Circumpolar Arctic tundra Vegetation Change is Linked to Sea-Ice Decline

US Bhatt[1], DA Walker[1], MK Raynolds[1], HE Epstein[3], G Jia[4], JC Comiso[5], R Gens[1], JE Pinzon[5], CJ Tucker[5], CE Tweedie[6], PJ Webber[7]

[1]UAF, [3]UVA, [4]CAS China, [5]NASA GSFC, [6]UTEP, [7]Mich State U

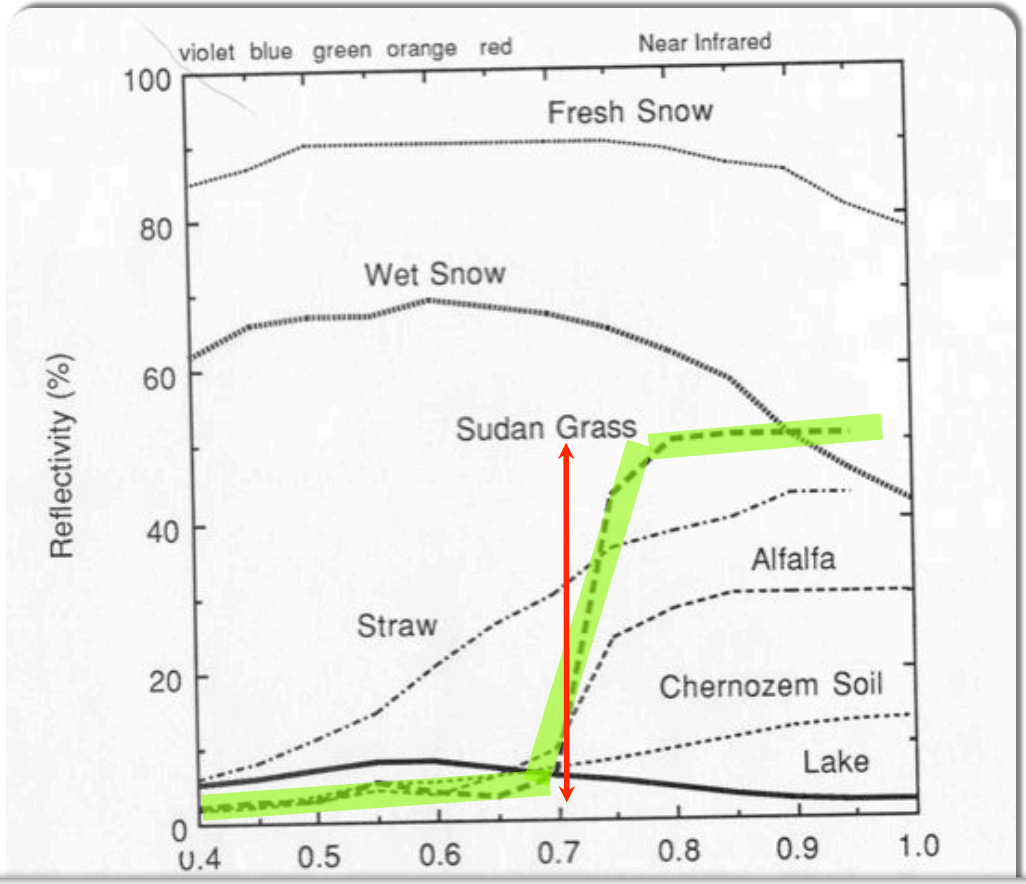
State of the Arctic, Tues. 16 March 2010, Miami, FL

Main Findings

- Increased vegetation productivity and tundra land warming are forced by coastal sea ice decline
- Regional heterogeneity in tundra response exists and is linked with mean climatology, seasonality, and local circulations.

Bhatt et al. [2010], in revision Earth Interactions

Solar radiation absorbed by plants depends strongly on frequency



- Green plants have low albedo in 0.4-0.7 micron range
- Green plants have higher albedo in the near infrared
- NDVI index is a proxy for vegetation activity.

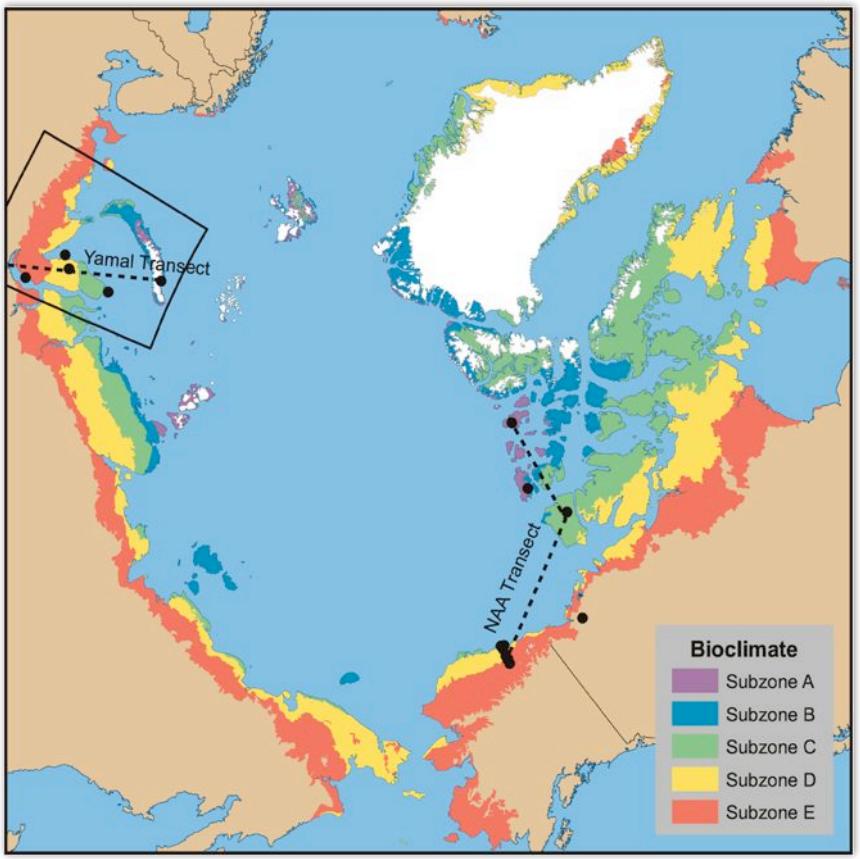
Deering [Ph.D. 1978] & Tucker [1979]

