



Long-term observations of remote-measured characteristics of Northern Europe ecosystem

Andrey Kiselev

St. Petersburg Scientific Research Center for Ecological Safety RAS

2020-06-17



Terra and Aqua satellites

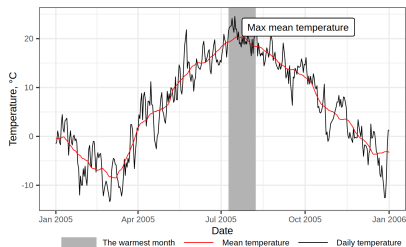
- **Instrument:** MODIS.
- **Scientific products:** MOD11A1 and MOD13A3 (MODIS/Terra), MYD11A1 (MODIS/Aqua).
- **Physical properties:** Land Surface Temperature (LST), Enhanced Vegetation Index (EVI).
- **Image geometry:** 1 kilometer spatial resolution in a 1200x1200 km grid.
- **Temporal coverage:** Since the 2000-02-24 for MODIS/Terra and 2002-07-04 for MODIS/Aqua.

GRACE satellite system

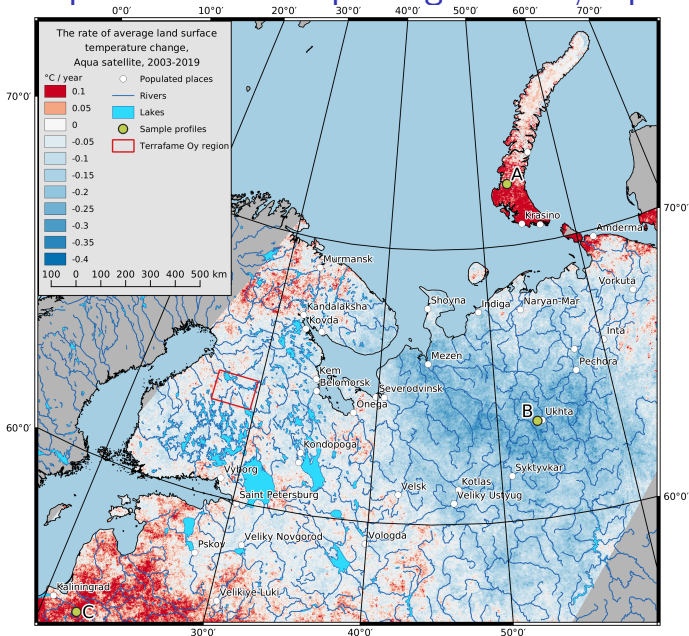
- **Physical property:** Liquid water Equivalent Thickness (LWT).
- **Image geometry:** 100 kilometers spatial resolution.
- **Temporal coverage:** 2002–2017.

Steps to build a temperature rate map:

- 1 Create an array of daily LST images for time frames 2000–2019 (Terra) and 2003–2019 (Aqua).
- 2 For each pixel find the “warmest month” (the warmest continuous 31-day period) in every year and compute a mean temperature over this period.
- 3 For each pixel build a time series from the “warmest month” values corresponding to the every year.
- 4 Compute a linear regression in order to find how those mean temperatures change over years.
- 5 The slope of the regression line (i.e. a rate of temperature change) is put on the final map.



