Sep 1979

Sep 2007

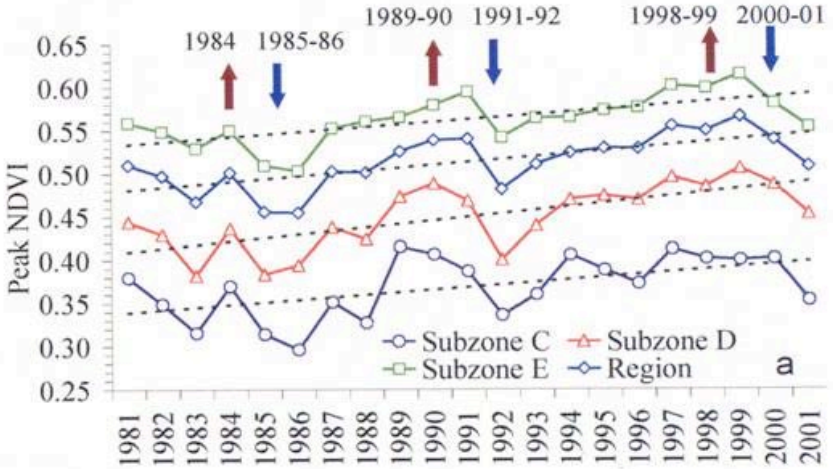
Greening of the Arctic: an IPY initiative

Is the retreat in sea ice affecting Arctic land areas?

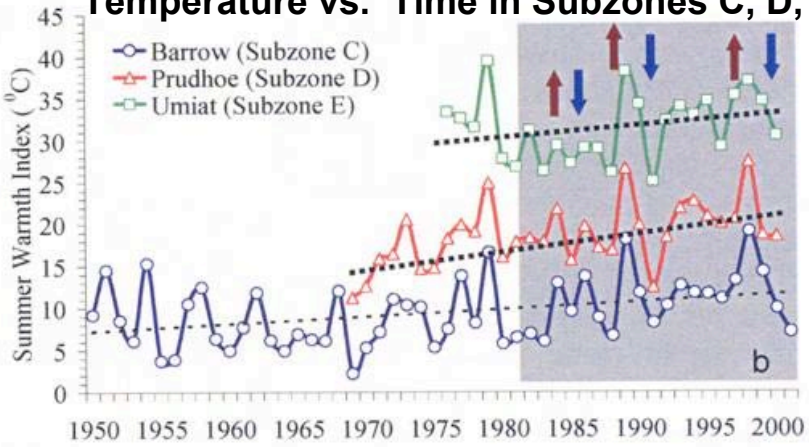
D.A. Walker, U.S. Bhatt, H.E. Epstein, M.K. Raynolds, G.J. Jia, J.C. Comiso, M.O. Liebman, N.A. Moskalenko, B.C. Forbes

AGU IPY session, San Francisco, 16 Dec 2008

Greenness vs. Time in Bioclimate Subzones C, D, and E



Temperature vs. Time in Subzones C, D, and E



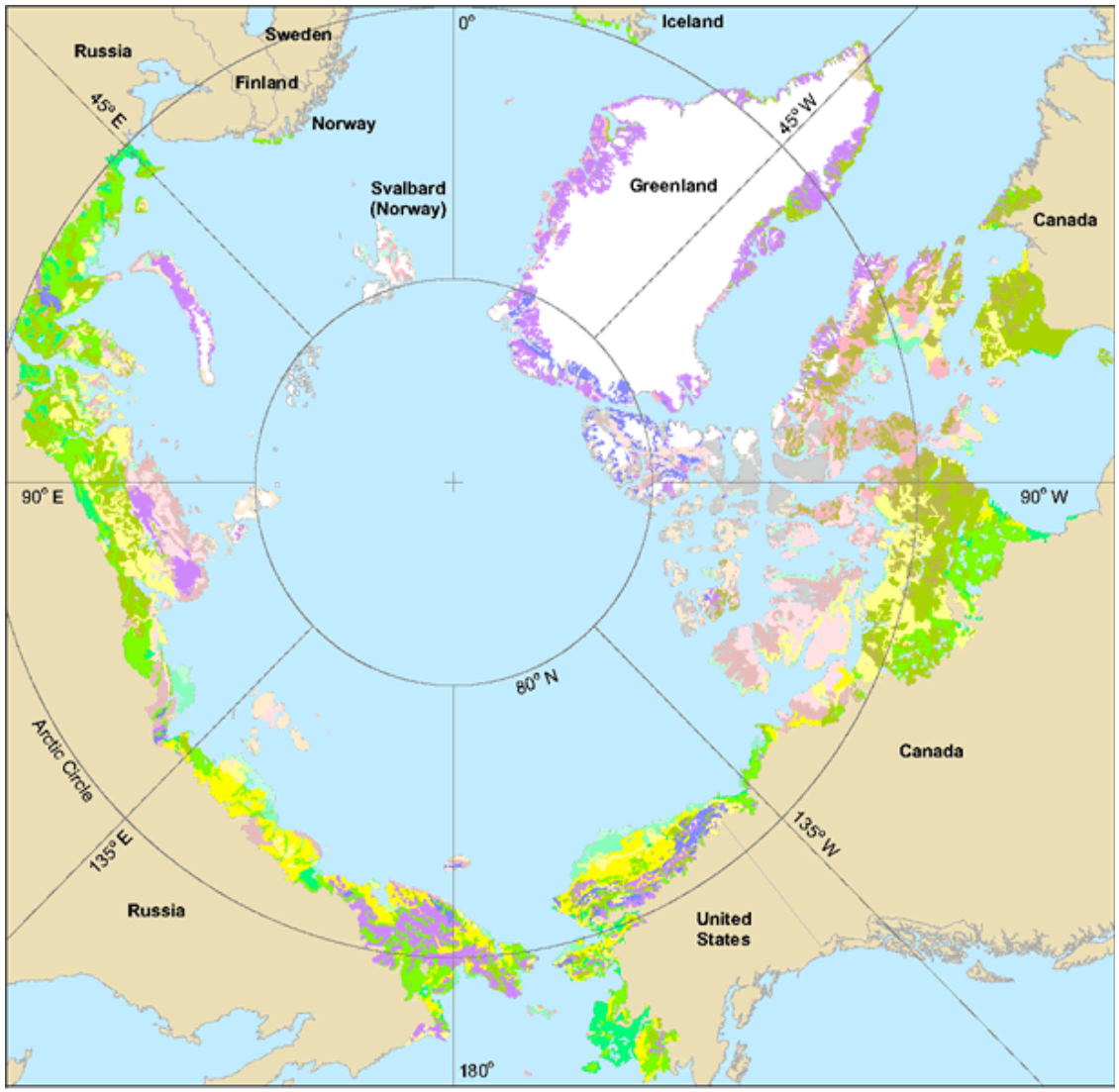
G.J. Jia et al. 2003. *Geophysical Research Letters.* 30: 2067.

