Remote sensing for monitoring forests in northern Russia, results and current challenges

Selected outcomes of the research project on ***Multiplatform remote sensing of the impact of climate change on northern forests of Russia***

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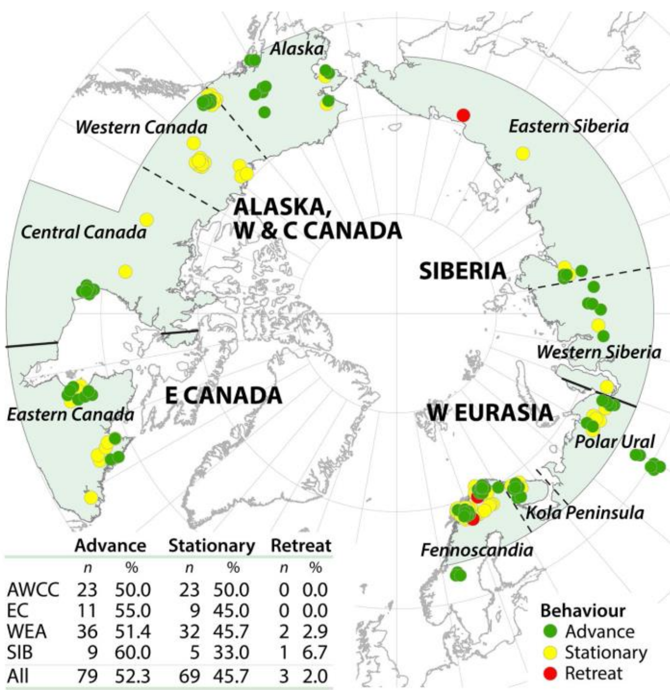
Background

Numerous studies point to forest and shrub tundra advance, and to the *Arctic amplification*—a more intense warming in the Arctic than over the rest of the globe

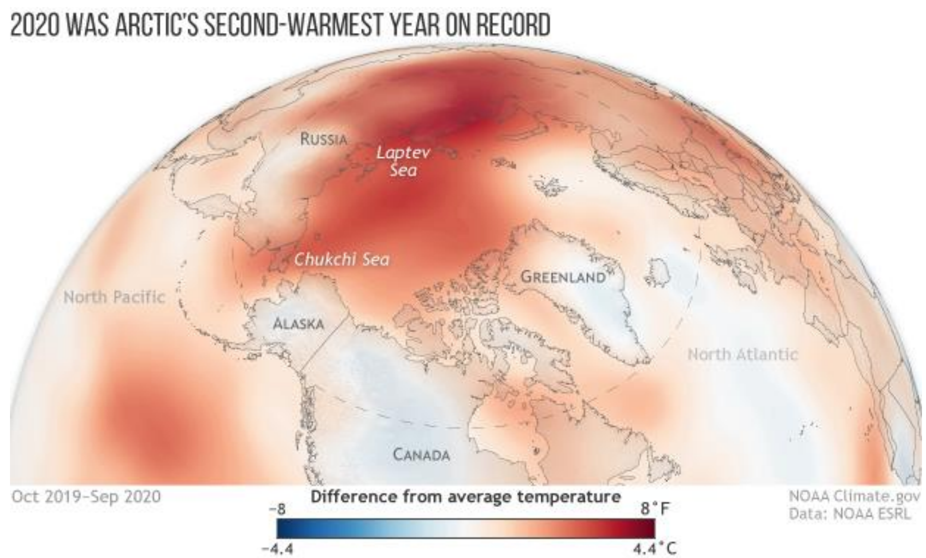
Since 2000, Terra/Aqua MODIS provides near-daily (weekly if account for clouds) imagery at 250 m resolution to monitor Arctic and subarctic vegetation, a high quality dataset to analyse phenological changes. **But** MODIS maps should be adapted for high latitudes

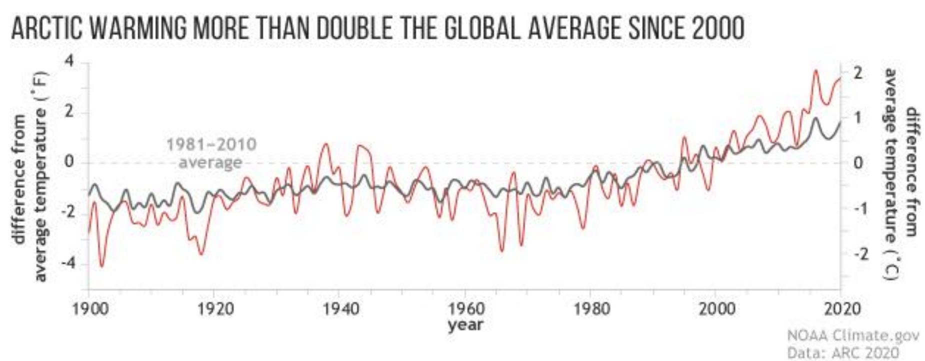
Multi-scale validation methods need to be developed for MODIS-derived maps (field-high-resolution images-MODIS images)



	Advance		Stationary		Retreat	
	n	%	n	%	n	%
AWCC	23	50.0	23	50.0	0	0.0
EC	11	55.0	9	45.0	0	0.0
WEA	36	51.4	32	45.7	2	2.9
SIB	9	60.0	5	33.0	1	6.7
All	79	52.3	69	45.7	3	2.0

Behaviour of the circumarctic forest-tundra Ecotone in 19th- early 21st century. *Rees, Hofgaard et al., 2020.* Is subarctic forest advance able to keep pace with climate change? *Global Change Biology*





Project goal:

to develop a methodology for assessing the dynamics of phytomass of northern forests of Russia since 2000 due to climate change, to provide such an assessment with validation at key sites, based on processing of multiplatform satellite and aerial imagery, ground surveys

