Panarctic linkages between greening of Arctic tundra, sea ice decline, and summer land temperatures

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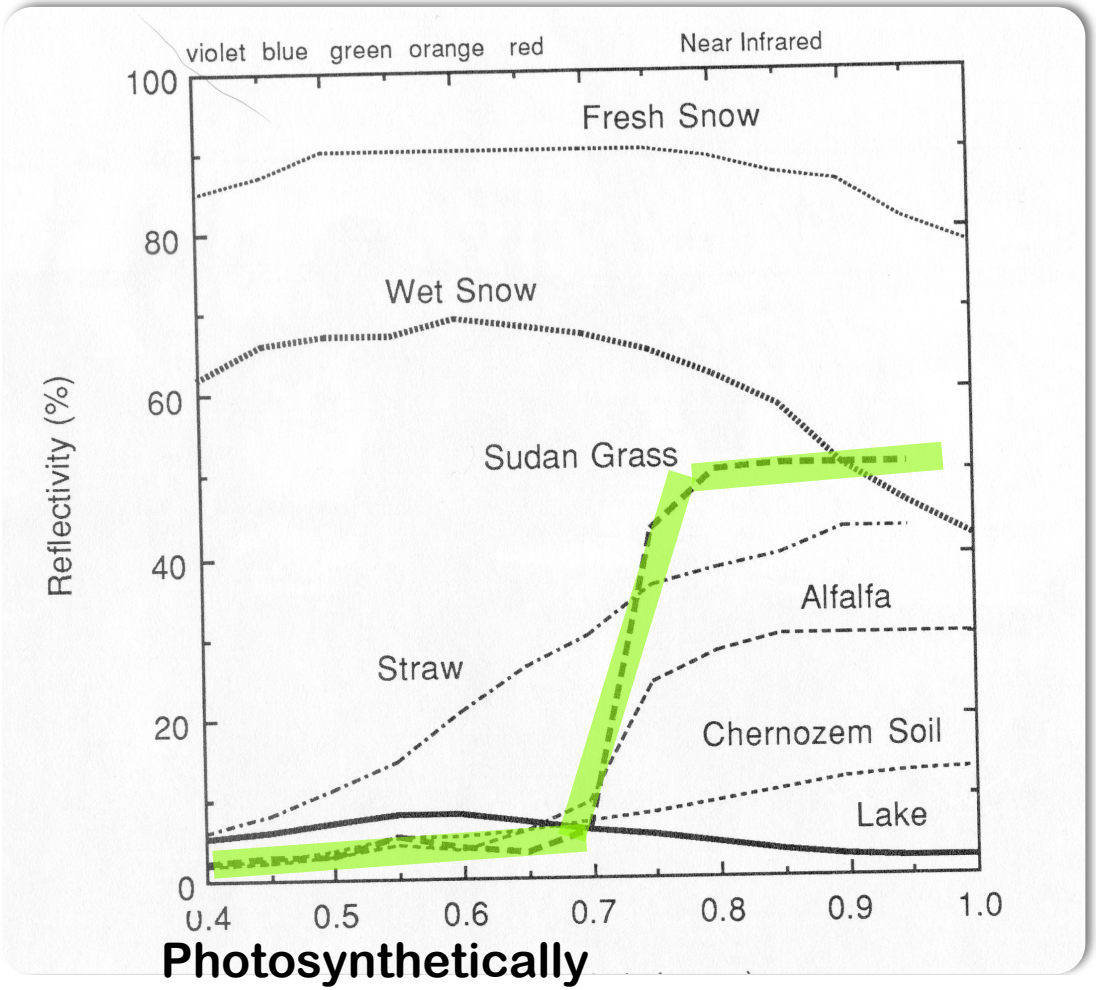
Main Point

Question: Is sea ice linked to observed trends and variability in tundra greenness?

Answer: Yes, it is linked and is most likely a primary driver of these changes.

Solar radiation absorbed by plants depends strongly on frequency



Photosynthetically active (0.4-0.7)

[Hartmann 1994]

- 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.

Normalized Vegetation Difference Index
NDVI = (NIR-R)/(NIR+R)

NDVI & SWI trends/variability similar
Ground measured biomass follows NDVI

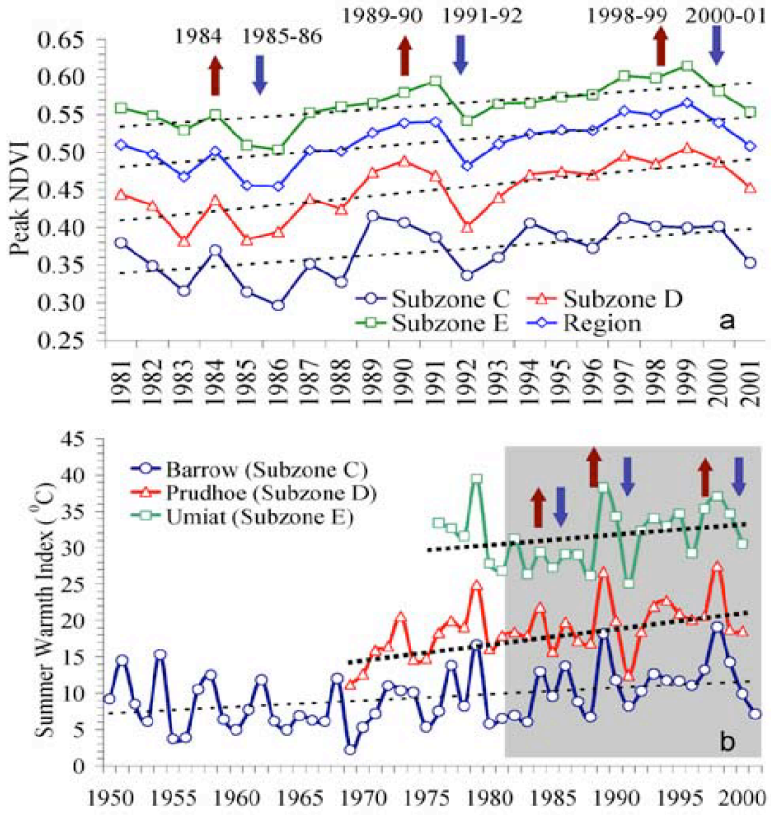


Figure 2. Time series of peak NDVI derived from 8-km resolution AVHRR data from 1981 to 2001 (a) and SWI over the past 22–50 years (b) among bioclimate subzones. Dashed lines are linear regressions. The shaded area highlights the period of SWI covered by NDVI data.

