Adaptation to rapid land-use and climate changes on the Yamal Peninsula, Russia: Remote sensing and models for analyzing cumulative effects

2009-2010 Annual Report to NASA

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Abstract

This report summarizes the first year of research for the NASA-LCLUC project entitled "Adaptation to rapid land-use and climate changes on the Yamal Peninsula, Russia: Remote sensing and models for analyzing cumulative effects". The report includes summaries of field work conducted in summer 2009, a project workshop in Rovaniemi, Finland in March 2010, work completed on the major components of the study, and a list of publications to date.

Study objectives and significance

Our principal goal is to develop better, more far-looking tools to predict the cumulative effects of resource development, climate-change, and traditional land use. To accomplish this we will employ a combination of analyses and models of climate/ vegetation change with social-ecological analyses.

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. The complex interactions between a rapidly changing climate, expanding resource development, and constantly evolving social, economic and political environments make it clear that more sophisticated models and approaches are needed to help in planning for the future of the Yamal. The tools developed here will also serve to examine similar changes that are occurring elsewhere in the Arctic and help the indigenous people adapt to the impending changes.

We are using 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 research is part also component of the Northern Eurasia Earth Science Partnership Initiatvie (NEESPI).

Major Accomplishments during the first year of funding

Field work along the Yamal Transect

Field research was done at Ostrov Belyy and Kharp in July 2009 (Fig. 1). Ostrov Belly is the northernmost location in a transect that traverses the Yamal Peninsula and completes the transect through four arctic bioclimate subzones on the peninsula plus two locations in forest-tundra transitions. Three data reports describe the data collected at the research locations during three summers of field research (2007-2009) (Walker et al. 2008, 2009, 2010) (available at the web site: http://www.geobotany.uaf.edu/library/reports/yamal_2009_dr091212embDRAFTa.pdf. The 2010 data report presents the vegetation, remote sensing and environmental data collected in 2009 at Ostrov Belyy (bioclimate subzone B) and Kharp (Forest-Tundra transition). The studies at Ostrov Belyy followed the same basic procedures used at the locations visited in 2007 and 2008. The data from Ostrov Belyy included: (1) a general description of the location and study sites with photographs, (2) maps of the study sites, study plots, and transects at each location, (3) tabular summaries of the vegetation, site factors, and soils at each relevé, (4) summaries of the Normalized Difference Vegetation Index (NDVI) and leaf area index (LAI) along each transect, (5) detailed soil descriptions and photos of the large soil pits at each study site, (6) contact information for each of the participants. The expedition also established permafrost and active-layer monitoring sites at the zonal site. The data from the permafrost studies will be presented in another report that will be included in the next annual report. At Kharp, observations were conducted during a one-day reconnaissance visit at the end of the expedition, and a short report by Gerald Frost summarizes the observations. The appendices to the report include: Appendix A — Names and addresses of the participants in the expedition; Appendix B — Vascular-plant species list from Ostrov Belyy; Appendix C — Soil descriptions of study sites; Appendix D — List of birds at Ostrov Belyy; Appendix E — List of mammals at Ostrov Belyy; Appendix F — Transect photos; Appendix G — Relevé vegetation and biomass photos; Appendix H — Relevé soil photos; Log of the 2009 Ostrov Belyy Expedition.

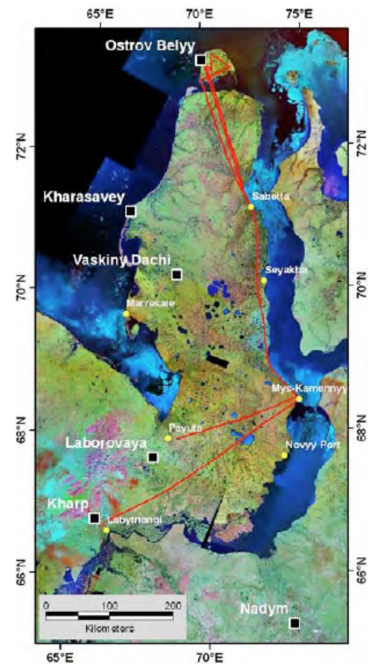

Fig. 1. Study sites along the Yamal transect (black squares). Red line shows the route of the helicopter to and from Ostrov Belyy in 2010.

Second Yamal Land-Cover Land-Use Change Workshop, Rovaniemi, 8-10 Mar 2010, and other conferences and workshops

The Second Yamal Land-Cover Land-Use Change Workshop was attended by 22 participants at the Arctic Centre, Rovaniemi, Finland, 8-10 March 2010. The agenda for the meeting is on the project web site http://www.geobotany.uaf.edu/yamal/rovMtg/agenda. The overall objectives of the workshop were to (1) review the goals of the project; (2) discuss the progress of each of the individual parts of the project; (3) adjust the goals in light of new discoveries, changing funding situation, and changing personnel; (4) discuss the 2010 and 2011 summer field seasons; (5) plan new publications and research; and take advantage of the special opportunity to meet with collaborators in NASA (Joey Comiso and Jorge Pinzon). A total of 30 presentations were made at the meeting (See "Publications, Unpublished talks and posters, citations 1-30, and the Yamal LCLUC website (http://www.geobotany.uaf.edu/yamal/rovMtg/posters).