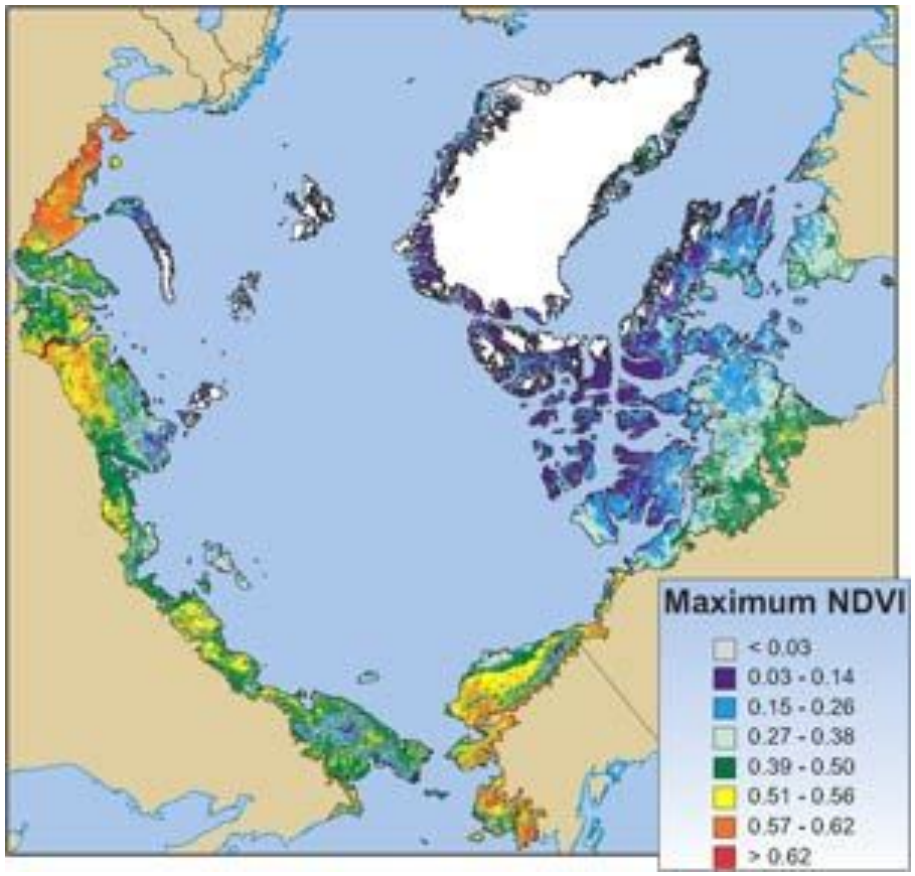
Normalized Vegetation Difference Index

Are NDVI and sea ice variations linked?

increasing trends in the Arctic [Jia et al. 2003; Goetz et al. 2005; Bunn et al. 2007]

Mean Tundra Vegetation Linked to Sea Ice





Circumpolar Arctic Vegetation Map

- 80% of the Arctic tundra (3.2 million km^2) < 100 km from ocean

Subzone A (mosses) to Subzone E (low shrubs)

Remote sensing data & methods

Data: 1982-2008 (27 yrs, weekly)

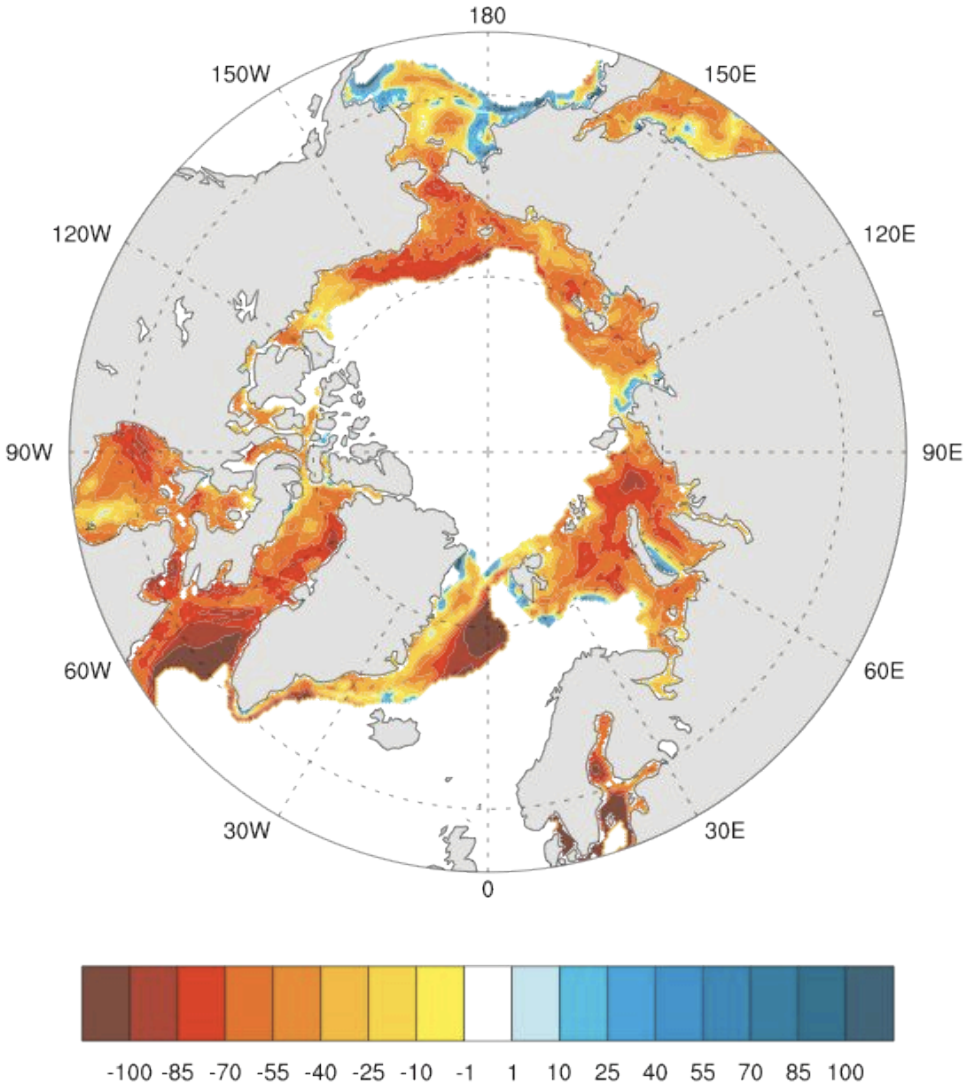
- Passive Microwave Sea Ice Conc. (25-km)
- AVHRR Land Surface Temp. (25-km)
- Gimms NDVI (Max and Integrated) (14-km)

New version that is corrected for Arctic

- Divided Arctic Ocean (Treshnikov, 1985) to examine trends and variability in 50-km land-ocean coastal domains