What did we knew prior to the Greening of the Arctic studies?

- **Peak summer greenness increased 17% in northern Alaska from 1981-2001 (Jia et al. 2003).**
- **We didn't know if the warming and greening in Alaska were extreme compared to other regions nor if they were somehow linked to what is going on with sea ice.**

The Arctic tundra is a maritime biome.

Circumpolar Arctic Vegetation Map

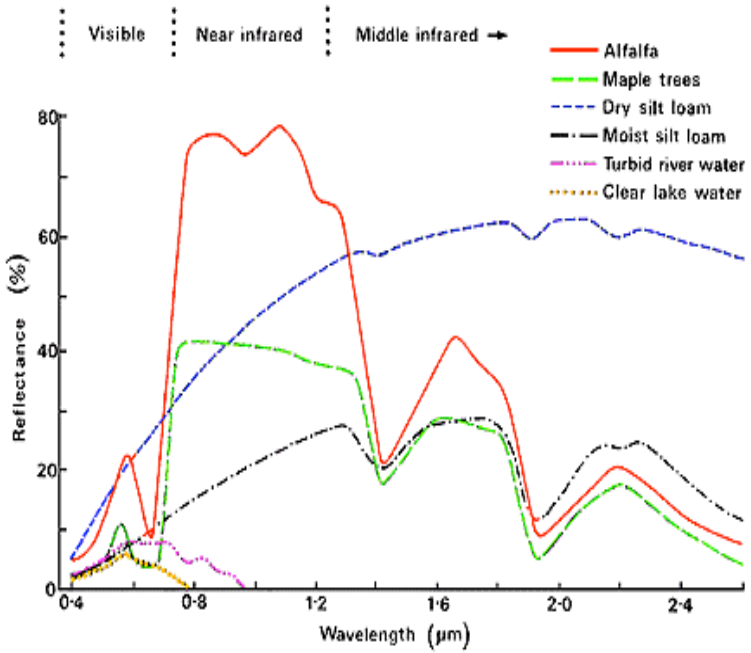


CAVM Team 2003. The Circumpolar Arctic Vegetation Map. CAFF Map No. 1.

- **Defined as the region north of treeline, 7.1 million km^2 (somewhat smaller than the contiguous 48 states).**
- **80% of the lowland tundra areas are within 100 km of an Arctic seacoast.**
- **Changes in the Arctic sea ice will very likely affect land ecosystems.**

Best quantitative evidence of widespread change comes from the Normalized Difference Vegetation Index (NDVI): An index of greenness

