Landslide and permafrost regimes near the Bovanenkovo gas field, Central Yamal, Russia

Earth Cryosphere Institute
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(1) Earth Cryosphere Institute SB RAS, Tyumen, Russia

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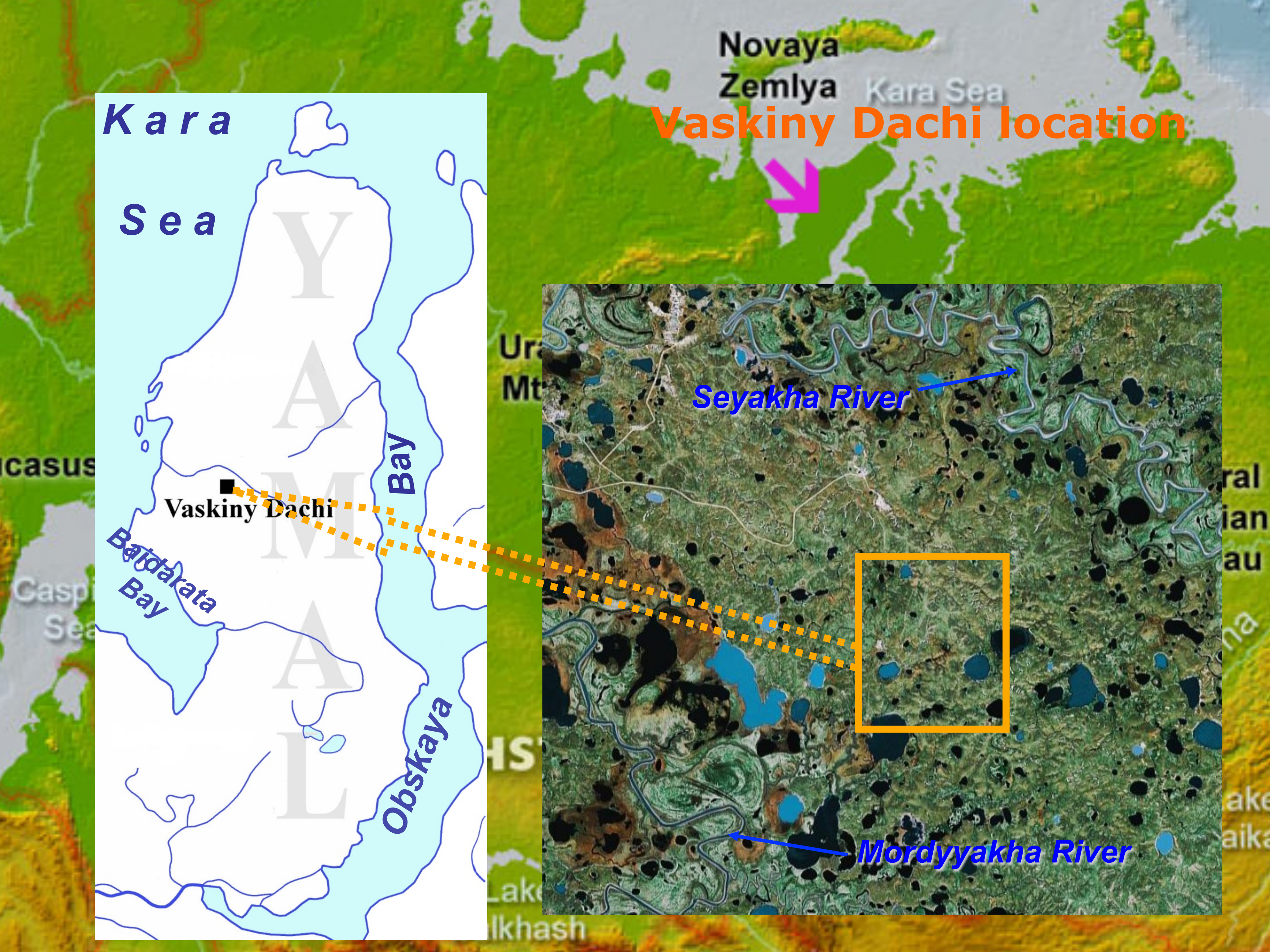


Vaskiny Dachi location
Novaya Zemlya
Kara Sea
Kara Sea
YAMAL
Vaskiny Dachi
Baidarata Bay
Obskaya Bay
Seyakha River
Mordyyakha River

I. Cryogenic landsliding

II. Active layer monitoring

III. Thermal denudation

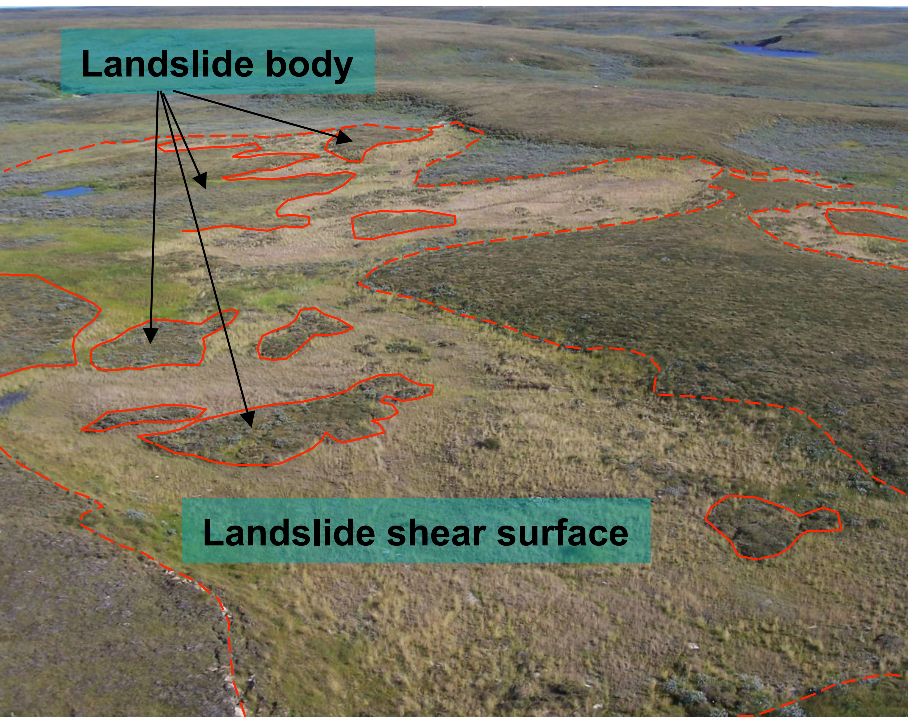
IV. Off-road vehicle tracks

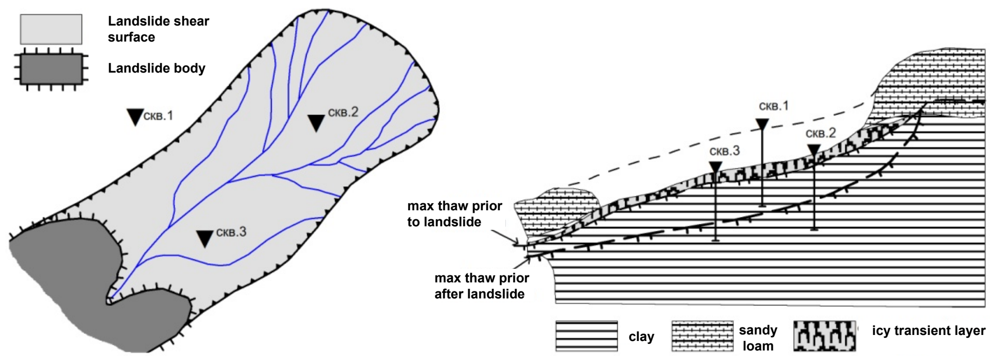
V. Snow differentiation

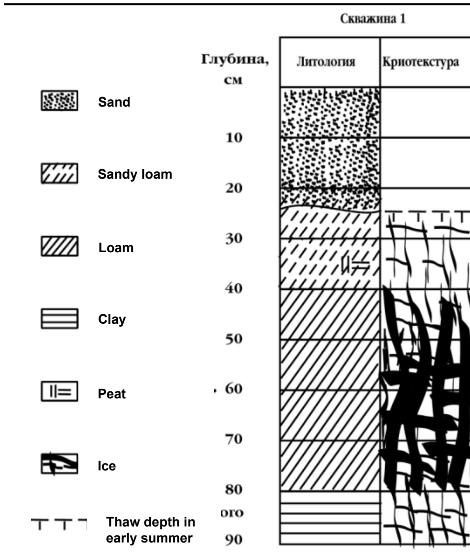
I. Landslides:

- Analysis of cryogenic landslide distribution depending on a landscape pattern.
- Cryogenic landsliding hazard assessment in different landscapes in typical tundra of Central Yamal.

