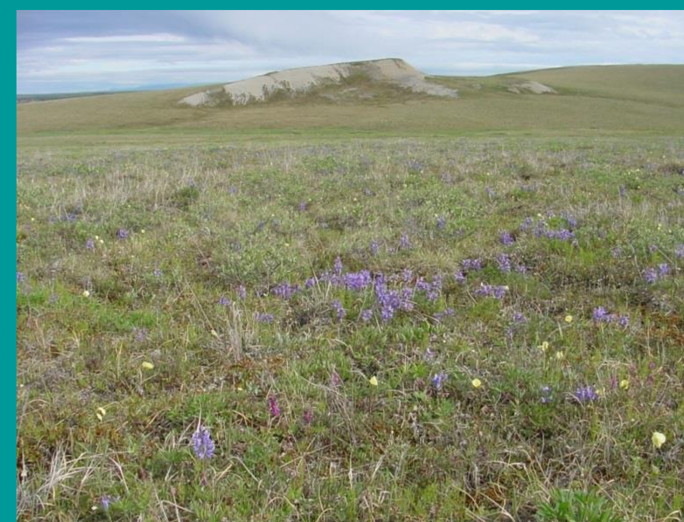
North American Arctic Transect

Subzone A

Subzone B

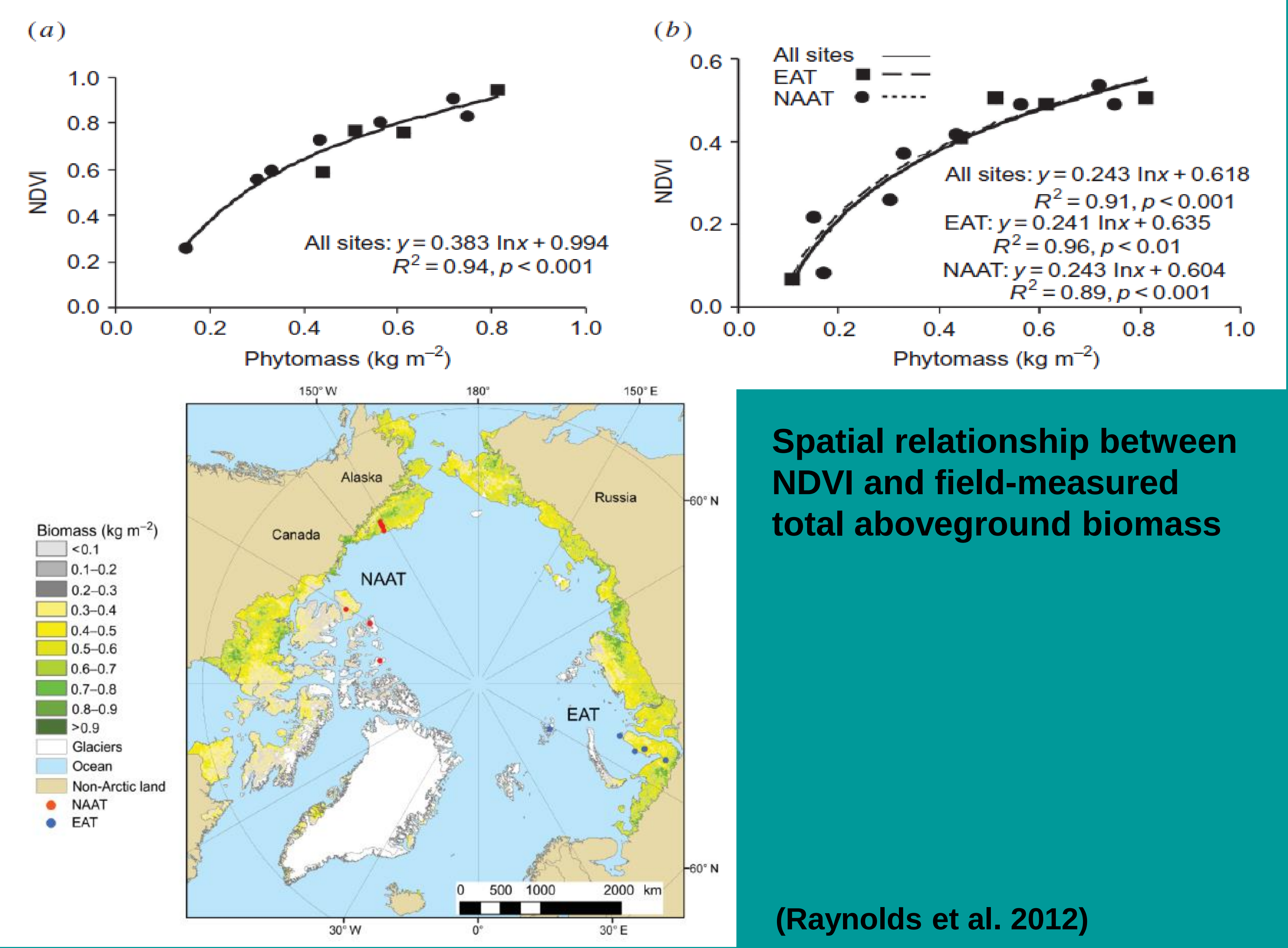
Subzone C

Subzone D



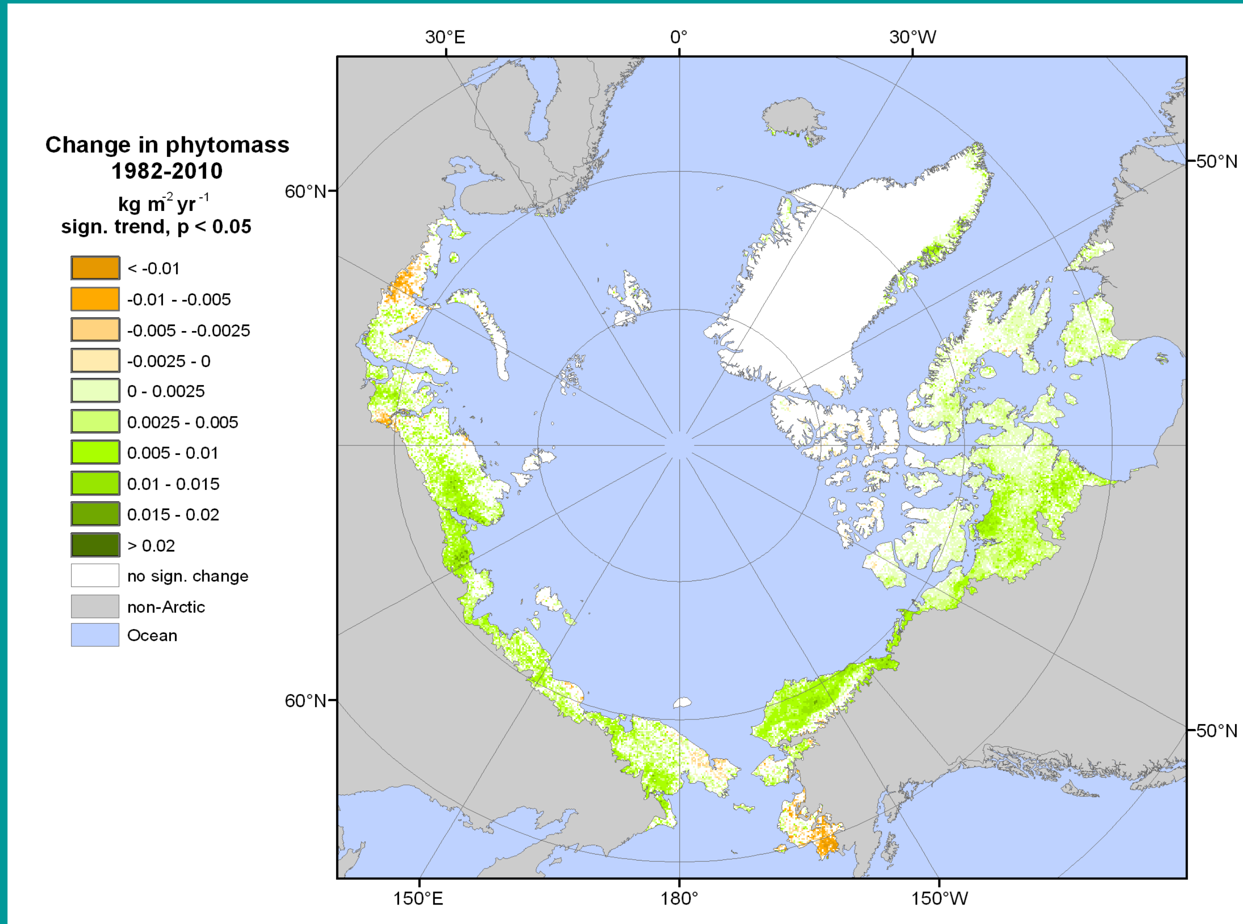
Subzone E

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



Spatial relationship between NDVI and field-measured total aboveground biomass

(Raynolds et al. 2012)

