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Analyzing intra-seasonal dynamics of ice-rich permafrost degradation in the Lena Delta using TerraSAR-X backscatter time-series

Background & objectives

Arctic warming accelerates the **rapid degradation of ice- and organic-rich permafrost landscapes** (i.e. retreat of riverbanks [1]). Yet, information at high temporal and spatial resolution is often lacking to describe the **rates and the timing of permafrost degradation** because cloud cover limits the use of optical satellite imagery. **Synthetic aperture radar (SAR)** operates independently of atmospheric distortions and could help to alleviate these issues.

Our **main objectives** are to:

1) assess the applicability of Terra-SAR-X SAR data for the monitoring of rapidly eroding riverbanks

2) identify the intra-seasonal timing of ice-rich riverbank erosion.

Study area

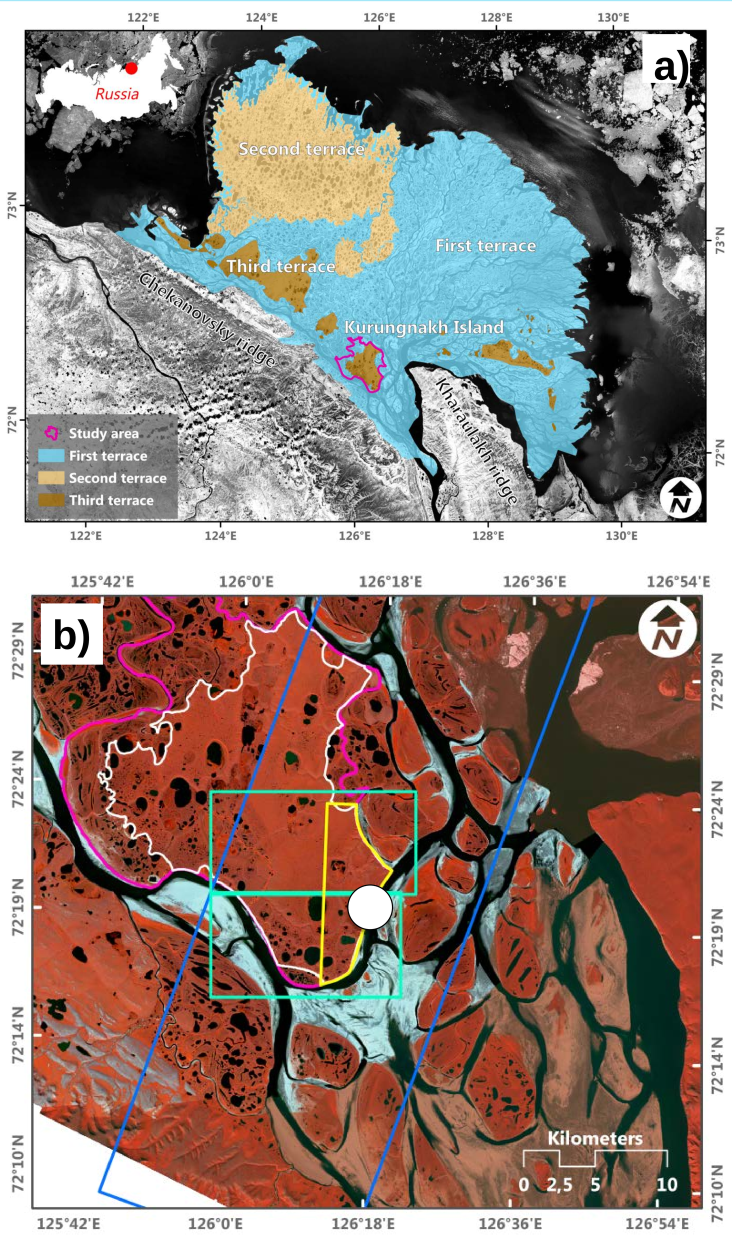
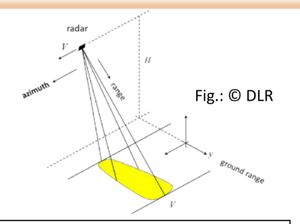


Figure 1: a) The Lena Delta in eastern Siberia can be characterized by three geo-morphological units [2,4]. The **test site** at the east coast of Kurungnakh is assembled of fine grained, organic- and ice-rich sediments of the third terrace (ice complex)[6]. Ice Complex cliff heights range from 30 to 60 MASL[5]. Background image: Landsat ETM+ 2000;
b) Extents of optical GeoEye-1 (light green) and Worldview-1 (yellow) reference images and extent of the TerraSAR-X (TSX)-time series (blue) over the test site **(white point)**. Background image: RapidEye scene from the 4th of August 2010 with band combination RGB = 521.

