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Environment Agency:

"Evaluation of heat islands in Estonian cities 2014-2019“

"Soojussaarte hindamine Eesti linnades 2014-2019“

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presenter: Olev Märtens, *IEEE senior member IMS, SPS,GRSS*

12.11.2020 presentation to remote sensing community

19.08.2021 presentation to IEEE Estonian section,

There are some links to the work, e.g.:

https://www.ilmateenistus.ee/kliima/soojussaared/

https://geoportaal.maaamet.ee/est/Kaardirakendused/Soojussaared/Soojussaarte-kaardirakenduse-kirjeldus-p724.html

Olev Märtens, *IEEE senior member IMS, SPS,GRSS*

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http://ieee-ims.org/

https://signalprocessingsociety.org/

http://www.grss-ieee.org/

Geoscience & Remote Sensing Society

(About) Me: Short Bio *(as at www.olev.eu/olev1)*

Olev Märtens has born in Tallinn, Estonia, 1960. He has an engineering diploma of **electronics** (CUM LAUDE) from 1983, PhD from 2000, both degrees from Tallinn University of Technology (TTU). He has experience in the R&D of electronics: engineering of precise AC instrumentation (1980-s) at the **Design Office of the Tallinn Radio Factory RET**, in SMEs (1990-s) and from 2000 being senior- and lead researcher and now as *professor (*of measurement electronics*) at Thomas Johann Seebeck Department of Electronics, TTU. He has participated in several EU and national projects. He is author on tens of technical papers and inventions and practical solutions of wide range of electronics (fields of signal and image processing, test&measurement (T&M) & instrumentation). One interest is **R&D of impedance** based solutions and applications. He is a member of the IEEE 20+ years. He has participated in the Texas Instrument's European University Program from 1990-s, promoting the **DSP-based technologies for T&M.**

Workshop of the remote sensing, **5.12.2014,** (Talllinn, Mektory, Anu Reinart, Mait Lang, *Seminar "Muutuste tuvastamine satelliidipiltidelt")*

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***(About)* Estonian Environment Agency:** https://www.keskkonnaagentuur.ee/en :

*The Estonian Environment Agency is a state authority administered by the **Ministry of the Environment** that was created on 1 June 2013 as a result of the reorganisation of the Estonian Environment Information Centre (EEIC) and the Estonian Meteorological and Hydrological Institute (EMHI).*

*The Estonian Environment Agency's field of activity is the fulfilment of the national environmental monitoring programme, the preparation of national and international reports in the field of environment, **evaluating environmental status,** ensuring vital services, including weather forecasts, and the maintenance and renewal of **monitoring stations** and equipment.*

Task of the done work:

- Downloading Landsat-8 satellite images from the heat wave period from the archive and ground temperature (LST) product making / processing;

  USGS, "Landsat-8." https://www.usgs.gov/

- analysis for larger cities (**Tallinn, Tartu, Pärnu, Narva, Kohtla-Järve, Viljandi, Rakvere**) - **assessment** (calculation) and (re-)**mapping** of the extent of heat islands in densely populated nearby areas;

Põhimõisted / ***Main Terms [UHI, heat-wave -2 levels of danger, LST,]***

• Urban Heat Island (UHI) urban places, where the temperatuure is **significantly** above the surrounding;

• Landsat-8 : U.S. Geological Survey with NASA- satellite for ground observation, launched 11.-th February 2013

Landsat 8 orbits the the Earth in a sun-synchronous, near-polar orbit, at an altitude of ***705 km*** *(438 mi), inclined at 98.2 degrees, and completes one Earth orbit every 99 minutes. The satellite has a* ***16-day repeat cycle*** *with an equatorial crossing time: 10:00 a.m. +/- 15 minutes.*

• Land Surface Temperature (LST) radiation (? or emissioon?) temperature of the surface; so not exactly air temperatuure, but still usable for assesment of UHI;

• Heatwave- nonusual increased temperatuure, at least for several days;

Estonian Environemnt Agency has criteria:

– dangerous level: for 3 days : > 27 °C peak value or mean(daily) > 20 °V;

– extremley dangerous level: for 3 days : > 30° C peak value or mean(daily) > 25 °V;

References (and previous work),

[1] G. Jovanovska Kaplan, U. Avdan, and Z. Yigit Avdan, “Urban heat island analysis using the Landsat 8 satellite data: A case study in Skopje, Macedonia,” 03 2018.

[2] V. Sagris and M. Sepp, “Landsat-8 TIRS data for assessing urban heat island effect and its impact on human health,” IEEE Geoscience and Remote Sensing Letters, vol. 14, pp. 2385–2389, Dec 2017.

[3] Keskkonnaagentuur, “Hoiatuste kriteeriumid.” http://www.ilmateenistus.ee/ilmatarkus/kasulik-teada/hoiatuste-kriteeriumid/, 2019. [Online]

[4] USGS, “Landsat-8.” https://www.usgs.gov/land-resources/nli/landsat/landsat-8?qt-science_support_page_related_con=0#qt-science_support_page_related_con, 2019. [Online].

[5] A.Roose et al, “Kliimamuutuste mõjude hindamine ja kohanemismeetmete väljatöötamine planeeringute, maakasutuse, inimtervise ja päästevõimekuse teemas (KATI). Lõpparuanne,” tech. rep., Tartu Ülikool, Keskkonnaministeerium, 2016.

From: ***V. Sagris and M. Sepp,*** *"Landsat-8 TIRS data for assessing urban heat island effect and its impact on human health," IEEE Geoscience and Remote Sensing Letters, vol. 14, pp. 2385–2389, Dec 2017.*

A number of algorithms have been designed by many researchers to calculate LST such as split-window (SW) algorithm,... The TIRS instrument of Landsat 8 collects two **thermal bands** **(10 and 11)** for the wavelength covered. by a single band on the previous TM and ETM+ sensors and therefore allows us to apply the SW algorithm [17]–[19].

Unfortunately**, since February 2014**, the Landsat team does not recommend to use the SW algorithm due to the larger **calibration uncertainty associated with band 11** [20].

