POLYAR – Process of Organic transport to the Lakes of the YAmal Region

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Introduction

Climatic and environmental fluctuations in the permafrost zone lead to activation of various cryogenic processes. This activation results in a strong redistribution of substances and changes in biochemical composition of the water bodies. Lakes in the Arctic are good indicators of changing natural conditions. These indicators are expressed in both: areal changes of thermokarst lakes, and changes in biochemical composition of water.

Thus, we analyze the interconnection between water bodies and their catchments on Yamal peninsula in temporal and spatial extent. Main objective of this research is to study which processes affect the quality and quantity of dissolved organic matter in the water bodies across the Yamal peninsula (central, eastern and coastal parts) in the continuous permafrost zone. The studies are based on batymetric in-situ measurements and water sampling, optical and SAR remote sensing, and topographic data analysis.

Climatic and environmental fluctuations in the permafrost zone lead to activation of various cryogenic processes. Photo by Author 2013, 2014 thermocircle.
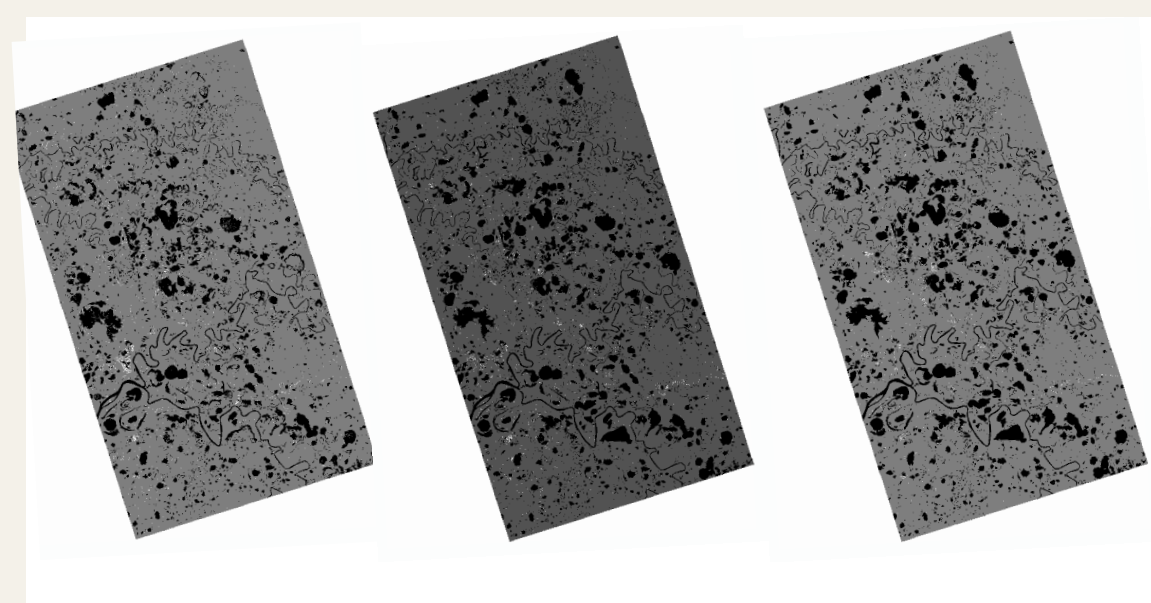
Bathymetry

