Remote Sensing of Drained Thermokarst Lake Basin Successions

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Background

Thermokarst Lakes (TKL)

- *TKL are important factors for northern hydrology, permafrost dynamics, and carbon cycling.*
- *TKL are abundant and highly dynamic landscape features of ground-ice rich lowland regions in Alaska, N Siberia, and NW Canada.*
- *TKL provide important ecosystem services as habitats, hydrological feature, biogeochemical hotspots, and for surface energy budgets.*

Drained Thermokarst Lake Basins (DTLB)

- *DTLB of different age are abundant and partially overlap each other, suggesting intense dynamics of lake formation and loss with complex carbon cycle histories (Grosse et al., 2013).*
- *Observing DTLB succession patterns will help to constrain impacts of lake loss on hydrology, permafrost aggradation, vegetation, carbon pools, and spectral land surface changes.*
- *RS helps characterizing DTLB.*

Objectives

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- *Determine recent and Holocene chronology of DTLB formation in the Panarctic.*
- *Characterize the spectral, morphological, and functional properties of DTLB.*
- *Relate surface properties to succession dynamics and time since drainage for different DTLB types.*

Approach

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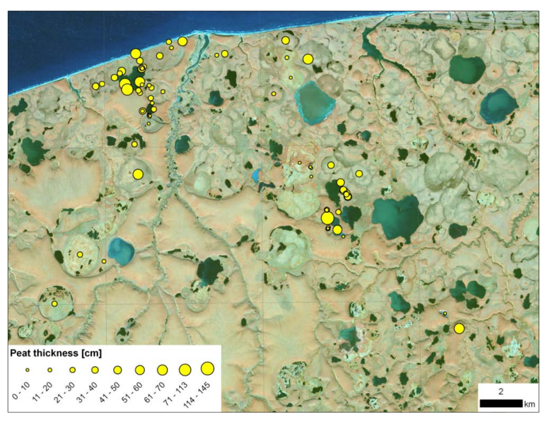
- *Use RS imagery + accelerated mass spectrometry ^{14}C dating to date lake drainage event.*
- *Derive spectral properties of DTLBs with known age to investigate succession patterns and their impacts on land surface characteristics over time.*

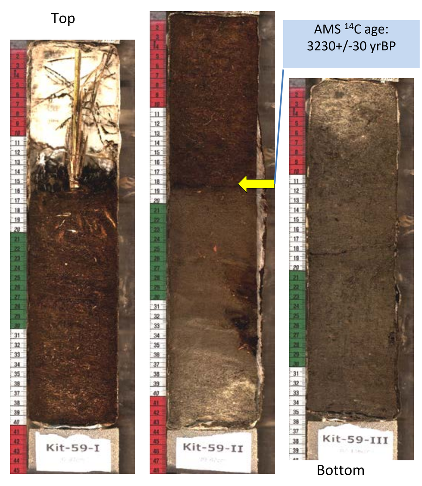
Field and Lab Methods

^{14}C-dating of peat layers indicative of post-drainage terrestrialization during the Holocene

