Vegetation biomass, leaf area index, and NDVI patterns and relationships along two latitudinal transects in arctic tundra

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INTRODUCTION

Analyses of vegetation properties along climatic gradients provide first order approximations as to how vegetation might respond to a temporally dynamic climate. Until recently, no systematic, detailed field study of tundra vegetation had been conducted along bioclimatic transects that represent the full latitudinal extent of the arctic tundra biome, although see McGuire et al. (2002) for a synthesis of existing high latitude transects. Since 1999, we have been collecting data on arctic tundra vegetation and soil properties along two such transects, the North American Arctic Transect (NAAT) and the Yamal Arctic Transect (YAT). The NAAT spans the arctic tundra from the Low Arctic of the North Slope of Alaska to the polar desert of Cape Isachsen on Ellef Ringnes Island in the Canadian Archipelago. The NAAT is described in detail in Walker et al. (2008), and Epstein et al. (2008) analyzed the patterns of aboveground vegetation biomass along the NAAT as a function of summer warmth index (SWI – sum of mean monthly temperatures > 0°C). The Yamal Arctic Transect located in northwest Siberia, Russia, presently ranges from the forest-tundra transition at Nadym to the High Arctic tundra on Belyy Ostrov off the north coast of the Yamal Peninsula (described in Walker et al. 2009).

METHODS

Our locations along the North American Arctic Transect were situated (from south to north) near Happy Valley, Sagwon, Franklin Bluffs, Deadhorse (Alaska), and Green Cabin (Banks Island), Mould Bay (Prince Patrick Island) and Cape Isachsen (Ellef Ringnes Island), all in Canada. The latitudinal extent ranges from approximately 69°N to 79°N. Our Yamal Arctic Transect (northwestern Siberia, Russia) locations were situated near Nadym, Laborovaya, Bovanenkova (Vaskiny Dachi), Kharasavey, and Belyy Ostrov. The latitudinal extent of this transect ranges from approximately 65°N to 73°N. At a minimum of two sites per location, using a combination of 50m x 50m grids, 50m transects, and réleve plots, we systematically sampled leaf area index (LAI), Normalized Difference Vegetation Index (NDVI), species composition, vegetation biomass, and soil characteristics.