It is very important to know the bottom structure and to take the water volumes in lakes into account and to know about re-suspension and wind influence that may also influence the CDOM behavior.
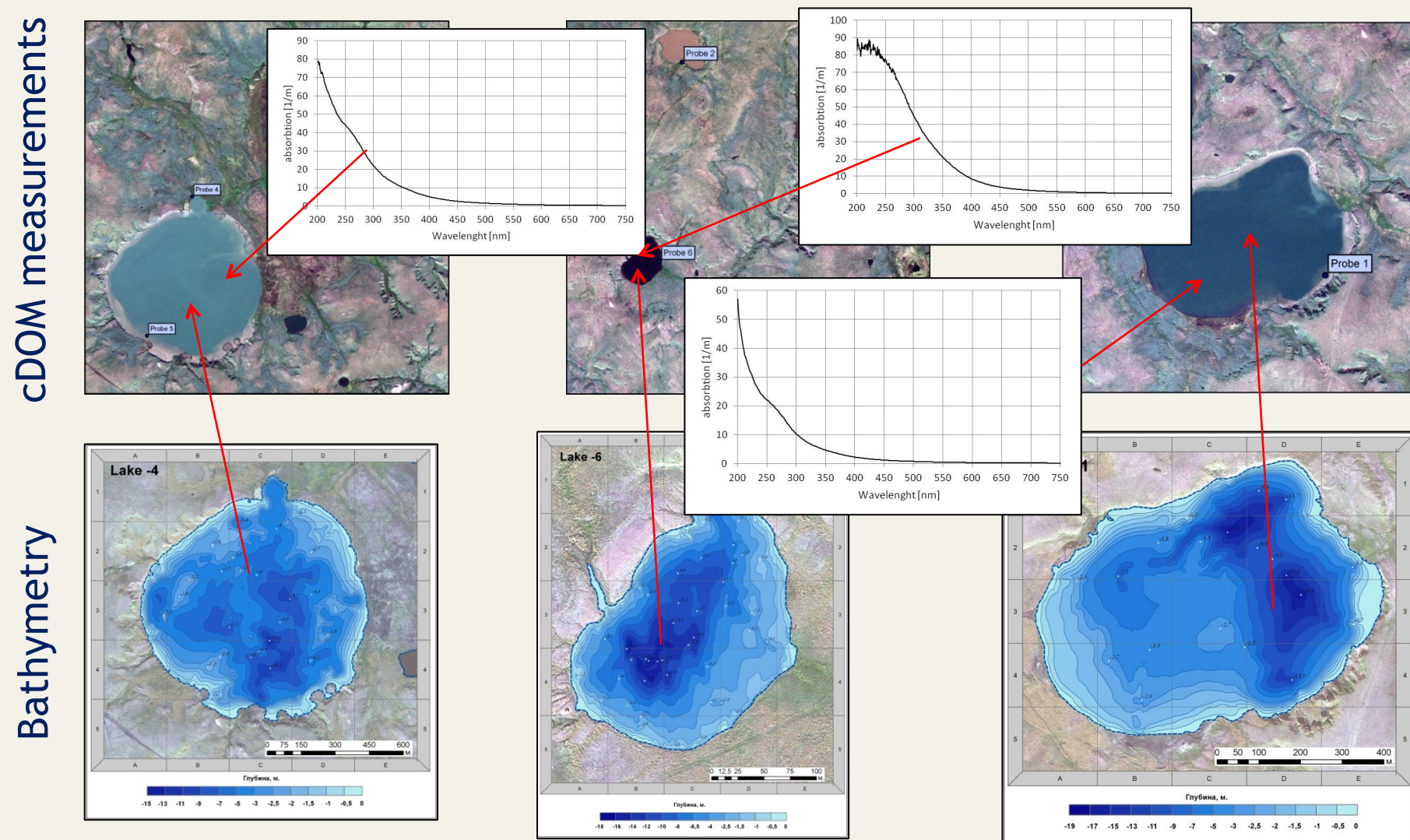
Bathymetry data (2012) for several lakes and the differences between lines CDOM absorption behavior.

Lake extent analysis

TSX backscatter 2010-07-07   2010-07-29   2010-08-31

TerraSAR-X , X-band applications for tundra permafrost landscapes: seasonal lake dynamics; snow extent, lakes surface roughness, landslide dynamics, elevation changes

To analyze lake extent dynamics we use radar remote sensing data TerraSAR-X. The water bodies detection algorithm is based on a TSX time series establishing a threshold value. Inter-annual changes in lake extent is highly pronounced for floodplain lakes and occur less for lakes located in higher geomorphological levels.

Results

- Coastal processes activity may led to significant increase of cDOM concentration in lakes. To predict these processes, detailed information about topography is needed (high spatial and high-temporal resolution DEMs).
- High correlation of cDOM concentration in lakes and abundant vegetation in lake catchments quantitatively shows interconnection between the catchment area system and water state in thermokarst lakes.
- Spatial maps of snow water equivalent can be produced based on snow survey data, DEM (elevation, slope, curvature) and optical satellite data (shrub map).