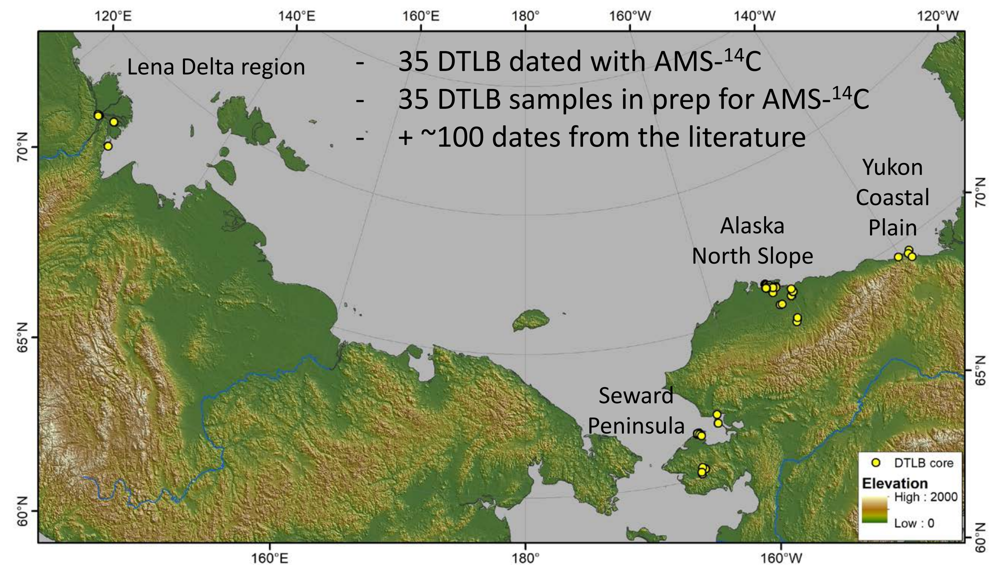
Permafrost coring in a DTLB



Details on permafrost coring sites in from DTLBs on the northern Seward Peninsula, Alaska

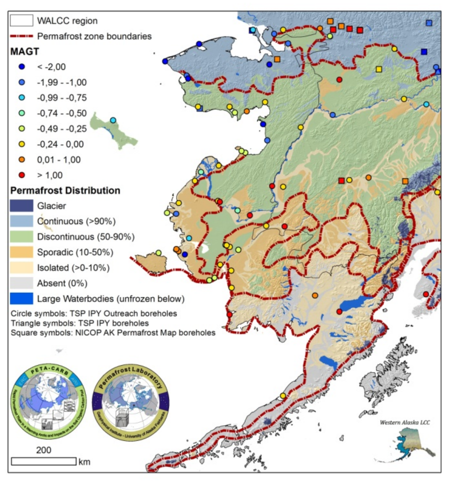


Kit-59 core, Seward Peninsula: (Length: 116 cm, Terrestrial peat: 57 cm)

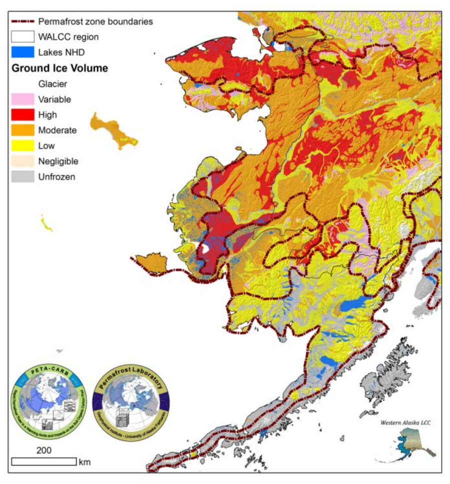


Location of ~100 DTLB coring sites in Siberia, Alaska, and Canada for 2010-2018

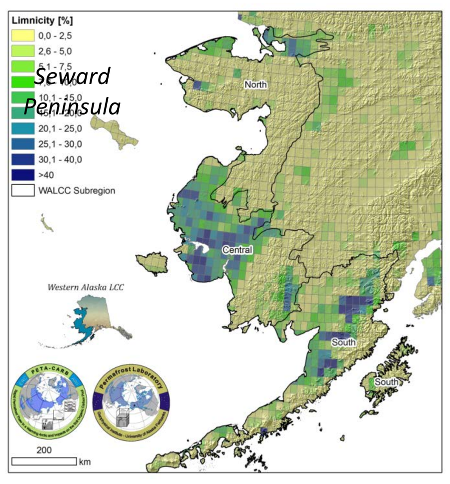
Example Region: Western Alaska



Permafrost distribution (Jorgenson et al., 2008) and mean annual ground temperature (MAGT) from borehole datasets (Jorgenson et al., 2008; IPA, 2010; K. Yoshikawa, UAF).



Ground ice volume in the WALCC region (Jorgenson et al., 2008).



