Changes in Tundra Greenness Linked to Sea-ice Retreat and Warmer Land Temperatures

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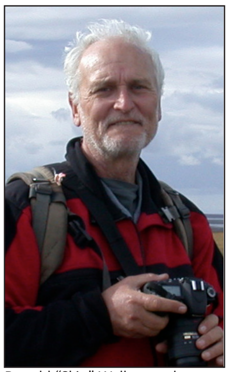
FAIRBANKS, Alaska— The Greening of the Arctic (GOA) IPY initiative is comprised of four projects each contributing to documenting, mapping and understanding the rapid and dramatic changes to terrestrial vegetation expected across the circumpolar Arctic as a result of a changing climate.



Donald "Skip" Walker on the Yamal Peninsula, Russia.

These changes will likely affect the permafrost, active layer, carbon reserves, trace-gas fluxes, hydrological systems, biodiversity, wildlife populations and the human habitability of Arctic ecosystems, says GOA principal investigator Donald "Skip" Walker, director of the Institute of Arctic Biology's Alaska Geobotany Center at the University of Alaska Fairbanks (UAF).

"If you have a map of Arctic vegetation, you have a lot of information about how the system works," Walker said. "Surprisingly, there are no long-term repeated measures of biomass in the Arctic. We'll be creating a baseline of vegetation data in a systematic way so that we can look at change over time."

Summary of GOA component projects:

1. North American Arctic Transect

The North American Arctic Transect (NAAT) was the first of the GOA projects which examined and recorded the greenness of biomass along a 1800-km (1118-mile) transect in the western North American Arctic which runs between Toolik Lake and Howe Island in Alaska, and between Inuvik and Isachsen in Canada. The NAAT is the only vegetation transect to traverse all five bioclimate subzones in the Arctic. A similar transect is being developed on the Yamal Peninsula and Franz Jozef Land in Russia as a component of the GOA initiative.

The Arctic landscape includes patterned-ground features including small regularly spaced circles, polygons, stripes and hummocks - striking features that have puzzled several generations of Arctic scientists. Geomorphologists and permafrost scientists have studied these features extensively, but the role of the vegetation had not been considered.

The NAAT team discovered how the vegetation affects the different types of patterned ground and modeled important processes involved in patterned-ground formation including how the plant canopy affects the flow of heat and water into the ground, the depth of thawing of the soil and frost heave.

One of the major findings of this project was that patterned ground controls how carbon from plant biomass is stored in soils. Chien Lu Ping and Gary Michaelson, scientists at the University of Alaska Palmer Research Station, jack hammered deep into the frozen layer of permafrost beneath patterned-ground features and found that physical processes involved in the formation of patterned ground drive organic matter deep underground where it can be stored in the permafrost. Much more carbon has accumulated in Arctic soils through this process than had been previously estimated. Such estimates are critical to understanding the role of the Arctic in global carbon budgets.

Patterned ground was mapped at 11 locations along the NAAT. Soils, permafrost temperatures, active layer thickness, biomass, leaf-area, spectral data and other ground survey information were collected as a baseline against which to monitor future changes. These data are critical to understanding how climate will affect Arctic ecosystems.

The NAAT/GOA is a legacy of the Biocomplexity of Patterned Ground Ecosystems project funded by the Bicomplexity in the Environment Program at the National Science Foundation (NSF).

Field work: Proposed for 2009 includes Inuvik, NWT; Green Cabin, Banks Island, Mould Bay, Prince Patrick Island, Isachsen, Ellef Ringnes Island and Nunuvut, Canada.

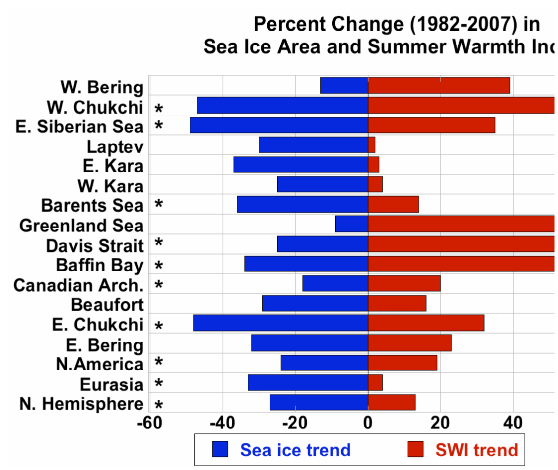
NAAT project personnel

2. Synthesis and Models to Examine Pan-Arctic Vegetation Change: Climate, sea ice, and terrain linkages

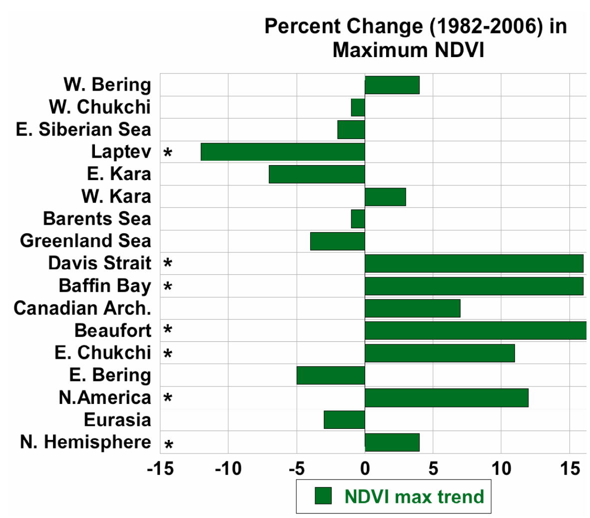
This GOA project uses ground data from the NAAT to directly address the question of how the terrestrial vegetation of the Arctic has responded to climate change to date and how it will respond in the future as portions of the Arctic Ocean become seasonally ice free as indicated by our current understanding of trends in sea ice.