Scheme of cryogenic translational landslide forming

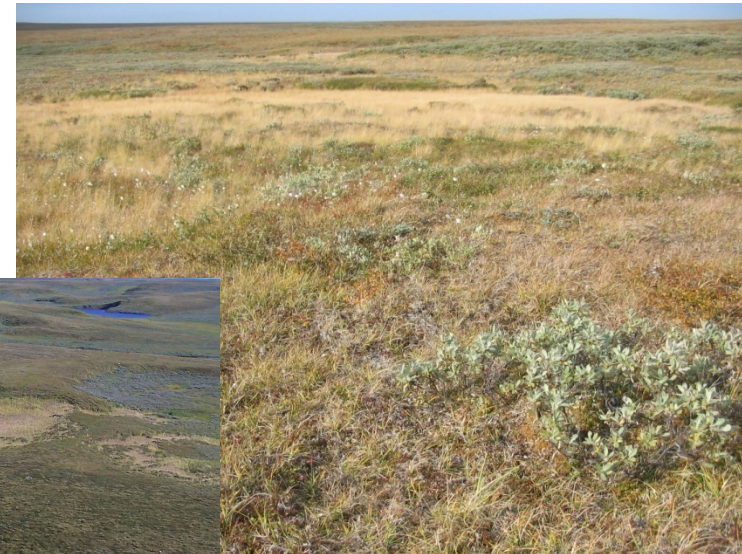




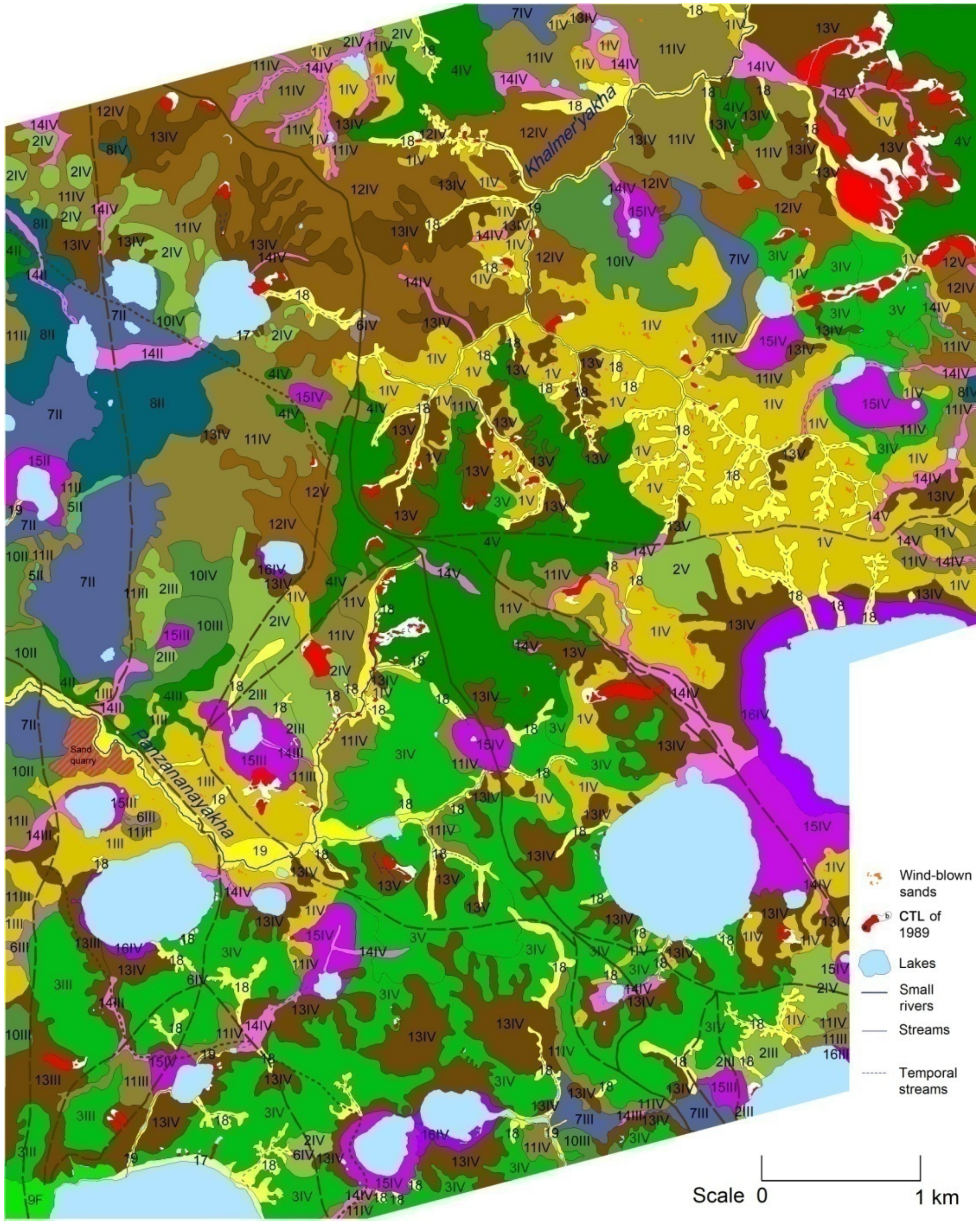


Forming of icy transient layer at the bottom of active layer at landslide slope (by Leibman & Kizyakov 2007)

Cryogenic Translational Landslides of 1989



Vaskiny Dachi Landscape Map



## on map	Color on map		Landscape complexes
	Landscape pattern	Active layer depth range	
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

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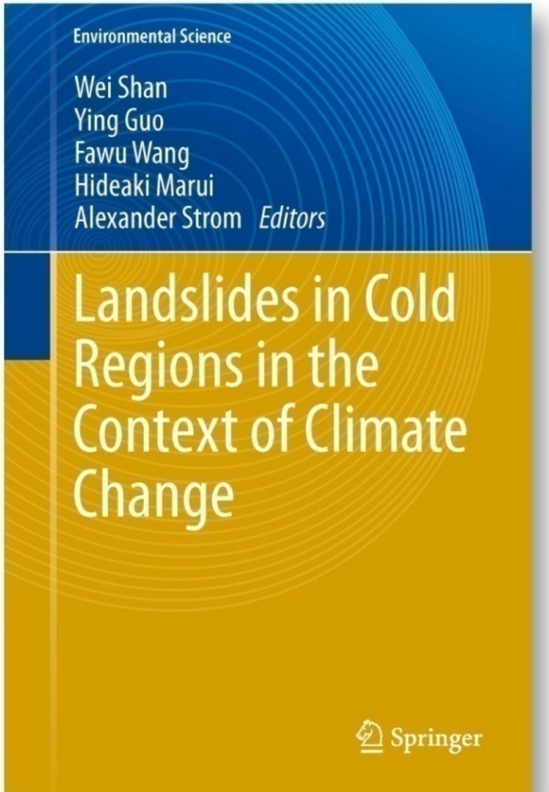

2014, XIII, 310 p. 217 illus., 184 illus. in color.

W. **Shan**, Y. **Guo**, F. **Wang**, H. **Marui**, A. **Strom** (Eds.)

Landslides in Cold Regions in the Context of Climate Change

Series: Environmental Science

- **Covers the different types of landslides in cold regions, including those under different geological and geomorphologic conditions**
- **Supplies specific methods for landslide monitoring and evaluation for cold regions**
- **Presents comprehensive countermeasures for landslides in cold regions**

Landslides in cold regions have different mechanisms from those in other areas, and comparatively few research efforts have been made in this field. Recently, because of climate change, some new trends concerning landslide occurrence and motion have appeared, severely impacting economic development and communities. This book collects key case studies from the cold regions all over the world, providing an overview of the general situation.

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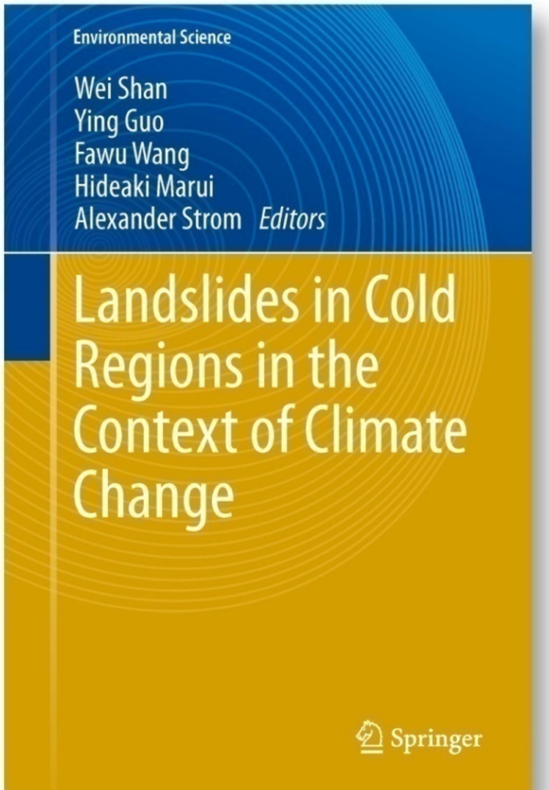

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Landslides in Cold Regions in the Context of Climate Change

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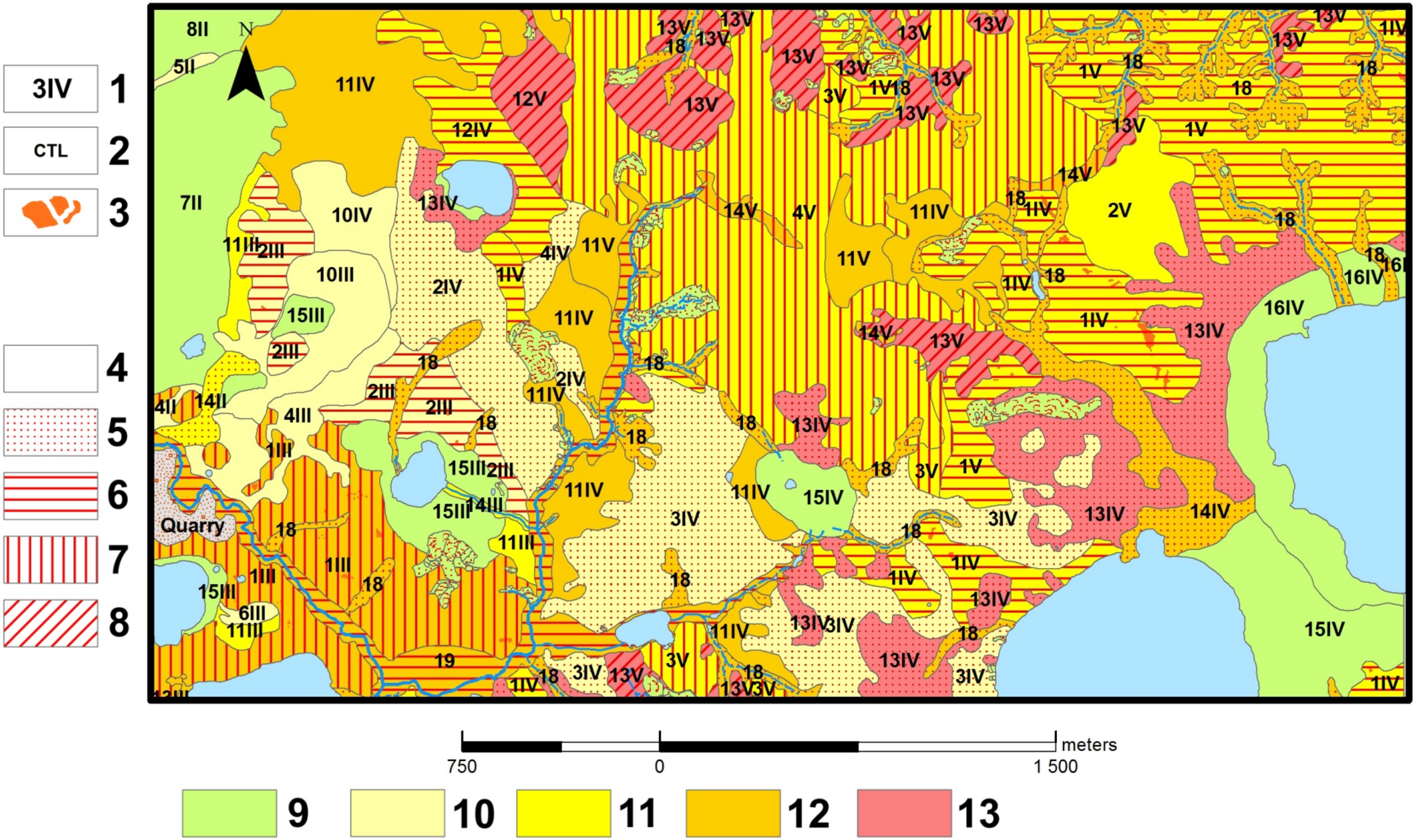
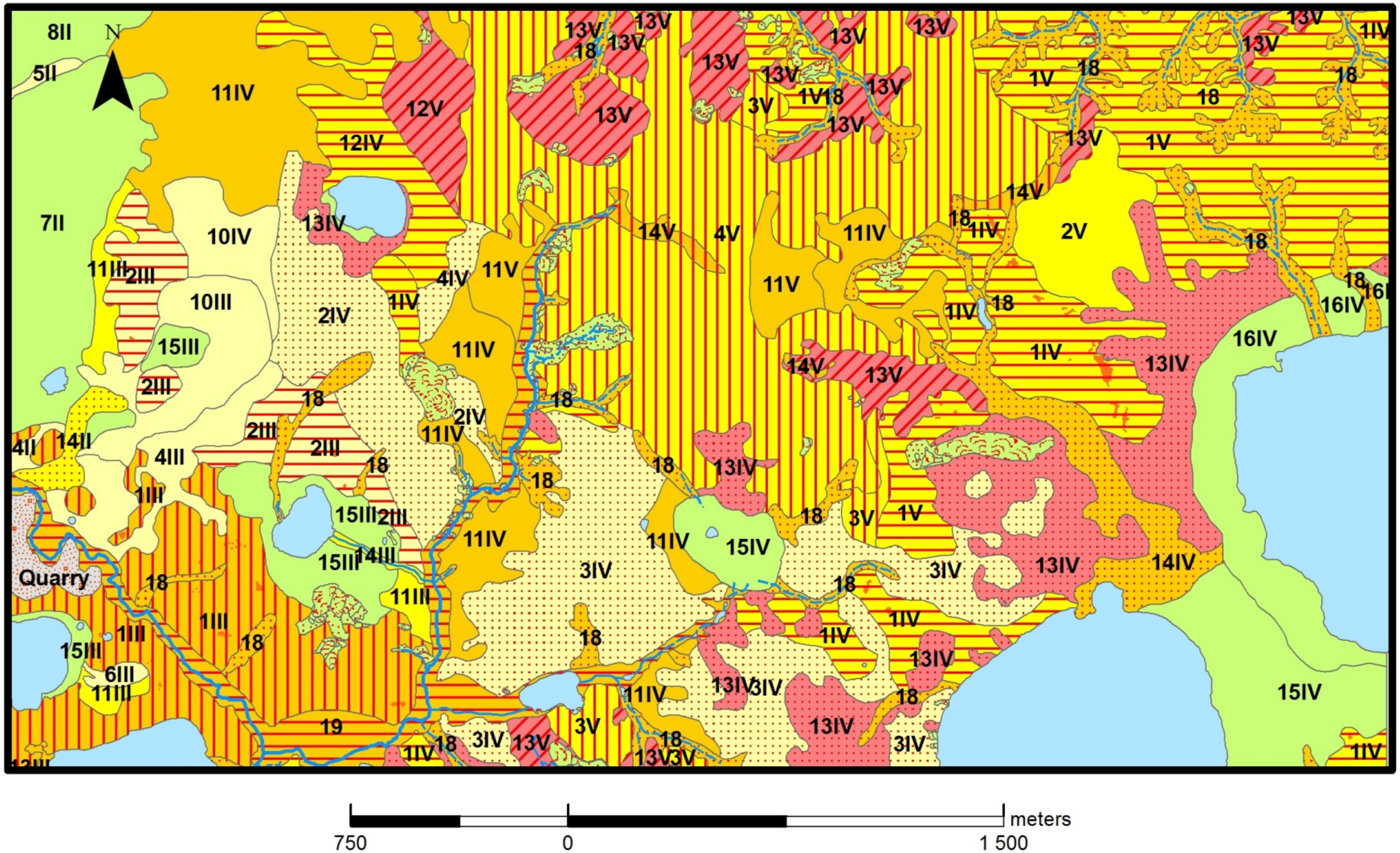
Map of Cryogenic Landsliding Impact/Hazard