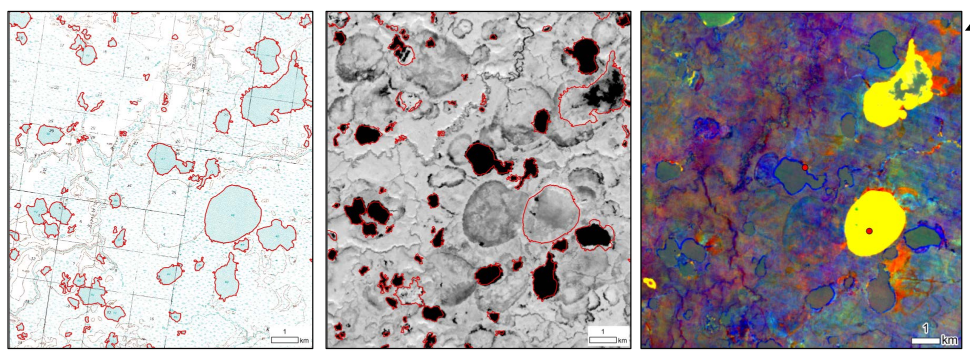
Limnicity in western Alaska.

Types of drained thermokarst lake basins

Remote Sensing Methods

I. RS-based land-water classification and identification of drainage events

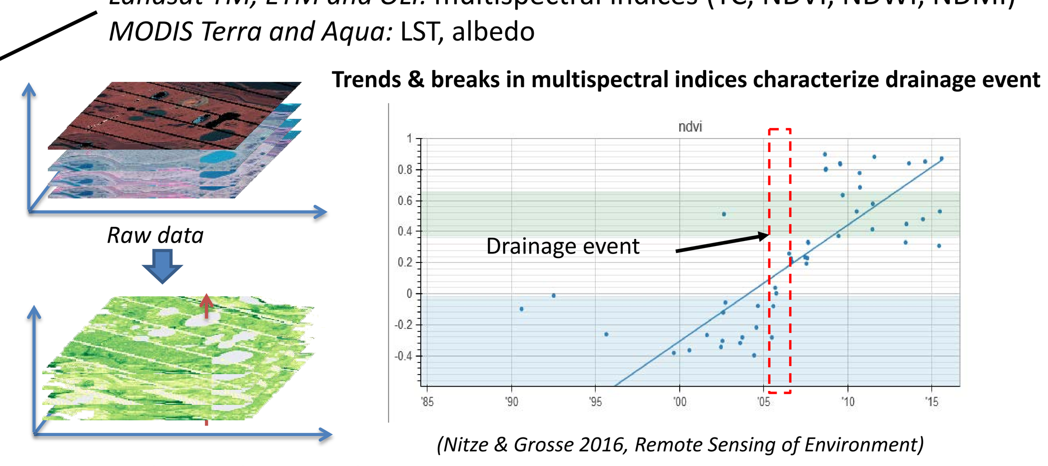
DTLBs from ca. 1950 - today
Historical topographic maps, aerial imagery, and Corona /Hexagon imagery
Landsat MSS: (NIR – G) / (NIR + G)
Landsat TM, ETM and OLI: (SWIR2 – G) / (SWIR2 + G)



1950 USGS Topo map | 2014 Landsat OLI | Landsat Tass Cap Trends 1985-2015

II. Temporal trends of DTLB spectral properties

Landsat TM, ETM and OLI: multispectral indices (TC, NDVI, NDWI, NDMI)
MODIS Terra and Aqua: LST, albedo