Sea Ice Decline - Large throughout Arctic

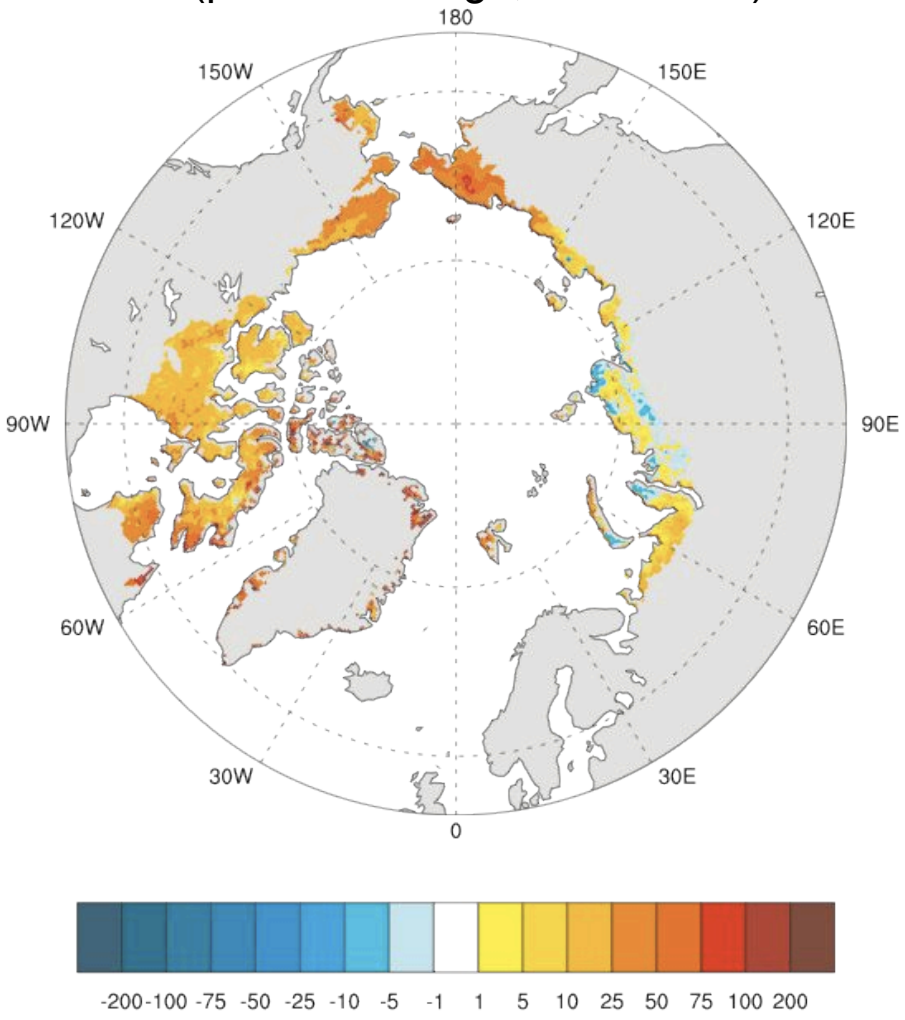
Sea Ice Concentration
(percent change, 1982-2008)



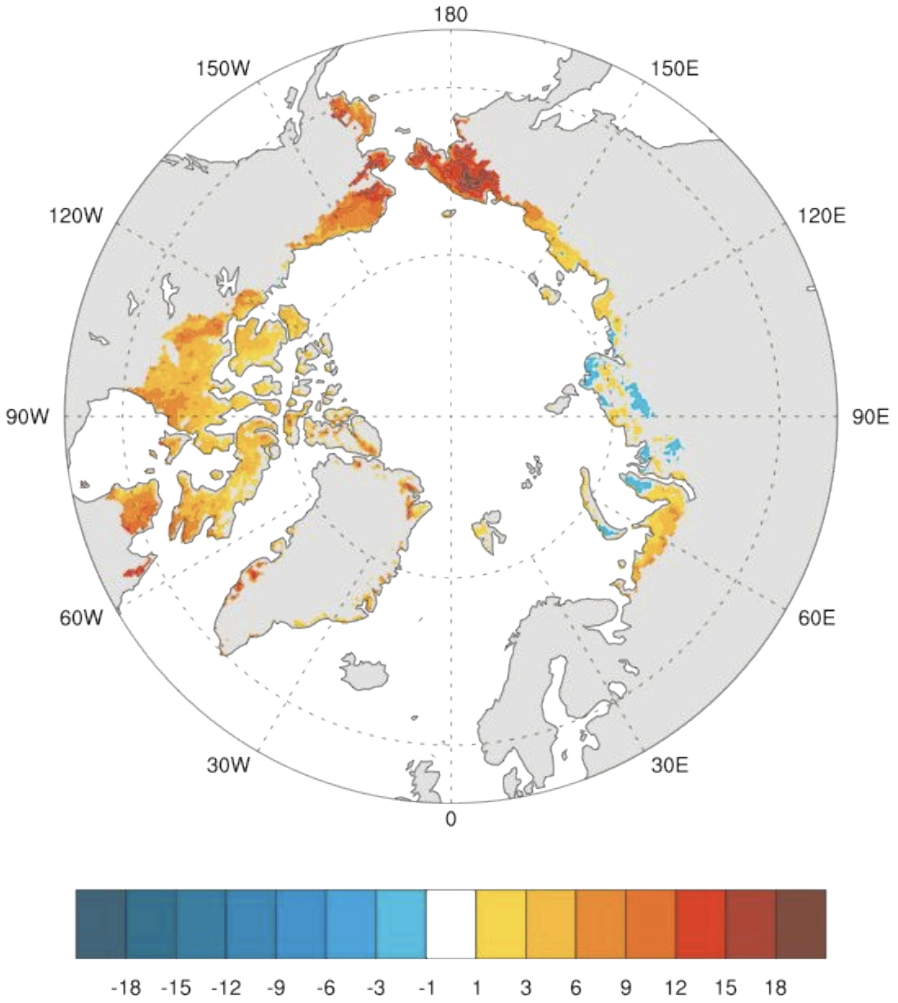
- Trend in long term mean 50% ice concentration level
- Arctic increases - pieces of mobile sea ice?
- Bering - due to recent Ts cooling

SWI Increase - Largest Beringia & Canada

Summer Warmth Index (SWI)
(percent change, 1982-2008)



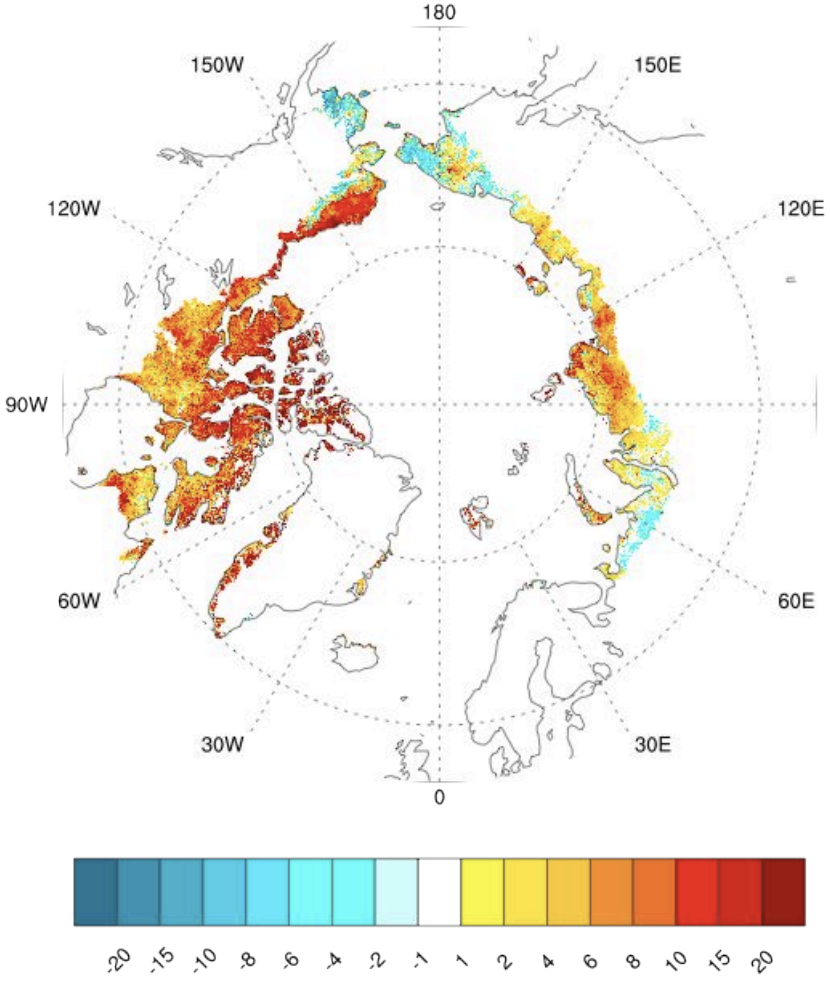
Summer Warmth Index (SWI) ˚C month
(magnitude change, 1982-2008)



