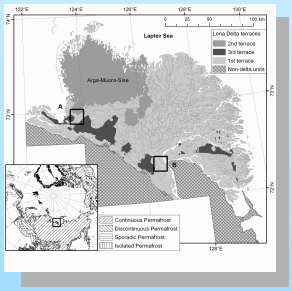
Application of field spectrometry and remote sensing data for permafrost surface studies in the Laptev Sea coastal lowland (Lena River Delta)

Mathias Ulrich[a], Guido Grosse[b], Sabine Chabrillat[c], Lutz Schirrmeister[a]

a - Alfred Wegener Institute for Polar and Marine Research, Potsdam, Germany
b - Geophysical Institute, Universtity of Alaska, Fairbanks, USA
c - German Research Center for Geoscience, GFZ, Potsdam, Germany

Introduction

The monitoring of permafrost coastal landscapes is a cornerstone of the quantification of future environmental changes and their impacts on Arctic coastal lowlands of the Lena River Delta, which link the Arctic continental region to the Laptev Sea. Thawing permafrost might cause massive landscape changes due to thermokarst and enhanced release of greenhouse gases from the large carbon storage of frozen deposits. In addition, current quantities of carbon and other nutrients in sediments, likely to be mobilized by ever increasing erosion, are only crudely known. Remote sensing and spatial data analysis are ideal tools to detect, study, and quantify changes in the Arctic tundra landscapes. For a successful interpretation of such data, considerable basic knowledge on the properties of these landscapes is required. This includes the characterization of vegetation, soils, geomorphology, and spectral surface properties.



Study areas

Location: Lena River Delta, Laptev Sea coast, North Siberia
Coverage: 29.000 km² (largest Arctic delta)
Study sites: A: Turakh (western delta); B: Samoylov and Kurungnakh (central delta)
Vegetation zone: Lowland tundra
Geomorphology: 1st terrace: Recent floodplains and Holocene sandy deposits (the modern „active" delta) (ca: 1 – 12 m a.s.l.)
2nd terrace: Characterized by sandy deposits, probably of Late Pleistocene fluvial genesis (ca: 11 – 30 m a.s.l.)
3rd terrace: Late Pleistocene accumulation plain of ice- and organic-rich deposits („Ice Complex") (ca: 30 – 60 m a.s.l.)
Special conditions: Situated in the zone of continuous permafrost (sediments are perennially frozen); dominated by fluvial-deltaic and periglacial processes; large portions are wetlands with strong heterogeneity in micro-relief, vegetation patterns, and soil moisture distribution

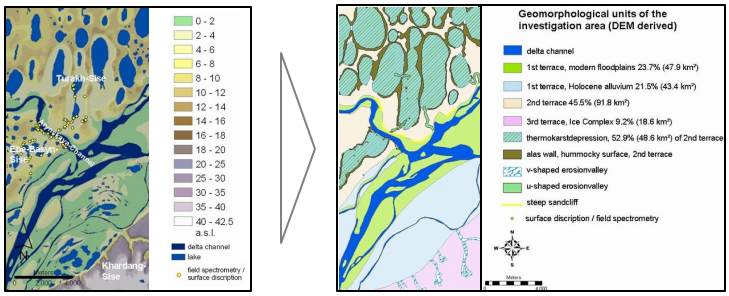
Main objectives

Development of general methods for the characterization and classification of typical periglacial landscapes in the Arctic coastal lowland of the Lena River Delta, and their applicability for remote sensing based analyses.

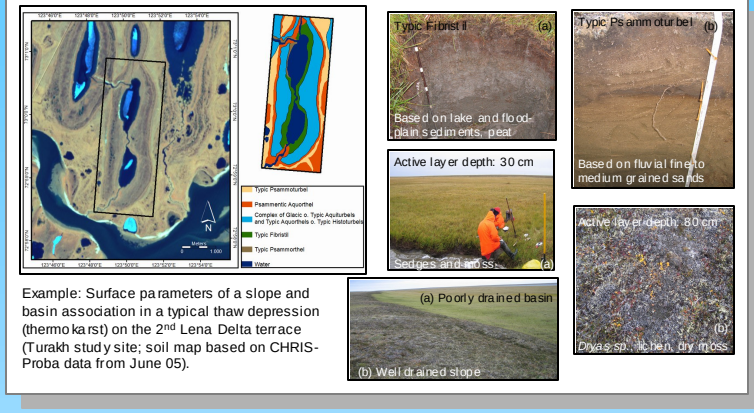
Development of a spectral database for periglacial / tundra surfaces in the Lena River Delta.

Development of a detailed Landsat 7 ETM+ land cover classification and a pedological map based on CHRIS Proba data shall provide the basis for detecting long term changes

Geomorphological analysis at study site level (example: Turakh)