Reflectance spectra of common ground-cover types



Normalized Difference Vegetation Index

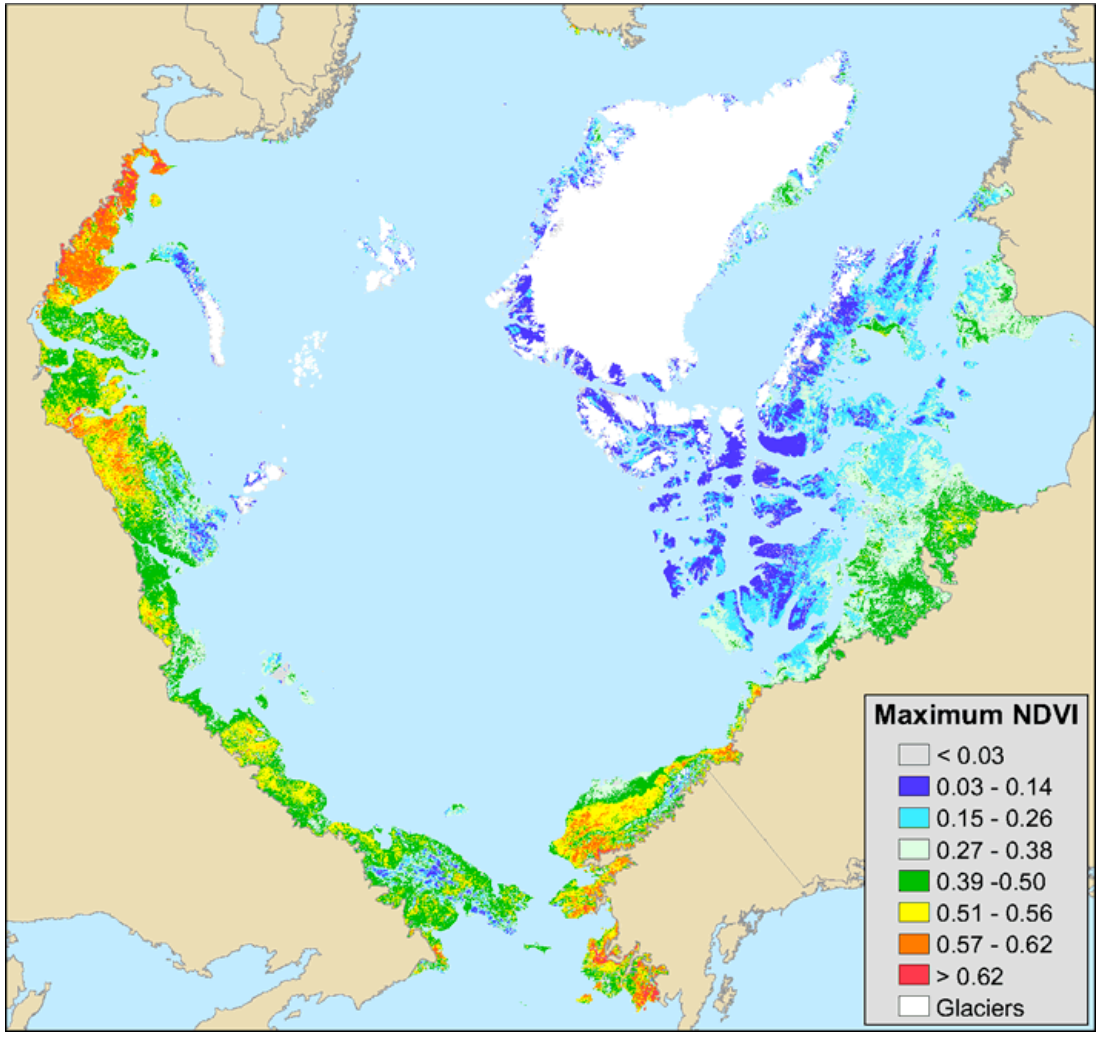
NDVI = *(NIR - VIS) / (NIR + VIS)*

NIR = spectral reflectance in the near-infrared band (0.7 - 1.1μm), where light scattering from the cell-structure of the leaves dominates.

VIS = reflectance in the visible, chlorophyll-absorbing portion of the spectrum (0.4 to 0.7μm).

In general, land cover with high reflectance in the NIR and low reflectance in the visible portion of the spectrum has dense green vegetation.