Acknowledgements

Water sampling
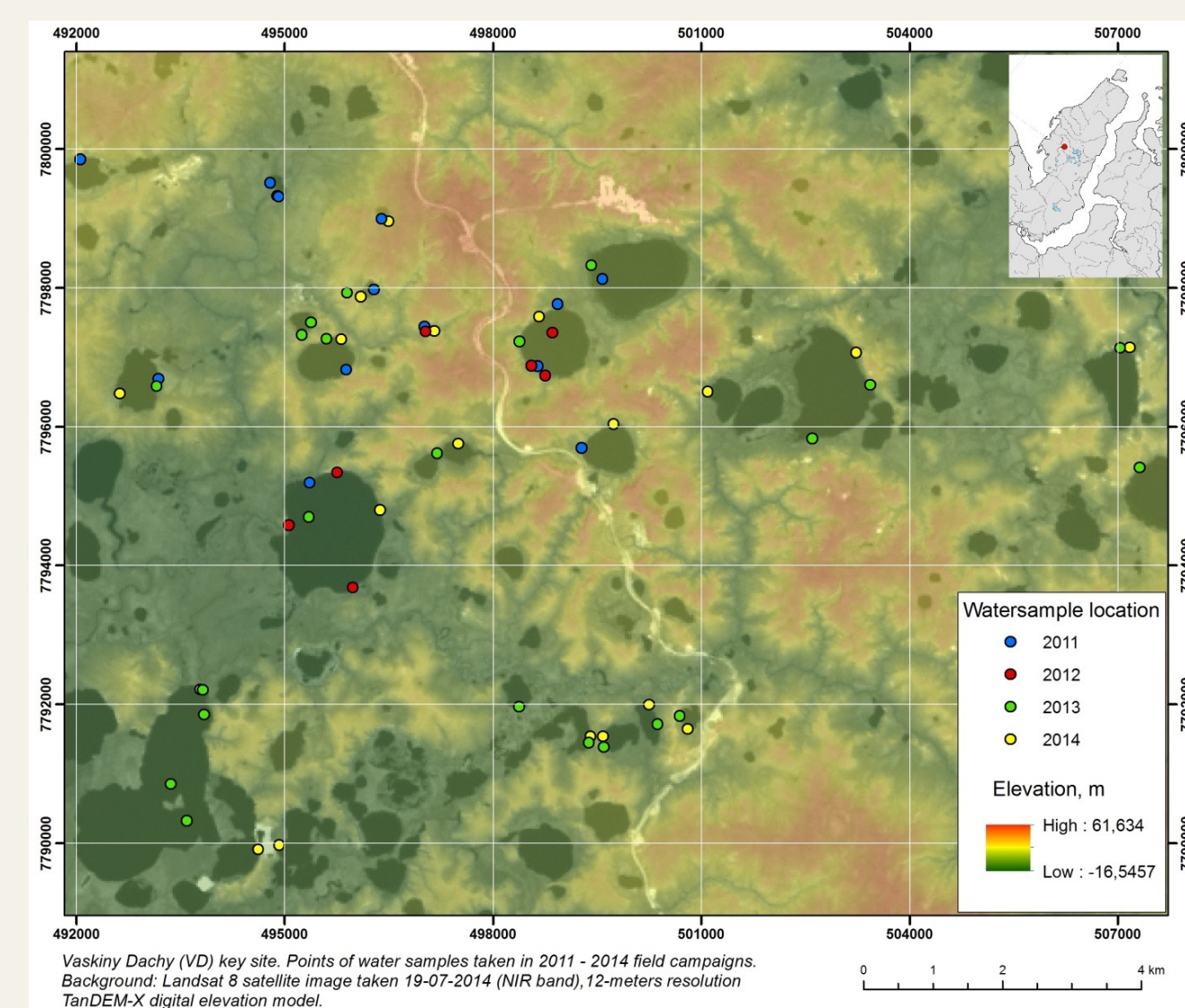
Lakes in the study area were chosen according different optical properties. The lakes were sampled for:

Vaskiny Dachy (VD) key site. Points of water samples taken in 2011 - 2014 field campaigns. Background: Landsat 8 satellite image taken 19-07-2014 (NIR band), 12-meters resolution TanDEM-X digital elevation model.

1) colored dissolved organic matter (CDOM) 2011-2014;
2) cations and anions (KA) 2014;
3) suspended matter (SPM) 2014.