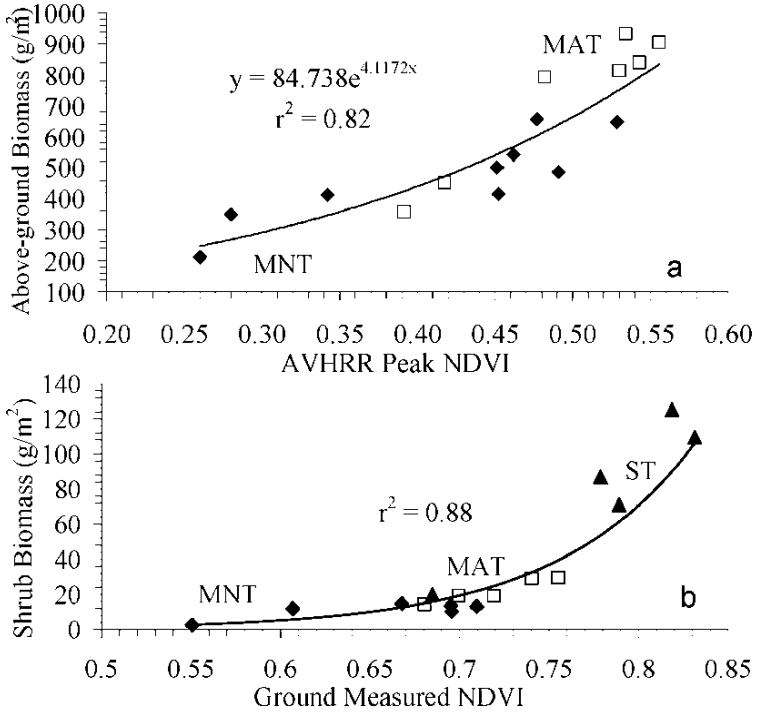


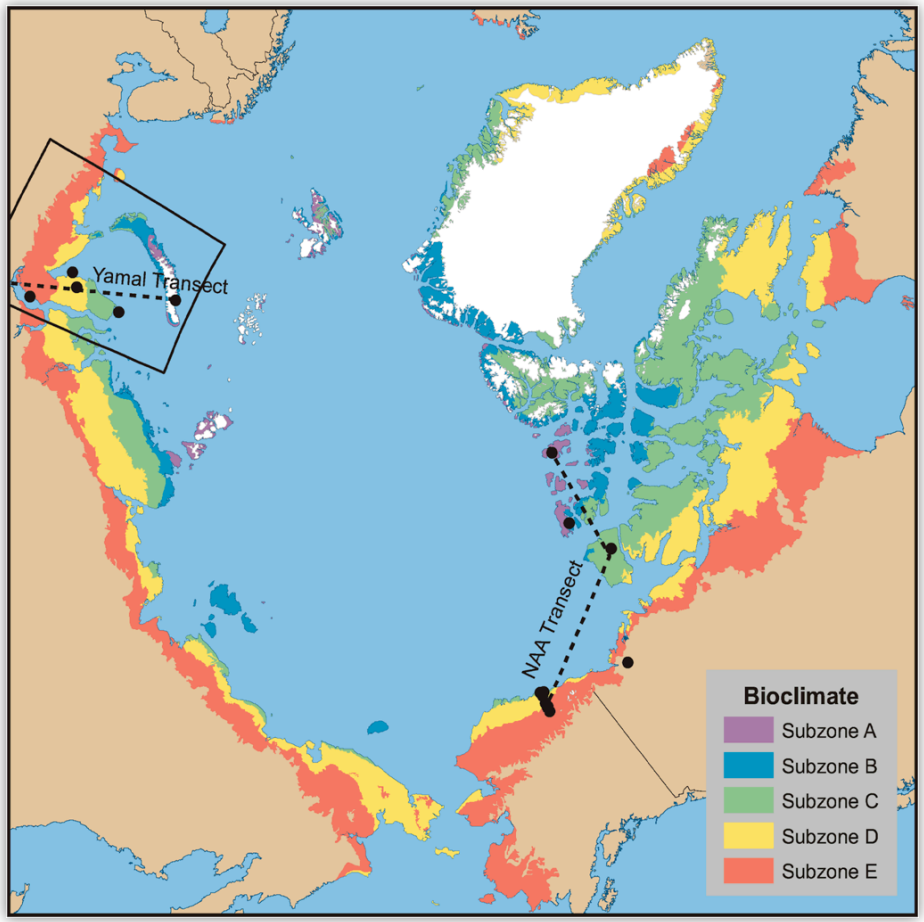
Figure 4. Correlations between NDVI and aboveground plant biomass. (a) AVHRR Peak-NDVI vs. total biomass on the North Slope; (b) ground measured NDVI vs. shrub biomass in Ivotuk.

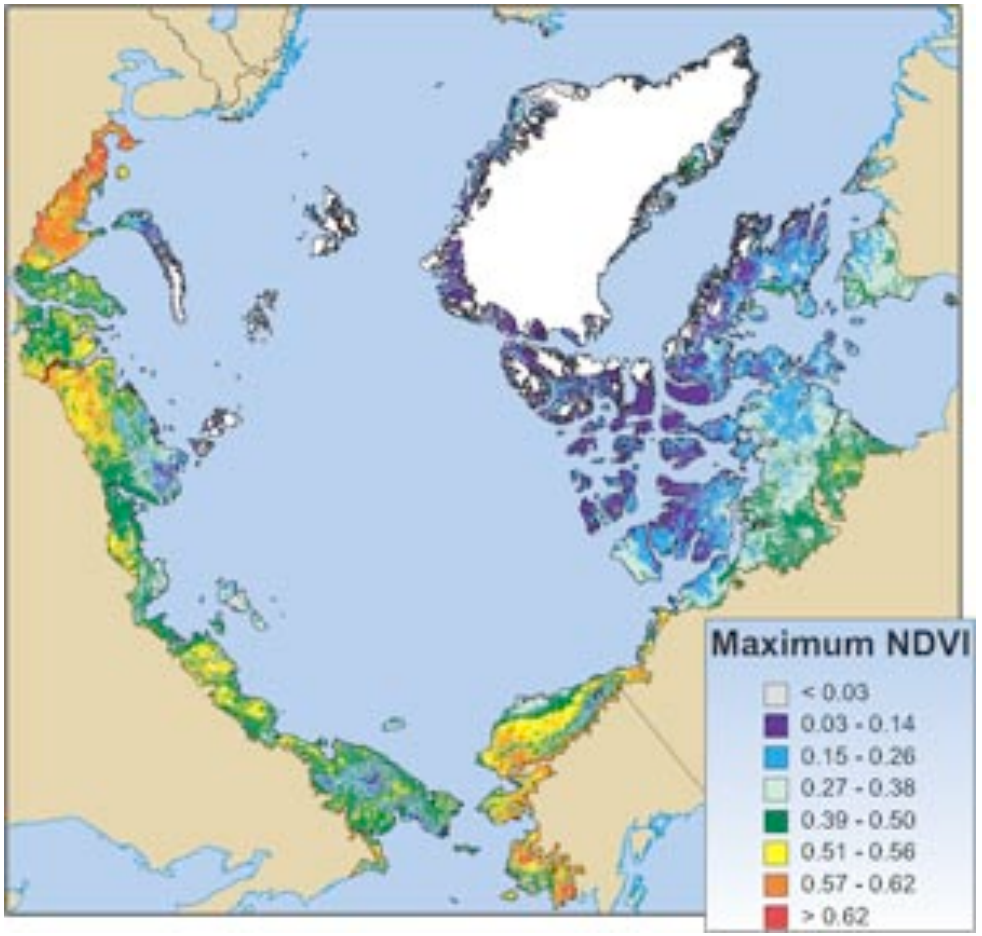
[Jia et al. 2003, GRL]

