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

Annual Report to NASA

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Project Goals:
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. In 2007-2008 we will establish a transect of six locations across the Yamal to investigate the combined effects of climate change and anthropogenic influences. We will investigate how vegetation changes in this heavily impacted region on poor sandy soils compares with other areas in the Arctic, especially a similar transect on loess soils with less grazing impact in North America. We are using a combination of ground-based studies, remote-sensing studies, and studies of Nenets land-use activities to help develop vegetation-change models that can be used to predict future states of the tundra. This research is in response to the Northern Eurasia Earth Science Partnership Initiative (NEESPI). It principally addresses the NEESPI science questions regarding the local and hemispheric effects of anthropogenic changes to land use and climate. Furthermore, it will use and contribute to NASA's global-change observations, particularly work exploring the consequences of the dramatic decline in the Arctic sea ice and the greening of terrestrial vegetation that is occurring in the northern latitudes. The project will combine the long-term record available through AVHRR and MODIS sensors with the most recent sensors that provide very detailed spatial and spectral information regarding land-cover/land-use change in the Arctic. The project is also the intersection of three International Polar Year (IPY) initiatives: (1) "Greening of the Arctic" (GOA), (2) "Cold Land Processes in NEESPI" (CLPN) and (3) "Circum-Arctic Rangifer Monitoring and Assessment" (CARMA).

First year activities:

There are four components of the research. In the first year, our budget was kept low ($59K) to conserve funds for the major field campaigns scheduled for 2007 and 2008 on the Yamal Peninsula, and to have a concerted focus on international planning. The principal objectives for each component in the first year were as follows:

1. *Human dimensions:* Consolidate the human-dimensions component of the project: (a) Establish dialogues with the Nenets people; (b) collect the relevant remote sensing imagery, and, (c) develop detailed plans for the 2007-2008 field campaigns with the Nenets people.
2. *Field work along the Yamal Transect:* Develop the logistic plans for field work in 2007 and 2008 that will characterize the climate, vegetation, permafrost and sols along the Yamal Transect.
3. *Remote-sensing:* Coordinate the remote-sensing components of the project: (a) Examine the general sea-ice conditions and the controlling climate patterns in the Arctic basin, with particular focus on the region surrounding the Yamal Peninsula; (b) agree on a way to subdivide the Arctic Basin for analysis of sea-land linkages;

(c) develop a land-surface temperature map of the Arctic region; (d) collect detailed imagery of each of the study's field locations; and (e) begin the analysis of circumpolar and regional changes in the normalized difference vegetation index (NDVI).

4. *Modeling:* Consolidate a modeling approach that will link the remote sensing information and history of land cover change (greening change) on the Yamal Peninsula with predictions of future change.

These objectives were discussed during five project meetings:

December 2005, San Francisco: Side meeting at the AGU meeting to introduce U.S. project participants and present goals of the project and develop first year objectives.

April 2006, University of Alaska Fairbanks: Oral presentation of the project at the NEESPI CLAC meeting with Russian participants in the project to establish Memorandum of Agreement between UAF researchers and Russian colleagues, and develop a schedule of field work for 2007-2008.

October 2006, University of Maryland: Project poster presented at the NASA LCLUC Team Meeting. Side meeting with a phone conference linked to those who could not attend to present early results of the climate analysis and to discuss progress on the sea-ice-LST-NDVI analyses.

December 2006, San Francisco: Side meeting at the AGU meeting to discuss the overall progress on the Greening of the Arctic project, and lay plans for the summer 2007, and plan a pre-field season meeting in Copenhagen.

February 2007, Copenhagen: Meeting at the Danish Polar Center to develop detailed plans for the 2007 summer field work at three sites along the Yamal transect.

Summary of progress for each project component:

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

The main work so far has been to establish the proper conditions for an appropriate dialogue with the Nenets people concerning land cover change on Yamal and their responses and adaptation strategies. The first step has been the purchase of very high-resolution Quickbird-2 satellite imagery from km 143 along road/railway corridor in subarctic tundra (CAVM subzone E) on southern Yamal Peninsula (Image date 11 July 2005). After examination, it has been decided to purchase supplementary archival Quickbird-2 data, to augment the original image in order to include more terrain characterized by upright shrubs from late lying snow patches and riparian areas (*Alnus fruticosa*, *Salix lanata*, *S. glauca*, etc).