Sample analysis in laboratory

Water samples were analyzed in Otto-Schmidt laboratory (Saint-Petersburg, Russia). For CDOM concentration a dual-beam spectrophotometer SPECORD was used. We see CDOM concentrations changing significantly between the years for some specific lakes .
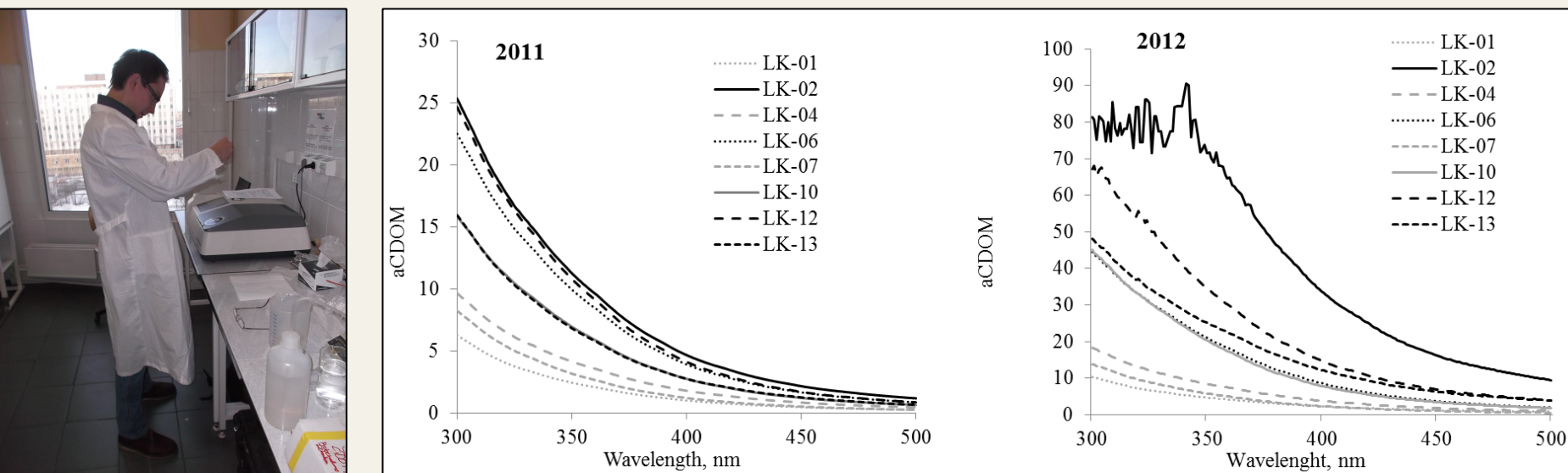
Left – laboratory analysis (Photo Birgit Heim), Right – absorption for lake samples (taken in 2011 and 2012)

