URBAN CLIMATOLOGY

5. Urban Remote Sensing

Paper to read

2007 Urban Remote Sensing Joint Event

Application of satellite Remote Sensing for Urban Risk Analysis: a case study of the 2003 extreme heat wave in Paris

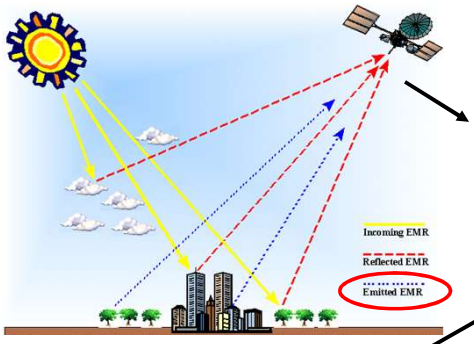
Bénédicte Dousset
Hawaii Institute of Geophysics and Planetology
University of Hawaii, Honolulu, USA
bdousset@hawaii.edu

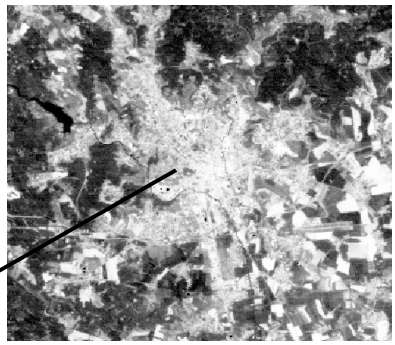
Françoise Gourmelon
Laboratoire Géomer
CNRS UMR-6554, Institut Universitaire Européen de la Mer
Plouzané, France
Francoise.Gourmelon@univ-brest.fr

Elena Mauri
Istituto Nazionale di Oceanografica e di Geofisica Sperimentale
Trieste, Italy
emauri@ogs.trieste.it

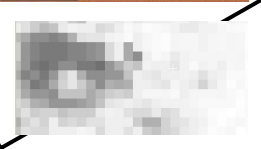
https://is.muni.cz/auth/el/sci/podzim2022/ZX601/um/67875456/05_Dousset-URS-07.pdf

5.1 Remote Sensing Principles





thermal imagery



Digital Numbers

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121 121 122 122 140 140 144
121 121 122 122 140 140 144
129 129 128 128 132 132 135
129 129 128(128)132 132 135
131 131 131 131 132 132 132
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135 135 131 131 135 135 134
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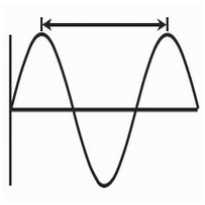
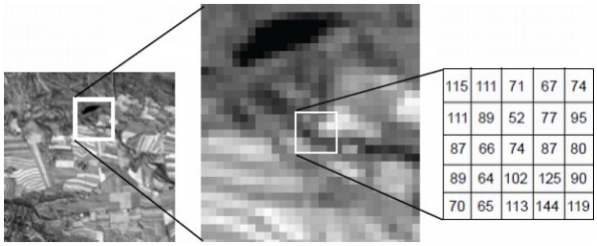
DN = f(LST)

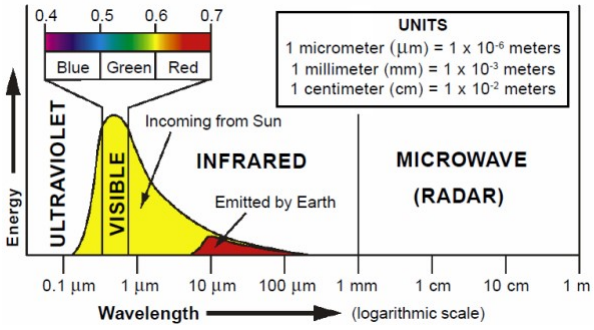
LST – Land Surface Temperature

5.1 Remote Sensing Principle





115	111	71	67	74
111	89	52	77	95
87	66	74	87	80
89	64	102	125	90
70	65	113	144	119



http://www.remote-sensing.net/concepts.html

5.1 Remote Sensing Principle

Stefan-Boltzmann law: The thermal energy radiated by a **black body*** is proportional to the fourth power of the absolute temperature