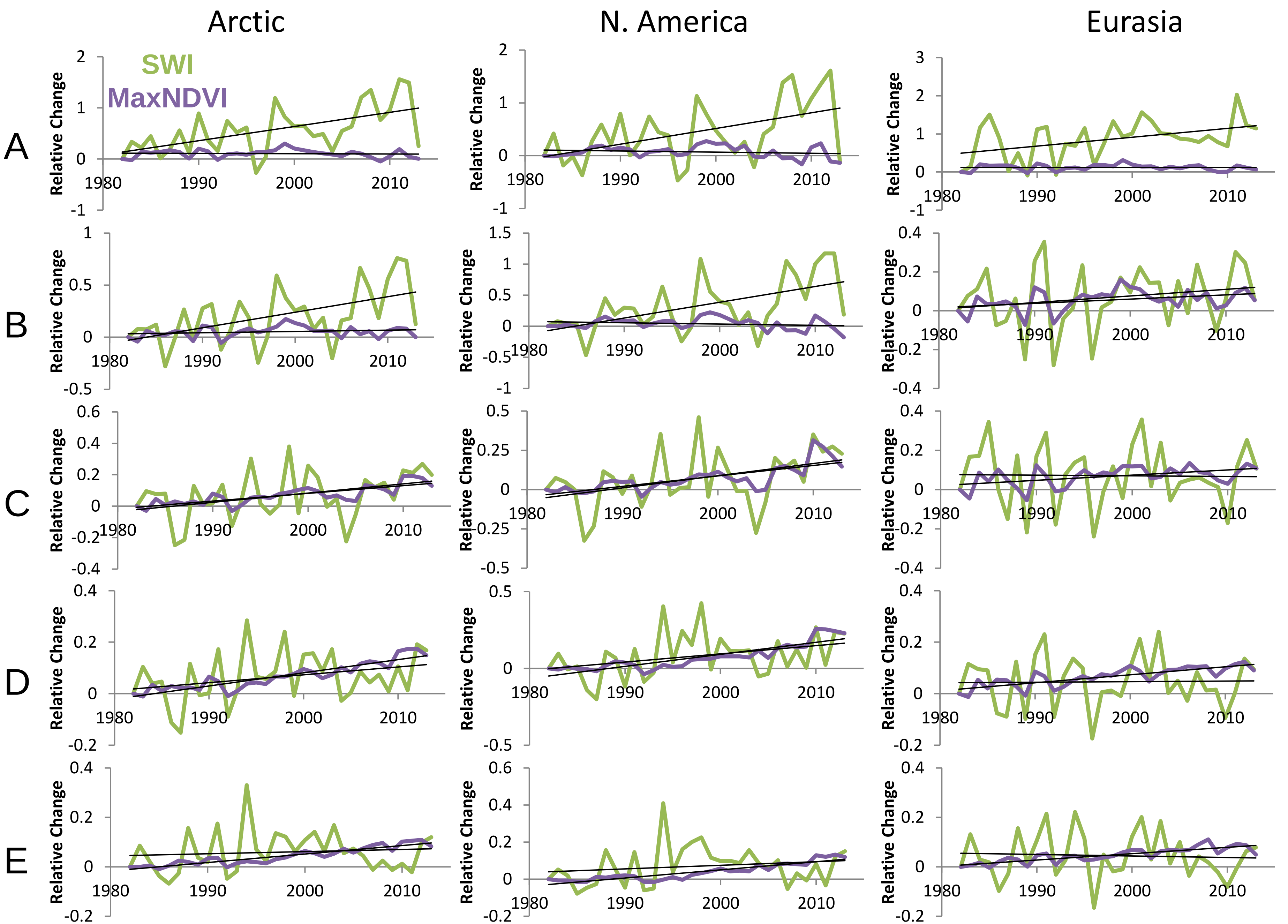


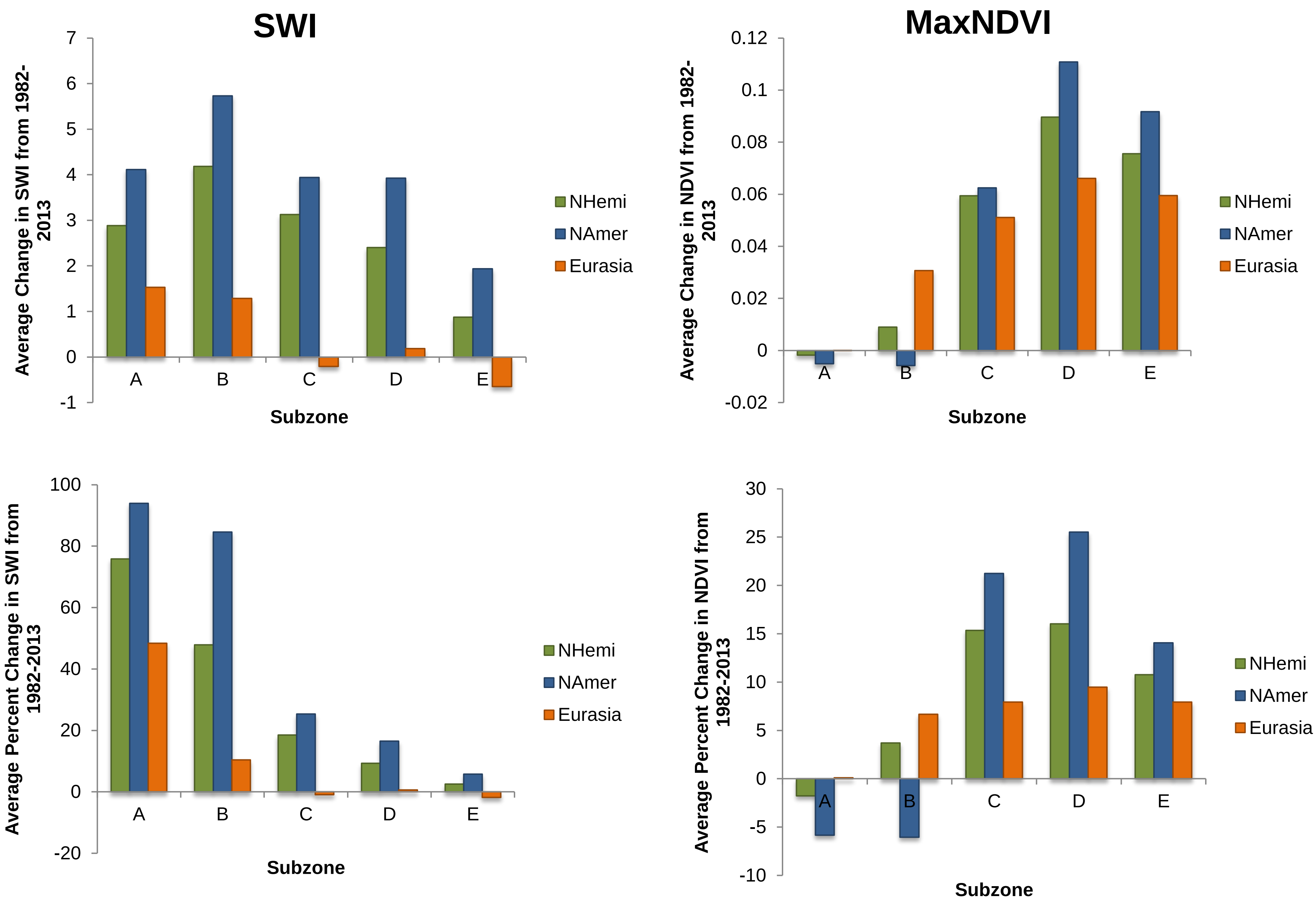
Bioclimate Subzone	Area (km²)	1982	SD	2010	SD	Change in mean biomass (g m⁻²)	Rate of change (g m⁻² y⁻¹)	1982	2010	Change	% change	Rate of change (% y⁻¹)
Greenland Ice Cap	1,795,920	83.8	14.0	84.4	18.0	0.6	0.02	0.15	0.15	0.0011	0.70	0.025
A	200,964	98.3	39.2	100.3	53.4	2.0	0.07	0.02	0.02	0.0004	2.05	0.073
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	2,037,020	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%).