Absorption values have risen in the same lakes in 2012. In summer 2012, air temperature and amount of precipitation was higher then in previous years (see figure below).
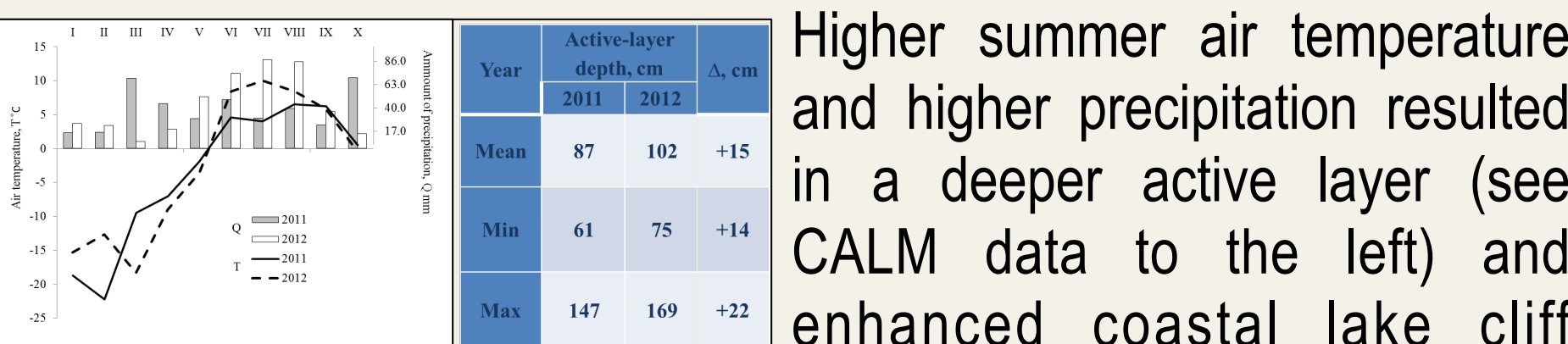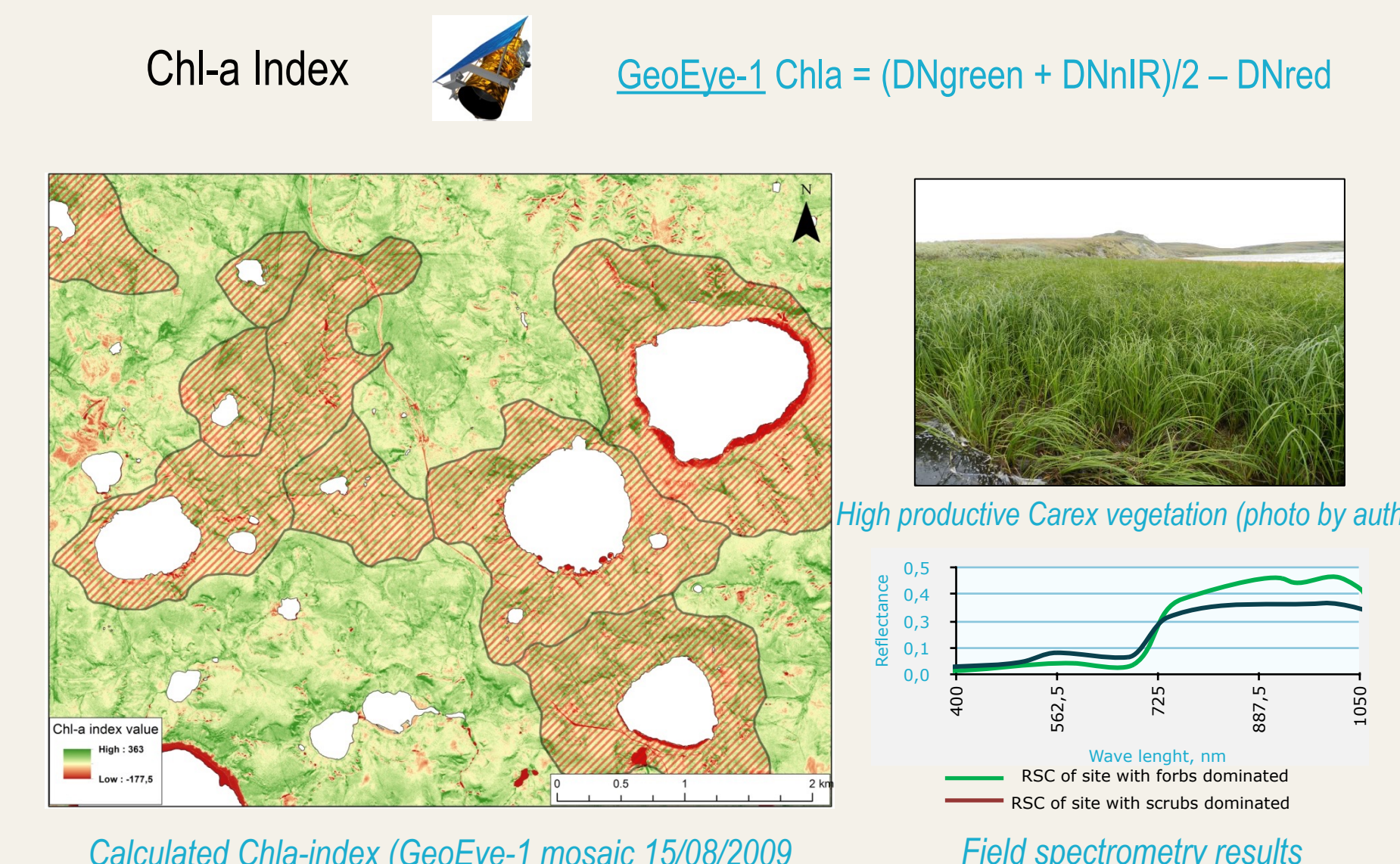

Meteorological data analysis for 2011 and 2012 + results of active layer measurements.

Higher summer air temperature and higher precipitation resulted in a deeper active layer (see CALM data to the left) and enhanced coastal lake cliff erosion in 2012.

Catchment based approach - vegetation

During the seasons, lakes receive material from the catchment areas on different pathways. Most relevant for permafrost landscapes is the snowmelt surface flow. For the snow melt flow and for intense precipitation events, the density and abundance of vegetation is a critical factor determing the input of organic matter into the lakes. Specifically in tundra permafrost landscapes it is relevant if there is abundant vegetation in the catchments.