In addition, we have made presentations at several other conferences and workshops including the 2009 and 2010 LCLUC All Scientists meetings (unpublished talks and posters citations 31-43), the Fall AGU meeting in San Francisco (Dec 2009), the State of the Arctic Meeting in Miami (Mar 2010), and the IPY Oslo Science Conference (Jun 2010). (See published abstracts, citations 1-16.)

Summaries from the each component of the project:

a. Human dimensions and analysis of shrub growth (Bruce Forbes):

A major publication regarding the resiliency and adaptation of the Nenets people to change was published and featured in the *Proceedings of the National Academy of Science* (Forbes et al. 2009). The Yamal includes a tightly integrated arctic social-ecological system (SESs). In contrast to northern Alaska and Canada, most terrestrial and aquatic components of West Siberian oil and gas fields are seasonally exploited by migratory herders, hunters, fishers, and domesticated reindeer (*Rangifer tarandus* L.). Despite anthropogenic fragmentation and transformation of a large proportion of the environment, recent socioeconomic upheaval, and pronounced climate warming, we find the Yamal-Nenets SES highly resilient according to a few key measures. The article details the remarkable extent to which the system has successfully reorganized in response to recent shocks and evaluates the limits of the system's capacity to respond. However, expansion of infrastructure, concomitant terrestrial and freshwater ecosystem degradation, climate change, and a massive influx of workers underway present a looming threat to future resilience.

Another part of this project component examined the correspondence between the growth rings of shrub willows and the summer air temperatures in the vicinity of the Yamal Peninsula (Forbes et al. 2010). Annual ring growth of an abundant and nearly circumpolar erect willow (*Salix lanata* L.) from the coastal zone of the northwest Russian Arctic (Nenets Autonomous Okrug) were correlated with station data from numerous sites in northwestern Siberia and Europe. The resulting chronology is strongly related to summer temperature for the period 1942–2005. Remarkably high correlations occur at long distances (41600 km) across the tundra and taiga zones of West Siberia and Eastern Europe. There is a clear relationship with photosynthetic activity for upland vegetation at a regional scale for the period 1981–2005, confirming a parallel 'greening' trend reported for similarly warming North American portions of the tundra biome. The standardized growth curve suggests a significant increase in shrub willow growth over the last six decades. These findings are in line with field and remote sensing studies that have assigned a strong shrub component to the reported greening signal since the early 1980s. Furthermore, the growth trend agrees with qualitative observations by nomadic Nenets reindeer herders of recent increases in willow size in the region. The quality of the chronology as a climate proxy is exceptional. Given its wide geographic distribution and the ready preservation of wood in permafrost, S. lanata L. has great potential for extended temperature reconstructions in remote areas across the Arctic.

These results were summarized in an invited talk at the 2010 NASA LCLUC All Scientists Meeting in Bethesda, MD (Forbes et al. 2010 unpub.)

b. Sea-ice, climate, land-surface temperatures, and NDVI characterization (Uma Bhatt, Skip Walker, Martha Raynolds, Jiong Jia, Howie Epstein, Jorge Pinzon, Joey Comiso).