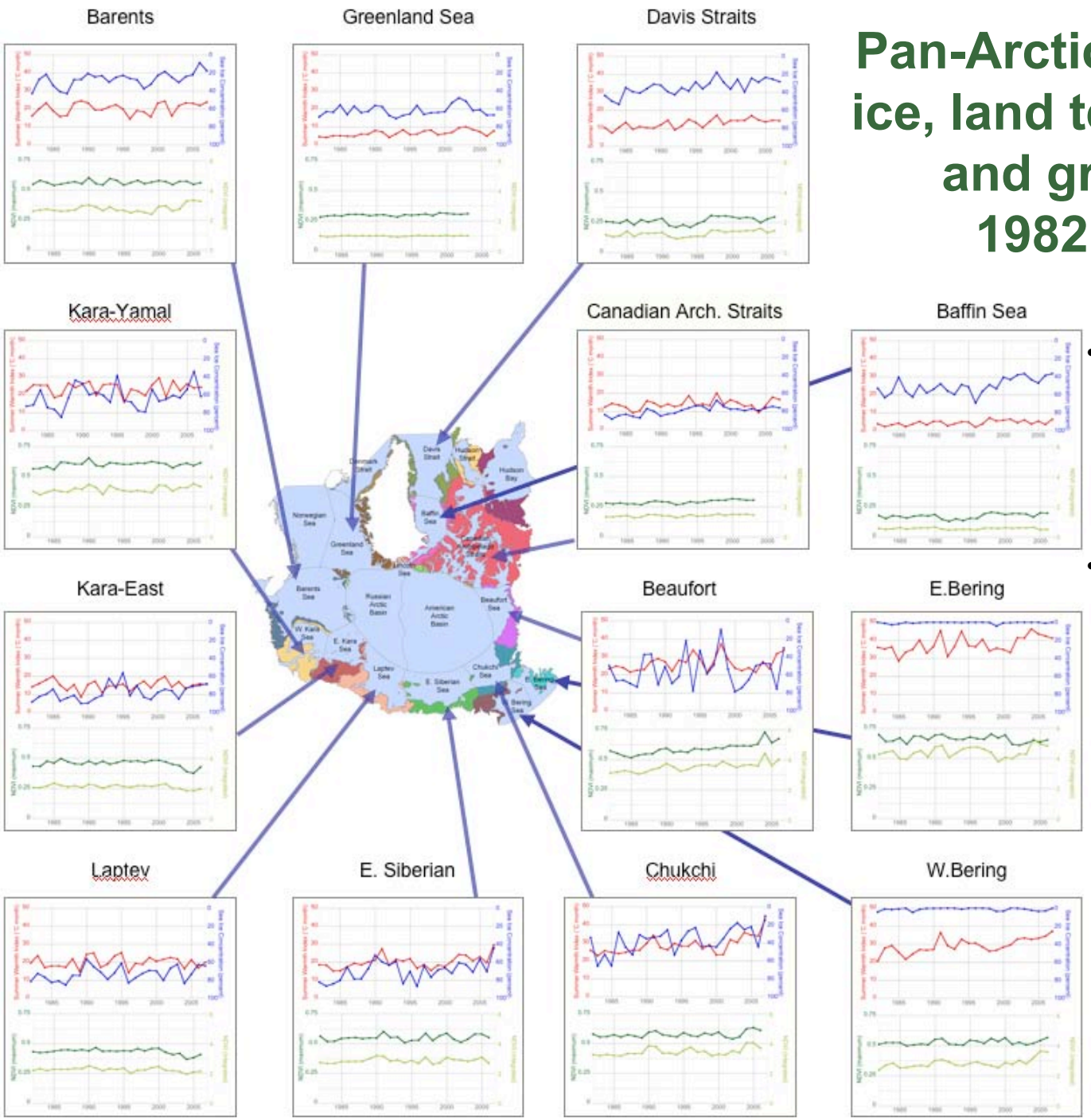
Circumpolar patterns of greenness



CAVM Team. 2003

Some of the differences are caused by climate. There is general trend of lower NDVI in the North and high NDVI in the south.

Some of the variation is caused by many other factors such as areas of recent glaciation, mountain ranges, wetlands, and the influence of ocean and atmospheric circulation patterns.



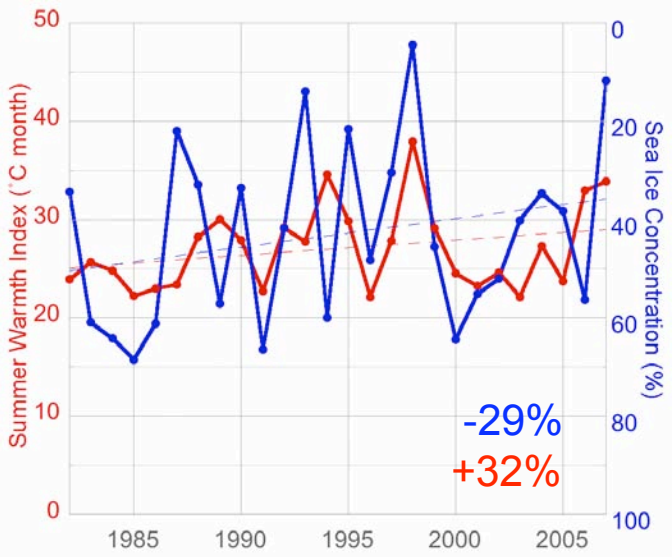
Pan-Arctic trends: Sea ice, land temperatures, and greenness, 1982-2007(6)

- **Analysis of 50-km buffers seaward and landward along each sea coast.**
- **Also linked these changes to various climate indices that reflect patterns of atmospheric circulation.**

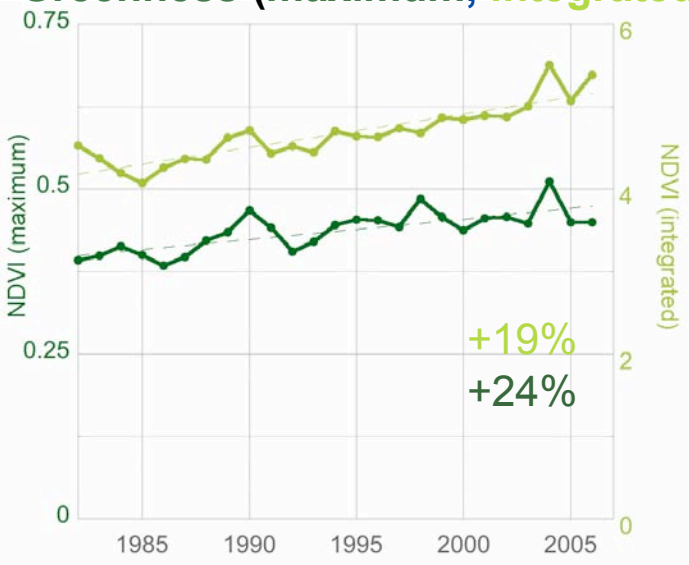
Bhatt et al: Yamal LCLUC Workshop, Moscow, 28-30 Jan 2008, and EGU 2008.

Example analysis for the Beaufort Sea

Sea ice (scale inverted)
Summer temperature



Greenness (maximum, integrated)



Coastal sea ice

- **Reduction of 29%**
- **One of most variable regions**

Land temperatures:

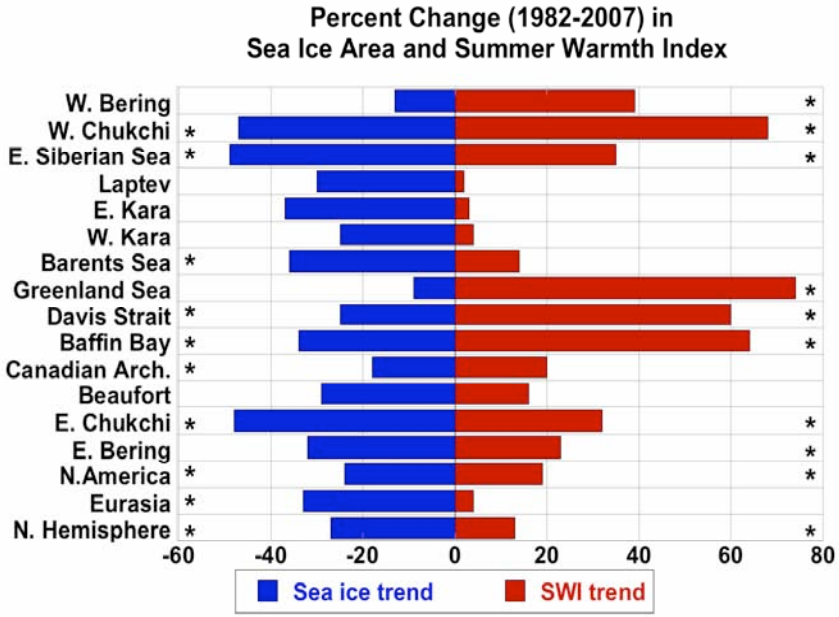
- **Total summer warmth increased 32%**
- **Also high variability.**