* black body is ideal absober / emitter of EM energy

Black body

$$M = \sigma T^4$$

M - thermal energy
T - absolute temperature
σ - the Stefan–Boltzmann constant

Real surfaces

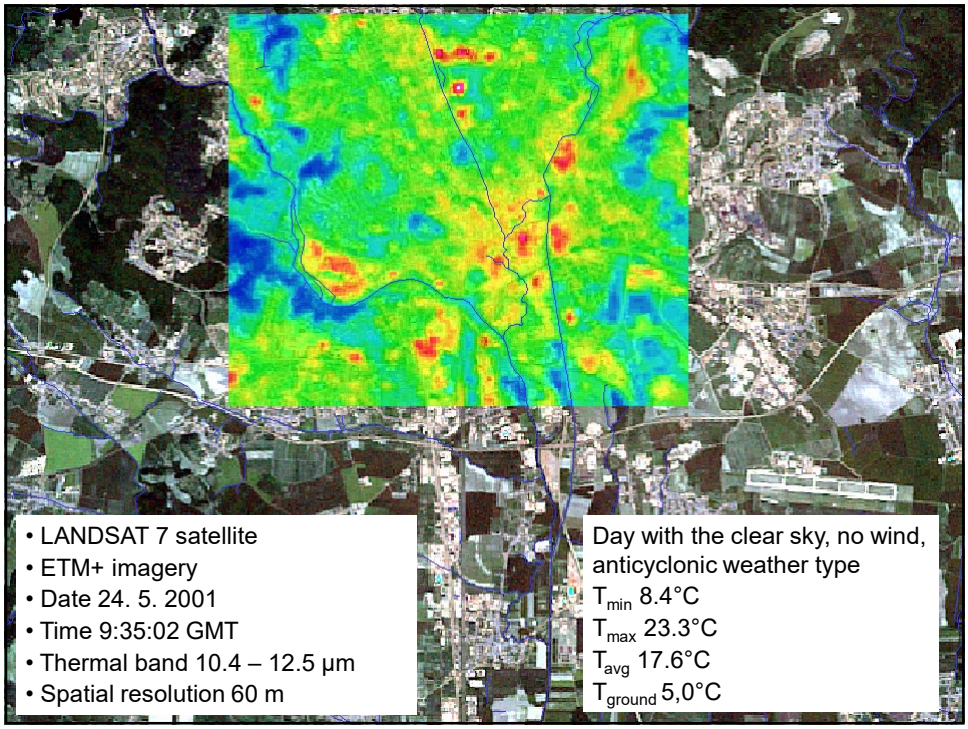
$$M = \varepsilon \sigma T^4$$

ε - emissivity

Emissivity is the measure of an object's ability to emit infrared energy. Emitted energy indicates the temperature of the object. Emissivity can have a value from 0 (shiny mirror) to 1.0 (blackbody). Most organic, painted, or oxidized surfaces have emissivity values close to 0.95.

There are at least **two problems** in urban remote sensing:

1) How to determine emissivity of real surfaces in highly heterogeneous urban environment
2) How to recalculate LST - Land Surface Temperature to air temperature

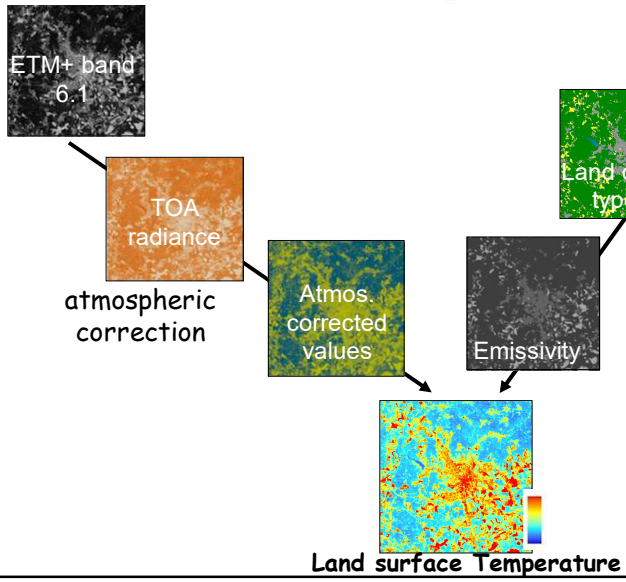


- LANDSAT 7 satellite
- ETM+ imagery
- Date 24. 5. 2001
- Time 9:35:02 GMT
- Thermal band 10.4 – 12.5 μm
- Spatial resolution 60 m

Day with the clear sky, no wind, anticyclonic weather type
T_{min} 8.4°C
T_{max} 23.3°C
T_{avg} 17.6°C
T_{ground} 5,0°C

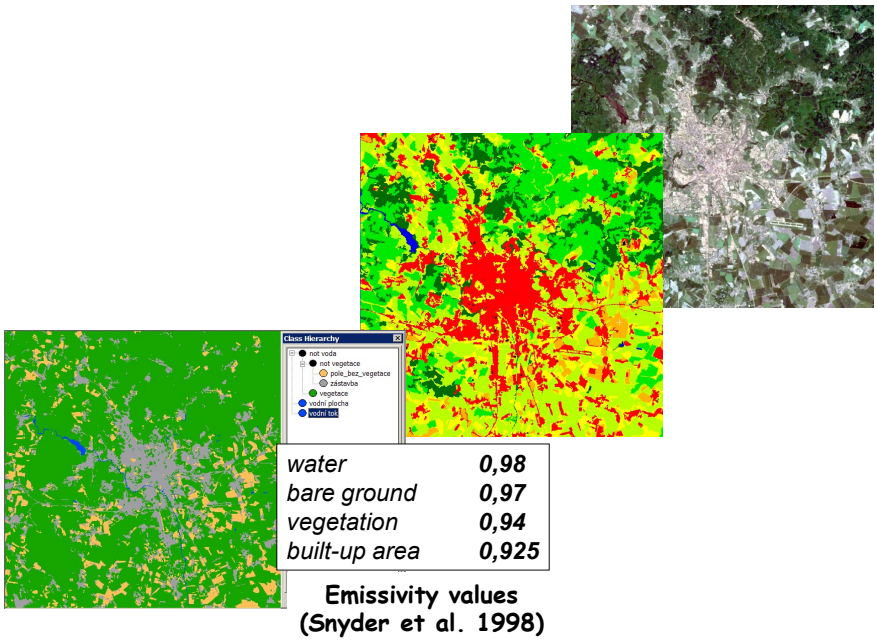
5.2 LST derivation from thermal imagery

$$L_{\text{sensor},\lambda} = \left[\varepsilon_\lambda B_\lambda(T_s) + (1-\varepsilon_\lambda)L^{\downarrow}_{\text{atm},\lambda}\right]\tau_\lambda + L^{\uparrow}_{\text{atm},\lambda}$$



