Application of Space-based Technologies and Models to Address Land-cover/Land-use Change problems on the Yamal Peninsula, Russia

Annual Report to NASA

February 14, 2008

By Skip Walker, project PI
University of Alaska Fairbanks

Introduction and summary

This research is one of the components of the Greening of the Arctic (GOA) project of the International Polar Year (IPY) and is funded by NASA's Land-Cover Land-Use Change (LCLUC) program. It is contributing to NASA's global-change observations regarding the consequences of the decline in the Arctic sea ice and the greening of terrestrial vegetation that is occurring in northern latitudes. The work is also part of the Northern Eurasia Earth Science Partnership Initiative (NEESPI). It addresses the NEESPI science questions regarding the local and hemispheric effects of anthropogenic changes to land use and climate in northern Eurasia.

The overarching goal of our research is to use remote-sensing technologies to examine how the terrain and anthropogenic factors of reindeer herding and resource development, combined with the climate variations on the Yamal Peninsula, affect the spatial and temporal patterns of vegetation change and how those changes are in turn affecting traditional herding by indigenous people of the region.

The Yamal Peninsula in northern Russia has undergone extensive anthropogenic disturbance and transformation of vegetation cover over the past 20 years due to gas and oil development and overgrazing by the Nenets reindeer herds. It has been identified as a "hot spot" for both Arctic climate change and land-use change.

This report presents the progress during second year of the project. It includes:

I. *Field work along the Yamal Transect:* (1) Three field research locations were established at Nadym (northern boreal forest), Laborovaya (southern tundra), and Vaskiny Dachi (typical tundra). (2) A data report describes the data collected at the research locations (Walker et al. 2008, http://www.geobotany.uaf.edu/yamal/datareport07.pdf).

II. *Yamal Land-Cover Land-Use Change Workshop:* (1) A workshop was convened in Moscow, 28-30 January 2008. (2) An abstract volume and talks are posted on the project web site http://www.geobotany.uaf.edu/yamal/.

III. *Summary of progress for each component:*

a. *Human dimensions:* (1) A study of the Nenets including history of changes in social structure related to Soviet changes and recent changes due to gas development is in progress. (2) Field work in collaboration with the ENSINOR project was conducted at Laborovaya and included a willow growth-ring analysis to develop a proxy temperature record for the Yamal Peninsula extending back approximately 80 years.

b. *Remote-sensing:* Two projects are in progress: (1) Examination of the general sea-ice conditions and the controlling climate patterns in the Arctic basin, with particular focus on the region surrounding the Yamal Peninsula. (2) Examination of the spatial and temporal patterns of NDVI and land-surface temperatures on the Yamal Peninsula and the whole Arctic.

c. *Modeling:* Three models are under development: ArcVeg, BIOME4, and TreeMig models. These are linking the remote sensing information and history of land cover change (greening change) on the Yamal Peninsula with predictions of future change. (2) A publication describes each of the three modeling approaches (Epstein et al. 2007).

d. *Soil temperatures and permafrost monitoring along the Yamal transect:* (1) Fifteen soil-temperature monitoring sites were established along the transect. (2) Historical data for the Nadym area are reported.

IV. *Plan for 2008 Field season:* Two alternatives are presented.

I. Field work along the Yamal Transect

We conducted an expedition to three sites in the Yamal region during the period 3-30 Aug 2007 (Fig 1). The purpose of the expedition was to collect ground-observations in support of remote sensing studies at three locations along the southern part of a transect that traverses all the major bioclimate subzones in the Yamal region.

Figure 1. *The Yamal Transect. Locations of the 2007 field research sites are shown as red dots. Green dots are planned sites.*

A data report presents the results from the expedition http://www.geobotany.uaf.edu/yamal/datareport07.pdf. The locations visited in 2007 were Nadym (northern taiga subzone), Laborovaya (southern tundra = subzone E of the Circumpolar Arctic Vegetation Map), and Vaskiny Dachi (typical tundra = subzone D). Data are reported from seven study sites – two at Nadym, two at Laborovaya, and three at Vaskiny Dachi.
The sites were chosen to be representative of the zonal

soils and vegetation, but also included variation regarding substrate (clayey vs. sandy soils) at each location. Usually this meant sampling sites of different geologic age. Most of the information was collected along five transects at each sample site, five permanent vegetation study plots, and one soil pit at each site.

The information in the data report includes: (1) background for the project, (2) general descriptions of each locality and sample site with photographs, (3) maps of the sites, study plots, and transects at each location, (4) summary of sampling methods used, (5) tabular summaries of the vegetation data (species lists, estimates of cover abundance for each species within vegetation plots, measured percent ground cover of species along transects, site factors for each study plot), (6) summaries of the Normalized Difference Vegetation Index (NDVI) and leaf area index (LAI) along each transect, (7) soil descriptions and photos of the soil pits at each study site, (8) summaries of thaw measurements along each transect, and (9) contact information for each of the participants. The data report also includes full documentation of the methods so that Russian partners can repeat the observations independently in future years.

II. Yamal Land-Cover Land-Use Change Workshop, Moscow, 28-30 Jan 2008

Twenty-five participants in the project met to discuss the results to date and plan for the future. This was the first opportunity for all the project participants to meet in one place. Twenty-three half-hour talks were presented during the first two days of the workshop. The final day was devoted to discussion of the 2008 field season and discussion of synthesis products including book chapters for the NASA book on land-cover change in northern Eurasia.

The agenda for the meeting, list of participants and abstracts are in the abstract volume http://www.geobotany.uaf.edu/yamal/abstractsvolume(3).pdf. The Powerpoint presentations from the workshop can be found at http://www.geobotany.uaf.edu/yamal/ppt.

III. Reports from major project components

a. Human dimensions (Bruce Forbes): Response of the Nenets people and their reindeer herds to land-use/land-cover change along the Yamal Transect.

The main fieldwork took place in summer 2007 in two stages along the road/railway corridor in subarctic tundra (CAVM subzone E) on southern Yamal Peninsula. Anu Pajunen (plant ecology) and Anna Degteva (social anthropology) went up in late May for reconnaissance and to try to arrange meetings with Nenets reindeer herders who would be crossing the road/railway in July at about the same time and place where the main ENSINOR/NEESPI team would be. However, a late spring thaw meant that animals were still far to the south and there was no possibility to meet them or their representatives in Salekhard.

A reconnaissance trip up the road with Sergei Khudi from Yamaltransgas, Department for Ecology and Labour, Health and Safety, Labytnangi, YNAO was organized to the vicinity of km 147. There was still significant snowcover on the ground, albeit melting quickly. A visit was made to a camp of Nenets near the road who were fishing in nearby lakes. Discussions were about the locations of summer camps near the road, the positive and negative impacts of the road/railway corridor (and gas development in general), and Anu checked the degree of willow cover, finding it fairly low near the road in places with little or no snow. Anu returned to Finland to prepare for the summer and Anna stayed longer to make additional contacts for her summer fieldwork with Nenets migrating near the corridor.

