Evaluation of land surface temperature (LST) patterns in the urban agglomeration of Krakow using different satellite data and GIS

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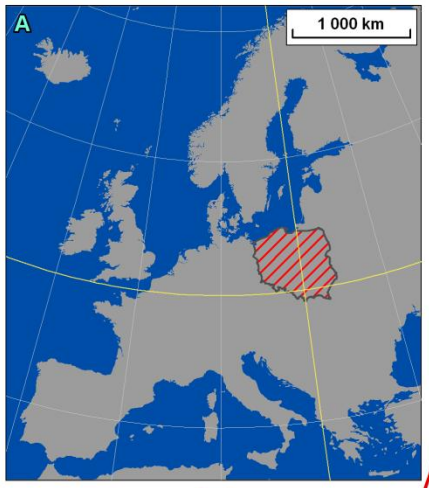
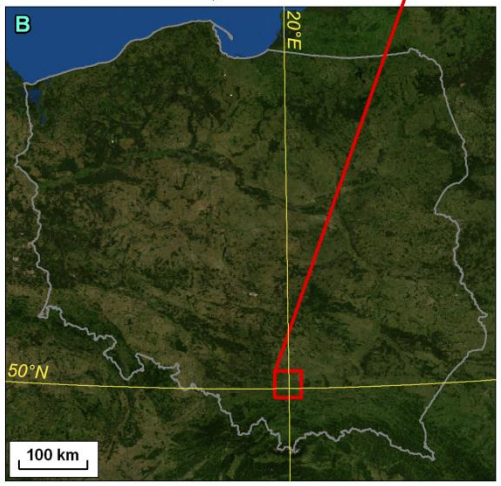
Research objectives

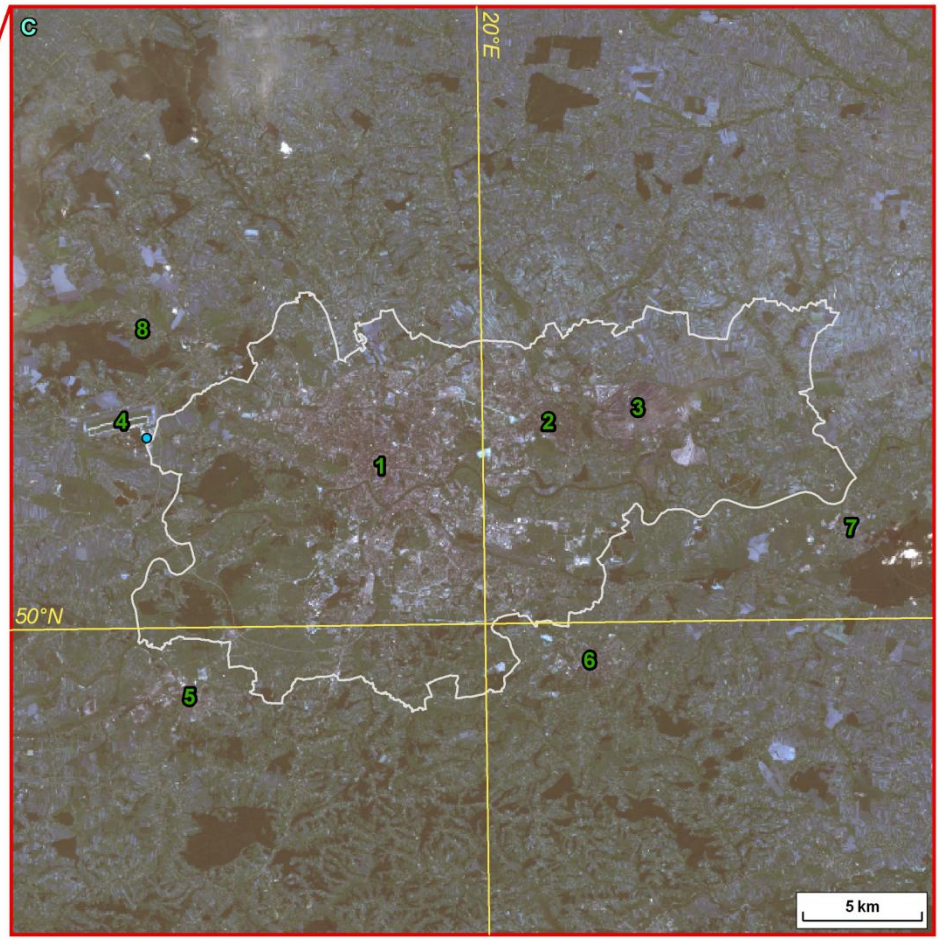
- Estimation of **spatial distribution and temporal variability of land surface temperature over Krakow and the surroundings** of the city with the use of different satellite data and different LST retrieval algorithms (single-channel / split window)
- Determination of **weather conditions at the time of satellite image acquisition** and its impact on the LST retrievals
- Evaluation of **relationship between the LST and different land use / land cover types** using **GIS techniques**
- Identification of other **natural and anthropogenic factors influencing land surface temperature pattern** in the city of Krakow
- Specification of **recommendations for municipal authorities** for better urban space management in order to neutralize negative effects of overheating in the city (especially in summer)

Study area

The city of Krakow (total area: 326.8 km^2, population: about 759 000) + surroundings







Light blue dot = Krakow-Balice weather station.

Characteristic places:
1 – Old Town,
2 – Centre of the Nowa Huta District,
3 – Steelworks in Nowa Huta,
4 – Krakow-Balice International Airport,
5 – Skawina,
6 – Wieliczka,
7 – Niepołomice,
8 – Zabierzow.

