Circumpolar Arctic greening:

Relationships to summer sea-ice concentrations, land temperatures and disturbance regimes

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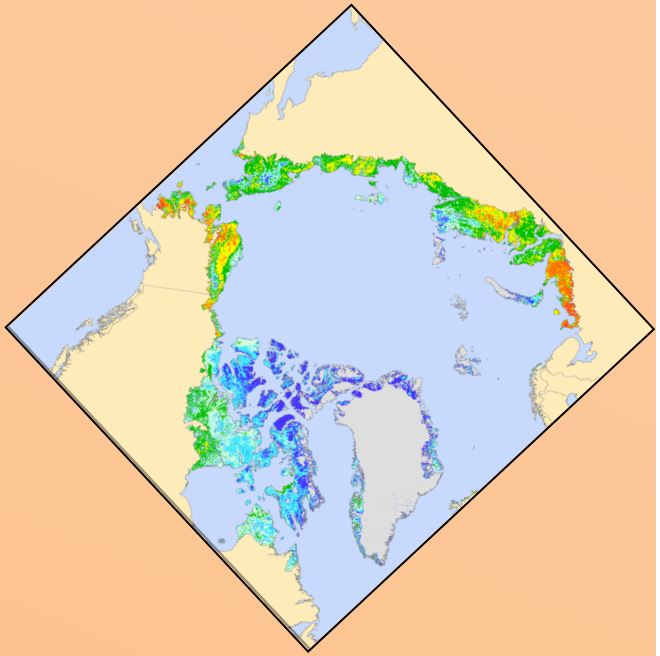
NASA: LCLUC
NEESPI program
NSF, ARCSS: Synthesis of Arctic System Science and Seasonality initiatives
Russian Academy of Science
ENSINOR project in Finland

Does the presence of summer sea ice affect tundra vegetation productivity?

Arctic Tundra Vegetation

March Sea-Ice Extent



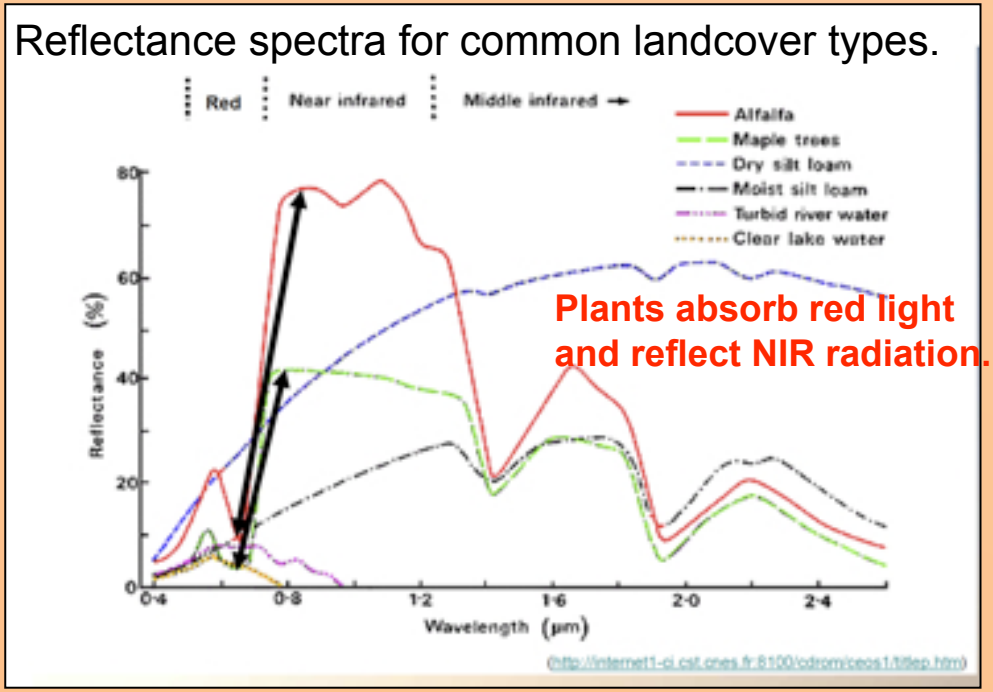
Max NDVI

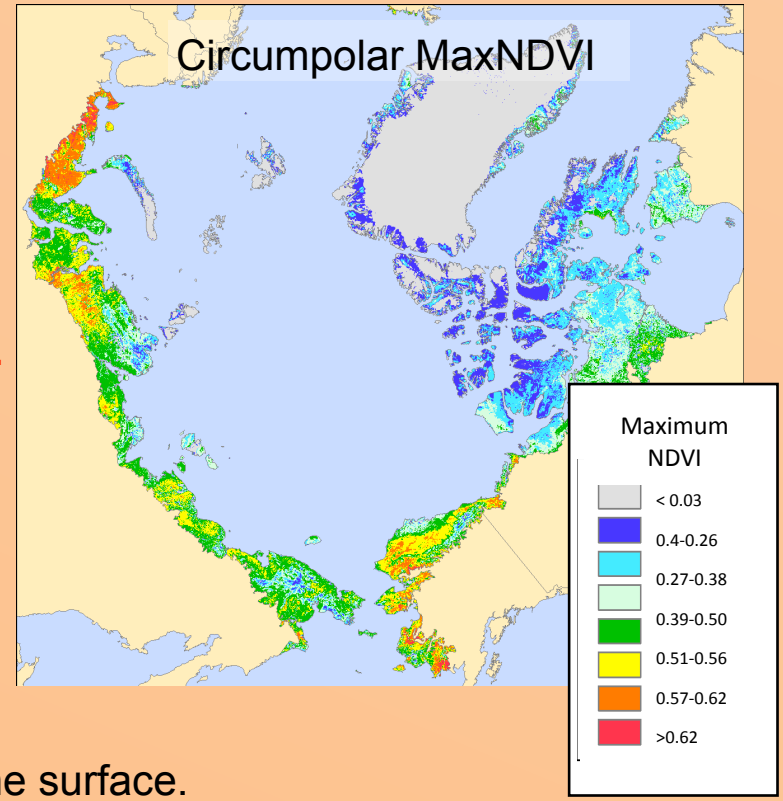
- 80% of Arctic tundra is within 100 km of ice-covered seas (100% is within 350 km).
- Models have shown that melting the sea ice will affect land temperatures and permafrost even at great distances from the Arctic Ocean.

