Greening of the Arctic: An IPY initiative

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Abstract: One of the key goals of IPY will be to characterize, monitor, and model the rapid and dramatic changes to terrestrial vegetation that are expected to occur across the circumpolar Arctic as a result of climate change. Changes in the biomass of terrestrial ecosystems will likely affect the permafrost, active layer, carbon reserves, trace-gas fluxes, hydrological systems, biodiversity, wildlife populations and the habitability of the Arctic. Changes in green biomass can be expected across the entire bioclimate gradient from treeline to the coldest parts of the Arctic. The Greening of the Arctic (GOA) initiative consists of a group of scientists who are part of four major components that will examine the spatial and temporal trends of greening in the Arctic, how these trends are affecting the indigenous people of the Arctic, and communicate the results of the study to students, scientists, government agencies, and the general public.

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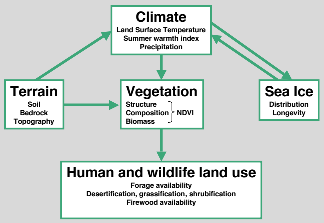
Component I: Sea Ice – Land-surface-temperature – Greening relationships

This component will examine in detail the 24-year record of greenness across the entire circumpolar Arctic as measured by the normalized difference vegetation index (NDVI) using satellite imagery (AVHRR and MODIS). The study will document historical trends of NDVI, areas of major increases or decreases in the NDVI, and link these trends to changes in sea-ice distribution, land-surface-temperatures (LSTs), snow-cover, bioclimate subzones, vegetation type, glacial history, and other variables in a circumpolar GIS database. Modeling studies will use the past trends in NDVI to predict future distribution of arctic vegetation using the BIOME4 model. Transient dynamics of the vegetation will be examined using the ArcVeg model. This component is already funded as an ARCSS Synthesis project.



Climate
Land Surface Temperature
Summer warmth index
Precipitation
Terrain
Soil
Bedrock
Topography
Vegetation
Structure
Composition
Biomass
NDVI
Sea Ice
Distribution
Longevity
Human and wildlife land use
Forage availability
Desertification, grassification, shrubification
Firewood availability

Fig. 1. The parts and interactions of the Arctic System that are being analyzed in the GOA project . Note there are no direct interactions between sea-ice and the vegetation, but changes in sea-ice distribution will have a large effect on terrestrial vegetation because of the feedbacks between the sea-ice and climate components of the system.

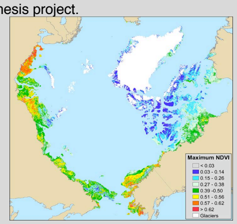


Fig. 2. Maximum NDVI of the Arctic. The GOA project will examine the spatial patterns of NDVI with respect to land-surface temperature, elevations, presence and type of permafrost, soil type, vegetation type, glacial history, and bioclimate subzones. Note the close proximity of all parts of the biome to the Arctic Ocean. 61% of lowland Arctic Tundra is within 50 km of the ocean 80% is within 100 km, and 100% is within 350 km. This strong linkage between the ocean and the tundra makes the biome particularly sensitive to changes in summer sea-ice distribution. From Walker et al. (2003).

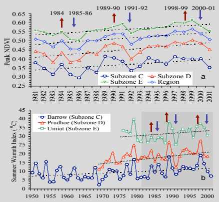
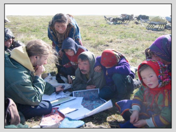


Fig. 3. The GOA project will also examine the temporal NDVI patterns for the whole Arctic. These data from northern AK show the trend in temperatures (lower diagram) and maximum (peak) summer NDVI (upper diagram) for the three bioclimate subzones in northern AK. The shaded area in (b) highlights the period of SWI covered by the NDVI data in (a). The arrows show years of corresponding increases (red) and decreases (blue) in NDVI and SWI. Regional NDVI increased by 17% between 1980 and 2000. From Jia et al. (2003).

Component II: Human dimensions of greening on the Yamal Peninsula, Russia

This part of the study is linked to the Circumpolar Arctic *Rangifer* Monitoring and Assessment (CARMA) project. It will examine the linkages between greening trends, the range and forage for the reindeer of the Nenets people, and the regional sea-ice conditions. The Russian component is funded by the NASA/USDA Land Cover Land-Use Change initiative and is part of the Cold Land Process in NEESPI (CLPN). NEESPI is the Northern Eurasia Earth Science Partnership Initiative, an interagency research program that is capitalizing on a variety of remote sensing and modeling tools to achieve a better understanding of Northern Eurasian terrestrial ecosystem dynamics.