Figure 2. *Nenets reindeer-herder camp with their teepee-like "chums" and abandoned oil derrick in the background, near the Vaskiny Dachi study location, Yamal Peninsula. Photo: Bruce Forbes.*

The main ENSINOR/NEESPI team arrived 4 July in Salekhard and at km 147 a few days later to set up base camp. Anna Degteva never returned in early June as she made contact with a Nenets family and decided to travel with them, remaining with them all summer, until late August. The main team included ENSINOR PI Bruce Forbes, as well as PhD students Timo Kumpula and Anu Pajunen. MSc students Elina Kaarlejärvi, Sara Bystedt and Juha Moilanen came as field assistants. The human dimensions team included local Nenets Piotr Khudi and social anthropologist Jochen Dietel. Piotr and Jochen traveled around to visit different private and state reindeer herders in the vicinity of the road. The main team stayed near base camp to conduct ground truth measurements for the Quickbird satellite image, including field spectrometer readings. Bruce Forbes and Sara Bystedt clipped biomass in the high shrubs (mostly *Alnus fruticosa* and *Betula exilis*) visible in the southwestern portion of the Quickbird image. Bruce Forbes also took disks from the stems of *Alnus* and *Salix lanata* in order to develop a dendrochronological proxy record of summer temperatures over the past 7 to 8 decades.

Figure 3. *Nenets herders and Florian Stammler reviewing satellite images, Yamal Peninsula. Photo: Bruce Forbes.*

Weather was extremely hot and dry most of the time, making the work difficult and slow going with lots of insect harassment to both people and reindeer at almost all hours of the day. However, the group established enough samples to successfully characterize the main land cover types visible in the Quickbird image. The social anthropologists also obtained a great deal of useful data on the Nenets perceptions of changes associated with the gas development in general and the road/railway corridor in particular. Experiences are somewhat variable, in that the road improves access for trade and movement of herders and their families into the big towns (Labytnangi/Salekhard). On the other hand, improved access into the tundra by gas workers has brought several problems, among them overfishing of lakes and rivers near the road, poaching of reindeer, and illegal sale of alcohol to herders. Also, for herders who have to cross the road/railway corridor on their north/south migration it is not easy as there are few suitable places to cross at all and no underpasses or overpasses to ease the movement of sledges over the embankments and iron rails. Airborne dust and continues to be a problem near the road and unvegetated quarries, coating both the snow and the vegetation and changing the species composition and affecting berries, and mushrooms. Also, the many abandoned quarries are full of rusted metal, broken glass and other trash that injures unsupervised animals who may wander into them. There is serious concern about a new road corridor under planning that will accompany the buried pipeline from Baidaratski Bay to Vorkuta, crossing the summer pastures of the Baidaratski Sovkhoz at a critical point near the sea where the herds congregate with young calves for insect relief and high quality forage.

b. Remote sensing (Jiong Jia, Uma Bhatt, Martha Raynolds, and Joey Comiso): Sea-ice, climate, land-surface temperatures, and NDVI characterization and changes along the Yamal Transect and comparison with the North American Arctic Transect.

Spatial analysis of vegetation greenness and land-surface temperatures (Martha Raynolds):

We analyzed the spatial distribution of vegetation greenness on the Yamal Peninsula using normalized difference vegetation index (NDVI) data sets derived from the Advanced Very High Resolution Radiometer (AVHRR) data, comparing NDVI with summer warmth index (SWI) at the ground surface, and other mapped characteristics. The SWI is the sum of the mean monthly temperatures that are above freezing (e.g., if the May, Jun, July, Aug and Sep mean temperatures are -3, 2, 3, 1, and -4 respectively, the SWI = 6). It is generally considered an index of the amount of summer warmth available for plant growth. NDVI on the Yamal is highest in the areas farthest to the south, and in the foothills of the Ural Mountains. NDVI is lowest in areas with many large lakes. The spatial variation of NDVI on the Yamal is due to a combination of many factors, including elevation, landscape, vegetation type, temperature (summer warmth index), and lake area. NDVI increases less with temperature on the Yamal than in most of the Arctic. NDVI on the Yamal increases with elevation due to better drained surfaces and better habitat for shrubs.

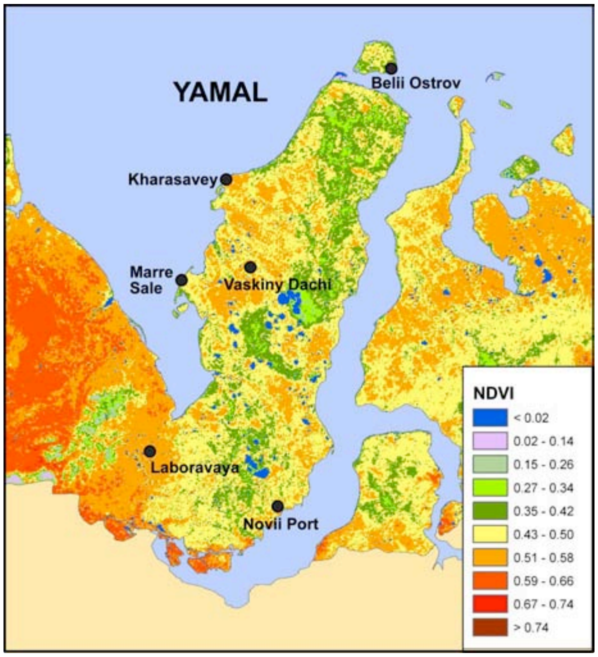


Figure 4. *Summer warmth index (SWI, 0˚C) of Yamal Peninsula, based on satellite-derived land-surface temperatures (mean of 1982-2003, Raynolds et al. 2008 (in press)).*

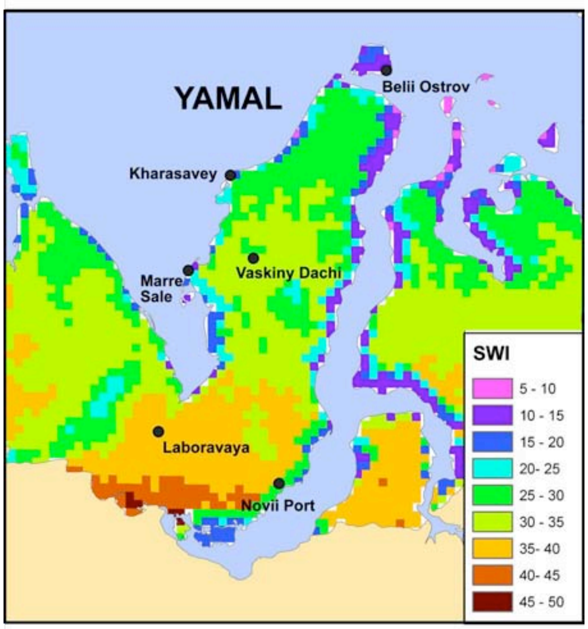


Figure 5. *Normalized difference vegetation index (NDVI) of Yamal Peninsula, based on maximum composite from 1993 and 1995 AVHRR data (CAVM Team 2003).*

Temporal analysis of vegetation greenness (Gensuo Jia)

In 2007 we focused on satellite data calibration, interannual trend detection, phenological analysis, and multi-variable analysis of vegetation-atmosphere interactions over Yamal region as well as circumpolar arctic. We combined multi-scale sub-pixel analysis and remote sensing time-series analysis to investigate recent decadal changes in vegetation photosynthetic activity along spatial gradients of summer temperature and vegetation in the Arctic tundra biome.