The multiscale concept

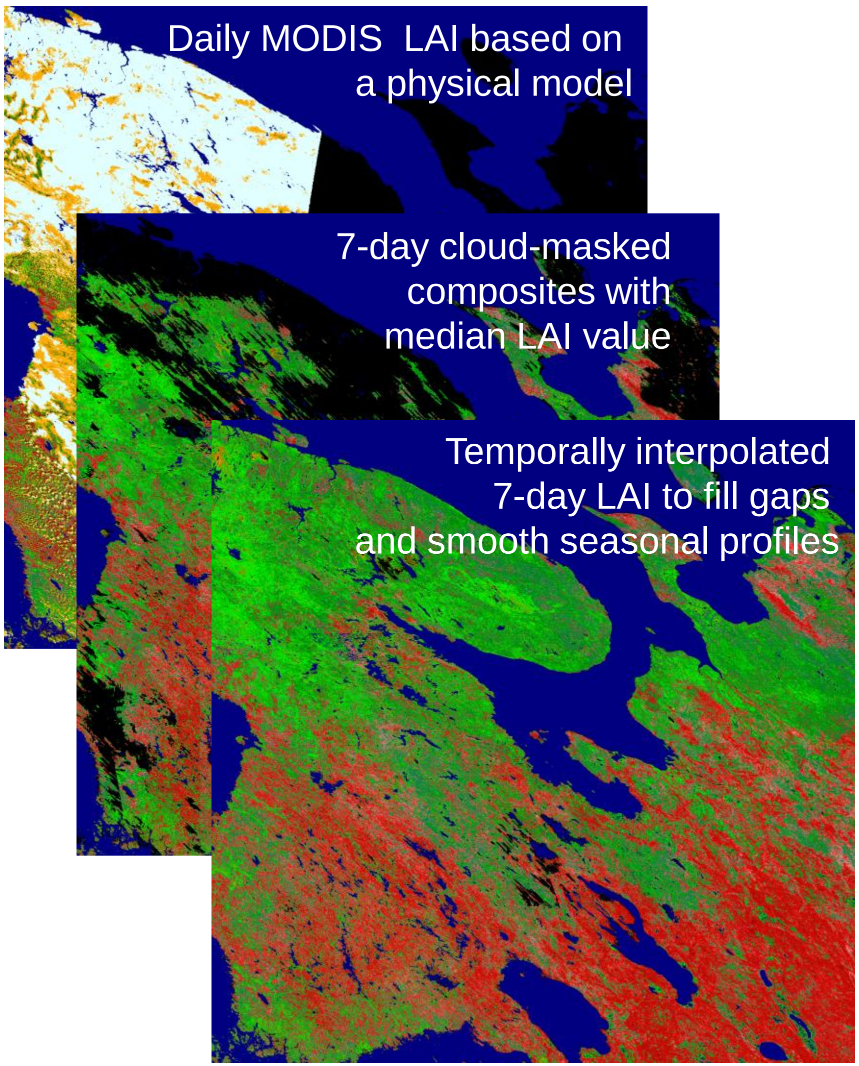
Analysis of MODIS LAI (Leaf Area Index), GSV (Growing Stock Volume) data series since 2000 г., comparison with climate dynamics for the whole of northern Russia. Determining the role of climate and other factors within model territories

Scaling up LAI and GSV data from the ground and UAV surveys to MODIS (through intermediate imagery from Sentinel 2 satellites), to validate MODIS maps

Assessing tree stand parameters (including LAI, GSV) within model territories using unmanned aerial vehicle (UAV) survey (from 50 and 100 m), field measurements and descriptions

Datasets and methods

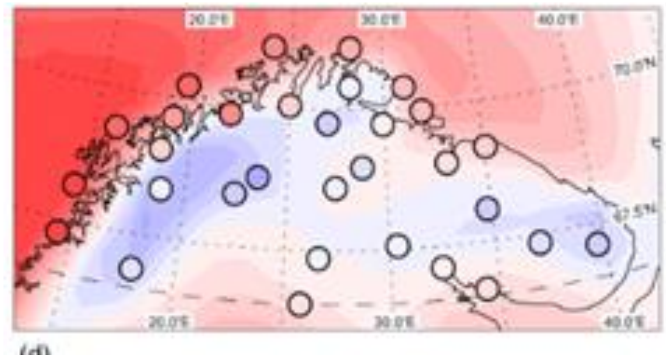
Leaf area index (LAI)=
one-sided green leaf area
per unit surface area



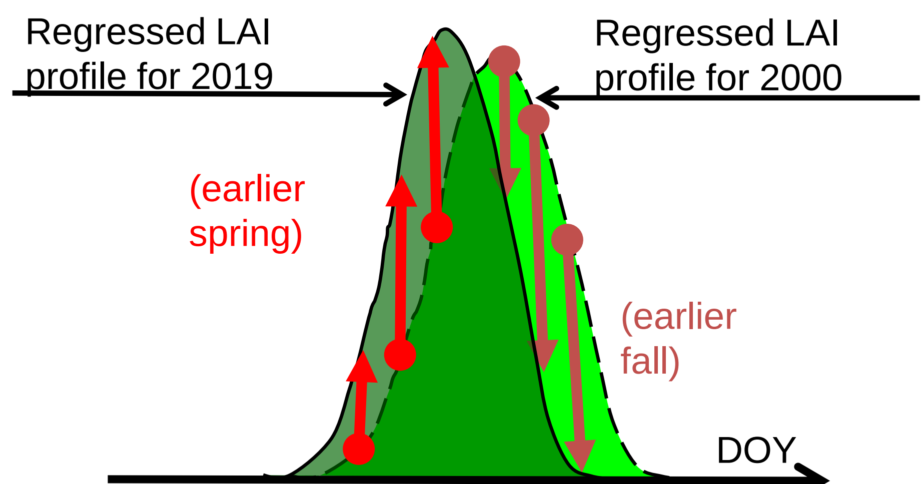
Temperature dataset: ERA Interim reanalysis