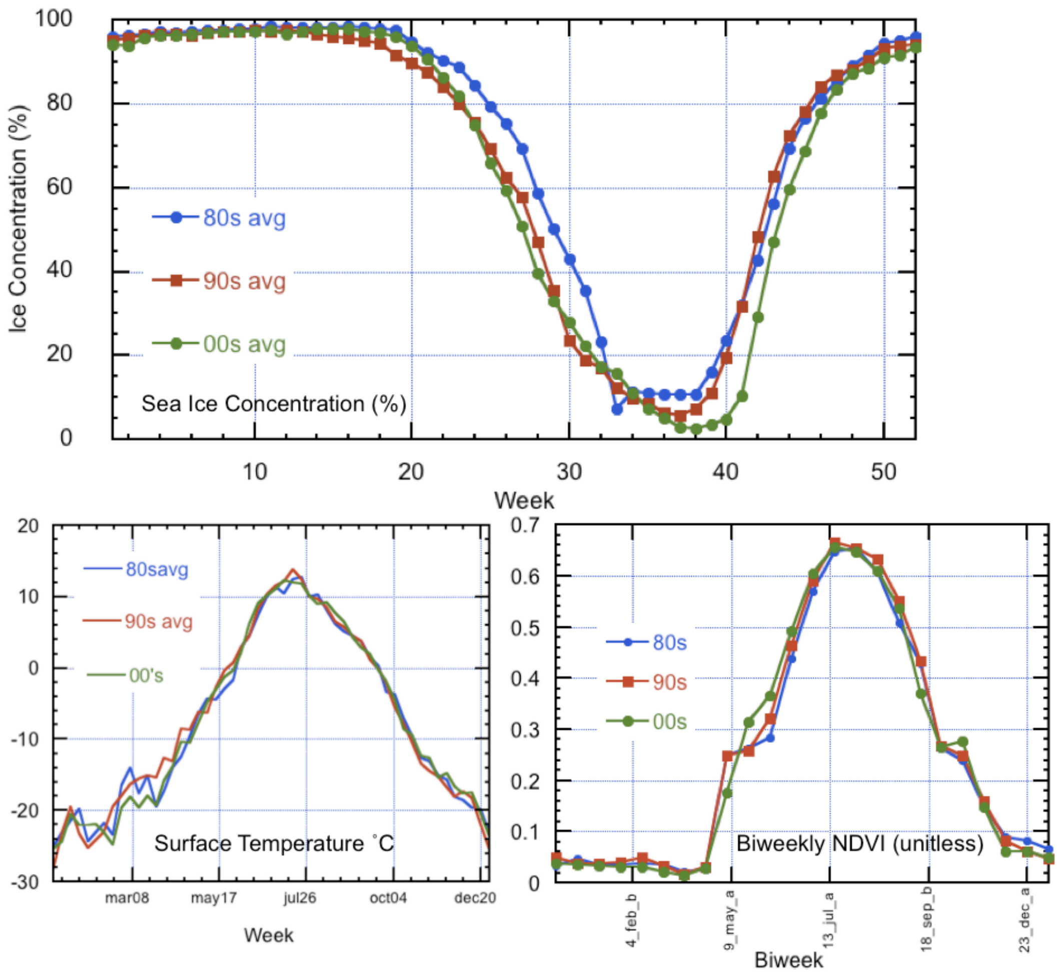

Figure 2. Yamal average decadal (1980s, 1990s and 2000s) value for weekly sea ice concentration (%) (top panel), weekly surface temperature (˚C) (bottom left panel) and biweekly NDVI (bottom right panel). Time series were constructed for a 50-km coastal terrestrial area along the Yamal for surface temperature and NDVI. Similarly, the sea ice concentration represents a 50-km coastal ocean area around the Yamal.

Bhatt et al. (2010) found using satellite observations from 1982-2008 that land warming is more pronounced in North Americ and Eurasia. Seasonality of sea ice in and around the Yamal as seen by the passive microwave data indicates an earlier breakup in spring starting in the 1990s and a later freeze up starting in the 2000s (Fig 2, top panel). The seasonality of surface temperatures suggests strong decadal variability with the spring warming in the 1990s and cooler spring temperatures in the 2000s. The decadal changes in NDVI suggest earlier greenup in the 2000s than previous decades in the Yamal. Overall, greening as measured by NDVI does not show large changes in the Yamal, while land temperatures have warmed overall but actually display some cooling in spring.

Another part of this study is examining the spatial controls of NDVI patterns on the Yamal and elsewhere in the circumpolar Arctic (Jia et al. 2009; Raynolds 2009; Raynolds and Walker 2009, Raynolds et al. 2010 submitted).

c. Ground measurements of NDVI-LAI-Biomass (Howie Epstein, Skip Walker)

NDVI, LAI, and biomass trends have now been determined for the entire Yamal transect. We have developed a comprehensive, synthetic dataset of field observations for vegetation and soil properties along the full Yamal bioclimate gradient (Epstein et al. 2010 unpub. and in prep., Walker et al., 2009, 2010 unpub.) These ground data from the Yamal are compared to remotely-sensed GIMSS AVHRR-derived values of NDVI and a comparable data set

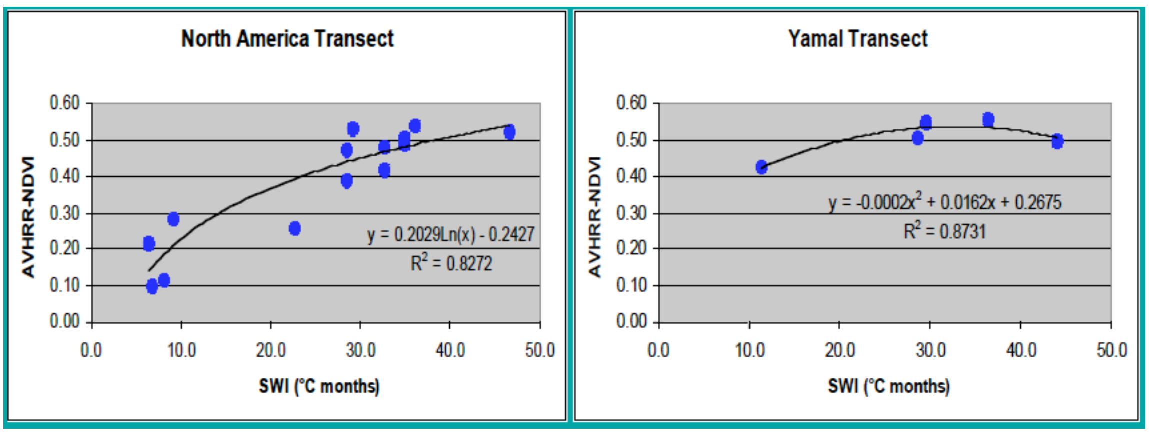

Fig. 3. Trends in AVHRR-derived NDVI along the North America and Yamal transects.

from the North America Arctic. The NDVI and biomass trends on the Yamal do not show as strong trends with temperature as they do in North America (Fig. 3). The NDVI and biomass trends are attributed to differences in glacial history, soil and disturbance regime along the two transects (Raynolds et al. 2010 unpub.; Walker et al. 2009).

