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Characterizing thermo-erosional landforms in Siberian ice-rich permafrost

Morphometric investigations using high resolution satellite imagery and digital elevation models

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Background:

Accelerated **degradation of Siberian ice-rich permafrost** (Romanovsky et al. 2010) could have substantial impacts on regional (e.g. water & energy balances) to global scale(e.g. carbon release to the atmosphere, Koven et al. 2011). The role of **linear permafrost degradation features** in this context is still uncertain (Morgenstern 2012).

Key Questions:

- What is the **spatial distribution** of thermo-erosional features in the study area?
- Which **types of thermo-erosional features** can be distinguished and what are their driving factors?
- Can **morphometric characteristics** of thermo-erosional features serve as indicators for delineation of stratigraphic units?

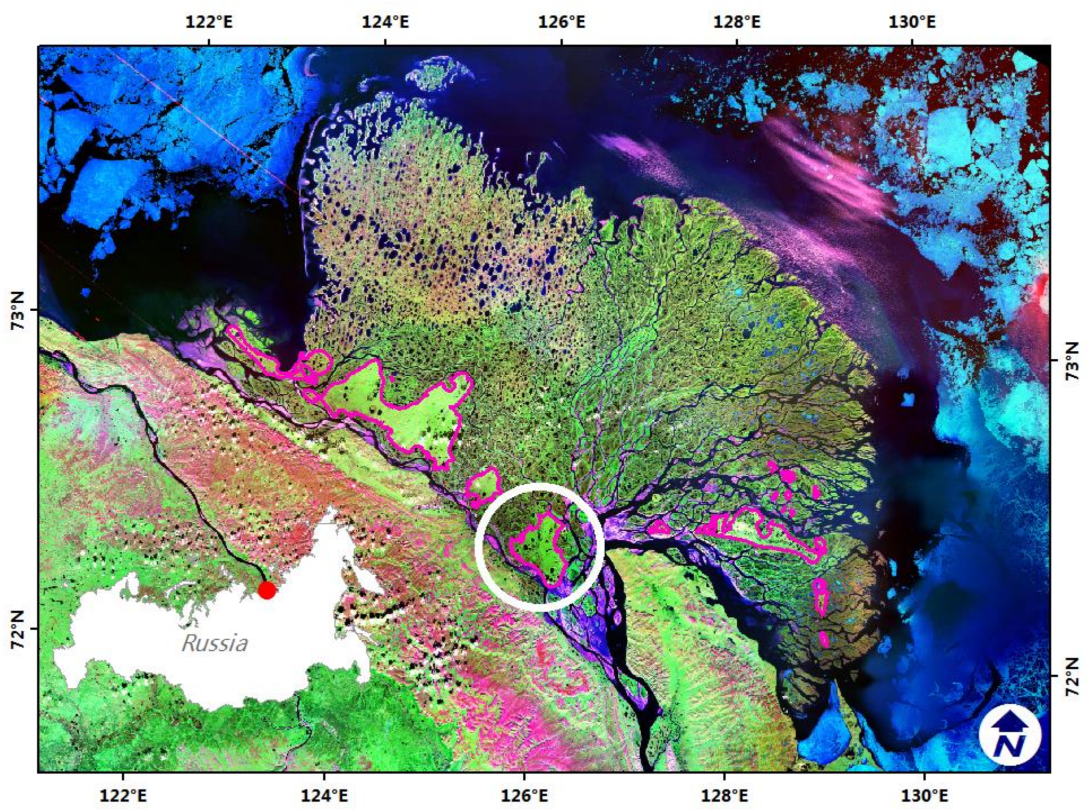

Fig. 1: Location of the study site

Study area

- **Kurungnakh Island** (central Lena Delta, Fig.1)
- **third main terrace** of the Lena Delta (Grigoriev, 1993)
- **ice- and organic-rich sediments (ice complex)** , lower boundary between 15-20 m a.s.l. (Schirrmeister et al. 2011)
- intensive thermokarst **and thermo-erosional activity → highly** dissected surface (Morgenstern et al., 2013)
- **key study area for Siberian ice-rich permafrost**
- maximum heights of 55 m a.s.l. in southeast, gradually decreasing towards northwest
- total area of 377 km² (270 km² with preserved stratigraphy),
- variety of **valley morphometries**