selected by comparing vs. station data.
Less noisy than ERA5

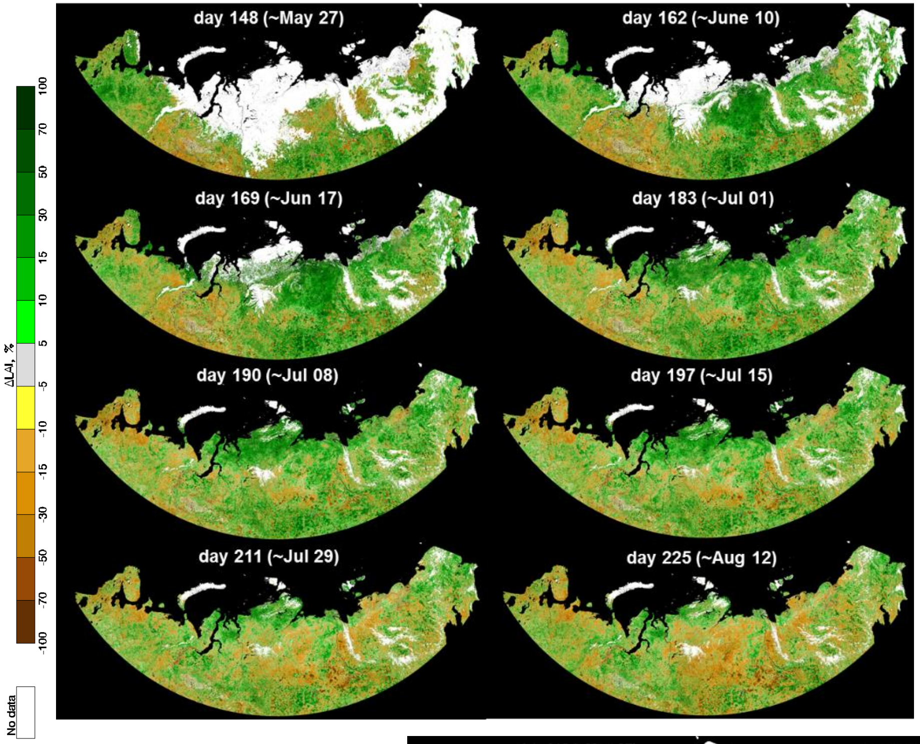
Cumulative sums SAT_{Σ} of t > 5 C

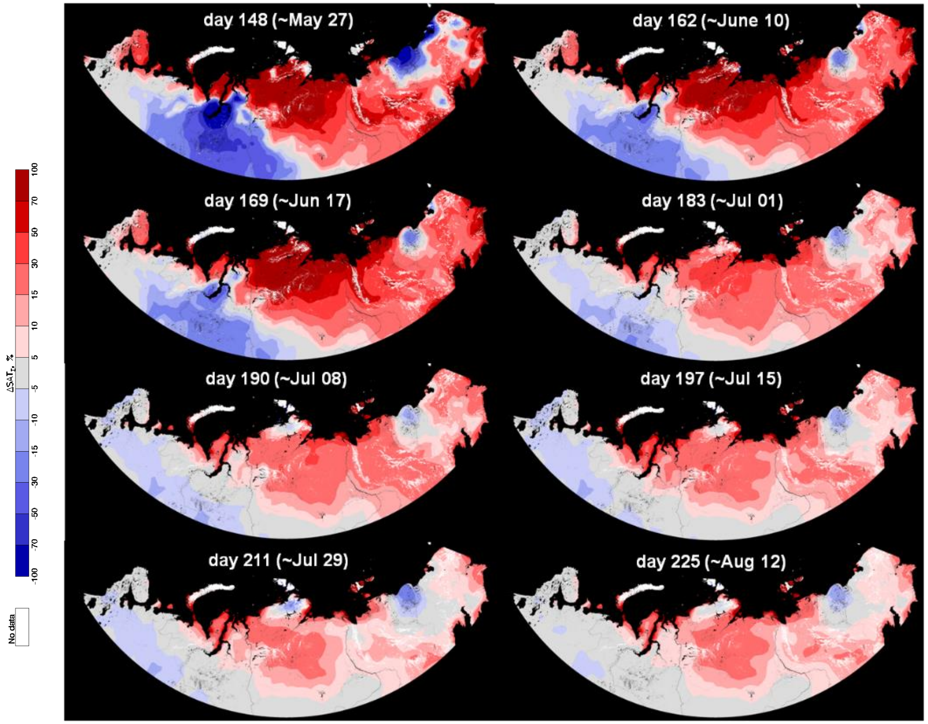


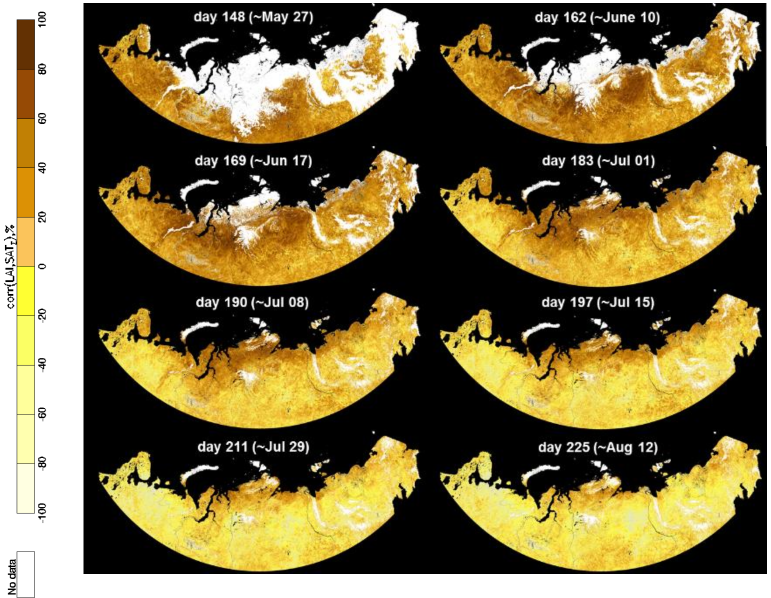
LAI dynamics: regression of whole seasonal profiles