Sea Ice: http://www.arctic.noaa.gov/reportcard/figures/seaice2009fig1.jpg

Vegetation and NDVI: http://www.arcticatlas.org/maps/themes/cp/cpvg

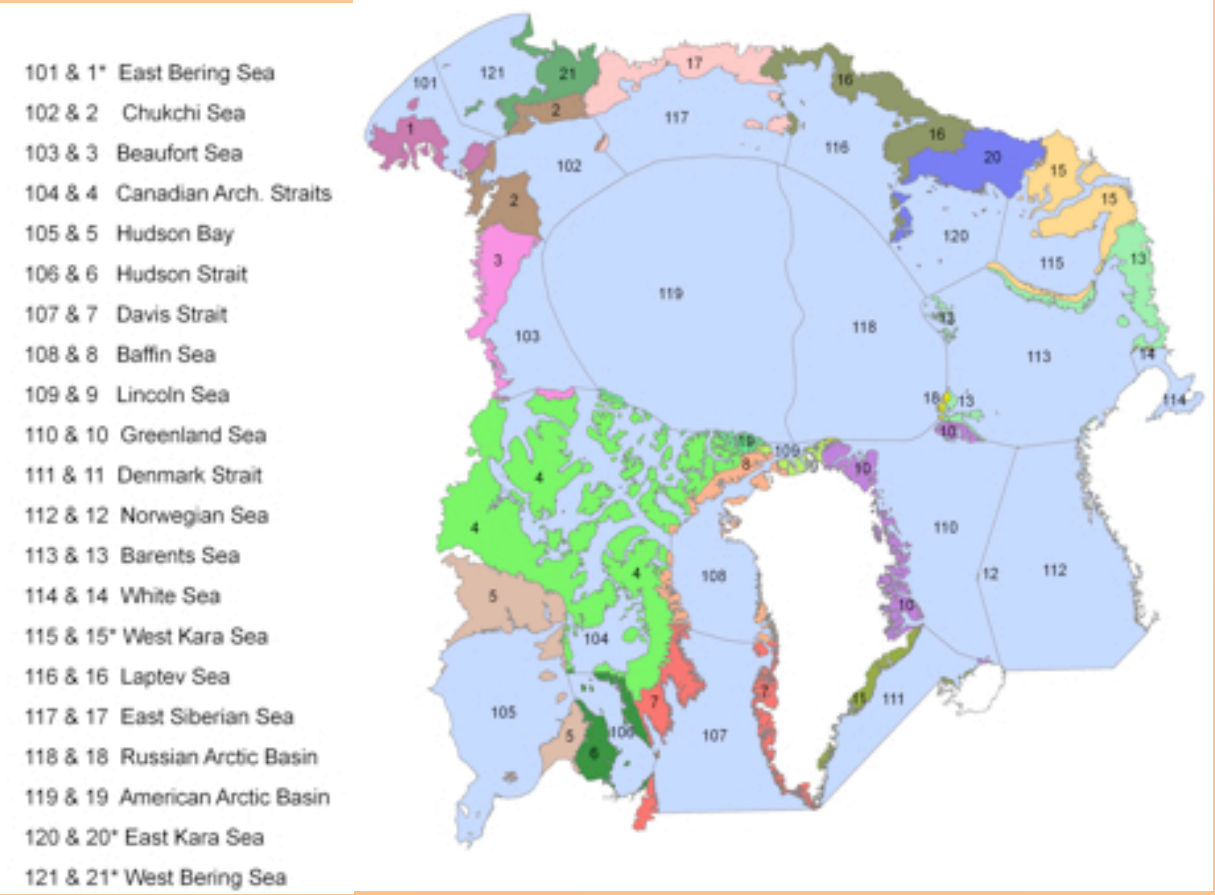
The Normalized Difference Vegetation Index (NDVI)





- NDVI is a measure of the photosynthetic capacity of the surface.
- Chlorophyll absorbs red light for photosynthesis and reflects near infrared light. The difference in the reflectance in these two channels is an index of vegetation abundance.
- **NDVI = (NIR-R)/(NIR + R).** The difference between the reflectance in the NIR and R portions of the spectrum is divided by the sum of the reflectances to adjust for variations in reflectance due to slopes and shadows.

