Planimetric and volumetric thermokarst change detection on ice rich permafrost, using remote sensing and field data

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1 INTRODUCTION

An expected increase of thermokarst activity will lead to a further degradation of ice rich permafrost. Lakes formed by thermokarst processes are known to be a spatially and temporally variable feature indicative for surface wetness and drainage conditions. In order to investigate recent cryomorphogenesis this study is aimed to determine lake and terrain height changes in an ice rich arctic landscape.

The investigation area is located in the south of the Lena Delta (Russia). Average sediment discharge of the Lena River is about 21 mil. t/a. In comparison to the whole catchment river bank erosion in the area of the delta contributes to the riverine sediment input to the Arctic Ocean above average. Ice Complex (IC) permafrost deposits of the third geomorphological terrace cover large areas of the southern Lena Delta, which is exceptionally exposed to an increasing river discharge and strong flood waters along the largest delta channels. On Kurungnakh Island belonging to the third terrace a well pronounced alas-Yedoma thermokarst relief is developed. Undissected Yedoma uplands (< 55m high) alternate with large thermokarst depressions (alasses, < 30m deep) formed by thawing of ground ice since the Bølling interstadial. Lakes can be found here within alasses and on the Yedoma uplands (see Morgenstern et al., this conference).

Using photogrammetric principles, GIS, and geodetic measurement techniques a geometric consistent dataset was created for monitoring purposes.

2 DATA AND METHODS

Digital Elevation Models (DEM) were developed from a triplet set of ALOS PRISM imagery (2006), a CORONA stereo pair (1968) and a tacheometric field survey of a thermokarst depression (7,5 km²), conducted in summer 2008.

Due to suboptimal imaging conditions, such as snow, large shadows in steep thermoerosional valleys, low-contrast in the tundra environment, compression artifacts and striping the PRISM data were resampled to 5m ground resolution. In comparison to the processing of separate image tiles and piecewise DEM generation, the combination of three possible PRISM epipolar pairs with various overlap ratios allow higher measurement accuracy and the immediate generation of one DEM over the whole investigation area. Accurate processing of CORONA data, which included the correction of several overlapping image distortions, allowed for the minimization of wrong height parallax measurement and led to the generation of a 5 m DEM, representing the relief situation in 1968.

The DEMs then were used for orthoimage generation to allow distance and area measurements. For 2D-change detection purposes another historical dataset (1964) consisting of two adjacent CORONA filmstrips was used. The extent of Ice Complex deposits (260 km²) served as an analysis mask for digitizing thermokarst lakes at a large scale.

3 RESULTS AND DISCUSSION

The DEMs could be used effectively for 3D-change detection. For the alas investigated in detail in the field various expansion rates up to 9 cm/a depending on exposition could be determined through differencing the CORONA and the field survey DEM. A comparison of the CORONA and the PRISM DEM shows negative terrain height changes within alasses, along thermoerosional valleys, and shores.

Along the two river bank sections Olenyokskaya (IC thickness < 15 m) and Buor Khaya (IC thickness < 30 m) a detected volume loss of 5.5 mil. m³ sands and 14.5 mil. m³ of the overlying Ice Complex equals an input of 0.4 mil. t sediment per year. Erosion at the Buor Khaya section (-13 mil. m³) exceeds the values at Olenyokskaya (-7 mil. m³) by about 90%. Because of the different Ice Complex thickness a comparison of planimetric erosion rates leads to a different evaluation of the dimensions of erosion. The Buor Khaya section retreats at rates of 2.9 m/a, which is only 60% higher than the 1.8 m/a retreat at the Olenyokskaya section.

Over the period 1964-2006 a decrease in water area (2291 to 2216 ha) about – 3.5% could be observed, caused mainly by 45 catastrophic lake drainage events while persistent lakes increased about 2%. These parallel processes of lake drainage and expansion well detectable with high resolution data reveal ongoing lake dynamics that are not reflected in the overall limnicity change (8.7 to 8.5%).