SWI - Summer Warmth Index- degree months > 0C

- **Arctic NDVI increasing 1981-2005 [Bunn et al. 2007]**

Mean Tundra Vegetation Linked to Sea Ice

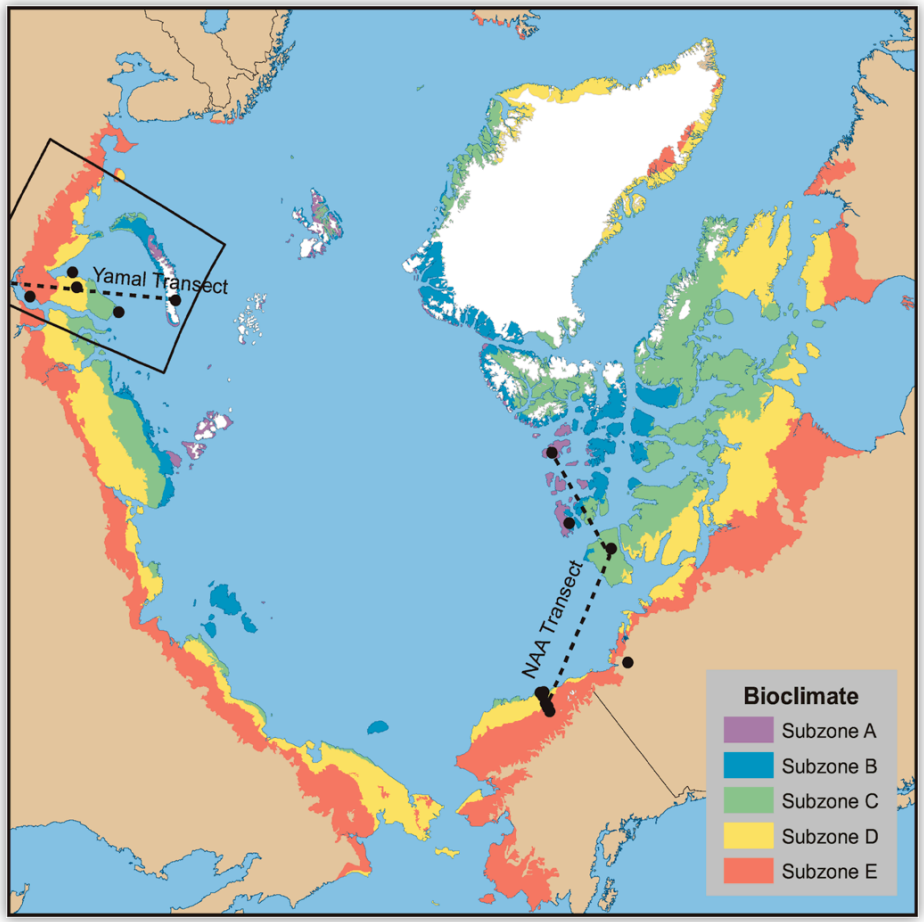


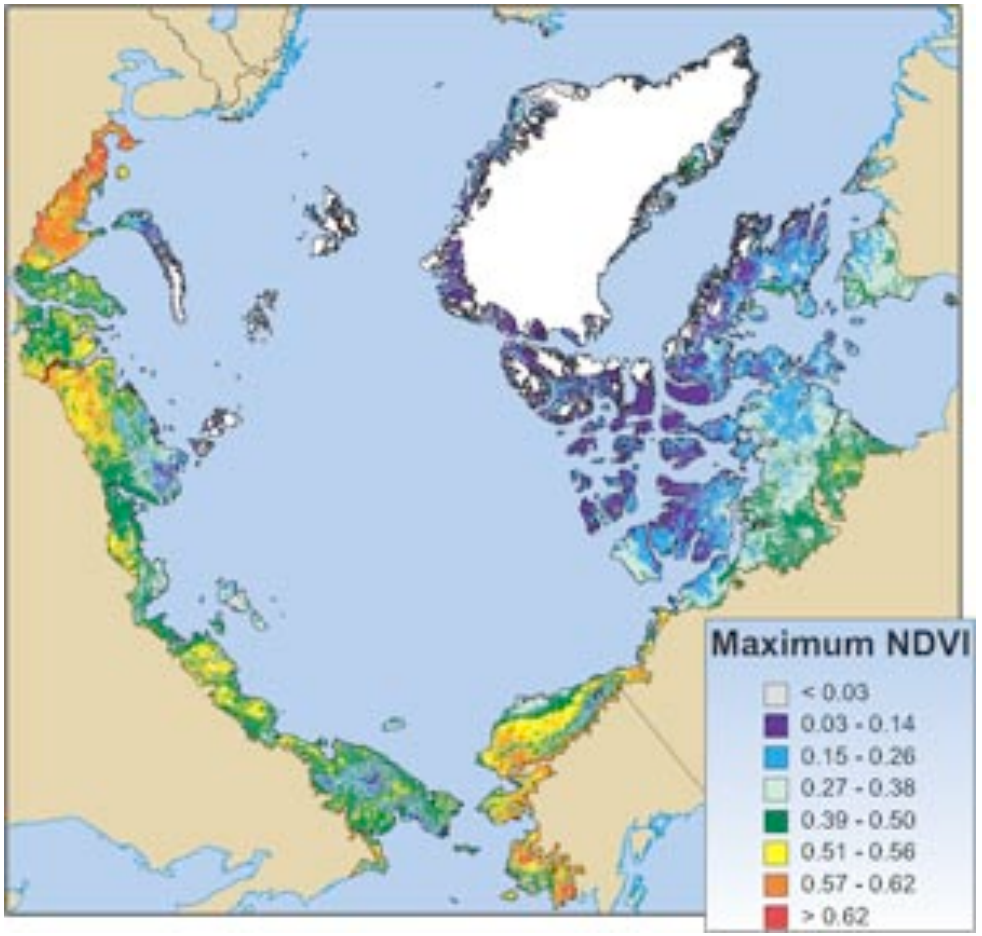


Circumpolar Arctic Vegetation Map

- 80% of the Arctic tundra (3.2 million km^2) < 100 km from ocean
- Subzone A (mosses) to Subzone E (low shrubs)

Mean Tundra Vegetation Linked to Sea Ice



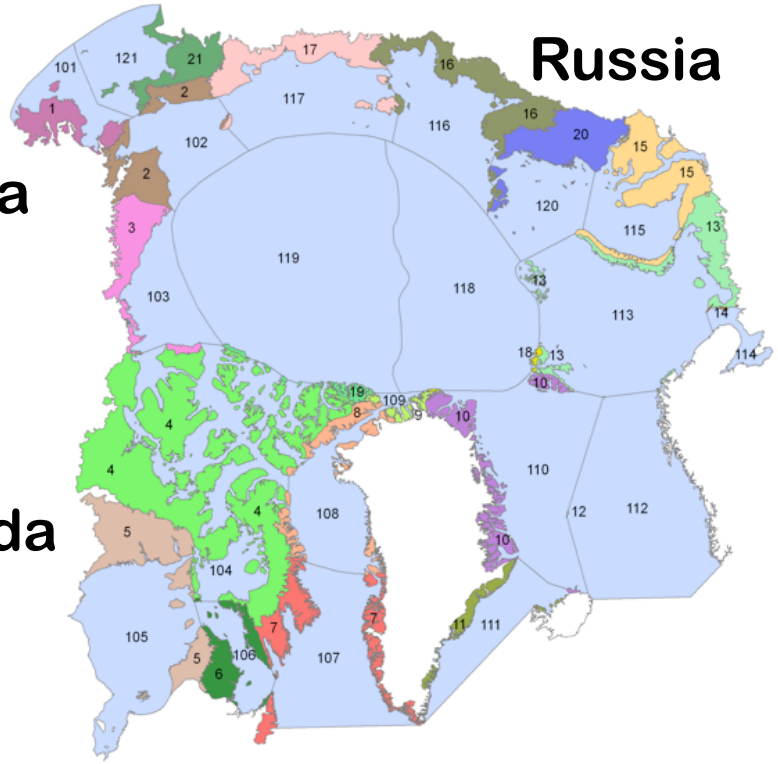


Are these Arctic tundra vegetation changes forced by changes in sea-ice?

