Thermokarst lake dynamics across the Arctic based on Landsat time-series

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Introduction

Observed and projected climate change in the Arctic increases the vulnerability of terrestrial ecosystems to disturbances. For example, significant increases in air temperatures especially in high latitudes (Polar amplification) will impact the stability of permafrost landscapes that cover 24% of the northern hemisphere and dominate large parts of the Arctic. So far, only small areas have been monitored regarding their landscape dynamics related to permafrost in an appropriate spatial scale. This study seeks to overcome this massive knowledge gap with an integrated geo-informatics approach based on remote sensing time-series.

Challenges

Rapid landscape dynamics
Remote locations
Large spatial extent
Cloud and snow cover
Data processing and handling

Current Knowledge Base

Only knowledge of local dynamics
Pan-Arctic lake data too coarse and static
Large diversity of data and methods
Little knowledge about the **Big Picture**

Goals

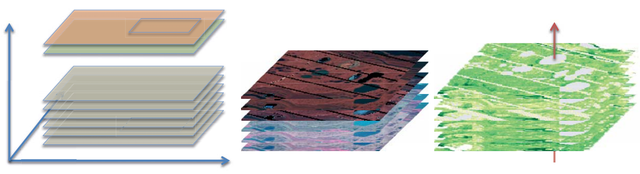
Monitoring of TKL dynamics
Scalable and transferrable process
Transferability and integration with other sensors (Sentinel-2)
Product easy to use and unterstand by stakeholders

Methods - Data Processing

Automated Data Processing

Usage of the full Landsat archive (TM, ETM+, OLI)
- Peak summer season (Jul, Aug), CC < 80 %
- Years 1984/1999 to 2014
- 1000‘s of scenes around the Arctic

Data pre-processing (Subset, Reproject, FMask, Stack)
Index calculation: Tasselled Cap, NDVI, NDMI, NDWI



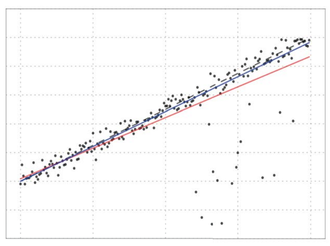
Trend Calculation

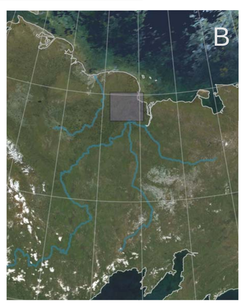
Linear trend/regression of index values over time

Robust Theil-Sen regression

Output: Slope, Intercept, Confidence Intervals

For detailed info see: Nitze & Grosse (2016)





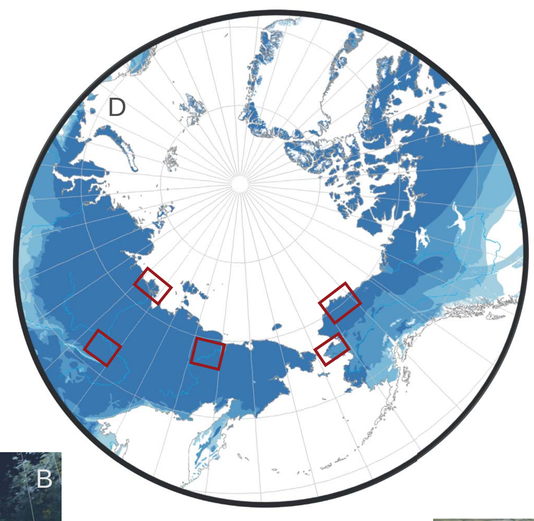


Fig 1: Overview of Study sites. A: Lena Delta and Yakutia, B: Kolyma, and C: Seward Peninsula and North Slope. D: Overview of Study sites within the Arctic permafrost region. Modified after Brown et al. (1997).

Methods - Trend Analysis

Temporal Landscape Dynamics

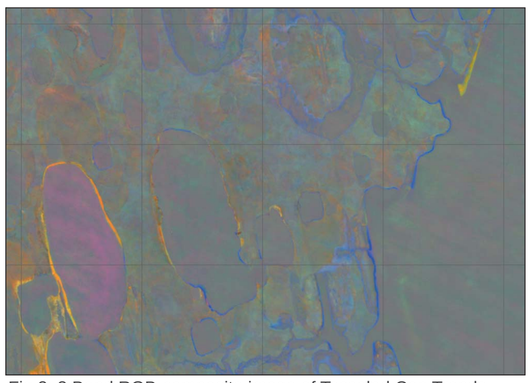


Fig 2: 3 Band RGB-composite image of Tasseled Cap Trends. R: Brightness, G: Greenness, B: Wetness. Grid Size 2km.

Fig 3: Drained lake margin on the Alaska North Slope. Photo: I.Nitze

Fig 4: Eroding thermokarst lake shore on the Alaska North Slope. Photo: I.Nitze

Methods - Lake Analysis

Classification

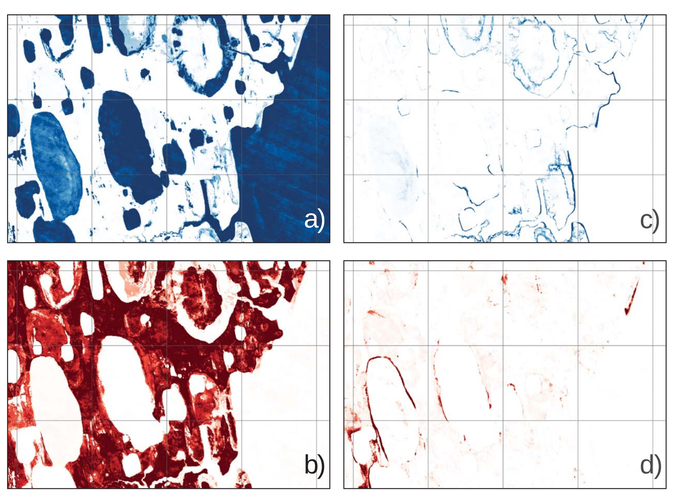


Fig 5: Random Forest Classification Probabilities of a) Water, b) Land, c) Transition Land to Water, and d) Transition Water to Land. Grid Size: 2 km.

