Spatio-temporal dynamics in tree and tall shrub cover near Kharp, northwest Siberia: 2009 field observations and proposed 2010 study plan

Abstract

Gerald V. Frost[1], Howard E. Epstein[1], and Donald A. Walker[2]

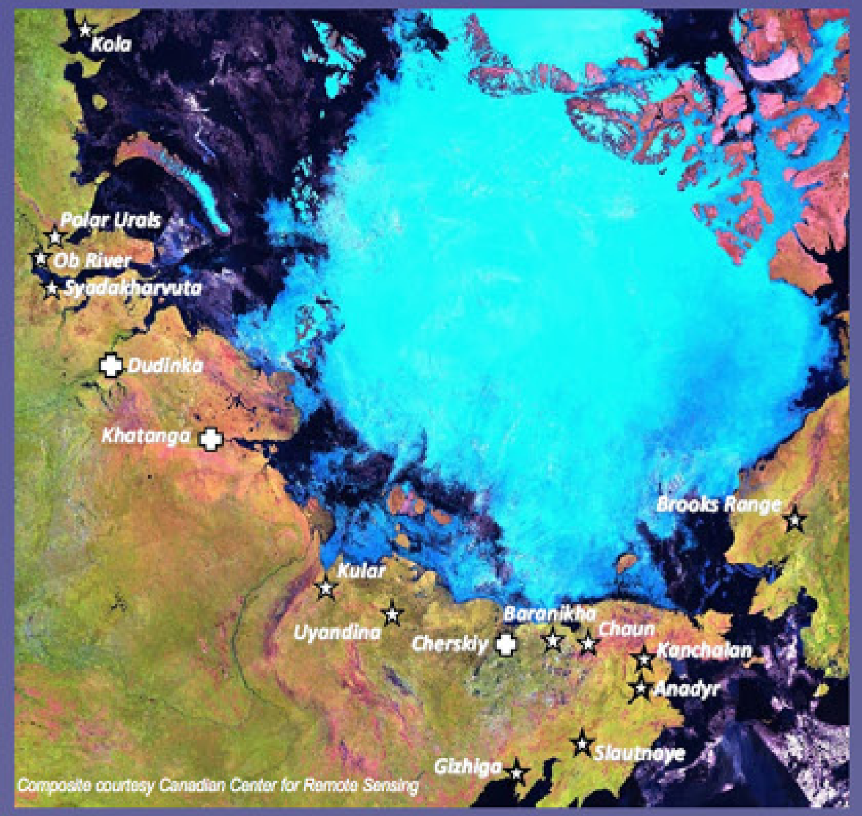
[1]University of Virginia, Charlottesville, VA, USA and [2]University of Alaska Fairbanks, Fairbanks, AK, USA

Comparison of high-resolution satellite imagery from 1968 (Corona) and 2003 (QuickBird) indicates that dramatic expansion of tall alder shrublands has occurred in the foothills of the Polar Urals near the town of Kharp, northwest Siberia. The Kharp area encompasses a broad ecotone of boreal forest and Low Arctic tundra. Observations made during a brief field visit in August 2009 indicate that most of the shrub expansion has occurred in areas affected by an antecedent high-intensity wildfire (≥100 yrs BP) that removed the surface organic layer. Mature Siberian larch trees are uncommon in the area visited, with all of the mature trees occurring within dense alder thickets that probably served as a firebreak. Alder recruitment both inside and outside of the burn is concentrated on microsites with mineral-dominated soils associated with cryogenic patterned-ground features. QuickBird imagery indicates that the regular spacing of small alders in much of the area mirrors the spacing of the underlying circle- and inter-circle areas. This pattern appears to be retained in well-established thickets, but the gaps between mineral-dominated circles probably become filled over time by the expansion of shrub canopies. Linkages between cryogenic patterned-ground features and shrub recruitment may explain the regular spacing of alders in open shrublands elsewhere in the low Arctic. Together, these observations highlight the role of disturbance in driving changes in shrub cover and NDVI in parts of the Low Arctic. A July 2010 field effort is tentatively planned for a ~63 km² study area near Kharp. The primary objective of the field effort is to determine the extent to which tall shrub expansion is associated with disturbance agents that create or maintain mineral-dominated edaphic conditions, from the landscape scale (wildfire) to the meter scale (frost boils). Soils, dendrochronology, and vegetation ground-truthing data will be collected in order to interpret the changes in shrub cover that are evident in the satellite imagery. Finally, vegetation and environmental data will be recorded at ten relevés that can be tied in with the existing relevé dataset for the Yamal Transect.