Initial consultations with Baidaratski sovkhoz personnel took place in November 2006 led by Dr. Florian Stammler from the ENSINOR project Arctic Centre, University of Lapland (Figs 1 and 2). Contact was made with Mr. Sergei Khudi employed by Yamaltransgas, Department for Ecology and Labour, Health and Safety, Labytnangi, YNAO. This is the regional affiliate for the state gas monopoly, Gazprom. Mr. Khudi is a local Nenets from the Baidaratski sovkhoz and expressed strong interest in the ENSINOR project and related research from the NEESPI project. The Baidaratski sovkhoz has experienced a number of impacts associated with the petroleum development and is eager to explore future scenarios that would accommodate mutual coexistence of oil & gas development with reindeer herding. As such, he is willing to make introductions to herders within the sovkhoz who may be knowledgeable about recent environmental changes. Mr Khudi will be invited to visit Arctic Centre in Rovaniemi in March 2007 to plan summer fieldwork with the participation of Nenets reindeer herders from Baidaratski sovkhoz. He will suggest initial brigades and families to make contact with. He has also offered to help with the increasingly stringent requirements to obtain permission for access to the tundra.

Figure 1. 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.*

Figure 2. Nenets herders and Florian Stammler reviewing satellite images, Yamal Peninsula. *Photo: Bruce Forbes.*

The main ENSINOR team will plan to be at km 143 in early-mid July in to overlap with the peak of the growing season in order to survey vegetation cover classes and shrub growth in approximately the same phenological state as captured by the Quickbird-2 image from 11 July 2005. A preliminary reconnaissance trip will be made in May when many of the reindeer brigades must cross the railway/road corridor near Laborovaya en route to their summer pastures near the coast of Baidaratski Bay. The purpose will be determine which brigades have been most affected by the development to date and to make direct contact and conduct initial consultations with them and mark their exact migration routes onto large-scale maps of the region.

In July the team will be broken into at least three sub-groups. The main group will remain within the Quickbird-2 image along the road/railway corridor to map visible cover classes in natural and anthropogenically disturbed tundra. One social anthropologist will live with non-migratory Nenets in the vicinity of the road/railway near km 143 who spend the summer mainly fishing. Another will travel to the coast of Baidaratski Bay to live with the brigades first met in May and consult in more detail with them about (i) the general condition of their spring/summer/autumn pastures; (ii) impacts related to changes observed in recent years that might be attributed to either climate or petroleum development; and (iii) their responses and adaptation strategies.

Field work along the Yamal Transect (Vlad Romanovsky, Marina Leybman, Natalia Moskalenko, and Skip Walker): Permafrost, climate, vegetation, and soil monitoring.

1. Schedule for 2007-2008. The following schedule of field work has been established for research at the locations along the Yamal Transect (Fig. 3).

Figure 3. The Yamal Transect. *Locations of the field research sites are shown as green dots.*

2007	
Jul 29-Jul 30	Fbks-Moscow
Jul 31	Moscow
Aug 1	Moscow-Nadym
Aug 2-8	Field work Nadym
Aug 9	Fly to Salekhard
Aug 10	Salekhard
Aug 11	Ferry to Labytnangh, then drive to Obskaya, drive to Km 143
Aug 12-19	Field work and Km 143 (near Laborovaya)
Aug 20	Fly to Vaskiny Dachi
Aug 21-31	Fieldwork at Vaskiny Dachi
Sep 1	Fly to Salekhard then to Moscow
Sep 2-4	Moscow
Sep 5	Fly to Fairbanks
2008 (tentative):	
Jul 29-Jul 30	Fbks-Moscow
Jul 31	Moscow
Aug 1	Moscow-Saleskhard
Aug 2	Fly to Belyy Island (Ostrov Belyy)
Aug 2-10	Field work on Belyy Island
Aug 11	Fly to Kharasavay
Aug 12-19-	Field work at Kharasavay
Aug 20	Fly to Marre-Sale
Aug 21-27	Field work at Marre-Sale
Aug 28	Fly to Vaskiny Dachi and then to Salekhard
Aug 29	Fly to Moscow
Aug 30-31	Moscow
Sep 1	Fly to Fairbanks
2009 (tentative):	
Aug 1-15	Russkaya Gavan on Novaya Zemlya or Kheisse on Franz Josef Land

2. Preliminary site selection.
Preliminary sample plots for field work in 2007 were chosen at Nadym and Vaskiny Dachi, two locations where the Russian collaborators have long experience. “Dry”, “mesic”, and “wet”, “ plots were chosen at each location to monitor biomass, active layer, NDVI and other parameters.

