A synthesis of remote-sensing studies, ground observations and modeling to understand the social-ecological consequences of climate change and resource development on the Yamal Peninsula, Russia, and relevance to the circumpolar Arctic

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Abstract:

The Yamal Peninsula region in Russia and the North Slope of Alaska are experiencing the most rapid land-cover and land-use change (LCLUC) in the Arctic due to recent oil and gas development, intensive subsistence use by the local Nenets people, extraordinarily sensitive permafrost environments, and rapid climate change (Forbes et al. 2009, Walker et al. 2009). This project will synthesize local and circumpolar studies conducted during two previous rounds of LCLUC funding. It consists of three main components:

- **Component 1. Synthesis of ground-based, remote-sensing and climate information from the Eurasia Arctic Transect and comparison with the North America Arctic Transect.**
- **Component 2. Synthesis of social-ecological changes related to Arctic oil and gas development.**
- **Component 3. Synthesis of modeled effects of climate change and land use on vegetation.**

The project will build on extensive studies of social-ecological systems in Arctic Alaska and the Yamal Peninsula, and projects that have linked ground-based geoecological information with satellite-derived information along two long transects in both regions that traverse the complete terrestrial Arctic bioclimate gradient.

Component 1. Synthesis of ground-based, remote-sensing and climate information from the Eurasia Arctic Transect, and comparison with the North America Arctic Transect.