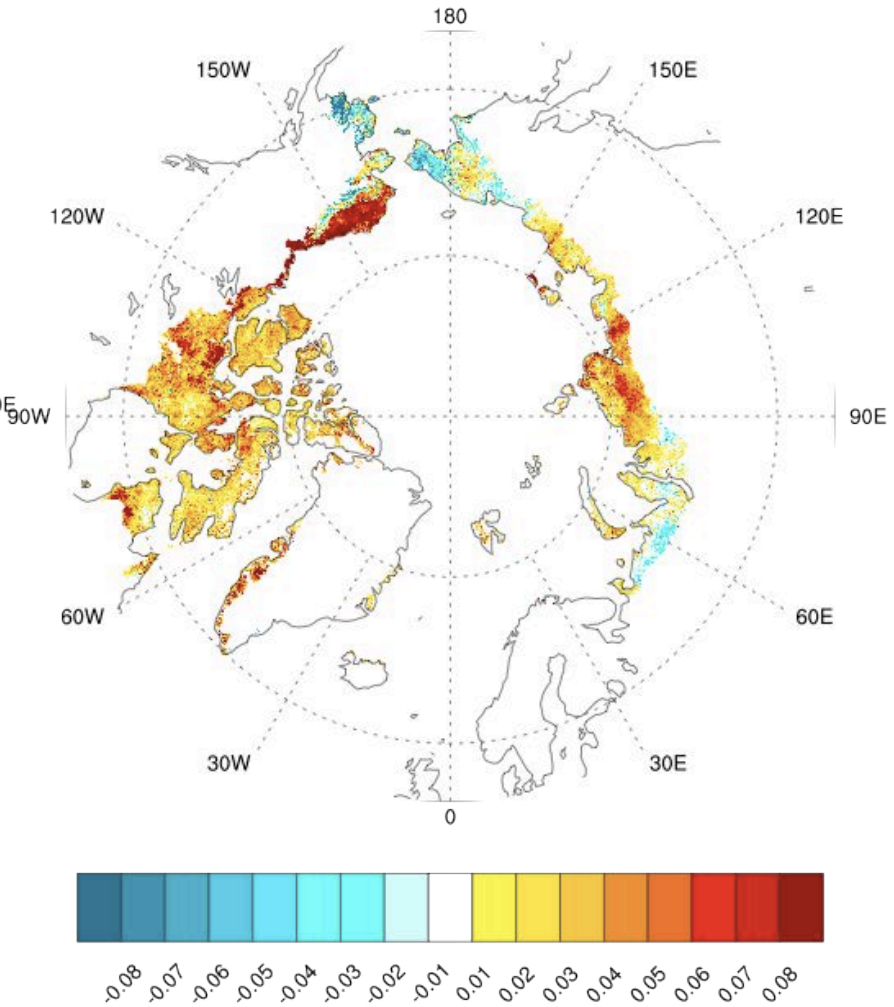
- **Canadian Arctic, Beringia & Taimyr**

MaxNDVI - Large Relative Changes

Maximum NDVI (MaxNDVI)
(percent change, 1982-2008)



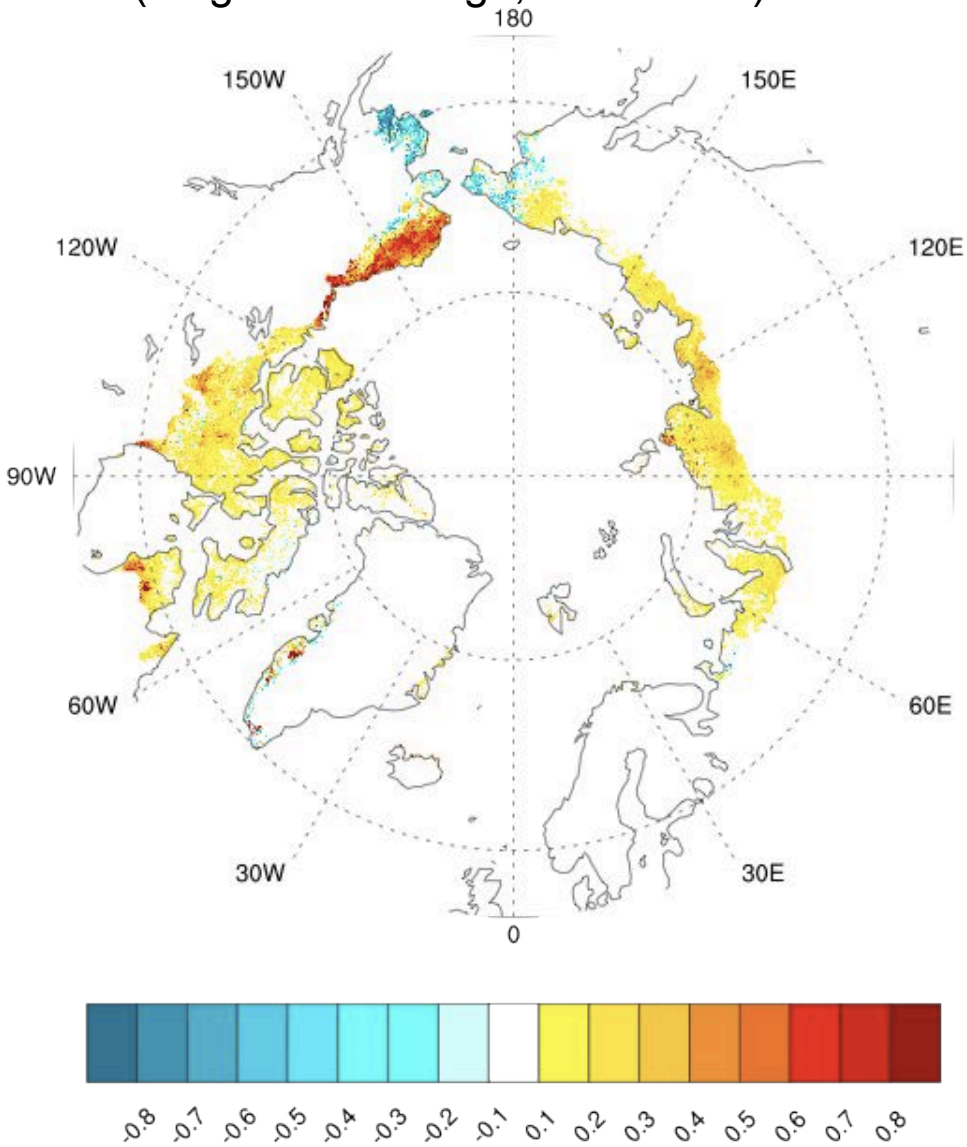
Maximum NDVI (MaxNDVI) unitless
(magnitude change, 1982-2008)