The Nadym site is located on lacustrine-alluvial plain composed of silty sands, with altitude ranging from 25 to 30 m. The main lithological unit is composed of sandy deposits interbedded with clays, with an occasional covering of peat. Permafrost underlies the area sporadically. Patches of permafrost are closely associated with peatlands, mires, and frost mounds. Three plots were chosen in 2006 for field work 2007 (Fig. 4).

Figure 4. Proposed sites for research at Nadym. Top: *Moist site with cloudberry-wild rosemary-Sphagnum-lichen peatland* ***Middle:*** *Hummocky tundra. Betula nana-wild rosemary-moss-lichen tundra with dry hummocks, frost boils, and pools.* ***Bottom:*** *Wet low shrub-sedge-moss mire. Photos: Natalia Moskalenko.*

Figure 5. Proposed sites for research at Vaskiny Dachi. Top*: Dry plot on hilltop with sandy-silty soils and sparse vegetation, organic layer less than 5 cm thick.* ***Middle****: Mesic plot on a high lake terrace with shrubby tundra, silty-clayey soils, organic layer up to 8 cm thick.* ***Bottom****: Wet plot on low lake terrace in wide valley bottom with sedge tundra, peat-silty soils, organic matter up to 15 cm thick. Photos: Marina Leybman.*

The "Vaskiny Dachi" site is located in the central Yamal Peninsula and occupies the top and slopes of the alluvial-marine plain. Its altitude ranges from 15 to 32 m. Altitude ranges is from 8 m of the Mordy-Yakha river flood plain to 56 m at the hilltops of the fifth "Salekhard" marine terrace. The upper portion of the lithological section at the hilltops is composed of sands and silts. Saline clays are frequent on slopes. Valley and lake bottoms are silty-peat, they are most poorly drained. The hilltops and adjacent slope facets are occupied by well-drained polygonal tundra, in combination with blowout sands. Slopes are covered by shrub tundra with abnormally tall willows, as well as poorly vegetated shear surfaces associated with modern landslides. Sloping terrain with poor to moderate drainage prevails at the Vaskiny Dachi site. Shear surfaces associated with modern landslides occupy a small portion of the slopes and are moderately to well drained. Representative Vaskiny Dachi plots are shown in Figure 5.

3. Equipment for Yamal transect. Fifteen sets of equipment for permafrost temperature measurements in relatively shallow (down to 15 meters) boreholes (4-channel Hobo U12 data loggers and temperature sensors on 6, 20 and 50 feet cables) were purchased and delivered to Russia for installation at several permafrost research sites along the Yamal transect. Some of these sets were installed during the 2006 field season. First data sets from these sites will be collected during the 2007 field season. Several deeper boreholes measurements also were accomplished in the summer of 2006 using Onset Corporation Water Pro single-sensor data loggers that were delivered to Russia in Spring 2006.

After the planning meeting in Copenhagen in February, exact number of shallow active layer soil temperature measurement sites within each of the three 2007 fieldwork locations will be nominated and necessary equipment will be purchased and delivered to Russia.

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.

Terrestrial ecosystems at high latitudes are warmth-limited and sensitive to alterations in surface temperatures and climate dynamics related to sea-ice extent and concentration. They are therefore expected to exhibit substantial changes in terms of structure and production in response to recent warming and sea-ice decline. This is especially the case for the western Russian Arctic as most of its tundra ecosystems are located either on islands in the Arctic Ocean or less than 100 km from the icy coasts.

During the first year of the project we focused on data preparation, calibration, and preliminary analysis of vegetation greenness, surface temperature, and sea ice extent and concentration. We organized two workshops and two phone conferences to discuss a common data platform including spatial and temporal resolution, map projection, division of bioclimate subzones, and so-called Treshnikov basins. We are now ready for multi-variable analysis of NDVI-temperature-sea ice interactions over each subzone and basin.

Artic Subdivisions (Martha Raynolds):

1. Arctic Ocean basins: We created a digital map in vector and grid format that divides the Arctic Ocean and surrounding lands into sections defined by Alexei F. Treshnikov, in his Atlas of the Arctic (1985) (Fig. 6). These subdivisions are being used for the analysis of sea ice and its relationship to temperature and NDVI. We also created maps of near-shore ocean (50 and 100 km distances from shore) to examine the influence of near-shore ice on land surface temperatures of adjacent land areas.
2. Bioclimate subzones: We divided the terrestrial area into bioclimate subzones as defined by Circumpolar Arctic Vegetation Map (CAVM 2003). The subzones are defined in part by long-term met-station air temperature data and comparison with the land-surface temperatures will give us an impression of where within each subzones changes are occurring most quickly.