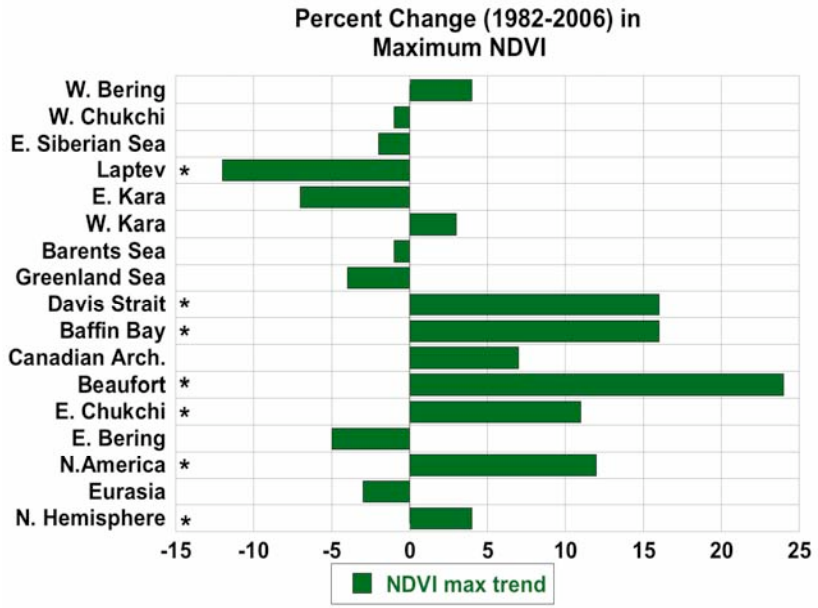
Maximum Greenness:

- **Maximum NDVI increased 24% (highest of any of the regions)**
- **Integrated NDVI (sum of the biweekly NDVI measurements) increased 19%**

Bhatt et al: Yamal LCLUC Workshop, Moscow, 28-30 Jan 2008, and EGU 2008.

Summary of trends





Bhatt et al. in prep.

Coastal sea ice

- **All areas show reduced ice.**
- **Overall change: -27%.**
- **E. Siberia Sea: -49%**

Land temperatures:

- **All areas show increased temperatures.**
- **North America: +19%**
- **Eurasia: +4%**

Greenness:

- **Mainly increases in N. America, Beaufort Sea: + 24%, also strong positive trends in Davis Straight and Baffin Bay.**
- **Many decreases in Eurasia, Laptev Sea: -12%**

- **Uncertain what reductions of NDVI in the E. Siberia, Laptev and E. Kara seas means with respect to plant biomass, but it reduces the net N. Hemisphere increase in NDVI to +4%.**
- **Using existing NDVI regressions, this translates to an annual increase in carbon for the Arctic tundra of about 0.07% of the annual global carbon emissions.**

Linkages between sea-ice, temperature and NDVI trends

Sea ice - temperature:

- 9 of 14 seas have strong negative correlations.
- Correlations strongest in Eurasia.

Temperature - NDVI:

- 12 of 14 have strong positive correlations.

Sea-ice - NDVI:

- 3 of 14 have strong negative correlations.
- Strong correlations for N. America and Eurasia.