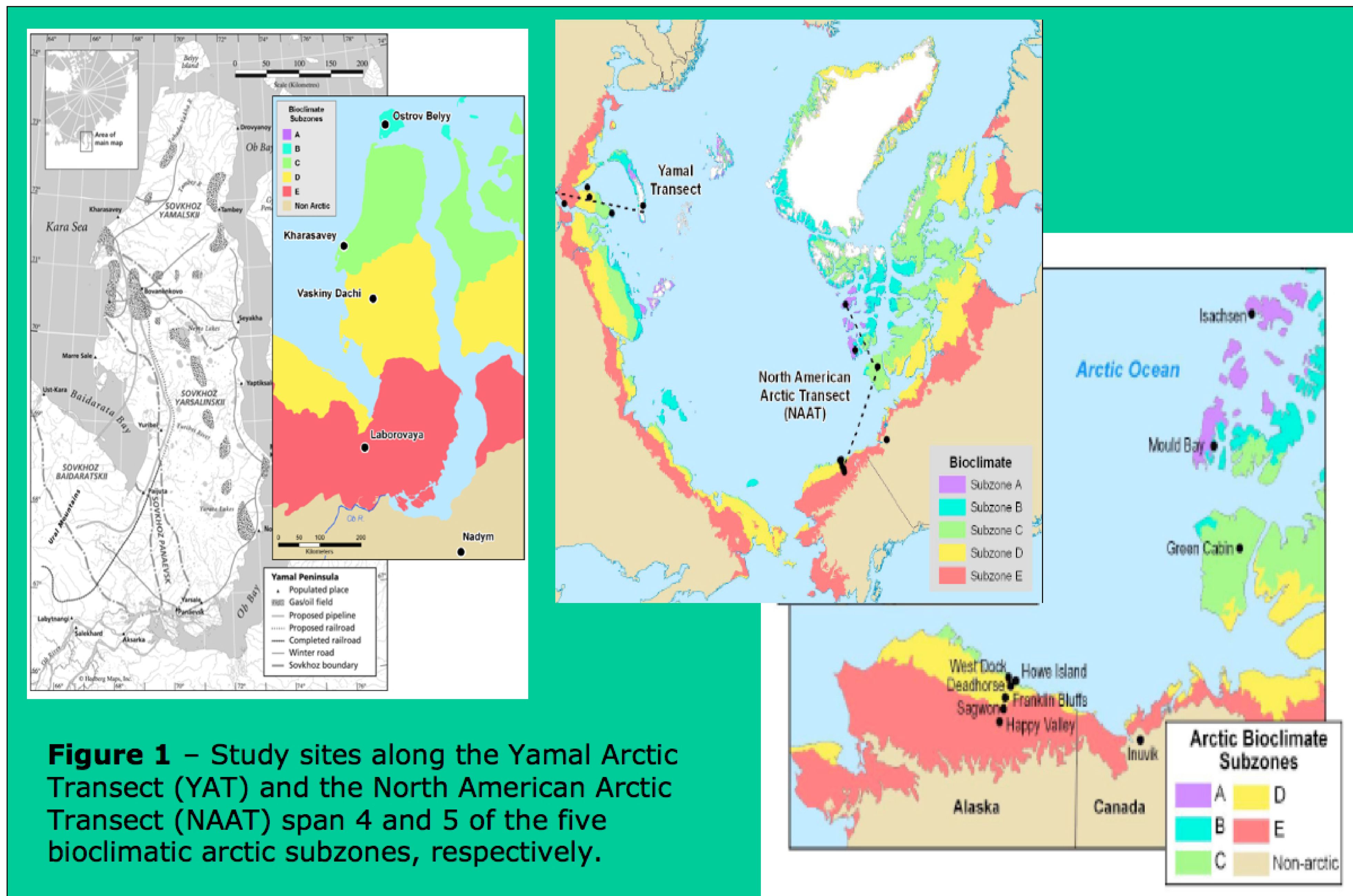

Figure 1 – Study sites along the Yamal Arctic Transect (YAT) and the North American Arctic Transect (NAAT) span 4 and 5 of the five bioclimatic arctic subzones, respectively.

SUMMARY - CONCLUSIONS

The summer warmth indices (SWI – sum of mean monthly temperatures greater than 0°C) range from 44.1 °C months to 6.5 °C months from south to north. Site-averaged LAI ranges from 1.51 to 0 along the transects, yet can be highly variable at the landscape scale. Site-averaged hand-held NDVI ranges from 0.67 to 0.26 along the transects, and is less variable than LAI at the landscape scale. Total aboveground live biomass ranges from approximately 700 g m^{-2} to < 50 g m^{-2} along the NAAT, and from approximately 1100 g m^{-2} to < 400 g m^{-2} along the YAT (not including tree biomass at Nadym). LAI and NDVI are related logarithmically (r^2 = 0.58, not shown) for the dataset. LAI is significantly related to total aboveground (live plus dead) vascular plant biomass (r^2 = 0.37), although there are a few outliers in the dataset at sites where prostrate shrubs are below the LAI sensor. NDVI is related as a power function with photosynthetic biomass (r^2 = 0.62). In general, for the same bioclimate subzone, particularly the more northern one, NDVI and total aboveground live biomass are substantially greater on the YAT compared to the NAAT. Some of this difference can be accounted for by the differences in measured non-vascular biomass. Since reindeer grazing on the Yamal Peninsula should reduce vegetation biomass to a greater extent than caribou grazing in North America, grazing differences are likely not responsible for biomass differences. However, different glacial and disturbance histories, soil substrates, and the resultant nutrient cycling processes could be hypothesized to yield these differences in vegetation biomass between the transects.