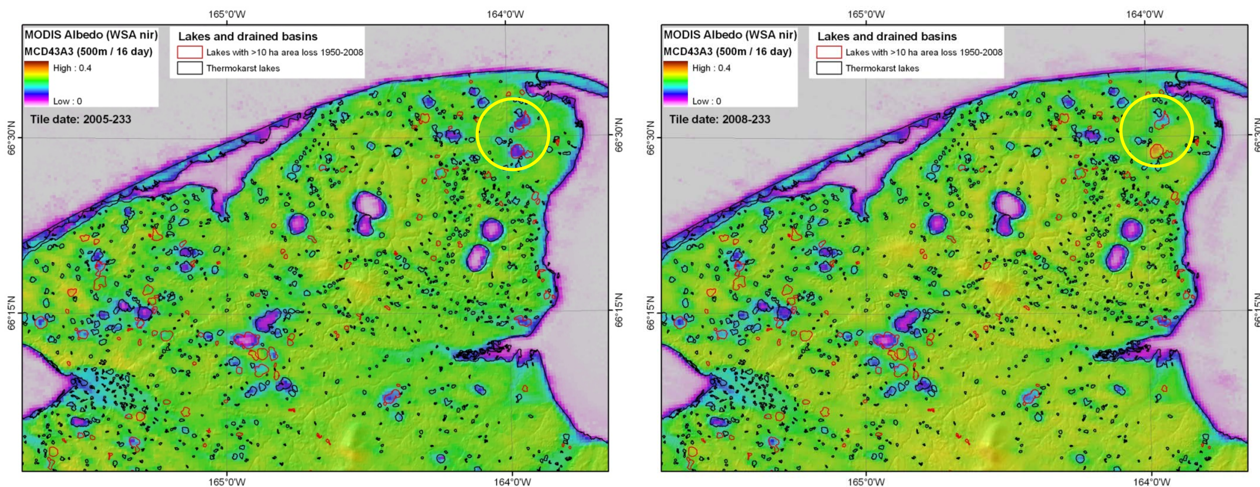


(Nitze & Grosse 2016, Remote Sensing of Environment)