Fig. 4. (Left) Nenets woman drives her sled across an eroding road in the gas field at Bovonenkova on the Yamal Peninsula. Component II will focus on how changes in greening and land-use patterns are affecting traditional herding by the indigenous people of the Yamal region, which has undergone extensive transformation of vegetation cover in the past 20 years (Forbes 1999). (Below) Formal semi-structured interviews with Nenets herders. Some of these are recorded on either digital tape or film, or both. in these cases we have medium or very high resolution satellite imagery of the areas we are discussing to focus on specific places and features that the herders can recognize easily. Photo: Bruce Forbes.



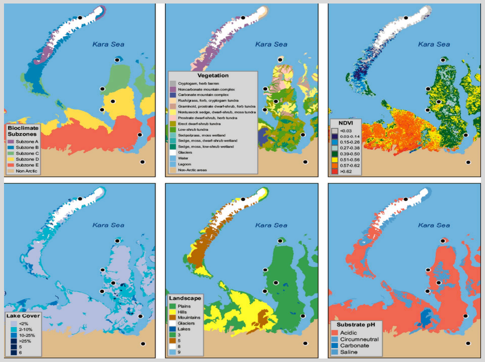
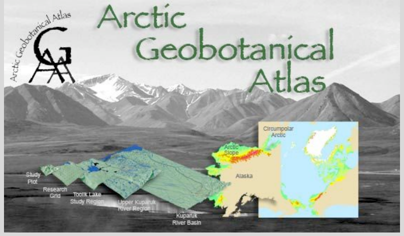
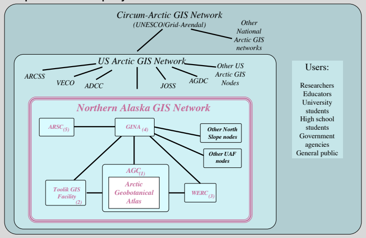


Fig. 5 (below). The Eurasian Arctic Transect. Black dots are proposed study locations in each of the bioclimate subzones along the Yamal Peninsula and Novaya Zemlya.

Component III: Arctic Geobotanical Atlas (AGA)

The AGA is an outreach/education component of the project that uses a variety of tools to help students, educators, scientists, land managers, and the public understand issues related to the greening of the Arctic. Users can download and use online GIS data from the Circumpolar Arctic Vegetation Map and other maps at several sites along the GOA transects, in combination with other remote-sensing products. This component is funded by an NSF grant. Linkage of the project to the University of the Arctic and Integrative Graduate Education and Research Traineeship (IGERT) will also occur in relationship to the human dimensions aspects of the project.





Circum-Arctic GIS Network
(UNESCO/Grid-Arendal)
Other National Arctic GIS networks
US Arctic GIS Network
Other US Arctic GIS Nodes
ARCSS
VECO
ADCC
JOSS
AGDC
Northern Alaska GIS Network
GINA
Other North Slope nodes
Other UAF nodes
Toolik GIS Facility
Arctic Geobotanical Atlas
WERC
Users:
Researchers
Educators
University students
High school students
Government agencies
General public

Figure 6. (Left) The Atlas focuses on the Toolik Lake Field Station and the surrounding region, and includes eight map scales up to the circumpolar Arctic. Maps in the atlas can be accessed by map scale, theme, region, or year. Other components of the atlas include a photo gallery of all plants, and mapping units in the atlas, supporting field data, extended descriptions of the mapping units, and a full bibliography. (Left) The AGA will be linked to a variety of local, regional and international networks through the worldwide web and be accessible with a variety of visualization tools including Swathviewer, GINA Map Server, and Terra Explorer (a software package that permits users to freely "fly" through digital 3-D terrain). The red box shows the Northern Alaska network centered at UAF. The red numbered nodes are part of the support team developing the AGA (AGC, Alaska Geobotany Center; GINA, Geographic Information Network of Alaska; ARSC, Alaska Regional Supercomputer Center; WERC, Water and Environmental Research Center).

Component IV: North American Arctic Transect (NAAT)

The NAAT proposal is pending in NSF. It would: (1) Create a legacy dataset of baseline information that represents the full range of zonal vegetation types in the Arctic. (2) Coordinate the science and data management of numerous projects interested in using the NAAT within the context of IPY. (3) Communicate the results of the studies through a three-part education/outreach component that includes an Arctic Field Ecology course, contributions to a new "Arctic Geobotanical Atlas" web site, and a field trip for the 9th International Conference on Permafrost.