Kharp Focus Area

Kharp is located in the eastern foothills of the Polar Ural Mountains near the base of the Yamal Peninsula, nowrthwest Siberia (right). Detailed vegetation and environmental data have been collected at 69 relevés along a ~900 km transect as part of the Yamal LCLUC project. The releves are distributed at tundra sites spanning four bioclimate subzones for Arctic tundra, as well as a forest-tundra site at Nadym (Figure 1). Field studies at Kharp would include establishment of ten releves that could be integrated into the existing dataset for the Yamal region. Predominant vegetation cover, surface geology, and disturbance history differ from Nadym. Thus, releve data from Kharp would be useful in evaluating the relationships among vegetation, environmental attributes, and NDVI along bioclimate and soil texture gradients (see ordination poster, this session). of relatively homogeneous, low-lying landscapes and is north-south trending. Existing releve data indicate a surprisingly weak relationship between aboveground biomass, shrub cover, and NDVI.

Vegetation Dynamics at Continental Scale



The Kharp focus area is part of a broader research effort examining state-level vegetation changes in low Arctic ecosystems since ~1965, and the sensitivity of the Normalized Difference Vegetation Index (NDVI) to recent changes. This research encompasses a network of ~15 sites with a much broader geographic distribution than achieved by previous studies. No field work is planned for other sites, although useful ground data may be obtained from collaborators (e.g., at Cherskiy).

All studies sites are ~45 km² in size. After image co-registration, a sampling grid overlay is applied to each photo pair and vegetation attributes are determined at each grid node in a GIS. The distance between grid nodes is 25 m., resulting in about 75,000 sampling points per study site. Additionally, the number of trees within each grid cell is counted for sites with higher-resolution Gambit imagery. For sites with multi-spectral QuickBird imagery, a spectral classification is used to assign vegetation attributes for grid nodes with water, prostrate tundra, and barrens. Sampling for shrubby areas is conducted manually in a GIS. From these data, the absolute (m²) and relative (%) change in tree and shrub cover are determined for each photo pair. Change in tree abundance is also determined for sites with Gambit imagery.

