Mapping of Active Layer Depths Using Correlation between Active Layer Depth and Vegetation Parameters on Central Yamal, Russia

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CALM
www.udel.edu/Geography/calm/

www.geobotany.uaf.edu/goa/

www.geobotany.uaf.edu/yamal/

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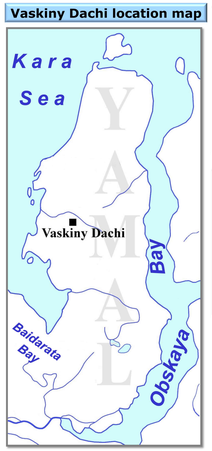
Vaskiny Dachi location map



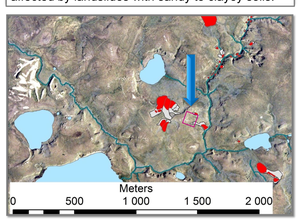
CALM grid location

Introduction

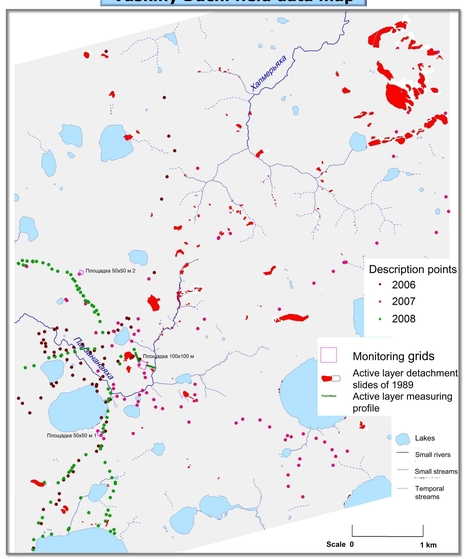
Mapping active layer depths at Vaskiny Dachi key site based on parameters of vegetation is discussed. Active layer depth measurements on a 100x100-m (CALM) and three 50x50-m LCLUC-Yamal grids were extrapolated to entire area of the key site using relationships between Normalized Difference Vegetation Index & Leaf Area Index and active layer depths.

Study area

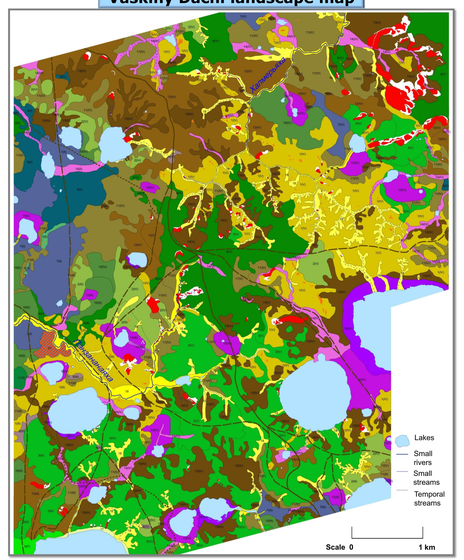
Vaskiny Dachi key site is located in the watershed of Se-Yakha and Mordy-Yakha rivers on Central Yamal, Russia. The area is represented by highly-dissected alluvial-lacustrine-marine plains and terraces.
The CALM grid was placed on the top and slope of a highly dissected alluvial-lacustrine-marine plain, affected by landslides with sandy to clayey soils.



Vaskiny Dachi field data map



Vaskiny Dachi landscape map



Results

The extrapolation of active layer depth measurements obtained on monitoring grids to entire area of key site is possible because landscapes described at monitoring grids are most typical for tundra of Central Yamal. Ranges of vegetation indices and the depth of thaw for the main surfaces, represented at Vaskiny Dachi key site were identified. Summarizing numerous data on the active layer depths for this region, including published by other researchers, it can be argued that on convex well-drained poorly-vegetated surfaces, including windblown sands, active layer depths exceed 100 cm. At the same time, on poorly-drained concave densely vegetated surfaces active layer depths are usually less than 70 cm. Relatively poorly-drained medium-vegetated surfaces are in an intermediate position. Our research showed that for these 3 categories of landscape the NDVI/LAI is usually less than 0.5/0.7 for convex poorly-vegetated, varied from 0.5/07 to 0.8/1.0 for relatively poorly-drained medium-vegetated and over 0.8/1.0 for concave poorly-drained densely vegetated surfaces, respectively.