1. Field work & Data fusion

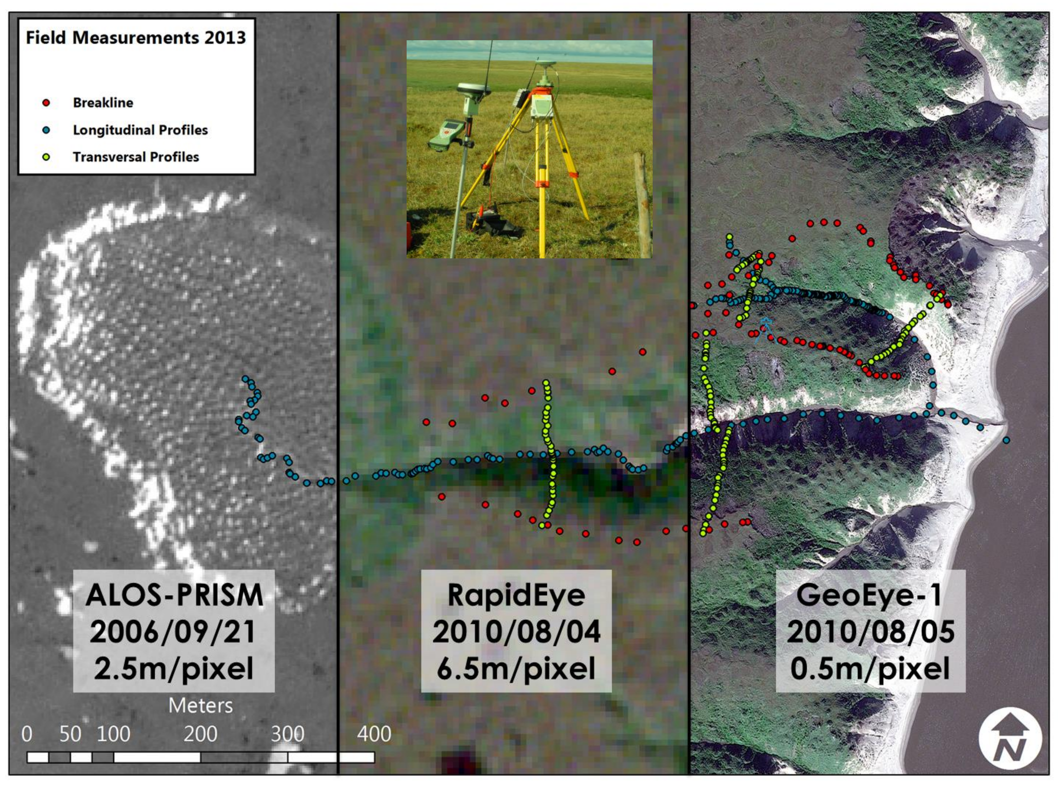

Fig. 2: Overview of satellite images used and field data (July 2013) for one of three study sites.

- 12 GCPs
- 29 Transversal profiles
- 7 Longitudinal profiles
- Surface descriptions

Geometric correction

- GeoEye-1(RMSE 0,36 m), RPC-model (Aguilar et al. 2012)
- RapidEye (RMSE 2,86m), RPC-model
- PRISM (RMSE 2,34 m), Toutins-model, image enhancement (Kamiya 2006)