Temperature rate map using MODIS/Aqua data

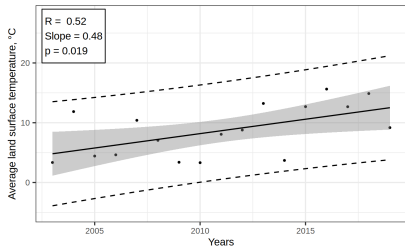




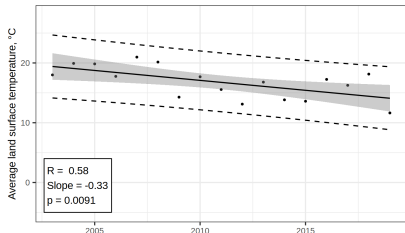
Sample profiles

A, Novaya Zemlia, increasing

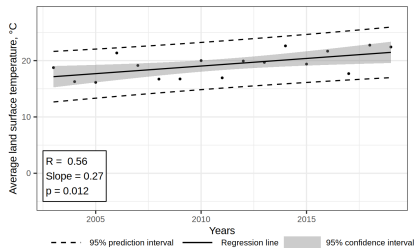
$\approx 0.5^\circ\text{C}/\text{year}$



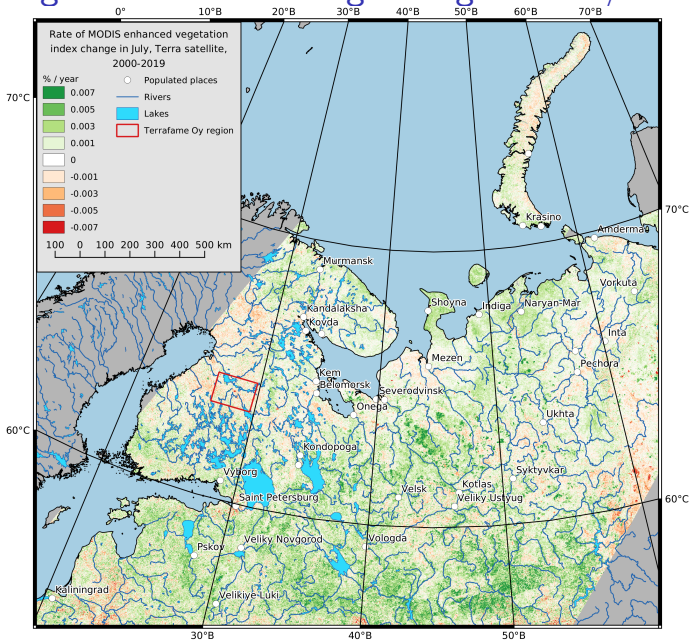
B, Ukhta, Komi Republic, decreasing $\approx 0.3^\circ\text{C}/\text{year}$



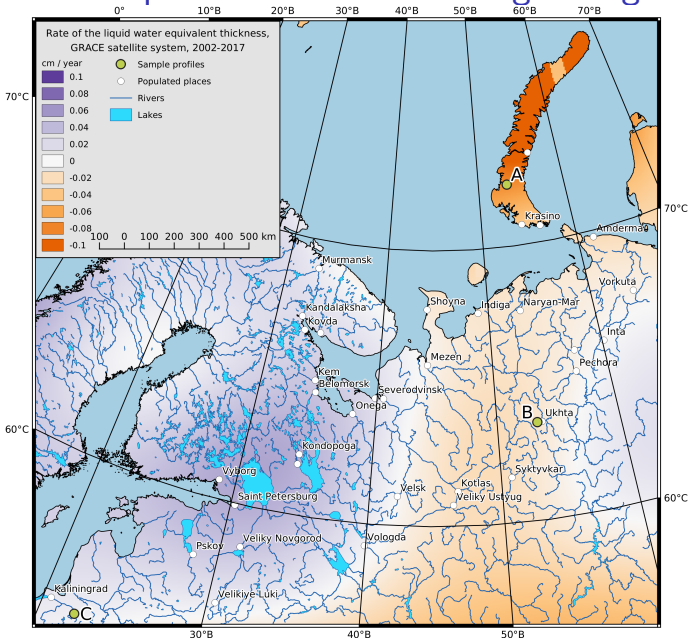
C, Baltic Region, increasing $\approx 0.3^\circ\text{C}/\text{year}$



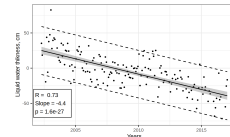
Vegetation index change using MODIS/Terra data



Water equivalent thickness change using GRACE data



A, Novaya Zemlia

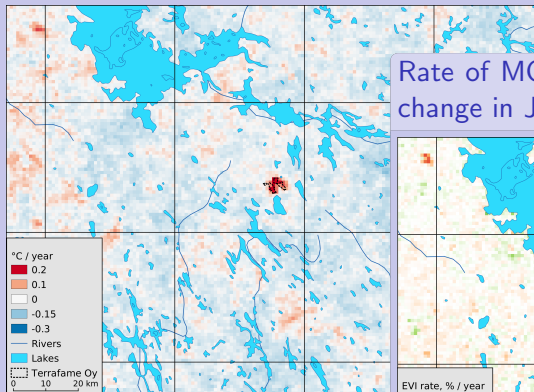


LWT decreasing with a rate of 4.4 cm per year. The permanent decrease of gravity field values in Arctic region may indicate a melting of the ice shield and permafrost degradation.