Seasonal trends for 8 dates, ΔLAI, Δ(SAT_{Σ}) in 2000-2019



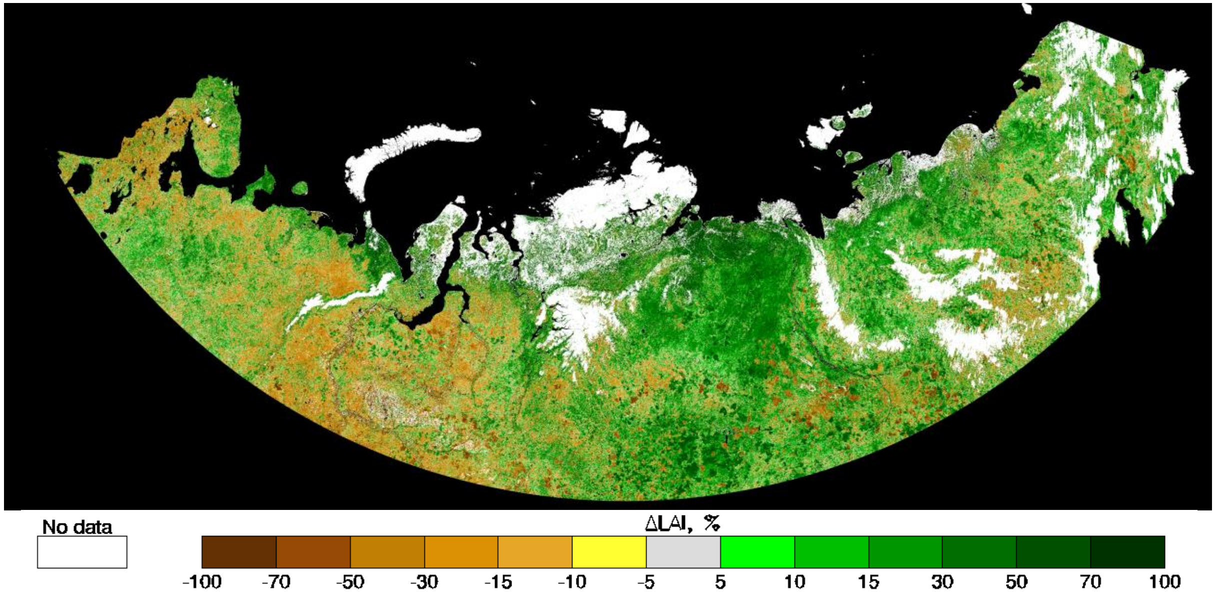




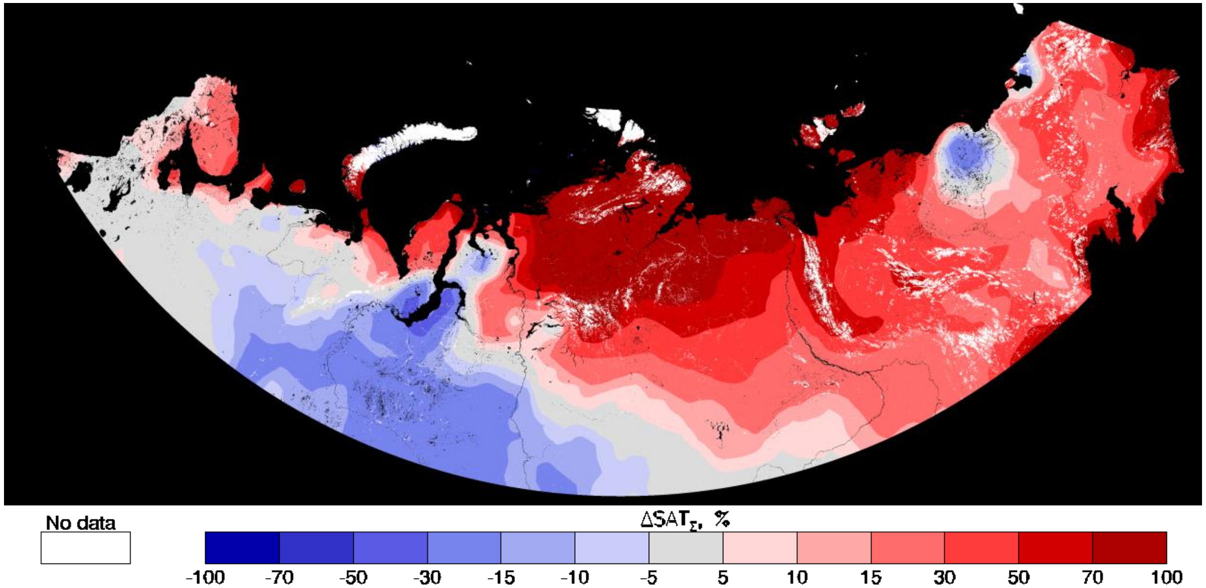
Seasonal trends for 8 dates, correlation (Δ LAI, Δ SAT_{Σ})

MODIS LAI trends and cumulative temperature SAT_{Σ} for 17 June, 2000- 2019

LAI trends were assessed throughout all seasonal profile with a 7-day interval. A linear regression was performed for each interval for the 20 years of MODIS observations (2000-2019). Results are shown as relative change in LAI (ΔLAI, %).

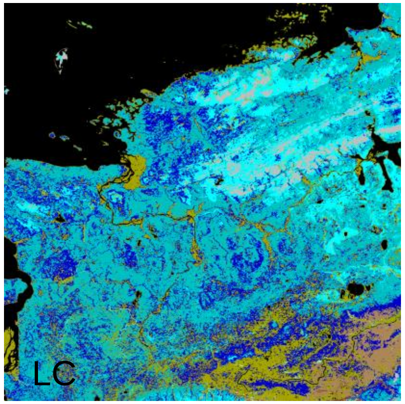


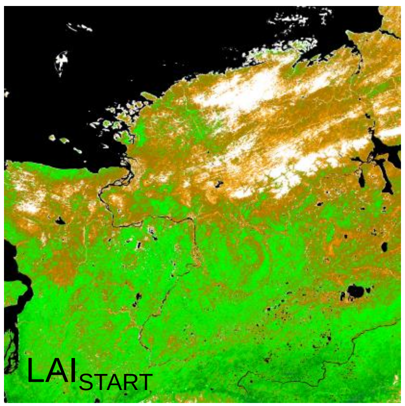
Cumulative temperature is calculated since 1 March and only for average day temperatures above +5C. Then linear trends ΔSAT_{Σ} are calculated. Time intervals correspond to the LAI product. ERA Interim dataset.

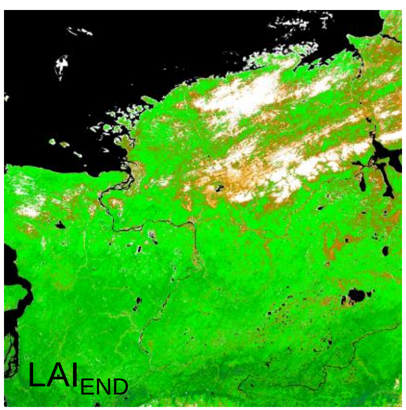


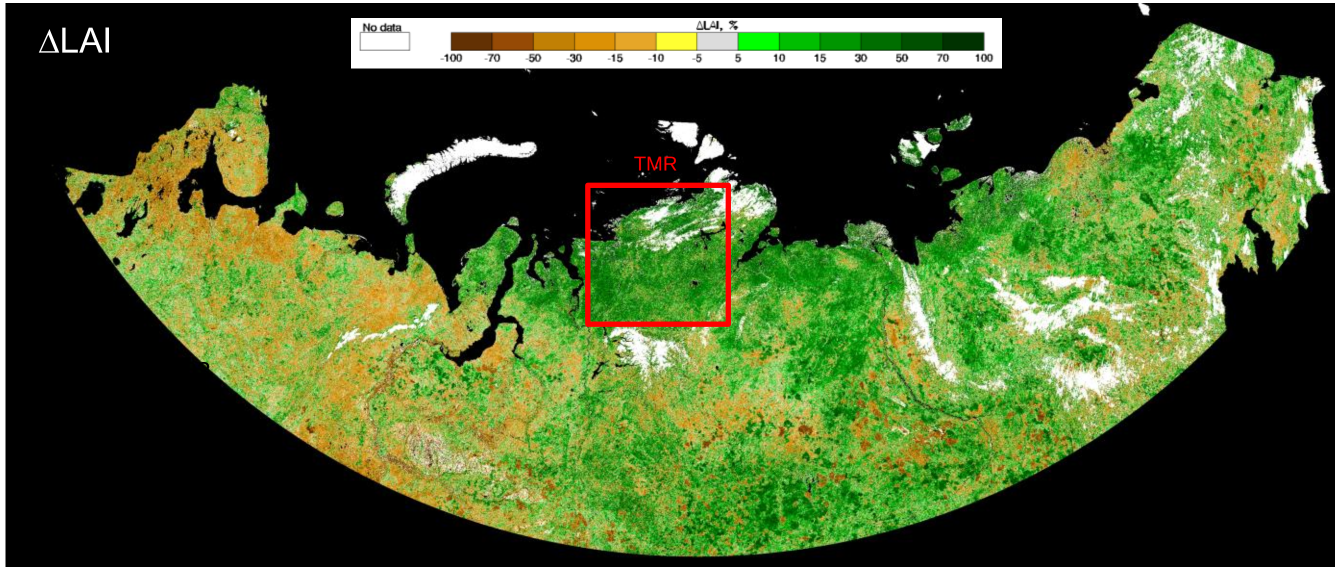
In spring the green leaf biomass is conditioned by cumulative temperature. The same is true for trends. Therefore the spatial distribution of LAI trends is very well explained by the SAT trends.