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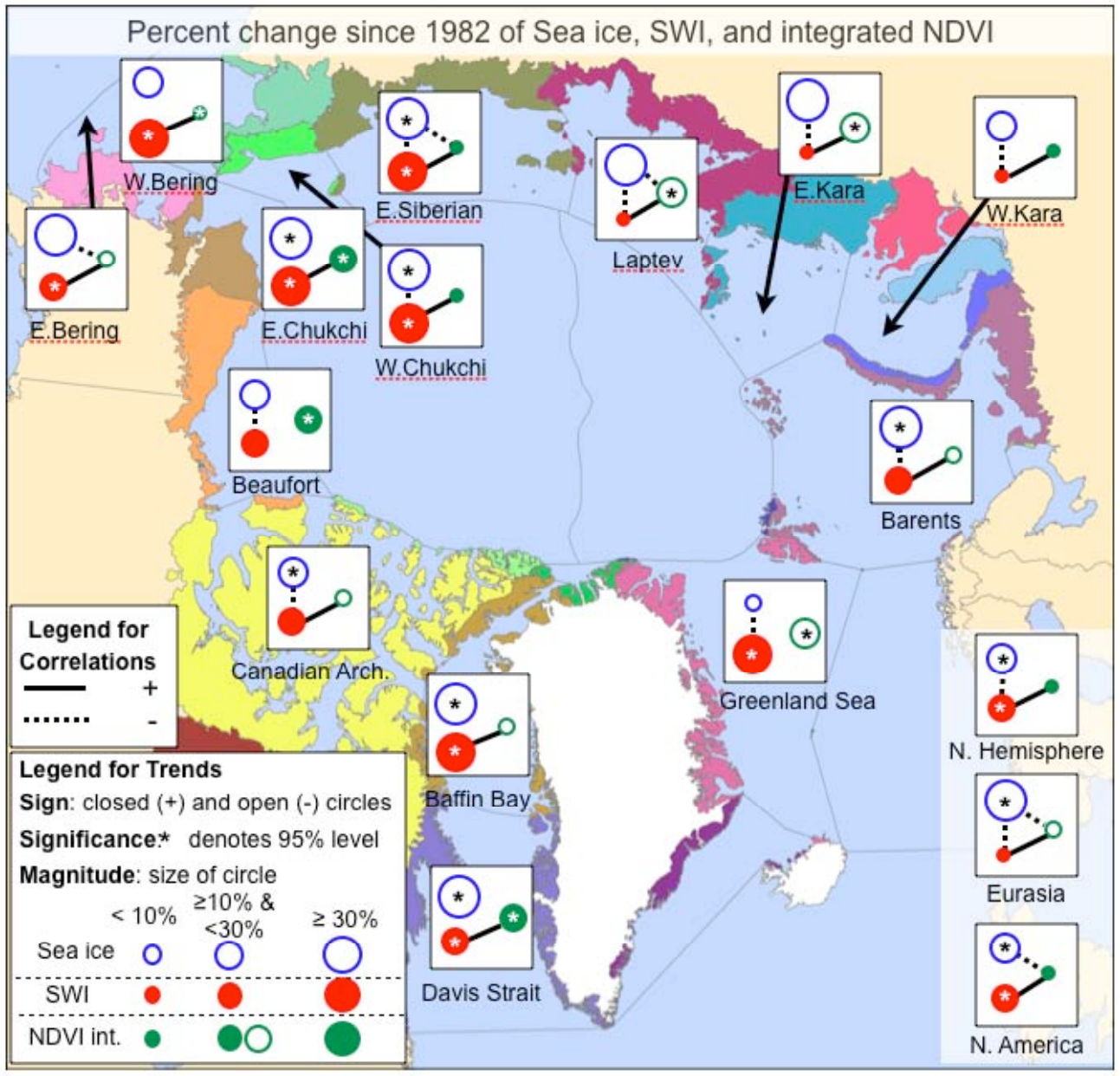
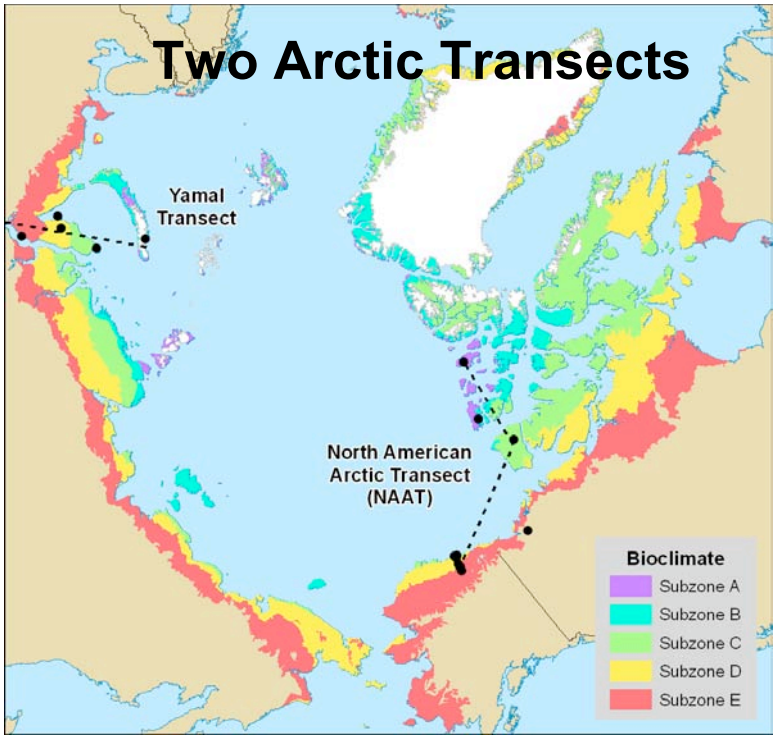
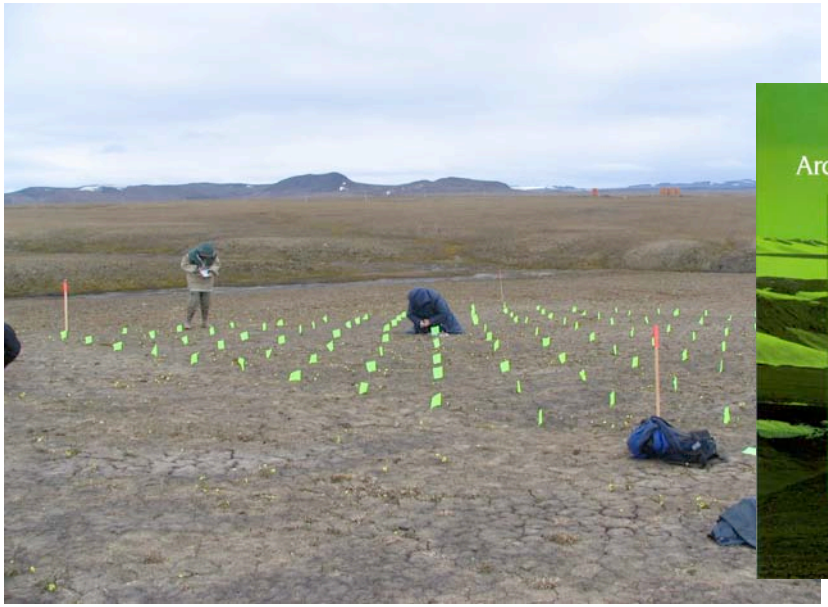


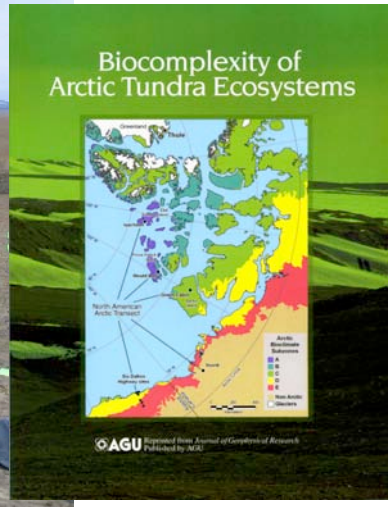
What is happening on the ground?

