Satellite-derived changes in the permafrost landscape of central Yakutia 2000–2011: Wetting, drying, and fires

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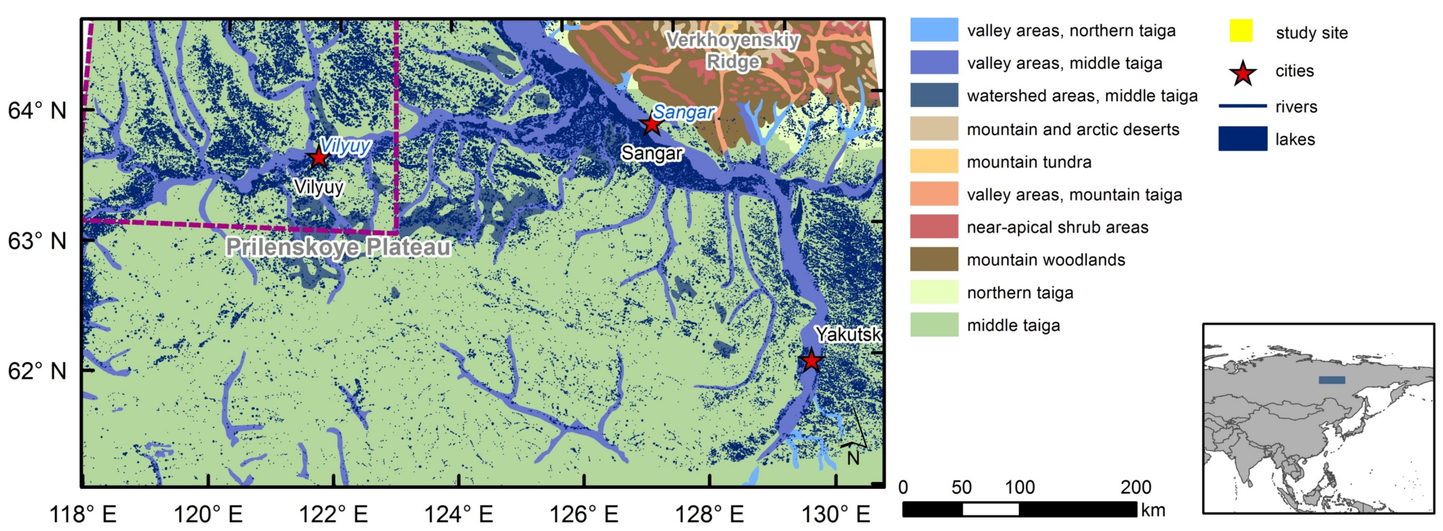
summary

The focus of this research has been on detecting changes in lake areas, vegetation, land surface temperatures, and the area covered by snow, using data from remote sensing in Central Siberia. Remote sensing products were used to analyze changes in water bodies, land surface temperature (LST), and leaf area index (LAI), as well as the occurrence and extent of forest fires, and the area and duration of snow cover. The remote sensing analyses (for LST, snow cover, LAI, and fire) were based on MODIS–derived NASA products (250–1000 m) for 2000 to 2011. Changes in water bodies were calculated from two mosaics of (USGS) Landsat (30 m) satellite images from 2002 and 2009.

This area experienced both large scale wetting and large scale drying during the study period probably related to the nature of the substrate conditions. The land surface temperatures showed a consistent warming trend, with an average increase of about 0.12 °C/year, but ranged up to 0.49 °C/year during September–October. This is about ten times higher than the global warming rate of 0.0116 °C/year (2000 to 2014) estimated by Karl et al. (2015). The spring warming trend is very likely to be due to changes in the area covered by snow: 80% of the area showed reduction in snow coverage in spring. The warming trend observed in fall does not, however, appear to be directly related to any changes in the area of snow cover, or to the atmospheric conditions, or to the proportion of the land surface that is covered by water (i.e., to wetting and drying).