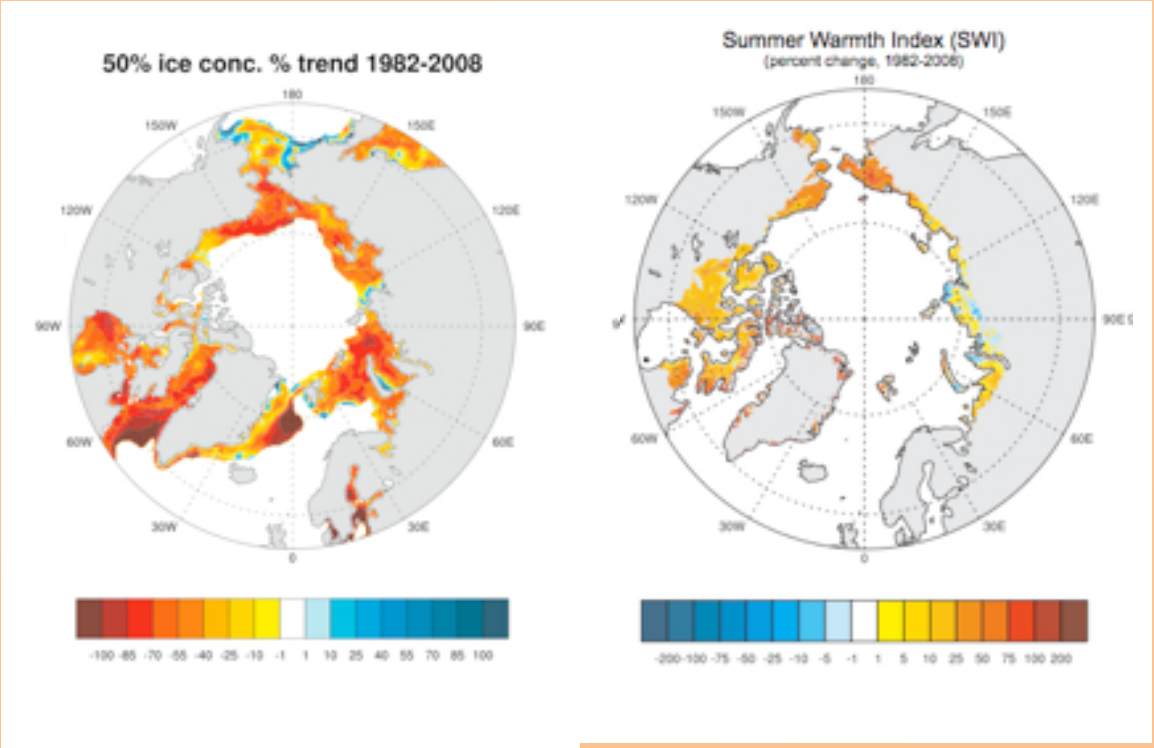
Study Framework: Division of Arctic Ocean and associated land masses

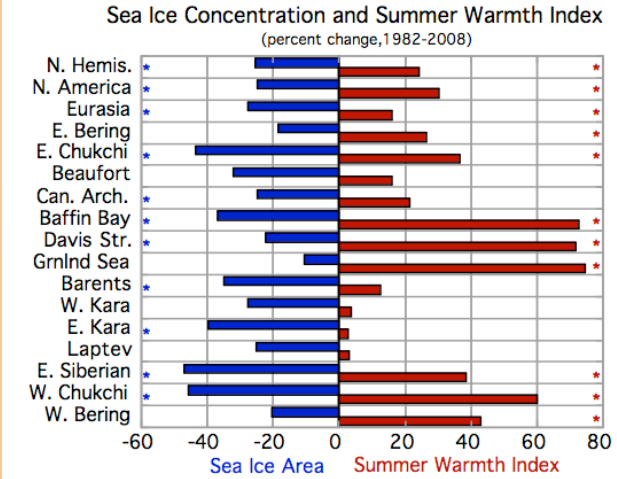


- Russian Arctic Atlas for seas.
- CAVM Florist provinces for land masses.
- Analysis of 50-km buffers seaward and landward along each sea coast and also for entire non-alpine tundra area.
- New $GIMMS_{3g}$ NDVI data set.

Uma Bhatt, D.A. Walker, M.K. Raynolds, J. Comiso, H.E. Epstein, G.J., Jia, J. Pinzon, and C.J. Tucker, 2009 submitted, Earth Interactions.

Circumpolar changes to early summer coastal sea ice, and summer land temperatures (1982-2008)