The data show positive relationships between summer warmth, NDVI, LAI, and aboveground biomass components; however, the Yamal transect has higher NDVI, lower LAI, higher total aboveground biomass, and higher moss biomass than the North America transect. These trends are attributed to generally warmer temperatures along the Yamal transect and suggest that the mapped boundaries for the bioclimate subzones on the Yamal need to be shifted northward. The observed trends in NDVI are also compared to ecological factors. The are positive relationships between summer warmth and organic-layer thickness, mineral-soil C:N, and parabolic relationships with mineral soil %C and active-layer thickness. The Yamal has lower mineral soil %C and greater active layer thickness than North America (possibly due to differences in nutrient cycling rates attributed to the generally sandier soils.) Several publications are in progress that will describe the vegetation and NDVI/LAI/Biomass trends along the Yamal transect and also compare these trends with those in North America (e.g., Epstein et al. 2010 in prep., Walker et al. 2010 in prep.).

d. Modeling (Howie Epstein, Qin Yu, Jed Kaplan, Heike Lischke, Ben Cook)

We are using the ArcVeg arctic tundra vegetation dynamics model (Epstein et al. 2007) to simulate the combined effects of temperature increases and different grazing regimes on the tundra vegetation biomass, productivity, and species composition. In a recently published paper (Yu et al. 2009), we simulated seven sites on the Yamal Peninsula that differ in their soil organic nitrogen (SON) quantities and that are found across three different bioclimate subzones (Fig. 4). A 2°C increase in temperature led to aboveground biomass increases ranging from ~150 g m^{-2} to 665 g m^{-2} depending on the subzonal climate and the SON. Increased grazing frequency from every 10 years to every 2 years, reduced the effects of climate change on tundra vegetation, yielding aboveground biomass increases ranging from ~100 g m^{-2} to ~370 g m^{-2}.

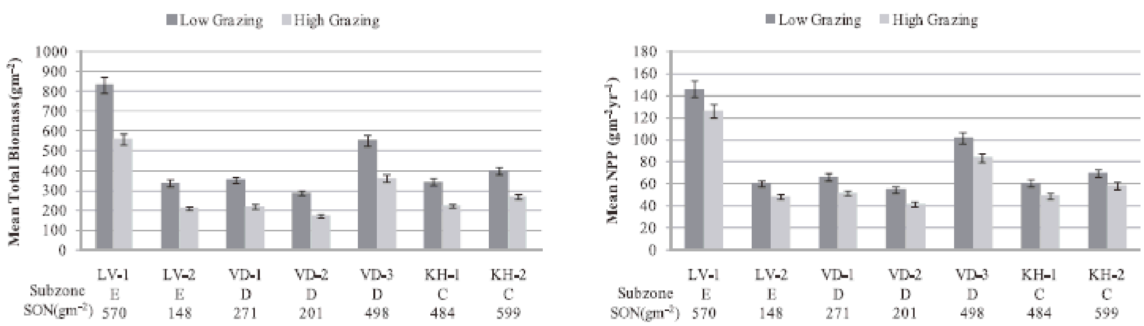

Fig. 4. Comparison of tundra biomass and net primary production (NPP) to low and high grazing regimes in three tundra subzones and different levels of soil organic nitrogen (SON). LV-1 = subzone E, loamy soil; LV-2 = subzone E, sandy soil; VD-1 = subzone D, loamy soil; VD-2, subzone D, mixed loamy and sandy soil; VD-3, subzone D, sandy soil; KH-1, subzone C, loamy soil; KH-2, subzone C, mixed loamy and sandy soil.

We are presently using the ArcVeg model to examine in more detail the plant functional type compositional changes in response to warming and altered grazing regimes on the Yamal Peninsula. The ArcVeg model is being updated to include our most recent understanding of reindeer grazing preferences and patterns. In addition to work specific to the Yamal, we are also in the process of conducting circumpolar simulations of tundra vegetation change, using circumpolar maps of tundra subzones, soils, grazing herds, and general circulation model (GCM) output. Jed Kaplan has recently developed a module for his BIOME4 model that simulates the temporal dynamics of soil temperatures and the active layer, which we hope to link with ArcVeg (Kaplan et al. 2010).

e. Remote sensing of land use land cover change (Howie Epstein, Skip Walker, Timo Kumpula, Bruce Forbes, Gerald Frost, Qin Yu, Hilmar Maier)

We have several efforts related to the remote sensing of land-use land-cover change on the Yamal Peninsula and other regions of Siberia and North America. Kumpula et al. (2010, unpub.) used Quickbird, ASTER, SPOT, and Landsat imagery to examine the impacts of development at the Bovanenkovo gas field in central Yamal on the tundra and its use by Nenets reindeer herders. We are continuing with this effort to use high and very high resolution satellite imagery to examine the effects of development on surface properties of the adjacent tundra, including surface temperatures, albedo, normalized difference vegetation index (NDVI) and normalized difference water index (NDVI). In addition to conducting further analyses of Bovanenkovo (Kumpula 2010, unpub.), we have expanded the scope of this effort to include gas extraction sites at Nadym, Bovanenkova, and Kharasavey as well as oil development sites near Prudhoe Bay, Alaska (Yu et al. 2010 unpub, Kumpula et al. 2010 unpub.; Forbes et al. 2010 unpub.). We have also begun to use the Landsat Decadal Survey imagery to develop land cover change maps for the entire Yamal Peninsula, including Belyy Ostrov off the north coast (Maier and Walker 2010a, b, unpub.).

