Spatial Patterns of Land Surface Temperature and NDVI on the Yamal Peninsula, Russia

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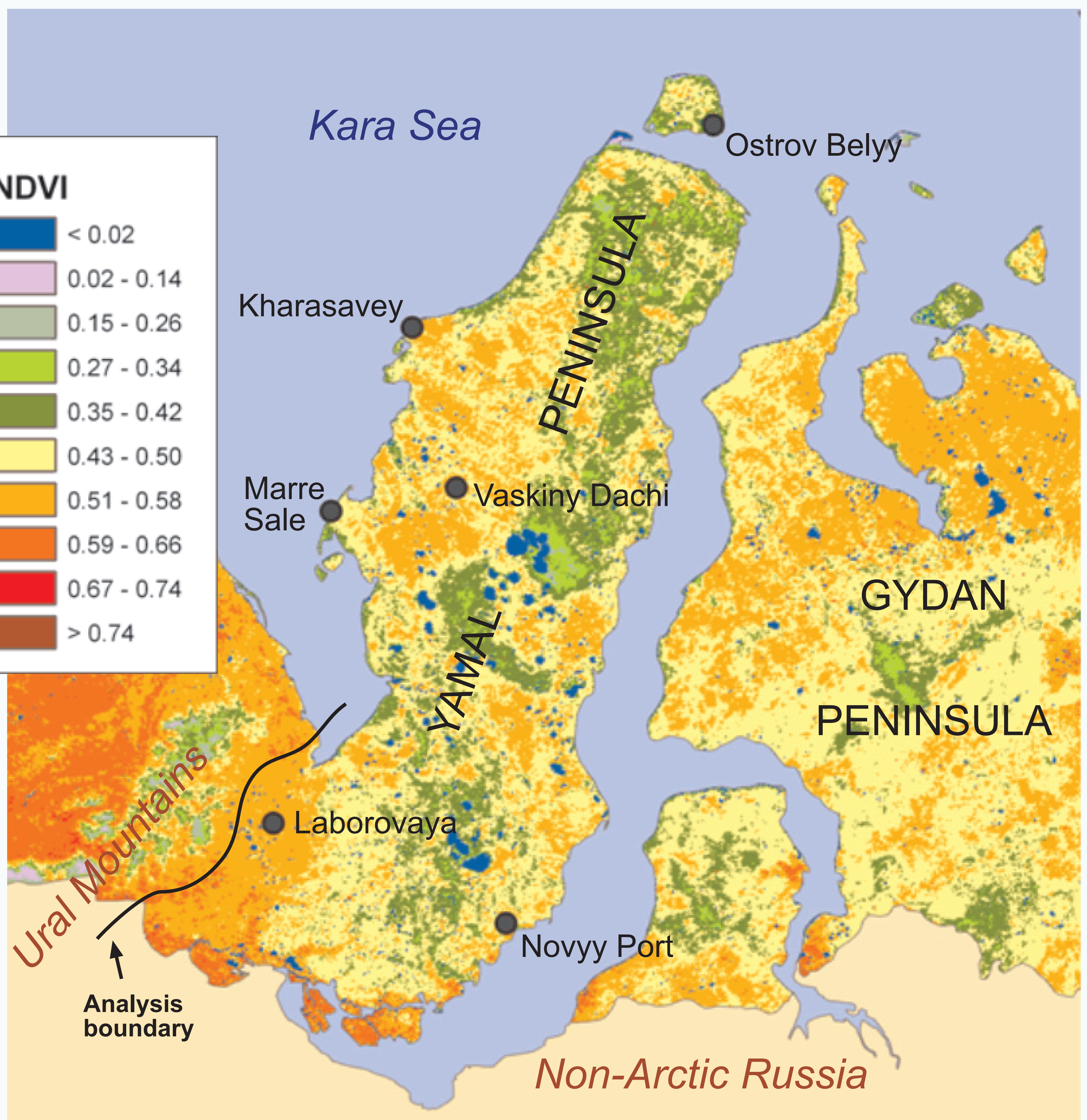

Figure 1. The Normalized Difference Vegetation Index (NDVI) is a measure of greenness. Data are from AVHRR 1993-1995 (CAVM Team 2003).