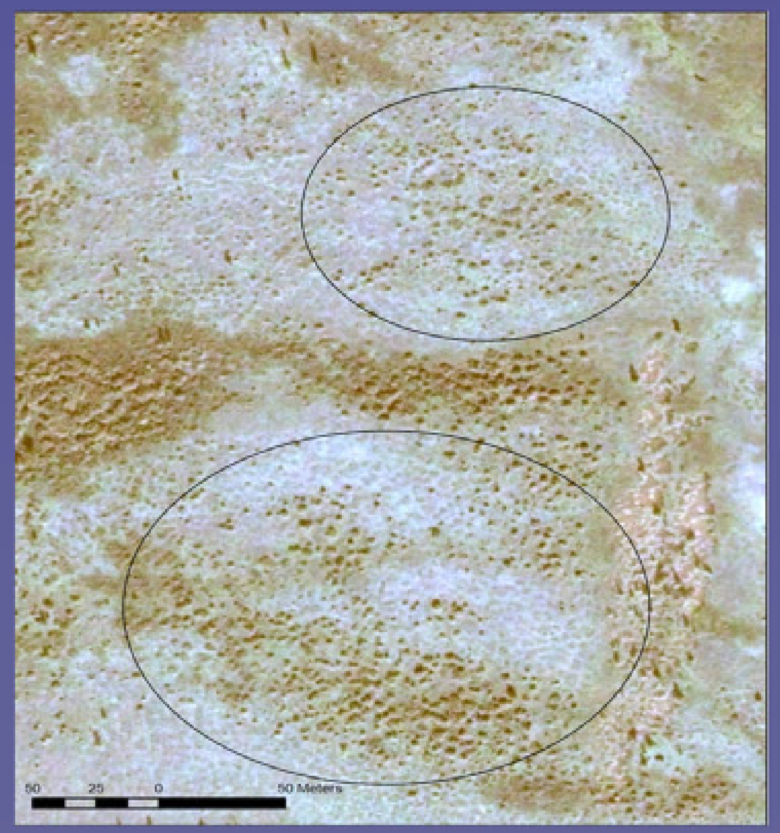
Ancillary environmental data are also incorporated into the vegetation change GIS. These data include (1) geomorphic and physiographic units digitized for each scene; (2) disturbance footprints (e.g., recent thermokarst); (3) elevation and hillslope extracted from ASTER DEMs; (4) climate data; and (5) multi-temporal NDVI data from AVHRR. These data are then used to rank the importance of local- and regional environmental factors in driving the observed vegetation changes.

Data summaries will relate the vegetation metrics and environmental strata within and among study areas. Inferential statistics (e.g., ANOVA) will be used to evaluate the relative influence of the environmental strata as determinants of the changes. Finally, NDVI data from AVHRR, QuickBird, and other sensors will be added to the vegetation change GIS to evaluate the relationship between the NDVI