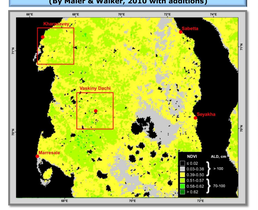
Surfaces	Active layer depths, cm	NDVI	LAI
Relatively drained poorly-vegetated and wind-blown sands	>100	< 0,5	< 0,7
Poorly-drained medium-vegetated	70 – 100	0,5 – 0,8	0,7 – 1,0
Wet concave densely vegetated	< 70	> 0,8	> 1,0

The distribution of active layer depths at Vaskiny Dachi key site is shown on the landscape map, compiled to assess landsliding hazard (Khomutov in prep.). Landscape complexes allocated through the analysis of landsliding hazard were grouped according to the identified ranges of vegetation indices and active layer depths. Fluvial forms (drainage hollows, ravines, small stream valleys) are included in contour with active layer depths more than 100 cm because they are subject to stream warming effect.

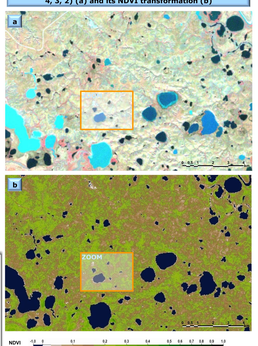
When determining the NDVI on satellite images with different resolution it is possible to assign the range of active layer depths to set of classes with a certain range of NDVI values.

Some examples of active layer depths mapping using automatic transformation of raw satellite data into NDVI values is displayed below.

The NDVI value image of the Yamal Peninsula created from Landsat TM Orthorectified Mosaics (acquired 1986-1995) (By Maier & Walker, 2010 with additions)

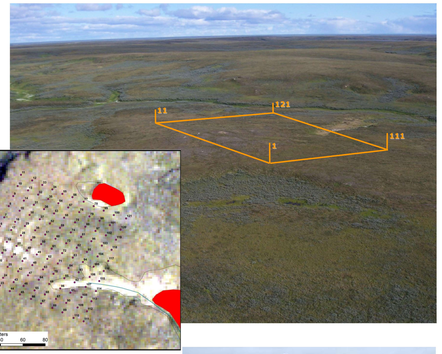


Landsat 7 ETM+ image, 31/08/2005, in false colors (Bands 4, 3, 2) (a) and its NDVI transformation (b)



In areas of interests two prevailing colors of NDVI values shows the general contours of active layer depths ranges. Yellow color (NDVI=0.39-0.50) / light green color (NDVI=0.51-0.57) indicate generalized contours with more / less than 100 cm active layer depths, respectively.

Vaskiny Dachi Scene of Landsat 7 ETM+ 31.08.2005 was automatically transformed with ENVI software by standard procedure using Band 3 and 4 of image to obtain NDVI classification. Used is the discrete NDVI scale (NDVI - [theory] and practice 2010).
Low resolution (15x15 m pixel) of Landsat does not allow detailed mapping of the active layer depths which local differentiation is so high.



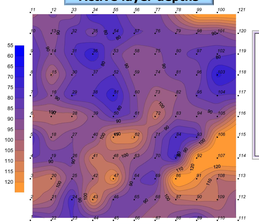
H.E. Epstein sampling NDVI using the PSII Spectrometer.
Photo by D.A.Walker, 2007

A.V. Khomutov & M.O. Leibman measuring active-layer depth.
Photo by G.V. Matyshak, 2007