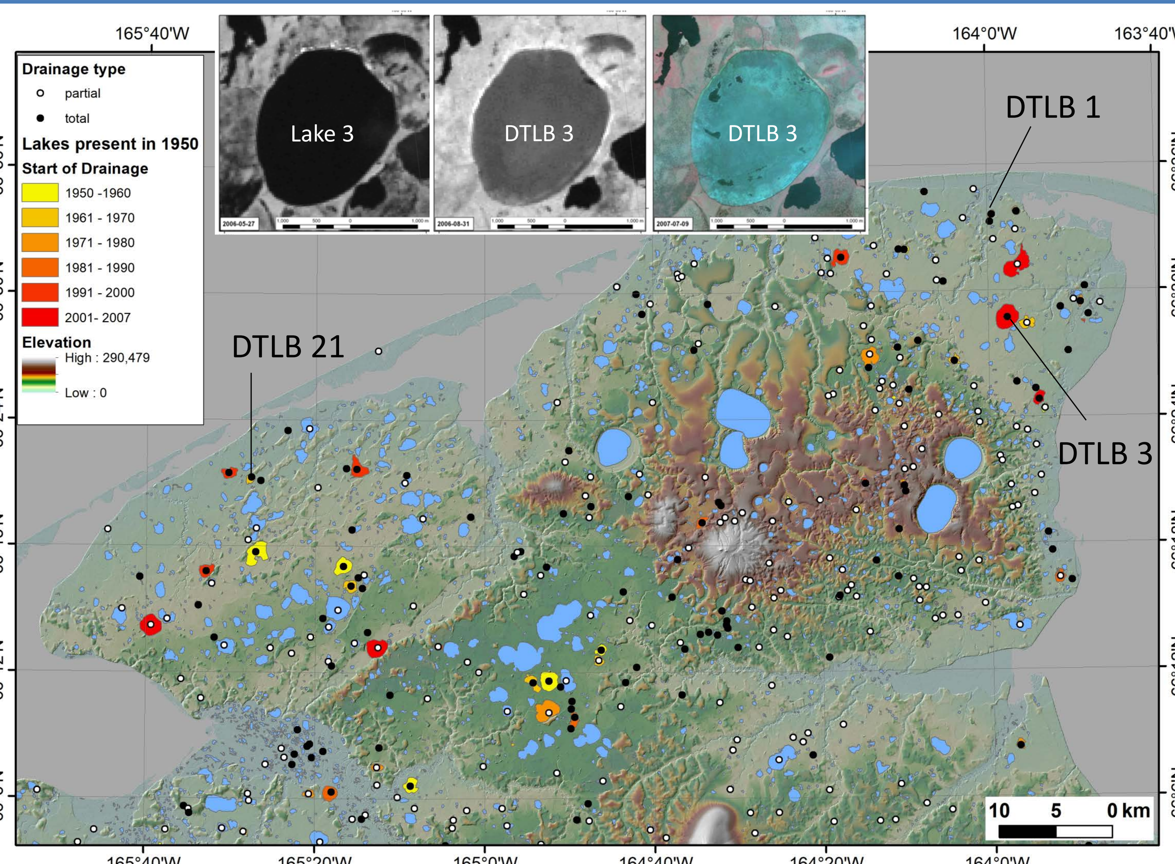
Results

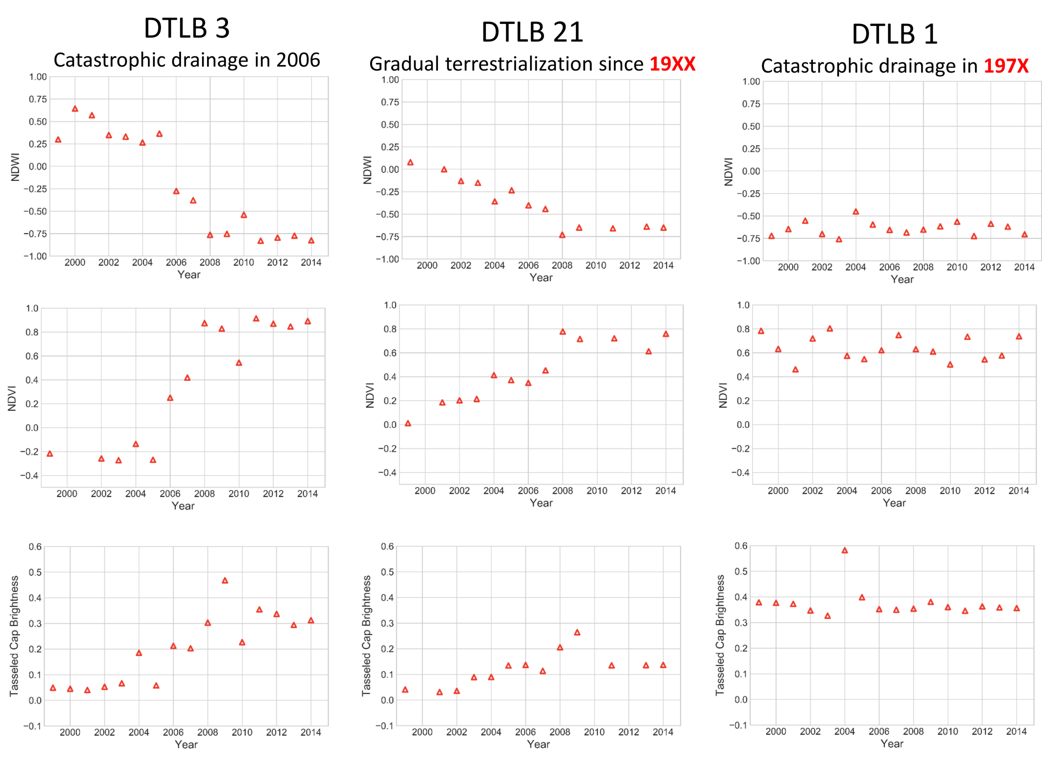
Processing Status

- *Lakes extraction from 1950 USGS maps: semi-automated method established, several lake districts completed.*
- *Super-temporal lake extraction and trend analysis from 1995-2015 Landsat: several lake districts completed.*



Albedo changes due to lake drainge





Landsat TM, ETM and OLI: multispectral indices (TC, NDVI, NDWI, NDMI)
Here shown only NDWI, NDVI, and TCB

Conclusions

- *Lake-rich landscapes in western Alaska are changing rapidly due to lake loss.*
- *Important lake drainage mechanisms are permafrost degradation around existing thermokarst lakes (lake expansion, talik growth), tapping by fluvial and coastal erosion, and gradual drying of shallow lakes.*
- *Multi-temporal, multi-sensor approach delivers a comprehensive picture of DTLB development over the last 65 years.*
- *Automated, super-temporal time series trend analysis with Landsat (and in the future also Sentinel-2) provides a fully scalable tool for region-wide DTLB characterization.*
- *More ^{14}C dates are needed to compare modern with Holocene drainage rates*

References

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