Greening of the Arctic: an IPY initiative

Is the retreat in sea ice affecting Arctic land areas?


AGU IPY session, San Francisco, 16 Dec 2008
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.

- Defined as the region north of treeline, 7.1 million km² (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

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

Normalized Difference Vegetation Index

\[
NDVI = \frac{(NIR - VIS)}{(NIR + VIS)}
\]

\(NIR\) = spectral reflectance in the near-infrared band (0.7 - 1.1\(\mu\)m), 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 0.7\(\mu\)m).
Some of the differences are caused by climate. There is a 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

- 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.

Example analysis for the Beaufort Sea

**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%

Summary of trends

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.

Legend for Correlations
- +
- -

Legend for Trends
- Sign: closed (+) and open (-) circles
- Significance*: denotes 95% level
- Magnitude: size of circle
- Sea ice: < 10%, ≥10% & <30%, ≥30%
- SWI
- NDVI int.
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.

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.

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

Walker et al. 2008, JGR-Biogeosciences

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

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.
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 jackhammered away to reveal buried organic horizon locked in permafrost table beneath nonsorted circle.

Photos: D.A. Walker


Subzone A “the poppy zone”

- Bioclimatic 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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