metric and recent vegetation changes, from the AVHRR-pixel scale to the plot sclae. Quantitative assessments of the pace and extent of changes in the structure of northern ecosystems will improve understanding of associated impacts to a range of climatic, hydrological, and biogeochemical processes within—and beyond—the Arctic.

Field Observations from August 2009

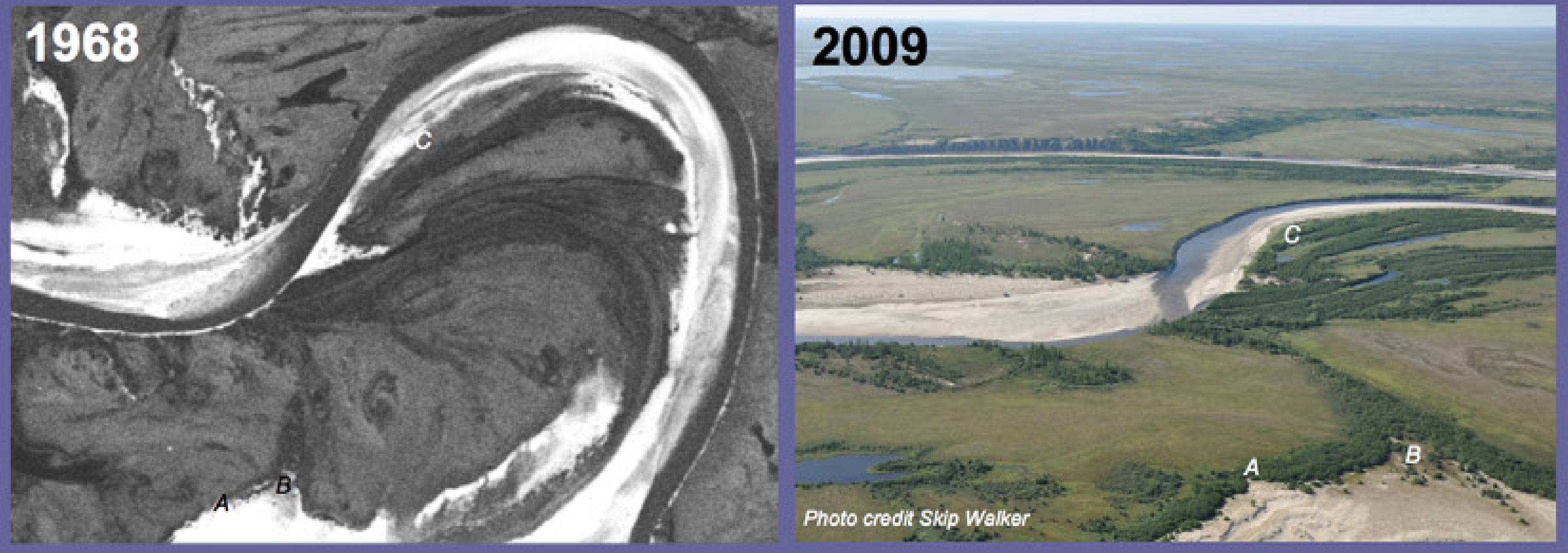
Corona (left) and QuickBird (right) satellite photos indicate rapid shrub expansion in foothills of the Ural Mountains near Kharp. The area is easily accessed ~4 km from the road to Labytnangi (route shown in inset, below left). A field visit revealed that most of the shrub expansion has occurred where surface organic soils were removed by wildfire ~100 YBP. Mature larches occur only in dense alder thickets that probably served as a firebreak. Sorted- and non-sorted circles are common (inset, below right).