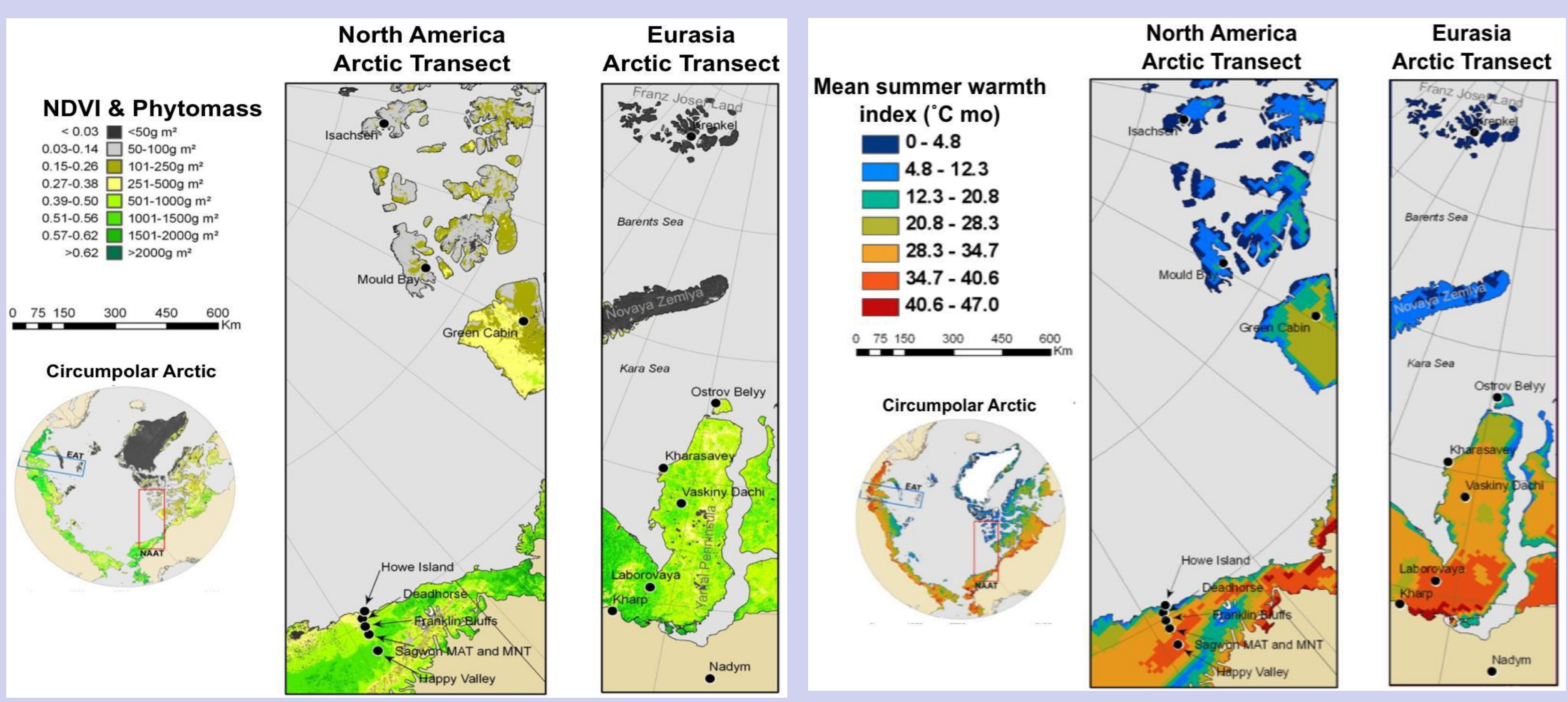

Fig. 1. The Circumpolar Arctic, North America Arctic Transect (NAAT) and Eurasia Arctic Transect (EAT). The left diagrams portray the patterns of plant productivity, and the right diagrams the patterns of summer warmth at the ground surface. Both data sets portray mean values based on 1982-2010 AVHRR data. Aboveground phytomass is highly correlated with the Normalized Difference Vegetation Index (NDVI) index. The summer warmth index (SWI) is sum of mean monthly temperatures above freezing. The dots are the primary study locations. The Bovanenkovo gas field is located near the Vaskiny Dachi location of the EAT, and Prudhoe Bay Oilfield is located near Deadhorse on the NAAT.

Task 1.1. Synthesis of information from the EAT.

Key question: "How do spatial and temporal patterns of spectral reflectance, particularly the normalized difference vegetation index (NDVI), vary with key landscape factors (vegetation composition, structure and biomass, soil chemical and physical properties, soil surface temperatures, active layer, permafrost temperatures, disturbance patterns) along the EAT?"

Deliverables: i) Four major disciplinary synthesis papers focused on the geoecological conditions along the EAT will parallel analyses from a comparable North America Arctic Transect: a) vegetation (authors: Walker, Breen, Ermokhina); b) soils (Matyshak), c) permafrost conditions (Leibman, Romanovsky), and d) spectral-reflectance characteristics of the EAT (Epstein, Buchhorn); ii) an interdisciplinary summary paper that integrates the disciplinary research (Walker et al.).

Task 1.2. Comparison of the EAT and NAAT.

Key question: "How do the spatial and temporal patterns observed along the relatively maritime EAT compare with the patterns along the relatively continental North America Arctic Transect (NAAT)?"

Deliverables: i) manuscript comparing the long-term climate and productivity trends of the maritime EAT to the continental NAAT in relationship to the geoecological and climate characteristics of both transects (Bhatt, Walker et al.), and ii) a paper comparing the seasonal dynamics of sea-ice, land-temperature and NDVI along maritime EAT and the more continental NAAT (Bhatt, Walker).

Task 1.3. Circumpolar comparison.

Key question: "Are the patterns of soil temperatures and NDVI along both transects related to circumpolar summer sea-ice and climate drivers and if so, what are the drivers?"

Deliverables: i) annual updates of sea-ice, Arctic land-temperatures, and Arctic NDVI patterns for the NOAA State of the Climate publication and the Arctic Report Card (Bhatt, Epstein), ii) a circumpolar raster-based vegetation map and area analysis (Raynolds), and iii) a paper that summarizes global seasonal patterns of sea ice, land temperatures, and NDVI in relationship to snow, humidity, and precipitation data (Bhatt et al.).

Presented at the NASA Land-Cover and Land-Use Change Science Team Meeting, Rockville, MD, April 23-25, 2014.

Component 2. Synthesis of social-ecological changes related to Arctic oil and gas development.