Land surface Temperature

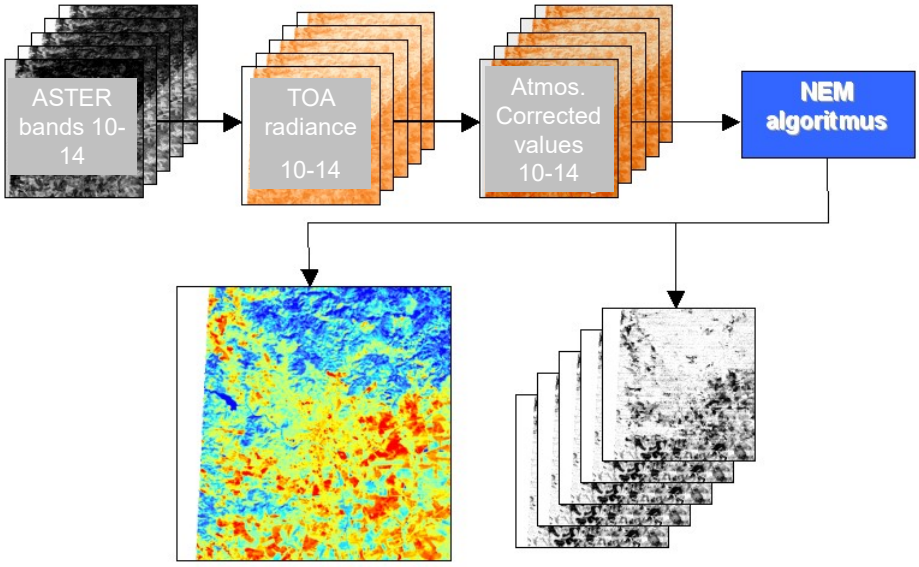
Emissivity map of basic land cover types



water	***0,98***
bare ground	***0,97***
vegetation	***0,94***
built-up area	***0,925***

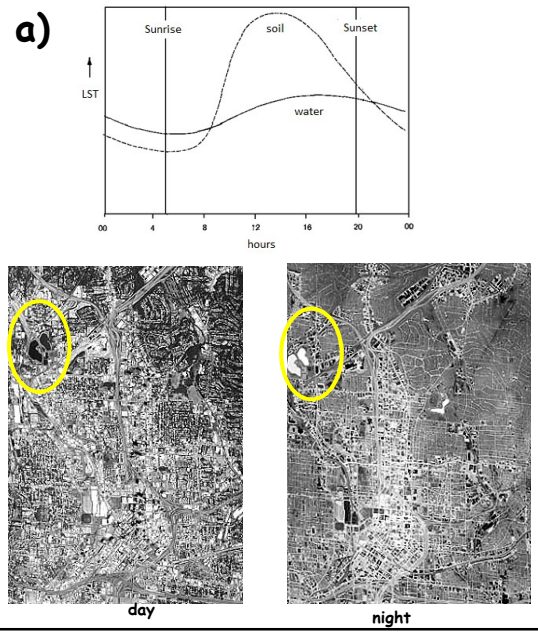
Emissivity values (Snyder et al. 1998)

LST derivation from several thermal images

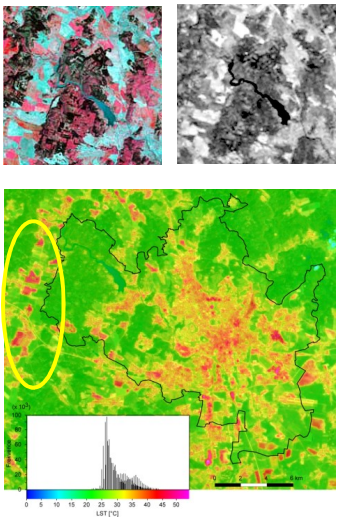


Appearance and interpretation of thermal imagery

a)



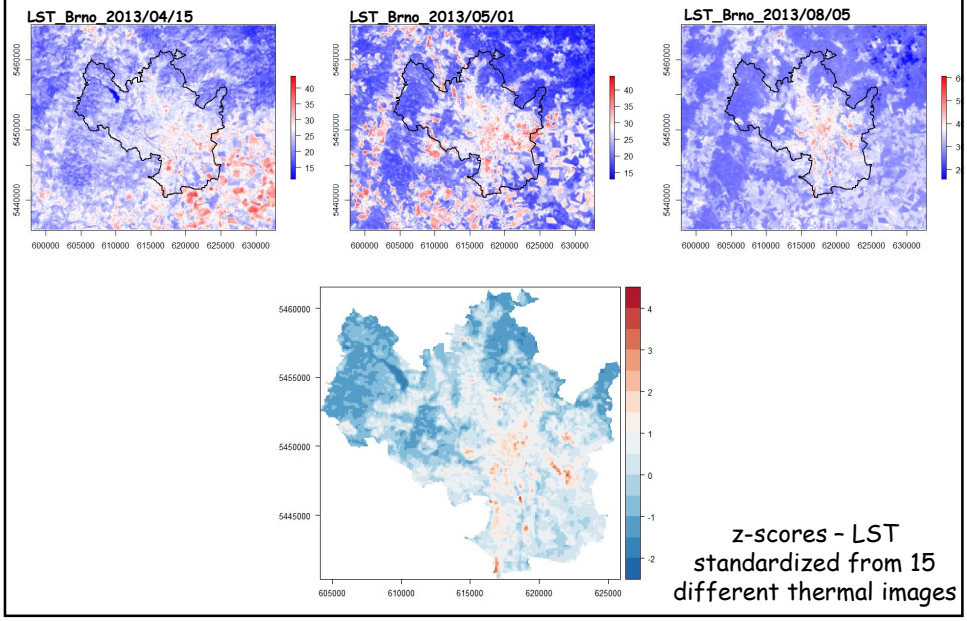
b)