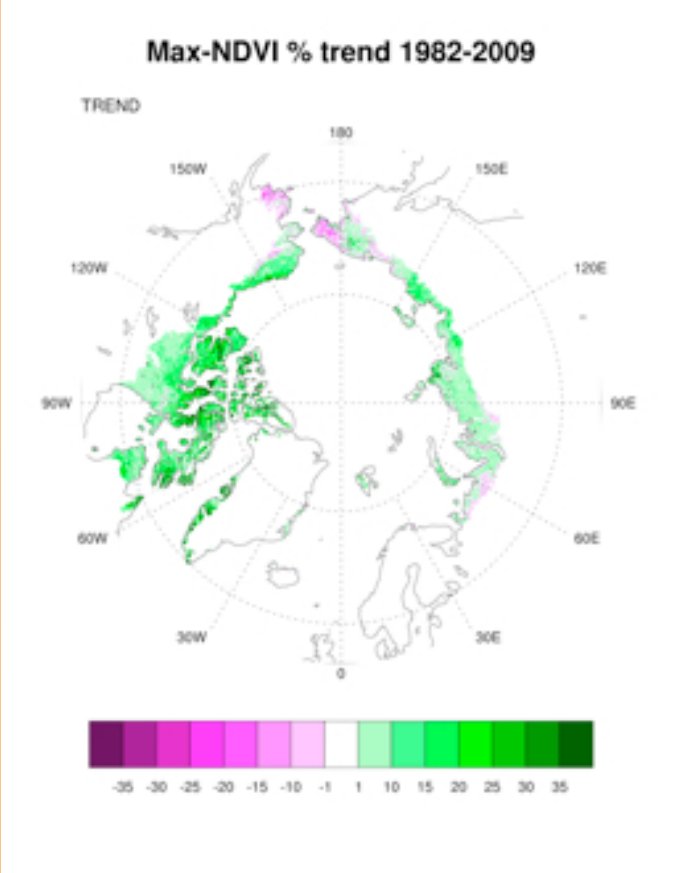


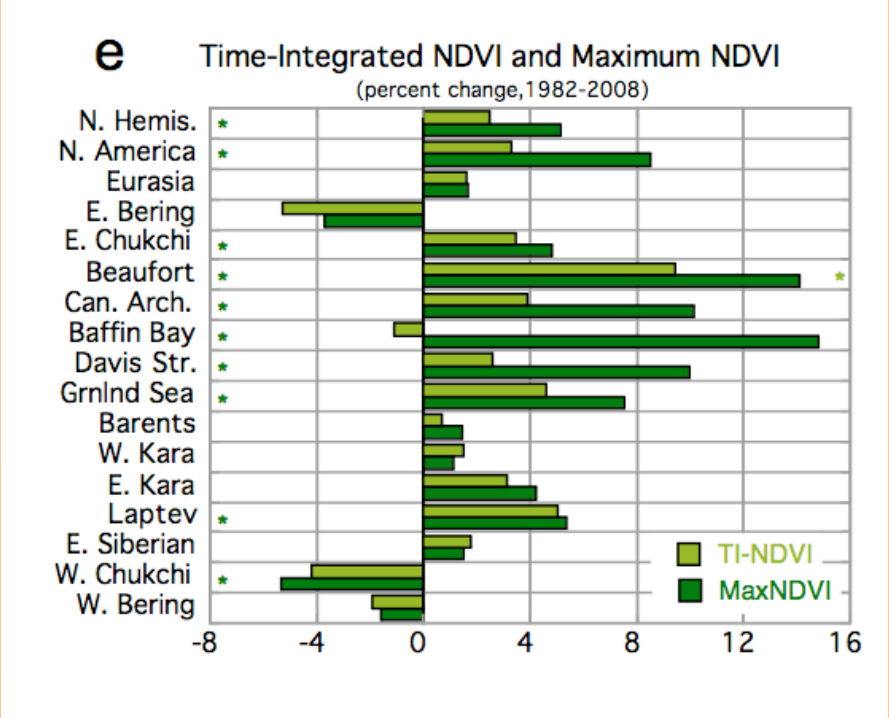


- Coastal sea ice: strongly decreasing throughout the Arctic except coastal areas of the Greenland Sea and parts of the Bering Sea. The strongest most significant trends are in the E. Siberian to Chukchi, and E. Kara regions (-40 to -44%).
- Summer warmth: increasing most strongly in the Canadian High Arctic and Greenland and in the Beringian region between the E. Siberian Sea and the E. Chukchi. Relatively small increases are seen between the Kara and Laptev seas.

Bhatt et al. 2009 submitted, *Earth Interactions*.

Percentage MaxNDVI change (1982-2008)

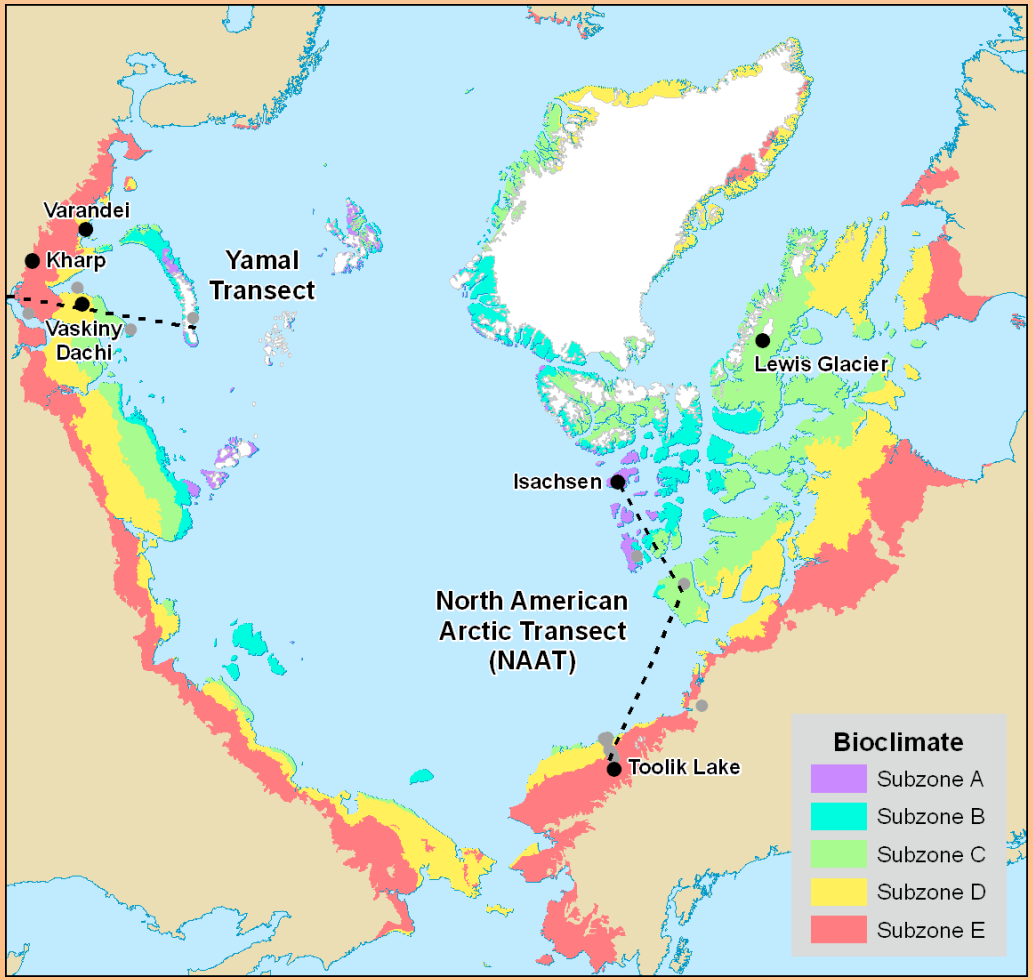




Bhatt et al. 2009 submitted, Earth Interactions and AGU poster

- Arctic wide: +5%
- Much greater change in North America (+9%) than in Eurasia (+3%).
- Large increases in (10-15%) in the High Arctic (northern Canada and Greenland) and the Beaufort Sea area.
- Other analyses (not shown) revealed strong positive correlations between NDVI and land temperatures and strong negative correlations with the percentage of coastal sea ice.