1 - landscape complexes, 2 - cryogenic translational landslides of 1989, 3 -windblown sands
Degree of modern landsliding impact: 4 – none (0%), 5 – low (0–1%), 6 – mean (1–5%), 7 – high (5–10%), 8 – largest (10% and more)
Degree of cryogenic landsliding hazard: 9 – impossible, 10 – minimal, 11 – average, 12 – serious, 13 – maximal.



The application of this method revealed the following:

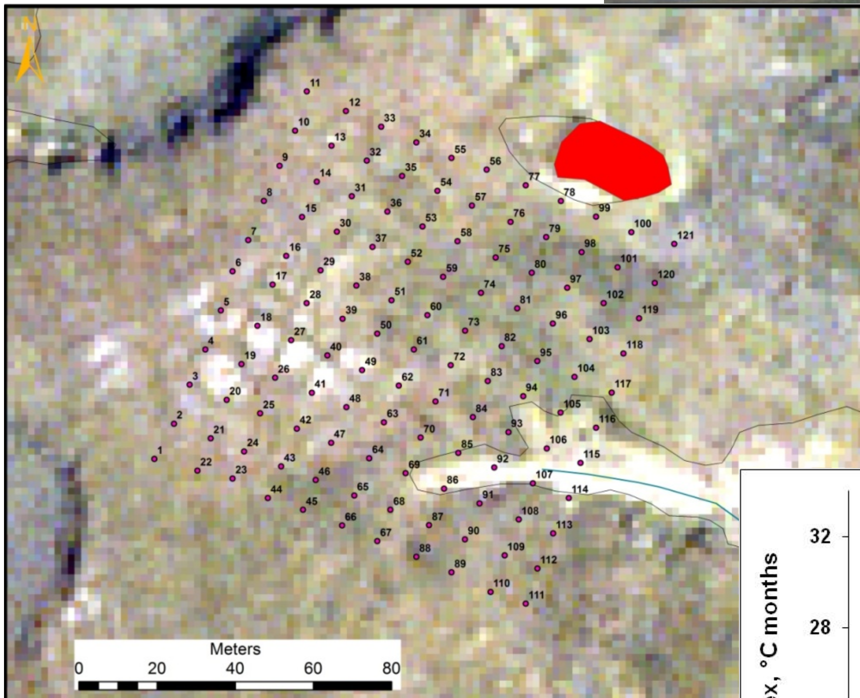
- Very high cryogenic landsliding hazard on concave shrubby slopes is characteristic of all geomorphic levels except Mordyakha river flood plain and 2nd river terrace.

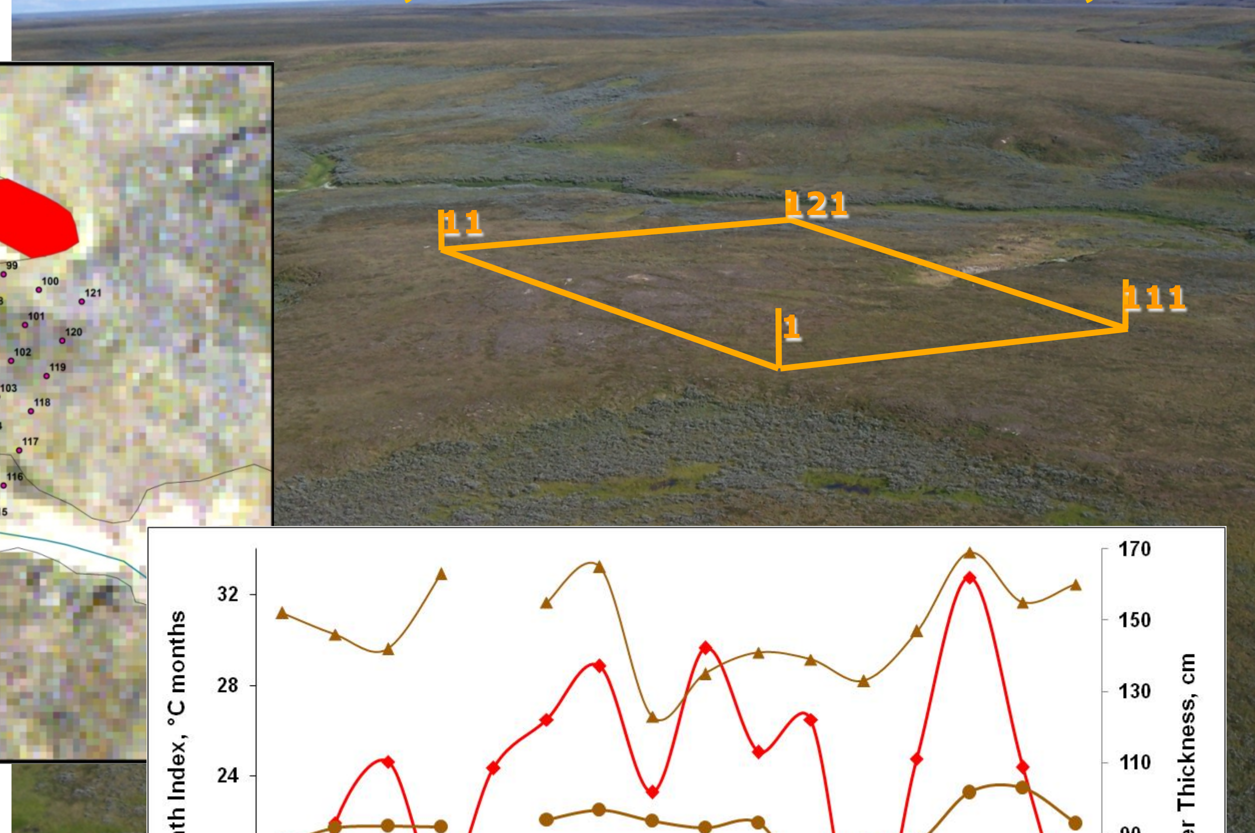
Risk of large-scale landsliding on gentle shrubby/partly shrubby slopes increases from low to high geomorphic levels. Small-scale landsliding on subhorizontal surfaces increases with the degree and depth of dissection by ravine and small stream valleys independently of geomorphic level.

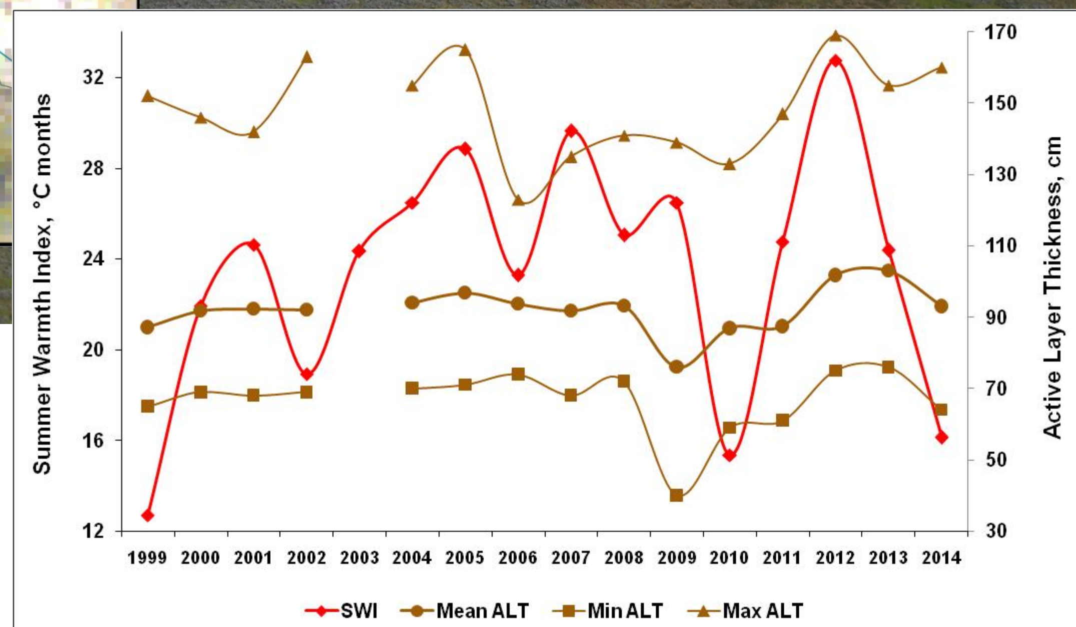
Landscapes in the key area are characteristic of typical tundra in the North of West Siberia. Therefore, the method tested at the key site can be applied to other plains of typical tundra zone with widely distributed tabular ground ice triggering cryogenic landsliding, north of Yuribey river as indicators of evolution of hazardous slope processes ongoing since the Late Holocene.