Fields without vegetation can have the same LST as the center of the city

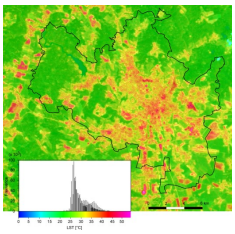
LST applications in Urban Climatology

LST spatial and temporal variability

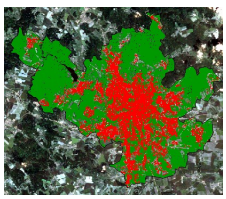


z-scores – LST standardized from 15 different thermal images

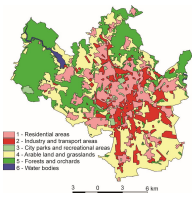
Intensity of SUHI estimate

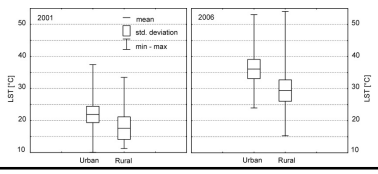


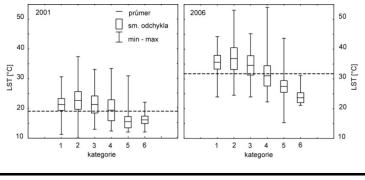
Overall SUHI magnitude



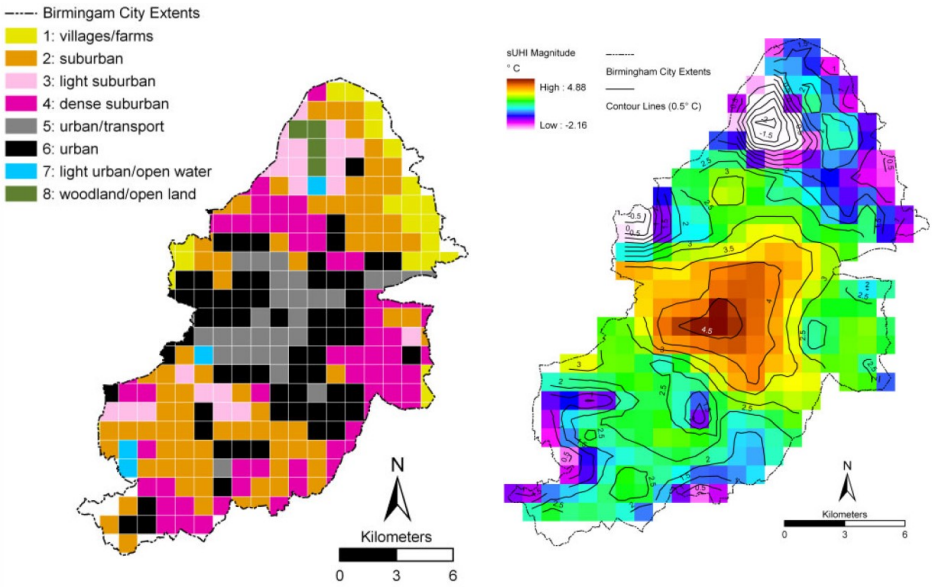
Contribution of individual LCZs to SUHI magnitude





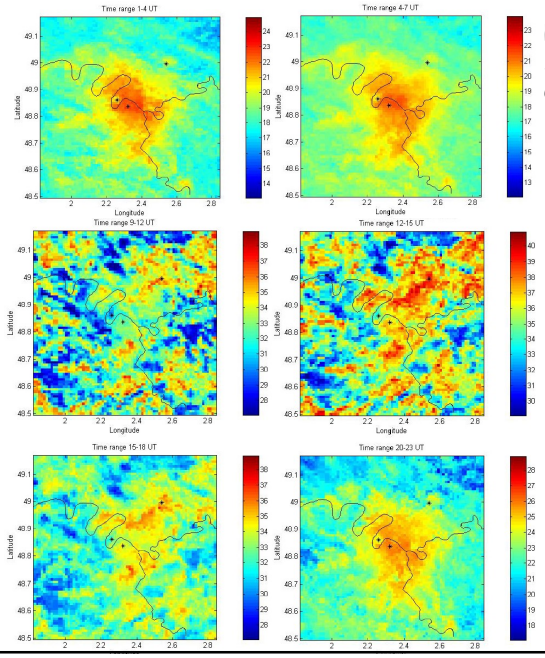


Heat waves mapping



Spatial distribution of land classification (left) and SUHI magnitude (right) within Birmingham city extents for heatwave event at 18 July 2006 (Tomlinson et al., 2010)

Urban Risk Analysis



Remote Sensing for Urban Risk Analysis: a case study of the 2003 extreme heat wave in Paris