Remote sensing data & methods

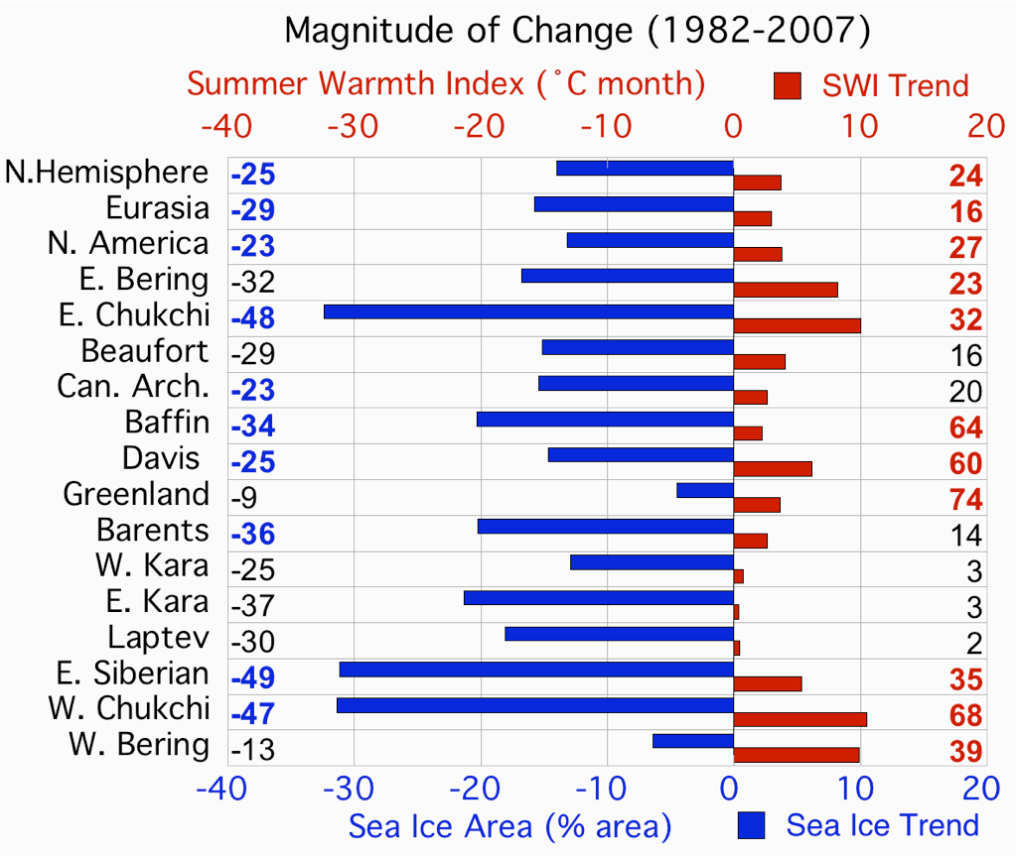
Data: 1982-2007 (26 yrs, weekly) at 25-km resolution

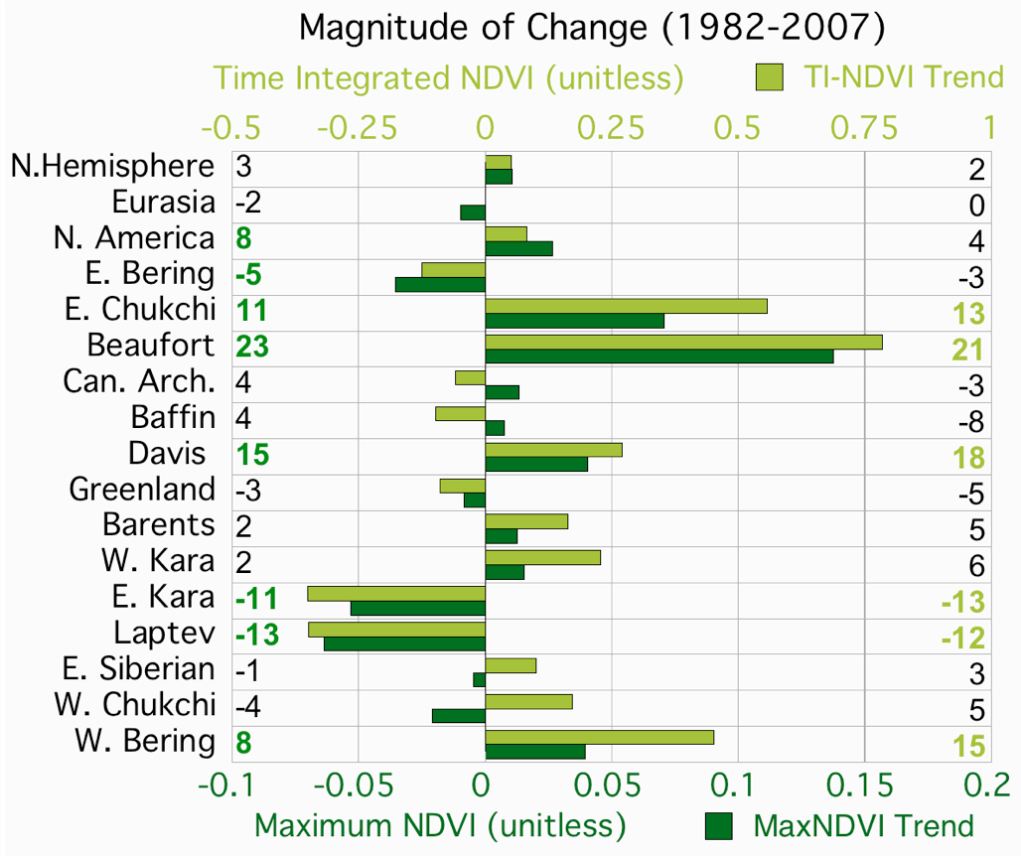
- **Passive Microwave Sea Ice Concentration**
- **AVHRR Land Surface Temperature**
- **Gimms NDVI (maximum and integrated)**