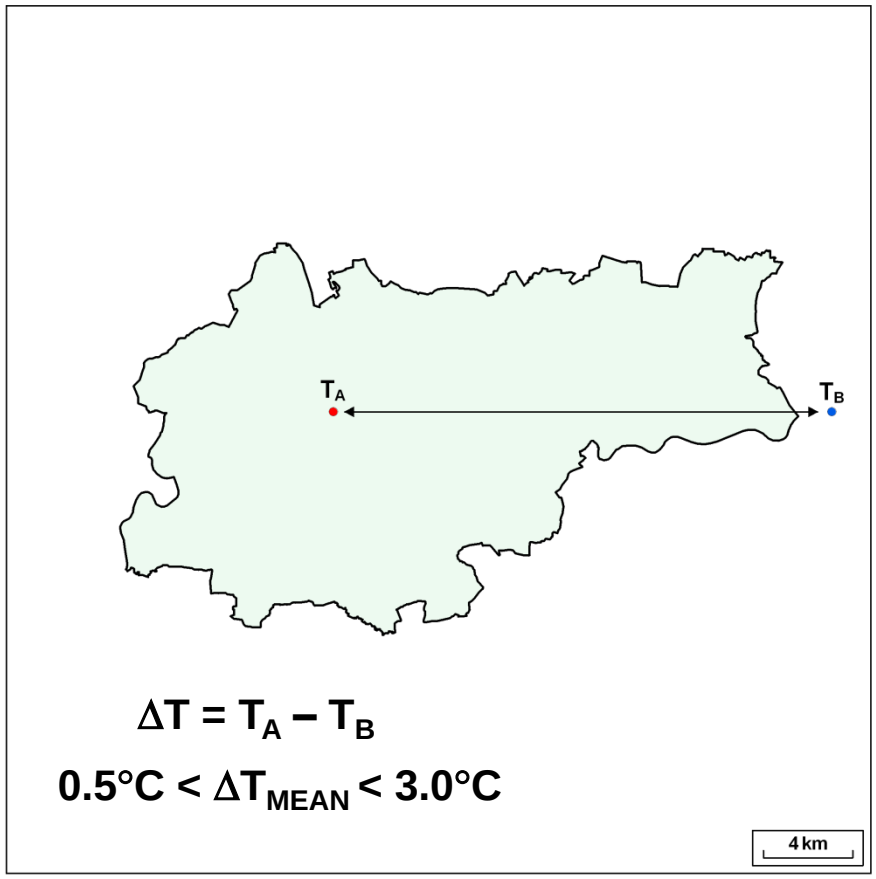
Background image:
Landsat-7/ETM+
'True Color' RGB
July 26, 2000

Background image:
NASA's Earth Observatory Blue Marble (2000) for July

Urban heat stress monitoring

Direct measurement:
thermometer or temperature sensor
Output parameter:
Urban heat island intensity [ΔT]

Indirect measurement:
ETM+ radiometer
Date: *July 26, 2000 r.*
Hour: *9:24 UTC*
Output parameter:
LST pattern



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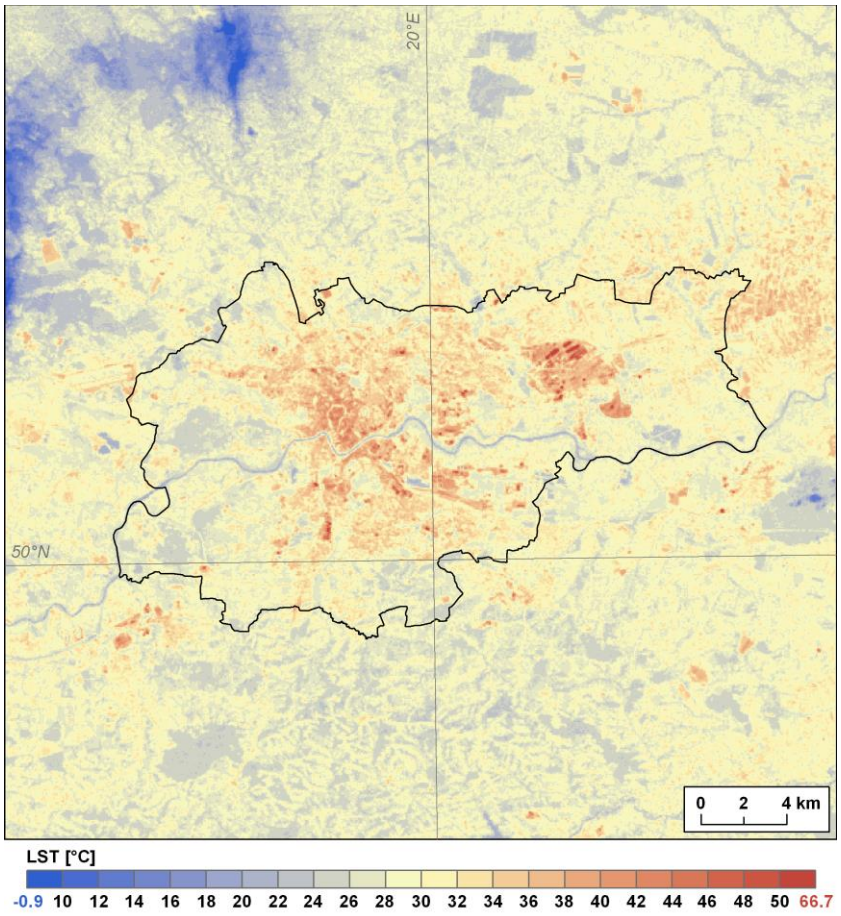