The major datasets used here are NASA Gimms data time series at 8-km pixel resolution and 15-day temporal resolution, MODIS land cover data, and geolocation data of field sites (Figure 6). The temporal analysis was performed with a 1982-2005 time series, stratified by bioclimate subzone and land cover. We examined the changes of vegetation greenness over the past 24 years as indicated by variations of the maximum Normalized Difference Vegetation Index (NDVI), spanning Low Arctic, High Arctic and polar desert ecosystems. Subpixel fractional vegetation cover was analyzed in order to select homogenously vegetated areas of tundra. Autoregression analysis was performed on NDVI time series of those homogenous pixels for each region. Data quality is low beyond 70 degrees north for 2004-2005 due to calibration errors, therefore, only pixels below 70 degrees north were included for those years.

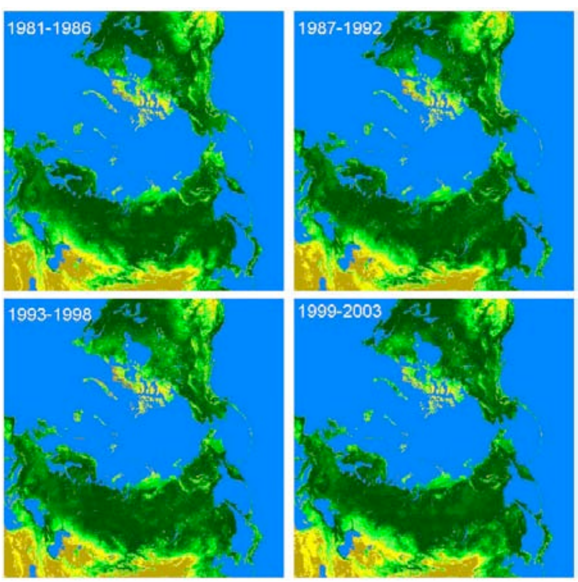


Figure 6. *Annual peak NDVI for (a) 1982-1986 average, (b) 1987-1992, (c) 1993-1998, and (d) 1999-2003 average over circumplolar arctic region.*

Linear trends in Arctic tundra vegetation greenness over the period were positive over Yamal region, as observed with NOAA AVHRR satellite (Figure 7). Vegetation greenness increased systematically in arctic tundra dominated areas as shown on image difference. The rate of change was +0.44%/yr over Yamal Arctic. For south of 70 degree north from 1982-2005, the rate of change was +0.34%/yr over the region. Vegetation productivities increase from north to south along bioclimatic gradient, therefore, NDVI is much higher in areas below 70 degree north compared to entire tundra biome. Meanwhile, the changes were heterogeneous over each region. The greatest greening trends were observed in the areas between high and low arctic, especially on islands and peninsulas, while there were less changes in polar desert in the north and shrub tundra in the south in term of peak values. The rate of greening detected here was higher than that reported in previous studies. This is likely due to two reasons: 1) we restricted our study area in tundra biome only with a phenological tundra-taiga boundary identification approach; therefore, there was less chance to mix information of boreal forest in the south; 2) we applied homogenous vegetated area approach to avoid noise from lakes and bare ground and more likely detect initial changes over tundra vegetation.

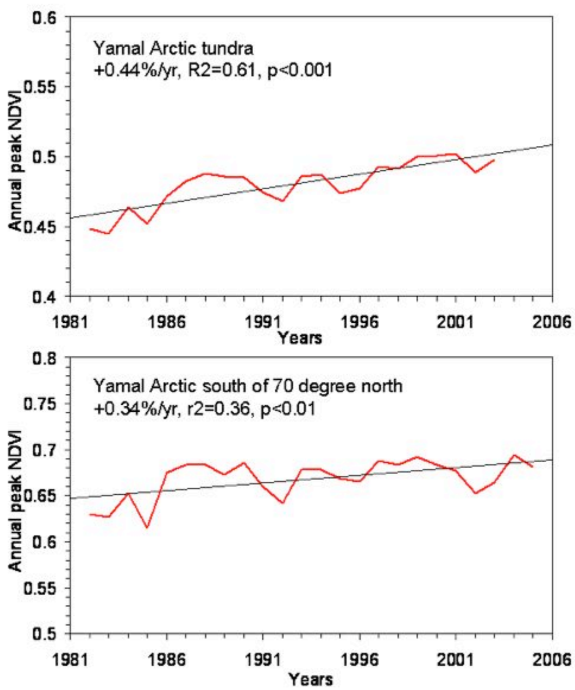


Figure 7. *Changes of annual peak vegetation greenness (NDVI) over the entire Yamal region from 1982-2003 (top) and below 70° N from 1982-2005 (bottom) as detected by NOAA AVHRR time series data. Annual peak NDVI represents the maximum NDVI values for each year. Black lines represent linear trends. Data quality is low beyond 70 degree north for 2004-2005 due to calibration errors. There are general trends of greening over the period. The trend is +0.44%/yr (r^2=0.61, p<0.001) over the entire region from 1982-2003 and +0.34%/yr (r^2=0.36, p<0.01) south of 70° N from 1982-2005.*

There were changes in phenological patterns over tundra biome in the two decades as well. Increases of vegetation greenness were observed in most of the summer periods in low arctic and mid-summer in high arctic. Peak greenness appeared earlier in high arctic and declined slower after peak in low arctic. Generally, tundra plants were having longer and stronger photosynthesis activities.

Climate-Sea Ice Analysis (Uma Bhatt and Joey Comiso):

Recent dramatic reductions in summer sea ice and especially the perennial ice have been documented (Comiso, 2002; Stroeve et al., 2006) and are of growing concern because of how they may impact the ecosystem at high latitudes. The expected changes include the thawing of the permafrost, changes in soil characteristics, changes in vegetation, and changes in the habitat and migration characteristics of fauna. It is hypothesized that an earlier ice melt forces atmospheric and land surface temperatures changes, leading to increased summer warmth and enhanced greenness of vegetation. Our study requires large scale and pan-Arctic changes and hence the need to utilize satellite data. The strategy is to use ice cover data derived from historical passive microwave data; surface temperature data derived from historical thermal infrared data, and NDVI data derived from visible channel data in the red and near infrared wavelengths. NDVI, which is the ratio of the difference and sum of the latter channels, has been used as a measure for greenness in vegetation.

Recent activities include improvements in the quality of the satellite surface temperature data sets through more effective cloud masking techniques and through improved consistency in calibration through the utilization of in situ surface temperature data. Improvements in the temporal consistency of NDVI is also attained through utilization of the albedo of a study area in the northern part of Greenland as the baseline and is assumed constant.

To investigate the nature of these relationships, climate analysis techniques are applied to high-resolution passive microwave sea ice concentration and AVHRR land surface temperatures to evaluate the direct relationship between coastal ice and the adjacent land. The analysis employs 25 km resolution SSMI passive microwave Sea Ice Concentration (Comiso 1999) and AVHRR Surface Temperature (Comiso 2006, 2003) covering the 26-year period from January 1982 to December 2007. The spatial variations of the climate-vegetation relationships are examined by performing analysis on the Yamal both regionally (Treshnikov 1985) in a 50-km terrestrial zone along the Arctic and for specific sites (Kharasavey, Vaskiny Dachi, Laborovaya, and Nadim). These relationships are compared and contrasted with those of the North American Transect.