2. DEM generation & validation

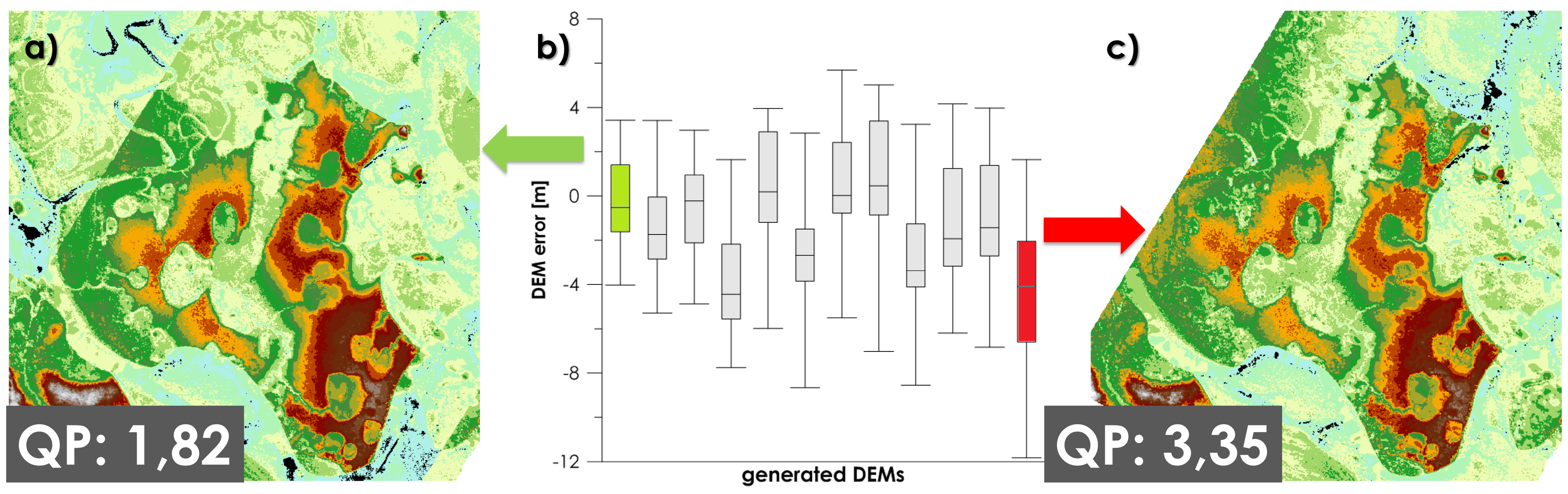

Fig. 3: Several **combinations of 14 ALOS PRISM stereopairs** were tested to 1) **get better matching results** on low-contrast and low-slope gradient yedoma upland 2) **decrease effect of occlusion** in valley floors 3) **decrease error** in areas with **coastal erosion. Validation** was done using 1104 DGPS points (Range 0-58 m a.s.l.), classified in 2m steps from 0 to 58 m. The final **quality parameter (QP)** is the standard deviation of the mean error per class. **a)** DEM from 6 stereopairs (2006 and 2009 imagery, 57 % matching), **c)** DEM from 2 stereopiars (2009 imagery, 29 % matching), **b) error ranges** of several generated DEMs with a) marked in green and c) marked in red.