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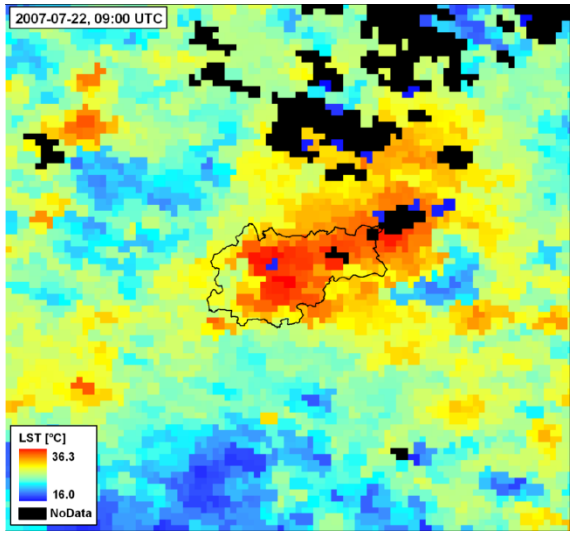
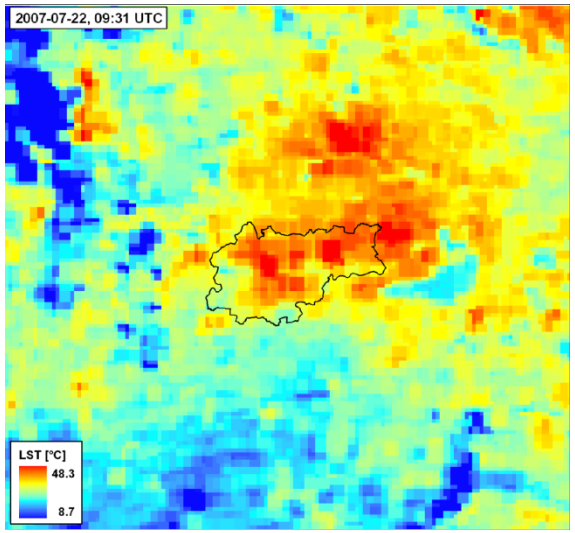
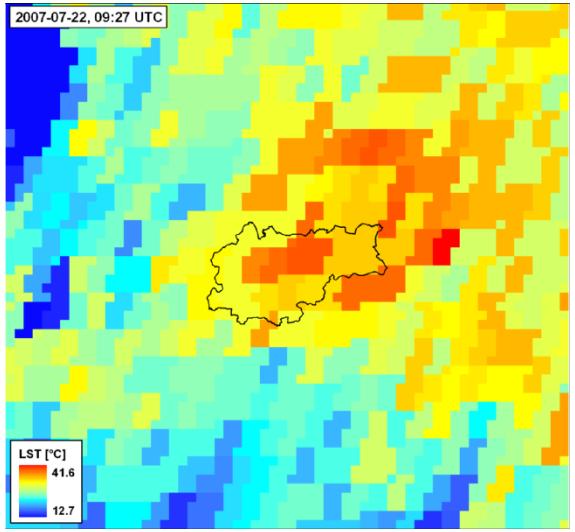
Comparative analysis of different satellite sensors