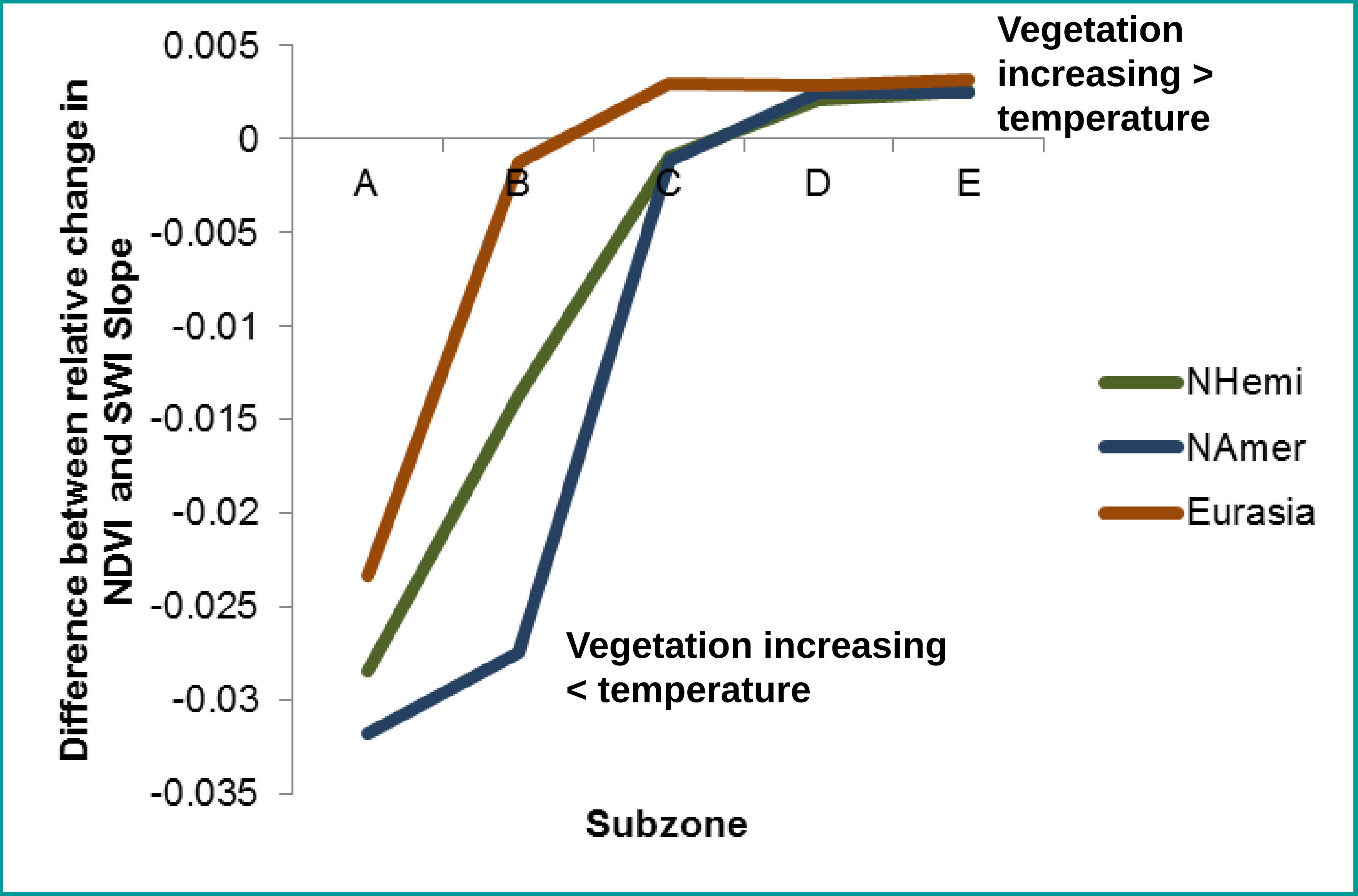
Epstein et al. (2012)

How do vegetation dynamics relate to temperature changes?

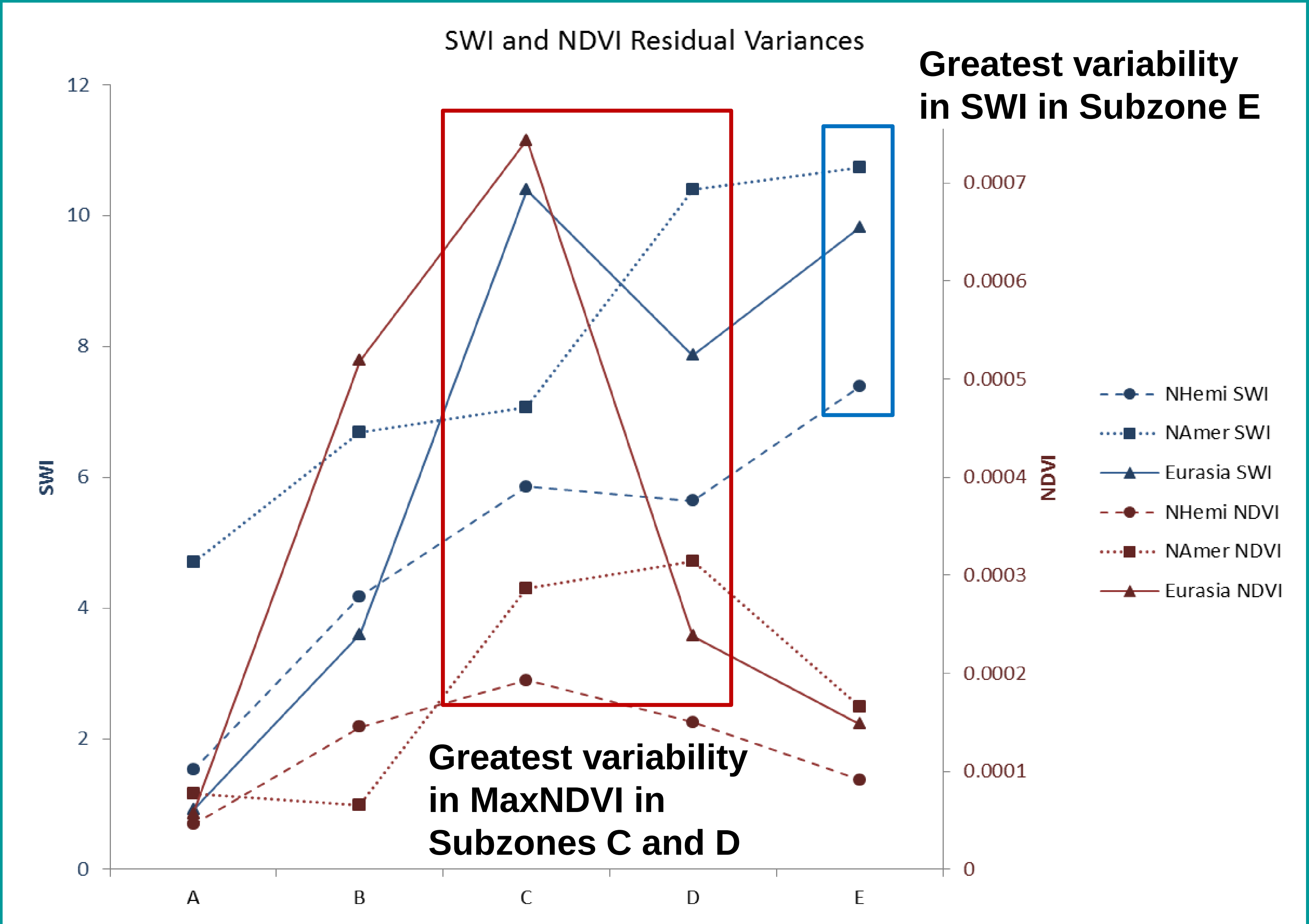



SWI
MaxNDVI
Average Change in SWI from 1982-2013
Average Change in NDVI from 1982-2013
Average Percent Change in SWI from 1982-2013
Average Percent Change in NDVI from 1982-2013
Subzone
A
B
C
D
E
NHemi
NAmer
Eurasia
7
6
5
4
3
2
1
0
-1
0.12
0.1
0.08
0.06
0.04
0.02
0
-0.02
100
80
60
40
20
0
-20
30
25
20
15
10
5
0
-5
-10