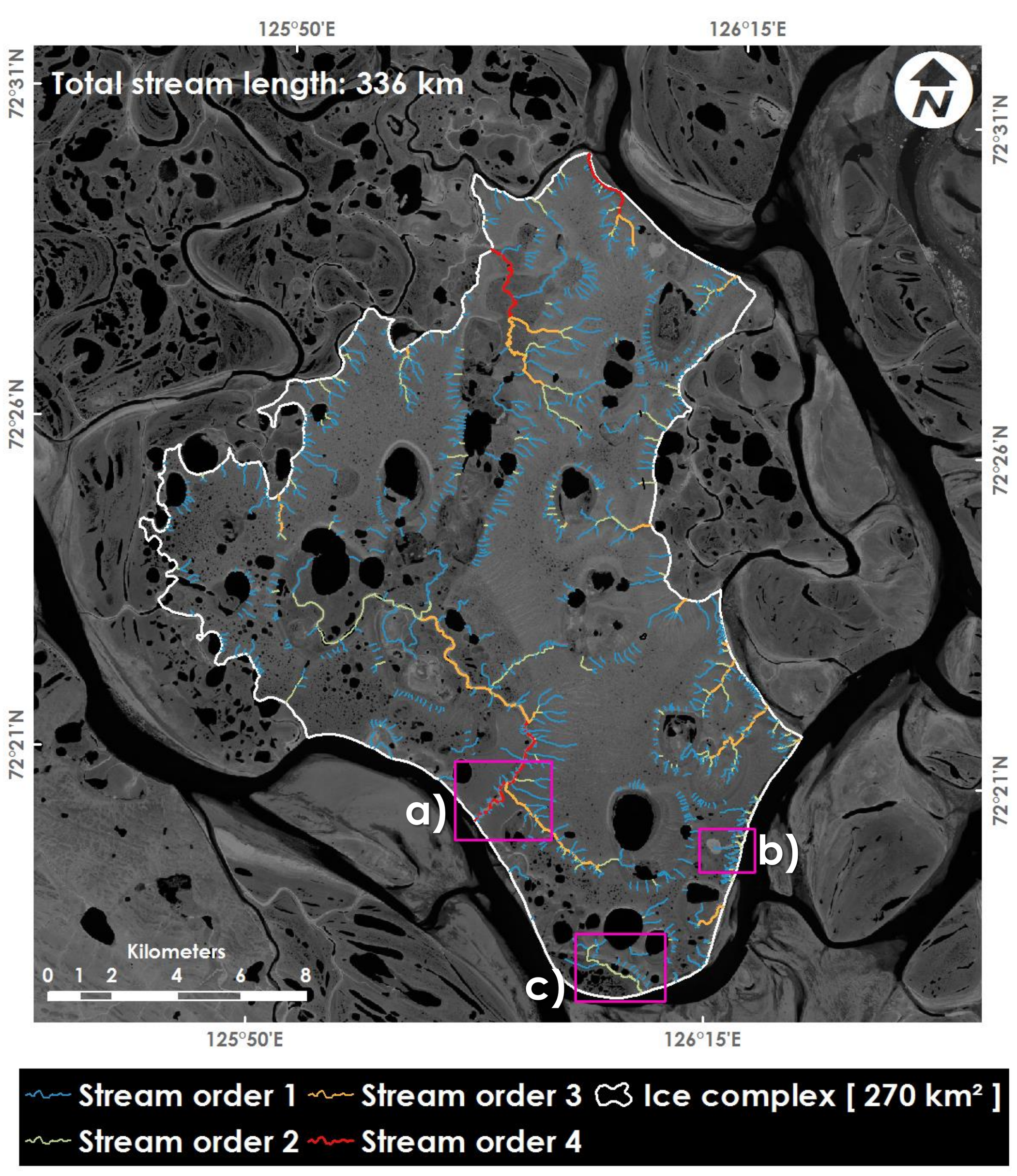

Fig. 4: Stream network of Kurungnakh Island. Stream order after Strahler (1957). Letters show the study sites (Fig. 5).

3. Results

- total flow length = 336 km
- drainage density = 0,8
- majority is first order (Fig.4)
- 50% are shorter than 230 m
- mainly on slopes of thermokarst basins and at the coastline
- longer streams with higher order are mainly present within thermokarst basins and connect these with each other