We find a relationship between sea ice cover and nearby land surface temperatures that is generally consistent with the notion that cooler land surface temperatures are found with above average ice conditions (Figure 8). For the Yamal, a regional analysis reveals that spring sea ice is decreasing, the Summer Warmth Index (SWI-degree months above 0 ˚C) is increasing, and NDVI displays no trends. Variations in the Kara-Yamal region are more closely associations with the North Atlantic Oscillation, a large-scale climate variability measure. SWI and ice area are significantly negatively correlated while correlations with NDVI are weak. Site specific analysis reveals small differences between the various stations for ice and SWI variability. In contrast, over the North American transect, the regional analysis displays strong upward NDVI trends and a large differences between individual sites. The North American Transect is more closely associated with variations of the Pacific Decadal Oscillation. A direct relationship between sea ice and vegetation greenness has not been established yet and our analysis suggests there exists a fairly complex set of interactions. During the evolution of the growing season, there are times when the local circulation plays a more important role than the large scale circulation. We are attempting to quantify the relative impacts of these two scales of atmospheric forcing on the productivity of tundra vegetation.

Future work will include lag analysis and regression techniques to further analyze the impact of the retreating ice cover to the Arctic vegetation, using the newly calibrated NDVI and the enhanced surface temperature data. We will also investigate such relationships in other regions, including NDVI in Alaska and the Canadian Archipelago versus sea ice in the Chukchi and Beaufort Seas. Multivariate analysis and neural network will be applied, if necessary, to identify the parameter that is most sensitive to changes in the Arctic vegetation.

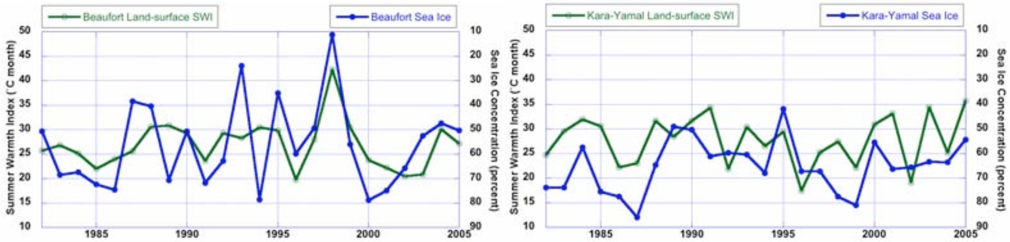


Figure 8. *Time series of land-surface temperature (LST) Summer Warmth Index (SWI, thawing degree months) and June-July (week 25-29) sea ice concentration in a 50-km zone over the land and ocean, respectively. Left panel displays the Beaufort Sea and right panel displays the Kara-Yamal region. Note that se- ice concentration scale is reversed. SWI and sea-ice concentration are negatively correlated (-0.43 for Kara-Yamal and -0.59 for Beaufort) with a significance at the 95% level or greater. Also note the greater range of variation of sea-ice concentrations and LST in the Beaufort than in the Yamal region.*

c. NDVI-LAI-Biomass-Foliar Nutrients on the Yamal Peninsula (Howie Epstein, Patrick Kuss, Elina Kaarlejärvi,Georgy Matyshak)

The LAI of vascular plants declined from an average of 1.08 m^2 m^{-2} at Nadym to 0.36 at Vaskiny Dachi along the 5° latitudinal transect (Figure 9). NDVI values of the tundra vegetation did not decline with latitude and were 0.60 for Nadym, 0.67 for Laborovaya and 0.58 for Vaskiny Dachi. This is likely due to the contribution of non-vascular, understory vegetation to the NDVI signal. Related, average foliar nitrogen concentrations were greatest at Laborovaya, the site with the highest NDVI. Average tundra vegetation biomass decreased with latitude from 1130 g m^{-2} at Nadym to 636 g m^{-2} at Laborovaya and 451 g m^{-2} at Vaskiny Dachi. Biomass was linearly related to LAI (r^2 = 0.60), but not so to NDVI; outliers for Nadym showed lower than expected NDVI values, probably due to the dominance of highly reflective lichens. A key result is that, even along this transect of approximately 500 km, the heterogeneity of vegetation properties within a location can be greater than that over the entire transect.

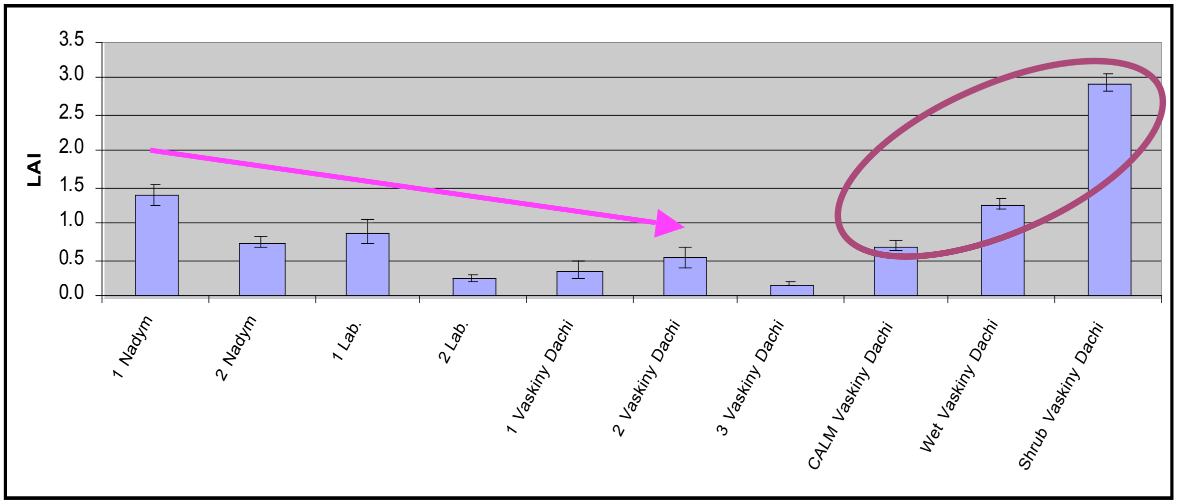
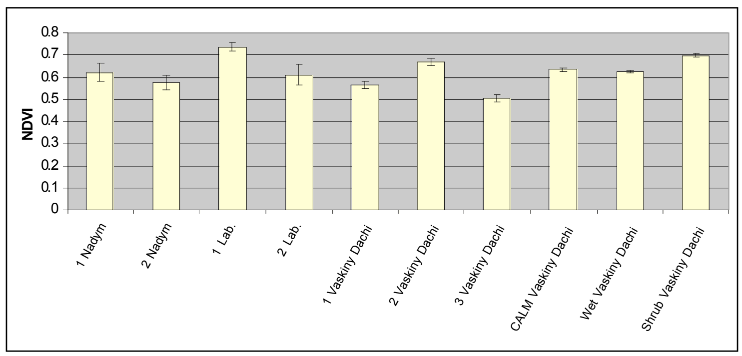
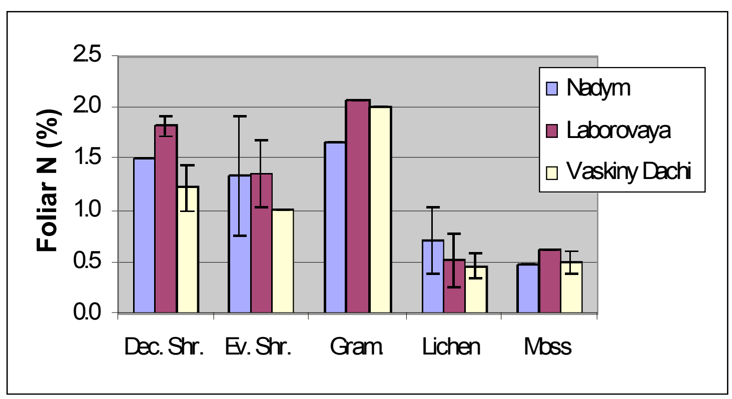