Difference between Vegetation (MaxNDVI) and Temperature Slopes

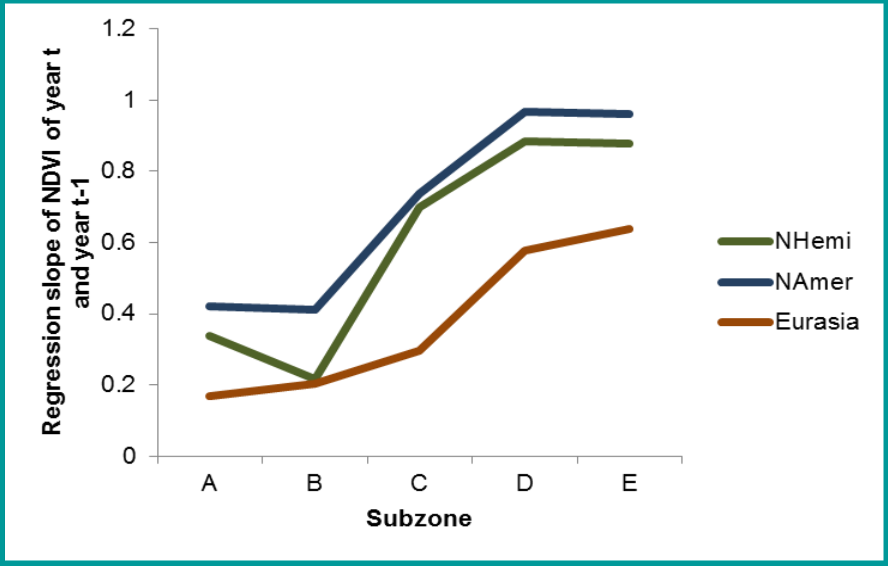


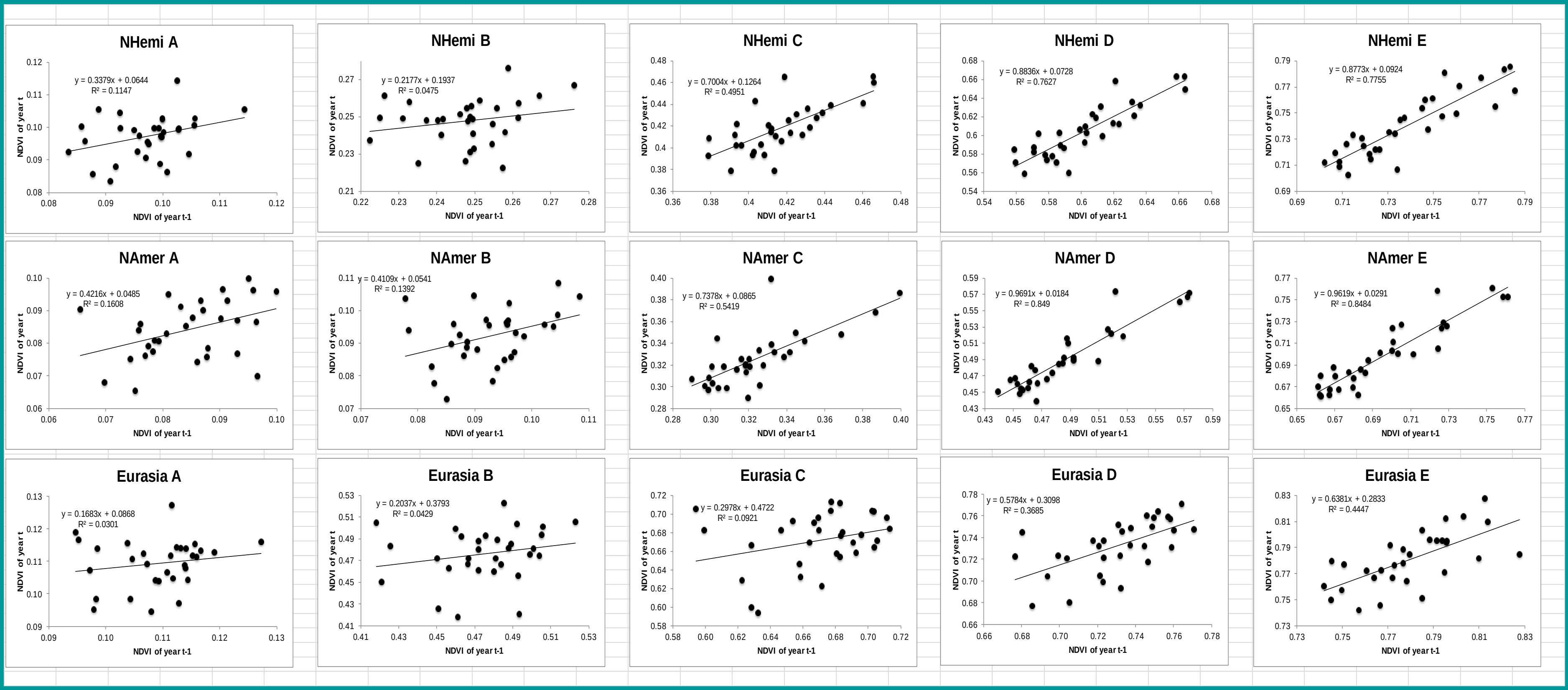
How does Inter-annual variability in temperature relate to interannual in vegetation?