Introduction

The Yamal Peninsula in Russia is used extensively by local reindeer herders and is undergoing rapid resource development. Like much of the Arctic it is also experiencing rapid changes in climate. A major question facing scientists and local managers is, "How will these changes affect the patterns of plant production in the region?" In most of the Arctic, plant production is stongly related to the amount of summer warmth available for plant growth (Raynolds et al. 2008). We investigate two questions here:

1. How strongly are the patterns of plant production on the Yamal (Fig. 1) related to summer land surface temperatures (Fig. 2)?

2. How strongly is plant production on the Yamal related to other mapped variables (Fig. 6-11)?

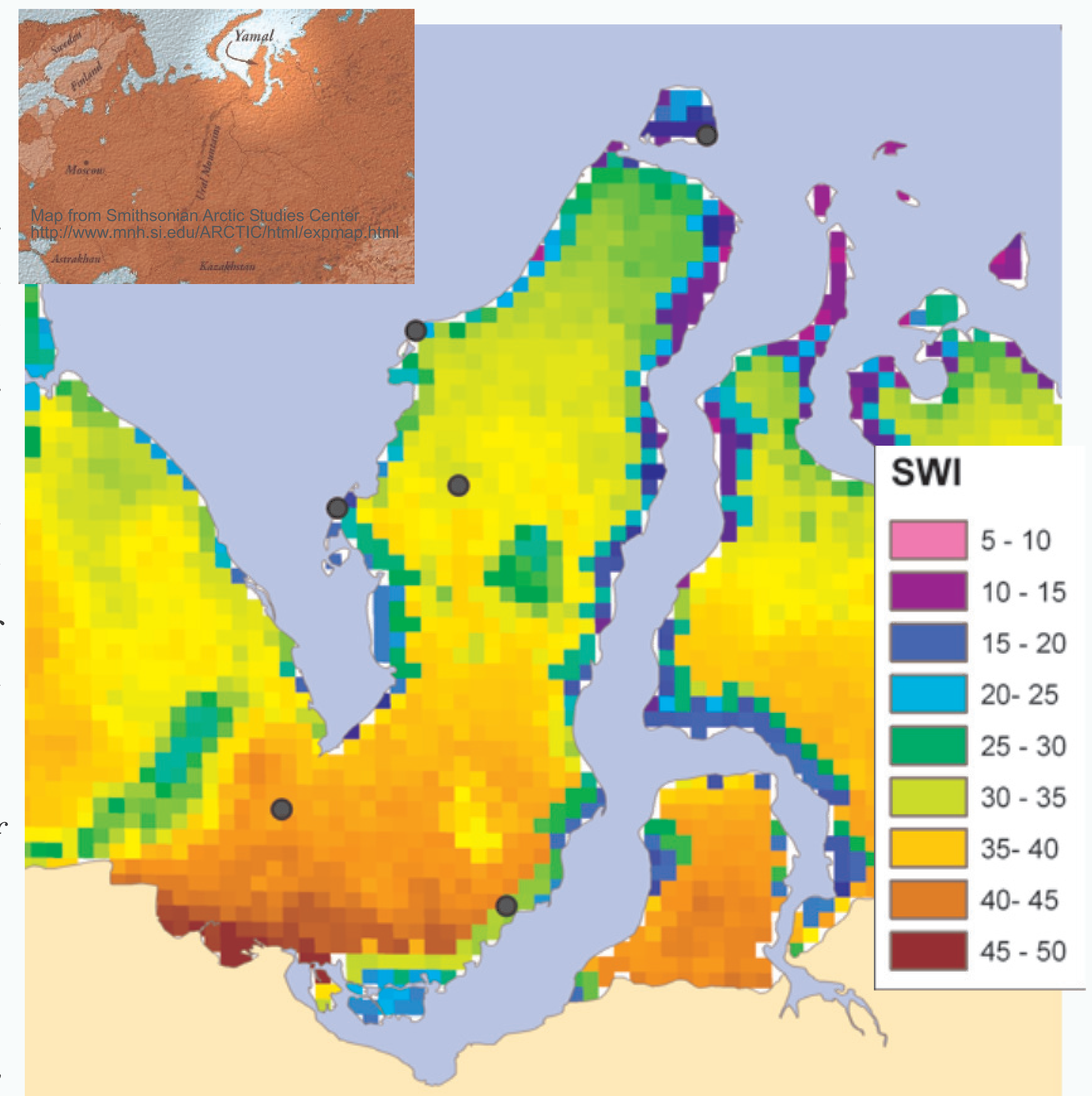

Figure 2. Summer Warmth Index (SWI) is the sum of the mean monthly temperatures > 0 °C. Data are means 1982-2003 (Raynolds et al. 2008).

Methods

Regression analysis between NDVI and SWI (Fig. 3) showed that SWI explained 22% of the variation in NDVI on the Yamal Peninsula, whereas in the Arctic as a whole (green line), SWI was much more strongly correlated with NDVI, explaining 58% of the variation.

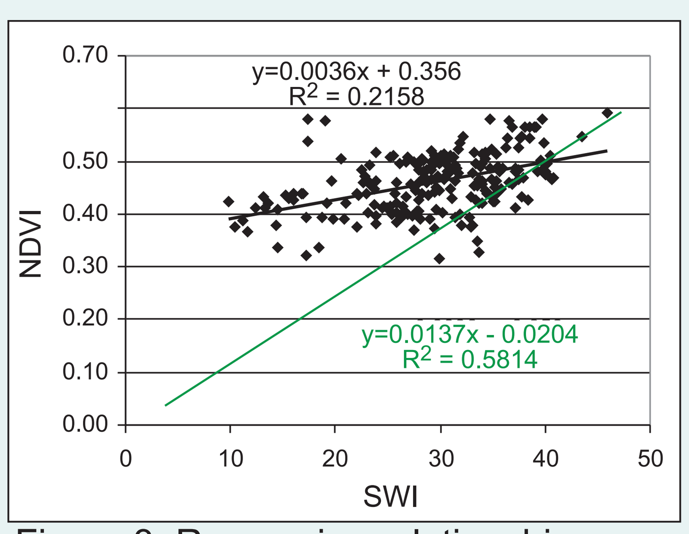

Figure 3. Regression relationship between NDVI and SWI.