Ground observations study framework: mainly along two Arctic transects



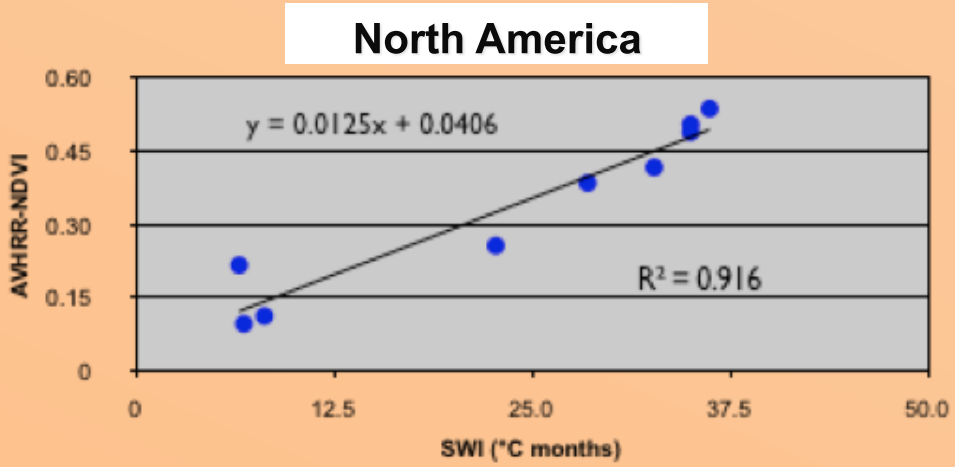
Bioclimate subzones as mapped by CAVM Team 2003

Through all 5 Arctic bioclimate subzones

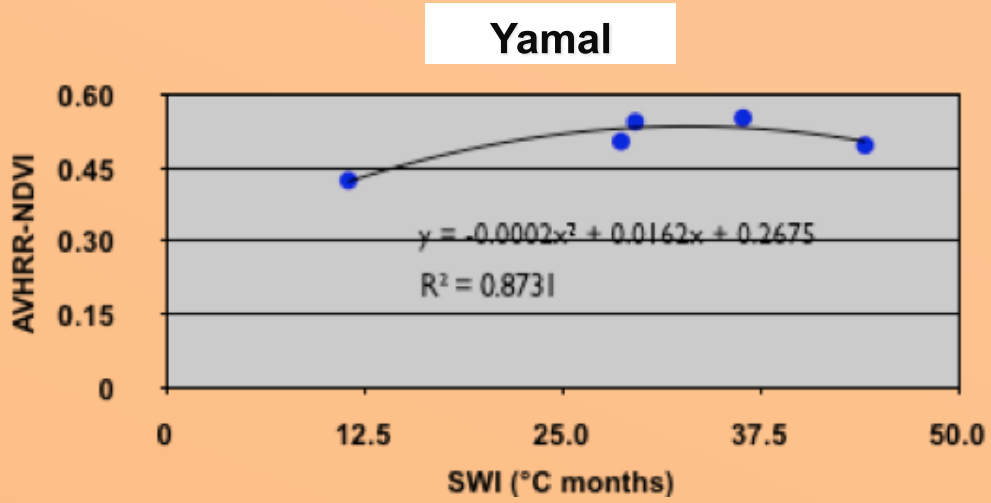
Sub-zone	MJT	Shrubs
A	1-3 ˚C	none
B	3-5 ˚C	prostrate dwarf-shrubs
C	5-7 ˚C	hemi-prostrate dwarf shrubs
D	7-9 ˚C	erect dwarf-shrubs
E	9-12 ˚C	low-shrubs

Along the tundra bioclimate gradient there is a 10˚ C change in the MJT, a 10-fold difference in zonal vegetation biomass, 10-fold increase in productivity, and a 5 to 10-fold increase in the diversity of vascular plants.

NDVI/biomass observations along 2 Arctic transects



- Strong correlation between summer temperature and NDVI along NAAT.
- Deceptive because there is also strong relationship to glacial history.



- Values are generally higher at low temperatures along the Yamal transect.
- Disturbance appears to be raising the NDVI values over large regions.
- Much more homogeneous substrates on the Yamal.

Epstein et al. 2009 AGU poster and in prep.

High Arctic (Subzone B): Rapid vegetation succession i**n polar desert landscapes near the Barnes Ice Cap**