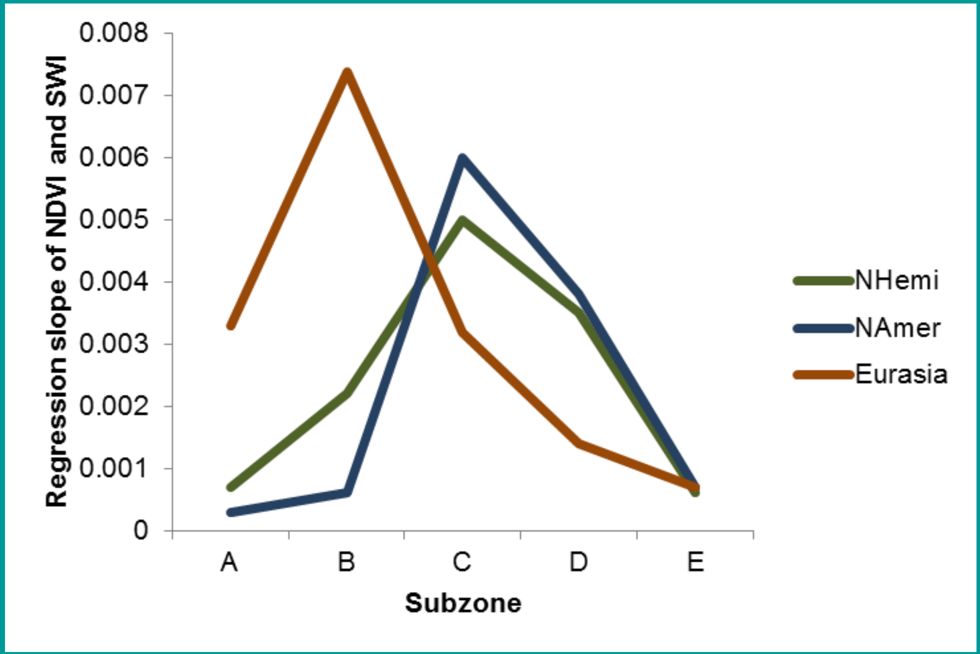
Relationships between MaxNDVI and MaxNDVI in the prior year increases from north to south

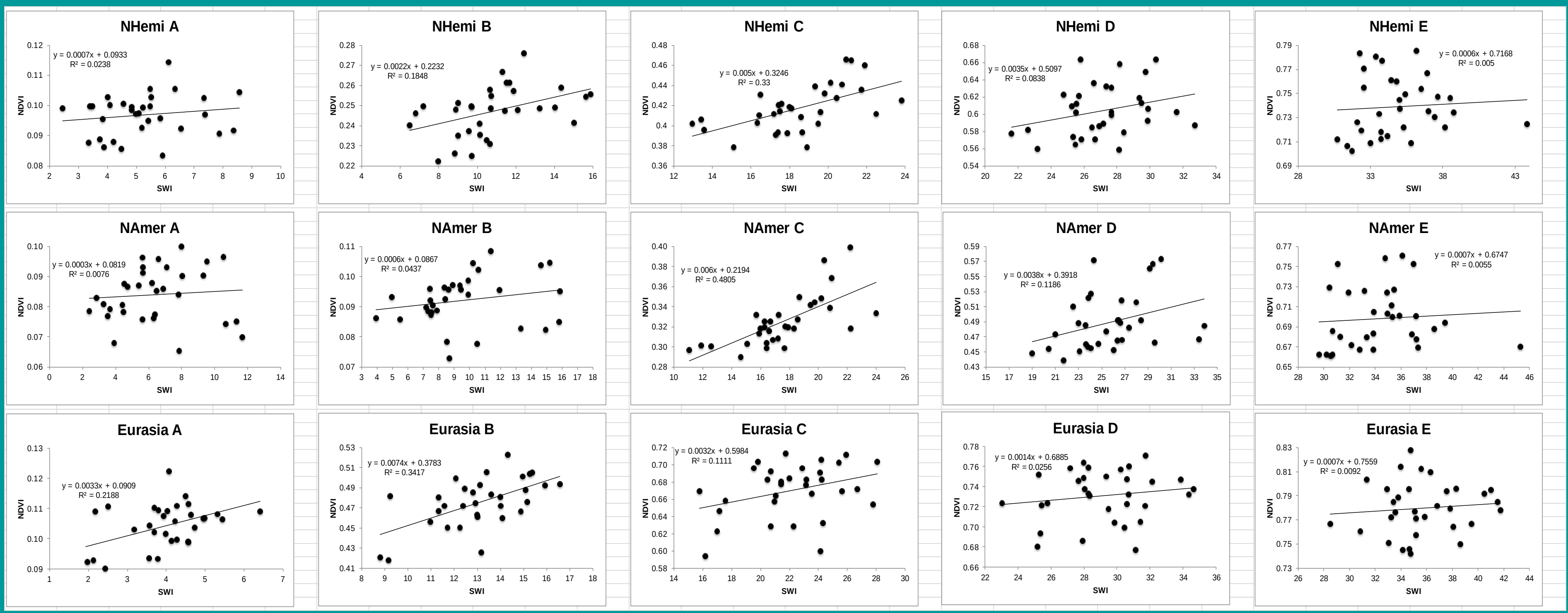
Largely driven by the increasing trend





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





Discussion – Long-Term Trends

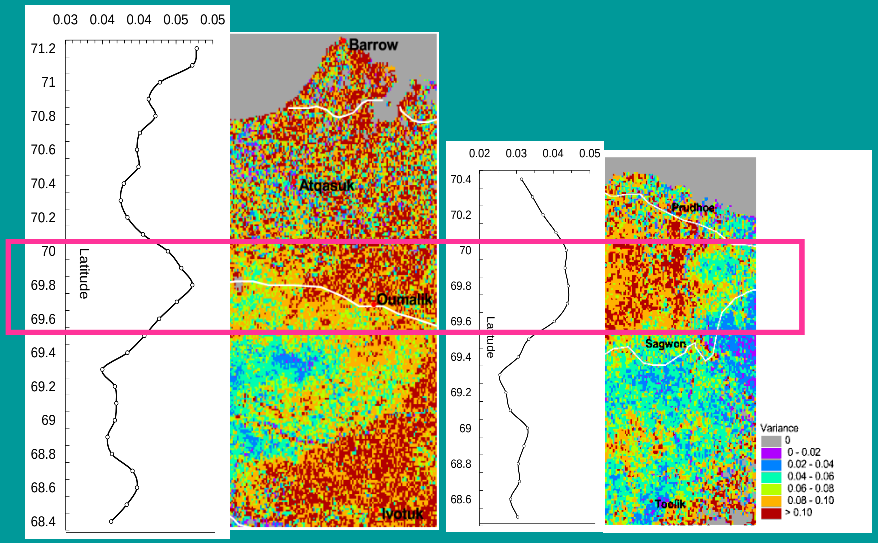
Greater responses in more southern subzones could be due to:

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

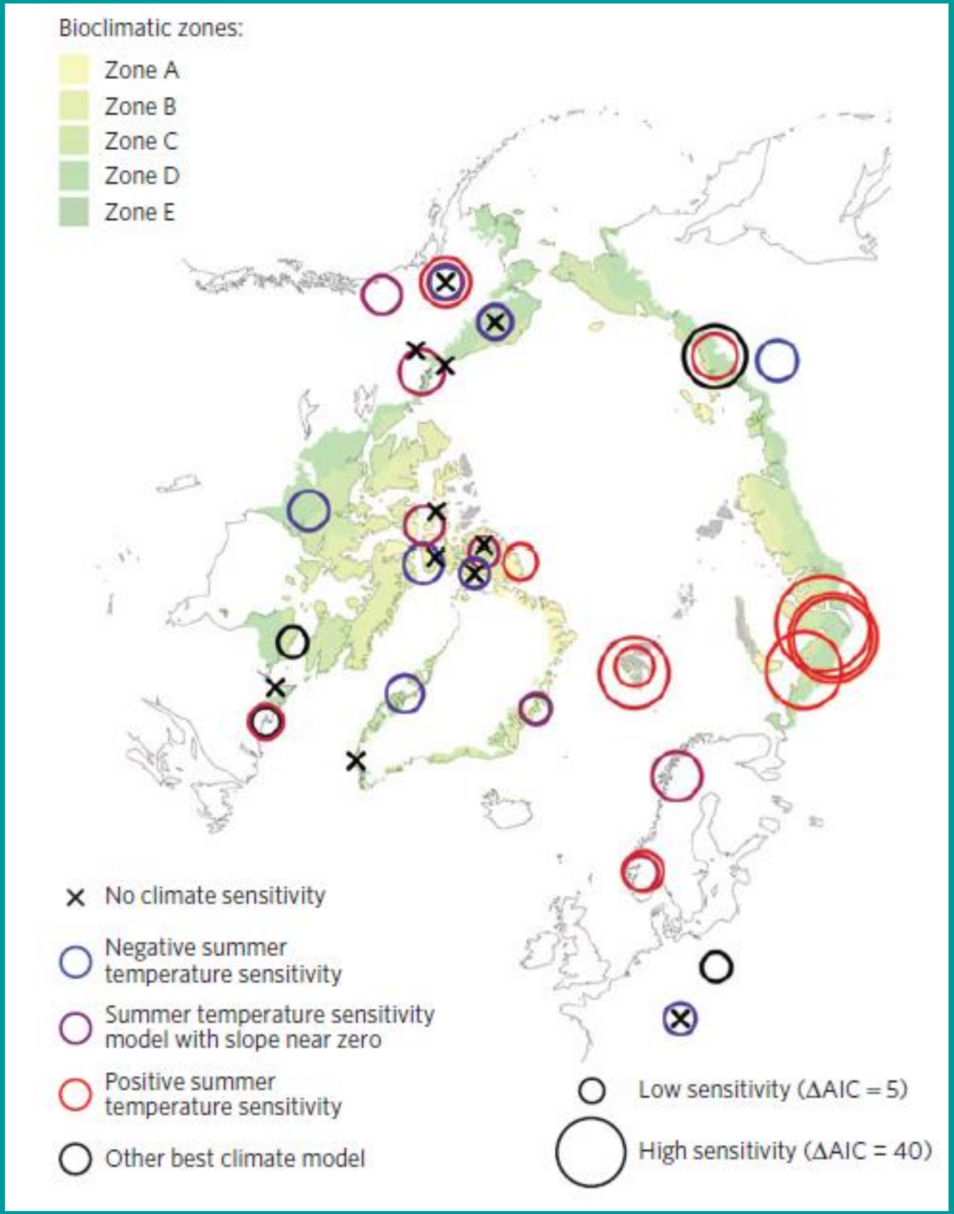
(D.A. Walker)

(G.V. Frost)