We used the Normalized Difference Vegetation Index (NDVI) to map spatial patterns of vegetation distribution on the Yamal Peninsula (Fig. 1). NDVI is a measure of relative greenness calculated as: NDVI= (NIR-R)/(NIR+R), where NIR is the spectral reflectance in the near-infrared where reflectance from the plant canopy is dominant, and R is the reflectance in the red portion of the spectrum where chlorophyll absorbs maximally. It is a good indicator of variation in arctic vegetation, increasing with the amount of biomass, productivity and leaf area index (Shippert et al. 1995, Riedel et al. 2005). It can be used to distinguish between arctic vegetation types (Hope et al. 1993, Stow et al. 1993). The NDVI data for this study came from AVHRR data from 1993 and 1995, using maximum NDVI values (CAVM Team 2003). Land surface temperatures were derived from thermal AVHRR bands (Comiso 2003). Summer Warmth Index, the sum of all mean monthly temperatures > 0 °C, was calculated for the period of record (1982-2003) (Raynolds et al. 2008). Other variables used in the analysis are from the Circumpolar Arctic Vegetation Map (CAVM) project, including GIS data provided by the Earth Cryosphere Institute in Moscow (Walker 2005). We analyzed the amount of variation in NDVI that was explained by each of the variables using linear regression and a general linear model.