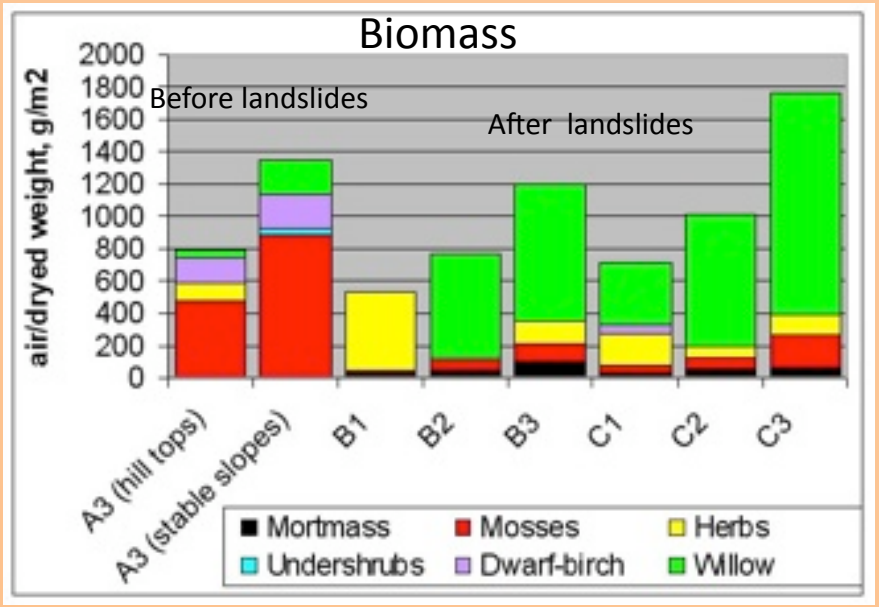
- Webber and Tweedie 2009:
- Repeat photographs of permanent vegetation 46 years after the initial studies.
- Vegetation is increasing most strongly along ponds and streams (where there is water and nutrients).
- Lichen communities are rapidly changing in the upland boulder fields.
- Helps explain the very large percentage NDVI changes seen in northern Canada and Greenland.

Webber and Tweedie 2009 Back to the Future project

Low Arctic (Bioclimate Subzone D): the effect of landslides on greenness and productivity patterns, central Yamal Pen.

Photos D.A. Walker

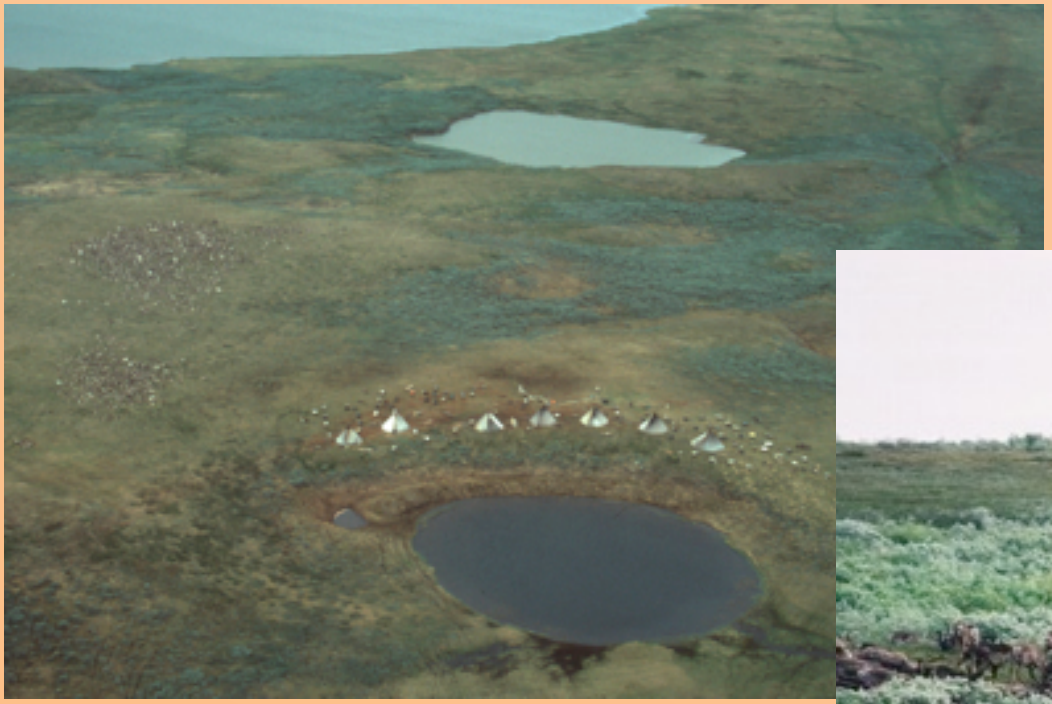
- 20+ years of information on permafrost-vegetation-nutrient relationships on landslides near Vaskiny Dachi.



Key:
A – stable areas
B – shear surface
C – landslide body
1 – young landslide
2 – old landslide
3 – very old landslide

Ukraintseva and Leibman et al. 2000, 2007, 2008

The changes in willow growth are affecting reindeer management.