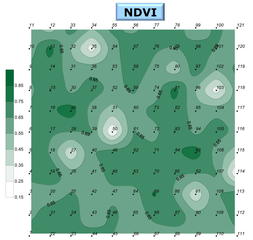
Methods

The active layer was monitored using a metal probe according to the procedure accepted by the CALM program (Brown et al. 2001) within a grid 100 x 100 m in 10-m increments. Ground and vegetation characteristics were recorded at each grid node.
NDVI was measured using a portable ASD PSII spectroradiometer, and LAI was estimated using a LICOR-2000 plant canopy analyzer. Indices were measured and data were kindly given to author by professor H.E. Epstein (University of Virginia) for further analysis. Indices measurements NDVI is essentially an index of green, photosynthesizing vegetation, as it strongly depends on the absorption of visible wavelength. LAI (as estimated by the LICOR-2000) is the total area of aboveground plant tissue divided by the ground area that is covered by the extent of the plant canopy. >

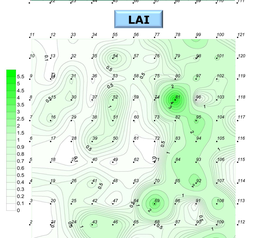
Active layer depths



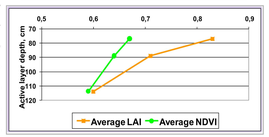
NDVI



LAI



Relation between the active layer depth and average vegetation indices



> Both NDVI and LAI are well positively correlated to the mass of aboveground vegetation, and this is true for Low Arctic tundra vegetation (Riedel et al. 2005).

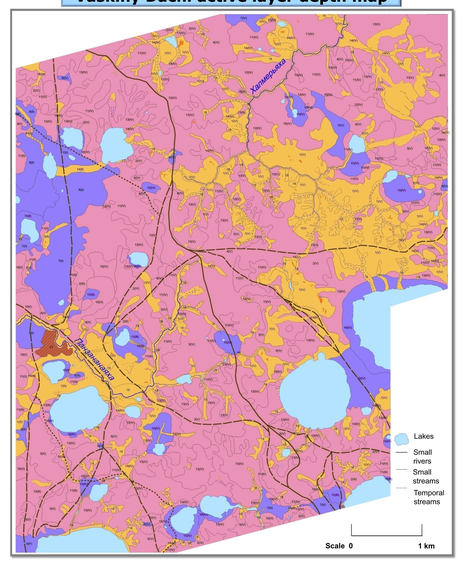
A database included ALD, NDVI, LAI, organic mat thickness, shrub height, dominant plant species and coverage of each plant community (Leibman et al 2008, Khomutov et al 2010). As expected, the average values of active layer depth have an inverse relationship with average values of the vegetation indices because, as a rule, higher vegetation indices correlate with higher insulating properties of vegetation. Then, to define an effect of different vegetation formations, their vegetation indices, as well as other parameters (height/thickness and coverage) were linearly correlated: NDVI to moss coverage, LAI to shrub height, and more.

The inverse relationship between active layer depth and NDVI depends most strongly on moss thickness and coverage, grass height and coverage, and shrub and sedge height. Shrub, sedge and lichen coverage slightly distorts this relation. The fact that average values of active layer depth have the inverse relation to average values of LAI means that shrubs and lichens are more important factors controlling relation between active layer depth and LAI.