Field observations (below right) indicated that alder recruitment is concentrated on the mineral-dominated centers of sorted- and non-sorted circles. This pattern is also evident in QuickBird imagery showing individual shrubs and the reticulate pattern of inter-circles (below left). The regular spacing of shrubs may be retained in dense stands where inter-circle areas are obscured by expanding shrub canopies. Alder has relatively high growth rates and is probably able to establish on microsites where tundra plants cannot due to seasonal frost heave. Linkages between alder recruitment and cryogenic processes could explain the regular spacing of alders in open tall shrublands occurring on patterned ground elsewhere in the Low Arctic (e.g., northwest Alaska).



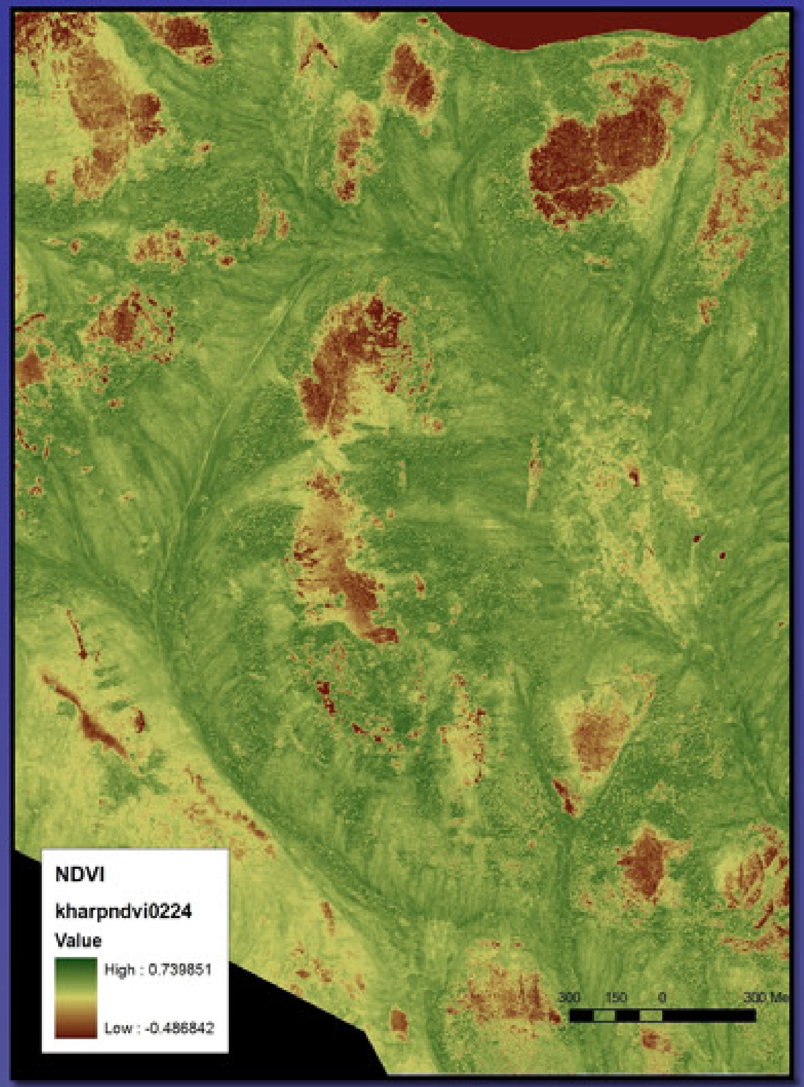
Yamal Peninsula

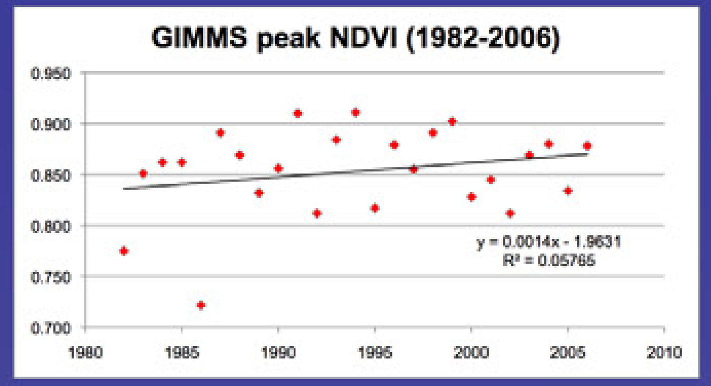
Alder cover is also associated with mineral-dominated substrates on the Yamal. 1968 Corona and 2009 oblique aerial photos along the Tanlova River indicate that most shrub expansion has occurred on on dune margins (A) and the point bar (C). Elsewhere on the Yamal, low willows shrublands are common in drainages and landslide features where marine silts have been exposed.