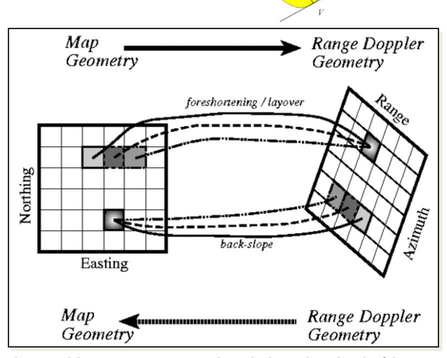
Datasets

- **TSX time-series** of 76 images with HH polarization (2012 to 2015)
- Two **very high resolution optical imagery** (August 2010 & 2014)
- **DGPS and time lapse** monitoring (June 2015)

SAR preprocessing



- Import of complex SLC SAR Image
- Radiometric Calibration
- Conversion to linear and scaling in decibel
- 1/1 Multilooking (2.3 m ground resolution)
- Coregistration & stacking
- Ellipsoid corrected geocoding



http://www.geo.uzh.ch/en/units/rsl/research/radar-remote-sensing-sarlab/research-projects/sar-geocoding

KEY FINDINGS

- **Riverbank cliff is characterized by x-band backscatter intensities greater than -7.5 db.**
- **TSX derived cliff retreat is in the same range as the reference datasets.**
- **The cliff top is detectable from June to October (thawing period).**
- **Constant cliff top retreat within the thawing season.**