II. Active Layer Monitoring

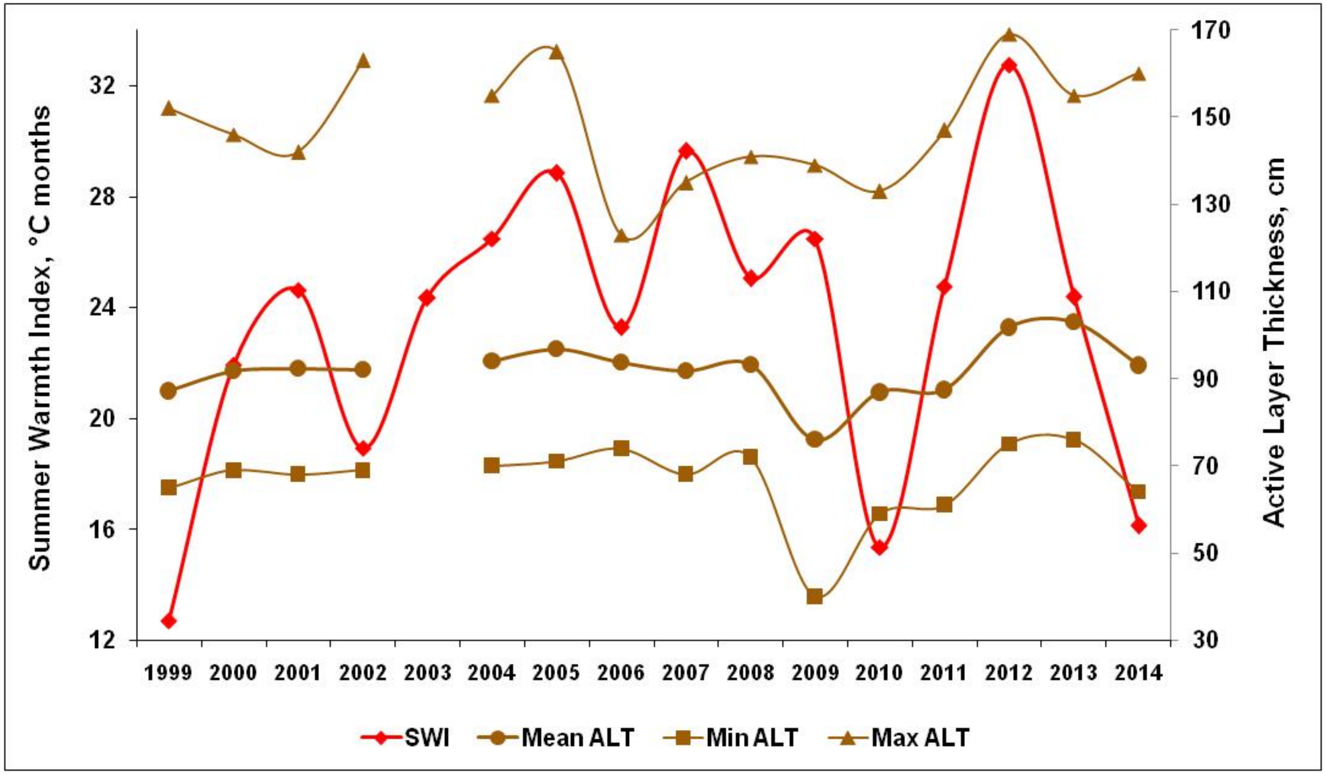
CALM, Yamal LCLUC, …



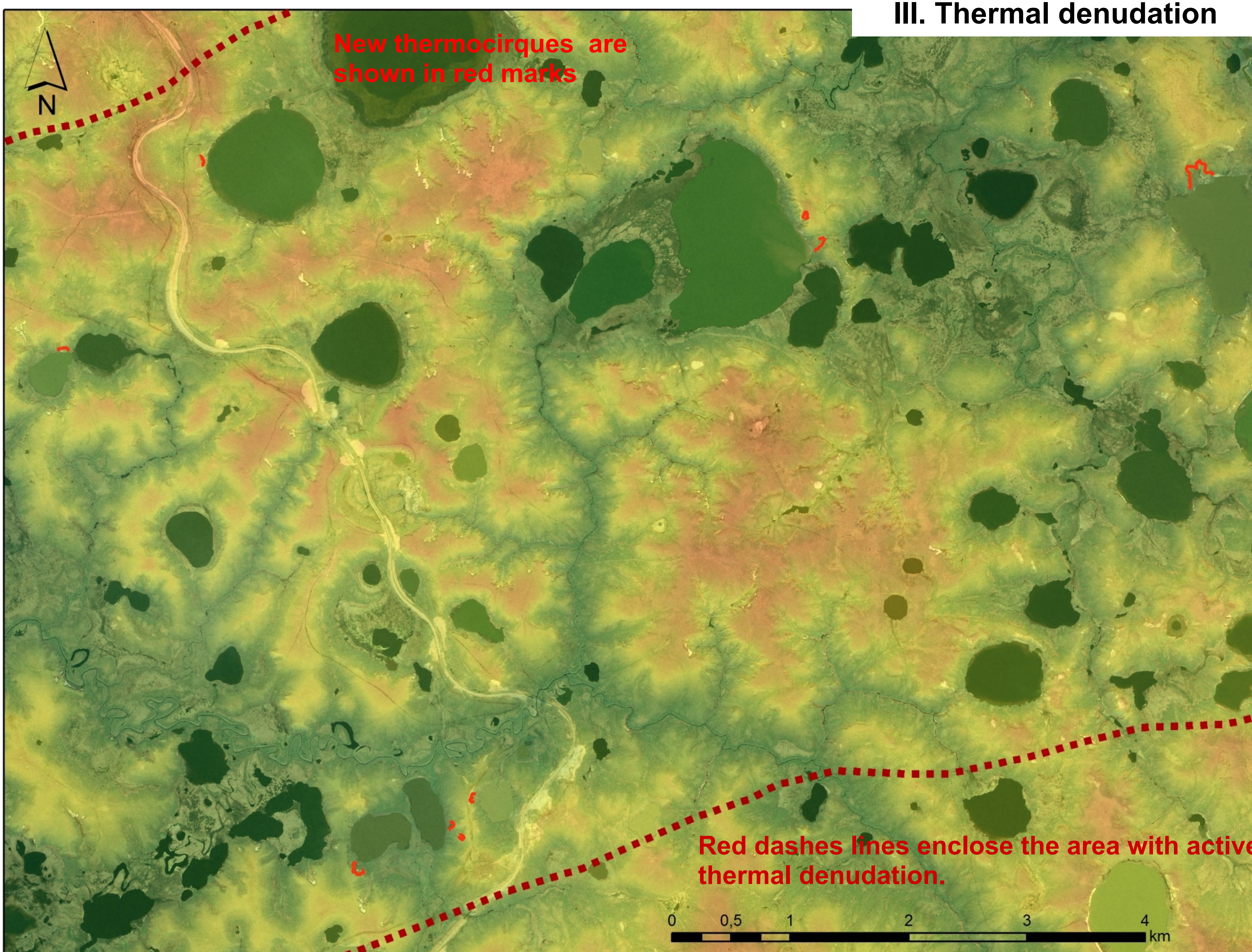




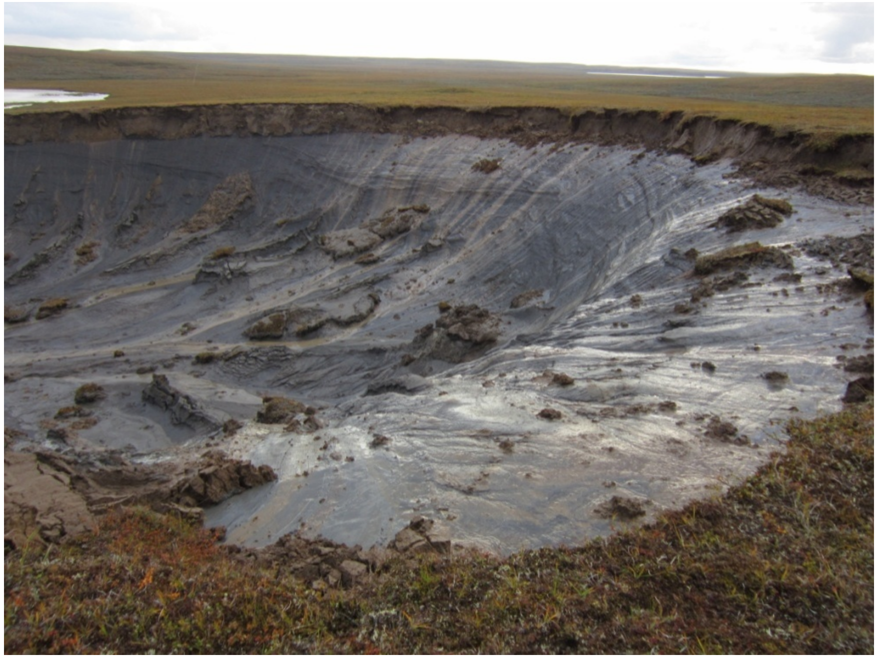
The active layer is monitored using a metal probe according to the procedure accepted by the CALM program (Brown et al. 2001) within a grid 100 x 100 m in 10-m increments. Different ground and vegetation characteristics were recorded at each grid node.

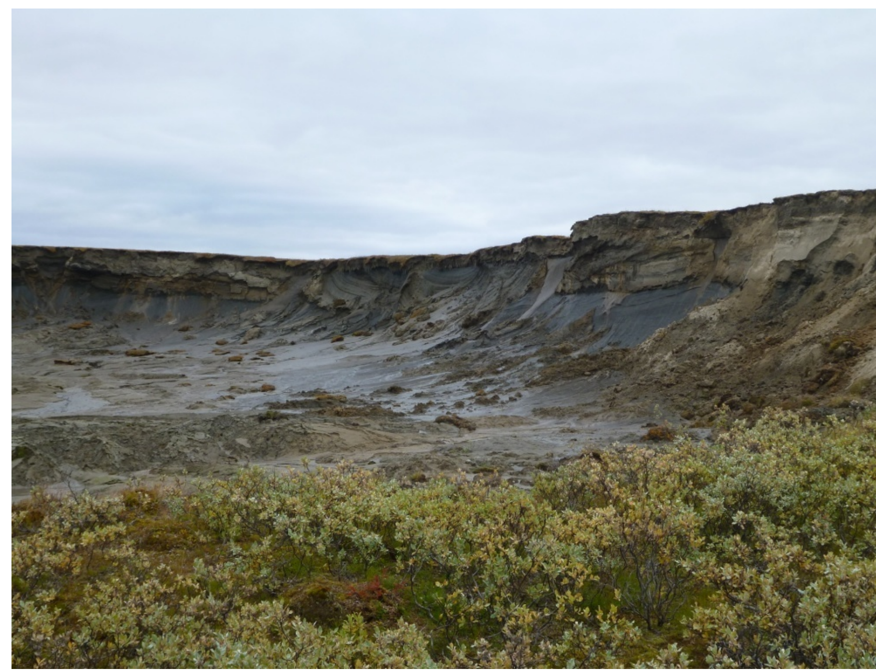


Year/Summer season	MAAT	Thaw index (till measure date)	Summer precipitation (till measure date)	Winter season	Freeze index	Winter precipitation
2004	-7.7	23,6	nd	2004-2005	-88.9	nd
2005	-5.4	21,7	146	2005-2006	-104.3	213
2006	-8,0	21,1	112	2006-2007	-100.0	136
2007	-5,0	21,4	68	2007-2008	-90.1	218
2008	-5,0	22,3	307	2008-2009	-97.5	253
2009	-8,3	11,2	61	2009-2010	-124.1	140
2010	-8,1	15,2	151	2010-2011	-91.4	247
2011	-4,4	16,3	108	2011-2012	-74.5	190
2012	-4,1	28,0	257	2012-2013	-101.8	144
2013	-7,3	21,5	114	2013-2014	-107.0	203
2014	-	12,9	115	-		
Mean	-6,4	19,6	144	-	-97.9	194