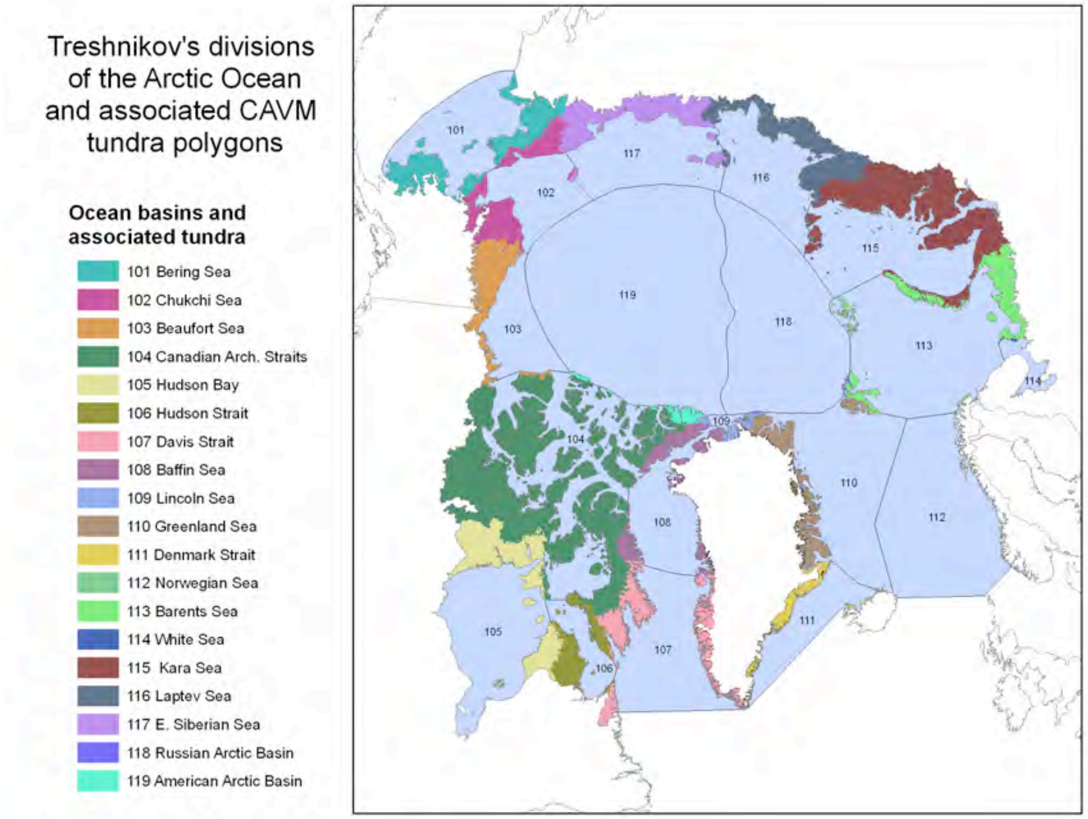


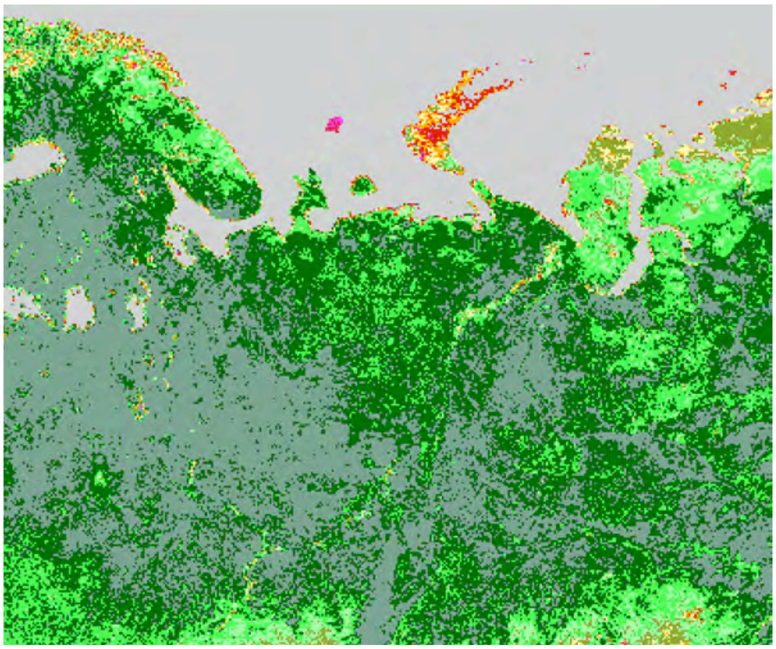
Figure 6*. Treshnikov's divisions of the Arctic Ocean and associated CAVM tundra polygons.*