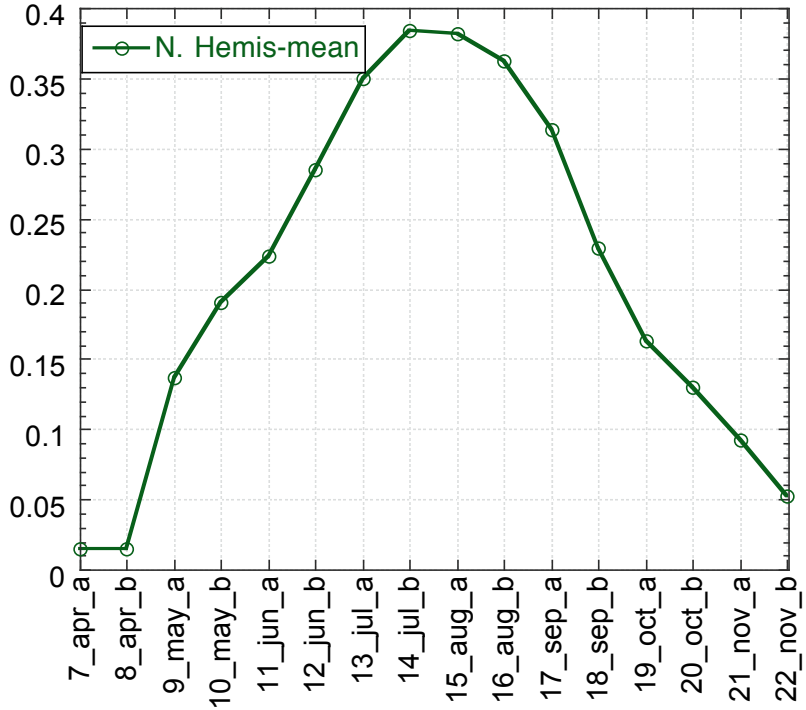


- **Canadian Arctic, Beringia & Central Eurasia**

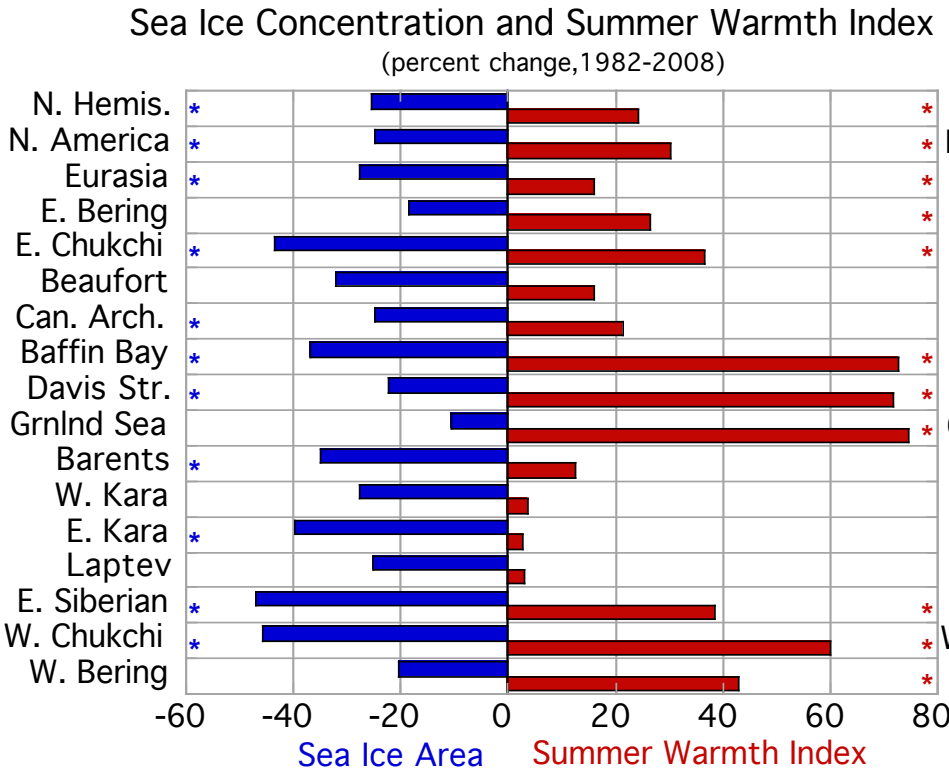
TI-NDVI - Large Relative Changes

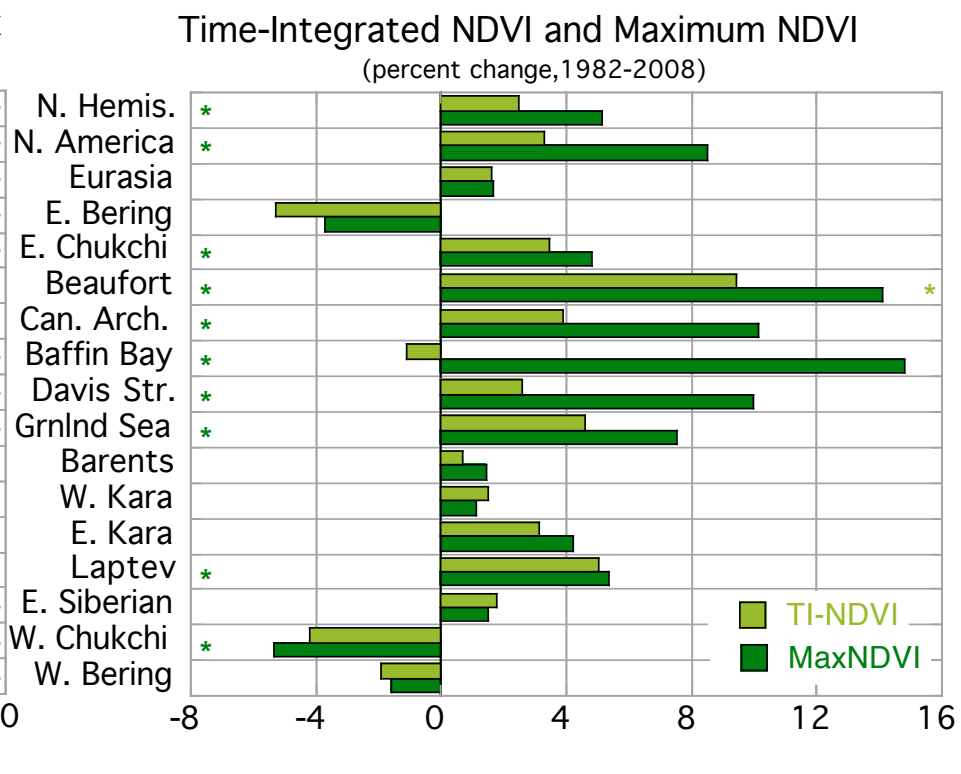
Time Integrated NDVI (TI-NDVI) unitless
(magnitude change, 1982-2008)