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RESULTS

LAI and NDVI

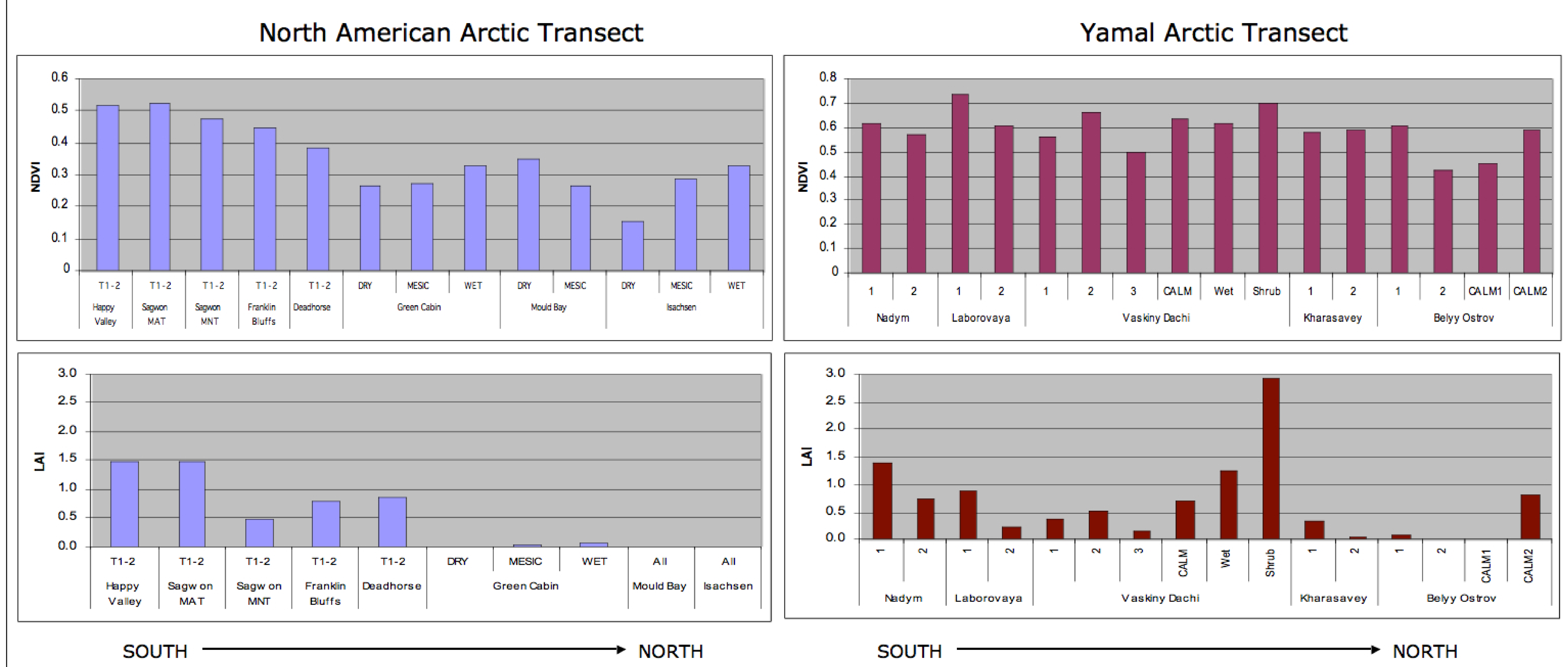

Figure 2 – Leaf Area Index (LAI) and Normalized Difference Vegetation Index (NDVI) for each site along both transects.

LAI and NDVI vs. Vegetation Biomass Components

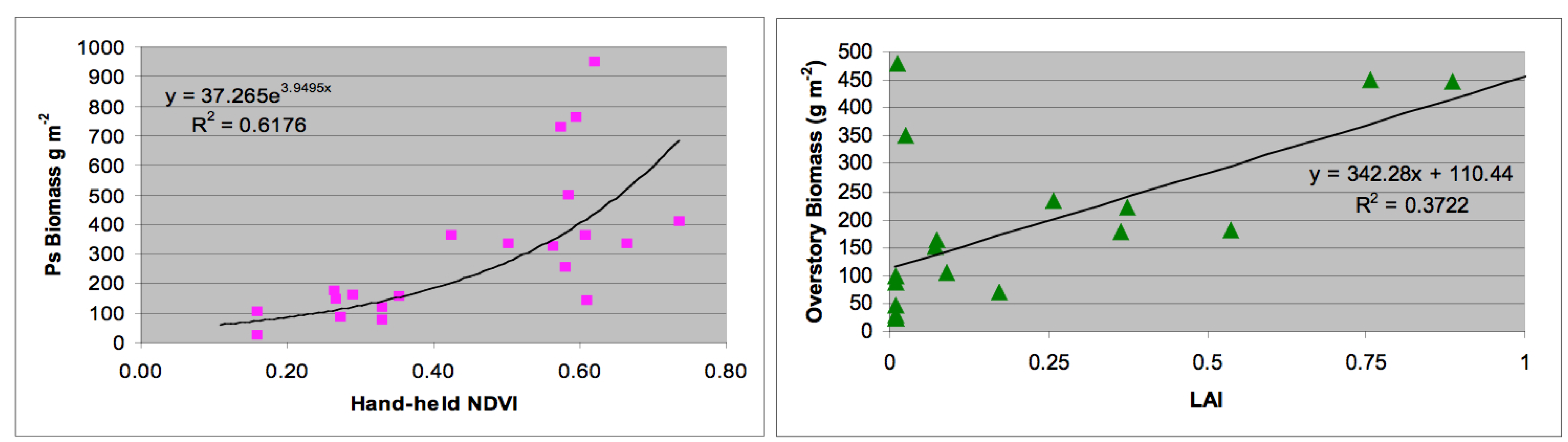

Figure 3 – Photosynthetic biomass (g m^{-2}) as a function of hand-held NDVI for all site. Overstory biomass (g m^{-2}) as a function of LAI for all sites.