Finally, we are examining dynamics of the forest-tundra ecotone across the Arctic using imagery from the Corona very-high-resolution satellite missions during the 1960s (Frost et al. 2009, 2010). Corona images are being paired with recent Quickbird images and analyzed for changes in the extent, cover, and abundance of trees and tall shrubs at the forest-tundra boundary. Several sites have been identified with dramatic changes in vegetation cover over the ~40 year period, including sites where shrub extent has increased and others where trees have been displaced by newly formed thermokarst ponds. The Kharp field site in the northern Polar Urals (Fig. 5) is one of these sites. The site was visited in summer 2009 and we discovered that an old fire is probably a contributing cause of the rapid alder shrub advancement in the area. Furthermore, we observed that shrubs reestablish most readily on mineral soils, particularly small patterned-ground features (frost boils). This is thought to lead to regularly spaced shrub savannas that are common near tree line, and which up until now have had no explanation. The fire/frost-boil/shrub savanna hypothesis is now being examined in more detail by Frost as part of his Ph.D. thesis research along the Dalton Highway in Alaska, where there are extensive areas that were burned in 2004-2005.

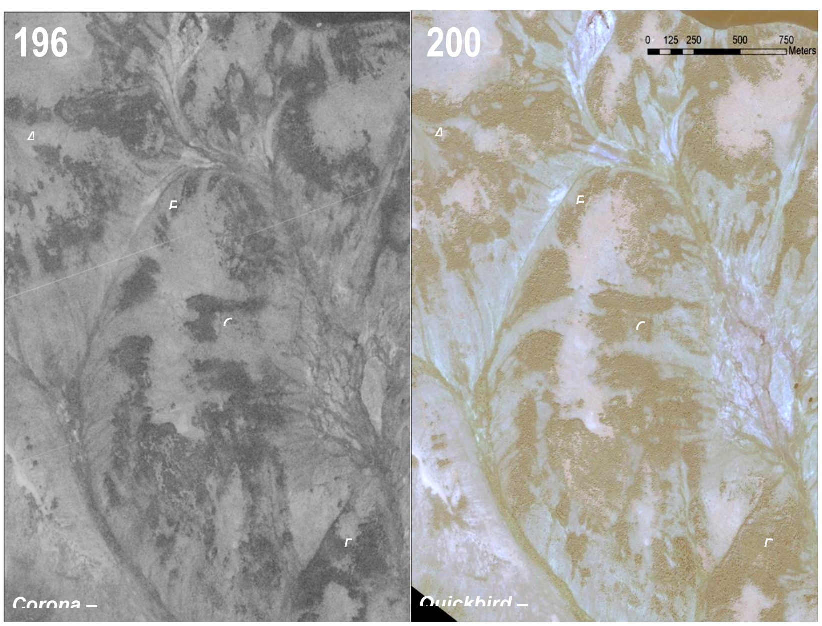

Fig. 5. Remote sensing images of the Kharp area in the northeastern foothills of the Polar Ural Mountains. (Left) 1968 Corona image showing extent of alder shrublands (most dark areas in the image). (Right) 2003 Quickbird image of the same area showing extensive infilling of alders, for examples note the areas in the vicinity of the letters A, B, C, and D.

Plan for 2010 and 2011 field seasons
The project will finish the Eurasian transect in summer 2010 on Hayes Island in the extreme High Arctic (bioclimate subzone A) of Franz Josef Land. The expedition is planned for 13 July-17 August 2010. During 2011, the shrub vegetation and lichen heathlands of Yamal will be characterized in more detail at locations near Vaskiny Dachi and near Nieto Lakes.

Publications

Journal articles and book chapters:

1. Bhatt, U.S., Walker, D.A., Raynolds, M.K., Comiso, J.C., Epstein, H.E., Jia, G.J., Gens, R., Pinzon, J.E., Tucker, C.J., Tweedie, C.E., and Webber, P.J., 2010 in press, Circumpolar Arctic tundra vegetation change is linked to sea-ice decline: Earth Interactions, doi: 10.1175/2010EI315.1 (available on line May 10 2010 at http://journals.ametsoc.org/doi/pdf/10.1175/2010EI315.1).

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3. Forbes, B.C., Stammler, F., Kumpula, T., Meschtyb, N., Pajunen, A., and Kaarlejärvi, E., 2009, High resilience in the Yamal-Nenets social-ecological system, west Siberian Arctic, Russia: Proceedings of the National Academy of Sciences, v. 106, doi: 10.1073/iti5209106, 22041-22048.

4. Goetz, S.J., H.E. Epstein, F. Achard, D. Alcaraz, U. Bhatt, A. Bunn, J. Comiso, M. Hansen, G.J. Jia, J.O. Kaplan, H. Lischke, A. Lloyd, D.A. Walker, Q. Yu. 2010. Vegetation productivity and disturbance changes across arctic northern Eurasia: Satellite observations and simulation modeling. *In:* Gutman, G. and P. Groisman, and Reissell. (ed.) *Eurasian Arctic Land Cover and Land Use in a Changing Climate.*

5. Groisman, P.Y., Clark, E.A., Kattsov, V.M., Lettenmaier, D.P., Sokolik, I.N., Aizen, V.B., Cartus, O., Chen, J., Conard, S., Katzenberger, J., Krankina, O., Kukkonen, J., Machida, T., Maksyutov, S., Ojima, D., Qi, J., Romanovsky, V.E., Santoro, M., Schmullius, C.C., Shiklomanov, A.I., Shimoyama, K., Shugart, H.H., Shuman, J.K., Sofiev, M.A., Sukhinin, A.I., Vorosmarty, C., Walker, D.A., and Wood, E.F., 2009, The Northern Eurasia Earth Science Partnership: An example of Science Applied to Societal Needs: Bulletin of the American Meteorological Society, v. 90, p. 671-688.