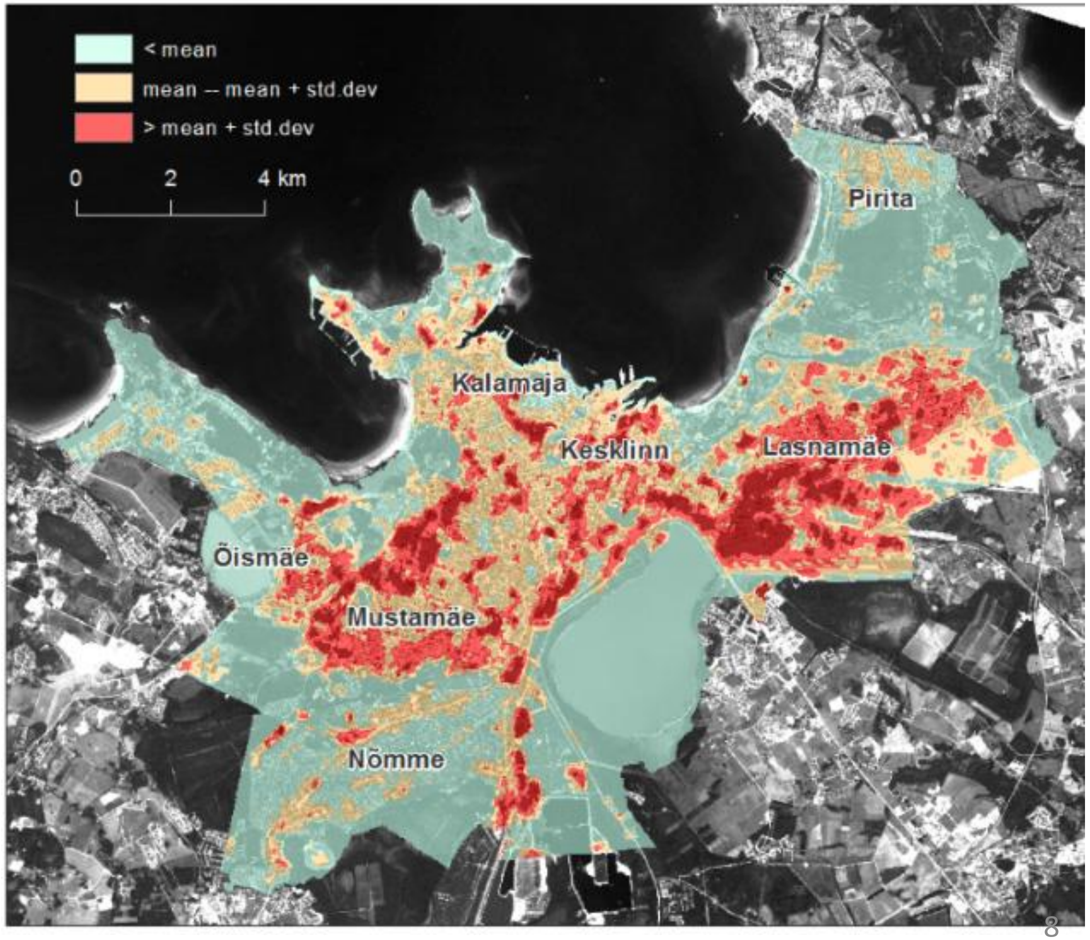
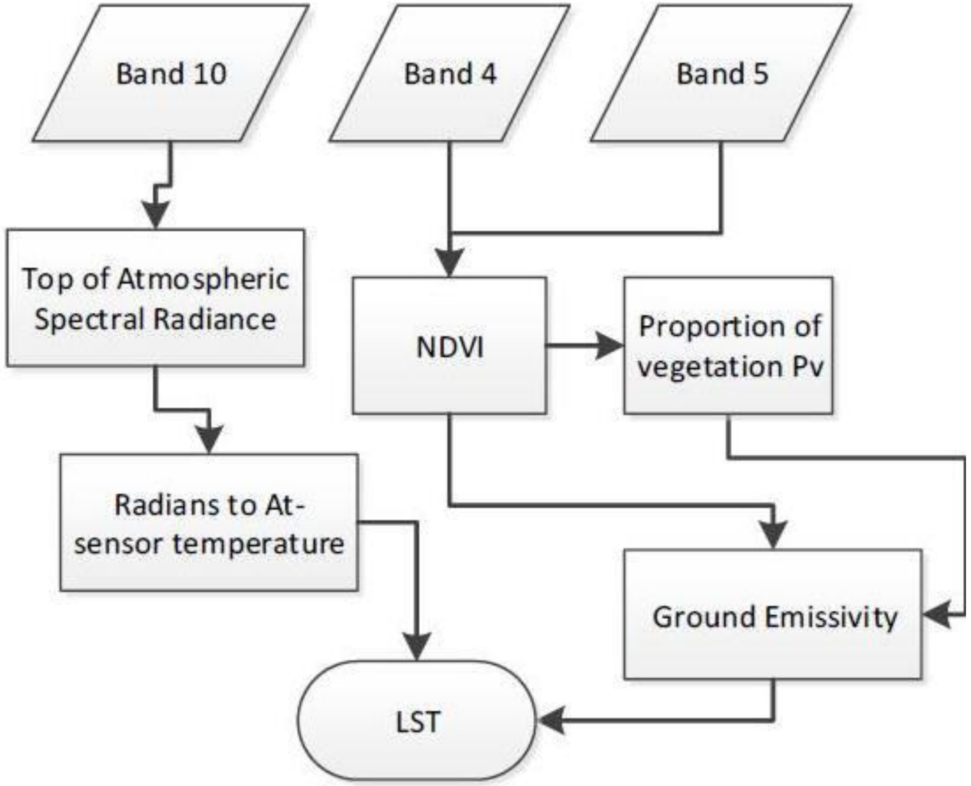


Fig. 4. SUHI in Tallinn, July 25, 2014. The green areas are outside the SUHI, the yellow areas are the areas over mean LST, and the red areas are "inside" the SUHI (over mean + std.dev). Dark red areas are the areas with the same surface temperature at July 9.



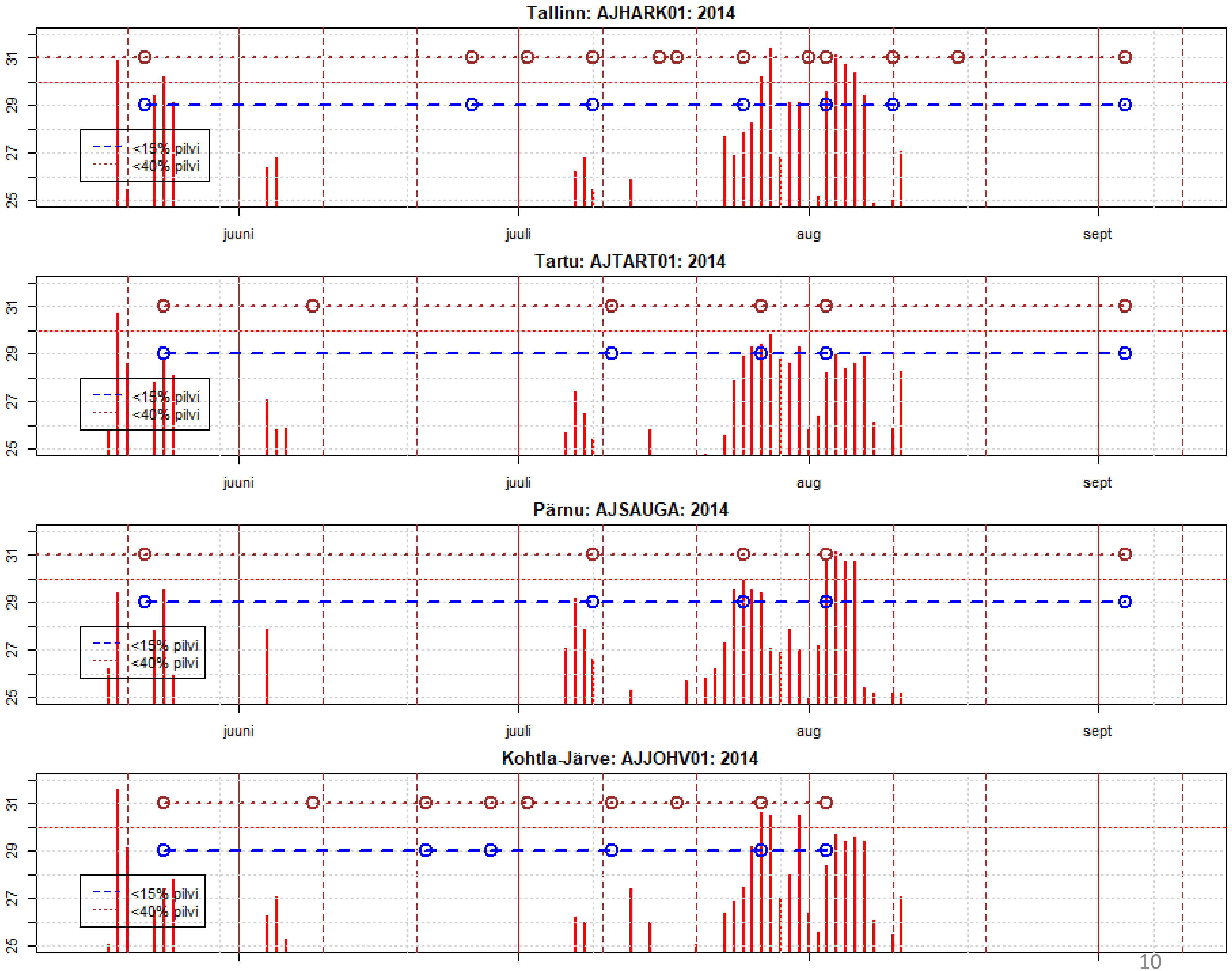
	Bands	Wavelength (micrometers)	Resolution (meters)
Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) **Launched February 11, 2013**	Band 1 - Coastal aerosol	0.43 - 0.45	30
	Band 2 - Blue	0.45 - 0.51	30
	Band 3 - Green	0.53 - 0.59	30
	Band 4 - Red	0.64 - 0.67	30
	Band 5 - Near Infrared (NIR)	0.85 - 0.88	30
	Band 6 - SWIR 1	1.57 - 1.65	30
	Band 7 - SWIR 2	2.11 - 2.29	30
	Band 8 - Panchromatic	0.50 - 0.68	15
	Band 9 - Cirrus	1.36 - 1.38	30
	Band 10 - Thermal Infrared (TIRS) 1	10.60 - 11.19	100
	Band 11 - Thermal Infrared (TIRS) 2	11.50 - 12.51	100