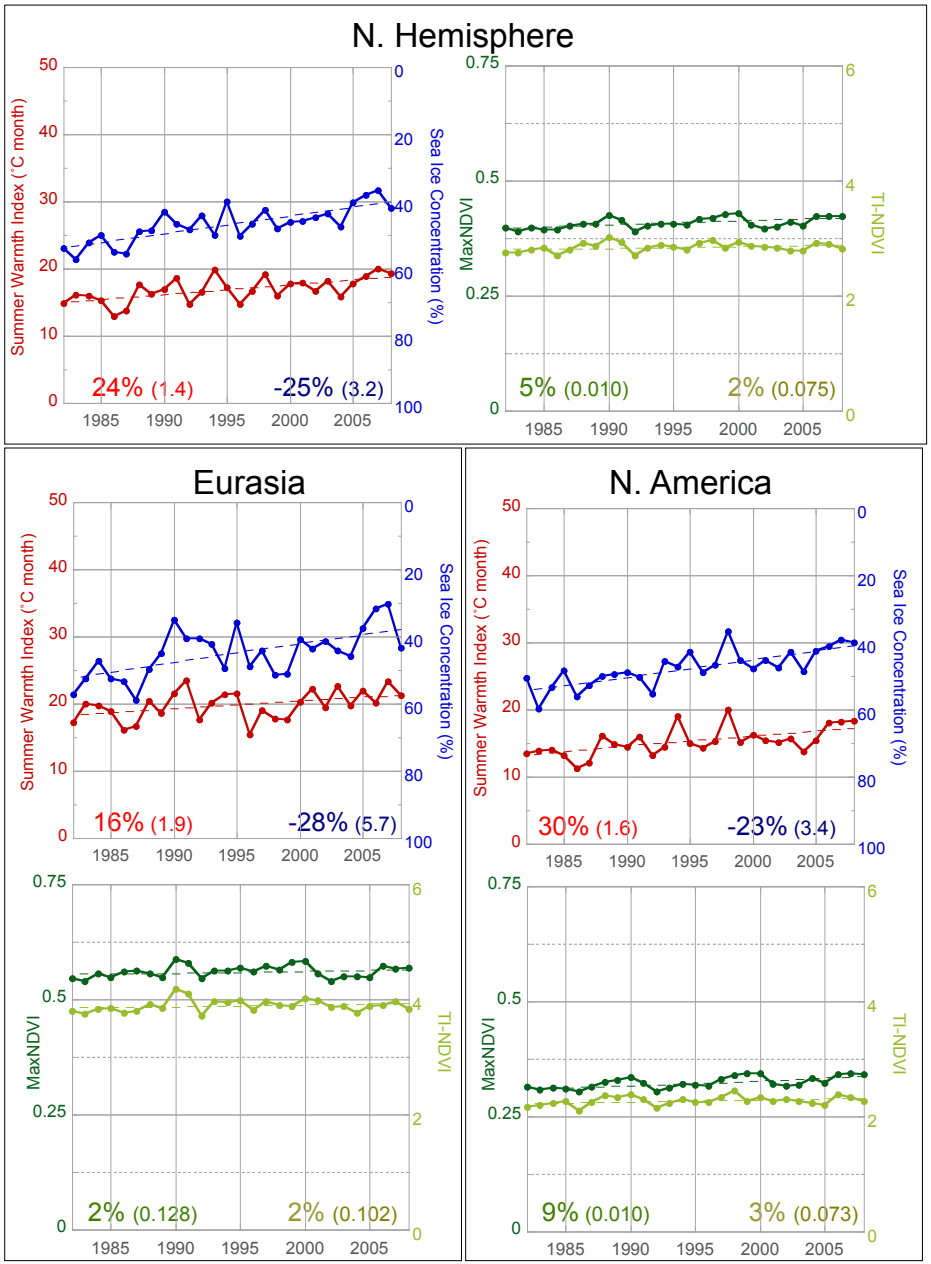
Pan-Arctic Trends (82-08) Vary Regionally





- **Large warming (%) High Canadian Arctic & Beringia**
- **NDVI trends large + Beaufort & High Canadian Arctic. Trends negative in Bering & W. Chukchi.**

Contrasts: N. America vs Eurasia

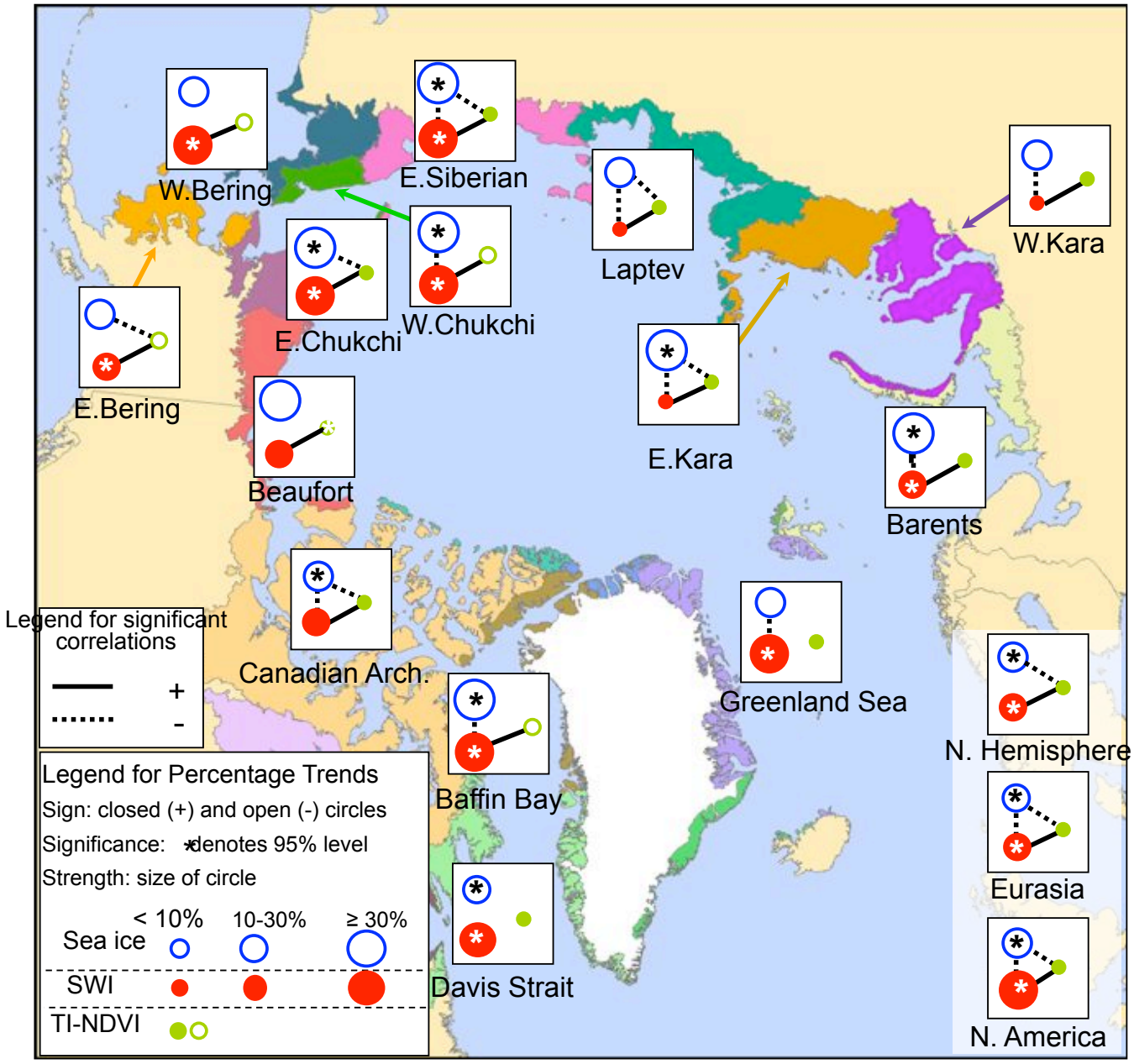


- Trends are larger in N. America (except sea ice)
- Variance is larger in Eurasia