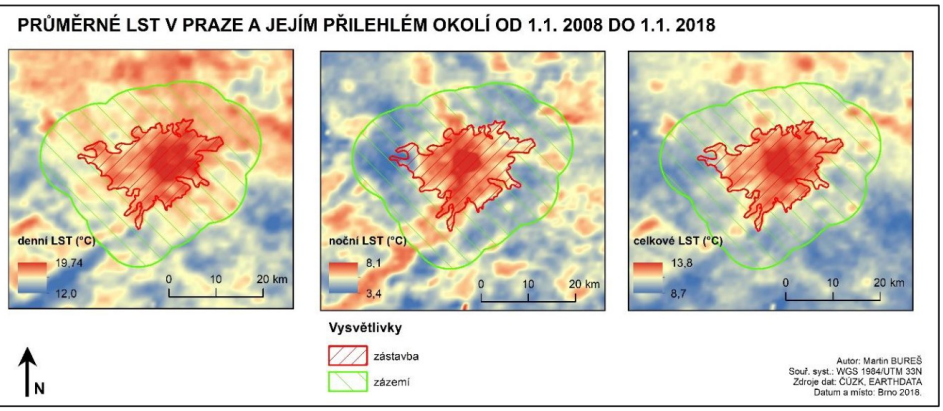
Average Land Surface Temperature infrared images over the heat wave event of August 4 to 13, 2003, for each of the diurnal time intervals. The color scales are in degrees Celsius.

Analysis was based on 50 images sensed by NOAA satellites 12, 16 and 17, over the Paris basin, from 4 to 13 August 2003.

The areas of the Paris region most vulnerable to heat stress were identified.

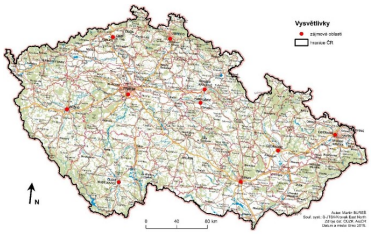
Modification of LST field due to anthropic activities in big CZ cities

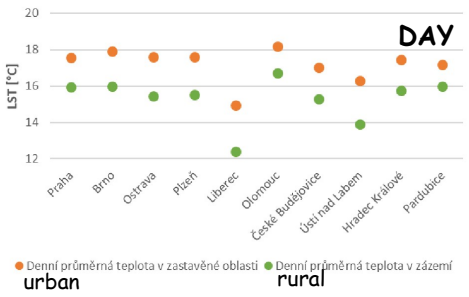
Data: eight-day composites of mean surface temperatures from the MODIS scanner with 1 x 1 km spatial resolution.

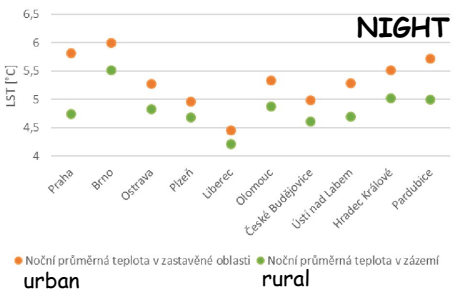


Spatial differentiation of surface temperatures (LST) in daytime (left), nighttime (middle) hours and their average (right) in Prague and its surroundings in the period 2008-2018

Modification of LST field due to anthropic activities in big CZ cities



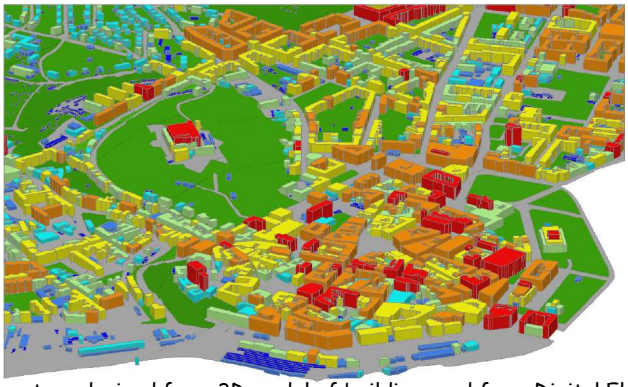




Average LST of the ten largest cities of the Czech Republic in built-up and rural areas in the period 2008-2018.

Another useful Remotely Sensed variables for UC

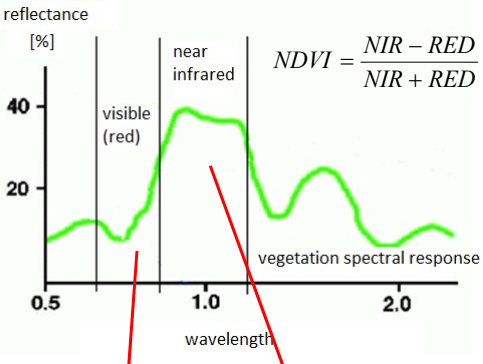
3D building model (active laser scanning)



Various parameters derived from 3D model of buildings and from Digital Elevation Model explain spatial variability of land surface temperatures.

Vegetation mapping

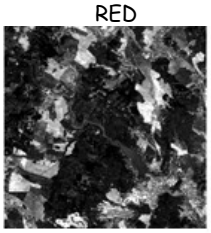
NDVI - Normalized Difference Vegetation Index