Fig. 2. Use of remote sensing products to aid in social science interviews. Florian Stammler interviewing members of a Nenets reindeer herders brigade, Bovanenkovo Gas Field, Yamal Peninsula. Photo by Bruce Forbes.

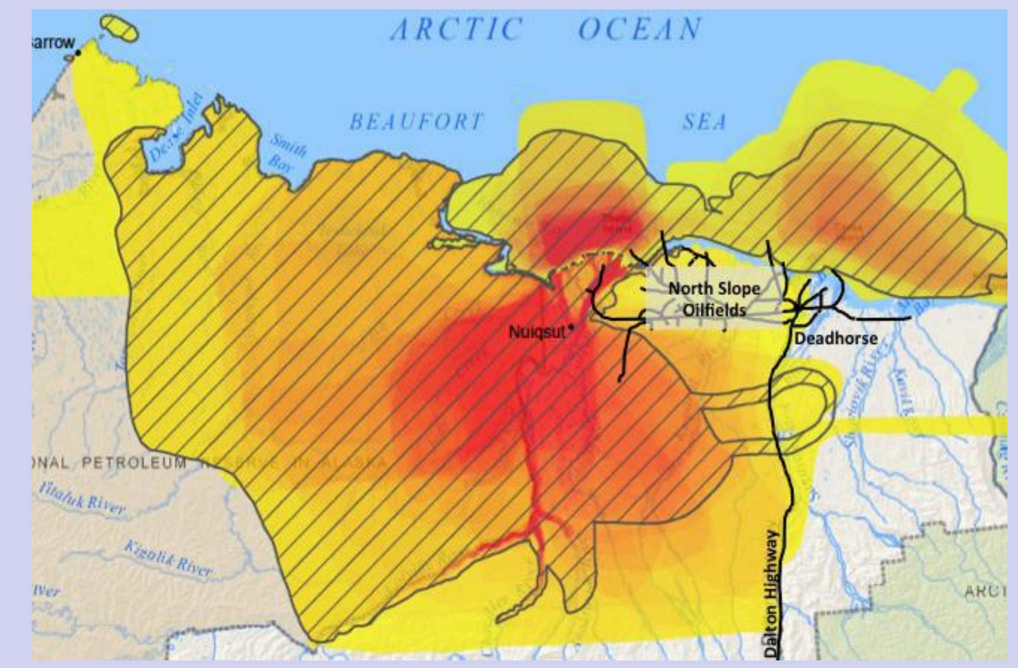

Fig. 3. Nuiqsut, Alaska use area in relationship to the oilfield complex. Shading portrays low (yellow) to high (red) village-use areas. Hatched areas show the use during last 12 months of the study. The figure is based on 756 use areas reported by 33 respondents, 1995-2006, illustrating low use within the North Slope oilfields. (Based on Braund and Associates 2010.)

Task 2.1. Synthesis of social-ecological information related to oil and gas development.

Key question: "Have the underlying climate and geoecological systems influenced local response to infrastructure expansion and climate change on the Yamal Peninsula and how are these patterns and responses compared to those of Northern Alaska?"

Deliverables: i) a manuscript comparing cumulative effects of climate and infrastructure changes to the Nenets (reindeer-herding) and Iñupiat (hunting) cultures (Kofinas, Forbes, Kumpula), and ii) a manuscript focused on the applications of remote sensing and GIS as tools for Arctic cumulative-effects research (Kumpula, Raynolds).

Task 2.2. A synthesis of international best practices of adaptive management using remote sensing.

Major goal: Synthesis of best practices of remote-sensing applications for addressing Arctic social-ecological issues related to expanding networks of infrastructure and rapid climate change.

Deliverables: i) a synthesis of international approaches to examine the cumulative effects that use remote sensing, GIS, and predictive models (Kumpula, Raynolds, Forbes, Walker), and ii) a synthesis of international best practices for adaptive management of Arctic local responses to cumulative effects of climate change and resource development (Kofinas, Forbes).

Component 3. Synthesis of modeled effects of climate change and land-use on vegetation.