LST –calculation scheme:

[1] G. Jovanovska Kaplan, U. Avdan, and Z. Yigit Avdan, “Urban heat island analysis using the Landsat 8 satellite data: A case study in Skopje, Macedonia,” 03 2018.

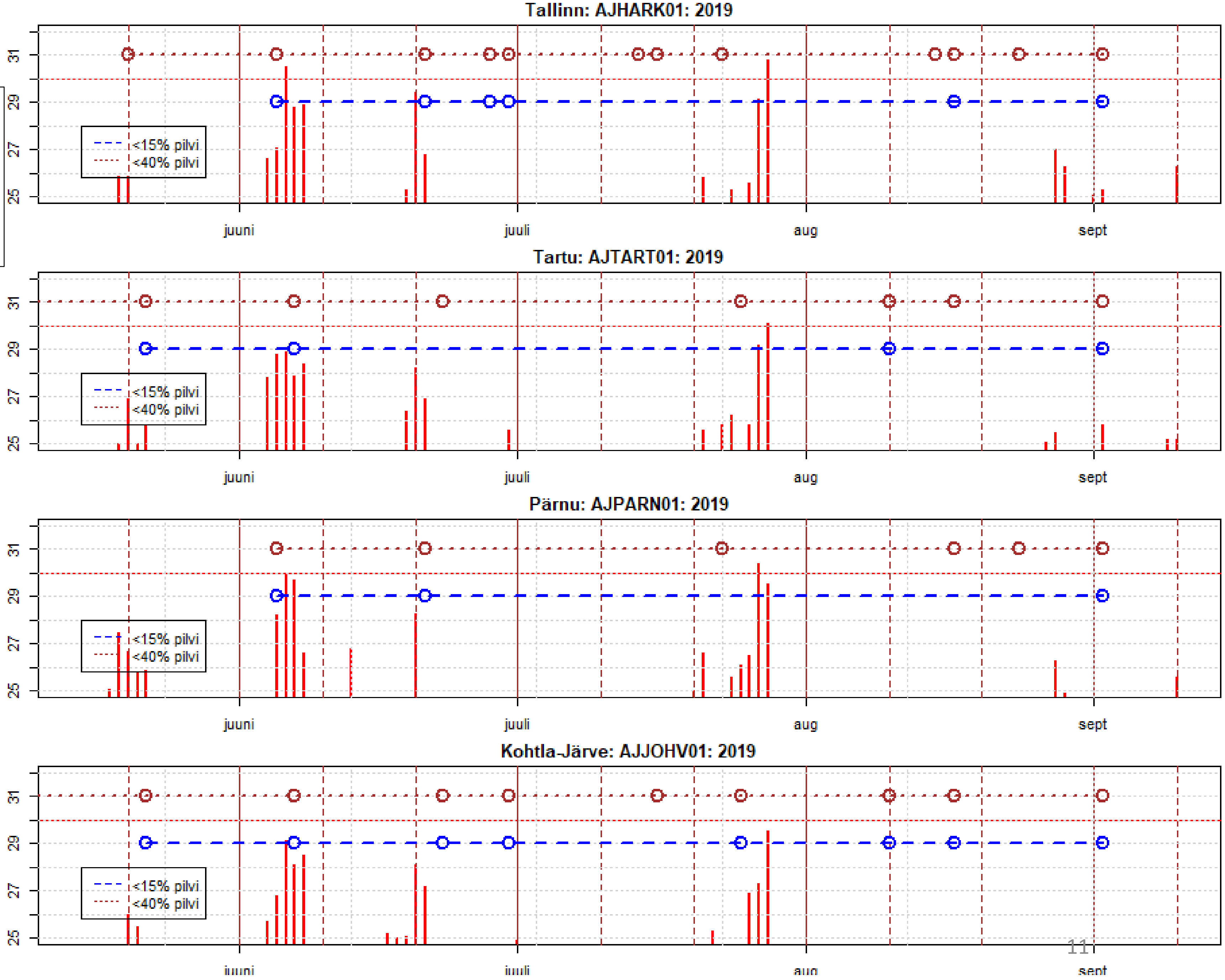
First selection of the time periods and images-sets: *Air temperature vs availability of images*

