# Landscapes and thermokarst lake area changes in Yedoma regions under modern climate conditions, Kolyma lowland tundra

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Recent landscape changes in the Yedoma region are particularly pronounced in varying thermokarst lake areas reflecting the reaction of the land surface on modern climate changes. However, although thermokarst lake change detection is essential for the quantification of water body expansion and drainage within a region, remote sensing-derived surface reflection trends additionally provide valuable information about the general landscape development. The aim of this research is to reveal the regularities of landscape and thermokarst lakes area changes in the Kolyma lowland tundra in comparison with meteorological data and geological and geomorphological features.

The Kolyma lowland tundra occupies about 44500 $km^2$ and is located in Northeast Yakutia within the continuous permafrost zone. Mapping of Quaternary deposits using Landsat images shows that Yedoma (Last Pleistocene remnants formed by ice-rich silty to sandy syngenetic deposits with large polygonal ice wedges) occupies only 16 % of the entire region, while the largest part of it is occupied by alas complex (72 %), formed as a result of Yedoma thaw during the Holocene (Veremeeva and Glushkova, 2016).

For the analysis of the landscape and thermokarst lakes area changes of the last 15 years, the entire available Landsat archive from 1999 until 2015 was used for time-series analysis. For this purpose around 800 scenes were processed with an automated workflow, undergoing several necessary processing steps, such as masking, data distribution and calculation of multi-spectral indices. Multi-spectral indices (Landsat Tasseled Cap, NDVI, NDWI, NDMI) were calculated for each unobstructed (cloud-, shadow- and snow-free) observation within the summer months (June to September) between 1999 and 2015. A robust linear trend analysis has been applied to each pixel for the spatial representation of changes of different land surface properties over the observation period. This map shows the magnitude and direction of changes for each multi-spectral index, which are used as proxies for different land-surface properties. For single locations, the entire time-series can be further analyzed in more detail. For the period from 1999 till 2005 air temperatures and precipitation have been analysed for several weather stations that existed in the region. The Landsat time series analysis for the last 15 years shows that the northern part of the region became wetter over the last 5 – 6 years. The alases are particularly affected by the wetting trend. The analysis of the meteo-data shows a trend of increasing air temperature and especially precipitation during the summer from 2010. The wetness increase, particularly on the coastal zone, is supported by the fact that air temperature trends are the largest at near-coastal meteorological stations. This increase of air temperatures and precipitation is likely connected to the reduced sea ice cover (Bekryaev et al., 2010). The strongest wetness increase were observed in the most northern part of the region within a 50 km wide zone along the East-Siberian sea shore between lowest stream of the Alazeya and Galgavaam rivers. This region is characterised by average terrain heights about 10-20 m, the yedoma and thermokarst lakes area here is about 10-20 %. There are less increase of wetness in the southern and eastern part of the coastal zone between Galgavaam and Bolshaya Chukochya rivers which is characterized by average heights of 0-10 m. The lakes area here is about 40 % and yedoma covers less then 10 % of the territory. Thus the strongest wetness trend for the northern coastal zone can be explained by the high degree of yedoma preservation and its thawing due to the coastal location and higher impact of the increasing temperatures and precipitation.

For the recent past from 1999 to 2015, thermokarst lake changes were analysed visually based on the time series trend. For most thermokarst lakes of the Kolyma lowland tundra lake area was increasing from 1999 till 2015, however the trend is not significant. Some of the lakes partially or completely drained. Thermokarst lakes area coverage was quantified based on seven Landsat 8 images for the time period 2013 – 2014. In order to ensure consistency regarding surface moisture, only images acquired from August till September have been used. Atmospheric correction of each image was done for radiometric normalization across the dataset. An increase in ground resolution of the 30m multi-spectral data was achieved through resolution merge with the panchromatic channel to 15m pixel size. Subsequent mosaicking, classification and raster to vector conversion was done for the entire Kolyma lowland tundra. Thermokarst lakes cover about 12.9 % of the Kolyma lowland tundra. For the key investigation area located in the southern tundra around Lake Bolshoy Oler, which covers an area of 2800 $km^2$ , a comparison with lakes mapped in CORONA images from July 21, 1965 and lakes mapped in the 2014 Landsat mosaic was carried for analysis of changes over time during a period of up to 50 years. The overall thermokarst lake area for this region in 1965 and 2014 was 590 and 549 $km^2$ respectively. This corresponds to a limnicity decrease of 1.5 % within the study site from 21.1 to 19.6 %. About one third of this lake area decrease is due to partial drainage of big lakes with the area in 1965 and 2014 of 141.8 and 96.3 $km^2$, respectively. Analysis of the summer air temperature and precipitation trends from the 1965 till 2015 also shown the trend of their increasing. Therefore, despite the fact that many persistent thermokarst lakes in the Kolyma lowland tundra are increasing in area, modern climate conditions generally seem to favor further relief drainage development. Consequently, thermokarst lake drainage outpaces thermokarst lake growth. This heterogeneous pattern suggests that permafrost degradation and aggradation in the region proceed simultaneously close together.

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References

Bekryaev R.V., Polyakov I.V., Alexeev V.A. 2010. Role of polar amplification in temperature variations and modern Arctic warming. J. Clim. 23(14): 3888–906.

Veremeeva A.A., Gklushkova N.V. 2016. Relief formation in the regions of the Ice Complex deposit occurrence: remote sensing and GIS-studies, tundra zone of Kolyma lowland, Northeast Siberia. Earth's Cryosphere, vol. XX, 1, pp.15-25.