Temporal vegetation greenness (Gensuo Jia):

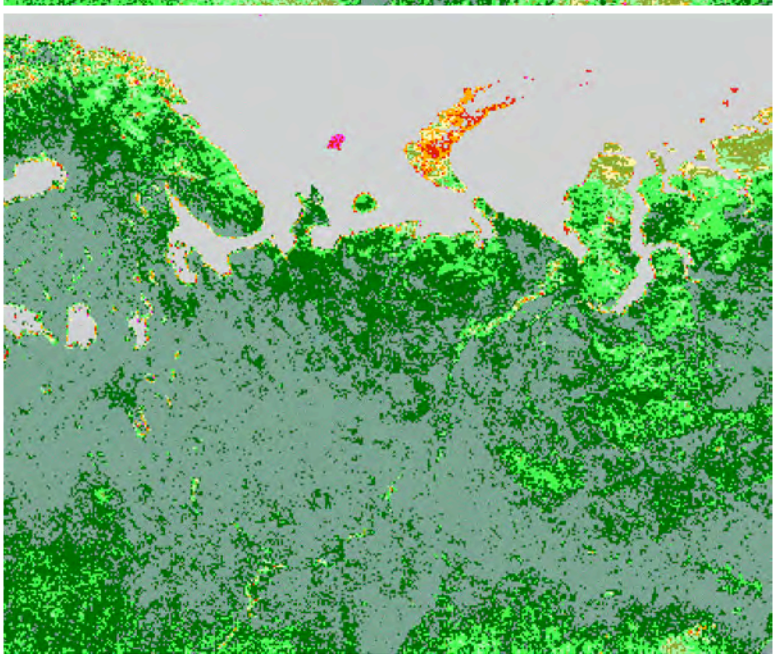
We analyzed long-term dynamics and trends of vegetation greenness using normalized difference vegetation index (NDVI) data sets derived from the Advanced Very High Resolution Radiometer (AVHRR) that provides a 23-year satellite record of bi-monthly changes in terrestrial vegetation in the region. To avoid effect of water body, snow, and bare ground, a 500m MODIS-based continuous vegetation field dataset was first used to examine the fractional covers of tundra, forest, bare ground, and lakes in the region, and then the most vegetated pixels were selected for subsequent temporal analysis. Annual peak NDVI was calculated and used for auto-regression time series analysis. The temporal analysis of AVHRR NDVI was stratified by bioclimate subzone and land cover types spanning all five bioclimate subzones. The temporal analysis is being performed over each Treshnikov basin as well. Image difference analysis was also performed over periods of 1981-1986, 1987-1992, 1993-1998, and 1999-2003 to investigate spatial patterns of the greenness variations.

Preliminary study indicates that vegetation greenness in Arctic tundra generally increased throughout the region over the past 23 years (Fig. 7). Annual peak values increased 0.52%/yr over the High Arctic where prostrate dwarf shrubs, forbs, mosses and lichens dominate and 0.33%/yr over the Low Arctic where erect dwarf shrubs and graminoids dominate. The increasing trends were almost continuous except for a short decline right after 1992 Pinatubo effect. This pattern was coincidental with an accelerated sea ice declining and increases of land surface temperature in the period (see next section). Meanwhile, there was a slight decrease (-0.07%) of NDVI in boreal forest region.