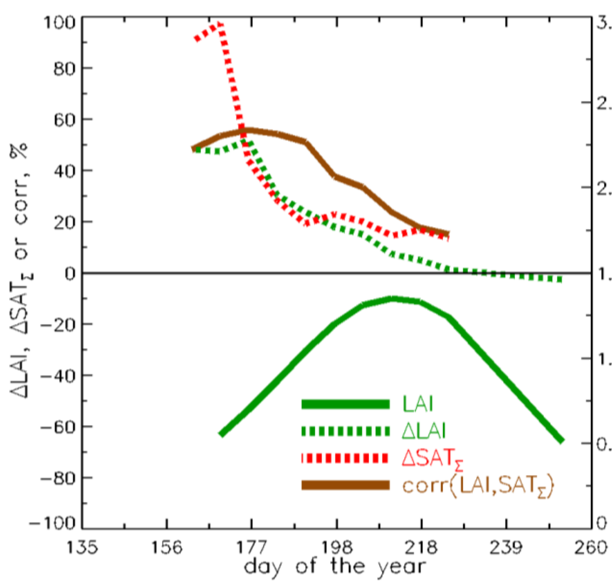
LAI & SAT_Σ, Taimyr peninsula, 01 July

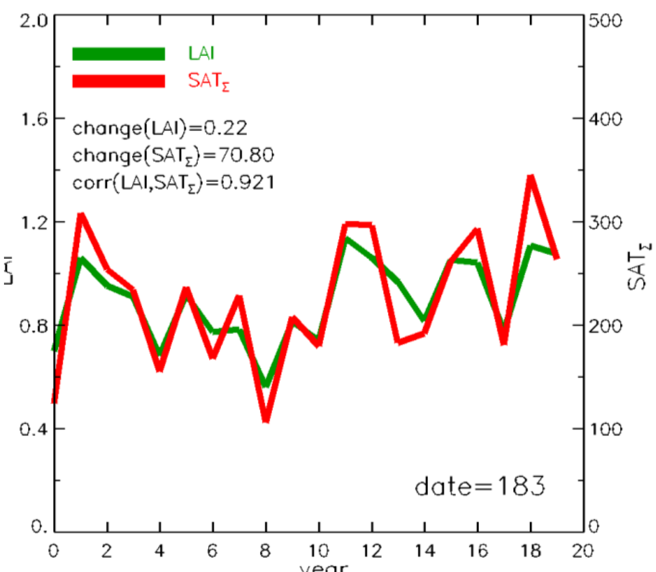


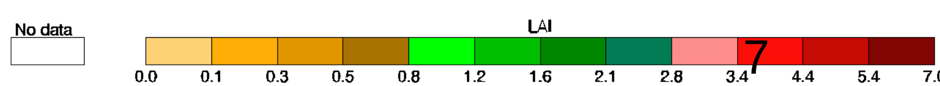




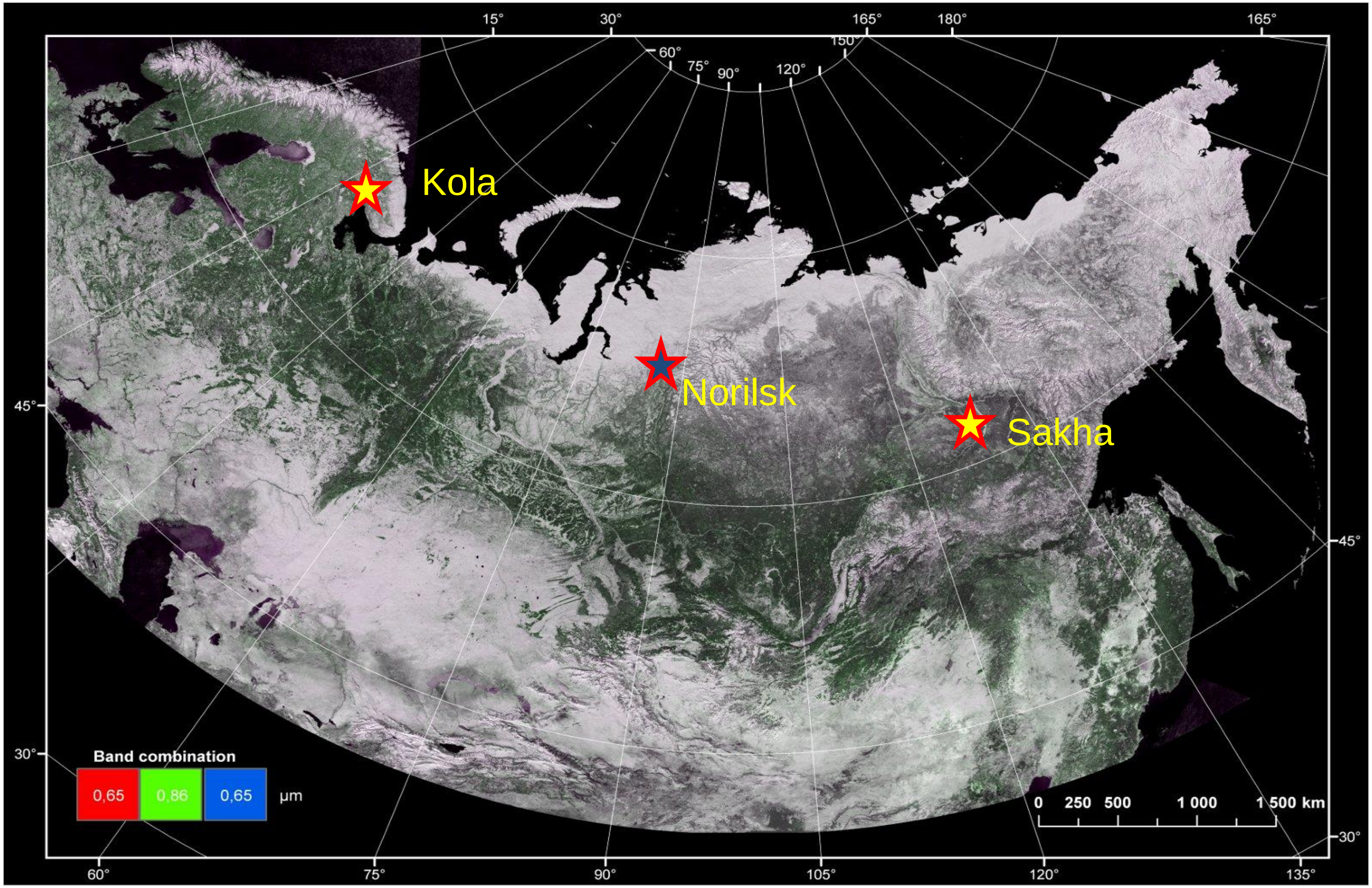






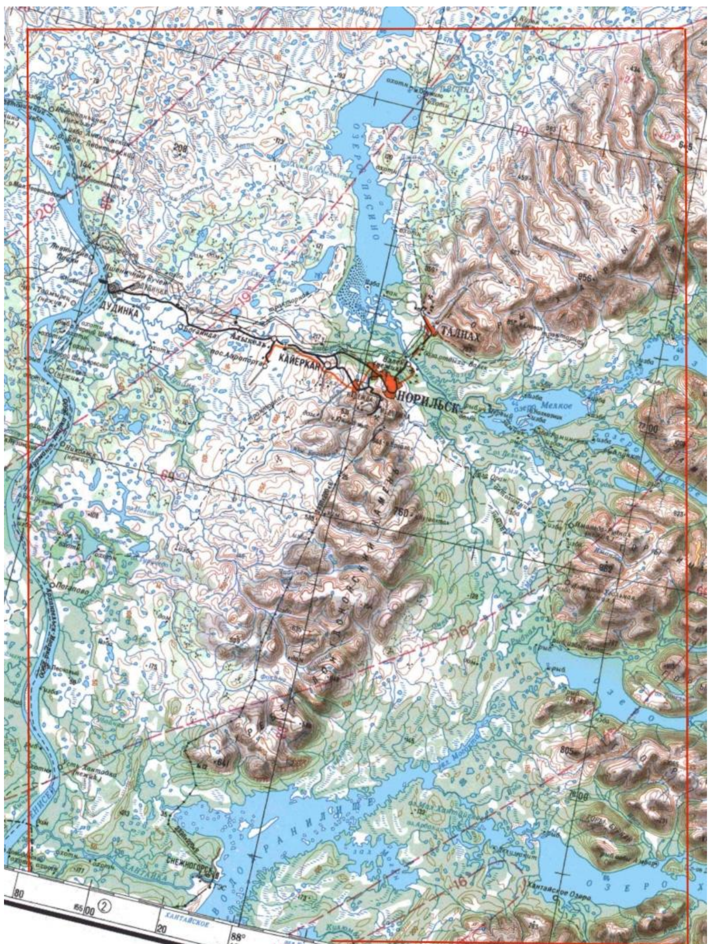


Key field regions



Noril'sk key region, area of large-scale industrial degradation since 1960s