- **Transects in North America and Eurasia through all five Arctic bioclimate subzones.**
- **Main goal is to determine how ecosystems change along the natural climate gradient.**
- **We are using the transects as analogs of what changes we might see as temperatures warm.**
- **Results from North America Arctic Transect are published.**



Base map: Walker 2005, *Journal of Vegetation Science,* 16: 267-282.



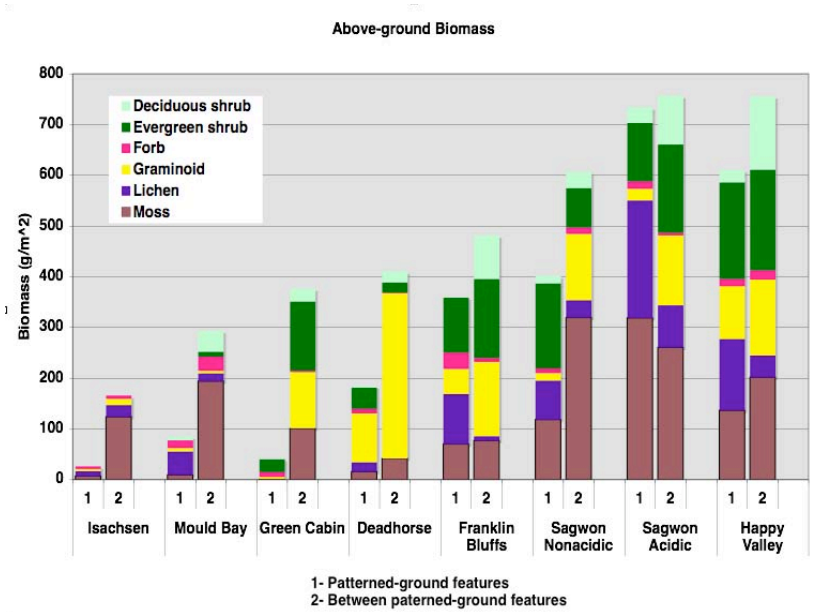


Special issue of JGR. 113: GO3S00-GO3S06.

Left: Isachsen Grid, Subzone A, Photo D.A. Walker

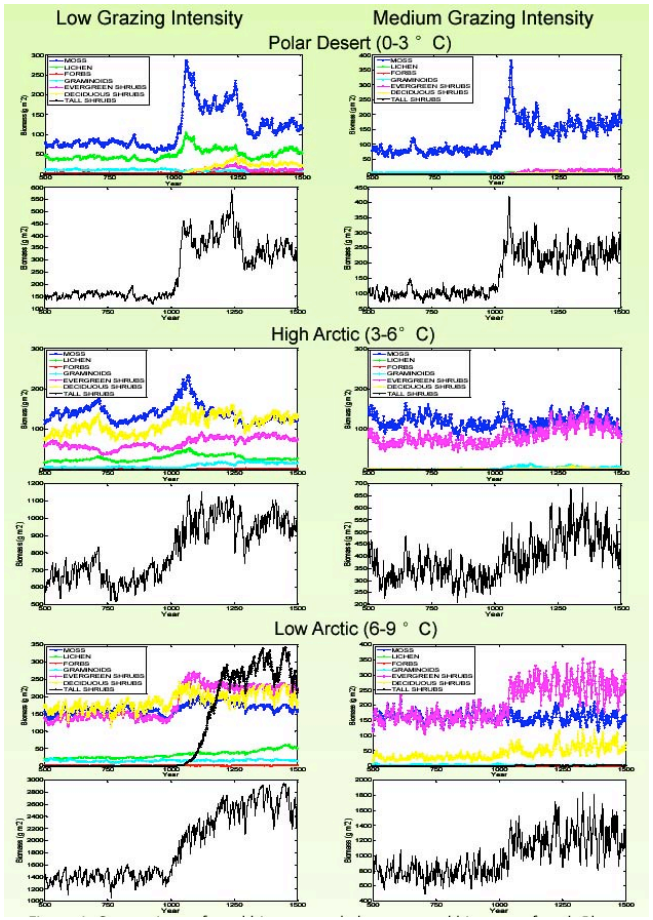
Trends along the transect are used for modeling response of vegetation to warming.

Biomass on patterned-ground features and zonal areas along the N. Amer. transect



Walker et al. 2008, *JGR-Biogeosciences*

Modeled response of plant growth forms in each bioclimate subzone



Yu and Epstein: 2008, NASA LCLUC conference.