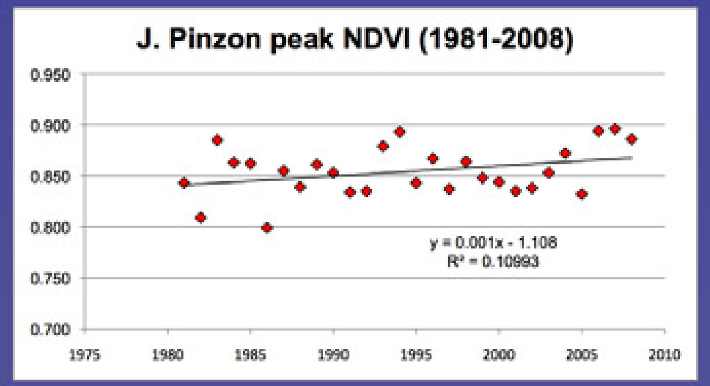


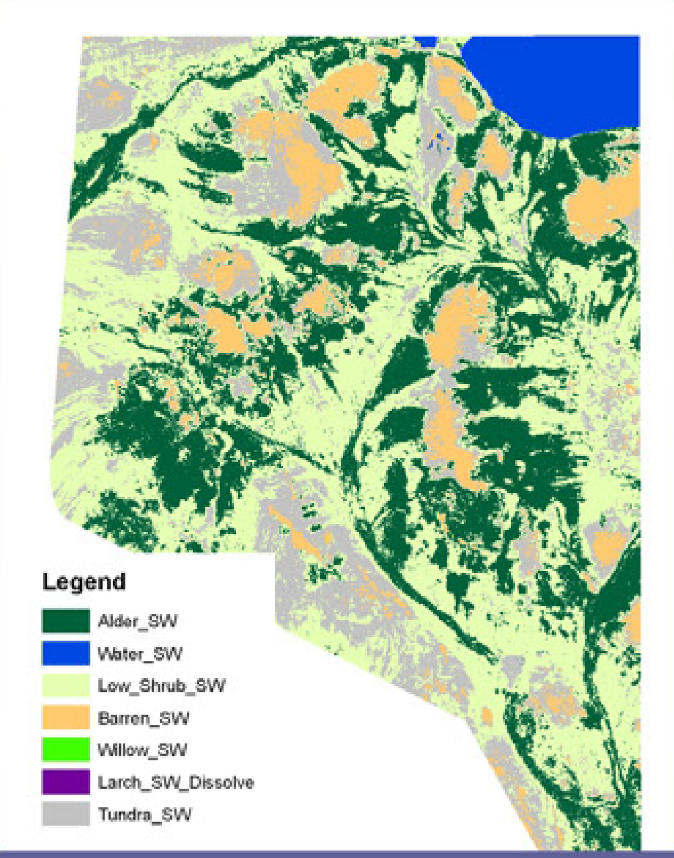
NDVI

Relating the satellite-based NDVI record to changes in the productivity and structure of Arctic vegetation has been an active area of recent research. Examination of NDVI at fine spatial scales where relationships with key geomorphic and hydrologic controls can be evaluated are likely to be useful in interpreting the coarse-scale signals, and determining what parts of the landscape are greening. An NDVI map for the Kharp area (below left) reveals fine-scale patterns that correspond to discrete vegetation types.. These signatures are useful in generating a spectral classification of vegetation for the area (below left). By describing the NDVI signature of common vegetation types, it is possible to infer the likely change in NDVI associated with vegetation changes since 1968. Global-scale NDVI products (such as GIMMS and Pinzon; below right) reveal modest (~3.5%) positive anomalies in NDVI for the single AVHRR pixel co-incident with the Kharp study area. This may be due in part to extensive barrens in area.



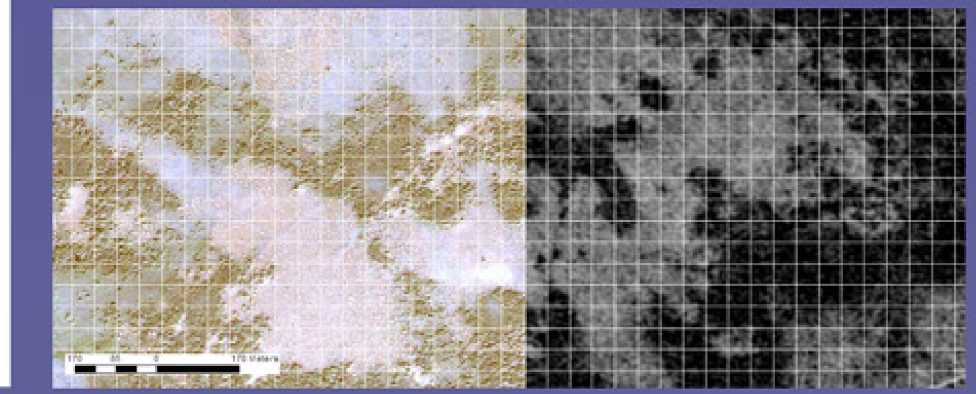






Proposed methods for summer 2010 field campaign

Primary objectives of a field effort tentatively planned for July 2010 are to (1) determine the date of the wildfire; (2) determine the footprint of the burn area and the degree to which new shrub cover is associated with mineral-dominated substrates; (3) validate patterns of alder occurrence on non-sorted and sorted- circles; (4) establish ten releves to be integrated with the existing dataset from the Yamal LCLUC study. A variety of sampling methods will be used, including soil pits, dendrochronology, releve sampling. This will help to interpret the changes evident in satellite photo comparisons (below).



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