Figure 9. *Trends in LAI (above), NDVI (right), and foliar nitrogen (right below) along the Yamal transect.*





d. Modeling (Howie Epstein, Qin Yu, Jed Kaplan, Heike Lischke, Ben Cook): Vegetation response along the Yamal Transect and comparison with the North American Arctic Transect.

BIOME4 (Jed Kaplan)

Modeling activities in the second year of the project included publication of preliminary results (Epstein et al., 2007), continued work on identifying model weaknesses and improving key physical process representations, and application of a new model specifically used for assessing tree species migration (TreeMig).

Our work on improving the BIOME4/LPJ Dynamic Global Vegetation Model (DGVM) with a specific emphasis on capability to model Arctic and subarctic vegetation led to the development of a new DGVM. This model is substantially based on LPJ and the NCAR CLM3.5 land surface scheme. To improve on the representation of permafrost, the land cover scheme includes 17 soil layers that extend to more than 100m depth. With this new model we have greatly improved our representation of soil heat and water flux and are able to simulate, e.g., permafrost dynamics. This is especially important for the comparison of the North American Arctic Transect (NAAT) and the Yamal regions, where vegetation dynamics are heavily influenced by permafrost and the different soil textures in these contrasting areas.

Using site-level soil and snow temperature profiles, collected by NEESPI collaborator V. Romanovsky, and the newly available 12.5 km remote-sensing based surface temperature dataset produced by J. Comiso, we are in the process of evaluating model performance at a variety of individual sites and across the entire Arctic domain. We expect that during 2008 we will be able to demonstrate the effectiveness of our new soil scheme and test the model performance at both the NAAT and Yamal regions. Through model simulations under a variety of scenarios, we will illustrate the importance of both climate change and human impact on soil and vegetation dynamics in these regions.

We have also taken a different modeling approach to investigate the role of plant migration on future land cover change at the polar treeline in the NEESPI region. We applied the TreeMig dynamic, spatio-temporal vegetation model along a latitudinal transect in central Eurasia to estimate the effect of climate warming on the northward encroachment of the boreal forest into areas currently occupied by tundra (Figure 10). Dispersal-limited model simulations indicate that particularly under scenarios of intense future climate warming in the Arctic, vegetation remains out of equilibrium with climate for several centuries, with the northward advance of the treeline retarded by several hundred km. Model results in Figure 10, along with preliminary results from the BIOME4 model were published in 2007 (Epstein et al., 2007).

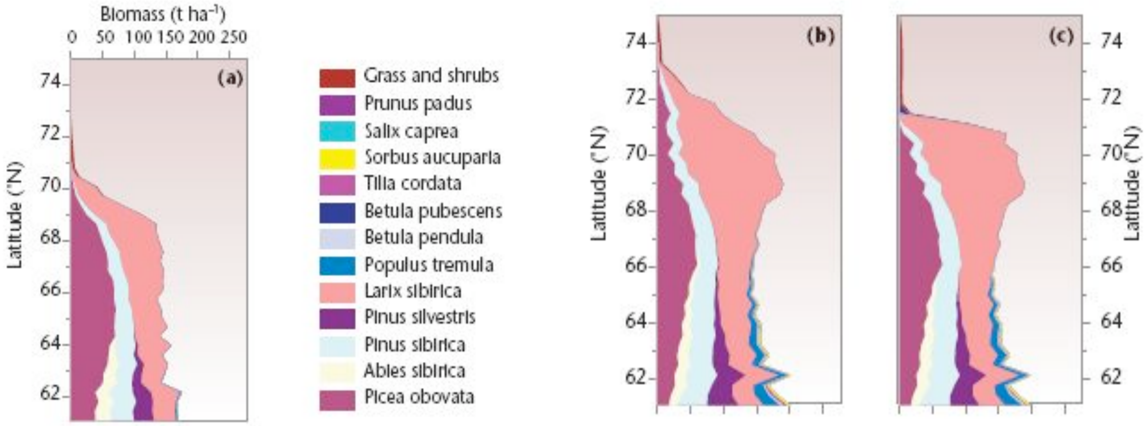


Figure 10. *TreeMig results. (a) Present distributions of tree biomass along a climate gradient in Russia. (b) Tree species biomass with 2.5˚C spring-summer warming and 7.5˚C fall-winter warming with succession only (viable seeds of all species are available all along the transect). (c) Same climate warming with succession and migration (migration of tree propagules required). The treeline advance is approximately 235 m/year with succession only and 177 m/yr in the succession – migration experiment (Epstein et al. 2007).*

ArcVeg (Howie Epstein)

For the ArcVeg modeling effort, in 2007 we generalized the plant functional types in the model to categories that would be appropriate circumpolarly. We developed a set of twelve plant functional types including: mosses, lichens, forbs, rushes, grasses, tussock-forming sedges, non-tussock-forming sedges, high arctic evergreen shrubs, high arctic deciduous shrubs, low arctic evergreen shrubs, low arctic deciduous shrubs, and tall shrubs. We completed the new parameterization for these twelve plant functional types, and validated the new version with biomass data from each of the five arctic subzones (A-E), using data collected during a prior project in Alaska and Canada. The model results and field data are relatively consistent both on the species level and in total biomass, indicating our model is making reasonable predictions (Figure 11).

Due to a present lack of soil organic nitrogen (SON) data from the Yamal region, we extrapolated SON for the Yamal using field data from Alaska and soil organic nitrogen data from an IGBP global soil survey. We also assumed that for the Yamal region, the managed reindeer graze more intensely and more frequently than do the caribou of North America. These differences are reflected in our simulation parameters for the Yamal region. We assumed that Subzones C, D and E (Mid- and Low-Arctic) are grazed more intensely than Subzones A and B (polar desert and High Arctic), which are off the mainland of the Yamal peninsula. We used two parameter combinations: for North America and Subzones A and B in Yamal, (0.1, 25%), indicating the system would be grazed every ten years, and 25% of plant biomass was removed by grazing; for Subzones C, D and E in Yamal, (0.5, 50%), indicating that 50% of plant biomass is removed every two years. In general, tundra in both North America and the Yamal for all subzones responds to climate warming scenarios with increasing total aboveground biomass. In both regions, woody plant biomass increases with warming. In Subzones C, D and E in the Yamal region, there are fewer abundant plant functional types and less biomass compared to the same Subzone in North America, due to heavy grazing by reindeer herds. Frequent grazing also increases the interannual variability in tundra primary productivity.