- **5-fold increase of biomass on zonal sites.**
- **Changes in the dominance of plant functional types.**

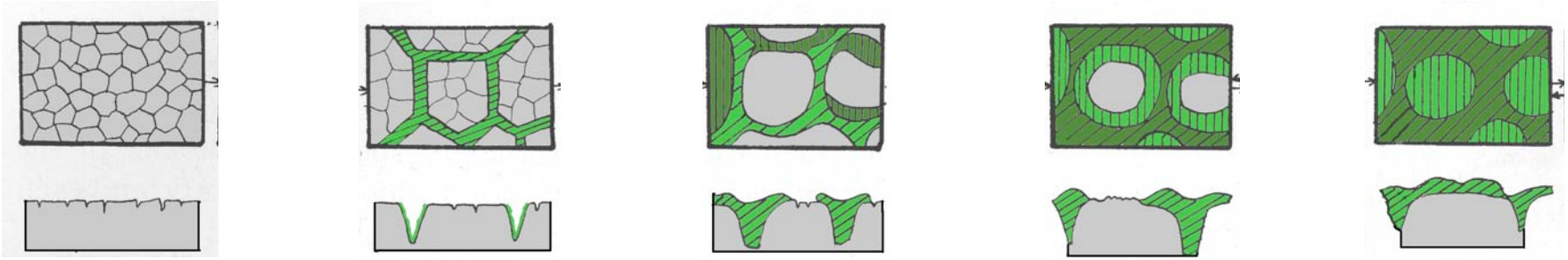
Vegetation productivity strongly affects the trend in patterned-ground forms along the Arctic bioclimate gradient.





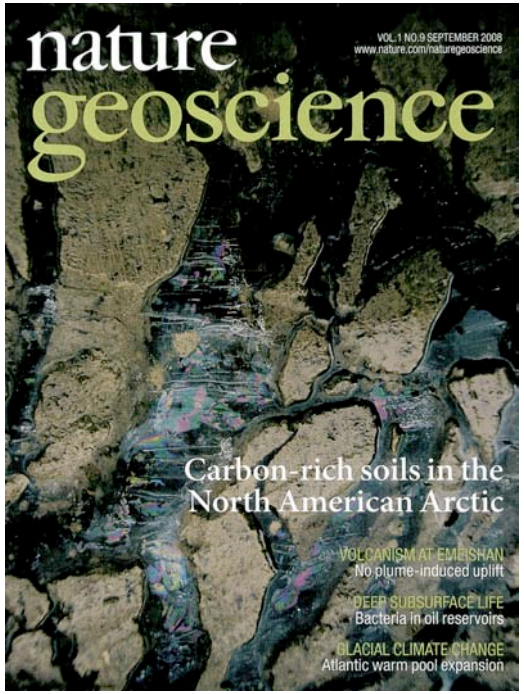
Photos: D.A. Walker. Drawings modified from Chernov and Matveyeva 1997

Sub-zone: A B C D E



Small non-sorted polygons → *Non-sorted circles* → *Earth hummocks*

Changes in vegetation also will affect a wide variety of other tundra properties and processes, including biodiversity of the tundra, thermal and hydrological soil properties, snow regimes, temperature and nature of the permafrost, animal habitat, human use of the landscapes.

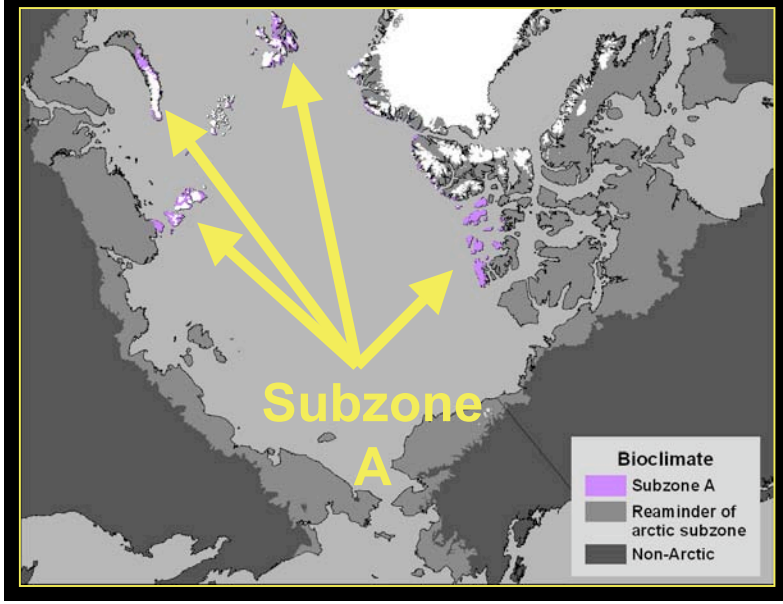


Ping et al. 2008. *Nature Geoscience,* 1:615-619.

Carbon is sequestered by patterned-ground formation processes deep in the active layer and permafrost, contributing to the high carbon stocks in Arctic soils.

Nonsorted circle with permafrost table jack-hammered away to reveal buried organic horizon locked in permafrost table beneath nonsorted circle.

Photos: D.A. Walker



Subzone A "the poppy zone"

- Bioclimate subzone A is characterized by the abundance of poppies and small forbs.
- Low diversity of plants and animals.
- No sedges.
- No woody plants.
- No peat.
- Low summer temperatures, and its proximity to summer sea-ice.
- Elimination of the summer sea ice will greatly reduce or eliminate this already rare subzone.

Photos: D.A. Walker

Yamal, Russia Transect

- Examines the linkages between greening trends, regional sea-ice conditions, and the range and forage for the reindeer of the Nenets people.
- .
- Talk discussing the Yamal transect:
  GC52A-07, Thu, 11:35h
  Cumulative effects of rapid climate and land-use changes on the Yamal Peninsula, Russia

Florian Stammler interviewing members of a Nenets brigade regarding historical changes in pasturelands. Combining remote sensing and traditional knowledge.

Photo: Bruce Forbes

Collaborators

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University of Virginia: **Howie Epstein, Qin Yu, Ben Cook, Domingo Alcaraz**

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REC-TEA, Chinese Academy of Science: **Gensu Jia**

Swiss Federal Institute for Forest, Snow, and Landscape Research: **Jed Kaplan, Heike Lischke**

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