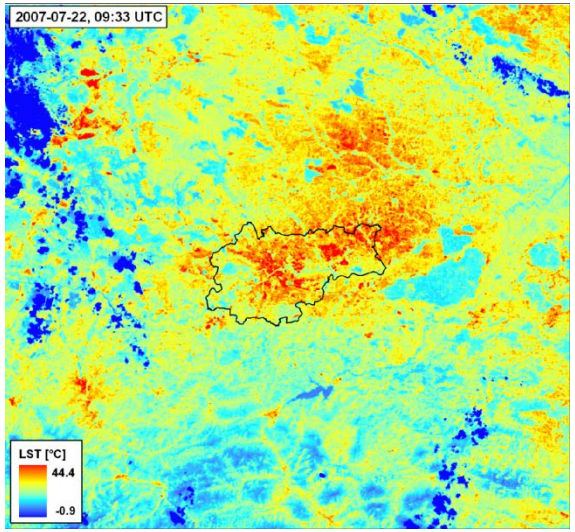
Terra/MODIS LST pattern



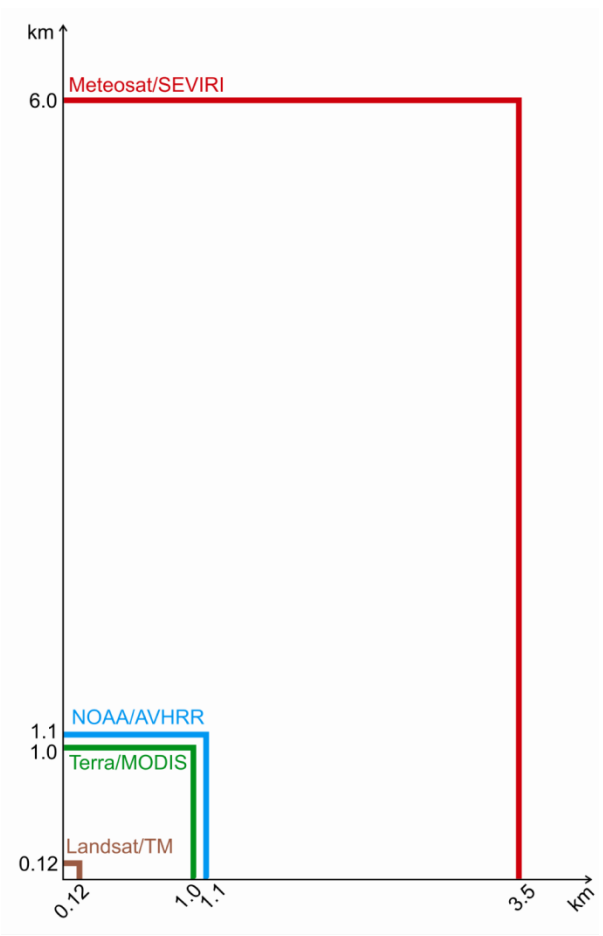
NOAA/AVHRR LST pattern



Meteosat/SEVIRI LST pattern

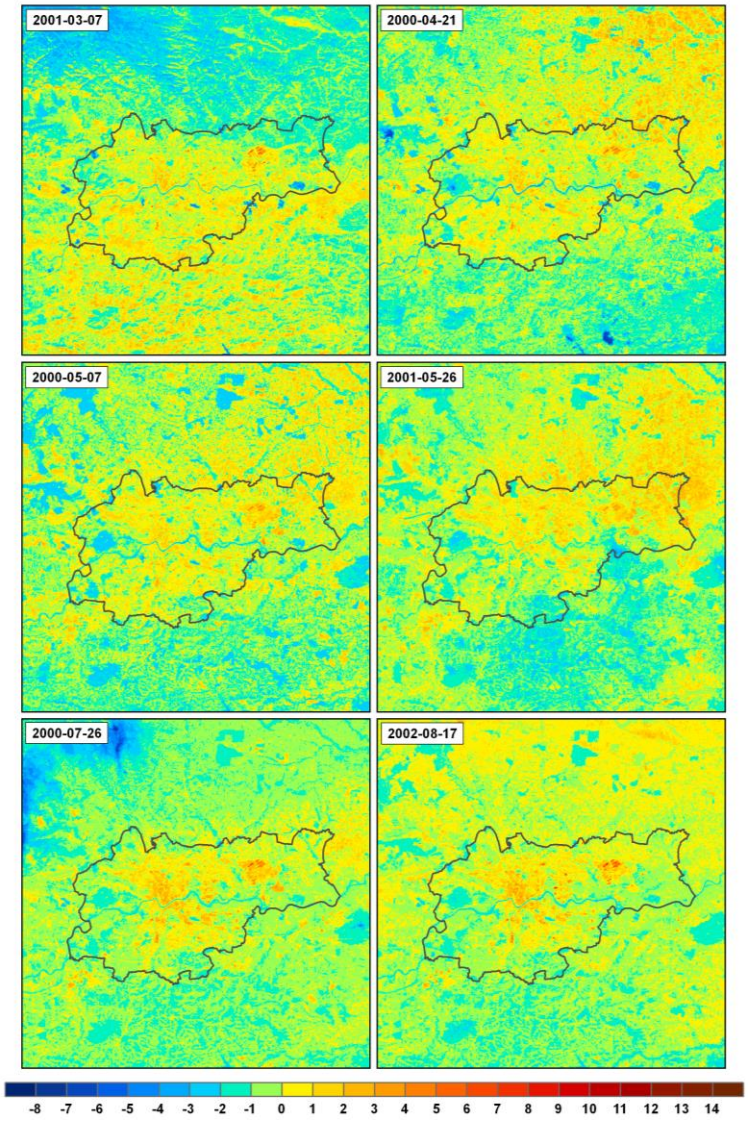


Landsat/TM LST pattern



Walawender J., Hajto M. (2009), *Assessment of thermal conditions in urban areas with use of different satellite data and GIS,* Proc. 2009 EUMETSAT Meteorological Satellite Conference, 21-25 September 2009, Bath, UK

Thermal stability → identification of cold and hot spots

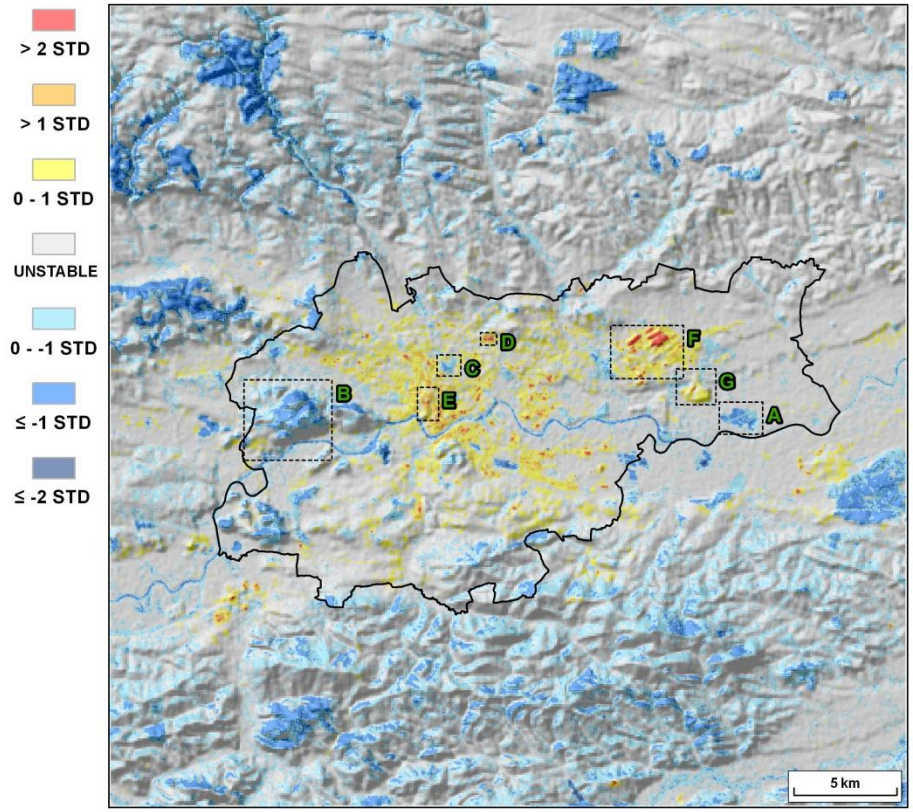


Standardized land surface temperature pattern

LST standarization and calculation of LST_S pixels frequency:

$$LST_S = \frac{LST_x - LST_\mu}{LST_\sigma}$$

$LST_S \rightarrow$ standard scores of the LST
$LST_x \rightarrow$ individual LST pixel value
$LST_\mu \rightarrow$ zonal mean LST value for the sample
$LST_\sigma \rightarrow$ sample's standard deviation



Thermal stability in the agglomeration of Krakow

Walawender J. P., Szymanowski M., M. Hajto J., Bokwa A. (2013), *Land surface temperature patterns in the urban agglomeration of Krakow (Poland) derived from LANDSAT-7/ETM+ data*. Pure and Applied Geophysics, doi:10.1007/s00024-013-0685-7.