In the final year of the project, we will incorporate the actual soil data from the Yamal into the model, improve the reality of the grazing subroutine in the model, and conduct a rigorous sensitivity analysis of the effect of grazing on tundra productivity and functional type composition.

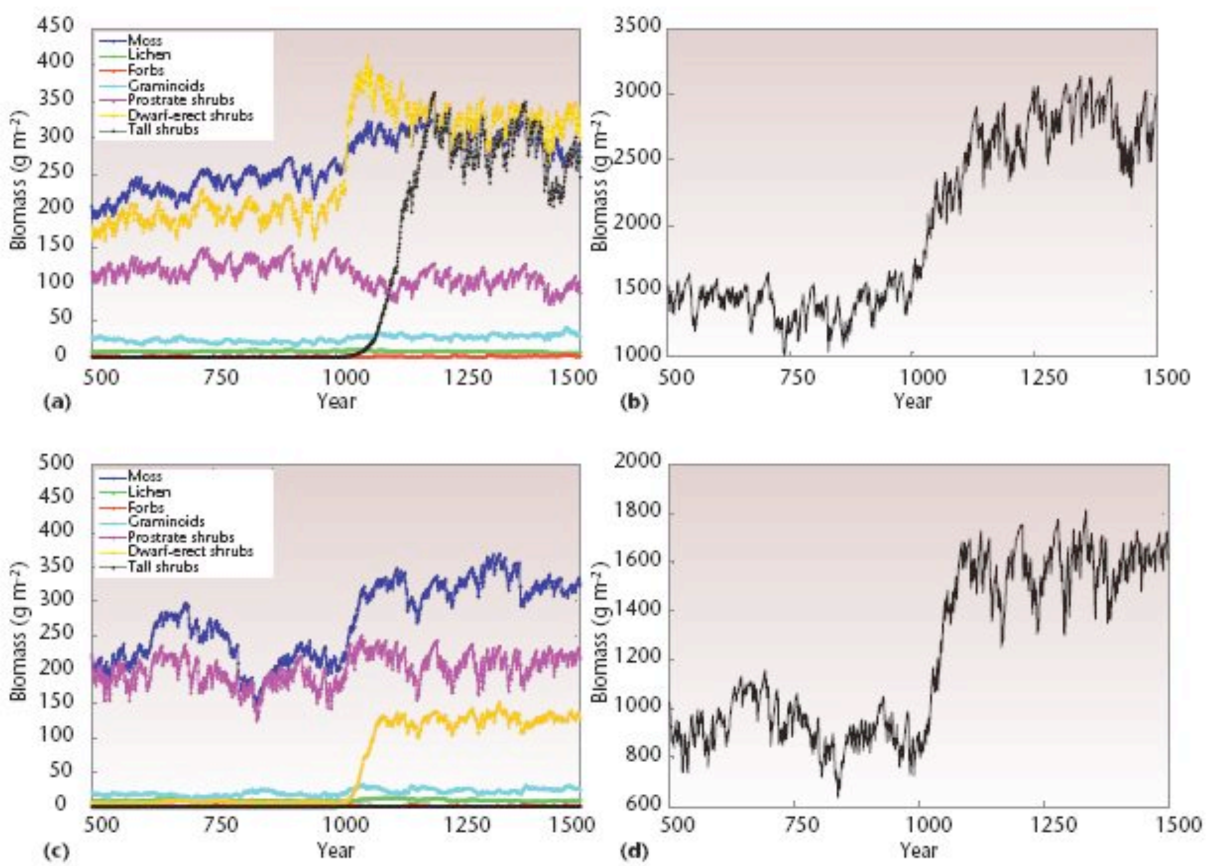


***Figure 11**. Examples of ArcVeg simulations for subzones E and D with climate warming on the Yamal Peninsula.*

d. Soil temperature and permafrost monitoring the Yamal Peninsula (Vlad Romanovsky, Nataliya Moskalenko, Marina Leibman)

During the summer 2007 field season, 15 soil temperature measurement sites were established (9 at the Nadym research area, 3 at the Laborovaya, and 3 at the Vaskiny Dachi research sites) (Table 1). Each site consists of one to three HOBO U23 mini data loggers with two temperature sensors each. Sensors were installed in the ground at different depth ranging from the ground surface (0.01 m) to 1.5 m (Figure 12). Temperature is measured every 3 hours and stored into the loggers memory. Twenty-six mini loggers were installed (14 in Nadym, 6 in Laborovaya, and 6 in Vaskiny Dachi). Temperature readings will be collected from the loggers during the 2008 field season. Historical data from the existing five permafrost monitoring boreholes were collected for the Nadym area from loggers placed in previous years (Figure 13).

Figure 12. *Installation of the temperature sensors and mini loggers at the ND PiCla site.*

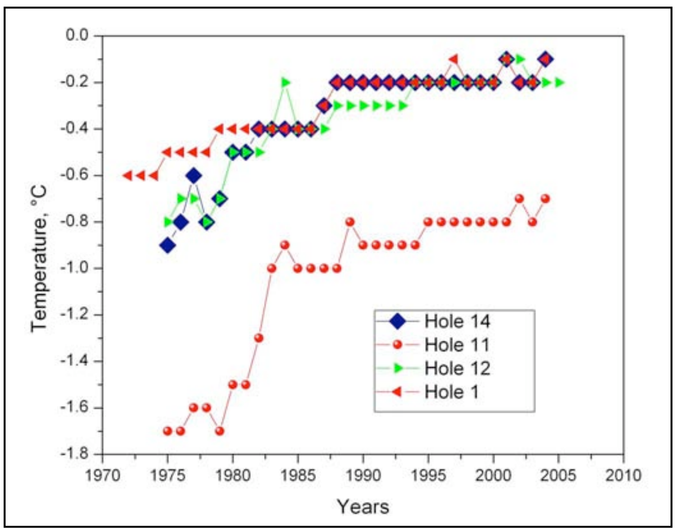


Figure 13. *Results of temperature measurements at 10-m depth in the different vegetation zones of the Nadym research area. Data provided by Dr. N. Moskalenko.*

Table 1. *Hobo data loggers installed along the Yamal transect in summer 2007.*

Research Locations	Transect Coordinates	HOBO #	Depths, cm	Coordinates
ND2-1,2,3	Forest grid (Skip)	1039818 1061042 1061037	Surface (0.01 m), Air 25, 50 100, 150	N65° 18' 48.2" E72° 53' 13.9"
ND3-1,2,3	Center of the CALM grid	1039821 1061053 1061049	Surface (0.01 m), Air 25, 50 100, 150	N 65° 18' 52.8" E 72° 51' 46.5"