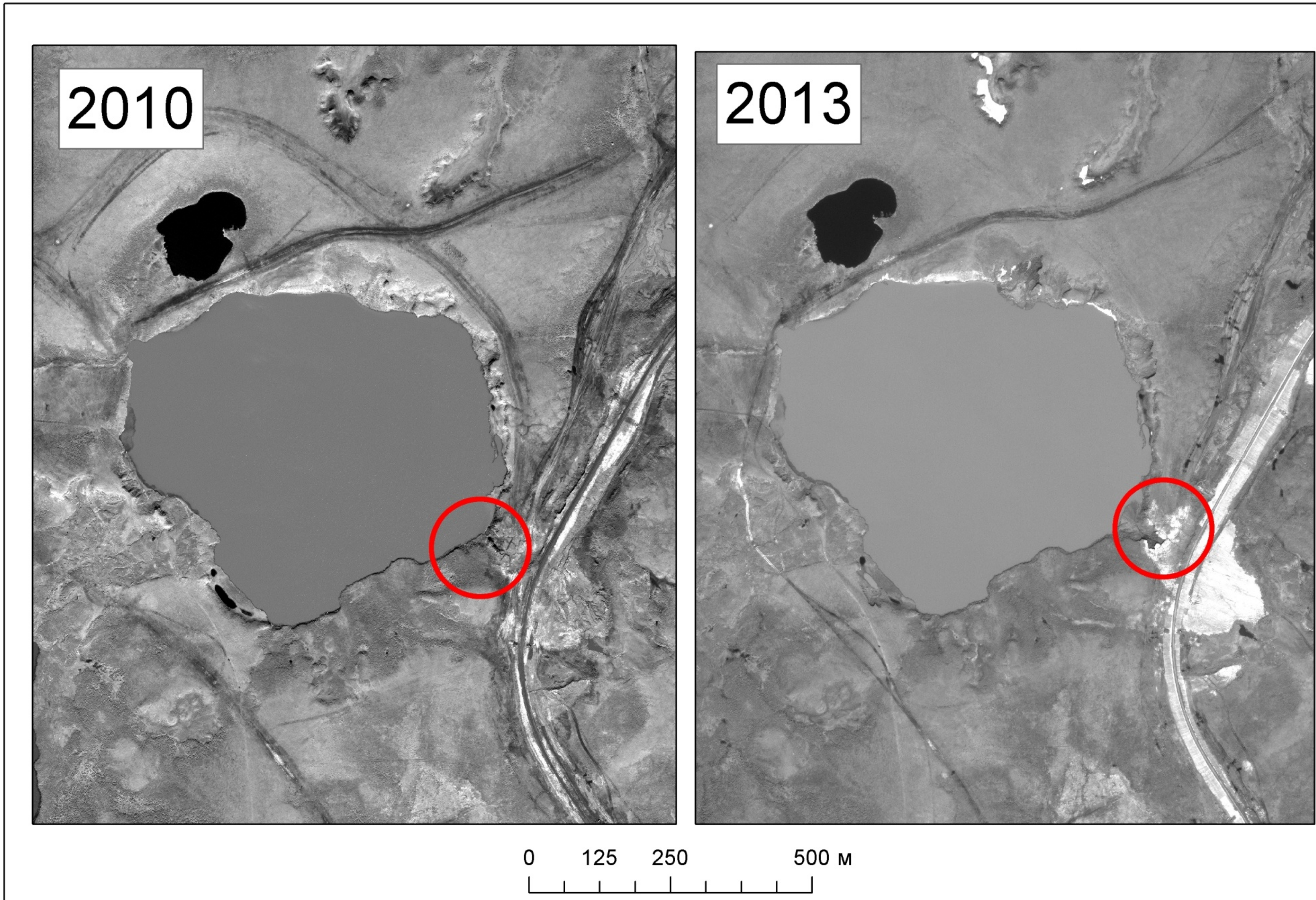


III. Thermal denudation
N
New thermocirques are shown in red marks
Red dashes lines enclose the area with active thermal denudation.
0
0,5
1
2
3
4
km



Thermal denudation and infrastructure



IV.

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Analysis of off-road vehicle-track dynamics on Yamal Peninsula, Russia

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ARCTIC CHANGE 2014

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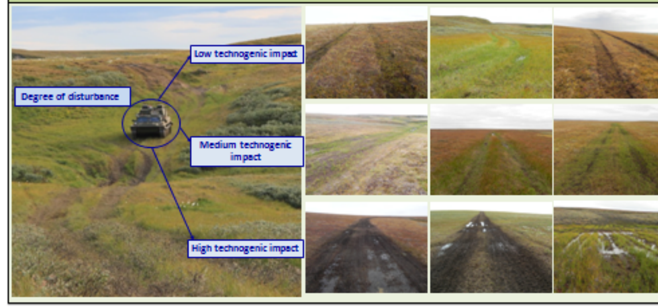
Results of the study of vegetation cover and active layer depth dynamics under technogenic impact in permafrost zone, particularly in the typical tundra subzone, are presented. Study of both vegetation cover and active layer disturbance after off-road vehicle traffic at Central Yamal had started in 1991 in connection with active gas field development and investigations for railway construction in this area (block A). As a result of 2012 field survey and measurements, vehicle tracks were subdivided into 3 groups according to the degree of disturbance: with low, medium and high technogenic impact (block B). The current state of abandoned vehicle tracks which were previously investigated was analyzed (block C). Noticeable recovery of old vehicle tracks is observed on all sites and recovered communities are similar to the original ones, or are replaced by more hydrophilic species. The least visible is recovery of dwarf shrubs and lichens. It contradicts the results obtained in the more southern subzone in Alaska. Old tracks in shrub tundra of Alaska are marked by dwarf birch while in Central Yamal recovery not only takes more time, but old tracks are marked by willow shrubs. Dwarf birch in old fully recovered tracks has less coverage compared to background. Recent tracks are re-vegetating mainly by grass-sedge pioneer groups. Active layer depth as a rule increase in the vehicle tracks. The degree of deepening results from more or less active traffic, and replacement of initial shrubby communities with high species diversity by mainly sedge communities (block D). The highest increase of active layer depth on old tracks is resulting from thermokarst development (Photo). When thermokarst does not develop and surface remains stable, active layer depth moves towards the background values. Next step included mapping of the system of vehicle tracks using aerial images of 1990 and satellite image GeoEye-1 of August 15, 2009 (block E). Two time slices were compared. Total length of vehicle tracks was 126 km in 1990 and 235 km in 2009 within 20 square km area. Total area affected by vehicle tracks was at least 0.51 square km (2.5 per cent) in 1990 and 0.95 square km (4.6 per cent) in 2009. Over 19 years total length of vehicle tracks has increased by 86 per cent. However, most of vehicle tracks appeared not to be actively used, they look like not used for a long time. Only 24.5 km (10.4 per cent) of 2009 tracks could be interpreted as actively used.

Photo. Thermokarst on old track

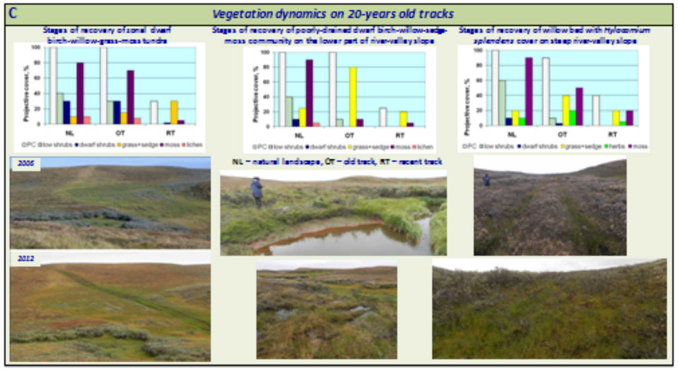
A — Study area

Examples of off-road vehicles and their tracks on Yamal Peninsula

B — Degree of disturbance by off-road vehicles



C — Vegetation dynamics on 20-years old tracks

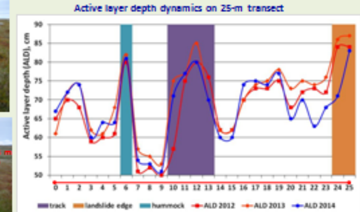


NL – natural landscape, OT – old track, RT – recent track

D — 25-m transect crossing not actively used track

25-m transect was established on flat subhorizontal watershed (4th Coastal-marine plane) with hummocky-tussocky shrub-herb-moss tundra. Transect crosses not actively used track re-vegetated with grass-sedge community. End of transect is on edge of recent landslide appeared in 1989 with partly displaced blocks with typical vegetation broken up by frost, desiccation, or edge cracks, 'floating' on the layer with excess pore pressure.

Active layer depth dynamics on 25-m transect

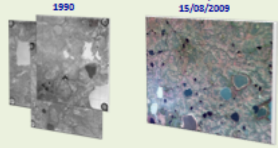


E — Remote sensing application

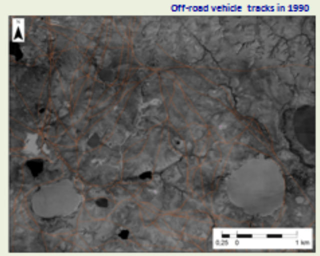
Available images

Aerial images 1990

GeoEye1 15/08/2009



Off-road vehicle tracks in 1990



Total area 20 sq.km

Length of tracks:

1990 - 126 km

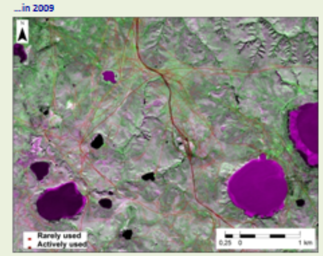
2009 - 235 km

Tracks in 2009:

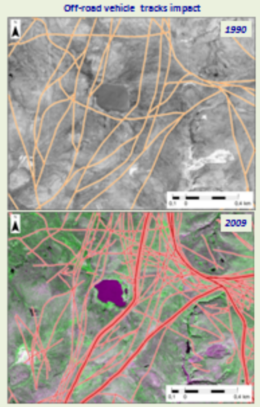
Rarely used – 210.5 km

Actively used – 24.5 km

...in 2009



Off-road vehicle tracks impact



Minimal area affected:

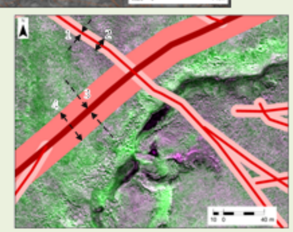
1990 – 0.51 sq.km

2009 – 0.95 sq.km (incl. 0.14 sq.km actively used)

Maximal area affected:

1990 – 1.71 sq.km

2009 – 3.22 sq.km (incl. 0.78 sq.km actively used)



Rarely used tracks

– 2.5-m buffer to estimate minimal impact

– 12.0-m buffer to estimate maximal impact

Actively used tracks

– 6.0-m buffer to estimate minimal impact

– 30.0-m buffer to estimate maximal impact

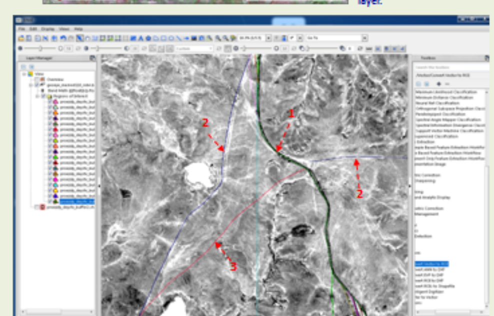
NDVI spatial statistic for the different types of off-road tracks

NDVI spatial statistic has been calculated for 3 types of tracks: 1) tracks with maximal impact on landscape (high technogenic impact); 2) tracks with average impact on landscape (average technogenic impact), 3) tracks with minimal impact on landscape (low technogenic impact).

Tracks were extracted from very high spatial resolution satellite image GeoEye-1 taken 15-08-2009 by manual digitizing in a GIS software package and the information about different types was collected during 2009-2013 field campaigns.

The 2.5-meter buffer zone algorithm was applied for polyline vector layer to obtain the polygons of tracks for spatial statistic calculation. The influence of the tracks for the surrounded vegetation could be much higher but we decided to analyze the vegetation properties directly on tracks.

Spatial statistic was calculated in ENVI 5.0 software using the ROI files for each type of tracks extracted from obtained polygon vector layer.



1 (green) – tracks with maximal impact on landscape (high technogenic impact, mean NDVI 0.37)

2 (blue) – tracks with average impact on landscape (average technogenic impact, mean NDVI 0.47)

3 (red) – tracks with minimal impact on landscape (low technogenic impact, mean NDVI 0.52)

Aknowledgements:

Program of Fundamental Research Department of Earth Sciences No. 12 "The processes in the atmosphere and cryosphere as factors of environment changes"

RFBR grant No. 13-05-91001-АНФ_a to the Earth Cryosphere Institute SB RAS

Presidential Grants for Science Schools No. 5582.2012.2, No. 3929.2014.5

NASA Land Cover Land Use Change (LCLUC) Program, Grant No. NNX14AD90G.