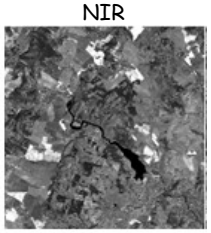
natural colors

NDVI

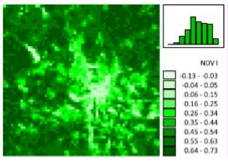
RED

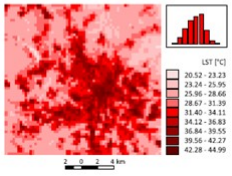


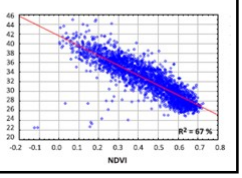
NIR



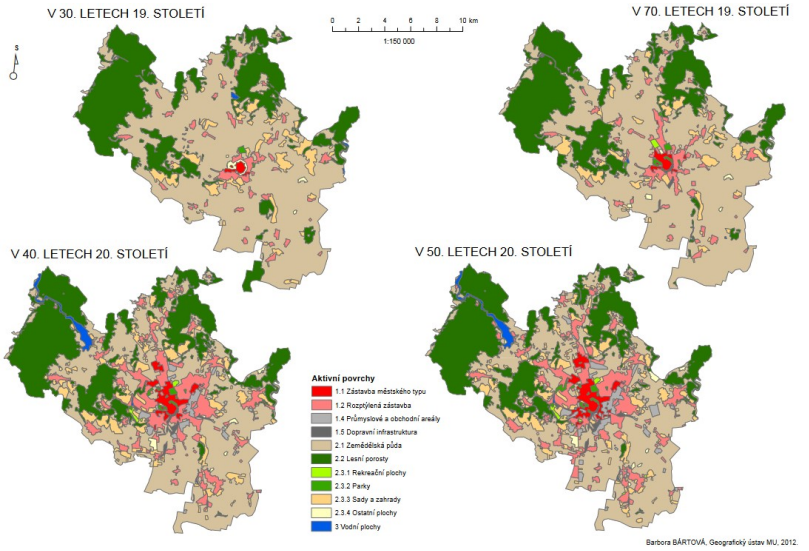
Vegetation amount and vigor strongly correlates with LSTs





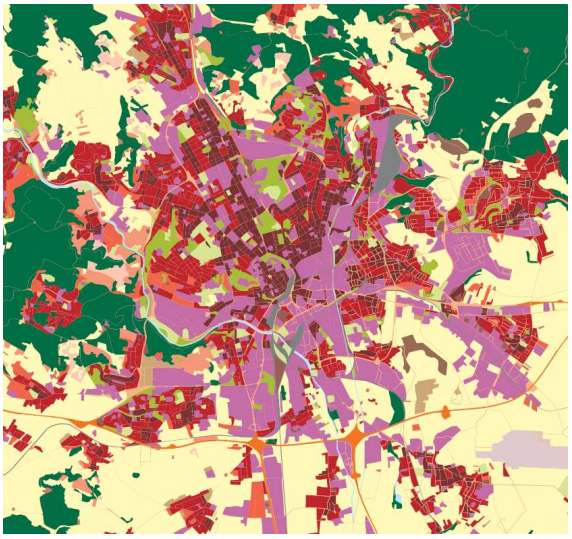


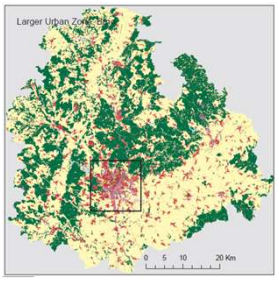
Mapping of land use / land cover changes, UHI growth

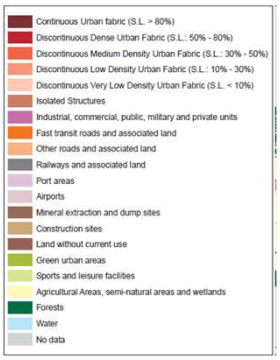


Urban atlas

LU/LC maps are derived via satellite imagery interpretation



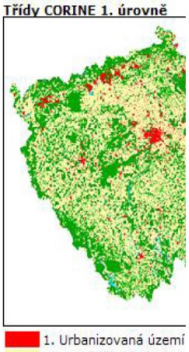




CORINE Land Cover

Úroveň 1
pro měřítka
menší než
1:1 000 000
- obsahuje 5 tříd

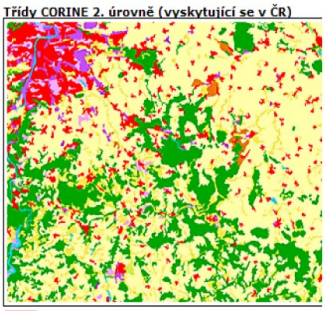
Třídy CORINE 1. úrovně



1. Urbanizovaná území
2. Zemědělské plochy
3. Lesy a polopřírodní
4. Humidní území
5. Vodní plochy

Úroveň 2
(1:500 000 až 1:1 000 000)
-obsahuje 15, tříd, v ČR 13

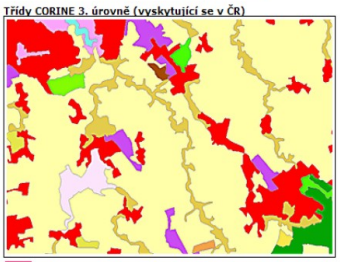
Třídy CORINE 2. úrovně (vyskytující se v ČR)



1.1. Obytné plochy
1.2. Průmyslové a obchodní zóny, komunikační sí
1.3. Doly, skládky a staveniště
1.4. Plochy umělé, nezemědělské zeleně
2.1. Orná půda
2.2. Stálé kultury
2.3. Pastviny
2.4. Různorodé zemědělské plochy
3.1. Lesy
3.2. Plochy s křovinnou a travnatou vegetací
3.3. Otevřené plochy s malým zastoupením ve bez vegetace
4.2. Vnitrozemská humidní území
5.1. Pevninské vody

Úroveň 3 (1:100 000)
- obsahuje 44 tříd, ČR 28.