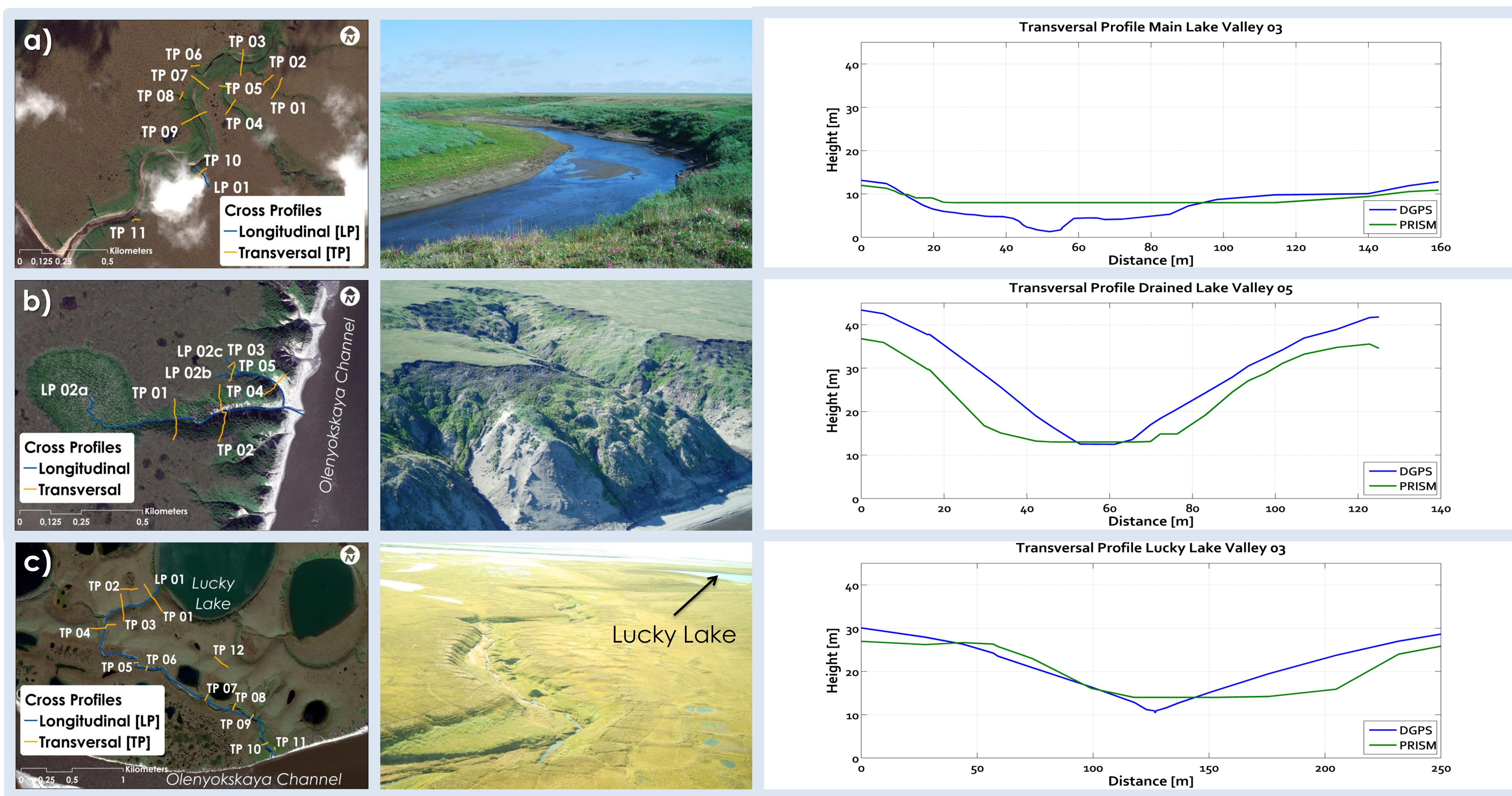

Fig. 5: Study sites with examplary transversal profiles derived from field data and DEM, a) Main Valley, b) Drained Lake Valley, c) Lucky Lake Valley.

4. CONCLUSIONS

Thermo-erosional landforms play an important role in permafrost degradation and are strongly **connected to thermokarst** features. **Short and non-complex** linear permafrost degradation features are the **predominant type** on Kurungnakh Island. **Complex valley networks** develop in areas of ice-rich permafrost that are highly **degraded by thermokarst** activity.

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