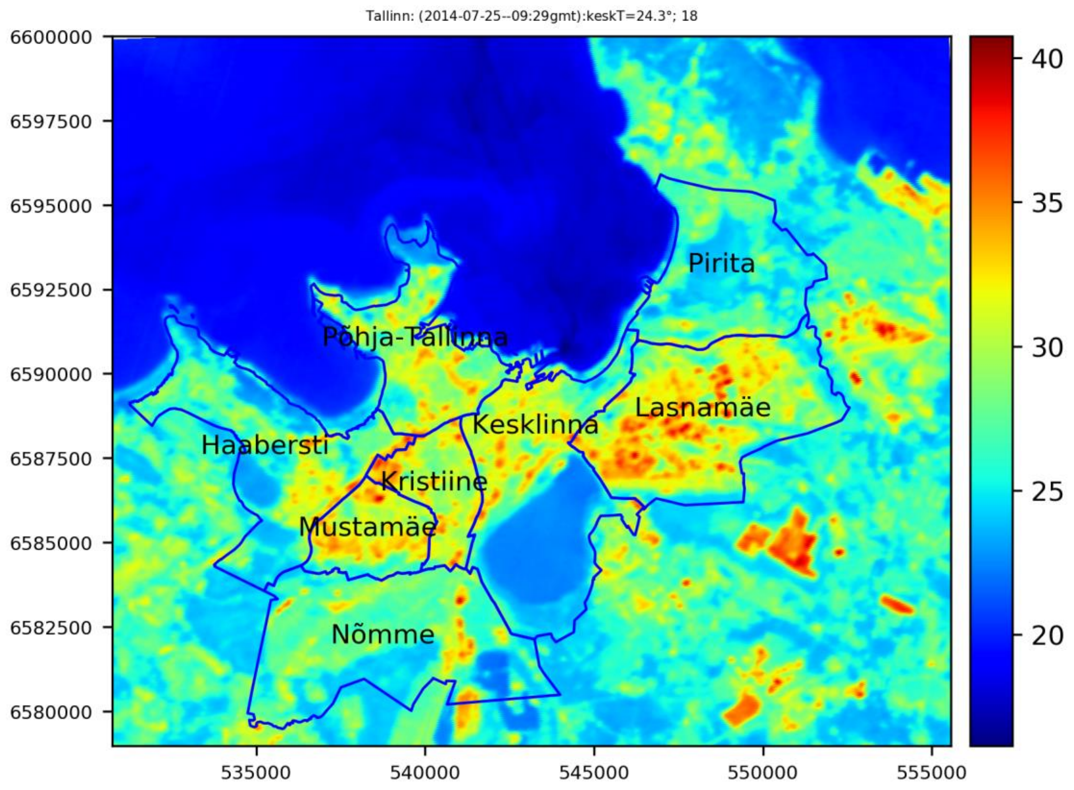
Example 2014: Air temperatuure 25..31 **°C at** weather station vs availability of satellite images *(<15% vs <40% clouds)*

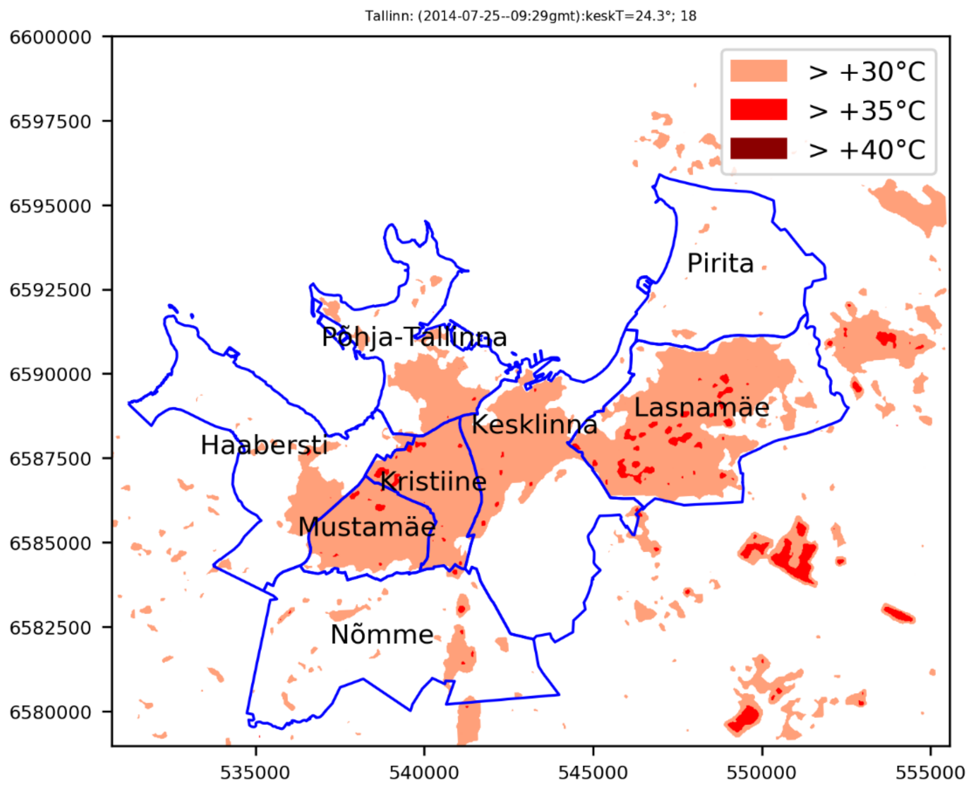


Selected periods:
2014 (25.-27. juuli) ,
2018 (15.juuli -30.august),
2019 (5-7.juuni ja 2.september).

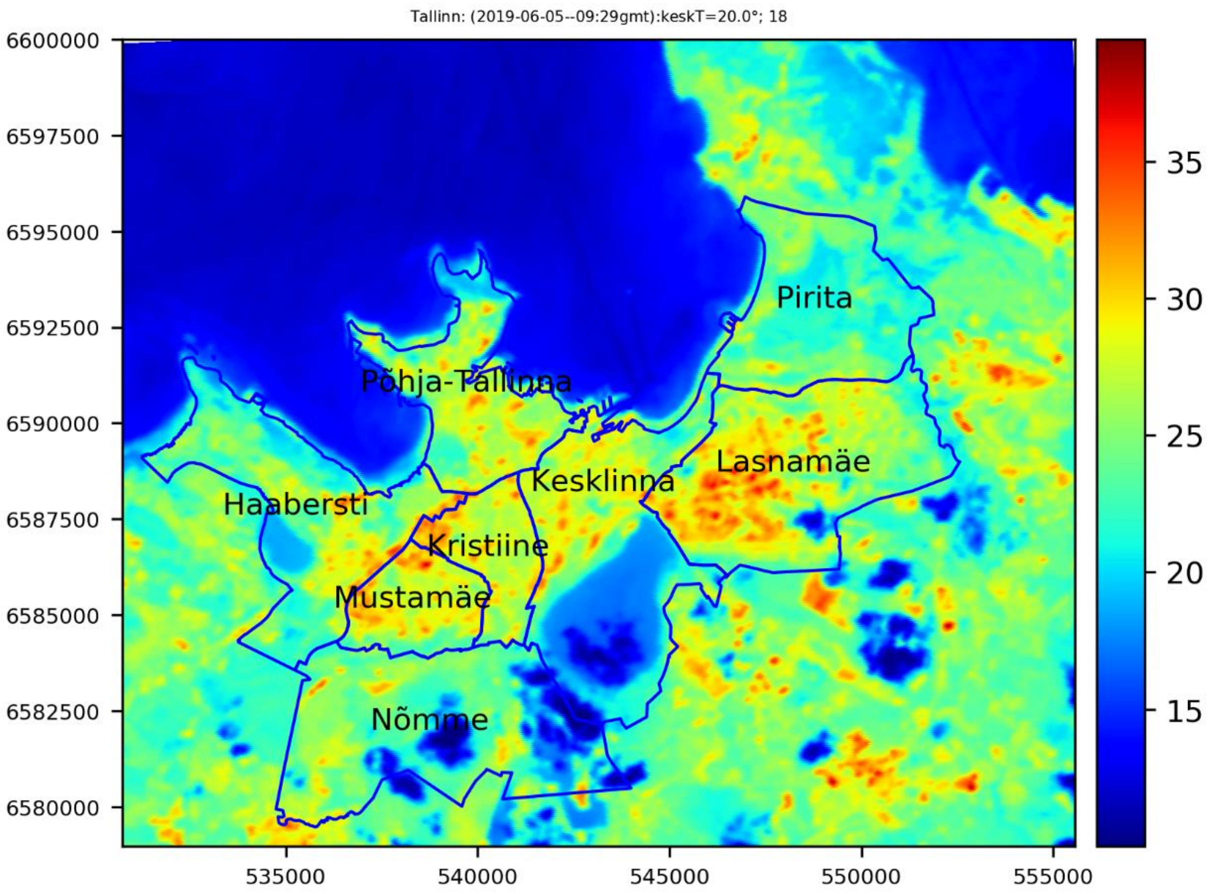
Example 2019:
Air temperatuure
25..31 **°C at**
weather station vs
availability of
satellite images
(<15% vs <40%
clouds)