Climate analysis, remote sensing analysis and vegetation-change models are used to track past greenness changes and to anticipate future changes in the land surfaces in the Arctic as measured from space. Greenness is determined by measuring the wavelengths and intensity of visible and near-infrared light reflected by the land surface into space and plugging those measurements into a greenness algorithm called the normalized difference vegetation index (NDVI).

Atmospheric scientist Uma Bhatt, from the UAF Geophysical Institute, examined satellite-derived sea-ice, land-temperature, and NDVI data along the coastlines of 14 seas composing the Arctic Ocean and adjacent ice-covered waters for the period 1982-2007. Bhatt found that periods of lower sea-ice concentration are correlated with warmer land-surface temperatures and higher greenness or NDVI values. The largest increase in NDVI was found along the Beaufort Sea Coast in northern Alaska, where the NDVI increased 24% during the 25-year record. This trend is consistent with observations regarding shrub



Percentage change in sea-ice area in late spring (when the long-term mean 50% concentration is reached) during 1982-2007 along the 50-km-seaward coastal margin in each of the major seas of the Arctic.



Percentage change in the summer land-surface temperature as measured by the summer warmth index (SWI = sum of the monthly mean temperatures above freezing) based on AVHRR surface-temperature data. Bottom: Percentage change in greenness as measured by the maximum Normalized Difference Vegetation Index (NDVI). Asterisks denote significant trends.

cover, modeling and experimental evidence linking temperature increases to increases in vegetation (biomass).

Walker's team submitted a new proposal to NSF which builds on this project and characterizes the seasonality of landscape greenness and how it is related to sea-ice concentration and thickness, ocean and land-surface temperatures, ocean heat fluxes, snow cover and vegetation. The project will focus in the Beaufort Sea area, where the greatest changes in greenness have occurred and along the Eurasian coast where greenness appears to have decreased.

NSF provided funding for this project, which is a component of the NSF Synthesis of Arctic System Science (SASS) program.

Field work: None
SASS project personnel

3. The NASA Yamal Project

The Yamal project is examining the spatial and temporal patterns of vegetation change on the Yamal Peninsula in northwest Siberia, Russia and how those changes are in turn affecting traditional herding by the indigenous Nentsy people of the region. The project uses remote-sensing technologies, ground-level sampling and interviews with the local people.

The Yamal has undergone extensive anthropogenic disturbance and transformation of vegetation cover during the past 20 years due to gas and oil development and overgrazing by reindeer herds. "The vegetation appears to be responding to climate change," Walker said. "Satellite-based data indicate a rapid greening is occurring in the Arctic, but when you look for ground documentation for this change there's virtually nothing out there."

"Surprisingly, there are no long-term repeated measures of biomass in the Arctic. We'll be creating a baseline of vegetation data in a systematic way so that we can look at change over time," Walker said.

NASA's Land-Cover Land-Use Change program provides funding for this project, which is also part of the Northern Eurasia Earth Science Partnership Initiative.

Field work: Yamal Peninsula: Belyy Ostrov (2009), Vaskiny Dachi (2010), Franz Jozef Land (2011).

Yamal project personnel

4. Arctic Geobotanical Atlas

The Arctic Geobotanical Atlas (AGA) project is the education and outreach component of the GOA project. It includes a Web-based, plant-to-planet Arctic Geobotanical Atlas which uses tools such as Google Earth to help students, educators, scientists, land managers, governments and the public to understand issues related to vegetation and vegetation change in the Arctic.

Users can download and use GIS data from the Circumpolar Arctic Vegetation Map and from maps at several sites along the NAAT and the Yamal Peninsula vegetation transect in combination with other remote-sensing products.

The AGA includes maps at eight different scales, from 1-m² plots to the entire Arctic. It focuses on research sites at the Institute of Arctic Biology's Toolik Field Station and Imnavait Creek, Alaska, but also covers the Kuparuk River Basin, northern Alaska, Arctic Alaska and the circumpolar Arctic. Geobotanical themes include geology, topography landforms, surficial geomorphology, soils and vegetation. The maps and Web site were developed at the Alaska Geobotany Center in collaboration with several other groups at UAF. Project personnel also maintain Web sites for the other GOA IPY initiative projects. AGA is linked to the Arctic Atlas of the University of the Arctic.

NSF provided funding for this project.

Field work: None
Project personnel. Donald A. Walker, PI., Edie Barbour, Hilmar Maier, Martha Raynolds: Alaska Geobotany Center, IAB, UAF; Jason Grimes, Cheryl Hass: Geographic Information Network of Alaska (GINA), Geophysical Institute, UAF.

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