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7. Raynolds, M.K., and Walker, D.A., 2009, Effects of deglaciation on circumpolar distribution of arctic vegetation: Canadian Journal of Remote Sensing, v. 35, p. 118-129.

8. Raynolds, M.K., 2009, A geobotanical analysis of circumpolar arctic vegetation, climate, and substrate. University of Alaska, Fairbanks. 260 p., Ph.D. Thesis, University of Alaska Fairbanks.

9. Walker, D.A., Bhatt, U.S., Raynolds, M.K., Comiso, J.C., Epstein, H.E., and Jia, G.J., 2009, The Arctic: Land: Vegetation, in Peterson, T., and Baringer, M., eds., State of the Climate in 2008, Bulletin American Meteorological Society Vol.90, Volume 90, p. S104-S105.

10. Walker, D.A., Leibman, M.O., Epstein, H.E., Forbes, B.C., Bhatt, U.S., Raynolds, M.K., Comiso, J., Gubarkov, A.A., Khomutov, A.V., Jia, G.J., Kaarlejaärvi, E., Kaplan, J.O., Kumpula, T., Kuss, H.P., Matyshak, G., Moskalenko, N.G., Orechov, P., Romanovsky, V.E., Ukraientseva, N.K., and Yu, Q., 2009, Spatial and temporal patterns of greenness on the Yamal Peninsula, Russia: interactions of ecological and social factors affecting the Arctic normalized difference vegetation index: Environmental Resaerch Letters, v. 4, doi:10.1088/1748-9326/4/4/045004, p. 16.

11. Yu, Q., H.E. Epstein, and D.A. Walker. 2009. Simulating soil organic nitrogen and grazing effects on arctic tundra vegetation dynamics on the Yamal Peninsula, Russia. Environmental Research Letters doi:10.1088/1748-9326/4/4/045027.

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1. Goetz, S. J., H.E., Epstein, D. Alcaraz, U.S. Bhatt, J. Comiso, G.J. Jia, J.O. Kaplan, H. Lischke, A., Lloyd, Q. Yu, and D.A. Walker, 2010: Recent Changes in Arctic Vegetation: Satellite Observations and Simulation Model Predictions. In: Eurasian Arctic Land Cover and Land Use in a Changing Climate Gutman, Garik; Reissell, Anni (Eds.) 1st Edition., 2010, VI, 226 p. 100 illus., Hardcover ISBN: 978-90-481-9117-8 (To be published: October 2010).

2. Walker, D.A., U.S. Bhatt, M.K. Raynolds, V.E. Romanovsky, G.P. Kofinas, J.P. Kuss, B.C. Forbes, F. Stammler, T. Kumpula, E. Kaarlejärvi, M.O. Leibman, N.G. Moskalenko, A.A. Gubarkov, A.V. Khomutov, D.S. Drozdov, H.E. Epstein, Q. Yu, G.J. Jia, J.O. Kaplan, J.C. Comiso, 2010: Cumulative effects of rapid land-cover and land-use changes on the Yamal Peninsula, Russia. In:Eurasian Arctic Land Cover and Land Use in a Changing Climate Gutman, Garik; Reissell, Anni (Eds.) 1st Edition., 2010, VI, 226 p. 100 illus., Hardcover ISBN: 978-90-481-9117-8 (To be published: October 2010).

Manuscripts in preparation and submitted

1. Alcaraz, D., J. Cabello, H. Epstein, and G. Jia. 2010 in prep. Trends in the surface vegetation dynamics of the tundra and taiga network of protected areas in Eurasia as observed by satellite sensors.

2. Bhatt, U. S., D. A. Walker, M. K. Raynolds, J. Comiso, and H. E. Epstein. 2010 in prep. Role of atmospheric processes in trends and variability of sea-ice, land-surface temperatures, and tundra vegetation greenness in Alaska. To be submitted to Atmospheric Research.

3. Epstein, H.E., D.A. Walker, M.K. Raynolds, A.M. Kelley, G. Jia, C. Ping, G. Michaelson, M.O. Leibman, E. Kaarlejärvi, A. Khomutov, P. Kuss, N. Moskalenko, P. Orekhov, G. Matyshak, B.C. Forbes, Q. Yu. 2010 in prep. Vegetation and soil attributes along two latitudinal temperature gradients in arctic tundra. To be submitted to Ecology.

4. Forbes, B.C., T. Kumpula, A. Gubarkov, D.A. Walker. (2010 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.

5. 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. (2010, in press) 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.

6. Raynolds, M.K., Huettmann, F., Walker, D.A., and Verbyla, D., 2010 submitted, Environmental controls of the distribution of circum-Arctic vegetation: Ecography.