Chl-a Index

GeoEye-1 Chla = (DNgreen + DNnIR)/2 – DNred

High productive Carex vegetation (photo by author)

Calculated Chla-index (GeoEye-1 mosaic 15/08/2009)   *Field spectrometry results*

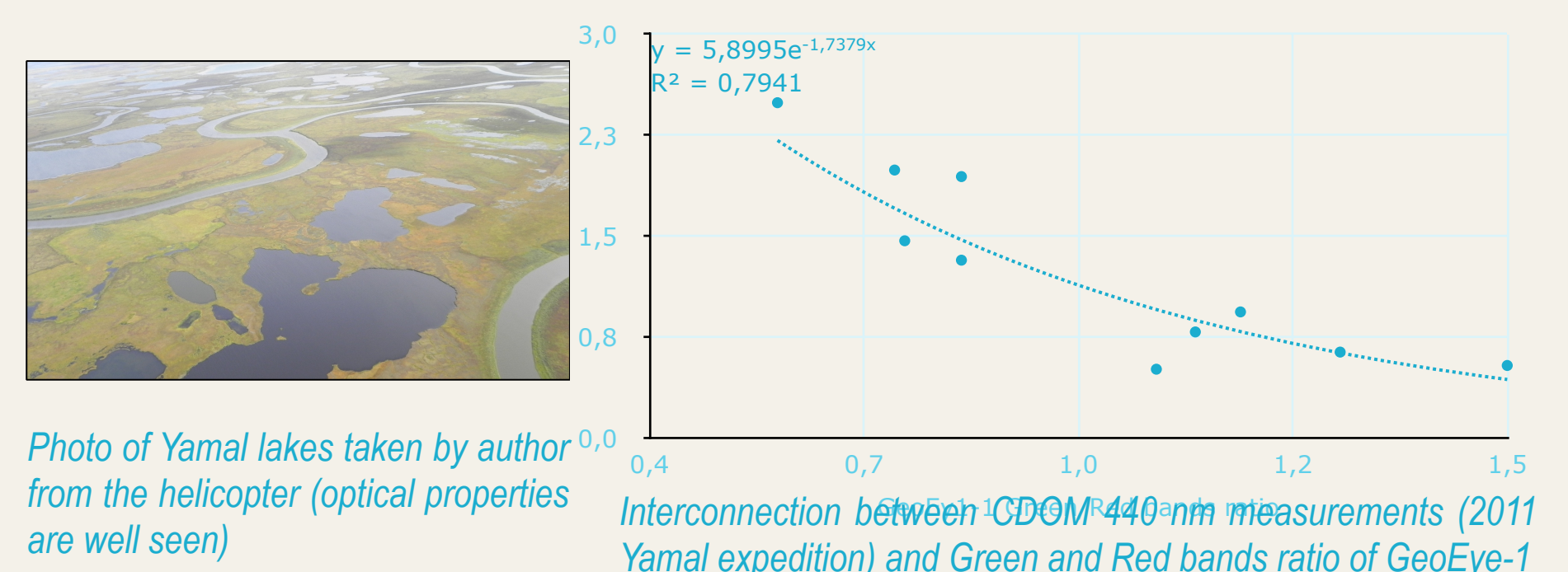RSC of site with forbs dominated
RSC of site with scrubs dominated