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

Pan-Arctic Trends (82-07) Vary Regionally

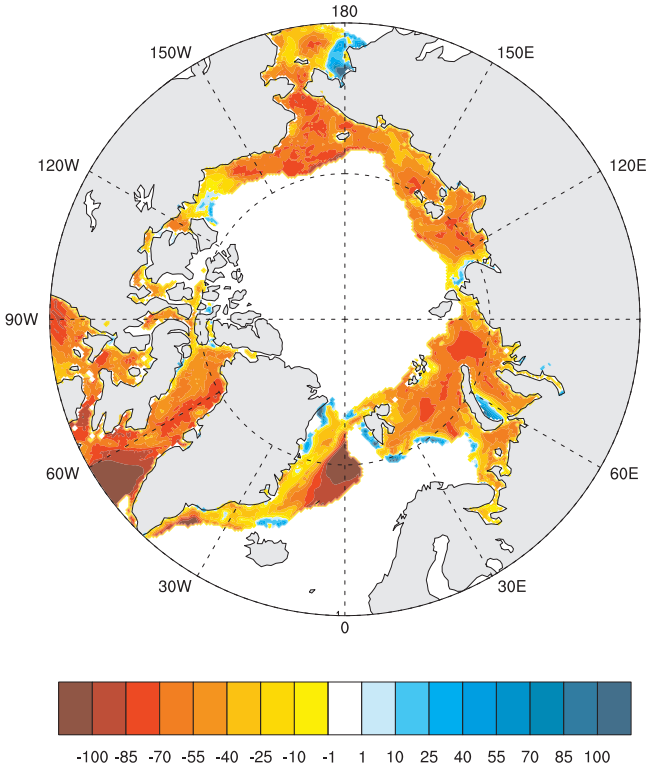




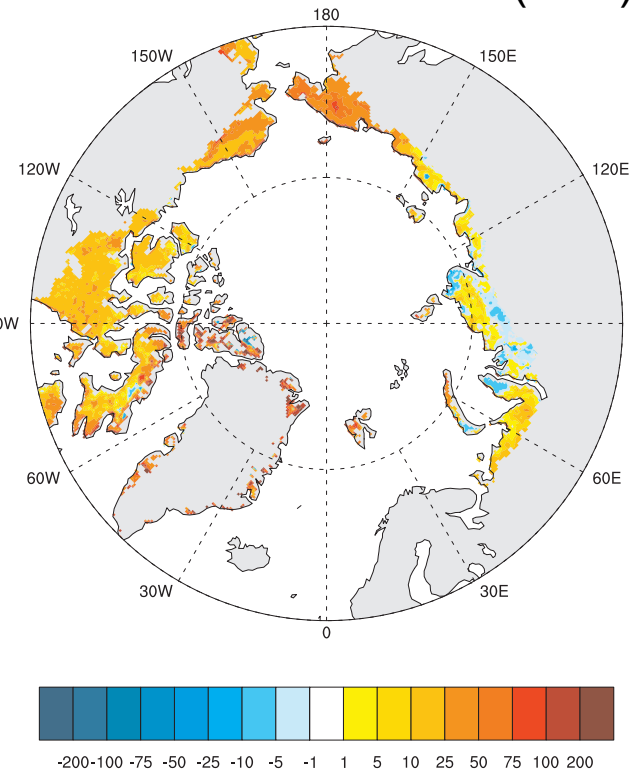
- **SWI and Ice trends same sign & consistent**
- **TI-NDVI and MaxNDVI trends vary in sign**

Pan-Arctic Trends over Tundra Vary

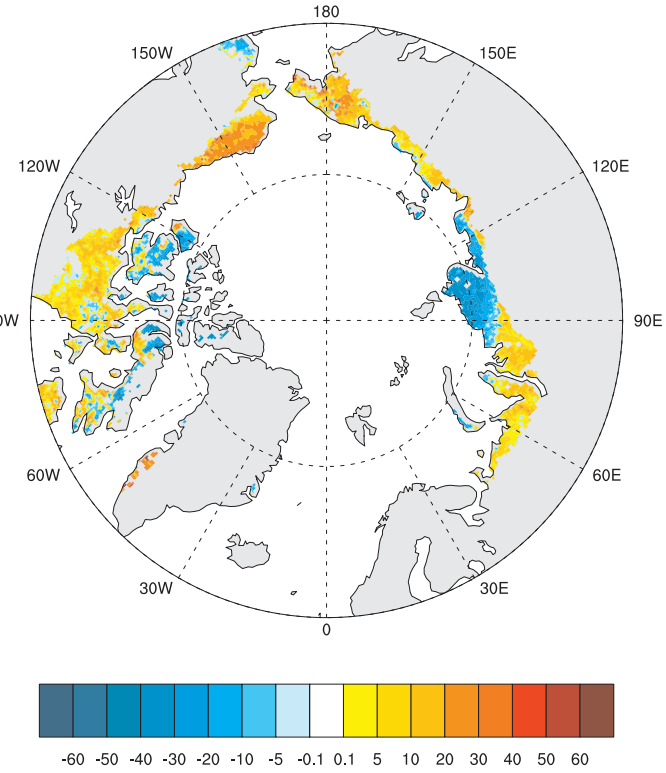
Sea Ice Concentration



Summer Warmth Index (SWI)

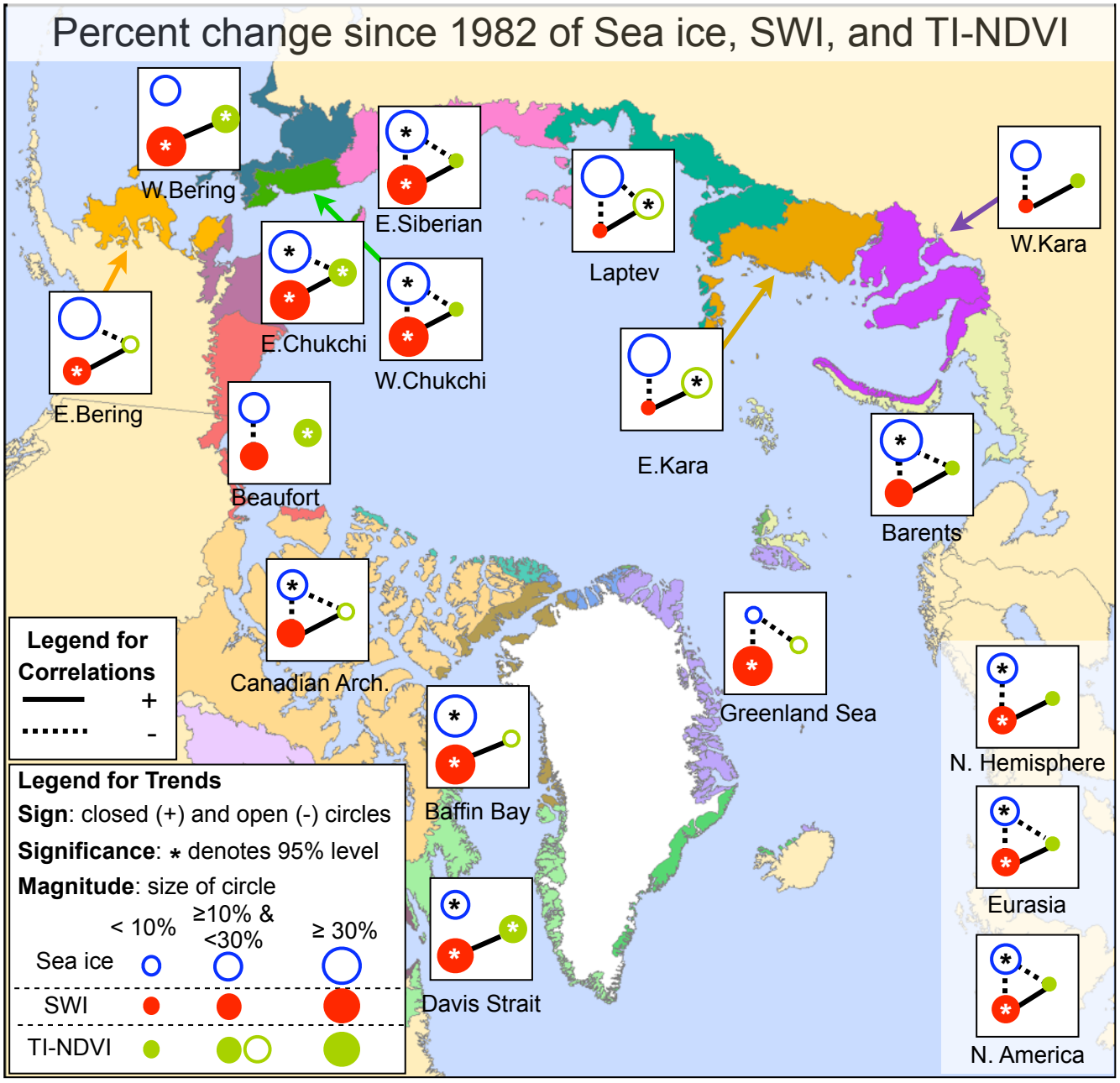


TI-NDVI



- **Trends of 50% average sea ice cover**
- **SWI shows cooling over Yamal, Taymyr (consistent with station data)**
- **TI-NDVI decreasing Seward Peninsula, Taymyr & Canadian Archipelago (Data issue concern)**