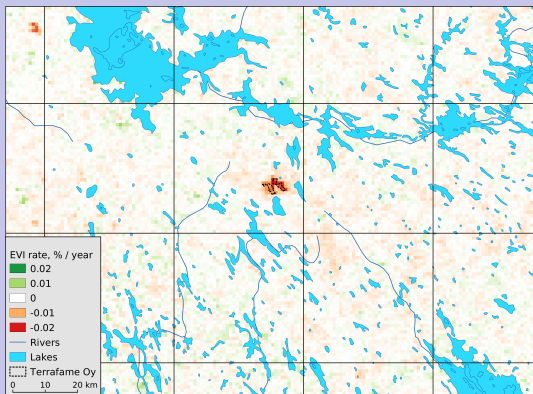
Thermal response of the mineral exploration facility



Rate of average land surface temperature change, Aqua satellite, 2003-2019



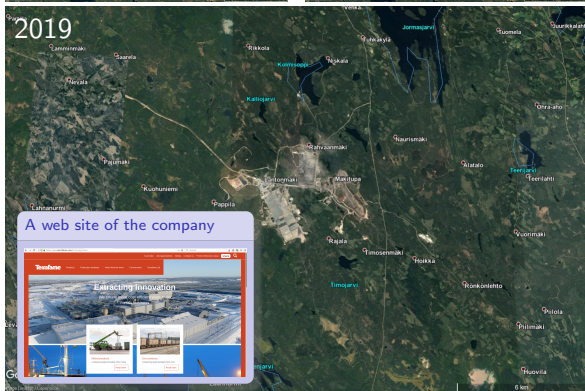
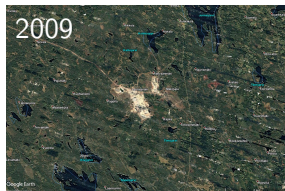
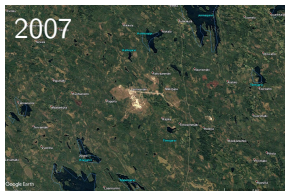
Rate of MODIS enhanced vegetation index change in July, Terra satellite, 2000-2019



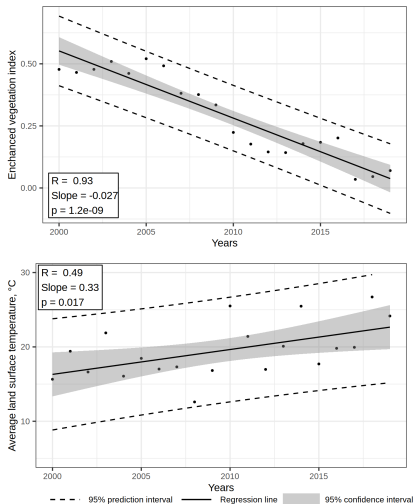
Thermal response of the mineral exploration facility



The development started around the year 2006 (Google Earth images)



Thermal response of the mineral exploration facility



The land-use pattern was changed dramatically and it results in thermal response that is easily detected. The estimated LST grow is $\approx 0.3^{\circ}\text{C}/\text{year}$.



- LST data obtained in the course of recent 17 years doesn't show a general increase of temperature in every ecosystems of Northern Europe. Some regions shows decreasing temperatures.
- Arctic regions are heating significantly, notable Novaia Zemlia Archipelago. Could be related to the ice shield melting and permafrost degradation.
- The impact of the human activity is perfectly visible in the forest ecosystems and results in substantial changes of thermodynamic properties.