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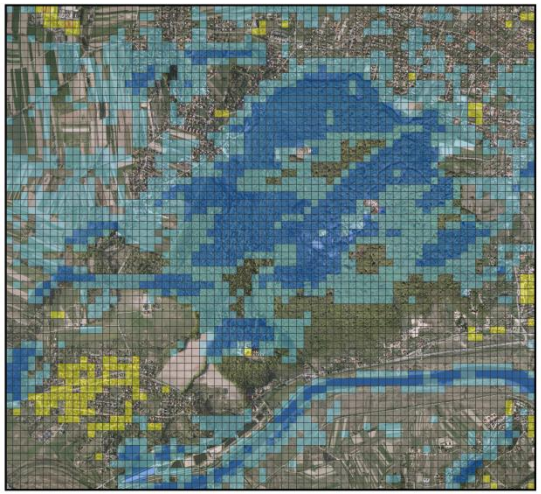
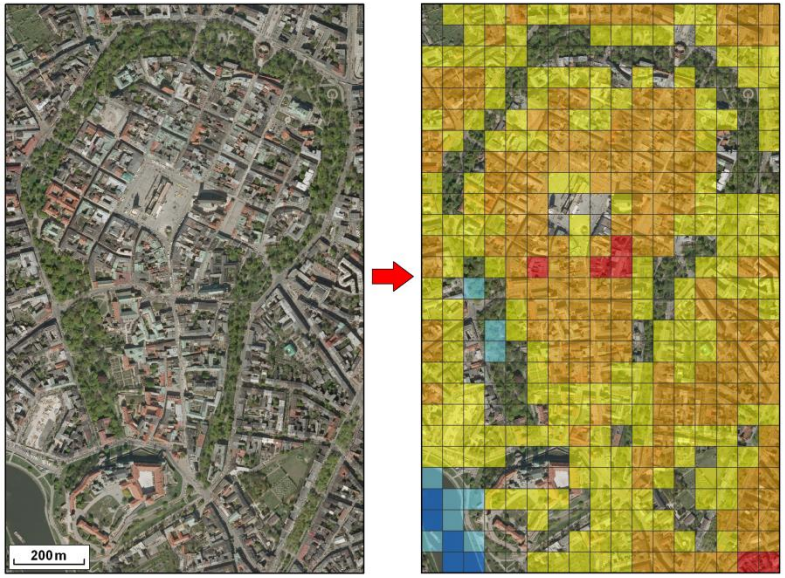
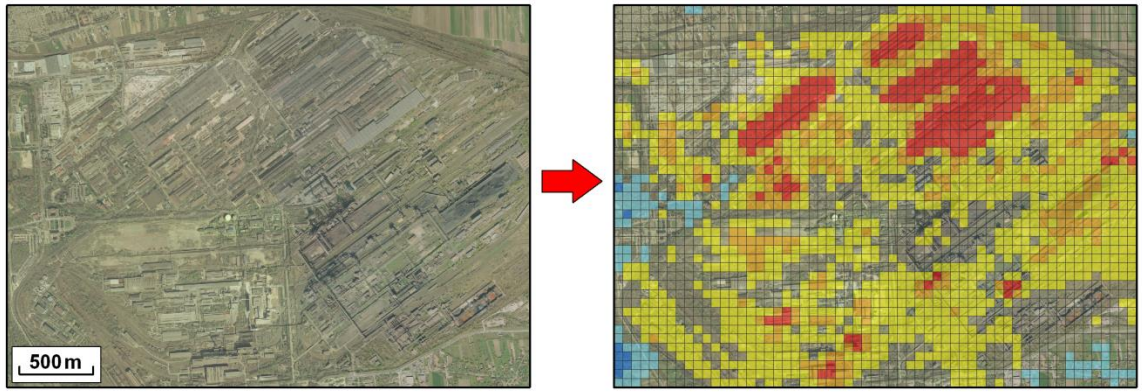


Thermal pattern of Wolski Forest



Thermal pattern of the Old Town in Krakow



Thermal pattern of of the steelworks in Nowa Huta

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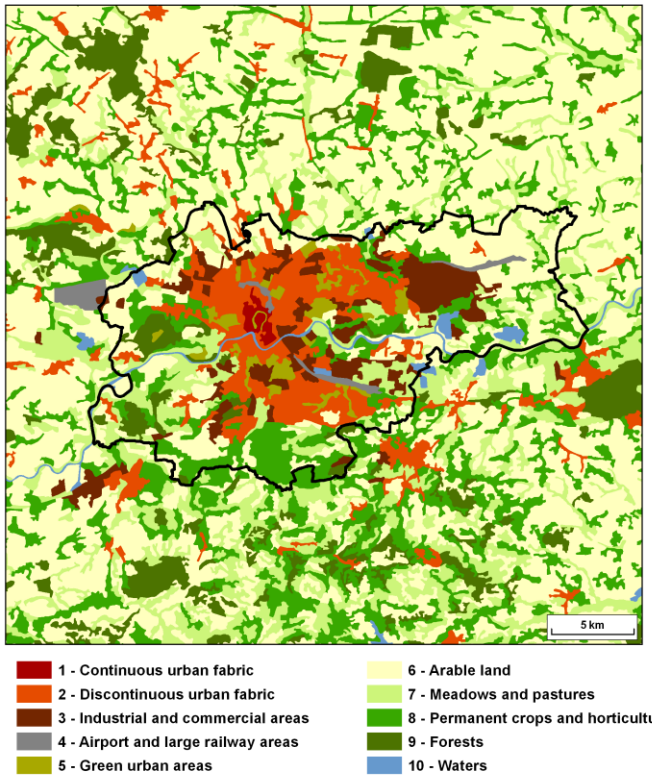
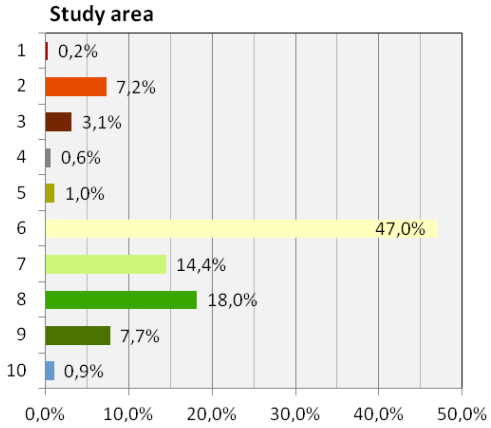
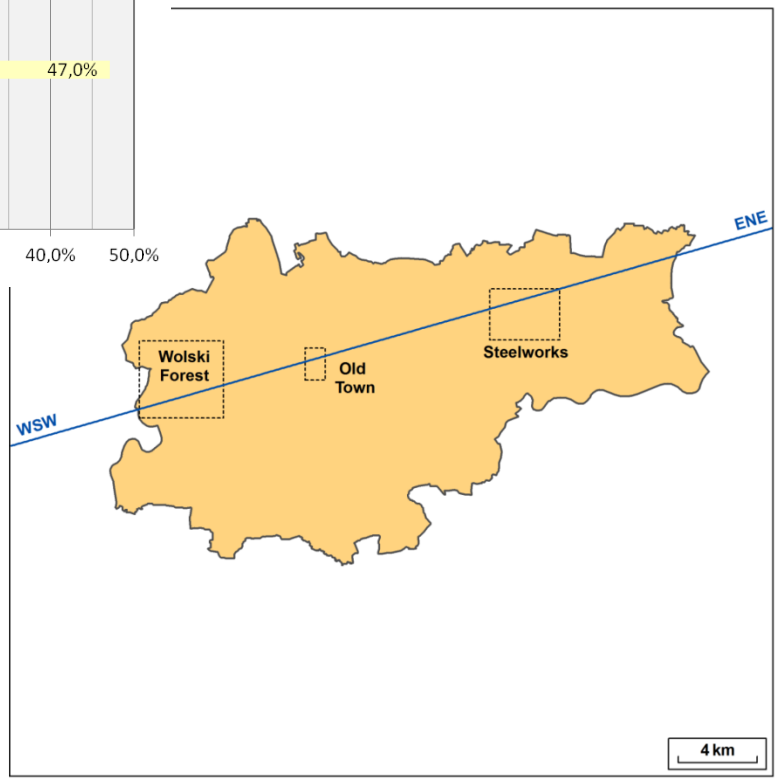
LST-LULC relationship