Authors are grateful to Damir Mullanurov (ECI SB RAS) and Renad Kireyabulatov (student of MSU) for help in a field work

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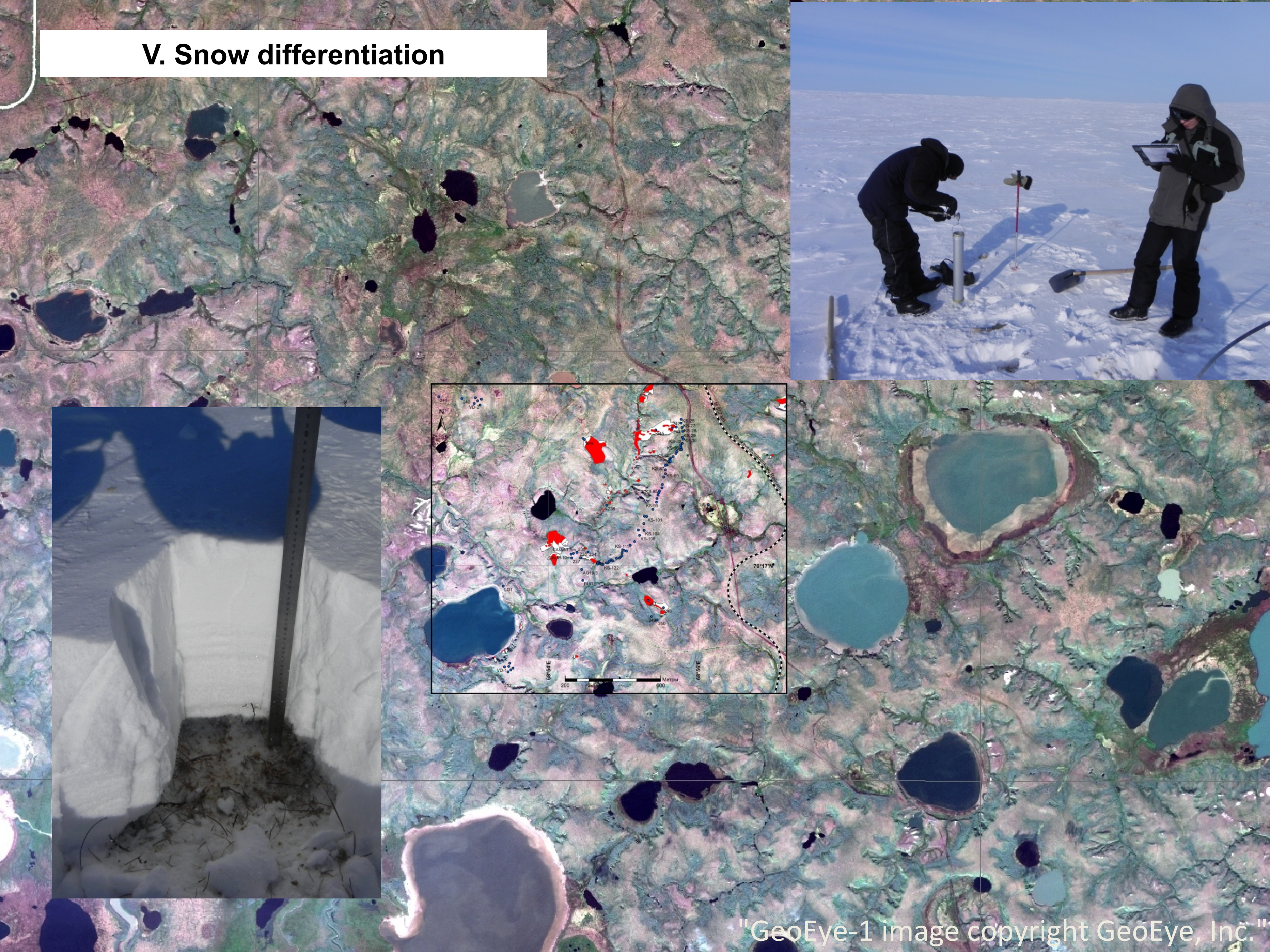
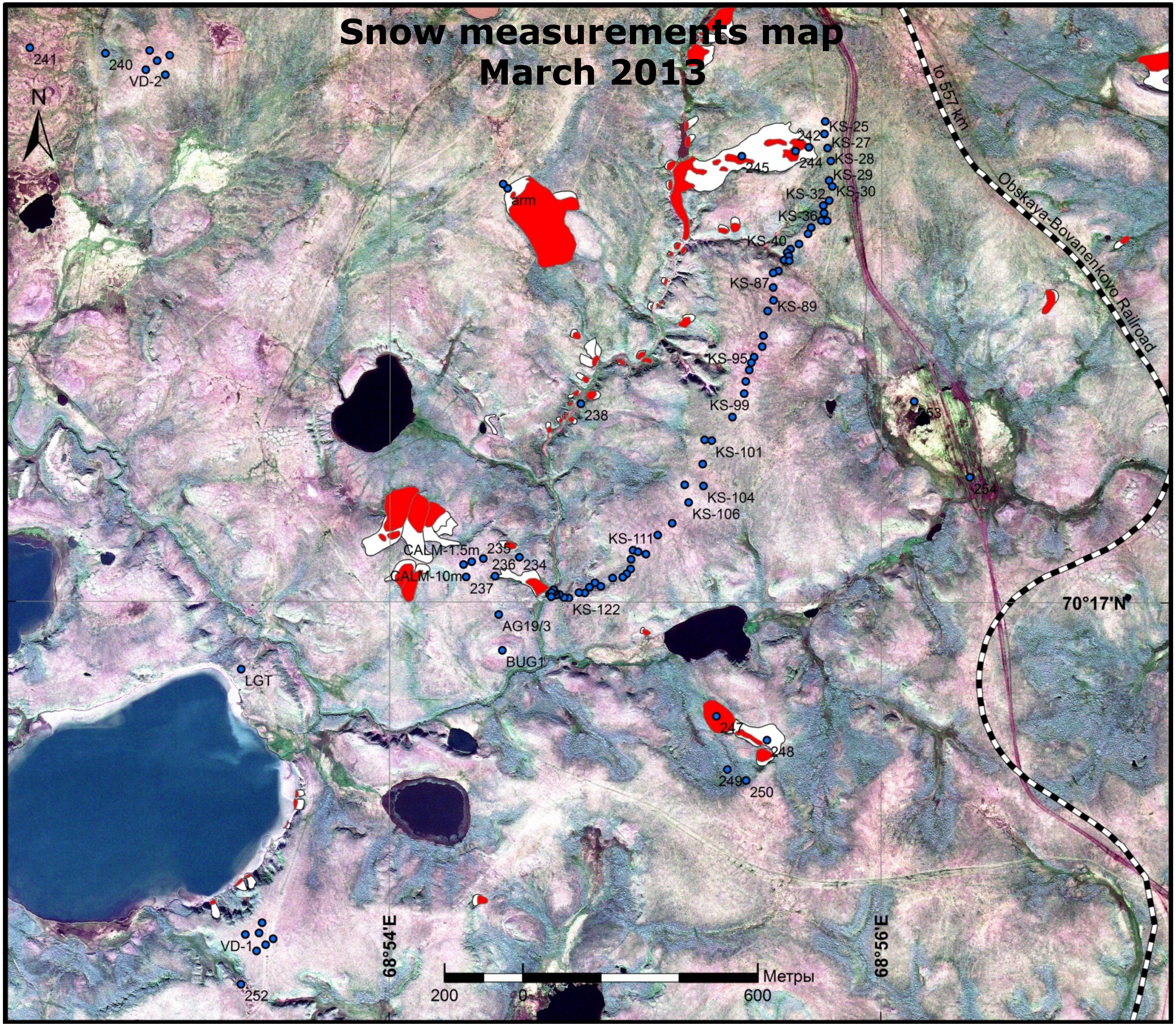
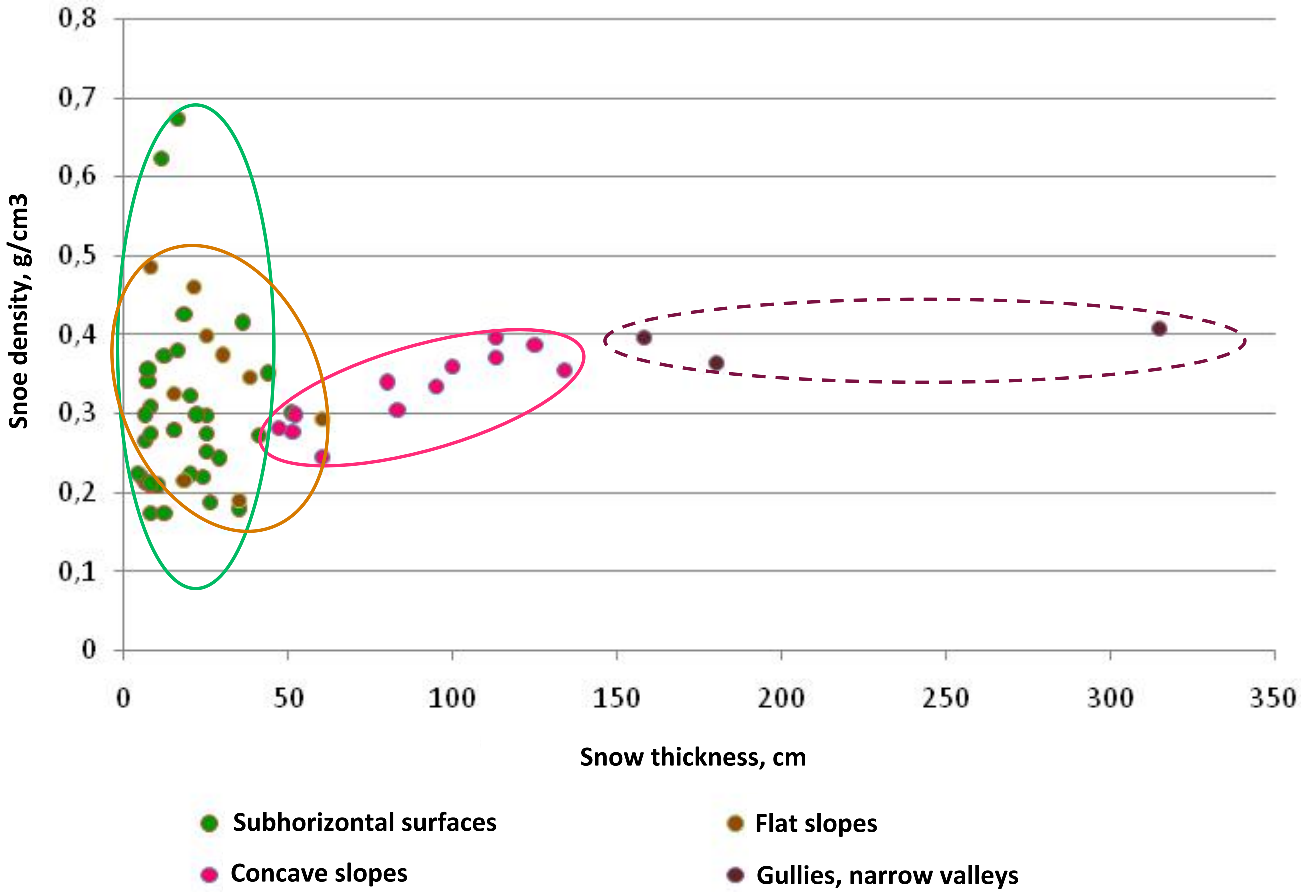
Poster presented at the international Arctic Change 2014 conference, Ottawa, Canada, 8-12 Dec 2014. Session T40. Rapid Arctic Transitions Related to Infrastructure and Climatic Change (RATIC).