Image courtesy: A.Tyagny-Ryadno



Maximum degradation is recorded in the Rybnaya River valley (SE from the metallurgical plants):

death of larch forests, degrading lichen cover in boggy areas, expansion of grasses and sedges

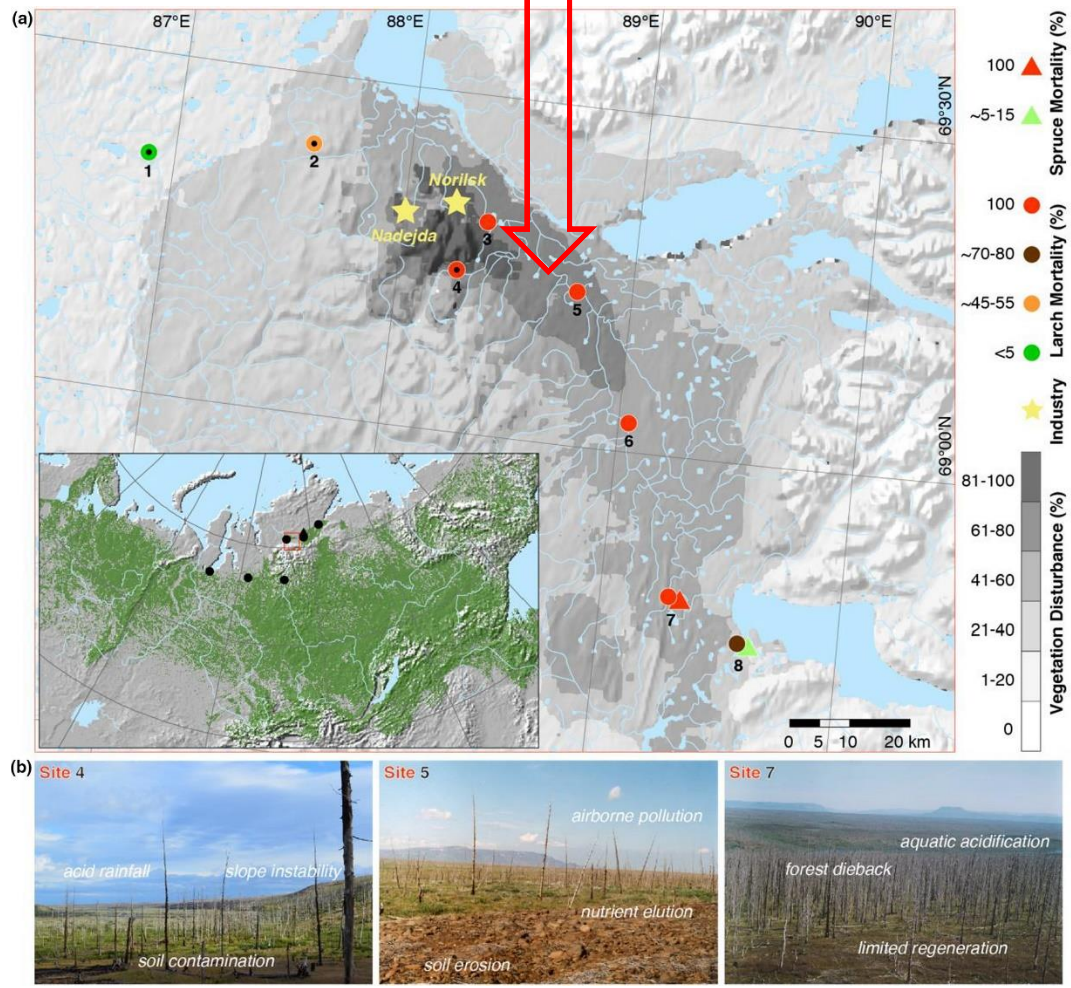
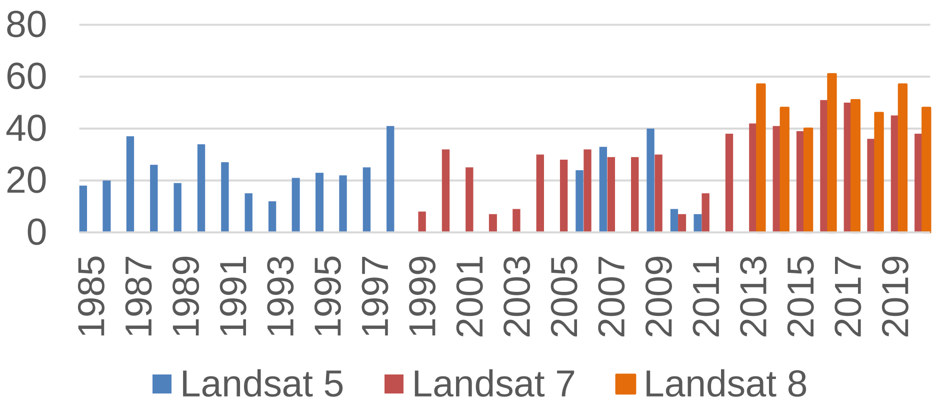