ND3-4	CALM grid, D10	1061045	92, 142	N65° 18’ 52.1” E72° 51’ 42.5”
ND PiCla	2nd terrace, lichen field	1039819 1061046	Surface (0.01 m), 50 100, 150	N65° 18’ 19.8” E72° 53’ 31.3”
ND Pingo	Residual surface	1039814	Surface (0.01 m), 59	N65° 17’ 57.0” E72° 53’ 04.2”
ND hole #11	3rd terrace	1039817	Surface (0.01 m), 59	N65° 18’ 54.5” E72° 52’ 28.3”
ND hole #THA	3rd terrace	1093624	Surface (0.01 m), 54	N65° 18’ 59.9” E72° 51’ 43.2”
ND hole #23a	3rd terrace	1061041	Surface (0.01 m), 129	N65° 18’ 52.9” E72° 51’ 40.4”
ND hole #1	3rd terrace	1061048	Surface (0.01 m), 150	N65° 18’ 31.1” E72° 49’ 26.3”
LB 1/1	T09+28	1061043 1061038	0, 8 (under organic) 50, 90	N 67° 42’ 24.4” E 67° 59’ 57.3”
LB1/2	T13-45	1061051 1061039	0, 8 (under organic) 50, 99	N 67° 42’ 23.7” E 68° 00’ 01.3”
LB 2	T16-25	1061036 1061040	0, 8 (under organic) 50, 100	N 67° 41’ 41.9” E 68° 02’ 17.0”
VD 1	T23+28	1039816 1061050	6 (under dead moss), 25 50, 90	N 70° 16’ 31.8” E 68° 53’ 29.9”
VD 2	T23-28	1039812 1061047	3.5 (under organic), 25 50, 100	N 70° 17’ 43.8” E 68° 53’ 00.5”
VD 3	T29-05	1093629 1039827 1039823	0, 25 25, 50 25, 100	N 70° 18’ 05.0” E 68° 50’ 28.7”

V. Plan for 2008 field season

The original plan for the 2008 field season included sampling at Marresale, Kharasavey, and Belyy Ostrov. Several things have occurred during the last year that makes this plan not feasible. First the cost of helicopter travel on the Yamal has increased considerably due to the devaluation of the dollar, increased fuel costs, and substantial increases in hourly charges from the helicopter company. Secondly, the person that was to act as camp manager for the expedition, Sergei Vasiliev, was seriously injured in an automobile wreck and is not expected to recover in time for the 2008 field season. We have investigated other methods of getting to the field sites including ship, but these would also cost more than our current budget allows.

We are considering two alternatives: (1) Cancel the 2008 field season altogether and conserve the funds for 2009 and apply for a supplement that would provide us sufficient funds to visit at least two of the remaining field sites. (2) Sample only the Kharasavey site in 2008. This may be feasible because Kharasavey is a village that could provide us lodging, meals, and lab space – making a field camp unnecessary. This site is also at the place where helicopters refuel regularly and it may be possible to schedule our field season to take advantage of other expeditions that would be traveling through Kharasavey. With this alternative we would also want to apply for a supplement so that we could sample the High Arctic sites of Belyy Ostrov and either Franz Josef Land or Novaya Zemlya in 2009. This is our preferred alternative.

VI. Publications

Journal articles and book chapters:

Cook, B.I., G.B. Bonan, S. Levis, and H.E. Epstein. 2007. Rapid vegetation responses and feedbacks amplify climate model response to snow cover changes. ***Climate Dynamics*** doi:10.1007/s00382-007-0296-z.

Cook, B.I., G.B. Bonan, S. Levis, and H.E. Epstein. The thermal insulative effect of snow in the climate system. ***Climate Dynamics*** in press.

Epstein, H.E., J.O. Kaplan, H. Lischke, and Q. Yu. 2007. Simulating future changes in arctic and sub-arctic vegetation. ***Computing in Science and Engineering*** 9:12-23.

Epstein, H.E., D.A. Walker, M.K. Raynolds, G.J. Jia, and A.M. Kelley. Phytomass patterns across the full temperature gradient of the arctic tundra. ***Journal of Geophysical Research -Biogeosciences*** in press.

Jia, G.J., H.E. Epstein and D.A. Walker, 2008, Vegetation greening in the Canadian Arctic related to warming, ***Journal of Geophysical Research - Biogeosciences*** (Submitted).

Kumpula, T., Forbes, B. & Stammler, F. 2006. Combining data from satellite images and reindeer herders in arctic petroleum development: the case of Yamal, West Siberia. ***Nordia Geographical Publications*** 35, 17-30.

Raynolds, M. K., J. C. Comiso, D. A. Walker, D. Verbyla. 2008 (in press). Relationship between satellite-derived land surface temperatures, arctic vegetation types, and NDVI. ***Remote Sensing of Environment***

Raynolds, M. K. in press 2007. Relationship of permafrost characteristics, NDVI, and arctic vegetation types. *Ninth International Conference on Permafrost*.

Richter-Menge, J., Overland, J., Proshutinsky, A., Romanovsky, V., Bengtsson, L., Brigham, L., Dyurgerov, M., Gascard, J.C., Gerland, S., Graversen, R., Hass, C., Karcher, M., Kuhry, P., Maslanik, J., Melling, H., Maslowski, W., Morison, J., Perovich, D., Przybylak, R., Rachold, V., Rigor, I., Shiklomanov, A., Stoeve, J., Walker, D., Walsh, J. 2006. ***State of the Arctic Report***, 36 pp, NOAA/OAR/PMEL, Seattle, WA.

van Bogaert, R., D. Walker, G.J. Jia, O. Grau, M. Hallinger, M. De Dapper6, C. Jonasson, T.V. Callaghan, 2007, Recent changes in vegetation, ***NOAA State of Arctic 2007***. (http://www.arctic.noaa.gov/reportcard/essay_vanbogaert.html)

Walker, D. A., H. E. Epstein, W. A. Gould, C. L. Ping, V. E. Romanovsky, Y. Shur, C. T. Tarnocai, R. P. Daanen, G. Gonzalez, A. N. Kade, A. M. Kelley, W. B. Drantz, P. Kuss, N. V. Matveyeva, G. J. Miochaelson, C. A. Munger, D. J. Nickolsky, R. A. Peterson, M. K. Raynolds, and C. M. Vonlanthen. 2008 in press. Arctic patterned-ground ecosystems: a synthesis of studies and models along a North American Arctic transect. ***Journal of Geophysical Research – Biogeosciences***.

Published abstracts:

Bhatt, U S, D Walker, M. Raynolds and J. Comiso, 2007: The Relationship Between Sea Ice Variability and Arctic Tundra on the Pan-Arctic, Regional and Site Scales, Poster U41C-0612, Eos Transactions, Fall AGU meeting, San Francisco California.Jia, G.J., H.E. Epstein, D.A. Walker, 2007, Trends of vegetation greenness in the arctic from 1982-2005, EOS Trans. AGU 88(52), Fall Meet. Suppl., B21A-0041.

Raynolds, M.K and D.A. Walker. 2006. Satellite land surface temperatures and tundra vegetation. Arctic Science Conference. Fairbanks AK, 2-4 October 2006. p 55.

Romanovsky, V.E., S S Marchenko, G Grosse, C R Duguay, M N Zheleznyak, D O Sergeev, Monitoring and Modeling of the Northern Eurasia Permafrost Dynamics, Eos Trans. AGU, 87(52), Fall Meet. Suppl., GC21B-04 INVITED, 2006.

Unpublished posters and talks:

Alcaraz, D., E. Chuvieco, and H. Epstein. Temporal trends in post-fire regeneration patterns of boreal forests using 1km AVHRR NDVI. American Geophysical Union Fall Meeting, San Francisco, CA, December 2007.