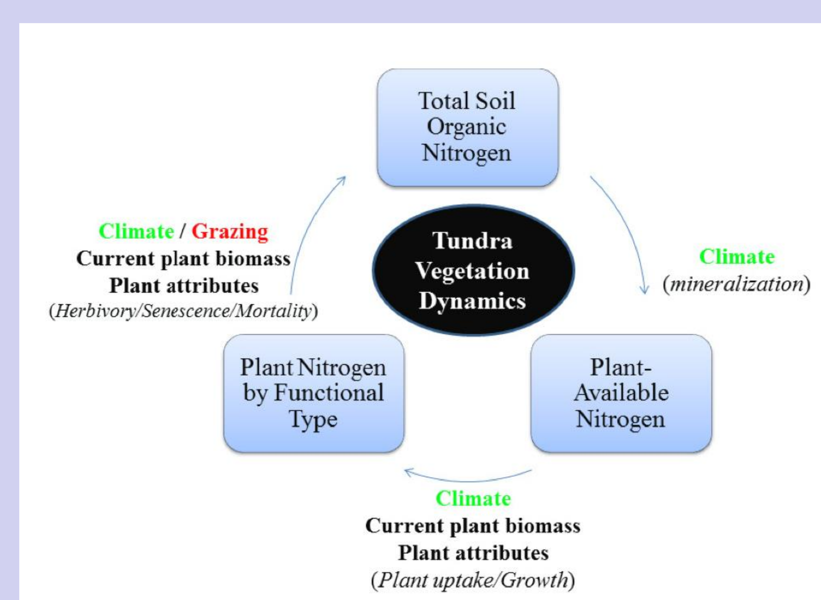

Fig. 4. Diagram of key components of simulations of tundra vegetation dynamics in the ArcVeg model. The model essentially runs with nitrogen mass balance equations, moving nitrogen among three major pools (total soil N, plant available N, and plant biomass N partitioned by 12 common tundra plant functional types) (Epstein et al 2007). Climate and grazing control nitrogen fluxes among these pools. Climate subzone, soil organic nitrogen levels and grazing regime dictate the simulated plant functional type composition and biomass for a particular tundra system. The model is parameterized for the 5 arctic bioclimatic subzones (Walker et al 2005). Soil organic nitrogen levels were taken from field data for each site, and extrapolated to account for available nitrogen in the active layer.