- Detailed analysis of atmospheric records at the time of satellite image acquisition
- Calculation of basic zonal statistics (min., max., and mean LST) for different LULC types
- LST profiles



Generalized land cover structure of the study area based on CORINE Land Cover 2000 database.

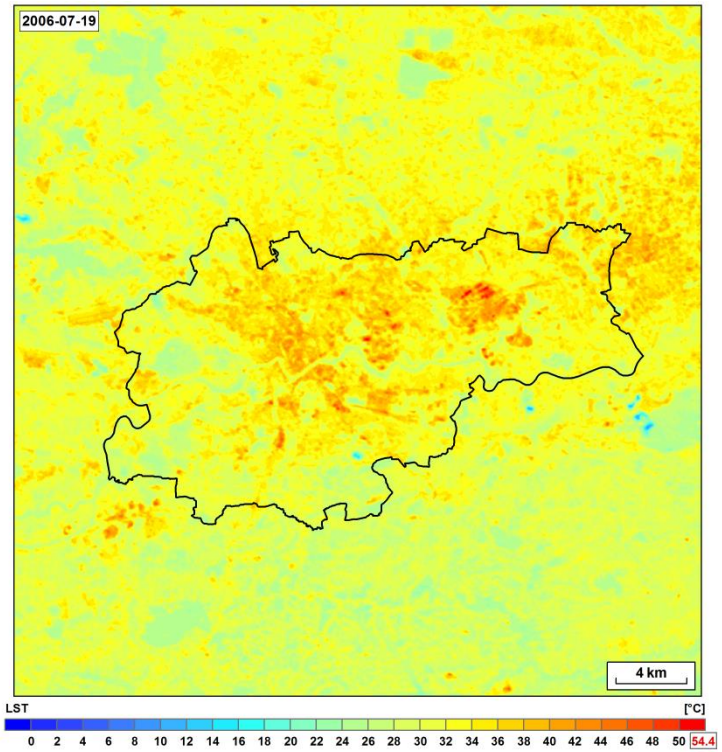


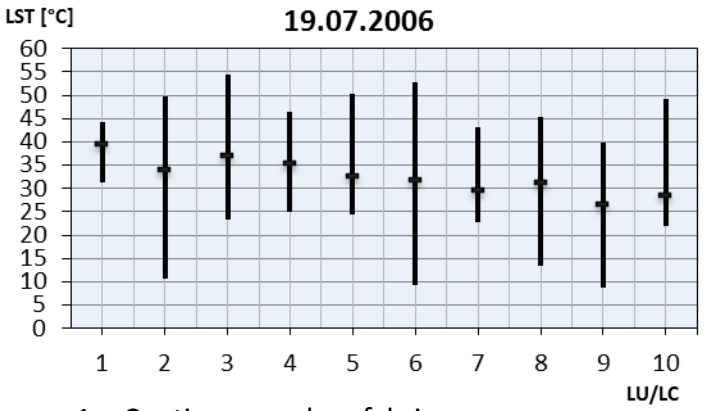


A cross section intersecting characteristic hot and cold spots in the city

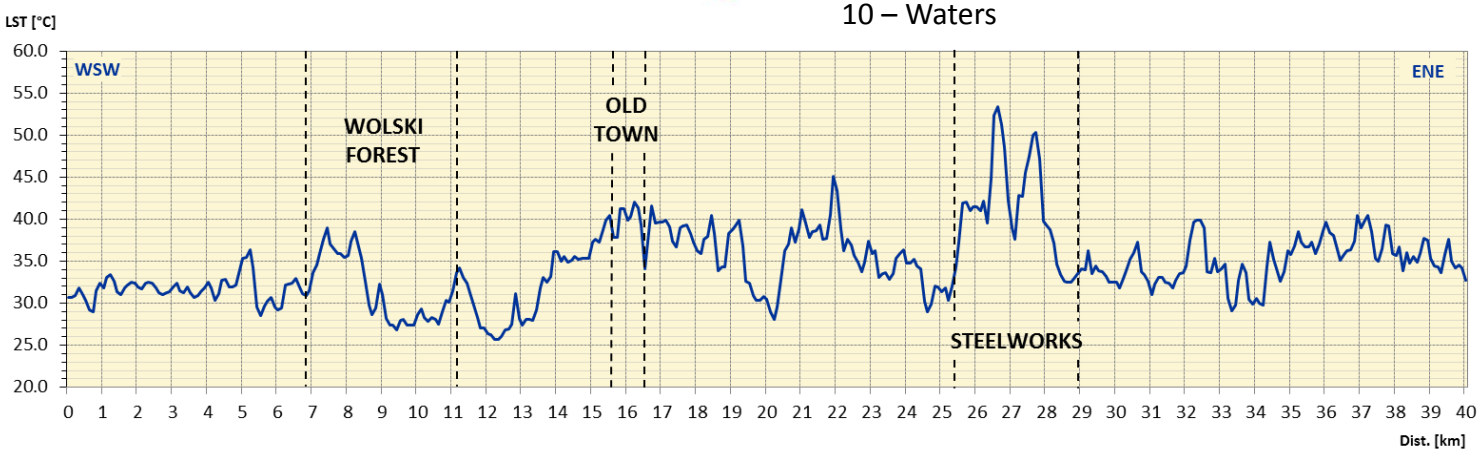
Summer time LST

ATMOSPHERIC PARAMETERS
Air temperature: 27.9°C
Relative humidity: 37%
Visibility: 50km
Cloud cover: 12%
Atmospheric pressure: 993.4 (1020.6) hPa
Wind speed: 4-5 m/s
Wind direction: W/NW