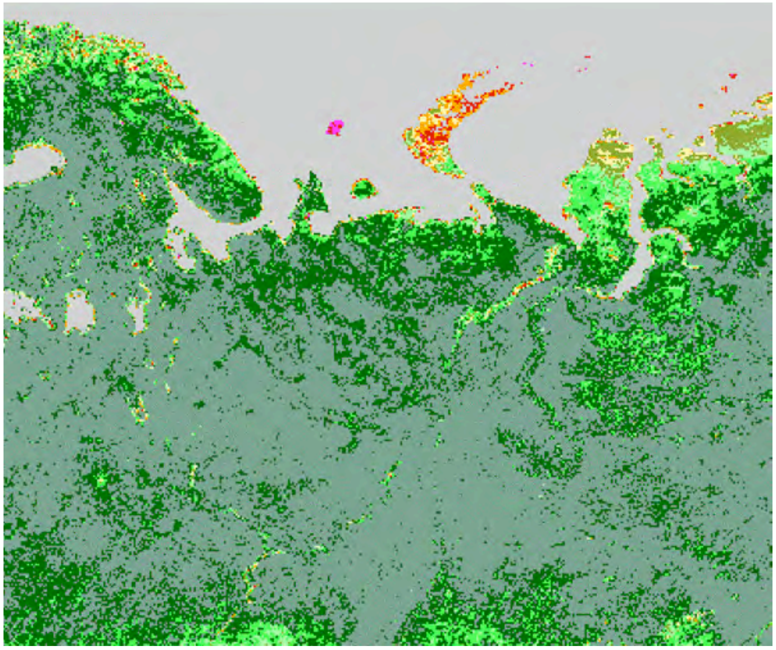
Vegetation greenness increased systematically in arctic tundra dominated areas as shown on image difference. However, the changes were heterogeneous over the region. Surprisingly, he greatest greening trends were observed in the northern High Arctic areas where the vegetation is most sparse, especially on islands and peninsulas, while there were less changes in shrub tundra in the south in term of peak values.



a) 1981-1986



b) 1987-1992


c) 1993-1998

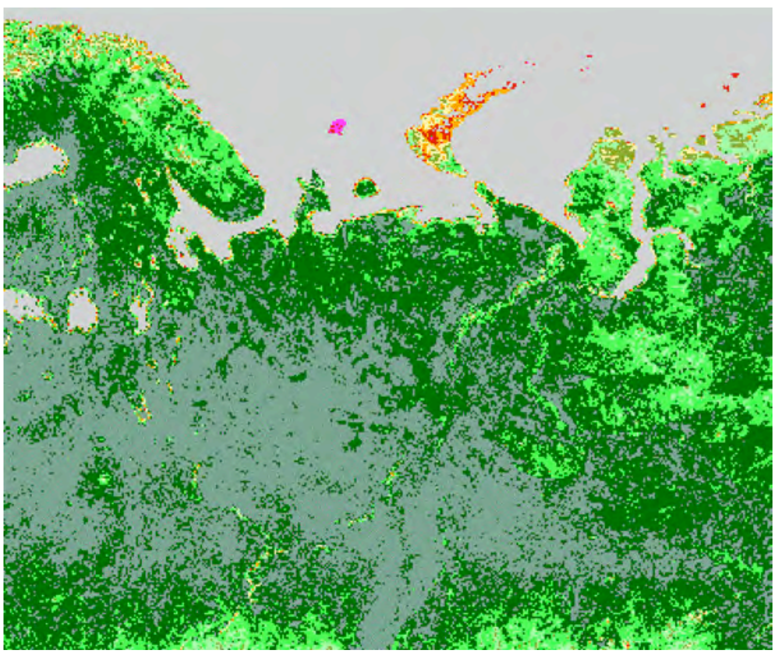

d) 1999-2003

Figure 7*. *Annual peak NDVI over the Yamal project area: *(a) 1982-1992 average, (b) 1987-1992, (c) 1993-1998, and (d) 1999-2003.*

Climate-Sea Ice Analysis (Uma Bhatt):

Recent dramatic reductions in the Arctic sea ice cover in recent years are well documented (e.g., Comiso, 2002) and are of growing concern because of how they may impact the ecosystem at high latitudes. The variability in sea ice cover is hypothesized to influence the nearby tundra vegetation by forcing atmosphere and land temperatures changes. It is hypothesized that an earlier ice melt leads to increased summer warmth, higher NDVI and enhanced greenness of vegetation.