Regression between NDVI and elevation (Fig. 4) showed that NDVI increased somewhat with elevation on the Yamal Peninsula. In the Arctic as a whole (green line), NDVI decreased slightly with elevation.

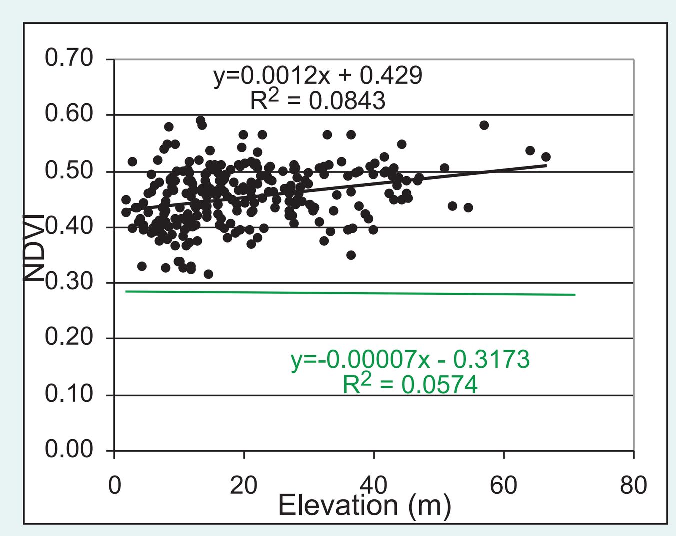

Figure 4. Regression relationship between NDVI and elevation.

Results

Figures 3 and 4 show the results of the regression relationships between NDVI and SWI, and NDVI and elevation.

Comparison of actual NDVI with predicted NDVI based on SWI/NDVI relationship for the whole Arctic (Fig. 5) showed less NDVI than expected (brown areas) for areas with many lakes, and more NDVI than expected along coasts and in the foothills of the Ural Mountains (green areas).

A General Linear Model (Table 1) showed that elevation and landscape together accounted for 49% of the variance in NDVI. Substrate (peat, clay or sand), vegetation mapping unit, SWI and percent lake cover were also significant, but less so. Together, these factors accounted for 62% of the variance in NDVI on the Yamal Peninsula.