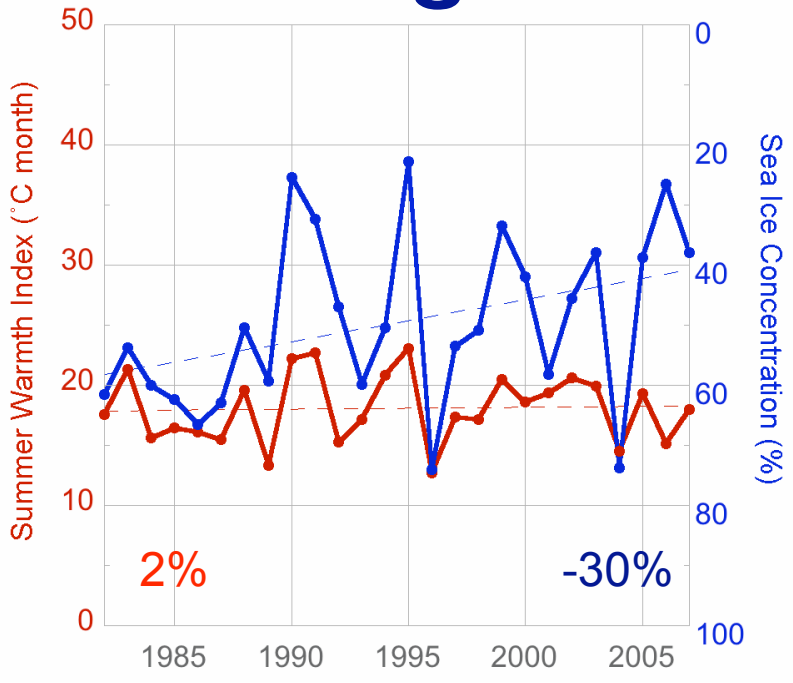
Sea ice correlated with SWI & NDVI

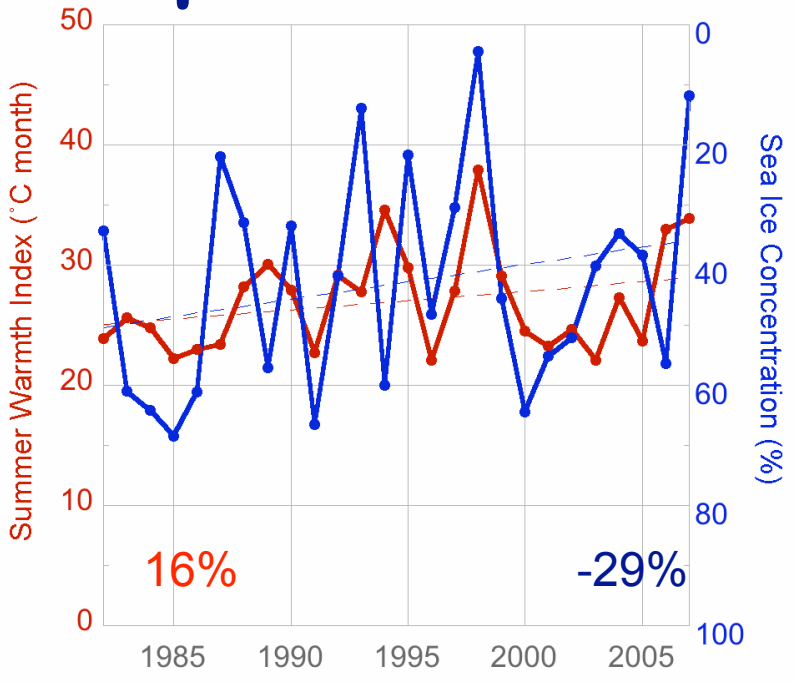


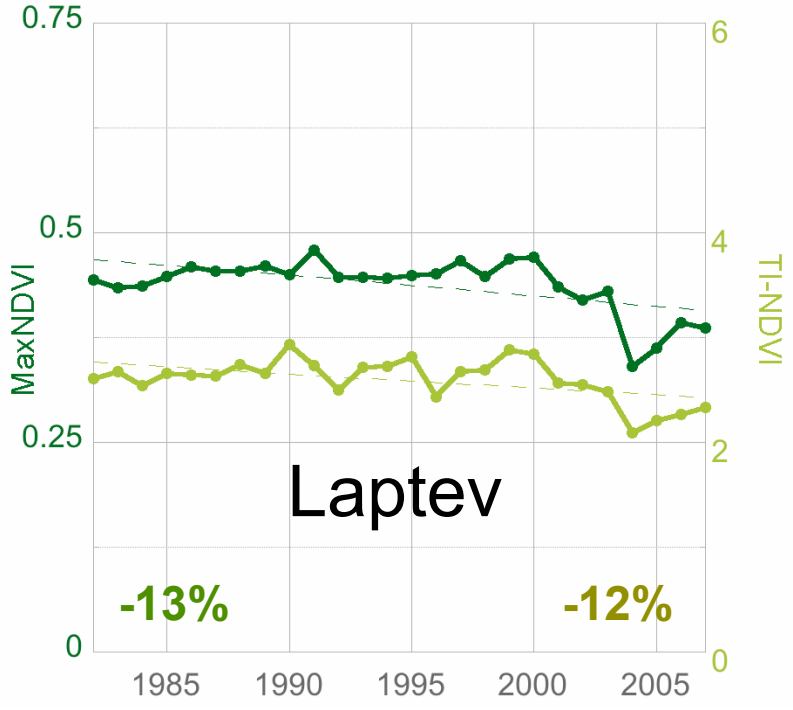
Correlations larger in 50-km coastal zone