Phenomena: increasing cloudiness (Cu hum)



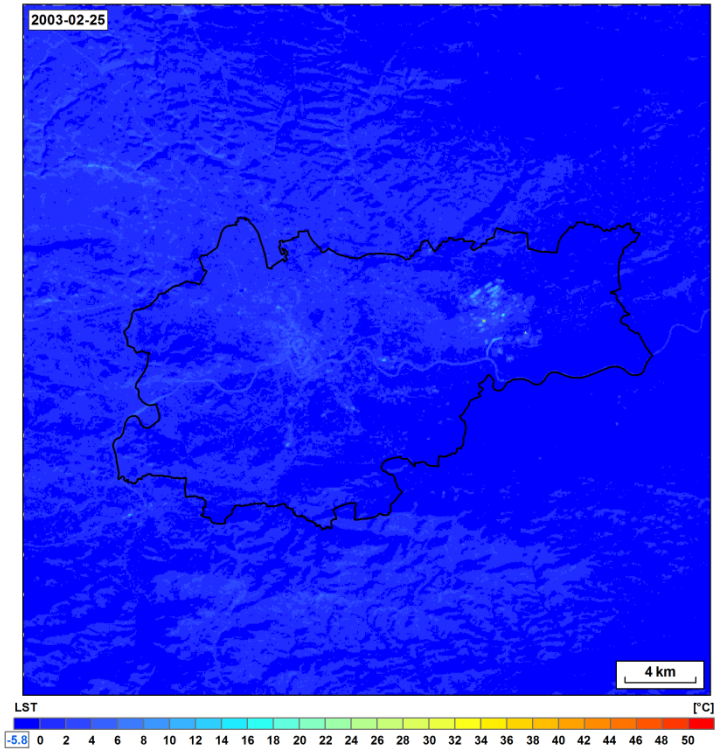


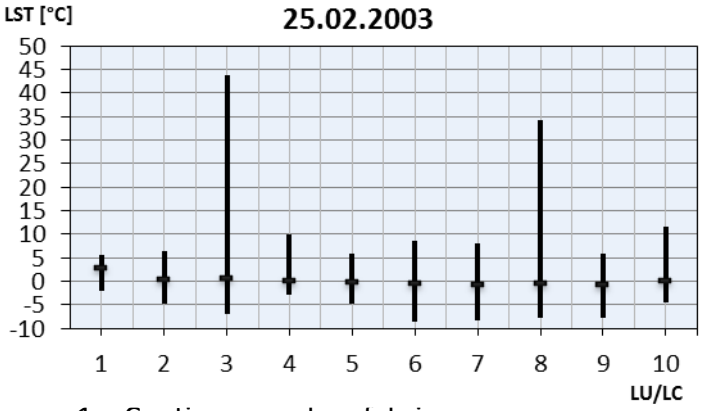
1 – Continuous urban fabric
2 – Discontinuous urban fabric
3 – Industrial and commercial areas
4 – Airport and large railway areas
5 – Green urban areas
6 – Arable land
7 – Meadows and pastures
8 – Permanent crops and horticulture
9 – Forests
10 – Waters



Winter time LST

ATMOSPHERIC PARAMETERS
Air temperature: -2.4°C
Relative humidity: 74%
Visibility: 5 km
Cloud cover: 0%
Atmospheric pressure: 1003.3 (1033.8) hPa
Wind speed: 3-4 m/s
Wind direction: E
Phenomena: mist, snow cover





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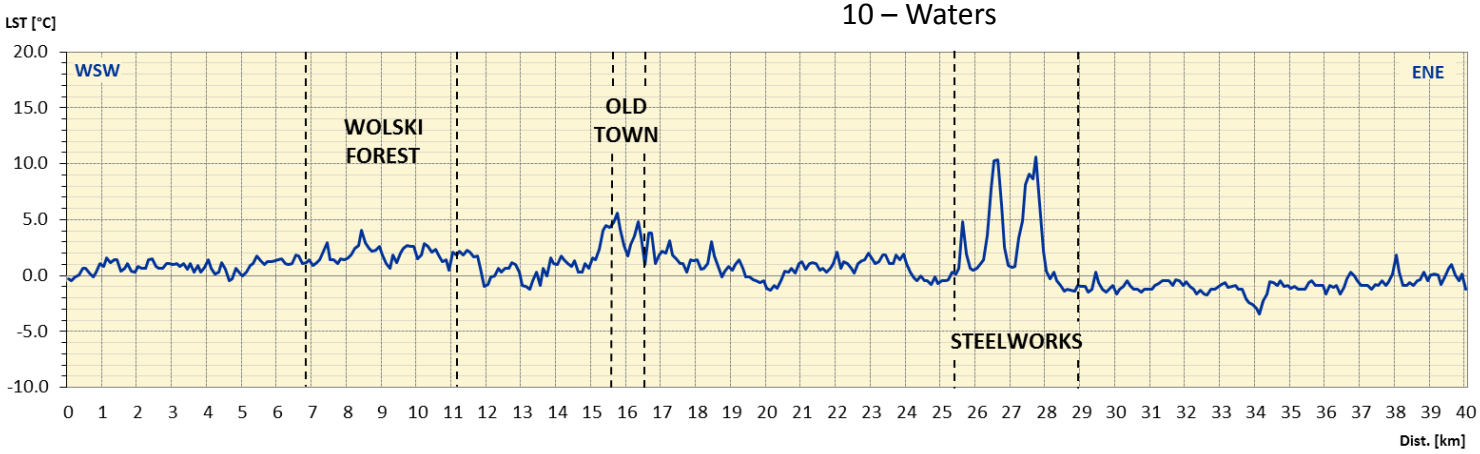