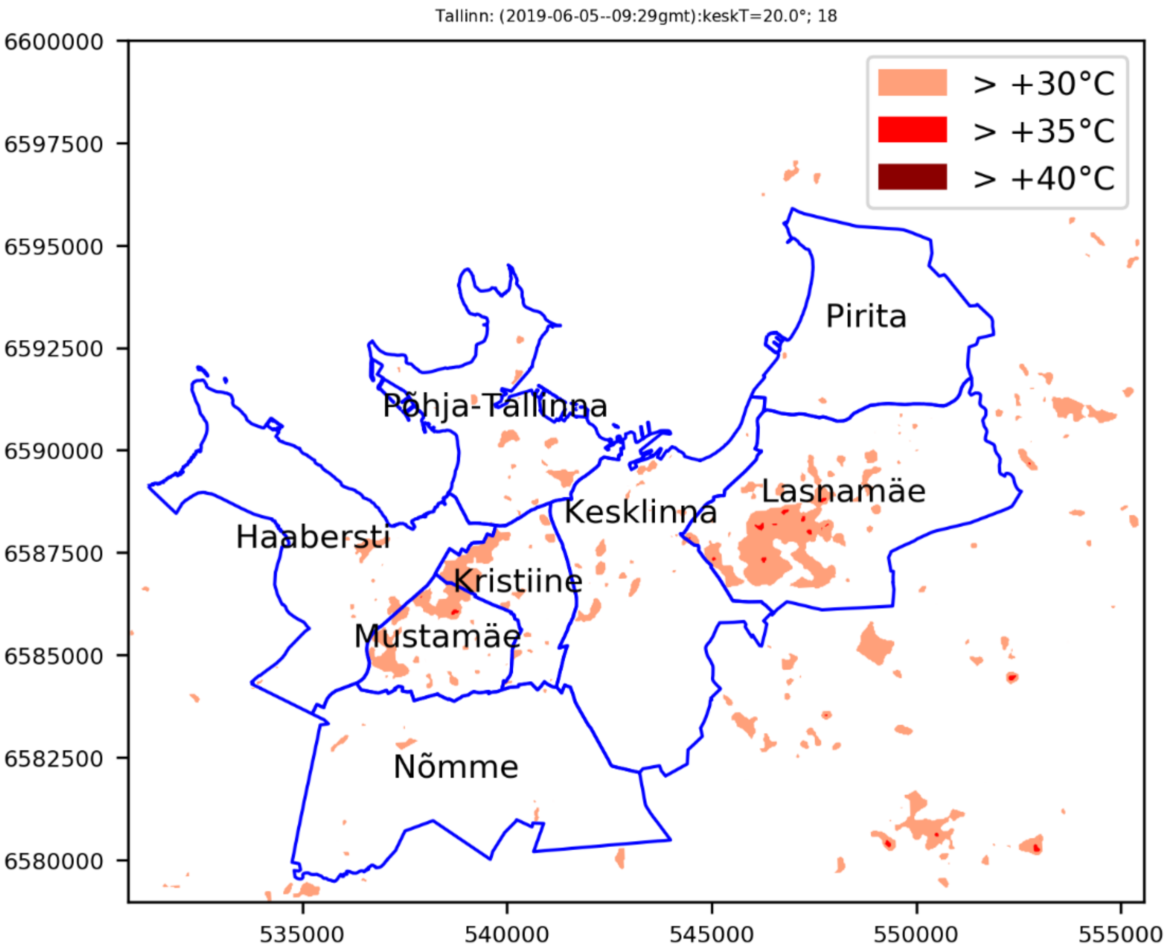




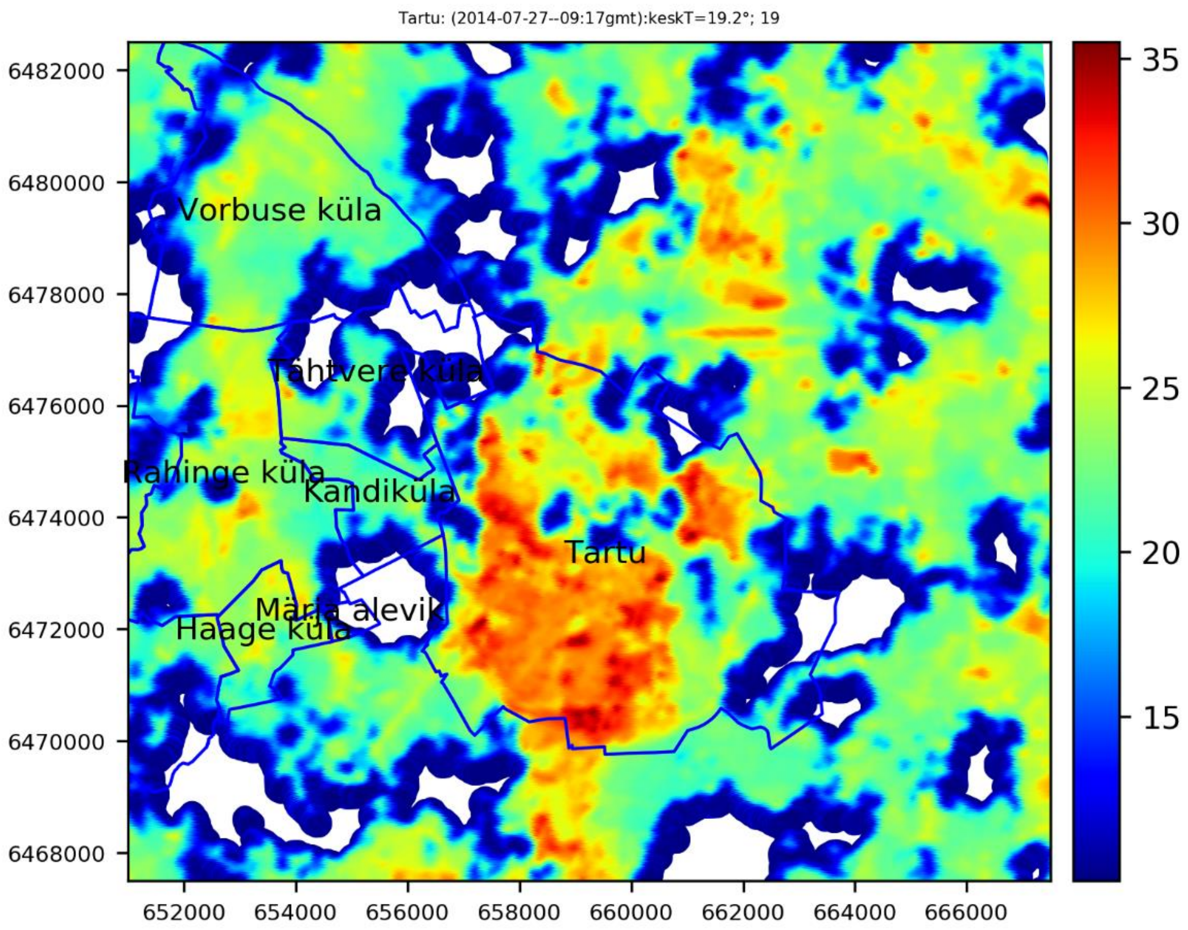


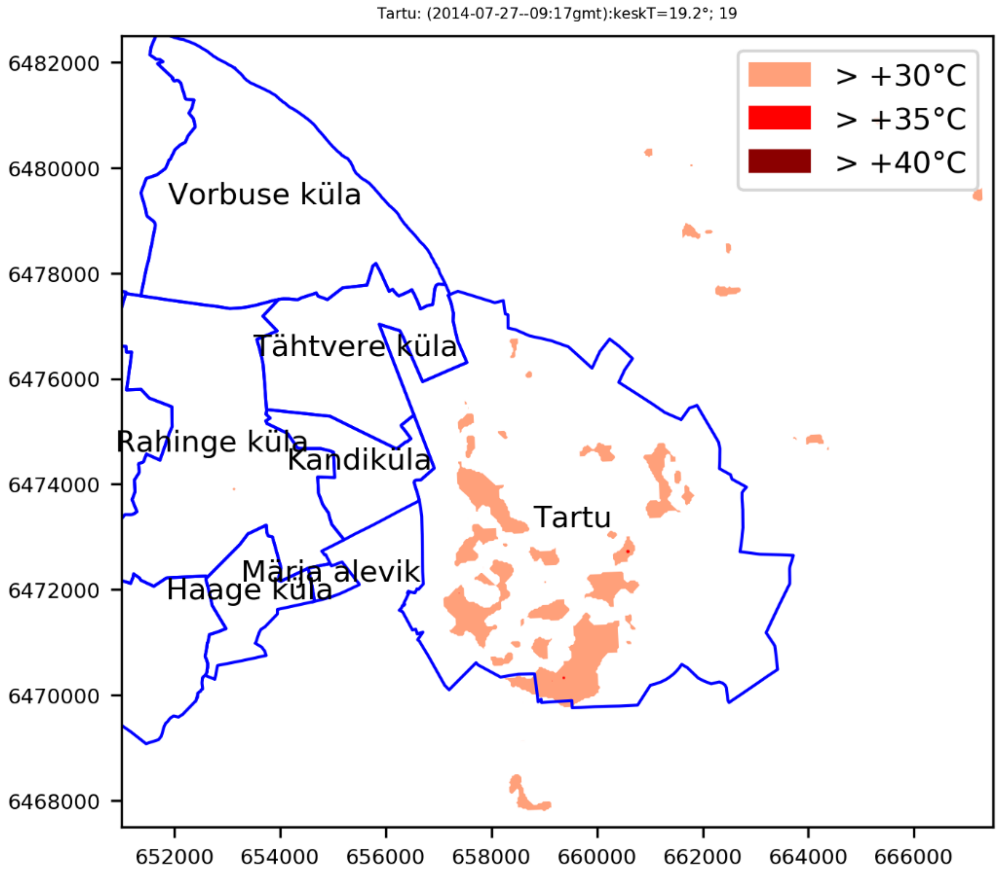
Example: Tallinn 25.7.2014



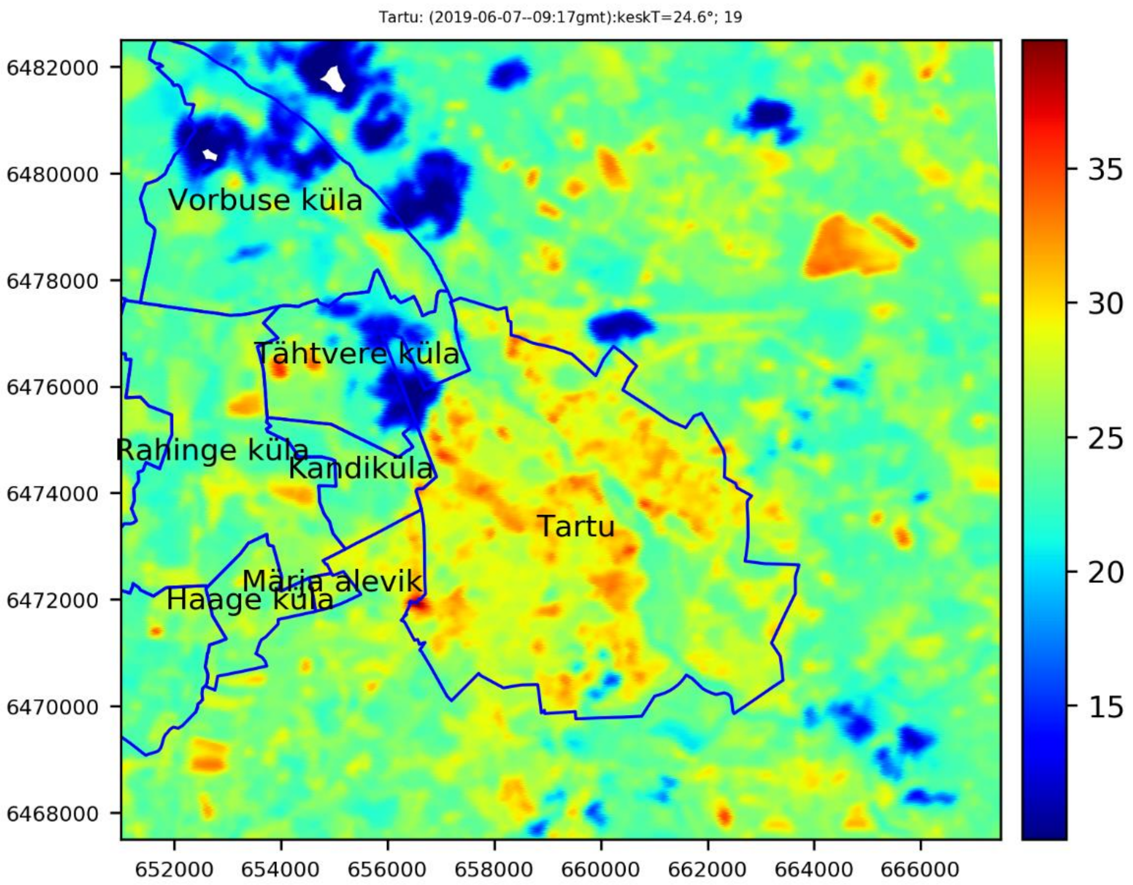


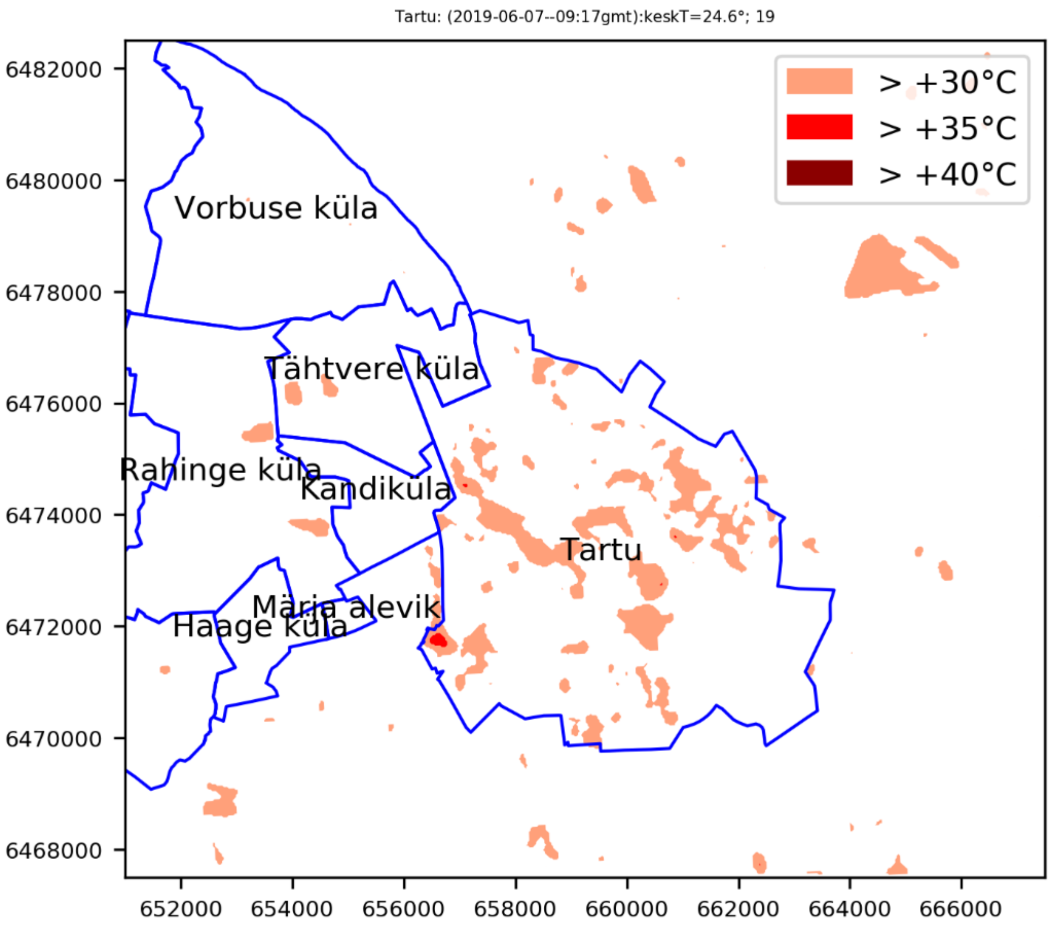
Example: Tallinn 5.6.2019



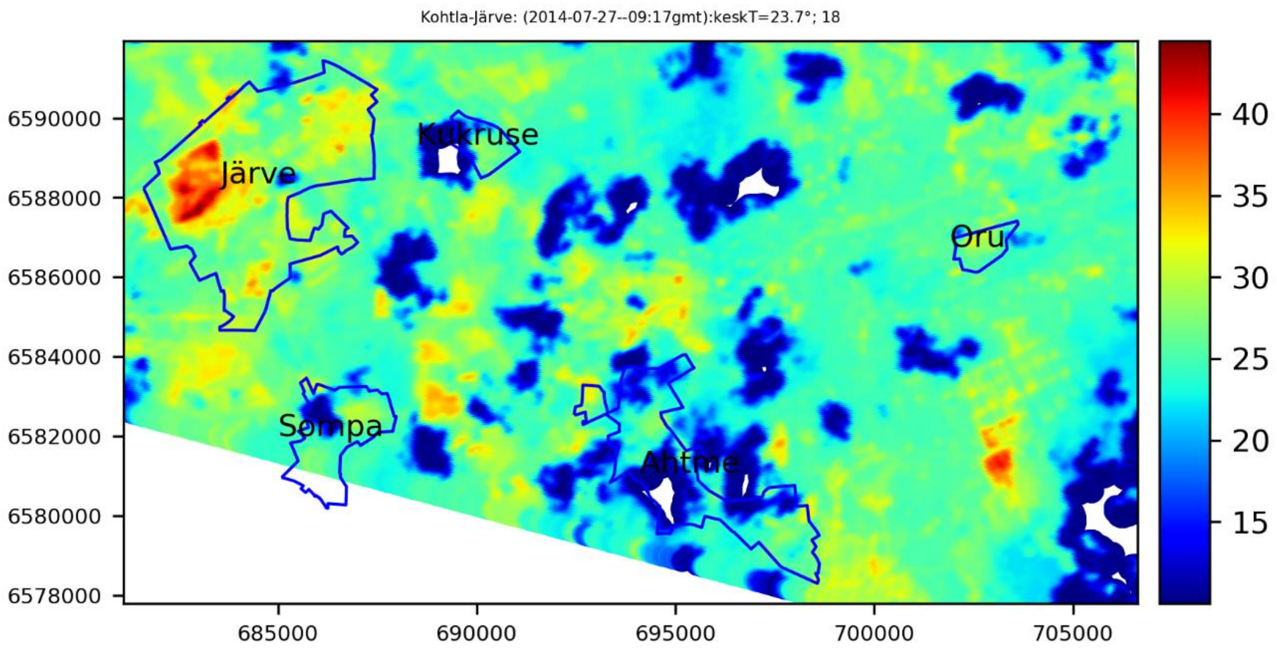


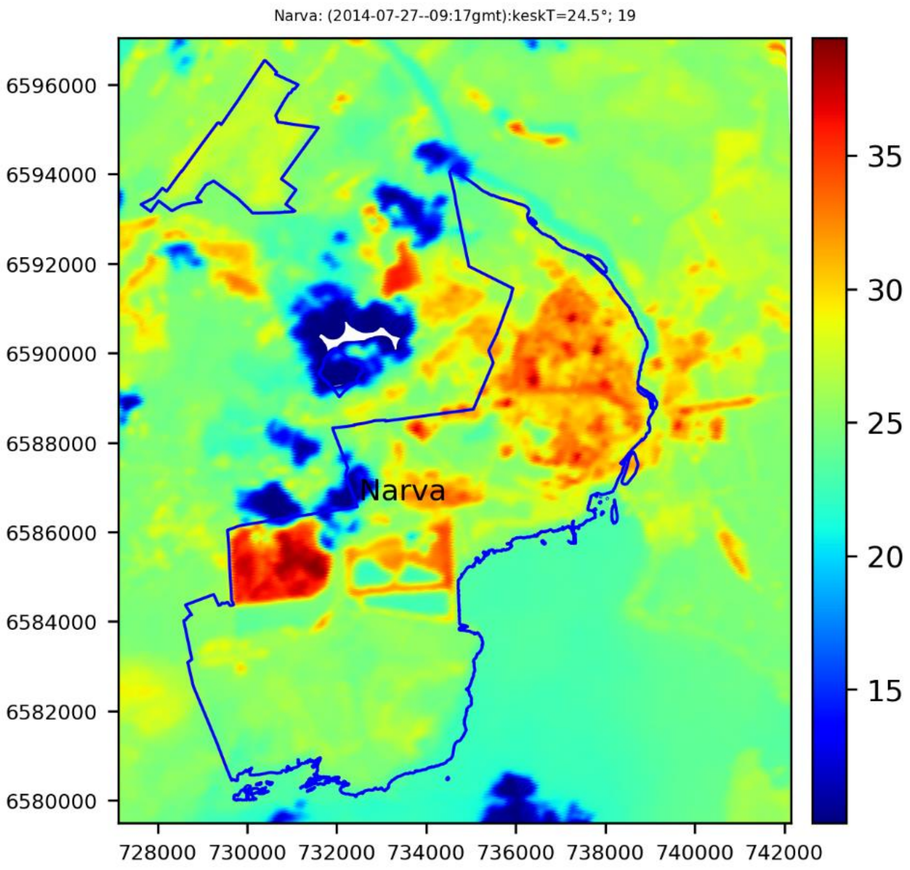
Example: Tartu 27.7.2014



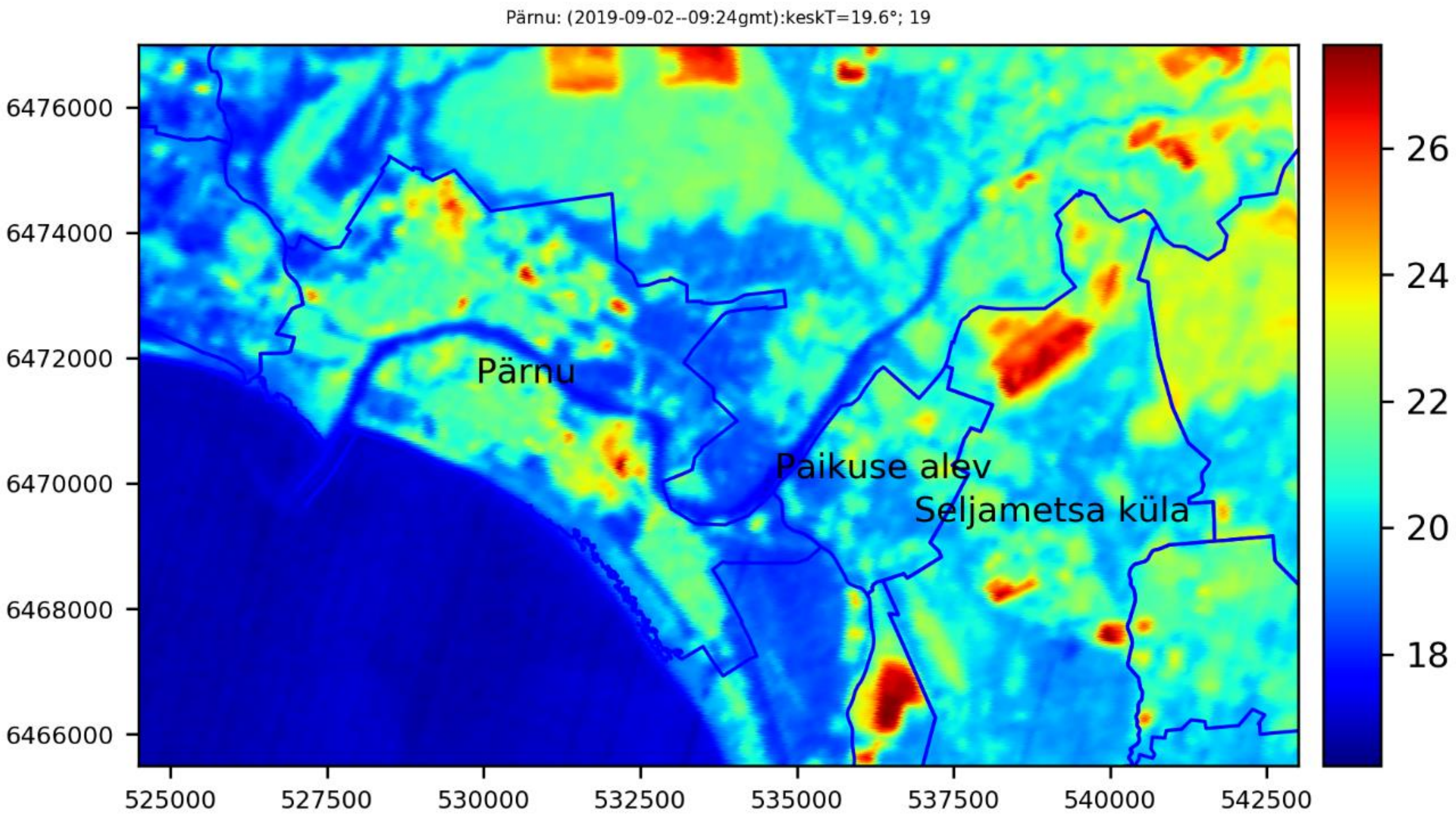


Example: Tartu 7.6.2019





Example: Kohtla-Järve &Narva 27.7.2014



Example: Pärnu 2.9.2019

Finding appropriate data sets and downloading data

```
import landsatxplore.api

username='olev.martens@gmail.com'
password=‘xxxxxxr'
apix = landsatxplore.api.API(username, password) # Init API & get key
node='EE'

 dataset=landsat8_dataset,
        latitude=…,         longitude=…,