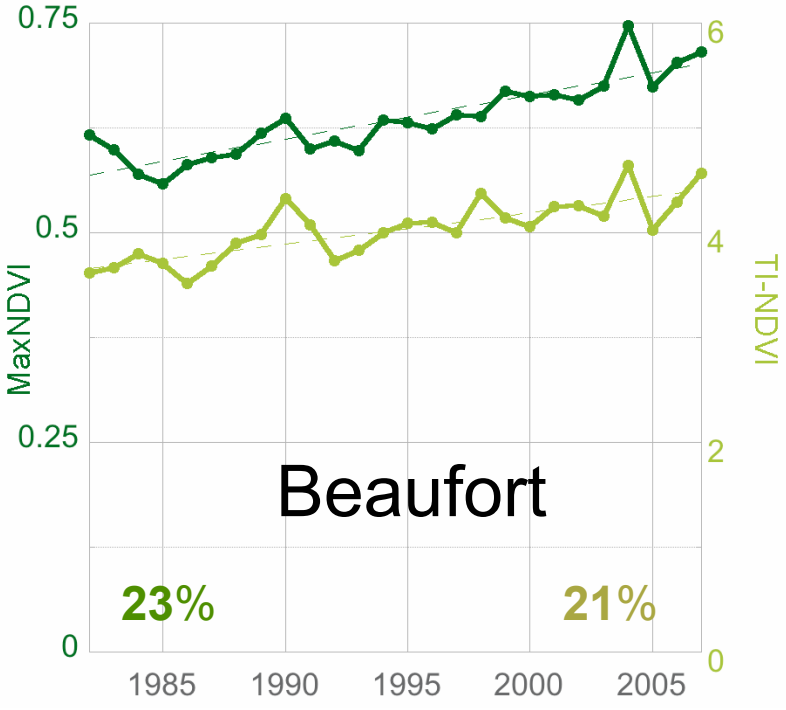
	Week of 50% ice conc.	sea ice & SWI	SWI &TI-NDVI	sea ice & TI-NDVI
Northern Hemisphere	**July 16-22**	**-0.48** (-0.23)	**0.52** (**0.51**)	*-0.38* (*-0.38*)
Eurasia	**July 9-15**	**-0.57** (**-0.45**)	**0.52** (**0.51**)	**-0.56** (**-0.51**)
N. America	**July 23-29**	**-0.58** (0)	**0.54** (**0.53**)	**-0.43** (-0.32)
E. Bering	**April 30 - May 6**	-0.20 (0)	**0.64** (**0.54**)	**-0.52** (**-0.43**)
E.Chukchi	**June 11-17**	-0.18 (0)	**0.66** (**0.63**)	**-0.42** (*-0.36*)
Beaufort	**July 16-22**	**-0.41** (-0.26)	*0.35* (0.29)	-0.19 (-0.21)
Canadian Archipelago	**August 6-12**	**-0.78** (**-0.43**)	**0.62** (**0.59**)	**-0.48** (**-0.49**)
Baffin	**July 2-8**	*-0.37* (**-0.39**)	**0.54** (*0.38*)	*-0.37* (-0.18)
Davis Strait	**May 21-27**	-0.10 (0)	**0.45** (**0.51**)	*-0.34* (-0.23)
Greenland	**July 30 - August 5**	**-0.46** (**-0.50**)	0.30 (0.27)	**-0.43** (**-0.42**)
Barents	**May 28 - Jun 3**	**-0.55** (**-0.44**)	**0.72** (**0.60**)	**-0.51** (**-0.45**)
W. Kara	**July 16-22**	**-0.41**(**-0.39**)	**0.62** (**0.60**)	*-0.36* (*-0.38*)
E. Kara	**August 13-19**	**-0.41** (-0.26)	**0.50** (**0.51**)	-0.11 (-0.16)
Laptev	**July 23-29**	**-0.71**(**-0.64**)	**0.59** (**0.54**)	**-0.53** (**-0.52**)
E. Siberian	**July 23-29**	**-0.64**(**-0.56**)	**0.56** (**0.61**)	**-0.67** (**-0.67**)
W. Chukchi	**July 2-8**	**-0.52** (**-0.44**)	**0.67** (**0.65**)	**-0.42**(*-0.38*)
W. Bering	**May 14-20**	0 (0)	**0.65** (**0.52**)	0 (0)