7. Walker, D.A., H.E. Epstein, G.J. Frost, J.J., M.K. Raynolds. 2010 in prep. Vegetation and environmental factors along a 900-km Arctic bioclimate transect on the Yamal Peninsula, Russia. To be submitted to the Journal of Applied Vegetation Science.

Published abstracts

1. Bhatt, U.S., D.A. Walker, M.K. Raynolds, J.C. Comiso, H. Epstein, G. Jia, R. Gens, J.E. Pinzon, C.J. Tucker, C. Tweedie, and P. Webber. Circumpolar arctic tundra vegetation change is linked to sea-ice decline. State of the Arctic Meeting, Miami, FL, March 2010.

2. Bhatt, U.S., D.A. Walker, M.K. Raynolds, H. Epstein, G. Jia, J. Comiso, and J.E. Pinzon. Seasonality of atmosphere-ocean-ice-terrestrial environment of arctic tundra. State of the Arctic Meeting, Miami, FL, March 2010.

3. Bhatt, U.S., D.A. Walker, M.K. Raynolds, M. Steele, H. Epstein, G. Jia, J.C. Comiso, J.E. Pinzon, C.J. Tucker. Seasonality of air-sea-ice-land variables for arctic tundra in Northern Eurasia and North America. American Geophysical Union Meetings, San Francisco, CA, December 2009.

4. Epstein, H.E., D.A. Walker, M.K. Raynolds, A.M. Kelley, G. Jia, C. Ping, G. Michaelson, M.O. Leibman, E. Kaarlejärvi, A. Khomutov, P. Kuss, N. Moskalenko, P. Orekhov, G. Matyshak, B.C. Forbes, Q. Yu. Vegetation biomass, leaf area index, and NDVI patterns and relationships along two latitudinal transects in arctic tundra. American Geophysical Union Meetings, San Francisco, CA, December 2009.

5. Epstein, H.E., D.A. Walker, M.K. Raynolds, A.M. Kelley, G. Jia, C. Ping, G. Michaelson, M.O. Leibman, E. Kaarlejärvi, A. Khomutov, P. Kuss, N. Moskalenko, P. Orekhov, G. Matyshak, B.C. Forbes, Q. Yu. Vegetation biomass, leaf area index, and NDVI patterns and relationships along two latitudinal transects in arctic tundra. State of the Arctic Meeting, Miami, FL, March 2010.

6. Epstein, H.E., Walker, D.A., Raynolds, M.K., Kelley, A.M., Jia, G.J., and Ping, C.L., 2010, Vegetation biomass, leaf area index, and NDVI patterns and relationships along two latitudinal transects in arctic tundra, Oral presentation IPY Oslo Science Conference, 8-12 Jun 2010, Oslo Norway.

7. Frost, G.V., H. Epstein, D.A. Walker. Spatio-temporal trends in tree and tall shrub cover in the Eurasian Low Arctic: evidence from 1960s and contemporary satellite imagery and ground observations. American Geophysical Union Meetings, San Francisco, CA, December 2009.

8. Frost, G.V., H.E. Epstein, and D.A. Walker. Spatio-temporal trends in tree and shrub cover in the circumpolar Low Arctic: Evidence from 1960 satellite photography and ground observations. State of the Arctic Meeting, Miami, FL, March 2010.

9. Jia, G.J., H. Epstein, D. Walker, Y. Hu, and C. Tucker. Satellie view of changing phenological patterns over arctic tundra biome. State of the Arctic Meeting, Miami, FL, March 2010.

10. Walker, D.A., U.S. Bhatt and H.E. Epstein. The Greening of the Arctic IPY Project. American Geophysical Union Meetings, San Francisco, CA, December 2008 (Invited).

11. Walker, D.A., Bhatt, U.S., Epstein, H.E., Raynolds, M.K., Frost, G.V., Liebman, M.O., Khumotov, A.V., Jia, G.J., Forbes, B.C., Comiso, J.C., Pinzon, J.E., Tucker, C.J., Webber, P.J., and Tweedie, C.E., 2009, Circumpolar Arctic greening:

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1. Walker, D.A., Orekhov, P., Frost, G.V., Matyshak, G., Epstein, H.E., Leibman, M.O., Khitun, O., Khomotov, A., Daanen, R., Gobroski, K., and Maier, H.A., 2010, The 2009 Yamal Expedition to Ostrov Belyy and Kharp, Yamal Region, Russia, Alaska Geobotany Center Data Report, Funded by NASA Grant No. NNG6GE00A, Alaska Geobotany Center, p. 49.

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Unpublished talks and posters

Second Yamal Land-Cover Land-Use Change Workshop, Rovaniemi, Finland, 8-10 March 2010:

1. Bhatt, U.S., D.A. Walker, M.K. Raynolds, J.C. Comiso, H.E. Epstein, G. Jia, R. Gens, J.E. Pinzon, C.J. Tucker, C.E. Tweedie, and P.J. Webber. Circumpolar Arctic Tundra Vegetation Change is Linked to Sea-Ice Decline. Abstract – PDF

2. Bhatt, U. S., Donald A Walker, M. K. Raynolds, H. E. Epstein, Gensuo Jia, J. C. Comiso, J. E. Pinzon, C. J. Tucker. Climatology and Seasonality of the ice-ocean-atmosphere-terrestrial system on the Yamal. Abstract – PDF