Table of Vaskiny Dachi landscapes

## on map	Color on map: Landscape pattern	Color on map: Active layer depth range	Landscape complexes
1			Rolling subhorizontal surfaces (convex hill tops and their slopes) with polygonal dwarf shrub-herb-lichen tundra with wind-blown sands on on sandy and silty soils, alternate with herb-shrub-moss tundra on silty and clayey soils
2			Flat subhorizontal surfaces with hummocky herb-dwarf shrub-moss-lichen and tussocky shrub-herb-moss tundra on silty and clayey soils (locally with wind-blown sands)
3			Flat subhorizontal surfaces with herb-dwarf shrub-moss tundra on silty and clayey soils, with patches of polygonal herb-shrub-lichen-moss tundra on sandy and silty soils
4			Flat subhorizontal surfaces with hummocky-tussocky shrub-herb-moss tundra on silty and clayey soils
5			Peripheral zone of flat subhorizontal surfaces with hummocky polygonal herb-dwarf shrub-moss-lichen tundra on silty soils (locally with wind-blown sands)
6			Flat subhorizontal surfaces with flat-topped polygonal cloudberry-sedge-lichen-sphagnum peatland on peaty silty, clayey and peat soils
7			Flat subhorizontal surfaces with dwarf shrub-sedge-sphagnum and cottongrass-sedge-moss bogs with patches of flat-topped polygonal peatland on peaty silty and clayey soils
8			Flat subhorizontal surfaces with cottongrass-sedge-moss bogs on silty and clayey soils
9			Flat rear zone of flood plain with tussocky sedge-moss and sedge-cowberry-moss communities on clayey soils
10			Flat slightly slopping surfaces with herb-moss-shrub tundra on silty and clayey soils
11			Flat gentle slopes with tussocky herb-grass-moss willow beds (dwarf birch presented) on clayey soils
12			Flat gentle slopes with tussocky shrub-sedge-sphagnum communities on silty and clayey soils
13			Concave gentle slopes with ancient landslide shear surfaces, with herb-grass willow beds on clayey and saline clay soils
14			Drainage hollows with cottongrass-sedge-moss communities on clayey soils
15			Khasyreis with herb-dwarf shrub-moss-lichen communities on more drained sites (with peaty silty and peat soils), with cottongrass-sedge-moss willow beds and dwarf shrub-sedge-sphagnum bogs on wetter sites (with peaty clayey and peat soils)
16			Low lake terraces with tussocky sedge-moss and sedge-cowberry-moss communities on peaty silty and clayey soils
17			Lake beaches with fragmentary cottongrass-arctophila communities on sands
18			Ravines and gullies with wet cottongrass-sedge-moss bottom and hummocky-tussocky slopes with herb-moss willow beds and dwarf birch on clayey soils
19			Small stream valleys with herb-moss willow beds on clayey soils
	a / b		Cryogenic landslides of 1989 overgrown to a various degree: landslide shear surfaces (a) with pioneer grass groups on saline clay; landslide bodies (b) with partly degraded typical vegetation on silty and clayey

Vaskiny Dachi active layer depth map



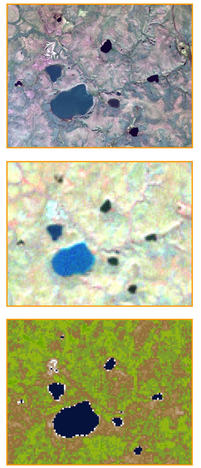
Active layer depths, cm

>100 | 70 – 100 | < 70

Therefore, searching for correct method of active layer depth mapping using correlation with vegetation parameters needs to be continued. One of the most important tasks is to find right correlation between ground and remote-sensing NDVI data.

On the one hand, wet surfaces of Second River Terrace and khasyreis show NDVI values by remote-sensing less than 0.5 and on the other hand, they are characterised by active layer depths mostly less than 100 cm (see compared fragments of GeoEye Mosaic, Landsat 7 ETM+ and its NDVI transformation). NDVI transformation image average values of NDVI for each 15x15 m pixel. This approximation levels the role of relatively small patches with well developed moss cover, high NDVI and shallow thaw.

GeoEye Mosaic 1m 15/08/2009 zoom (a), false color Landsat 7 ETM+ image 31/08/2005 zoom (b) NDVI transformation zoom (c)



Conclusions:

Local scale study shows that for convex well-drained poorly-vegetated surfaces with active layer depths over 100 cm NDVI/LAI is usually less than 0.5/0.7, for poorly-drained concave densely vegetated surfaces with active layer depths less than 70 cm NDVI/LAI is over 0.8/1.0. Relatively poorly-drained medium-vegetated surfaces with active layer depths varying from 70 to 100 cm are in an intermediate position, with NDVI/LAI ranging at 0.5/07 and 0.8/1.0.

Exception is fluvial forms which are affected by stream warming. Though drainage hollows, ravines and small stream valleys have thick vegetation cover and high NDVI, they are characterized by deep active layer (more than 100 cm).

Mapping of the active-layer depth through its correlation with vegetation indices, using NDVI transformation of satellite images can be effectively used after more studies are applied.

Data Sources:
Landsat 7 ETM+. USGS Earth Resources Observation and Science Center (EROS). Scene: LE71660102005243ASN00, Date: 15/08/2005. Online_Linkage: http://earthexplorer.usgs.gov/
"GeoEye-1 image copyright GeoEye, Inc."

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