Discussion – Interannual Variability



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

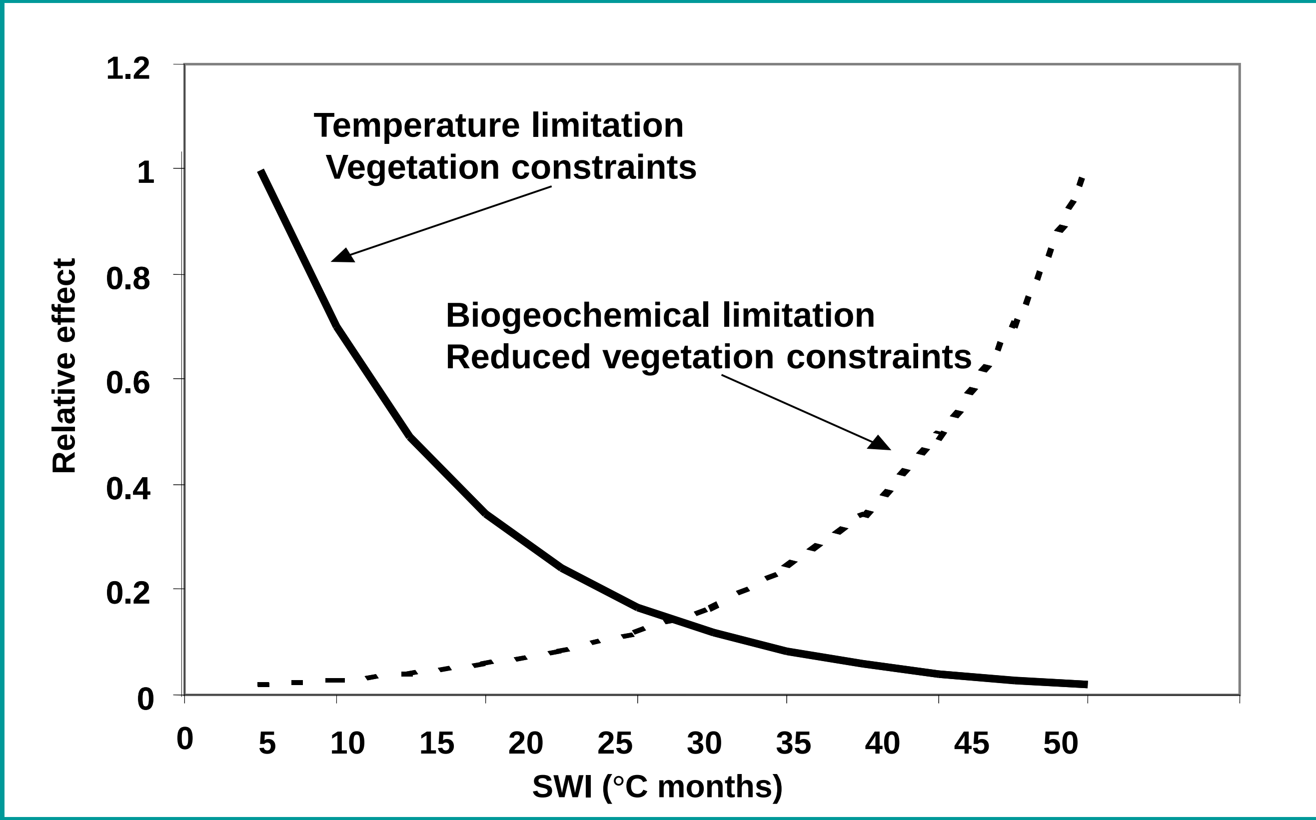


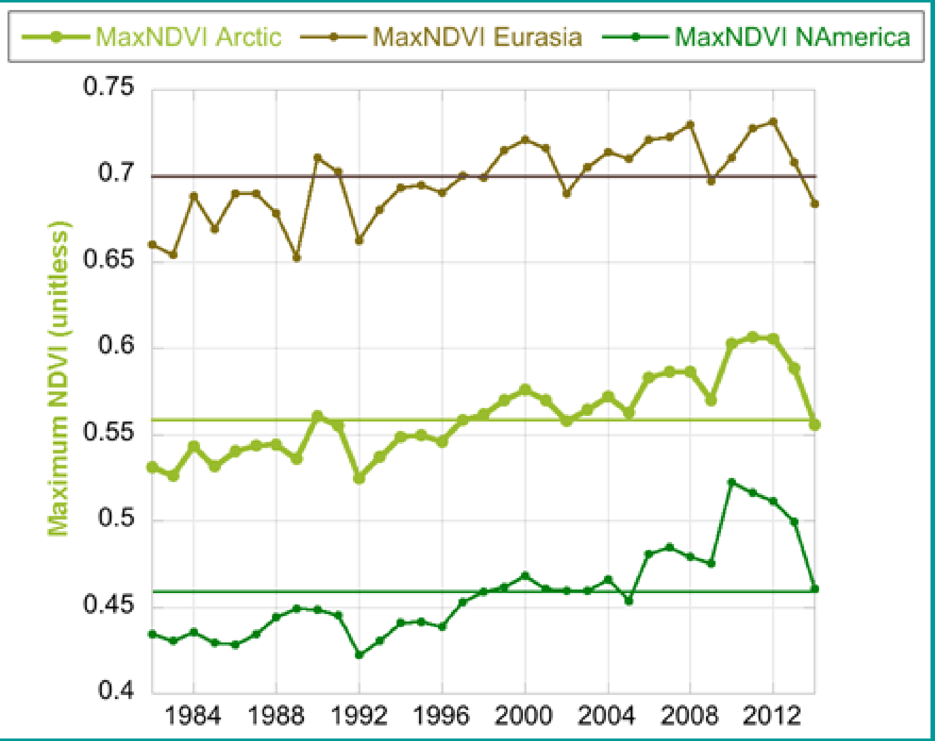
Greatest sensitivity of shrub growth to temperature at the transition between the Low and High Arctic (Myers-Smith et al. 2015)

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.

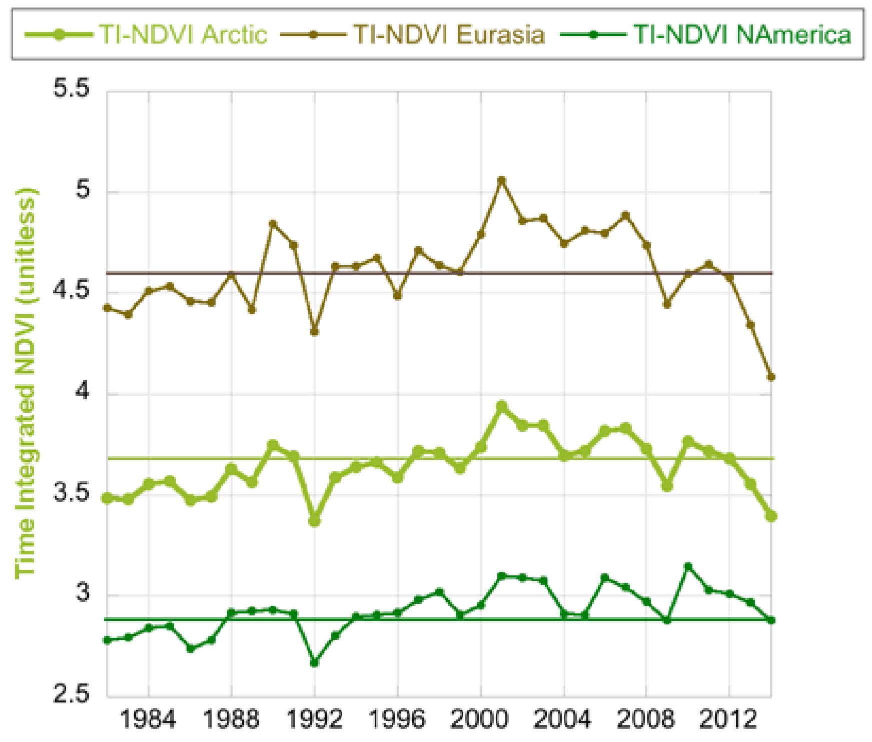




MaxNDVI (peak greenness)

Trends are apparently changing over the last several years, particularly for TI-NDVI

TI-NDVI (temporally integrated greenness)



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

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