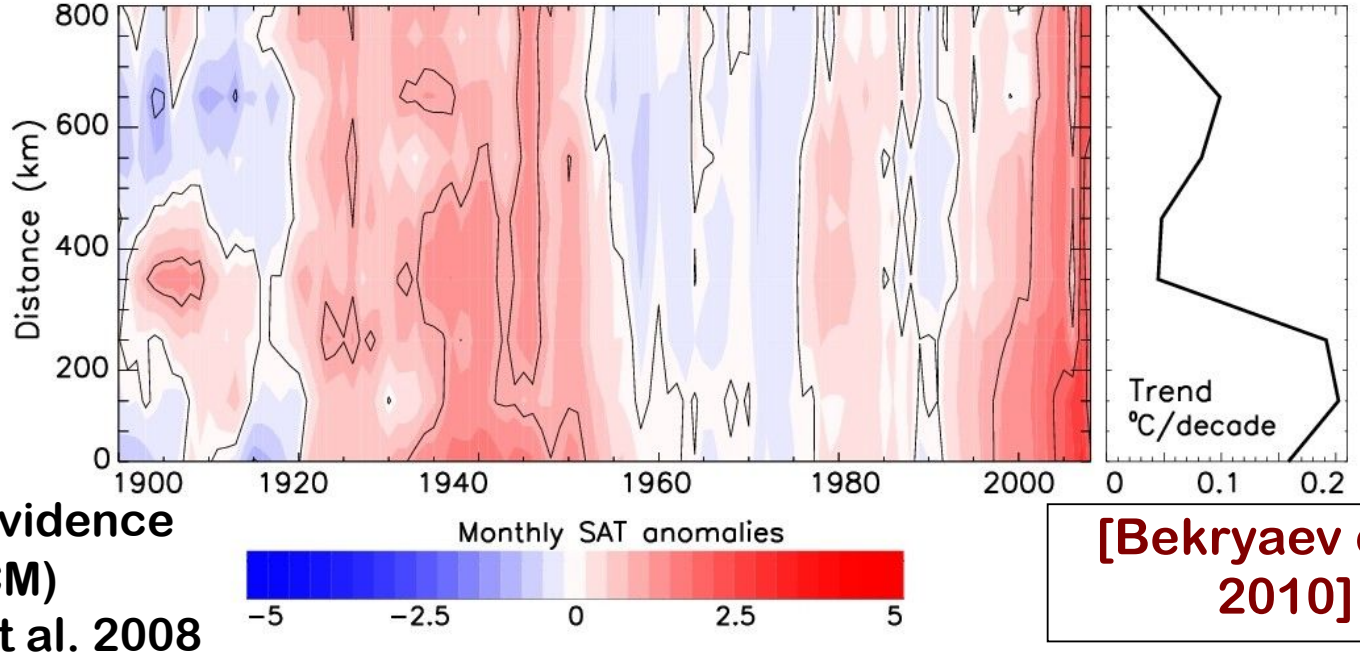
Correlations larger in 50-km coastal zone

	Avg. 50% ice conc.	sea ice & SWI	SWI & TI-NDVI		sea ice & TI-NDVI	
N. Hemis.	16-22Jul	-0.49	(-0.32)	0.64	(0.57)	-0.56	(-0.55)
N. America	23-29Jul	-0.56	(-0.40)	0.60	(0.57)	-0.53	(-0.50)
Eurasia	9-15Jul	-0.58	(-0.40)	0.67	(0.65)	-0.51	(-0.41)
E. Bering	30Apr-6May	-0.12	(-0.04)	0.57	(0.48)	-0.47	(-0.47)
E.Chukchi	11-17Jul	-0.13	(-0.02)	0.55	(0.51)	-0.41	(-0.37)
Beaufort	9-15Jul	-0.37	(-0.31)	0.50	(0.31)	-0.20	(-0.17)
Can. Arch.	6-12Aug	-0.77	(-0.66)	0.78	(0.76)	-0.64	(-0.65)
Baffin Bay	2-8Jul	-0.38	(-0.46)	0.55	(0.44)	-0.35	(-0.37)
Davis Str.	21-27May	0.05	(-0.19)	0.35	(0.35)	-0.27	(-0.26)
Grnlnd Sea	30Jul-5Aug	-0.46	(-0.54)	0.29	(0.12)	-0.17	(-0.16)
Barents	21-27May	-0.50	(-0.44)	0.65	(0.45)	-0.34	(-0.33)
W. Kara	16-22Jul	-0.41	(-0.36)	0.56	(0.54)	-0.28	(-0.24)
E. Kara	13-19Aug	-0.41	(-0.30)	0.78	(0.74)	-0.46	(-0.43)
Laptev	23-29Jul	-0.68	(-0.59)	0.74	(0.76)	-0.69	(-0.61)
E. Siberian	23-29Jul	-0.62	(-0.53)	0.60	(0.62)	-0.64	(-0.63)
W. Chukchi	2-8Jul	-0.54	(-0.49)	0.52	(0.45)	-0.36	(-0.32)
W. Bering	14-20May	-0.09	(-0.05)	0.39	(0.13)	0.16	(0.14)

Sea ice correlated with SWI & NDVI



Sea ice decline ==> SWI & NDVI increase

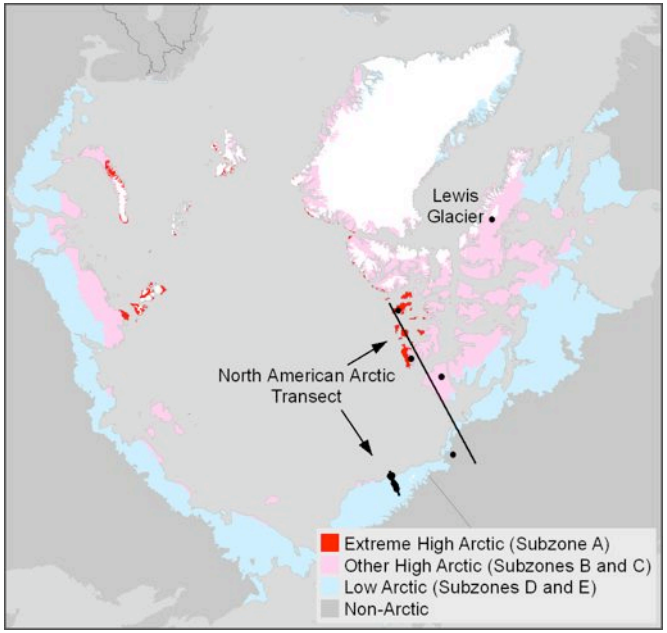


[Bekryaev et al. 2010]