NDVI compared to expected values based on SWI

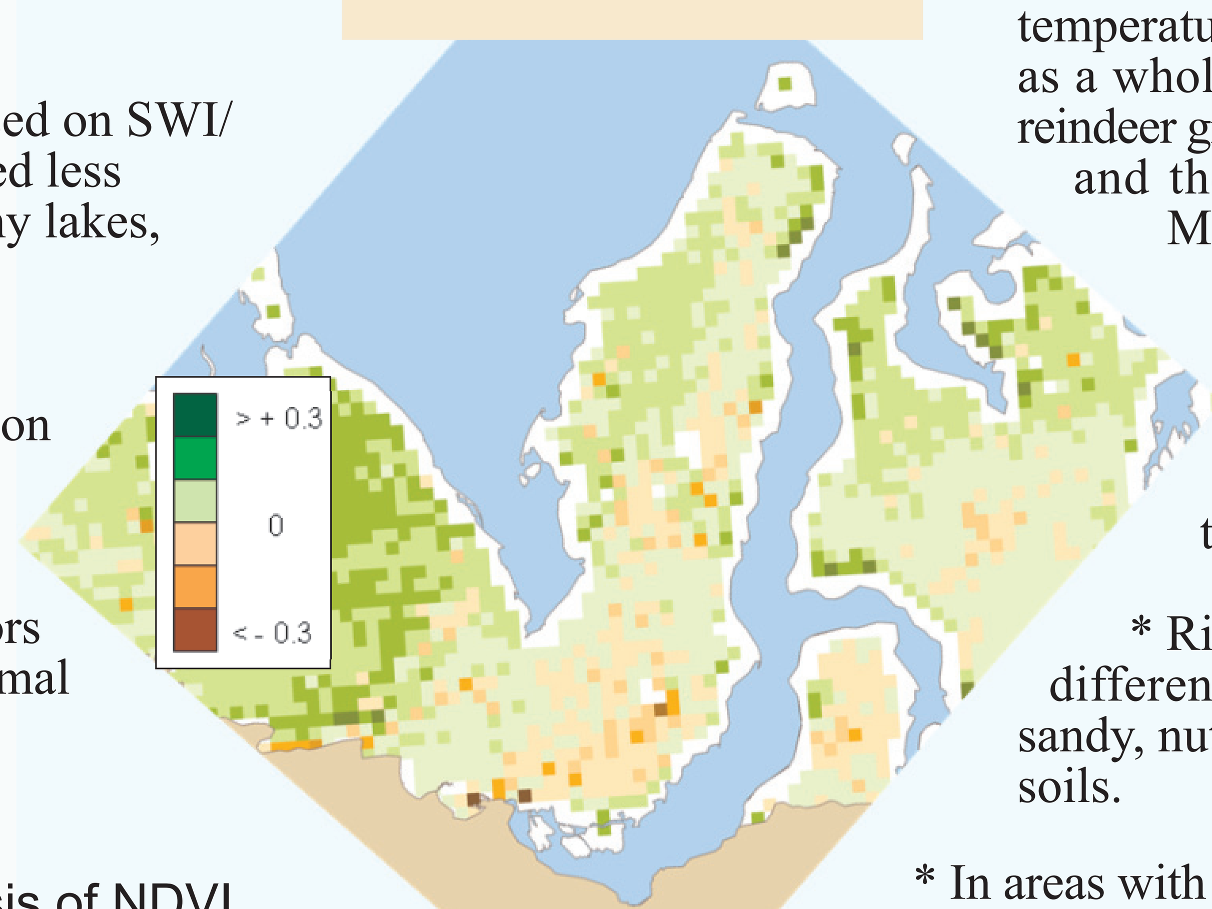

Figure 5

Table 1. Results from General Linear Model analysis of NDVI

	Deviance	Residual Df	Residual Deviance	% Deviance accounted for	Significance
Null		280	2.06516		
Elevation	0.60322	279	1.46194	29.21	< 0.000000
Landsape	0.40732	278	1.05462	19.72	< 0.000000
Substrate	0.10083	277	0.95380	4.88	< 0.000000
Vegetation unit	0.08868	276	0.86512	4.29	0.000004
SWI	0.03856	275	0.82655	1.87	0.000112
Lake area	0.03245	274	0.79410	1.57	0.000934
TOTAL				61.55	

Conclusions

* NDVI on the Yamal Peninsula increases with summer temperature, but the relationship is less strong than for the Arctic as a whole. This is likely to due to a host of factors, including reindeer grazing, substrate differences between valleys and uplands, and the physiognomic boundary associated with the Ural Mountains in the southwestern portion of the map.

* Contrary to global patterns, NDVI on the Yamal increases slightly with elevation. The range of elevations is very small, as most of the Yamal is below 60 m. The trend is partially due to the fact that the highest elevations are in the warmer south.

* River drainages had higher NDVI than upland areas, with different landscape type and substrate texture. Uplands have sandy, nutrient-poor soils whereas the valleys have finer-grained soils.

* In areas with many lakes, the low NDVI value of the water masks the vegetation signature.