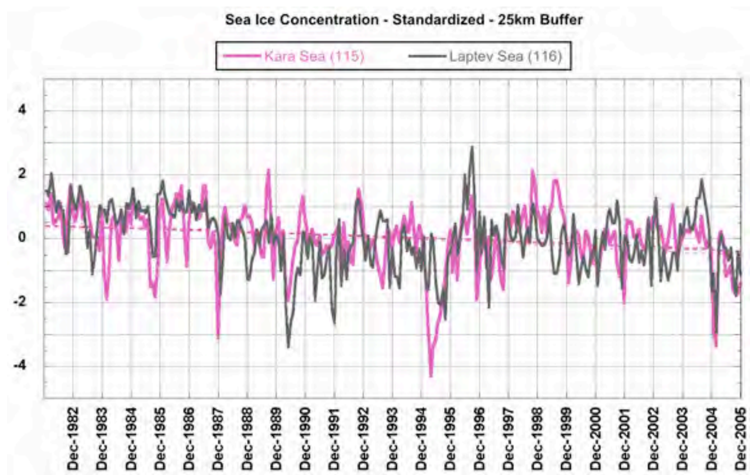


Figure 8. Standardized time series of ice concentration in a 25km zone along the coast in the Kara and Laptev Seas, as defined by Treshnikov. *Y-axis units are standard deviations from the 26-yr mean.*

To investigate this question, climate analysis techniques are applied to 25 km resolution passive microwave sea ice concentration (Comiso 1995) and AVHRR land surface temperatures (Comiso 2006, 2003) covering the 24-year period from January 1982 to December 2005 to evaluate the direct relationship between coastal ice and the adjacent land. The spatial variations of the climate-tundra relationships are examined by performing analysis regionally as defined by bioclimate subzones. Results from our preliminary analysis indicate that cooler land surface temperatures are usually found adjacent to regions where the ice conditions are above average.

The remote sensing data are divided over land into bioclimate subzones as defined by Circumpolar Arctic Vegetation Map (CAVM 2003) and over the ocean into basins as defined by Treshnikov (1985). Fig. 1 presents time series of ice concentration in a 25km zone along the coast in the Kara and Laptev Seas, as defined by Treshnikov. These ocean domains are most relevant for studying the Yamal peninsula and both show a decreasing trend in ice cover over the record of analysis.

To quantify the effect of sea ice, sea ice indices were estimated, using satellite ice concentration data, and our results show that they are highly correlated with land surface temperatures in nearby regions. The robustness of the relationships will be quantified using significance testing for all seasons and during the 25 years of available satellite data. This analysis will be repeated using weekly remote sensing data to more clearly define the strength of the relationships. The associated atmospheric circulation is also being analyzed to study how the surface parameters changes during different phases of the Arctic Oscillation and related phenomena.

Modeling (Howie Epstein and Jed Kaplan): Vegetation response along the Yamal Transect and comparison with the North American Arctic Transect.

BIOME4 (Jed Kaplan) - Modeling activities in the first year of the project centered on identifying model weaknesses and improving key physical process representations. For the BIOME4/LPJ model used by J. Kaplan (WSL) this work involved a major revision of the biophysical core of the model. After several months of work, the model improvements are nearly finished and we expect to generate important new results in 2007.

After evaluation of modeled soil temperature and moisture profiles compared to those measured in at Arctic sites, including areas along the NAAT and Yamal transects, we realized that our representation of soil heat and water flux was inadequate. This is especially important for the comparison of the NAAT and Yamal regions, where vegetation dynamics are heavily influenced by the different soil textures in these contrasting areas. The dynamics of the permafrost active layer, surface runoff, and variability in snow depth are key processes to controlling tundra vegetation development and growth. These were represented too simplistically in the two layer, uncoupled soil physics scheme used in the standard version of BIOME4/LPJ. This deficiency has been acknowledged in the BIOME4 model, and is particularly known as a limitation to correctly simulating circumarctic vegetation patterns (Kaplan et al., 2003).

To improve the representation of soil physics in the vegetation model, we surveyed the field for more sophisticated approaches. We decided that the fully coupled heat-moisture scheme used by the NCAR Community Land Model (CLM3) would be appropriate. The CLM3 model is very well documented and all of the model source code is freely available in the public domain. Using the extensive technical documentation available for the model, in 2006, the 15-layer soil and snow model was implemented into LPJ. This work has been completed as of January 2007, and we are now underway with an extensive model evaluation and test phase.

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 will evaluate model performance at a variety of individual sites and across the entire Arctic domain. We expect that during 2007 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.