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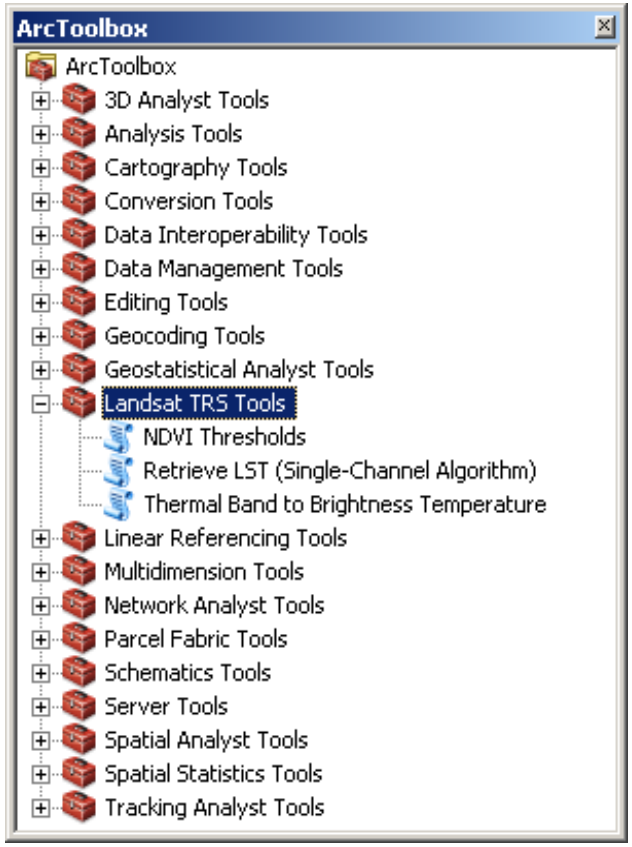
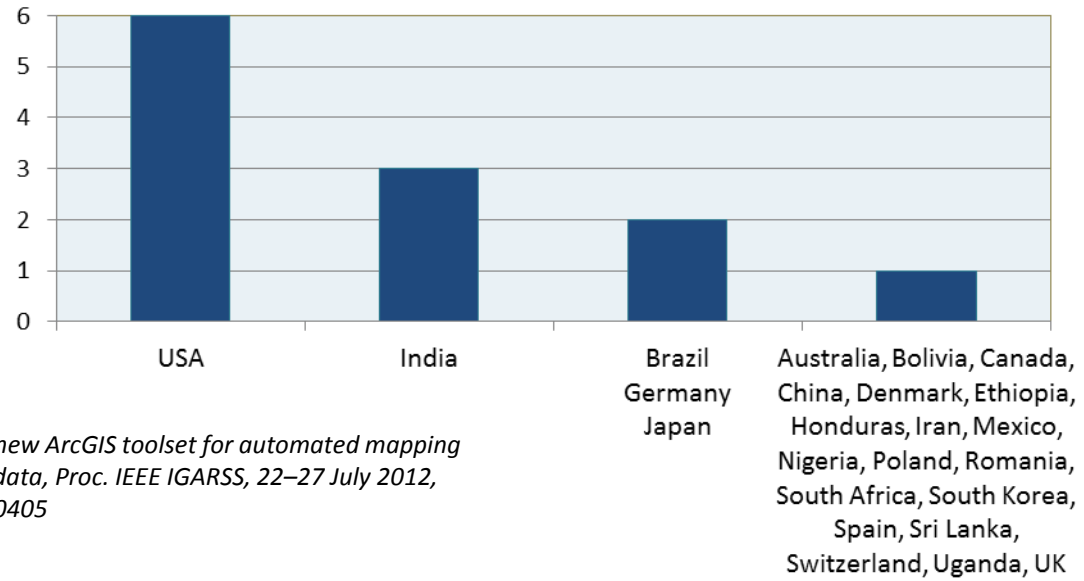
Landsat Thermal Remote Sensing (TRS) Tools for ArcGIS Desktop 10+



- additional ArcGIS Desktop 10+ toolbox for automatic retrieval of brightness temperature (*BT*), land surface emissivity (*LSE*) and land surface temperature (*LST*) from LANDSAT data.
- three separate tools created with Python scripting language
- freely available for scientific (non-commercial) use
- currently 34 users in 24 countries all over the World:



WALAWENDER, J.P., HAJTO, M.J., and IWANIUK, P. *(2012), A new ArcGIS toolset for automated mapping of land surface temperature with the use of LANDSAT satellite data, Proc. IEEE IGARSS, 22–27 July 2012, Munich, Germany, 4371–4374, doi: 10.1109/IGARSS.2012.6350405*

Concluding remarks

- **Large spatial variability of land surface temperature in Krakow** is caused by mosaic of various natural and artificial surfaces (2 centers of the highest heat emission and a few characteristic hot and cold spots recognized)
- Land surface temperature is strongly **influenced by: LULC type, vegetation cycle, topography, building structure and atmospheric conditions**
- **Satellite data** are valuable source of information on thermal conditions in urban areas (**spatially continuous LST record**)
- GIS makes it possible to **integrate satellite LST retrievals with other spatial databases in order to evaluate environmental factors behind surface temperature pattern.**
- Land surface temperature maps of urban areas are **important contribution for sustainable urban development** (the concept of green cities)
- **ArcGIS Landsat TRS tools found its users worldwide** (different applications) – no Landsat LST-EDR available so far (?)
- International cooperation (exchange of experiences) seems to be very important

Thank you for your attention!

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