The project will serve as a magnet for other studies interested in examining all aspects of change along the Arctic climate gradient. The science part of this project will focus on collecting plant biomass data, which are critical to understanding the causes of a recent large increase the greenness of the Arctic that has been detected with satellite-based sensors. Biomass, leaf-area, spectral data and other site information will be collected from each location along the NAAT to provide a baseline against which to monitor future changes. The NAAT will be a component of the Arctic Observing Network (AON) affiliated with the flagship observatory at Toolik Lake, AK.

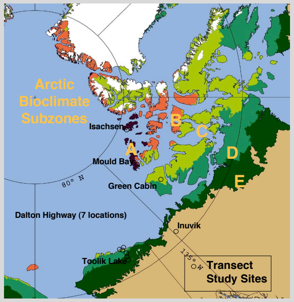
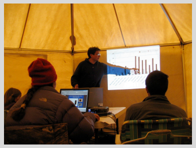


Fig. 7. The North American Arctic Transect traverses all five Arctic bioclimate subzones (CAVM Team 2003) with study sites in 11 locations, 7 in Alaska and 4 in Canada.

Table 1. Key data sets and models at three scales along the NAAT as part of the Biocomplexity project and the NSF Greening of the Arctic SASS project. (Source or person(s) collecting the data is listed in parentheses.)

	Macroscale (Climate gradient to circumpolar)	Mesoscale (Toposequence to regional)	Microscale (Patterned-ground elements to 10-m grids)
Climate	Trends in air and ground temperature, snow depth along the climate gradient (Romanovsky, US Weather Service, Environment Canada). Circumpolar land-surface temperature (Comiso)	Trends in soil temperatures, and snow distribution along toposequences (Romanovsky).	Soil temperatures, and snow depth on patterned-ground elements. (Romanovsky) Snow profiles on patterned-ground elements (Walker et al.) Snow depth maps (10 x 10-m grids) (Raynolds, Munger).
Permafrost	Trends in permafrost temperature, n-factor unfrozen water content, active layer depth, and frost heave along the climate gradient. (Romanovsky, Kade). Circumpolar permafrost map (Brown et al.)	Trends in n-factor, active layer depth, and frost heave along the toposequences (Romanovsky, Kade) WIT/ArcVeg model of patterned-ground formation (Daanen, Misra, Epstein)	Heave, active layer depth, soil-water content, unfrozen water, and n-factor within patterned-ground elements (Romanovsky). Active-layer and snow-depth maps (10 x 10 m grids) (Raynolds, Munger)
Geology/ geomorphology	Circumpolar patterns of landscape age, glacial geology, bedrock,and physiography. (CAVM Team, Raynolds)	Surficial geomophology along toposequences. (Walker et al.)	Elements of patterned-ground features. (Walker et al., Tarnocai) Thermo-mechanical model of differential frost heave (Nickolsky, Romanovsky) DFH model of heave initiation (Peterson, Krantz)
Soils	Circumpolar Soils Map (Tarnocai and Ping) Circumpolar Carbon Map (Tarnocai) Trends in soil C and N along the climate gradient (Ping and Michaelson)..	Soil associations along toposequences (Ping). Trends in soil chemical and physical characteristics along toposequences. (Ping and Michaelson)..	Pedon within each patterned ground element (Ping). Cryptogamic crusts in each patterned ground element. (Michaelson) Physical and chemical properties of soils in each patterned-ground element. (Ping and Michaelson).. N-cycling in each patterned-ground element (Kelley).
Soil biota	Trends in soil invertebrates, microbes, fungi/ mycorrhizae along the climate gradient. (Gonzalez, Timling)	Trends in soil invertebrates, microbes, fungi/ mycorrhizae along toposequences. (Gonzalez, Timling)	Soil invertebrates, microbes, fungi/ mycorrhizae in patterned-ground elements. (Gonzalez, Timling)
Vegetation	Circumpolar AVHRR NDVI, and vegetation(CAVM Team, Raynolds, Epstien, Jia) Trends in zonal vegetation biomass along the climate gradient (Walker et al., Epstein) Buried seed bank along the climate gradient (Kelley) ArcVeg succession models along the climate gradient (Epstein)	Plant communities along toposequences (Kade, Vonlanthen et al.). 10 x 10-m vegetation maps along toposequences (Raynolds, Munger)	Plant communities within patterned-ground elements (Kade, Vonlanthen et al., Matveyeva, Daniëls). 1 x 1-m vegetation maps (Kade) Handheld LAI and NDVI of patterned-ground elements. Biomass of plant communities (Walker et al., Epstein). Buried seed bank within patterned ground elements (Kelley)

Fig. 8. Camp facilities. (a) Main camp at Isachsen with two yurts for laboratory space, dining, and (b) evening seminars. (c) Arctic Field Ecology Camp at Isachsen with large dome for classes and cooking.



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