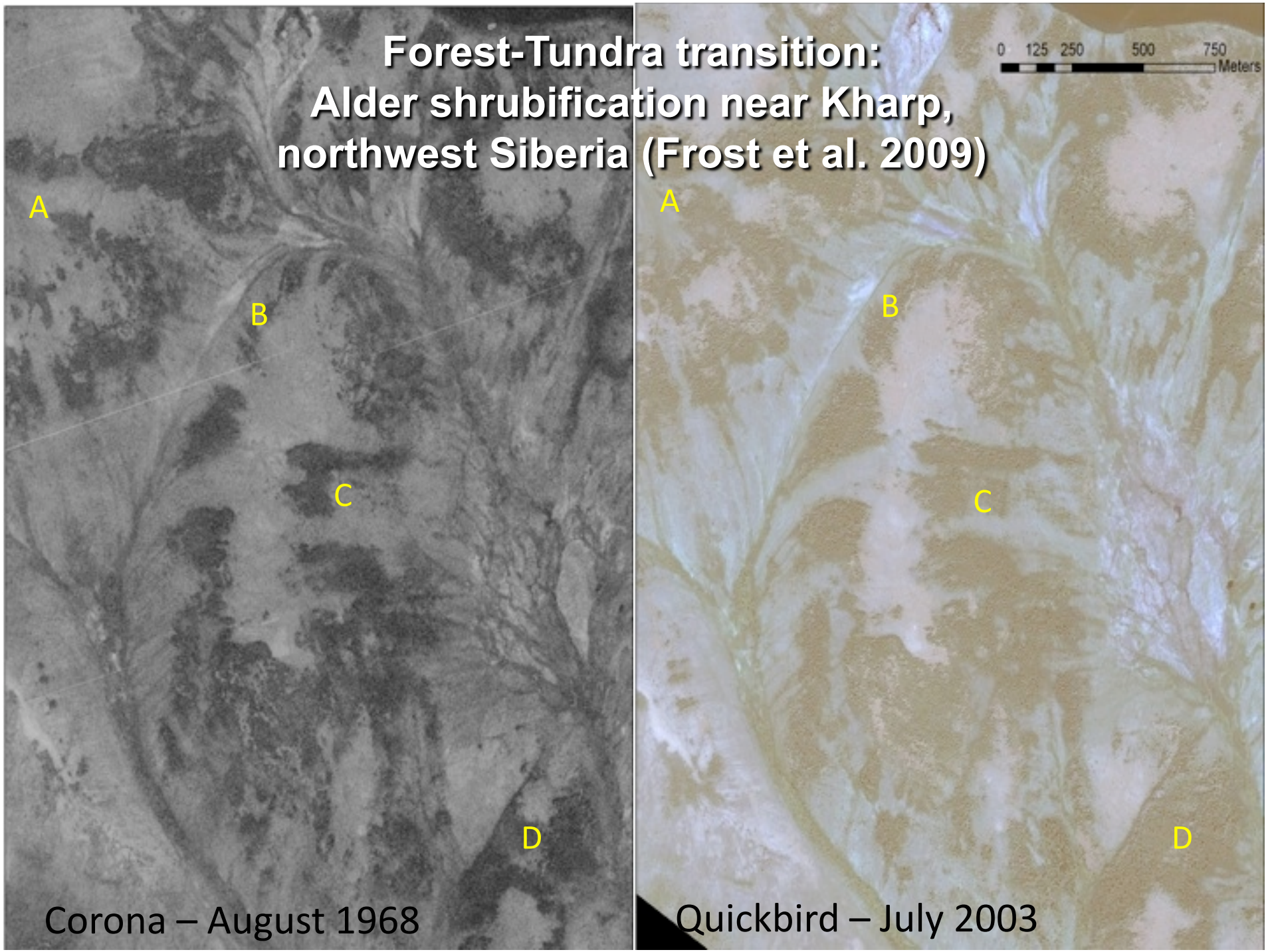


Nenets camp on Yamal in *Salix* low shrub tundra

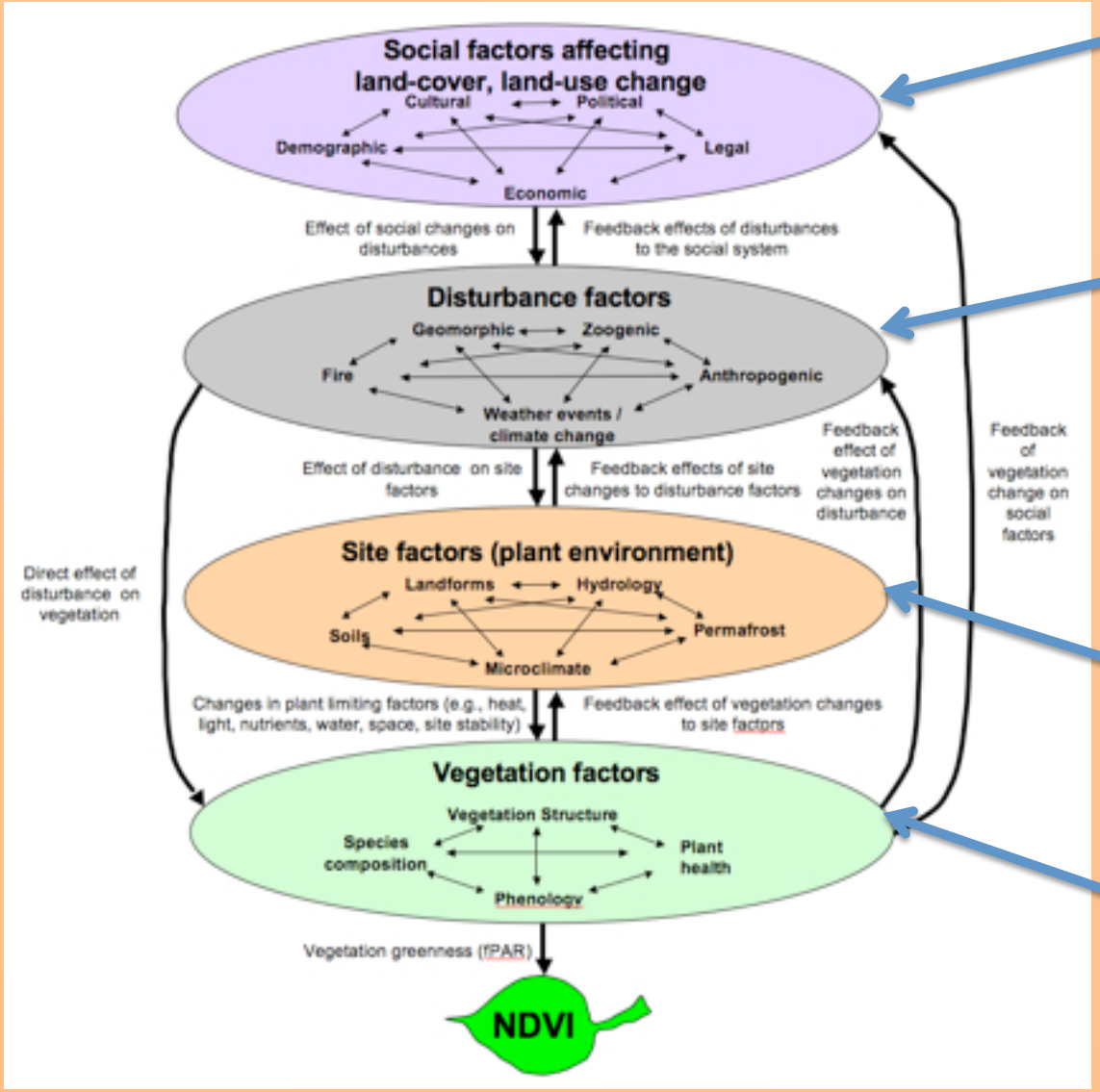
Forbes et al. 2009 *PNAS*, ENSINOR project

Reindeer grazing *Salix* thickets in Nenets Okrug. If they grow over ≈ 2 m high, herders can lose sight of animals.