To extract the areas of green vegetation biomass, an index of chlorophyll-a (Chl-a) was calculated using a GeoEye-1 mosaic taken 15.08.2009. The calculation is based on a green, red, NIR bands combination. High productive vegetation is highly absorbing in the red and scatters in the green and NIR.
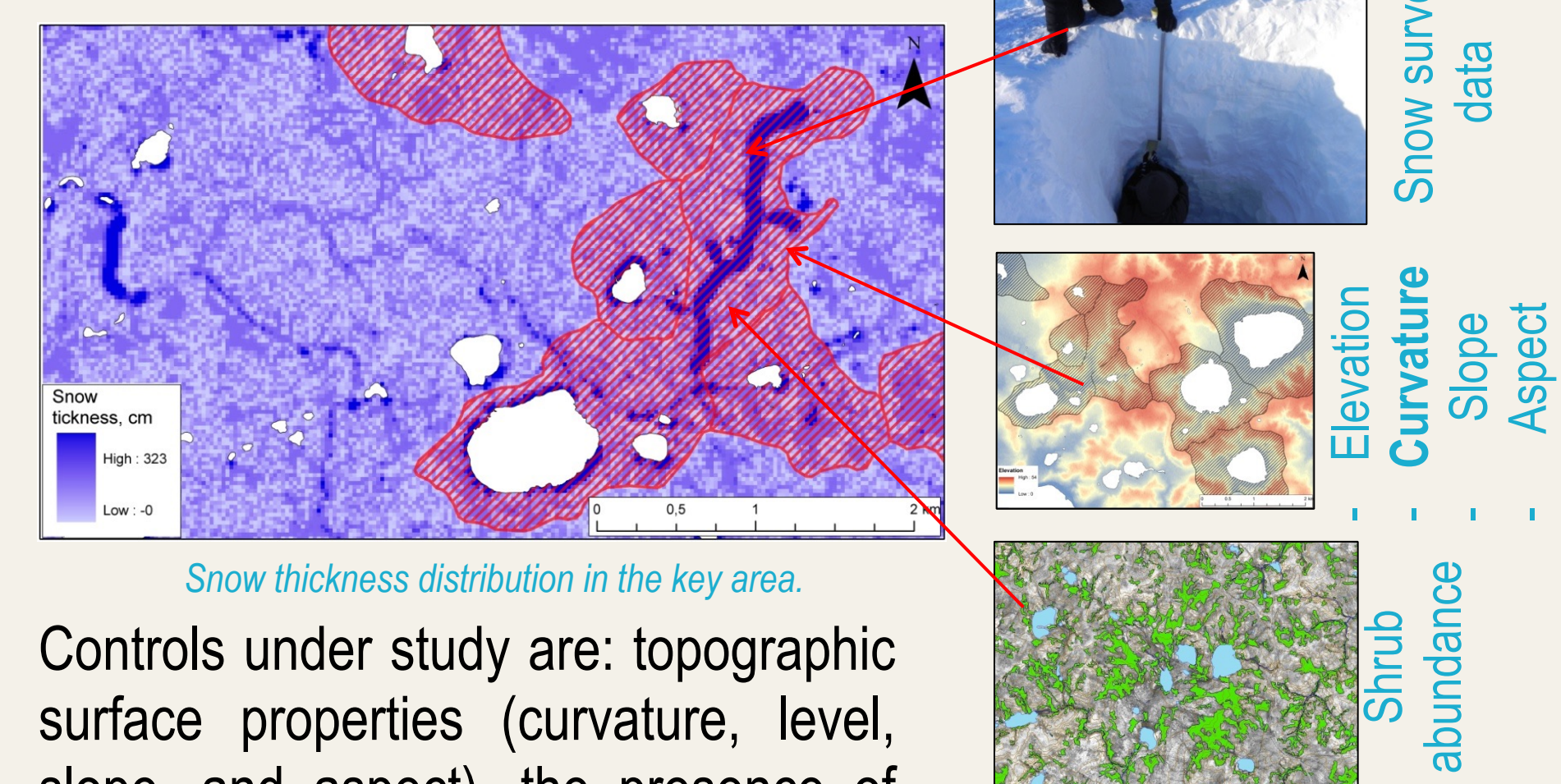
Acknowledgements

Remote-Sensing CDOM observation

To analyze CDOM concentration in lakes using optical rempote sensing data an algorithm described in Kutser et al. (2005) was used. It is based on the spectral ratio of the green vs. the red band, which is well correlated with CDOM absorption at 440 nm. Here the evaluation for several lakes is shown on the figure below (atmospheric corrected GeoEye-1 satellite image taken in 15/08/2009, NGA license, University Alaska Fairbanks, NASA LCLUC Yamal; CDOM absorption from 2011 Yamal expedition).

Photo of Yamal lakes taken by author from the helicopter (optical properties are well seen)

Interconnection between CDOM 440 nm measurements (2011 Yamal expedition) and Green and Red bands ratio of GeoEye-1

$y = 5,8995e^{-1,7379x}$
$R^2 = 0,7941$

Catchment based approach - snow

It is assumed that the more snow is in catchment the more active erosion processes will be in spring season and more matter can be transported into the lakes. To analyze a snow distribution in catchments an approach for snow water equivalent (SWE) spatial mapping for tundra landscapes has been developed. The methodology is based on statistical analysis of snow survey data and on GIS-analysis.

Snow thickness distribution in the key area.