NDVI vs. Summer Warmth Index

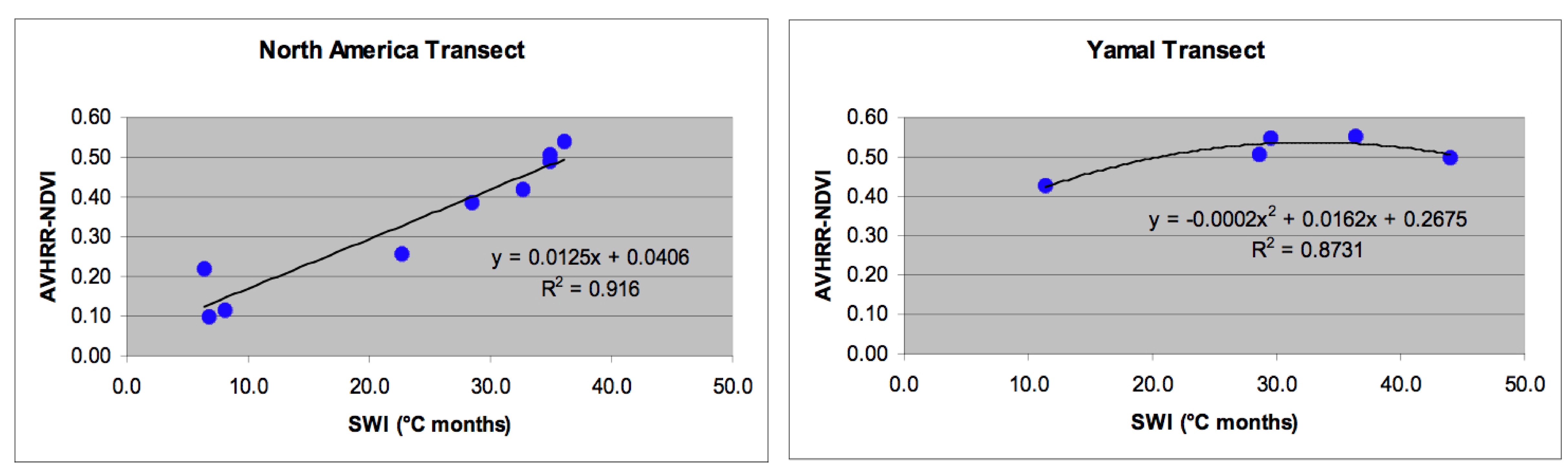

Figure 4 – AVHRR-NDVI as a function of Summer Warmth Index (SWI – sum of mean monthly temperatures >0°C) for the NAAT and YAT. NDVI on the Yamal remains high in areas with lower summer temperatures.

LITERATURE

Epstein, H.E., D.A. Walker, M.K. Raynolds, G.J. Jia, and A.M. Kelley. 2008. Phytomass patterns across the full temperature gradient of the arctic tundra. Journal of Geophysical Research - Biogeosciences doi: 10.1029/2007JG000555.

McGuire, A.D, C. Wirth, M. Apps, J. Beringer, J. Clein, H. Epstein, D.W. Kicklighter, J. Bhatti, F.S. Chapin III, B. de Groot, D. Efremov, W. Eugster, M Fukuda, T. Gower, L. Hinzman, B. Huntley, G.J. Jia, E. Kasischke, J. Melillo, V. Romanovsky, A. Shvidenko, E. Vaganov, D. Walker. 2002. Environmental variation, vegetation distribution, carbon dynamics, and water/energy exchange in high latitudes. Journal of Vegetation Science 13:301-314.

Walker, D.A., H.E. Epstein, V.E. Romanovsky, C.L. Ping, G.J. Michaelson, R.P. Danaan, Y.Shur, R.A. Peterson, W.B. Krantz, M.K. Raynolds, W.A. Gould, G. Gonzalez, D.J. Nicolsky, C.M. Vonlanthen, A.N. Kade, P. Kuss, A.M. Kelley, C.A. Munger, C.T. Tarnocai, N.V. Matveyeva, and F.J.A. Daniels. 2008. Arctic patterned-ground ecosystem: A synthesis of field studies and models along a North American Arctic Transect. Journal of Geophysical Research Vol. 113, G03S01, doi:10.1029/2007/JG000504

Walker, D.A., M. O. Leibman, H. E. Epstein, B. C. Forbes, U. S. Bhatt, M. K. Raynolds, J. C. Comiso, A. A. Gubarkov, A. V. Khomutov, G. J. Jia, E. Kaarlejärvi, J. O. Kaplan, T. Kumpula, J. P. Kuss, G. Matyshak, N. G. Moskalenko, P. Orekhov, V. E. Romanovsky, N. K. Ukraientseva, and Q. Yu. 2009. Spatial and temporal patterns of greenness on the Yamal Peninsula, Russia: Interactions of ecological and social factors affecting Arctic NDVI. Environmental Research Letters in press.