- Modeling evidence

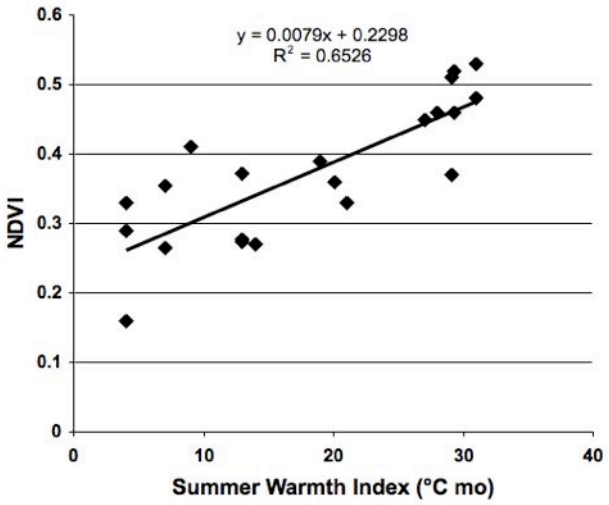
(Fixed ice GCM)

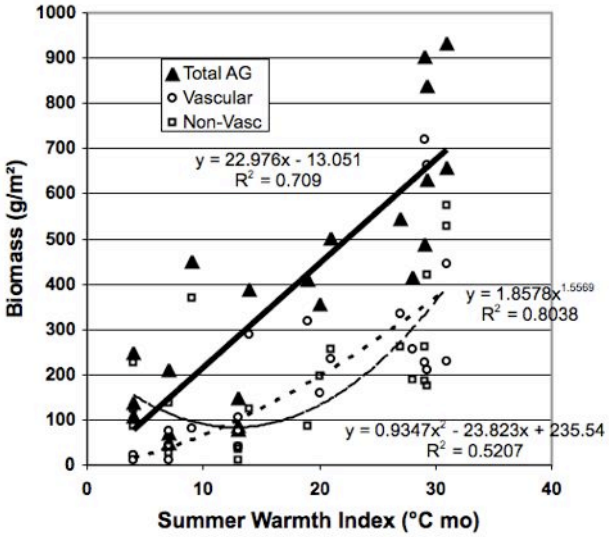
- Lawrence et al. 2008
- Deser et al. 2010
- Bhatt et al. 2008
- Observational Evidence
- Rouse 1991 & Haugen and Brown 1980
- Mean NDVI map
- Bekryaev et al. 2010 (accepted to J. Climate) Largest warming on land is close to the coast when ice declines (MDV). Ice increases result in cooling but magnitude is smaller.
- Alternate Theory: Is the forcing from comes from the south?



North American Arctic Transect biomass measurements linked with SWI & NDVI

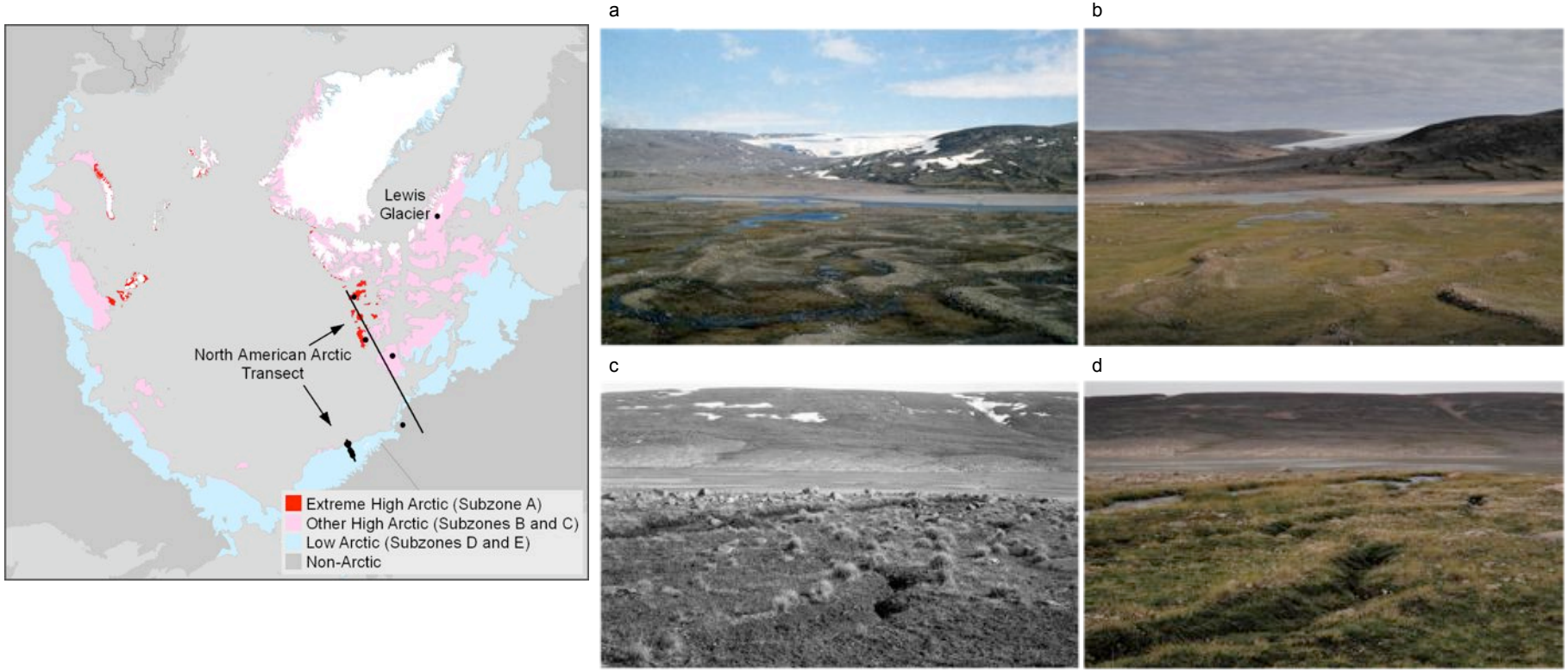
SWI increases from 4 - 31 ˚C month, NDVI increases from 0.15-0.52 and biomass from 50 - 920 g m^{-2}.





[Epstein et al. 2008]

46 years of Vegetation Change: Baffin Island



- Repeat photos of Lewis Glacier after 46 year show increases in vegetation in recently deglaciated areas (500 years).
- Retreating glaciers may help explain large NDVI trends in Greenland Sea, Baffin Bay & Davis Strait.

[P. Webber & C. Tweedie]

Conclusions

Relationships between sea ice, SWI, and NDVI suggest ice is a key driver of the terrestrial changes.

- Arctic trends are spatially heterogenous even within a season.
- Consequence: If Northern Canada coastal sea ice continues to declined leading to +2 C warming then, Subzone A would be impacted as new species move in.

Typical subzone A zonal vegetation at Isachsen, Ellef Ringnes Island, Nunuvut, Canada. Yellow flowers are Papaver polaris. Photo: D.A. Walker.

Thank you for your attention

Acknowledgments

- This work was supported by NSF ARC-0531180, NASA NNG6NE00A, NSF ARC-0902175, NASA Land Cover Land Use Change on the Yamal Peninsula.

- This project is part of the Greening of the Arctic project of the International Polar Year and the Northern Eurasia Earth Science Partnership Initiative (NEESPI).