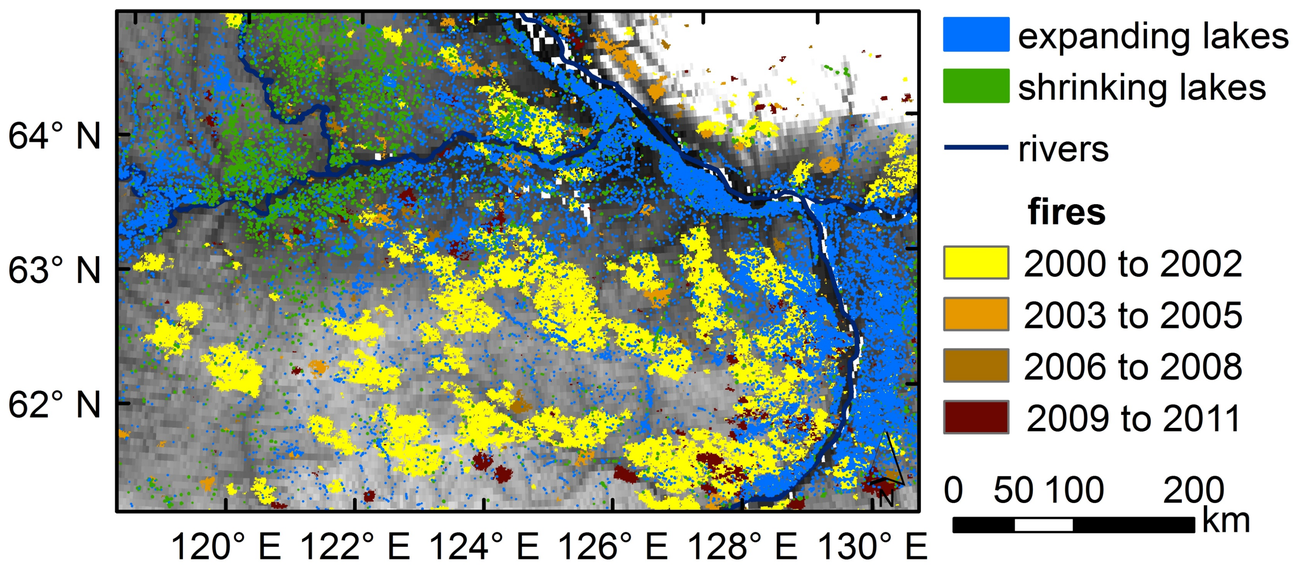


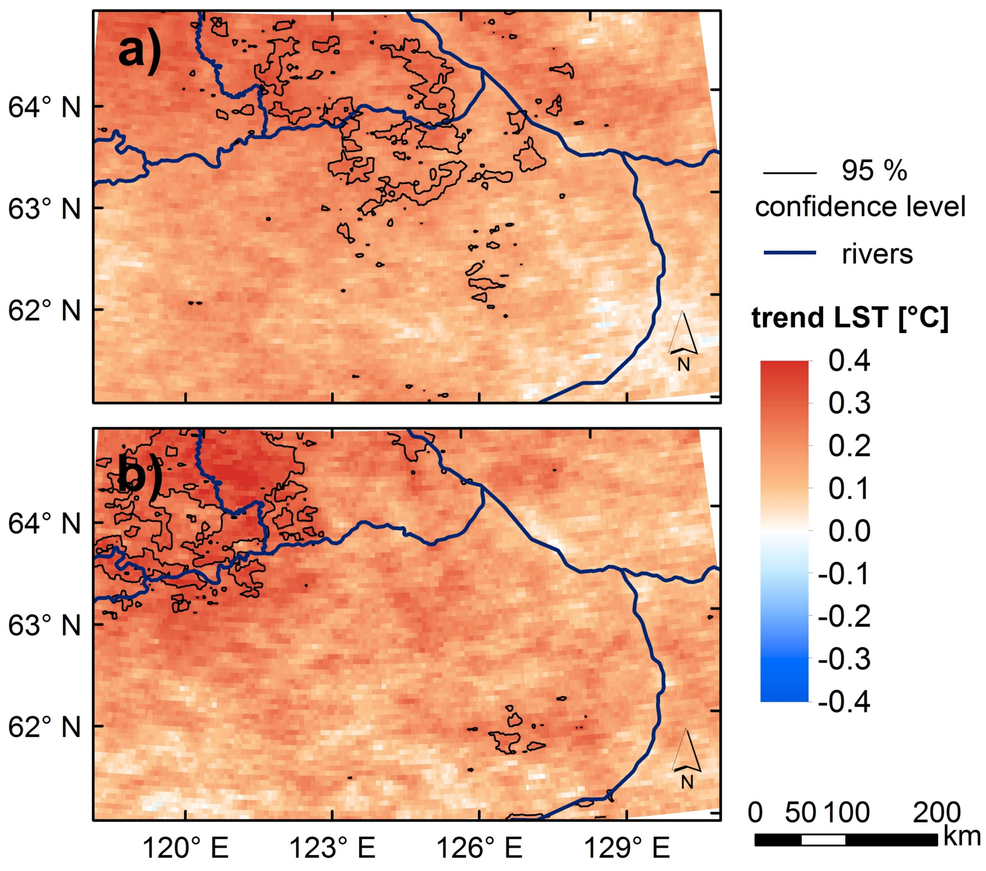
The study area (315,000 km^2) covers the main (central) part of the Lena River catchment in the Yakutia region of Siberia (Russia), extending from east of Yakutsk to the central Siberian Plateau, and from the southern Lena River to north of the Vilyui River. Approximately 90% of the area is underlain by continuous permafrost. The area has a high population density compared to other permafrost regions and can therefore be important for the study of rapid land surface changes and the resulting socio-economic effects. Landscape characteristics (Fedorov et al., 1989) and lakes (Landsat Mosaic, 2002, this study).

The area burned by fires between 2000 and 2011 amounted to 17% of the total study area. Large forest fires occurred to the west of the Lena River in 2002 producing the largest fire scars in the region. More recent forest fires also occurred, both to the west and to the east of the Lena River, including large fire events in 2006 and 2009 that produced large fire scars.

We identified areas in which lakes are growing and areas in which lakes are drying out, all located on continuous permafrost. Overall, the land surface became wetter between 2002 and 2009. Lakes increased by 17.9% between 2002 and 2009, but this increase varied in different parts of the study area, ranging between 11% and 42%.

forest fire- lake area





land surface temperature

Left: MODIS-derived bi-monthly trends in land surface temp. (2000 to 2011) for a) April and May, and b) September and October. Isolines represent the 95% confidence interval for rejection of the null-hypothesis.

Land surface temp. indicated intense surface warming trend. The average warming was 0.12 °C/year. The average rate of warming during the April–May transition period was 0.17 °C/year, and 0.19 °C/year in the September–October period, with maximum of up to 0.49 °C/year during September–October.

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Data (original data, digitized version of the maps, metadata) are archived under PANGAEA: http://dx.doi.org/10.1594/PANGAEA.855124
Fedorov, A.N., Botulu, T.A., Varlamov, S.P., 1989. Permafrost Landscapes of Yakutia (Explanation Note to the Geocryological Landscape Map of the Yakutian ASSR, Scale 1:2,500,000). GUGK, Novosibirsk (in Russian).
Karl, T.R., Arguez, A., Huang, B., Lawrimore, J.H., McMahon, J.R., Menne, M.J., Peterson, T.C., Vose, R.S., Zhang, H.-M., 2015. Possible artifacts of data biases in the recent global sur- face warming hiatus. *Science* (aaa5632).