ArcVeg (Howie Epstein) – The ArcVeg model is a tundra vegetation dynamics model that is driven by changes in temperature, length of the growing season and concomitant changes in soil nitrogen mineralization. The model was developed using a sparse dataset of tundra vegetation and soils collected at various sites throughout the Arctic of Alaska and Canada. The model was originally parameterized for twenty different plant types as a means of interacting with a model of caribou foraging for northern Alaska and Canada.

Our major goal for the ArcVeg model in this project is to be able to apply it to the Yamal Peninsula. In order to do that, we first felt that we should generalize 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 have just completed the new parameterization for these twelve plant functional types, and we are validating 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.

We have been able to run some preliminary scenarios for the Yamal Peninsula (Figure 8), using reduced soil organic nitrogen compared to that in the finer-texture soils of Alaska and Canada; however, we will be collecting data with which to parameterize the model for the Yamal Peninsula during our field campaign this summer. The data items that need to be collected are: soil organic nitrogen, grazing intensity, foliar nutrient contents and aboveground biomass of each of the plant functional types, for each of the Arctic subzones.

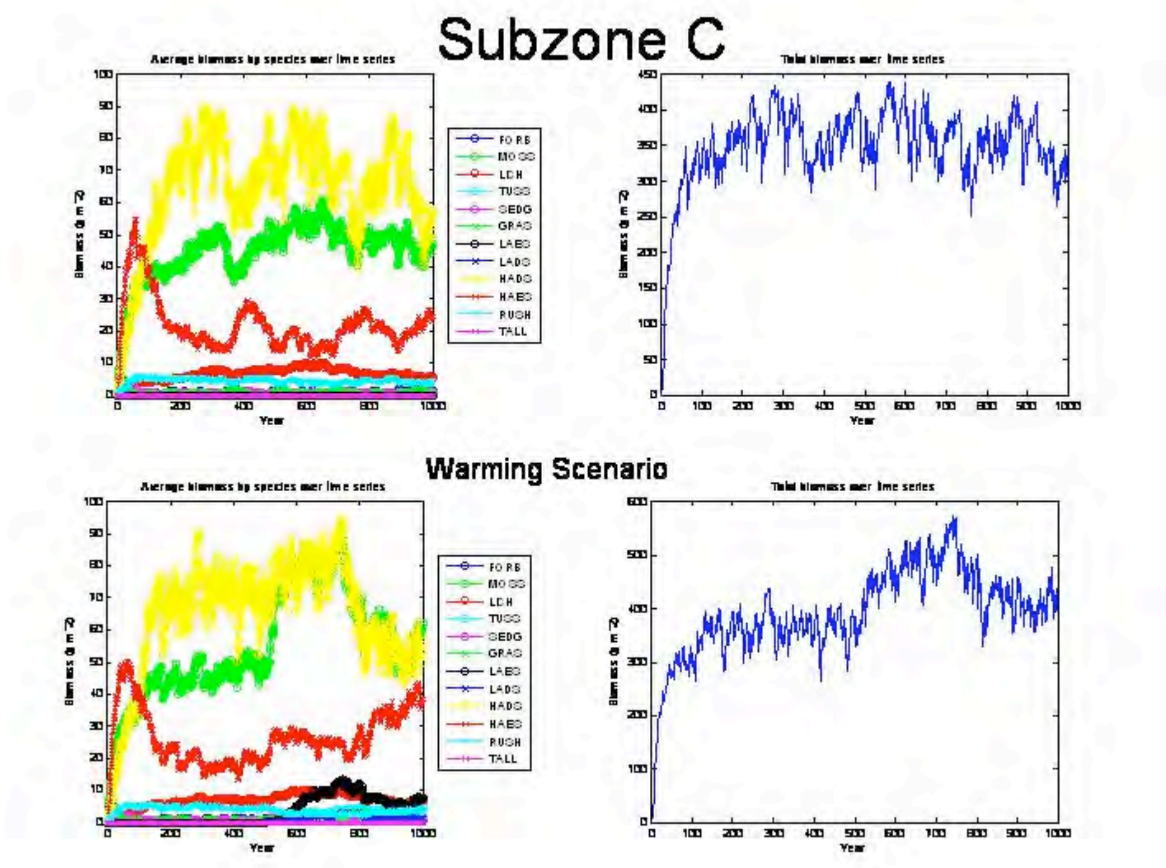


Figure 9. Simulation of vegetation dynamics for Subzone C of Yamal Peninsula with and without climate warming.

Publications, posters and talks presented during the first year:

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.

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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.

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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.

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.

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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., 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.

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