Results

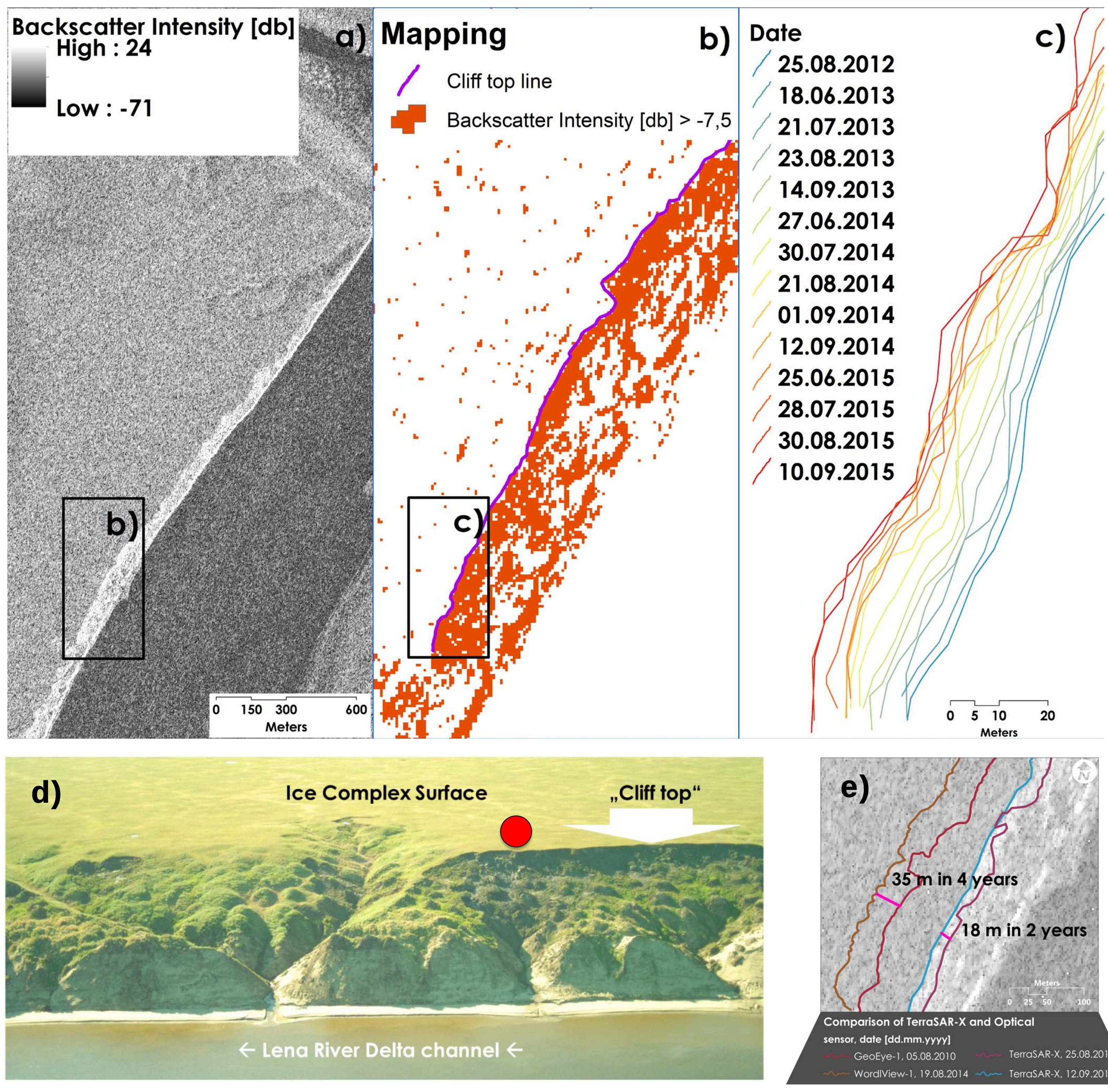


Figure 2: Cliff top retreat at the test site: **a)** TerraSAR-X scene from 21.08.2014 showing the test site; **b)** a threshold of -7.5 was statistically defined and applied to Terra-SAR-X images before mapping the cliff top; **c)** cliff top lines from TerraSAR-X images within the thawing season; **d)** field photo from 2013 showing the transition (cliff top) between undisturbed ice complex and the eroding cliff; red point = position of time-lapse camera; **e)** Comparison of cliff top retreat from optical reference dataset and from TerraSAR-X imagery.

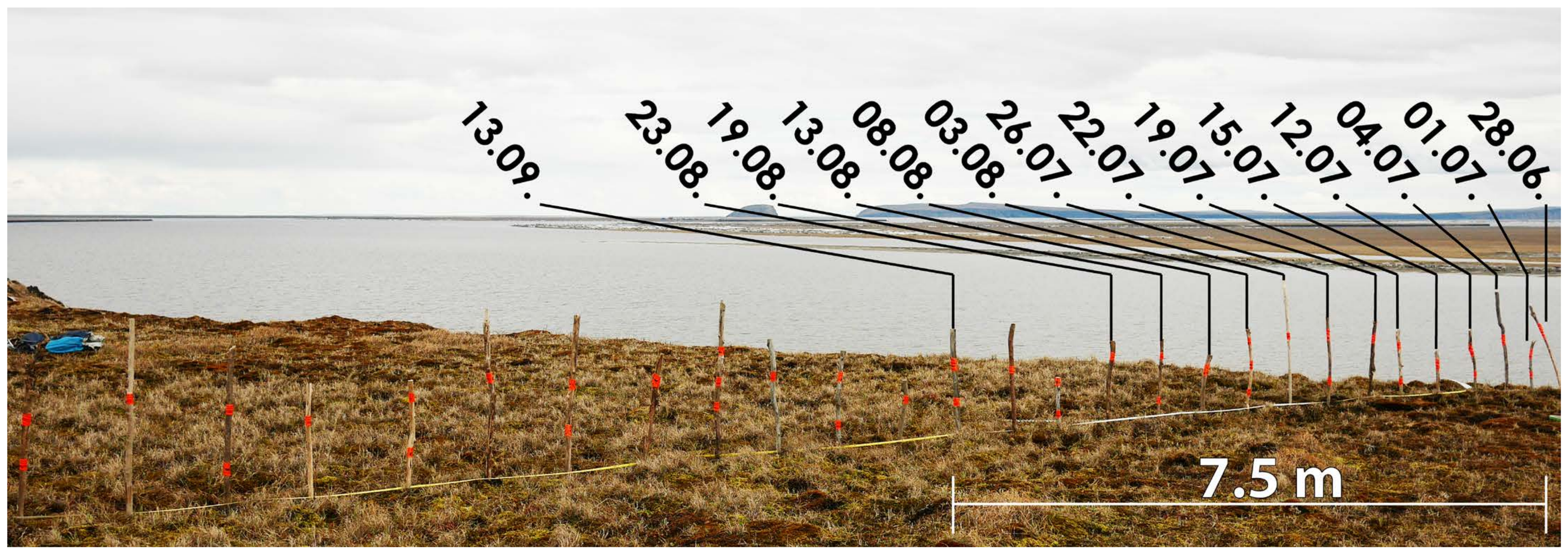


Figure 3: Time-lapse camera setup at the test site. We installed 29 wooden markers every 50 cm perpendicular to the cliff top and a Brinno TLC200 Pro time lapse camera viewing from South to North. Pictures were taken every four hours from 28.06.2015 to 13.09.2015. In that period 15 markers were eroded, equaling 7.5-m of cliff top retreat.

Conclusion

Terra-SAR-X backscatter time-series show high potential for monitoring rapid permafrost degradation with high spatial and temporal resolution within the thawing season. Our preliminary results indicate that cliff top erosion of ice-rich riverbanks is constant over the thawing season, not event driven (i.e. spring floods).

References
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