Forest-Tundra transition: Alder shrubification near Kharp, northwest Siberia (Frost et al. 2009)



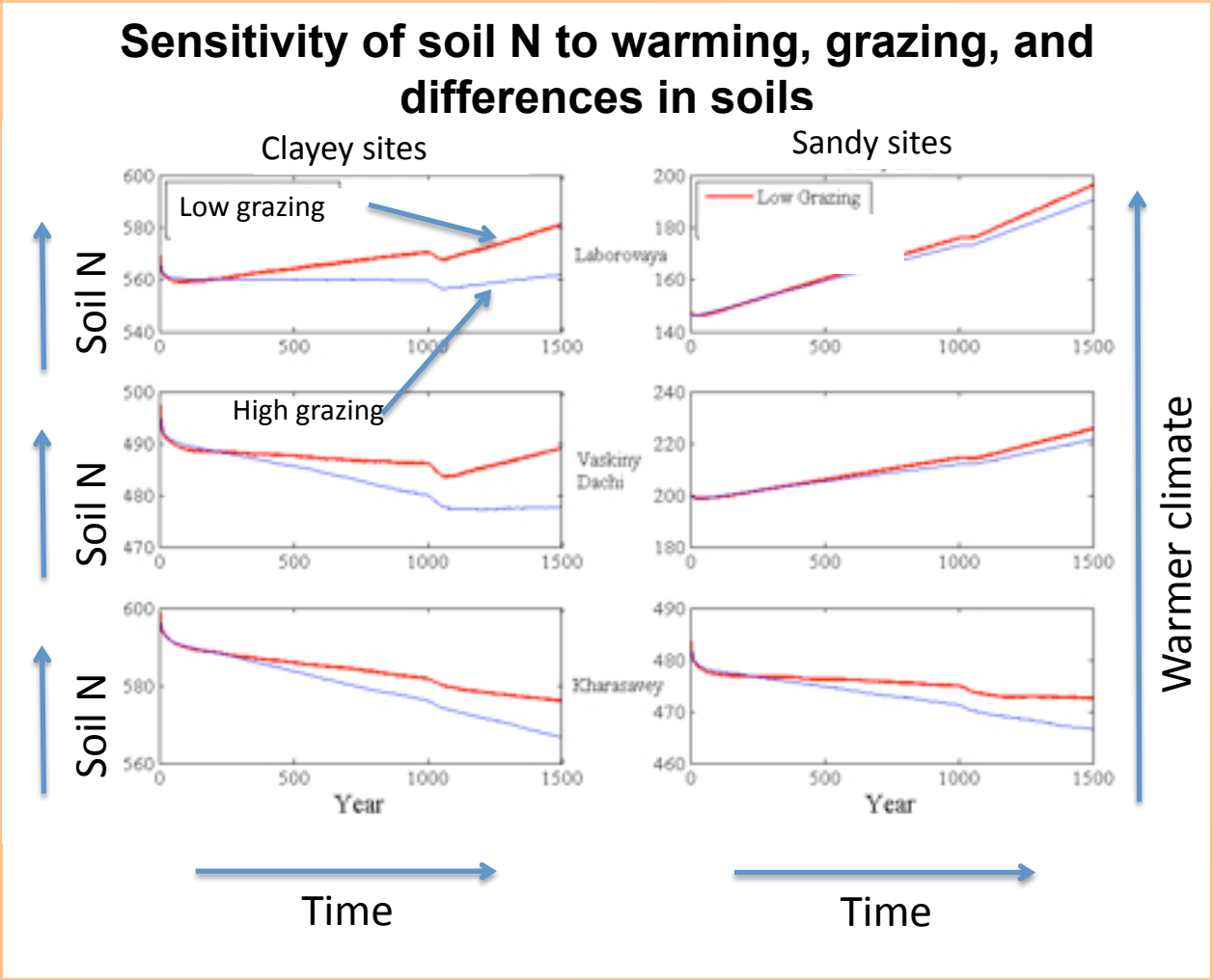
Complex of factors affecting NDVI patterns



- A wide variety of social factors affect many tundra disturbance regimes.
- Climate change is one of several disturbance factors affecting tundra productivity and NDVI patterns.
- Immediate plant environment controls plant production and composition.
- A wide variety of vegetation-related factors affect NDVI.

Walker et al. Environmental Research Letters, 2009

Models are helping to unravel the effects of various types of disturbance (H. Epstein and students):



- Grazing suppresses vegetation response to warming.
- Herbivory has greater effect in clayey (nutrient-rich) sites.

Yu, Q. et al. 2009 AGU poster: Simulating the effects of soil organic nitrogen and grazing on arctic tundra vegetation dynamics on the Yamal Peninsula, Russia

Summary

- At the circumpolar scale, NDVI is increasing and is temporally correlated to changes in sea ice and summer land temperatures.
- At the regional and landscape levels the most rapid changes in NDVI are occurring where there are disturbances and the disturbance types vary along the bioclimate gradient.
- Modeling studies are helping unravel the complex effects of climate change and disturbance.