Bhatt, U.S., D.A. Walker, M.K. Raynolds, J. Comiso. 2007. Influence of Regional Sea Ice Variability on Arctic Tundra. 7th International Conference on Global Change: Connection to the Arctic (GCCA-7), Fairbanks Alaska, February 2007.

Brown, J. and V. E. Romanovsky, Status report on the International Permafrost Association,s contribution to the International Polar Year. In Proceedings of the International Conference: Earth Cryosphere Assessment: Theory, Applications and Prognosis of Alternations, Tyumen,, Russia, May 2006, Vol. 1, pp. 13-19, 2006.

Cook, B.I., G.B. Bonan, S. Levis, H.E. Epstein, and T.M. Smith. Amplification of climate model response to snow cover fraction parameterization through dynamic vegetation. American Geophysical Union Fall Meeting, San Francisco, CA, December 2006.

Epstein, H.E. Greening of the Arctic: Assessing tundra dynamics with remote sensing and modeling. Earth System Science Partnership Open Science Conference, Beijing, China, November 2006.

Epstein H.E., D.A. Walker, P. Kuss, and E. Kaarlejärvi. (1) LAI, NDVI, and vegetation biomass for Low Arctic sites in the Yamal Region of Russia (2) An overview of modeling vegetation and ecosystem dynamics in arctic tundra. NEESPI Yamal Project Meeting, Moscow, Russia, January 2008.

Jia, G.J., H.E. Epstein, and D.A. Walker. Trends of vegetation greenness in the Arctic from 1982-2005. American Geophysical Union Fall Meeting, San Francisco, CA, December 2007.

Forbes, B.C. 2006. Effects of petroleum development on reindeer herding in northwest Russia: Combining scientific and traditional knowledge. Presented at the conference: Earth System Science Partnership, Beijing, China, 9-12 November 2006.

Moskalenko N.G. Overview of vegetation, dynamics, and disturbance and recovery studies in the Nadym and Yamal areas. *Yamal Land-Cover Land-Use Change Workshop*. Moscow, 28-30 January 2008:12-13.

Orekhov P.T. Lake ecosystems in different landscapes in the Nadym region. *Yamal Land-Cover Land-Use Change Workshop*. Moscow, 28-30 January 2008:14.

Ponomareva O.E. Overview of Nadym region: Climate, zonation, physiography, geology, permafrost. *Yamal Land-Cover Land-Use Change Workshop*. Moscow, 28-30 January 2008:11.

Raynolds, M.K., Comiso, J.C. and D.A. Walker. 2006. Comparison of arctic tundra bioclimate subzones and AVHRR surface temperature, and relationship to NDVI. 9th Bi-Annual Circumpolar Remote Sensing Symposium, Seward, Alaska, 16-19 May 2006.

Raynolds, M.K., D.A. Walker and J.C. Comiso. 2008. Spatial patterns of land surface temperature and NDVI, and their relation to vegetation distribution on the Yamal Peninsula. Yamal LCLUC Conference, Moscow, Russia, 28-30 January, 2008.

Raynolds, M.K., D.A. Walker and J.C. Comiso. 2008. Circumpolar AVHRR Surface Temperature and its Relationship to Bioclimate Zones and NDVI. Conference at Komarov Botanical Institute. St. Petersburg, Russia, 5 February 2008.

Raynolds, M. K. 2007. The relationship between permafrost and the distribution of arctic vegetation types. AAAS conference, Anchorage, AK, 24-26 September 2007.

Romanovsky, V., S. Marchenko, C. Duguay, and J. Walsh, Permafrost dynamics within the Northern Eurasia region and related impacts on surface and sub-surface hydrology, NEESPI Focus Center Workshop, Fairbanks, Alaska, April 6-8, 2006.

Romanovsky, V., S. Marchenko, and J. Brown, Thermal State of Permafrost (TSP): The US Contribution to the International Network of Permafrost Observatories, NEESPI Focus Center Workshop, Fairbanks, Alaska, April 6-8, 2006.

Walker, D.A. 2006. Application of space-based technologies and models to address land-cover/land-use change problems on the Yamal Peninsula, Russia. Oral presentation at the NEESPI-CLAC meeting. University of Alaska Fairbanks, 6-8 April 2006.

Walker, D.A. 2006. Greening of the Arctic: an IPY initiative. Oral presentation at the Arctic AAAS meeting, Fairbanks, AK, 2-4 Oct 2006.

Walker, D.A., U. Bhatt, J.C. Comiso, H.E. Epstein , B.C. Forbes, G.J. Jia , J.O. Kaplan, M.O. G.P. Kofinas, Leibman, N. Moskalenko, M.K. Raynolds, V.E, Romanovsky. 2006. Application of space-based technologies and models to address land-cover/land-use change problems on the Yamal Peninsula, Russia. Poster presented at the NASA Land-Cover and Land-Use Change Science Team Meeting, University of Maryland, October 10-12, 2006.

Walker, D.A., R. Daanen, A.N. Kade, G. Michaelson, D. Nicolsky, R. Peterson, C.-L. Ping, C. Munger, M.K. Raynolds, V.E. Romanovsky, C. Vonlanthen, H.E. Epstein, A.M. Kelley, W.A. Gould, G. Gonzalez, W.B. Krantz, and C.T. Tarnocai. Interactions of physical and biological processes in the formation of small patterned-ground features across the arctic climate gradient. American Association for the Advancement of Science – Arctic Meeting, October 2006, Fairbanks, AK.

Walker, D.A., H.E. Epstein , , G.J. Jia , U. Bhatt, V.E, Romanovsky, J.C. Comiso, J.O. Kaplan, C. Markon, M.O. Leibman, N. Moskalenko, B.C. Forbes, G.P. Kofinas, C.T. Tarnocai, C.L. Ping, H.A. Maier, M. Nolan, P. Prokein, T. Heinrichs, J. Grimes, M.K. Raynolds, C. Munger, B., Sharpton, A. Balsar. 2006. Greening of the Arctic: an IPY initiative. Poster presented at ICARP II meeting, Copenhagen, Denmark, 10-12 Nov 2005.

Manuscripts in preparation:

Alcaraz, D., J. Cabello, H. Epstein, and G. Jia. Trends in the surface vegetation dynamics of the tundra and taiga network of protected areas in Eurasia as observed by satellite sensors.

Cook, B.I., H.E. Epstein, T.M. Smith, and J.O. Kaplan. Artic Oscillation and El Niño Southern Oscillation induced climate impacts and terrestrial ecosystem responses.

Goetz, S.J., F. Achard, D. Alcaraz, U. Bhatt, A. Bunn, J. Comiso, H.E. Epstein, M. Hansen, G.J. Jia, J.O. Kaplan, H. Lischke, A. Lloyd, D.A. Walker, Q. Yu. (in prep.) Vegetation productivity and disturbance changes across arctic northern Eurasia: Satellite observations and simulation modeling. Northern Eurasian Earth Science Partnership Initiative – Land Cover Land Use Change.

Forbes, B.C., T. Kumpula, A. Gubarkov, D.A. Walker. (in prep.) Applications of remote sensing to human dimension issues of land-cover change on the Yamal Peninsula, Russia. Northern Eurasian Earth Science Partnership Initiative – Land Cover Land Use Change.