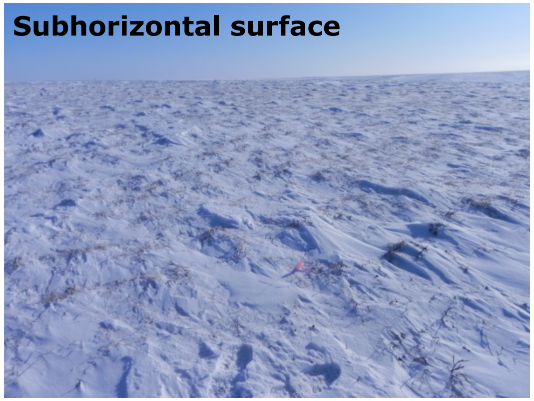
V. Snow differentiation

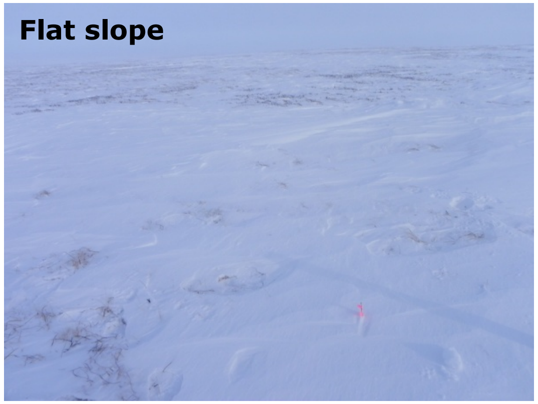


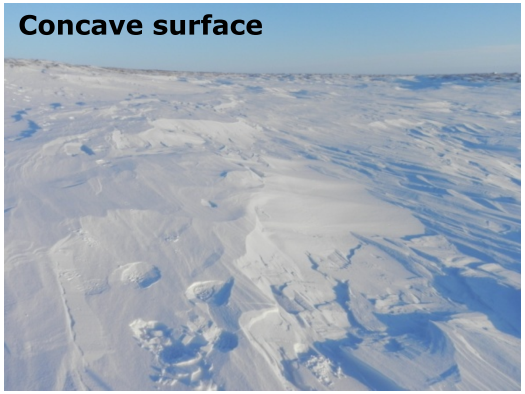

Snow measurements map
March 2013
N
241
240
VD-2
arm
245
242
244
KS-25
KS-27
KS-28
KS-29
KS-30
KS-32
KS-36
KS-40
KS-87
KS-89
KS-95
KS-99
KS-101
KS-104
KS-106
KS-111
KS-122
238
253
254
CALM-1.5m
235
236
234
CALM-10m
237
AG19/3
BUG1
LGT
247
248
249
250
VD-1
252
lo 557 km
Obskaya-Bovanenkovo Railroad
70°17'N
68°54'E
68°56'E
200
0
600
Метры

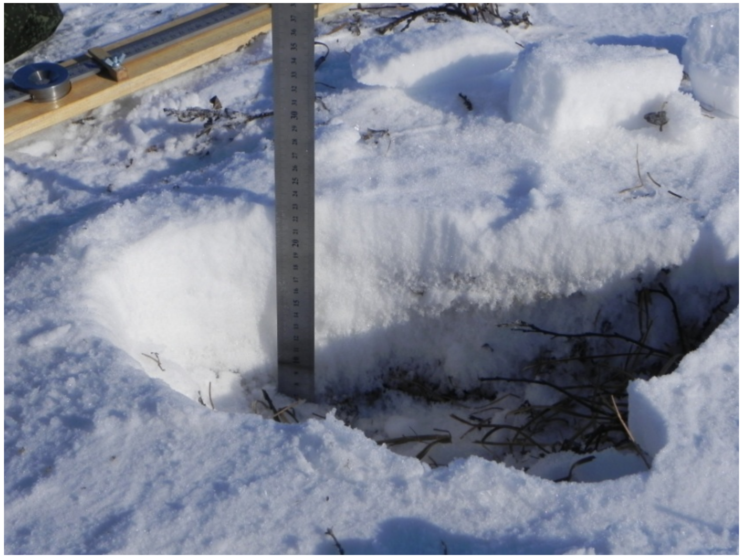
Relation of snow parameters





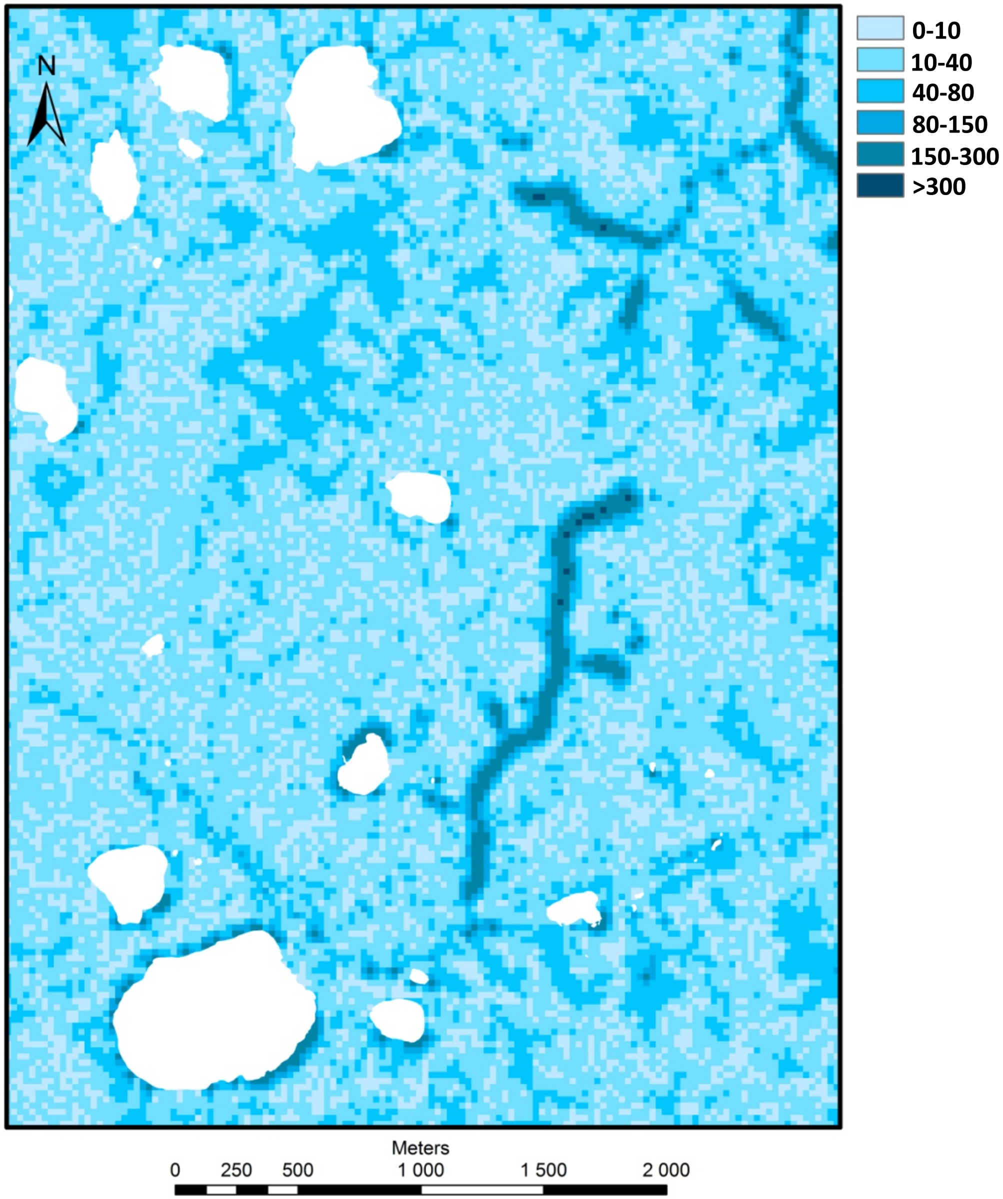




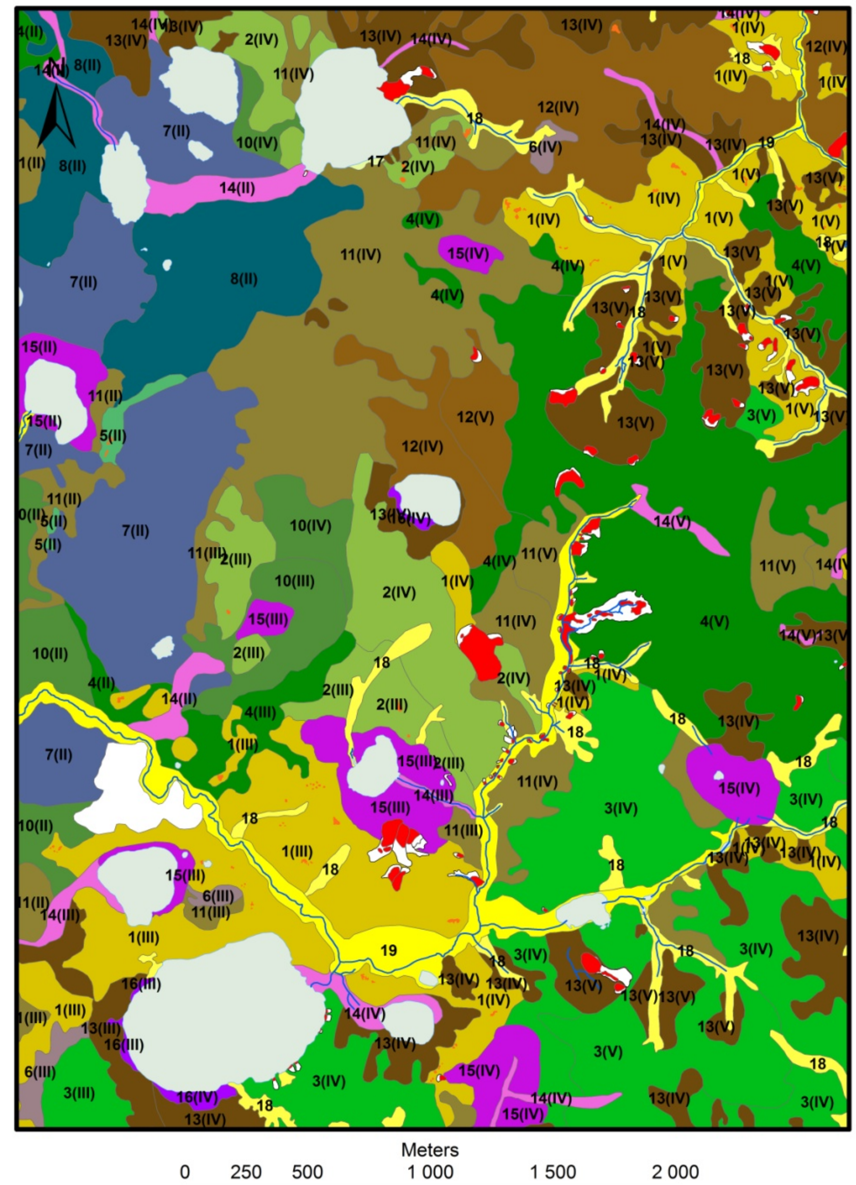



Mapping of snow cover

Map of snow thickness (model)