        start_date= …,
        end_date= ….,
        max_cloud_cover=10)

      klen= len(scenes)

#=========

apix = landsatxplore.api.API(username, password) # Init API & get key
scene0= scenes[0]
xid= scene0['entityId']
ee.download(scene_id=xid, output_dir='c://OlevTemp')
apix.logout()# Log out
#--
```

Processing of downloaded data

(BTW: final maps to be in Estonian Coordinate System of 1997 -EPSG:3301, reprojection is slow in the software)

- from PIL import Image
- import matplotlib.pyplot as plt
- import matplotlib.image as mpimg
- import numpy as np
- import geopandas as gpd
- import pandas as pd
- from pyproj import Proj, transform
- from shapely.ops import nearest_points
- from shapely.geometry import Point, Polygon
- from shapely import geometry
- from geopandas import GeoSeries
- import pyproj
- import rasterio
- import rasterio.plot
- ##https://scikit-image.org/docs/dev/auto_examples/segmentation/plot_label.html
- from skimage import data, io, filters
- from skimage.filters import threshold_otsu
- from skimage.segmentation import clear_border
- **from skimage.measure import label, regionprops, find_contours**
- from skimage.morphology import closing, square
- from skimage.color import label2rgb
- #import cv2

```
# Arvutusskeem allolevalt lingilt:
#https://geogeek.xyz/how-to-calculate-land-surface-temperature-with-landsat-8-images.html
##1.- Calculation of TOA (Top of Atmospheric) spectral radiance.

radiance_mult_band_10= 3.3420e-4
#radiance_add_band_10 = 0.1000
TOA = 0.0003342 *arr10b + 0.1

##== 2.- TOA to Brightness Temperature conversion
##BT = (K2 / (ln (K1 / L) + 1)) − 273.15
BT = (1321.0789 / np.log ((774.8853 / TOA) + 1)) – 273.15

#NDVI = Float(Band 5 – Band 4) / Float(Band 5 + Band 4)
NDVI_Pv = np.divide ((arr5b – arr4b), (arr5b + arr4b +1e-40))

##5.- Calculate Emissivity ε
eps = 0.004 * NDVI_Pv + 0.986

##6.- Calculate the Land Surface Temperature
##LST = (BT / (1 + (0.00115 * BT / 1.4388) * Ln(ε)))
LST = (BT / (1 + (0.00115 * BT / 1.4388) * np.log(eps)))
```

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- co-authors Riina Pärg and Jekaterina Služenikina, but also to Maris Arro, Agne Aruväli ja Svetlana Pudova) for both support and also the opportunity for such interesting Project

Thanks for listening and interest!
Ideas or comments (business, technical, …)
Q & A

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