Snow survey data
Elevation, Curvature, Slope, Aspect
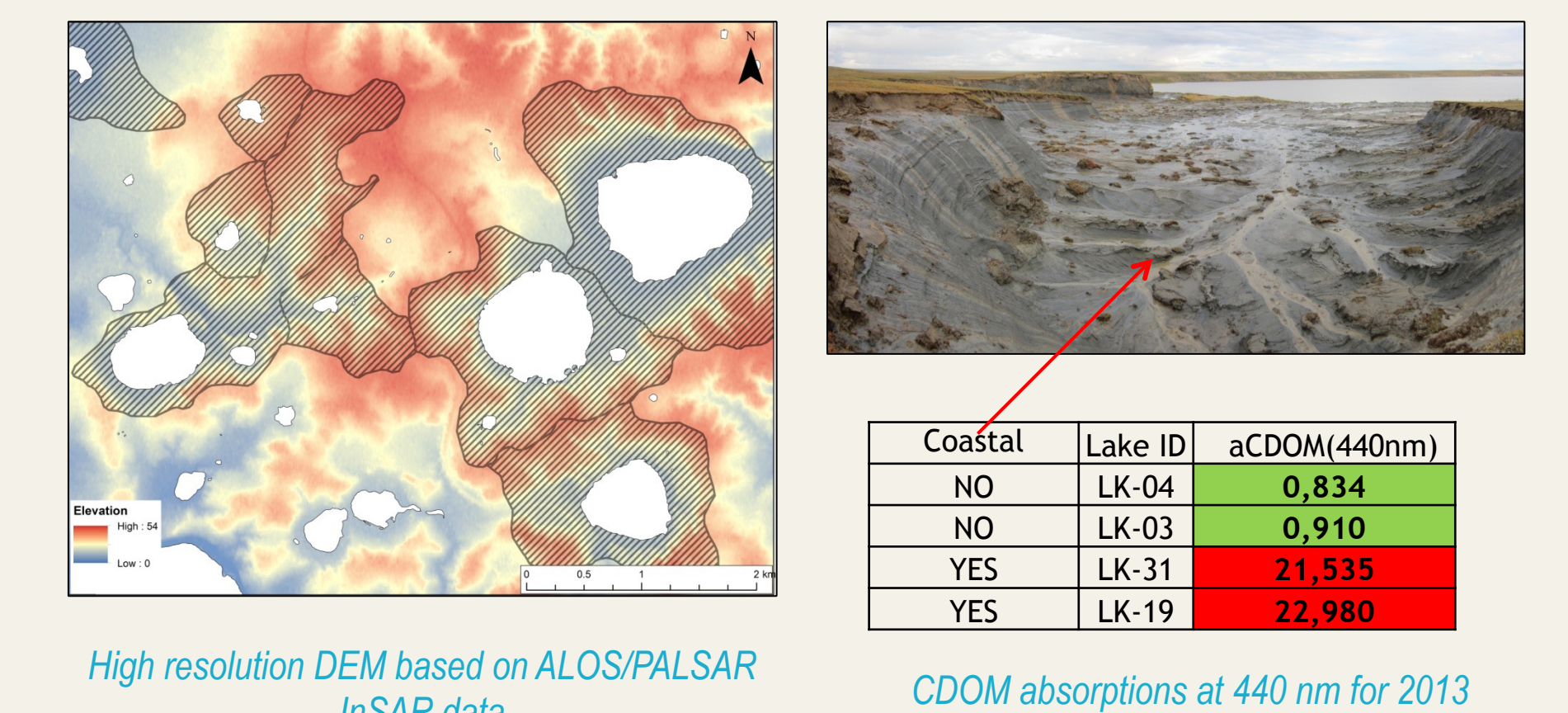Shrub abundance

Controls under study are: topographic surface properties (curvature, level, slope, and aspect), the presence of shrub vegetation, wind direction, participating in re-distribution of snow.

The curvature parameter is selected as the main factor to control snow thickness. It describes the surface properties from the viewpoint of the degree of convexity and concavity.

Catchment based approach – coastal activity

To assess the possibility of the organic matter transport from catchments to lakes it is necessary to analyze the intensification extent of coastal processes (thermoerosion, thermoabrasion, cryogenic landslides). The activity of the described processes depends mainly on climatic and background conditions (topography, hydrology).

High resolution DEM based on ALOS/PALSAR InSAR data   *CDOM absorptions at 440 nm for 2013*

Coastal	Lake ID	aCDOM(440nm)
NO	LK-04	0,834
NO	LK-03	0,910
YES	LK-31	21,535
YES	LK-19	22,900

To assess the baseline conditions we plan to develop a topographic index, which will characterize the slopes, the active-layer properties (landscapes based). This should be done with the use of ground-based observations, DEM and very high spatial resolution remote sensing data. Such an analysis will provide material for the planning of sampling during the summer field season, by which the sampling data analysis will be compared with the analysis data.

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