3. Comiso, J. C. State of the Cryosphere in the Arctic. Abstract - PDF

4. Drozdov, D.S.. Yamal Peninsula maps and GIS information. Update on ECI activities and permafrost research on the Yamal. Abstract - PDF

5. Epstein, H.E., D.A. Walker, M.K. Raynolds, A.M. Kelley, G.J. Jia, C.L. Ping, G.J. Michaelson, M.O. Liebman, E. Kaarlejärvi, A.V. Khomutov, P. Kuss, N.G. Moskalenko, P. Orekhov, G. Matyshak, B.C. Forbes, and Q. Yu. Vegetation biomass, leaf area index, and NDVI patterns and relationships along two latitudinal transects in arctic tundra. Abstract – PDF

6. Forbes, B. C., M.M. Fauria, P. Zetterberg. Deciduous shrub growth and the greening of the Arctic in West Siberia. Abstract - PDF

7. Forbes, B. C., F. Stammler, T. Kumpula, N. Meschtyb, A. Pajunen, E. Kaarlejärvi. High resilience in the Yamal-Nenets social-ecological System, West Siberian Arctic, Russia. Abstract – PDF

8. Frost, G.V., D.A. Walker, M.K. Raynolds, and H.E. Epstein. Ordination and gradient analysis of vegetation and environmental properties on the Yamal Peninsula.

9. Frost G.V., D.A. Walker, H.E. Epstein. Summary of 2009 field observations and proposed 2010 study plan for Kharp study site, northwest Siberia. Abstract - PDF

10. Gubarkov, A.A.. Issues of Yamal Peninsula gas fields development. Abstract - PDF

11. Heim B., Bartsch A., Boike J., Hubberten H.-W. DUE Permafrost: a spaceborne permafrost monitoring and information system. Abstract - PDF

12. Jia, G., Y. Hu, H. Wang, H.E. Epstein, D.A. Walker. Greening and Seasonality: Multi-scale Approaches. Abstract - PDF

13. Kaplan, J.O., J.R. Melton, M. Pfeiffer and P.M. Collins. Large-scale dynamic modeling of soil-vegetation interactions. Abstract

14. Khitun, O. V. and N.G. Moskalenko. Summary of Yamal vegetation and flora. Second Yamal Land-Cover Land-Use Change Workshop, Rovaniemi, Finland, 8-10 March, 2010. Abstract - PDF Khitun, O. and O. Rebristaya. Concrete Flora Concept as a Base for Floristic Investigations in the Russian Arctic. Abstract - PDF

15. Khomutov, A.V., M.O.Leibman, H.E. Epstein. Relation between active-layer depth, NDVI and LAI along the Yamal Transect. Abstract - PDF

16. Khomutov, A.V., M.O. Leibman. Landscape pattern and cryogenic landsliding hazard analysis at Vaskiny Dachi, Central Yamal. Abstract

17. Kumpula, T., B.C. Forbes and F. Stammler. Land-use and land-cover changes in Yamal peninsula. Abstract - PDF

18. Leibman, M.O., A.A. Gubarkov, A.V. Khomutov, N.G. Moskalenko, P.T. Orekhov, O.E. Ponomareva, I.A. Gameev. Geocryological Map of the USSR, 1:2,500,000, 1991. Abstract - PDF

19. Maier, H.A. and D.A. Walker. Yamal Peninsula, Russia: Landsat TM Mosaic Image (1:1M scale), Land-Cover Maps and NDVI Maps of the LCLUC Study Areas (1:250K-1:300K scales). Abstract - PDF

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21. Moskalenko, N.G. Vegetation Dynamics at the Nadym and Kharasavei sites in the West Siberia North. Abstract - PDF

22. Orekhov, P. and M. Leibman. Yamal Peninsula, climate, zonation, physiography, geology, permafrost. Abstract - PDF

23. Pinzon J.E. and C.J. Tucker. GIMMS 3g NDVI set and global NDVI trends. Abstract - PDF

24. Raynolds, M.K., D.A. Walker, U.S. Bhatt, J.E. Pinzon, J.C. Comiso. NDVI trends 1981-2008 in the circumpolar Arctic and Yamal. Abstract - PDF

25. Stammler, F. Humans and animals on northern Yamal: uncovering unknown patterns of movement and settlement. Abstract - PDF

26. Streletskiy, D.A., F.E. Nelson, N.I. Shiklomanov. Spatial and temporal variability of active-layer thickness under changing climatic conditions in Northwest Siberia. Abstract - PDF

27. Ukraintseva, N.G.. High Willow Shrubs in Yamal: Reasons of Their Wide Expansion and Methods of Biomass Assessment. Abstract - PDF

28. Walker, D.A. Welcome, goals of the workshop, and overview of the project. 2010. Abstract - PDF

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30. Yu, Q. H.E. Epstein, D.A. Walker. Controls on arctic tundra vegetation dynamics on the Yamal Peninsula, Russia - an integrative study using ArcVeg and multi-temporal Landsat imagery. Abstract – PDF

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31. Bhatt, U., D.A. Walker, M. Raynolds, J. Comiso, H. Epstein, J. Jia, and R. Gens. Greening of arctic tundra is linked to warming summer land temperatures and sea-ice decline. NASA Land Cover Land Use Change Meeting, Bethesda, MD, April 2009.

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