Třídy CORINE 3. úrovně (vyskytující se v ČR)



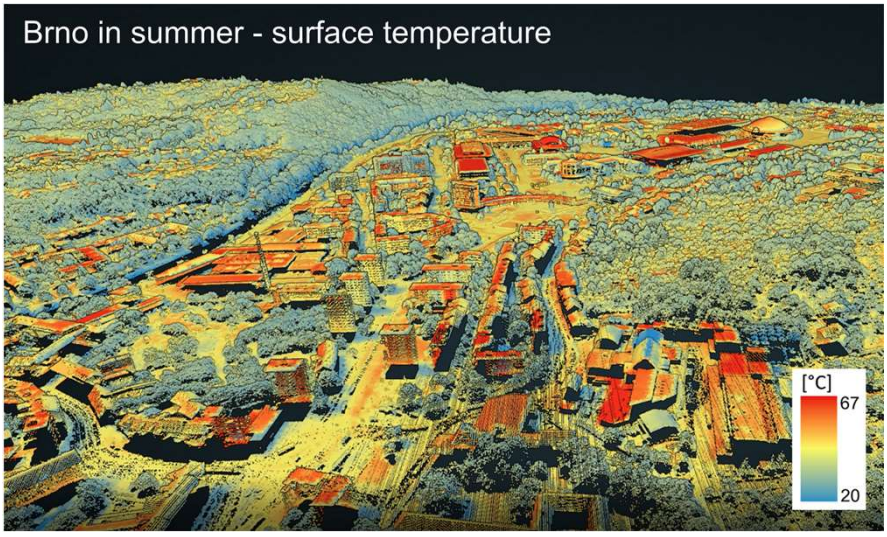
1.1.1. Souvislá městská zástavba
1.1.2. Nesouvislá městská zástavba
1.2.1. Průmyslové a obchodní areály
1.2.2. Silniční a železniční síť s okolím
1.2.3. Přístavy
1.2.4. Letiště
1.3.1. Oblasti současné těžby surovin
1.3.2. Haldy a skládky
1.3.3. Staveniště
1.4.1. Městské zelené plochy
1.4.2. Sportovní a rekreační plochy
2.1.1. Nezavlažovaná orná půda
2.2.1. Vinice
2.2.2. Sady, chmelnice a zahradní plantáže
2.3.1. Louky a pastviny
2.4.2. Směsice polí, luk a trvalých plodin
2.4.3. Zemědělské oblasti s přirozenou vegetací
3.1.1. Listnaté lesy
3.1.2. Jehličnaté lesy
3.1.3. Smíšené lesy
3.2.1. Přírodní louky
3.2.2. Stepi a křoviny
3.2.4. Nízký porost v lese

www.cenia.cz

Aircraft remote sensing

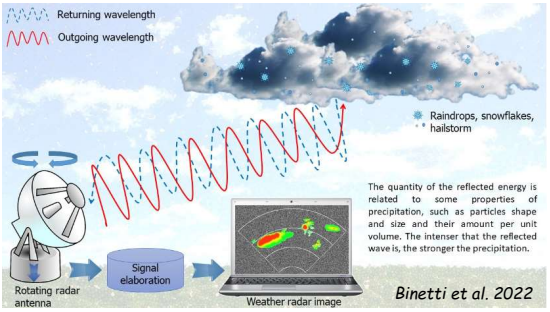
- Detailed LST mapping
- Urban Vegetation and Ecology Monitoring

CzechGlobe
CZECHGLOBE
Global Change Research Institute, CAS

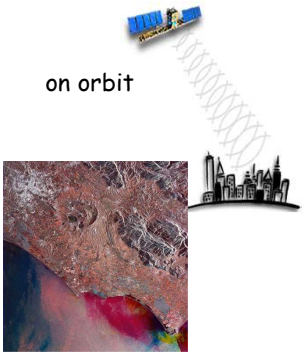


Weather RADAR

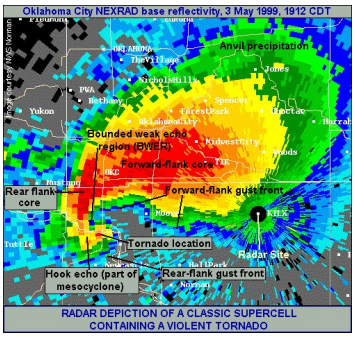
active system ground based



on orbit

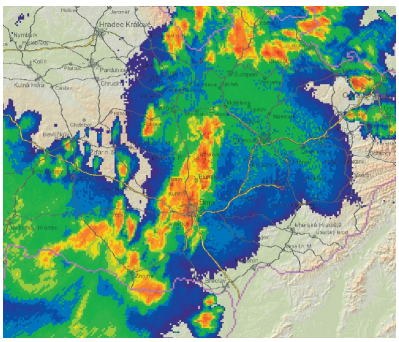


- precipitation monitoring
- real-time („now-casting")
- lower atmosphere 3D structure
- severe weather phenomena (thunderstorms, hails, tornadoes,…)