Acknowledgements

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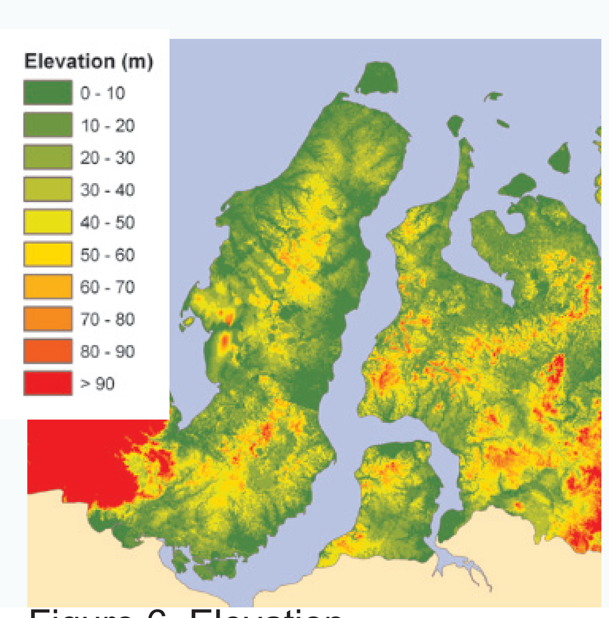