Figure from Kirdyanov et al., 2020

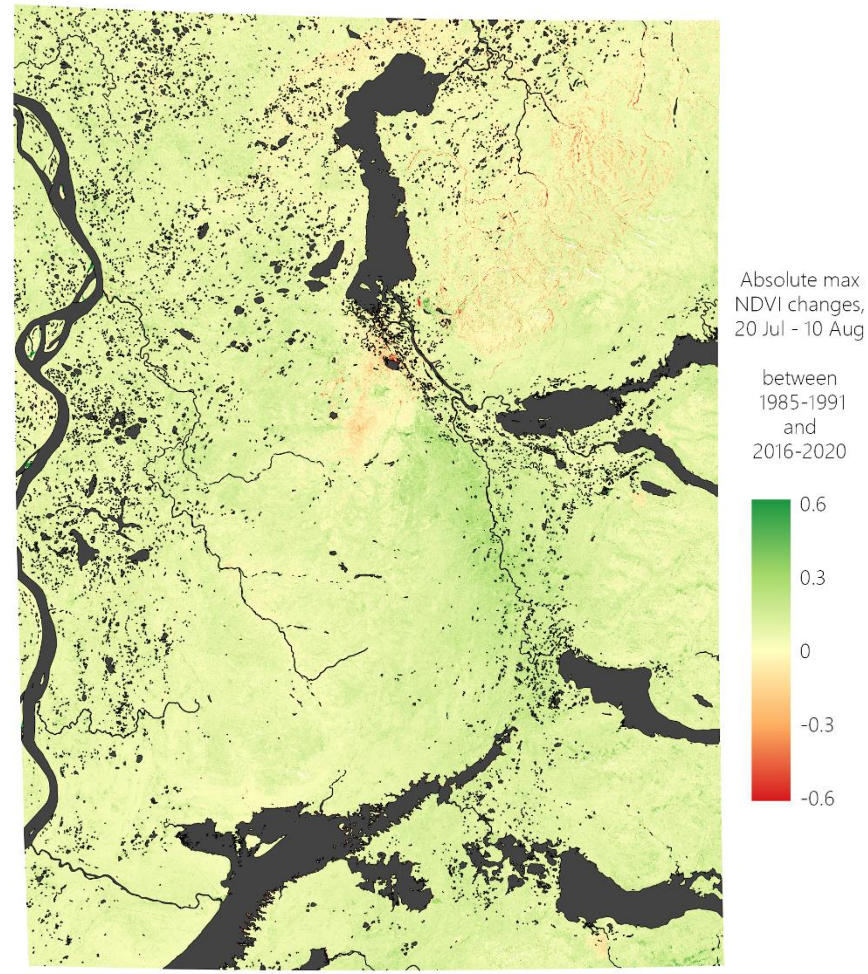
Changes of Normalised Difference Vegetation Index (NDVI) for Noril’sk in 1985-2019, imagery from Landsat satellites, Google Earth Engine

- Imagery screened for cloud cover
- Computed maximum NDVI for summer period (July 1st – August 10th) for each year from Landsat 5-8 Surface Reflectance;
- max NDVI changes show overall increase, small areas of decrease, in the mountains and industrial built-up areas.
- How to determine statistically significant change?

-> analysis of the whole dataset: statistical testing of every pixel.



Availability of Landsat imagery for the AOI 1985-2019



Mann-Kendall Trend Analysis

$$\tau = \frac{(\text{number of concordant pairs}) - (\text{number of discordant pairs})}{\binom{n}{2}}.$$

Normalised difference between the numbers of each of following cases:

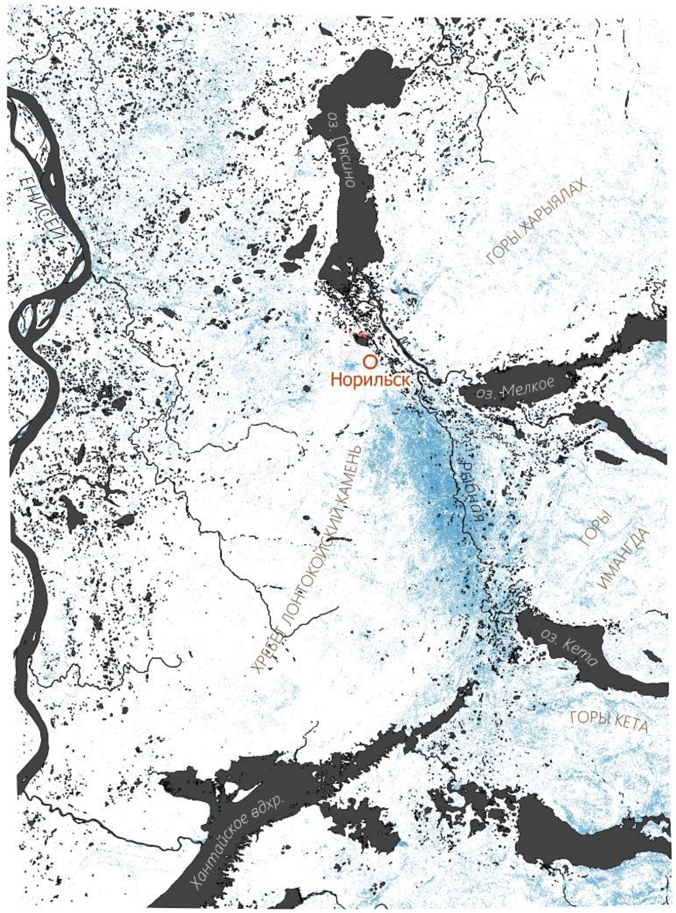
$Y_{x+1} > Y_x$

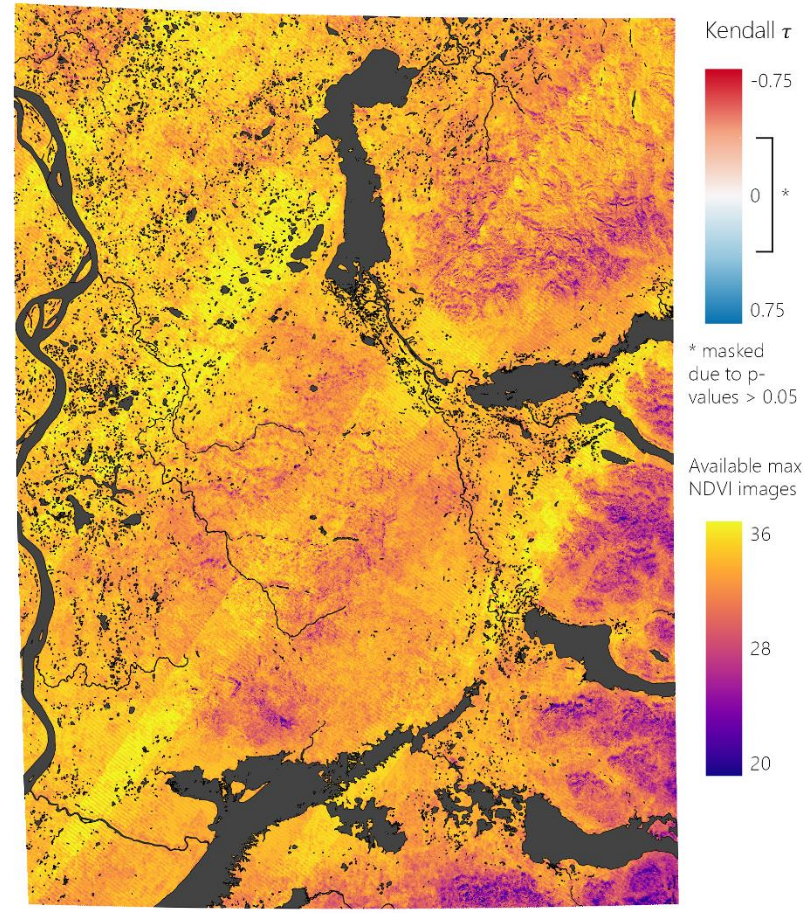
and

$Y_{x+1} < Y_x$

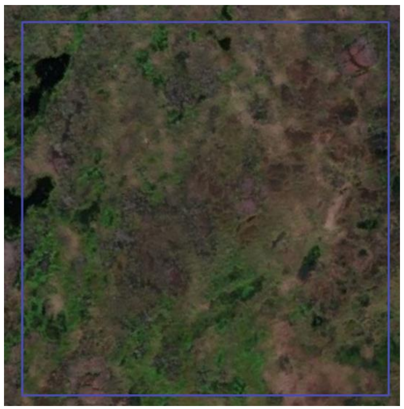
Where Y is max NDVI each year

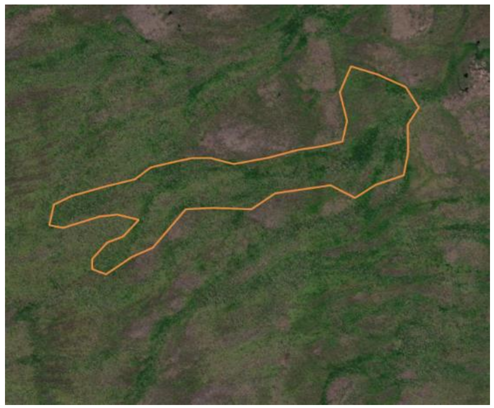
** Area showing significant trends has enough observations*

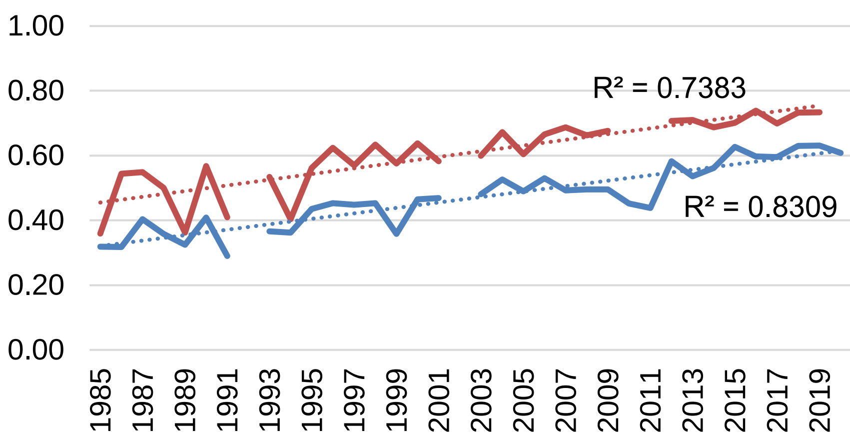




The greatest NDVI growth: small valleys



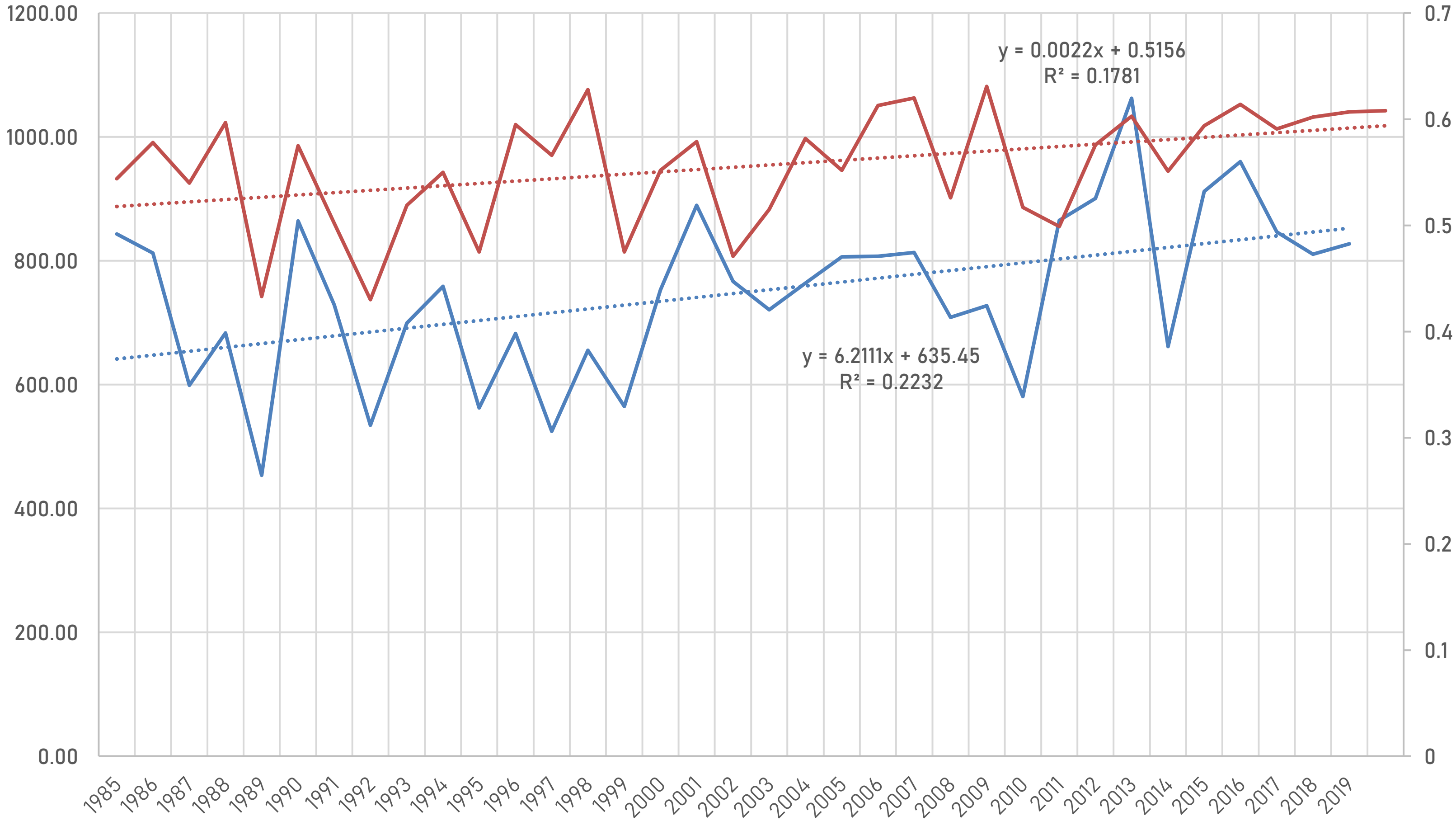




Pollution-resisitant grasses (Equisetum sp., Graminea grasses) and shrubs (willow, alder) are present and regenerating.

However, regeneration of larch trees is only happening in some areas further away from the pollution source (field data of 2021).

Comparison of SAT_{Σ} and max NDVI trends



Cumulative summer temperatures above +5°C between May 1st – August 10th 1985 – 2019 within 68-70°N and 85-90°N based on ERA-Interim reanalysis data (blue line, left axis) and maximum NDVI averaged over the key region (red line, right axis).

Future work and challenges

- Case-study time series for other key regions (Sakha, Kola)
- Analysis of exceptional forest fire activity and recent climate in Sakha
- National-scale analysis of precipitation (snow and rain) trends vs. forest biomass trends. Presumably trends and correlations less evident than for temperatures, area-by-area analyses may be required

THANK YOU FOR YOUR ATTENTION!

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