Object Recognition

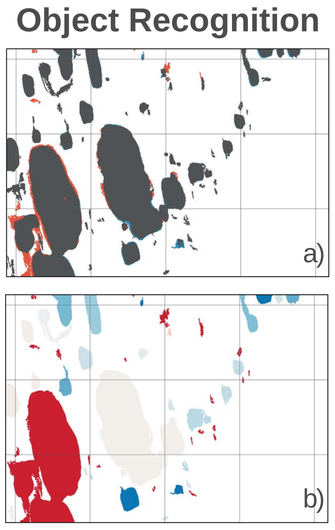


Fig 6: a) Stable (grey), growing (blue) and shrinking lake objects (red). b) Relative lake change budget for individual lakes. Grid Size: 2 km.

Results - Regional Overview

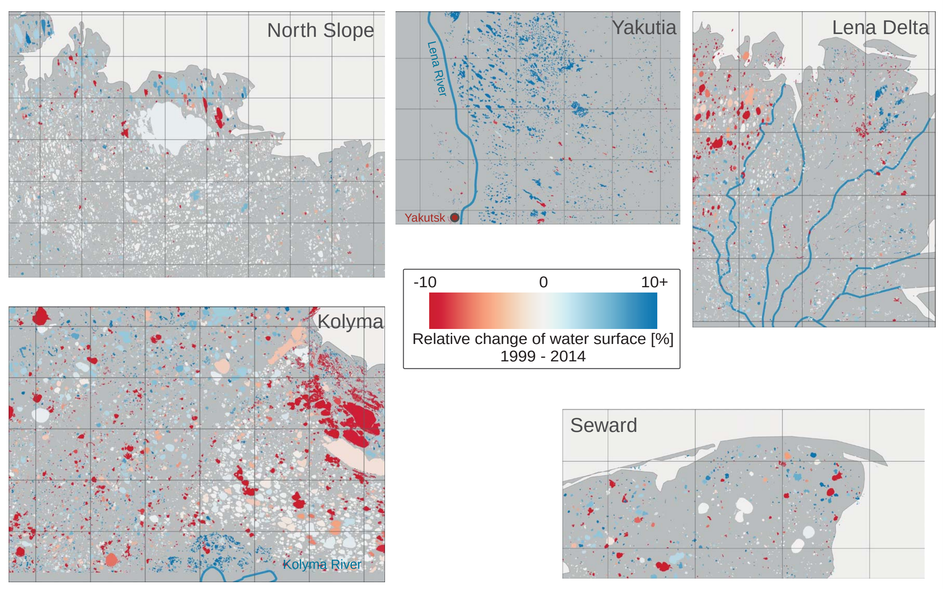


Fig 7: Relative lake area change of individual water bodies in all study sites between 1999 and 2014. Grid Size: 25 km.

Quantification

Strong Lake Dynamics within Study Sites
Spatial Diversity - Clusters of:
- Dynamic vs. Static
- Growing vs. Shrinking

Moderate regional-scale lake area changes
- Lake are size decrease in Lena Delta (-3.0 %), Seward (-5.7 %) , and Kolyma (-2.9 %)
- Nearly balanced on Alaska North Slope (+0.2 %)

Massive lake area increase in Central Yakutia
- Refill of formerly dry thermokarst lake basins (Alas)

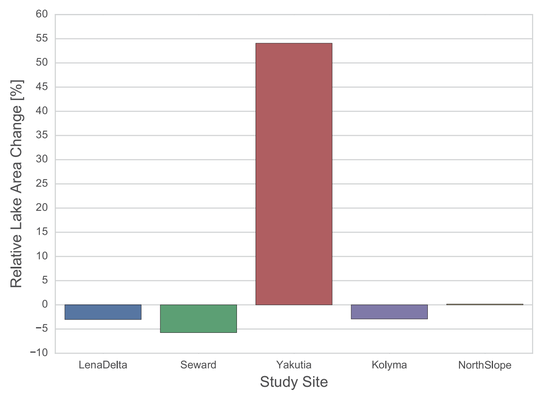


Fig 8: Relative lake surface budget of study sites between 1999 and 2014.

Summary and Outlook

Land surface trend analysis on Landsat archive
Automated lake detection and characterization
Transferrable approach across the Arctic
Varying thermokarst lake dynamics between regions

Integration of higher resolution Sentinel-2 data
Development of dynamic pan-Arctic thermokarst lake database
Distribution of result datasets via Open Access data portals (Arctic Permafrost Geospatial Centre & PANGAEA)

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References:
Brown, J., Ferrians, Jr. O. J., Heginbottom, J. A., and Melnikov, E. S.: Circum-Arctic map of permafrost and ground-ice conditions, 1:10 000 000, Map CP-45, United States Geological Survey, International Permafrost Association, 1997.

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