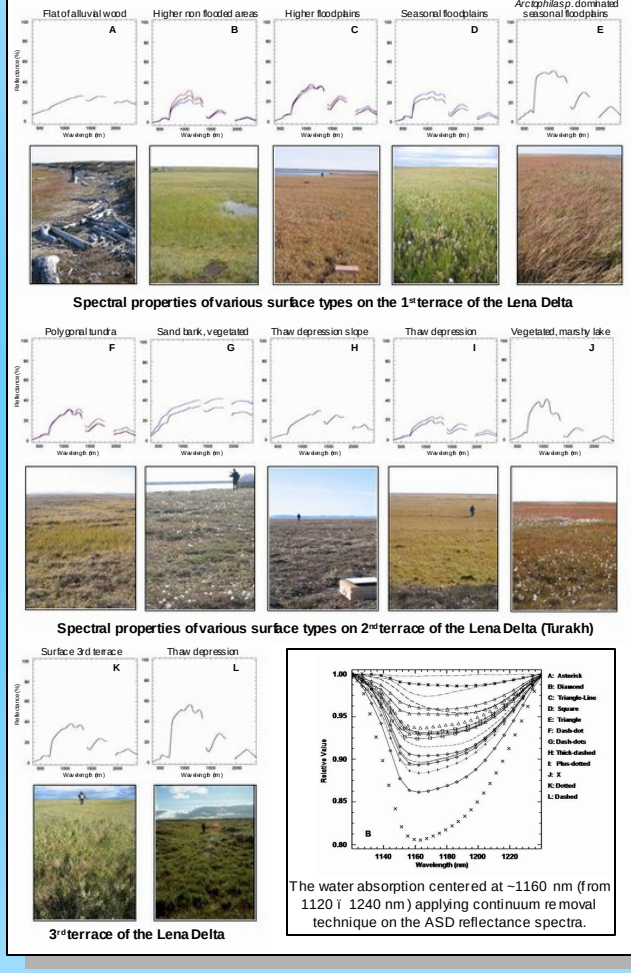


Characterization of vegetation, soils, and active layer depth



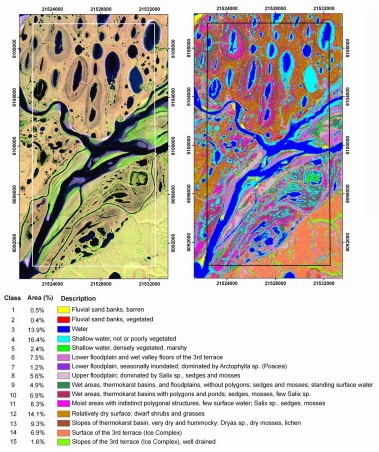
Example: Surface parameters of a slope and basin association in a typical thaw depression (thermokarst) on the 2nd Lena Delta terrace (Turakh study site; soil map based on CHRIS-Proba data from June 05).

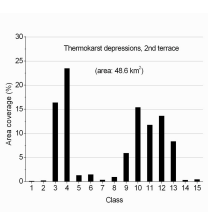
Field spectrometry with an ASD FieldSpec Pro FR (Summer 05)



The water absorption centered at ~1160 nm (from 1120 – 1240 nm) applying continuum removal technique on the ASD reflectance spectra.

Maximum-likelihood classification of a Landsat 7 ETM+ subset





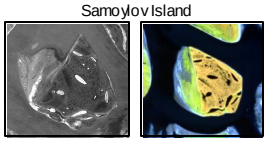
We produced a detailed land cover classification of each geomorphological terrace at the Turakh study site based on our field investigations and a Landsat-7 image subset. The diagrams show exemplary classification results for the area of the thermokarst depressions on the 2nd terrace (see geomorphological analysis above).

Long-term change detection

Acquired multi-temporal and multi-sensoral remote sensing data

Sensor	Samoylov	Turakh
Corona	22-Jun-64	22-Jun-64
	18-Jul-64	9-Aug-80
	1-Oct-65	
	29-Sep-68	
	16-Jul-75	
Landsat-1 MSS	26-Jul-73	
Landsat-7 ETM+	27-Jul-00	26-Jul-01
	5-Aug-00	28-Jul-01
	30-Jun-01	
CHRIS-Proba	4-Jul-05	29-Jun-05
	13-Jun-06	15-Jul-05
		10-Jul-06

Samoylov Island



Corona 22-Jun-64 | CHRIS-Proba 04-Jul-05

Results

A variety of field investigations and lab analyses (image and spectra processing, terrain modelling, spatial data analysis) were carried out for the assessment of periglacial surface properties in the Lena River Delta.

More than 500 field spectra were acquired from 19 sites in the delta. 12 different surface classes were extracted from these spectra. The classification indicates significant differences in surface properties between the delta main terraces, and thus their good spectral separability.

Remote sensing based image classification was successfully applied for the detailed characterization of land cover units in the study sites.

CHRIS-Proba data was used for the classification of soils in a thaw depression.

A multi-temporal image stock for change detection analysis was compiled.

Conclusion

The combination of a variety of field and lab studies provides an excellent ground truth dataset for the analysis of multispectral remote sensing imagery and the classification of periglacial surfaces.

The first step for the development and maintenance of a spectral database for Arctic periglacial regions is done.

The unique dataset acquired provides the base for further analysis of multi- and hyperspectral imagery (e.g. Chris-Proba) in the Lena River Delta tundra.

Outlook

Multi-temporal, hyperspectral CHRIS-Proba satellite data and optical ALOS PRISM/AVNIRR2 satellite data will be used for further analysis and classification of the Lena River Delta coastal lowlands and comparison of the results with existing classifications.

The field spectra datasets will be used for comparison with satellite derived spectra from CHRIS-Proba and other sensors.

Related Publication

Ulrich, M., Grosse, G., Chabrillat, S. & Schirrmeister, L. (in revision). Arctic periglacial surface features as environmental indicators using field spectrometry and remote sensing data. Remote Sensing of Environment.

(Contact: Mathias.Ulrich@awi.de)