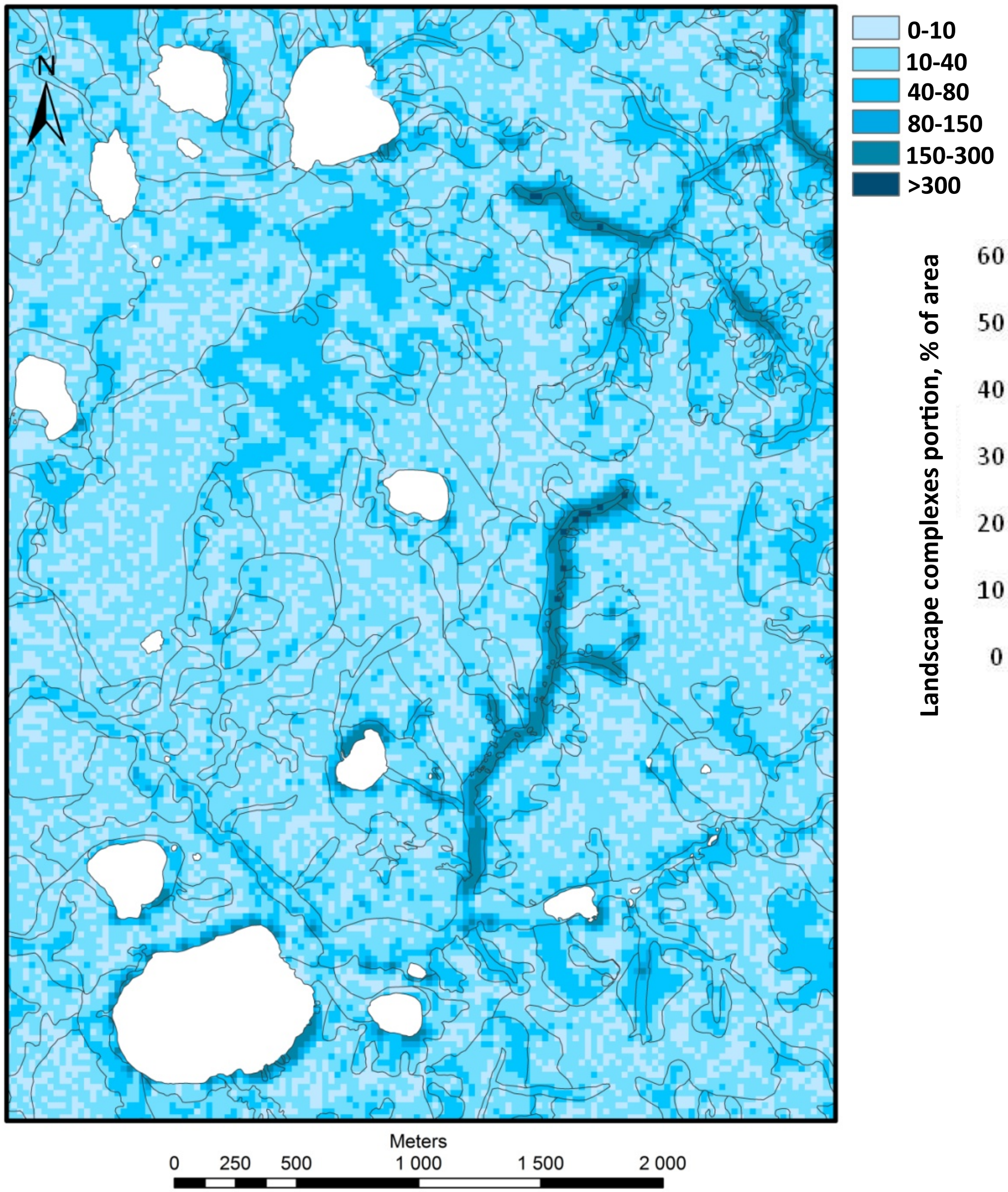


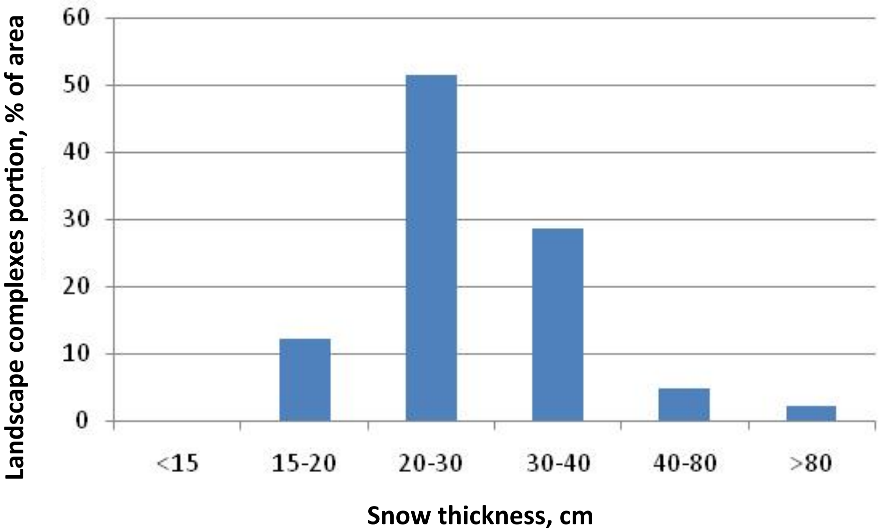
Landscape map



Mapping of snow cover

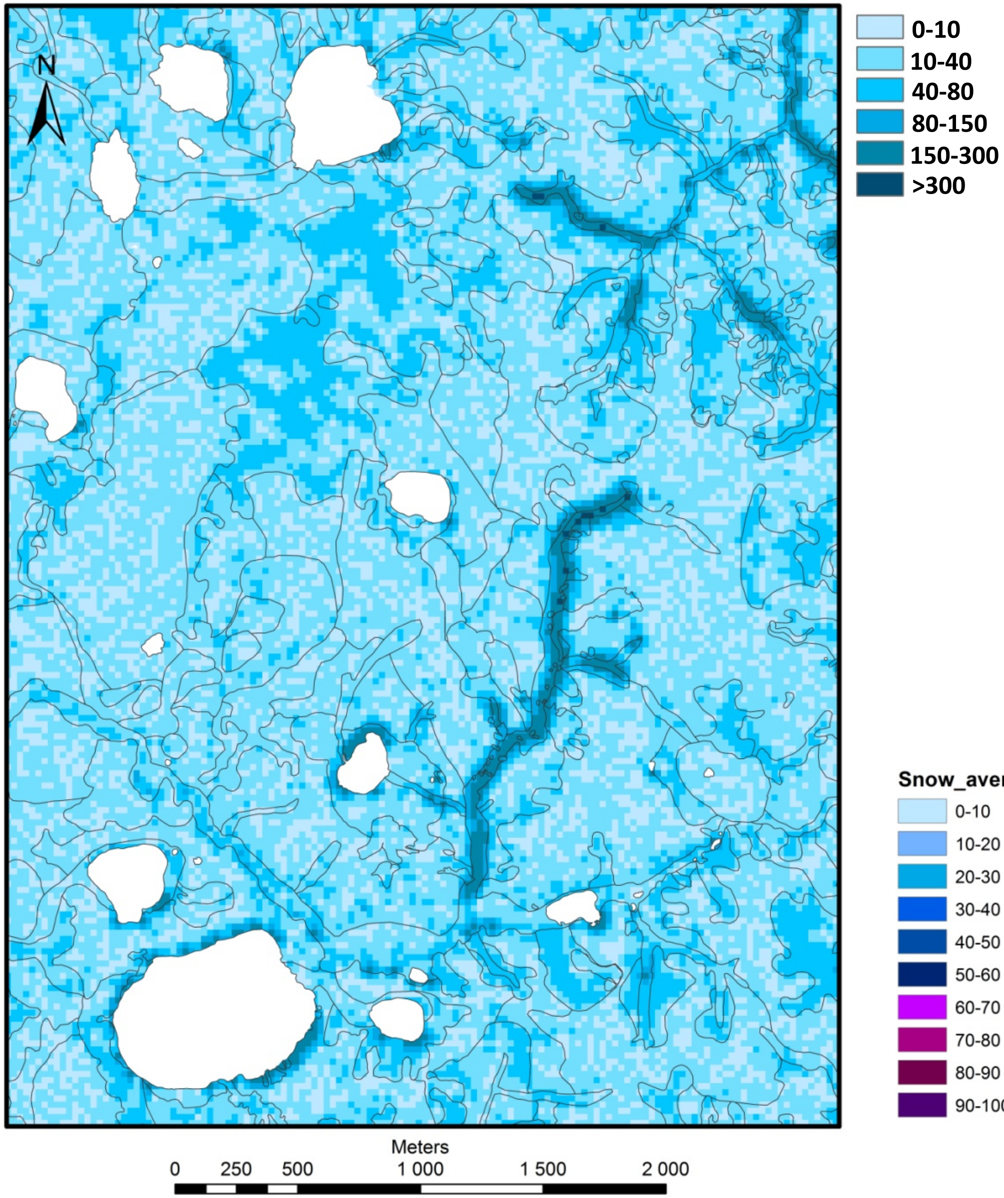
Map of snow thickness (model)



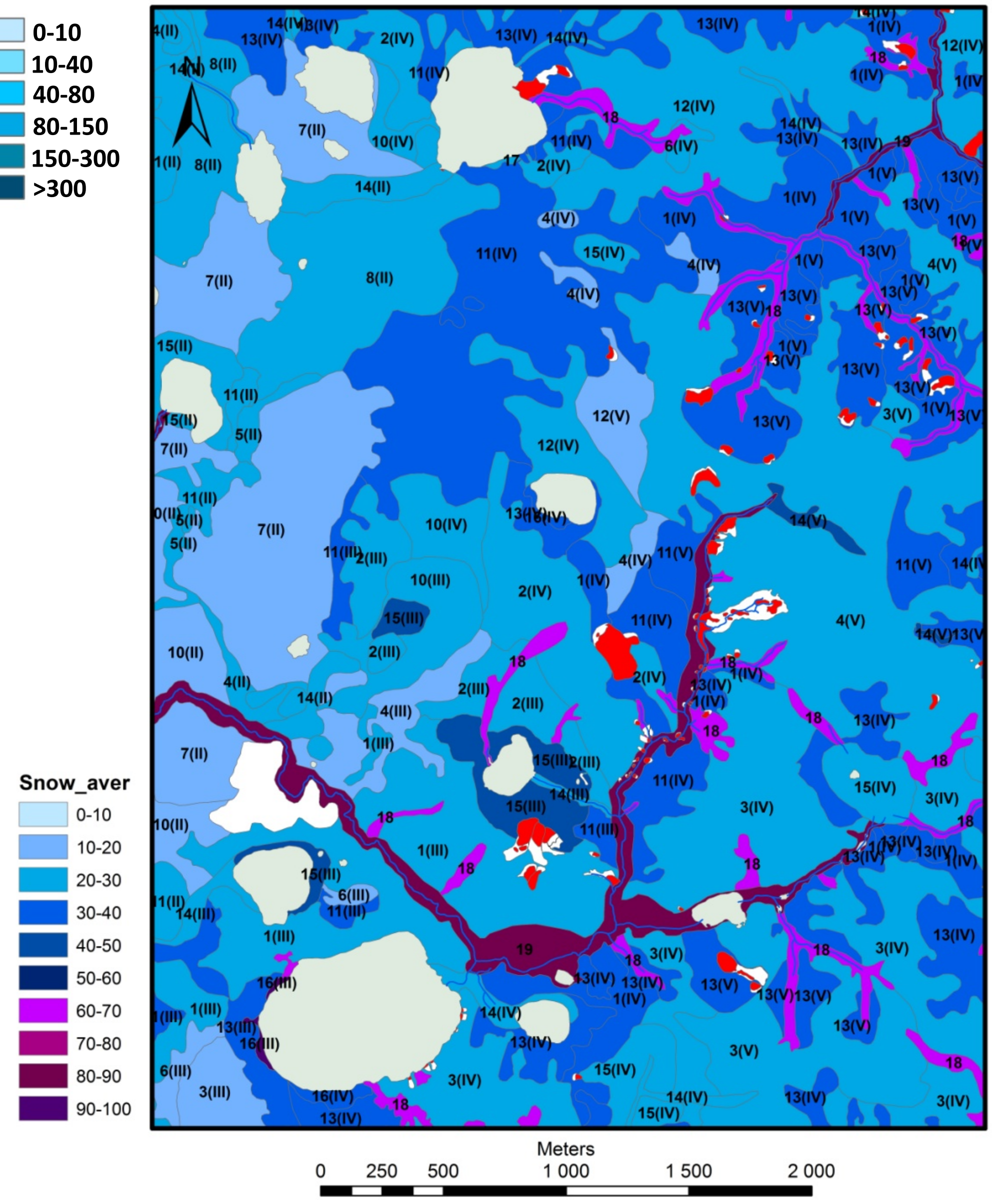


Mapping of snow cover

Map of snow thickness (model)



Snow differentiation on landscapes




Thank you
for your attention!