Contrasting Trends: Laptev vs Beaufort



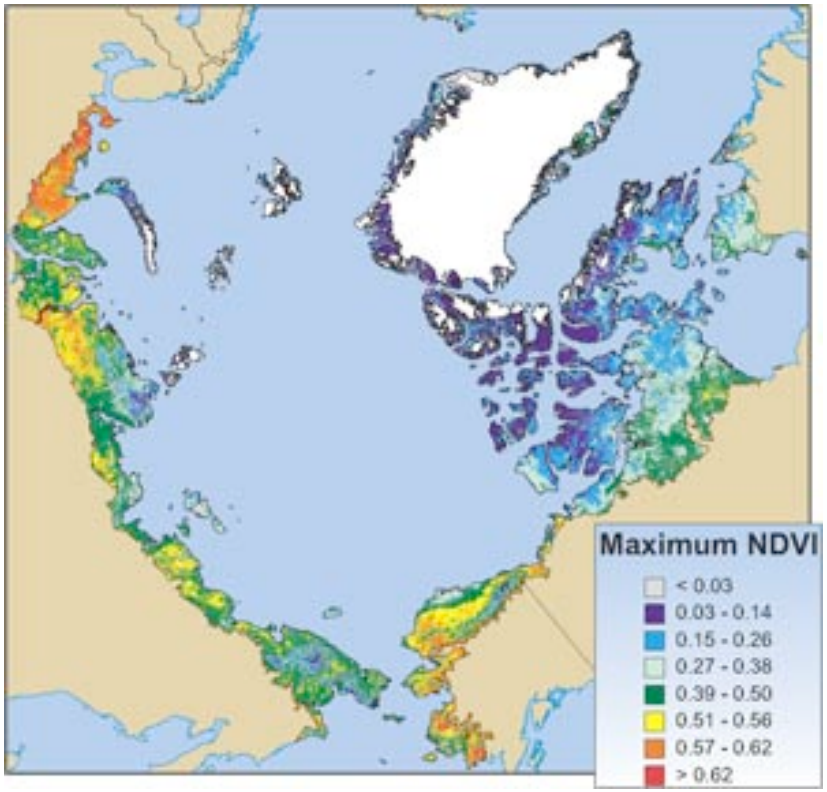






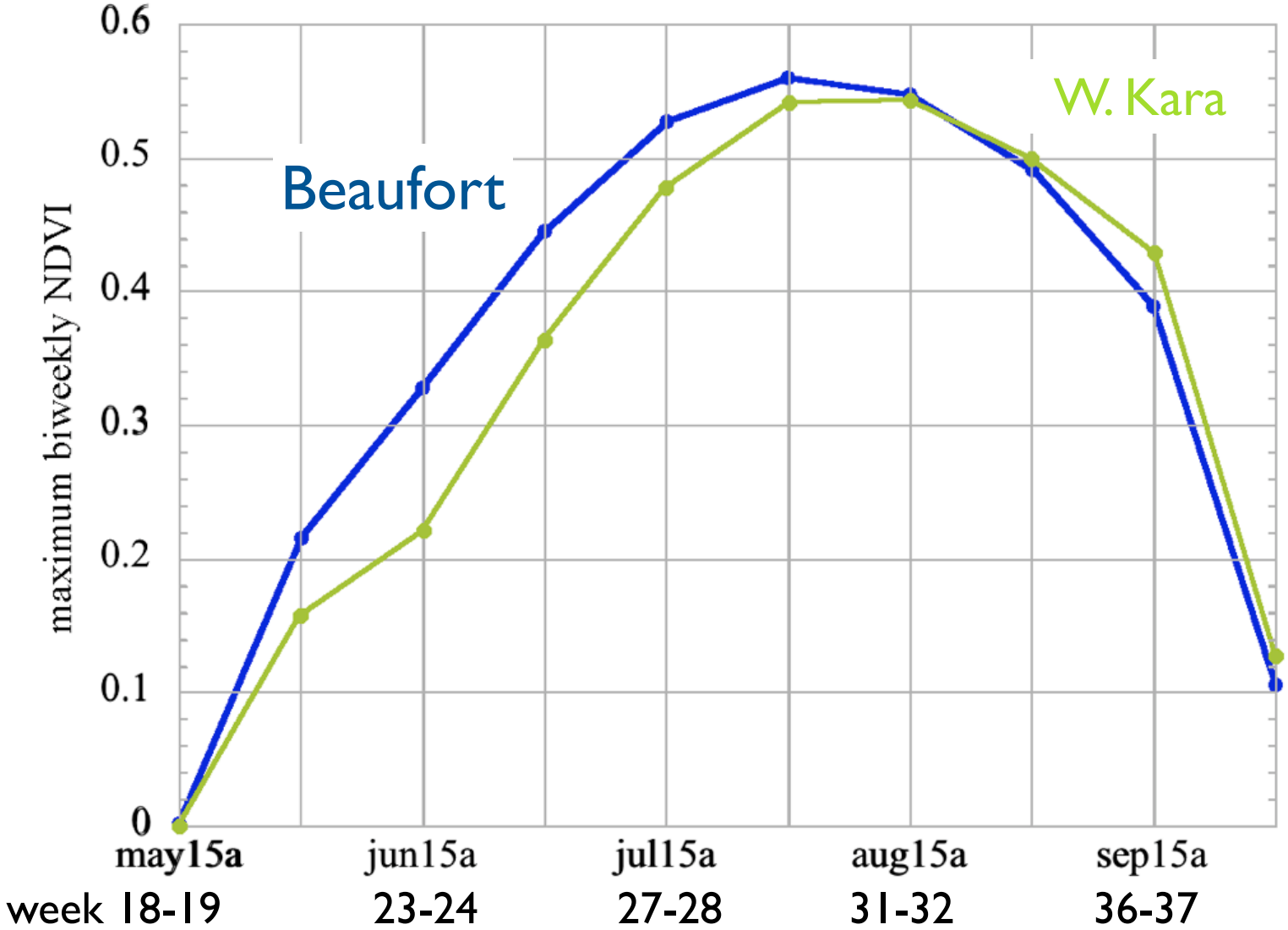
Sea ice decline ==> SWI & NDVI increase

- Modeling evidence (Fixed sea ice GCM experiments)
  - Lawrence et al. 2008
  - Bhatt et al. 2008
- Observational Evidence
  - Rouse 1991
  - Haugen and Brown 1980
  - Mean NDVI map ==========>



- Another option is that the forcing from comes from the south(??)

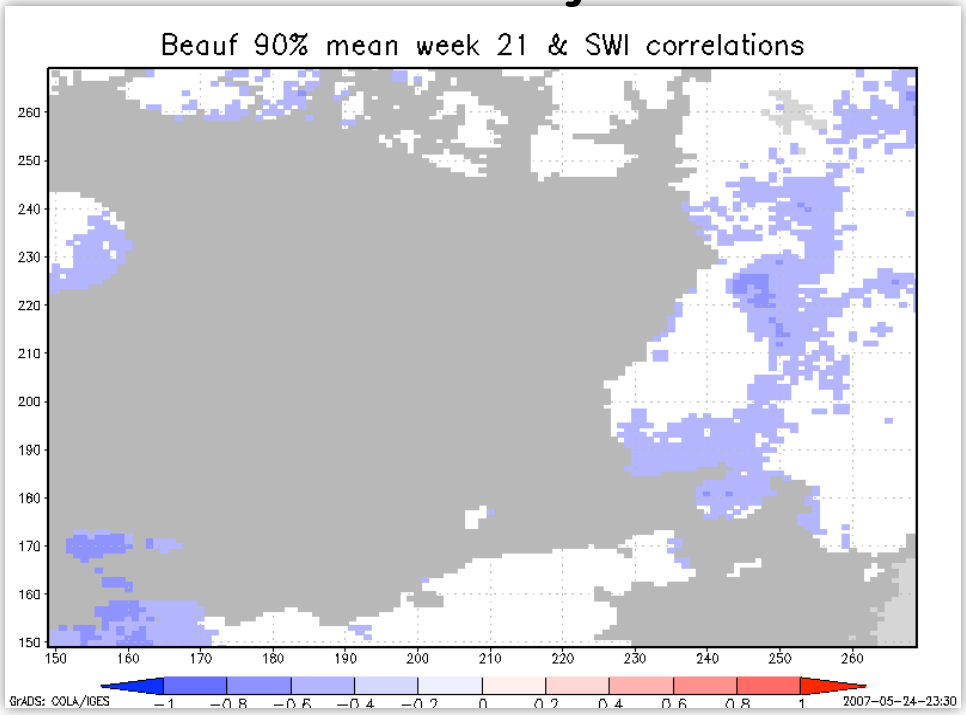
Beaufort greens up earlier than W. Kara



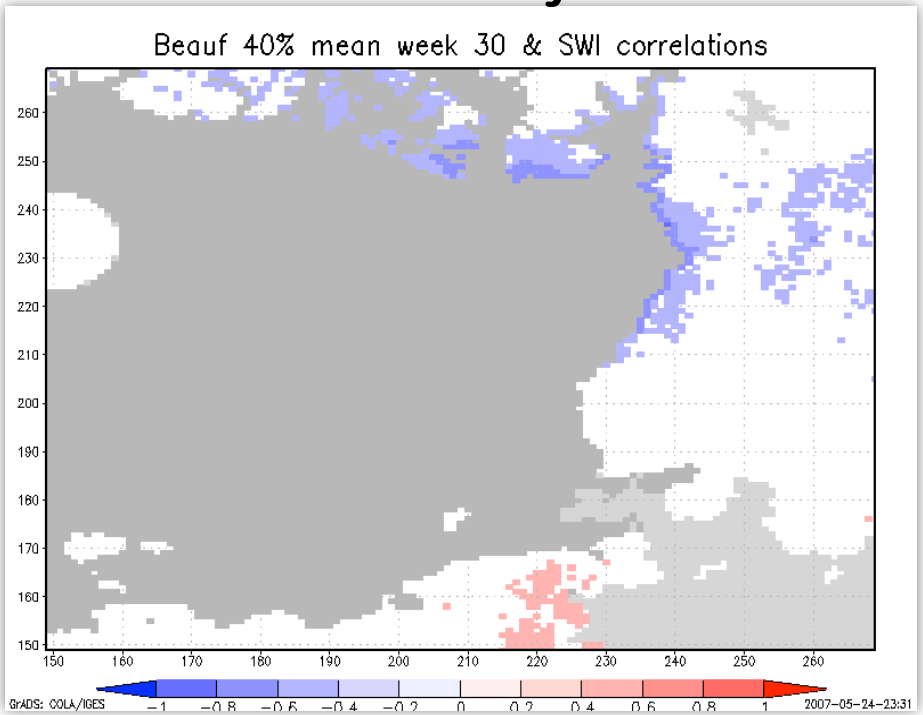
- **Seasonality of ice different in these regions**

Correlations between ice and SWI are more local in summer: Beaufort

Late May



Late July



- Negative correlation less ice==> warmer growing season
- More localized later in summer, when winds are typically onshore

Ecological consequences of perennial ice declines: Impacts to Subzone A

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

- **Northern Canada has shown little decrease thus far but if coastal ice declined then Subzone A would be impacted as new species move in.**

Conclusions

- Arctic NDVI trends are more heterogenous than previously thought.
  - E. Siberian to Beaufort vs Taymyr peninsula
- Coastal sea ice correlated with land temperatures and Time Integrated NDVI.
  - Correlations plus other evidence suggest ice is a key driver of the terrestrial changes
- Regional differences are likely linked to seasonality of air-sea-land parameters & atmospheric circulation

Thank you for your attention

Acknowledgments

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