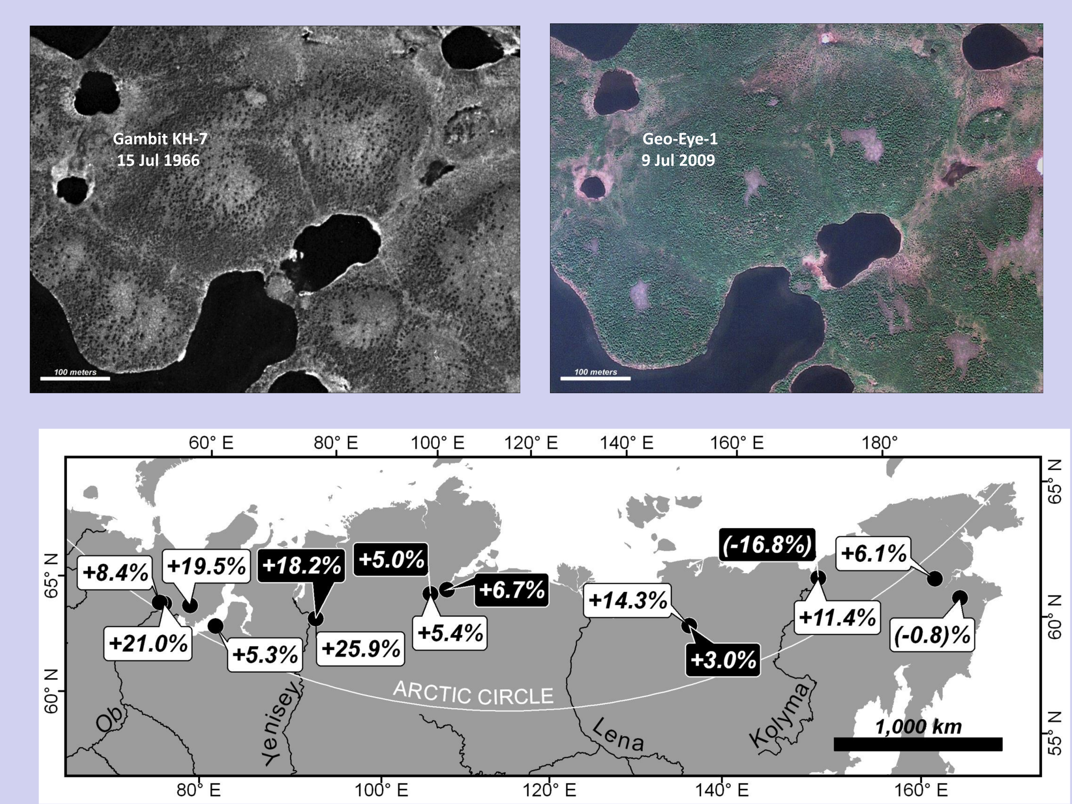

Fig. 5. (Top) Comparison of Gambit KH-7 spy satellite image taken in 1966 with Geo-Eye-1 image of the same area taken in 2009, illustrating increases in shrub cover. The individual dark shrubs in the left image and the dark green areas of the right image are Alnus viridis. *(Bottom) Percentage changes in shrub cover (white boxes) and tree cover (*Larix*, black boxes) at 11 forest-tundra transitions across Russia between 1960s and 2000s. (Based on Frost and Epstein 2014).*

Task 3.1. Circumpolar ArcVeg modeling synthesis.

Key question: "How will regional and circumpolar Arctic vegetation respond to differing scenarios of climate change and land use?"

Deliverable: A manuscript on the circumpolar ArcVeg modeling synthesis of climate and grazing effects (Yu, Epstein).

Task 3.2. Shrub expansion synthesis.

Key question: "What is the history of tall-shrub expansion across the forest-tundra ecotone of northern Siberia in relationship to landscape variables and climate change?"

Deliverable: Manuscript on tall shrub expansion synthesis throughout northern Siberia (Frost, Epstein, Forbes, Yu).

Funded by NASA LCLUC program grant no. NNX14AD90G.

Overall goal: Toward an adaptive management approach to address the cumulative effects of rapid Arctic social-ecological transitions related to Arctic land-use and climate changes.

This project addresses two main issues. The first is a need for a clearer hierarchical understanding of the spatial and temporal patterns of Arctic LCLUC, including those related to rapidly expanding oil and gas infrastructure, indigenous land use, and climate change. The Yamal Peninsula and northern Alaska have also been the targets of intensive remote-sensing studies, ground-based observations, and social-ecological studies from earlier NASA-sponsored LCLUC studies and other projects. The initial focus of the proposed synthesis will be on the Yamal and the Eurasia Arctic Transect, where we will combine our results with the work of others who have worked on the peninsula. We will then broaden the interpretation with a comparison with the contrasting climatic, geoecological, permafrost, infrastructure, and social conditions of the North America Arctic Transect, and finally use the results from both transects to aid in interpreting circumpolar spatial and temporal patterns of Arctic LCLUC change. The tools we use in the comparison include detailed field studies, remote sensing, sociological studies, and modeling.

The second issue is how to use this information to help policy makers, local governments, and industry develop effective adaptive management approaches to respond to change. Funds from this project will be used to help fund workshops devoted to applications of remote sensing to Arctic LCLUC and adaptive mangagement approaches under a new International Arctic Science Committee (IASC)-sponsored initiative called Rapid Arctic Transitions due to Infrastructure and Climate Change (RATIC).

Fig. 6. US and Russian investigators collecting vegetation, soil, permafrost, climate, and and ground-based spectral data at the northernmost LCLUC research site on the Eurasian Arctic Transect at 80˚ 37' N, Hayes Island, Franz Jozef Land Archipelago, Russia. Photo: D.A. Walker.

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