Figure 6. Elevation

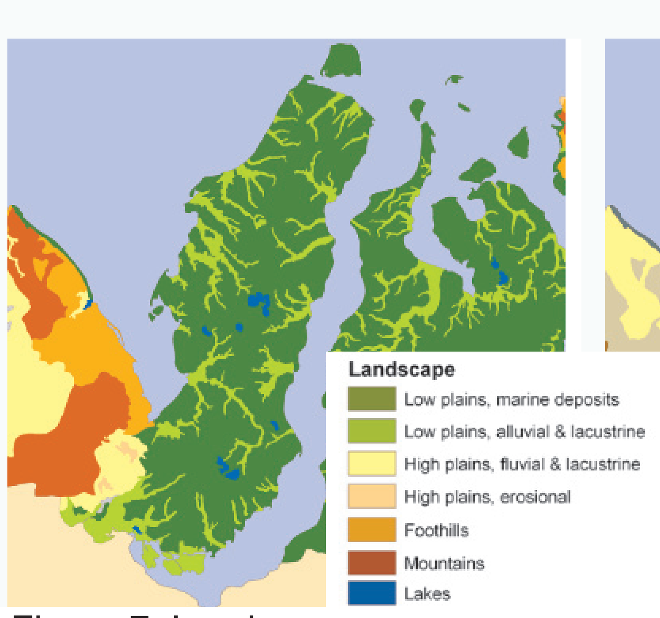

Figure 7. Landscape

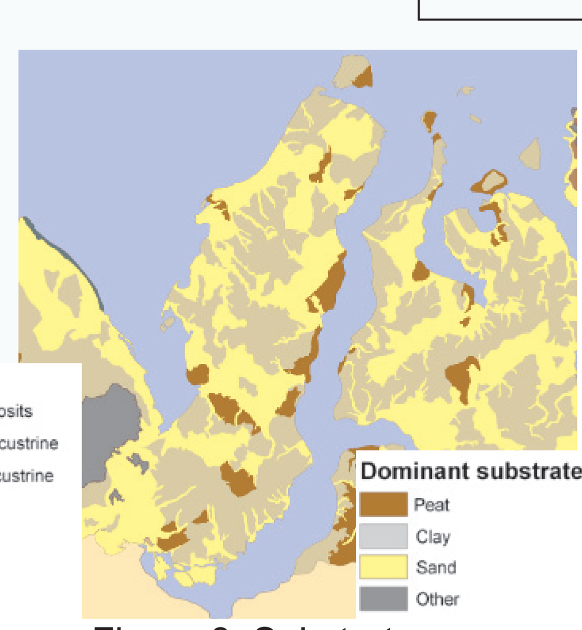

Figure 8. Substrate

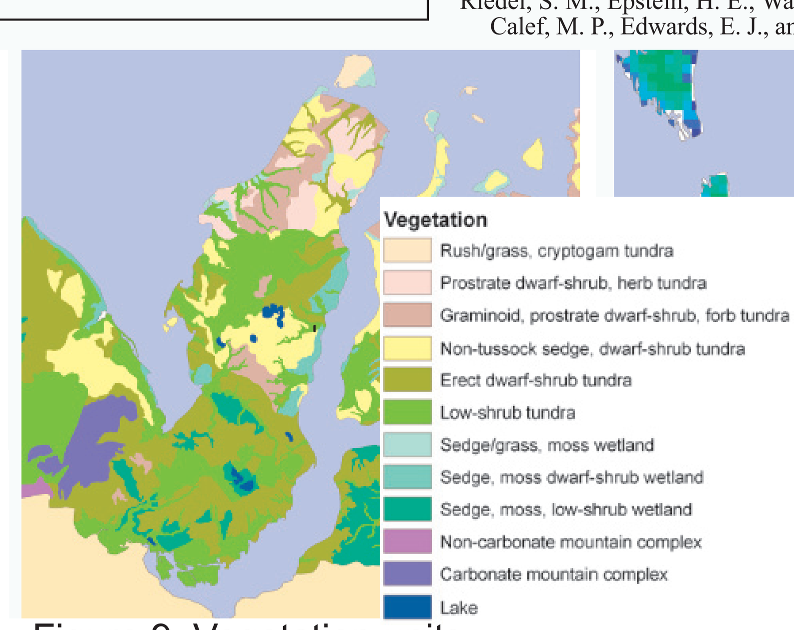

Figure 9. Vegetation units

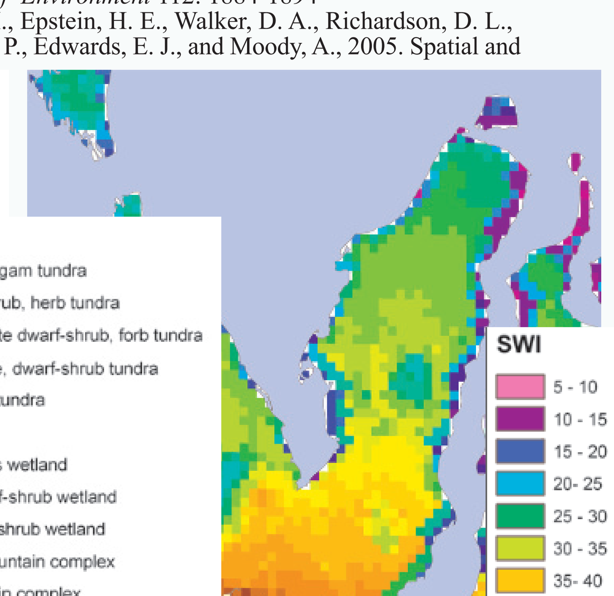

Figure 10. SWI

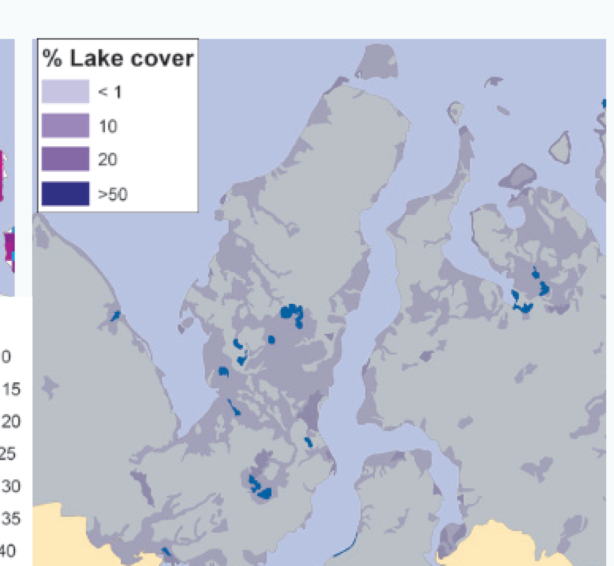

Figure 11. Percent Lake Cover