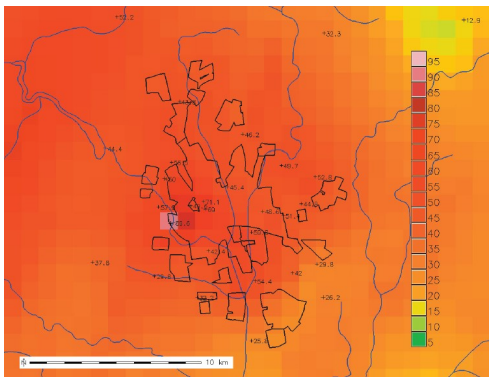


https://climavision.com/resources/what-is-weather-radar-guide/

Precipitation and weather RADAR



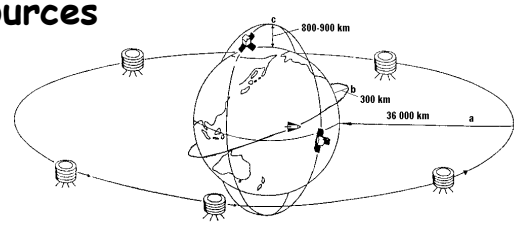
Spatial distribution of radar reflectivity (maximum values in vertical direction) measured at meteorological radars Skalky and Brdy at 15 July 2009, 19:25 hours of central European summer time

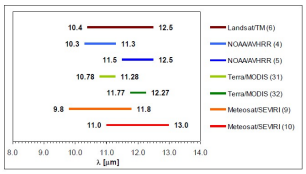


Spatial distribution of daily precipitation totals (mm) computed as a **combination of radar-based precipitation estimate and rain-gauge measurements** from 15 July 2009 (measured at 16 July 2009, 08 h CEST). Spatial distribution of precipitation totals is given in 1 x 1 km grid

LST satellite data sources

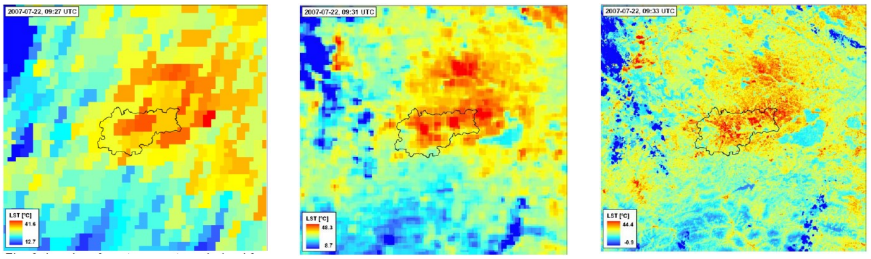
- spatial resolution
- spectral resolution
- time resolution





- Meteorological satellites
- Satellite systems for environmental applications

LST of Krakow (Poland) derived form Meteosat, NOAA, and Landsat satellite data

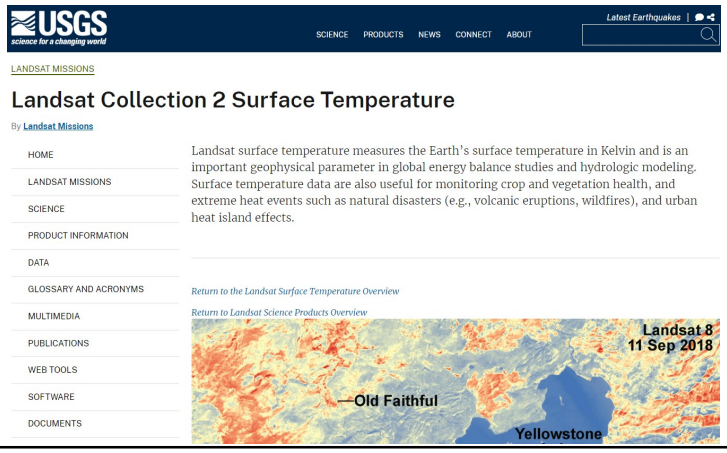


Walawender and Hajto, 2008

LST data sources

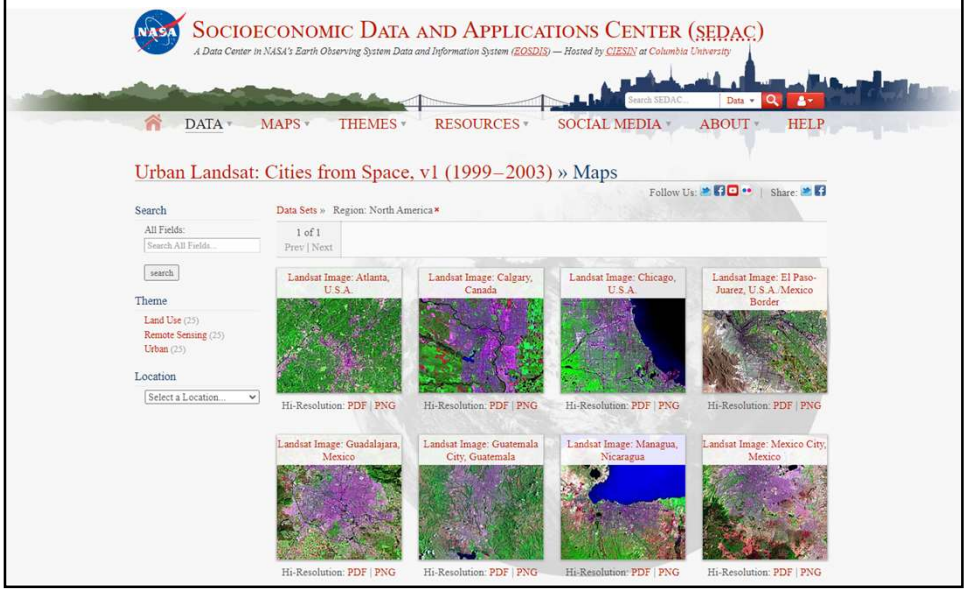
- LST calculated from raw thermal imagery and metadata
- LST offered as a standard product

https://www.usgs.gov/landsat-missions/landsat-collection-2-surface-temperature



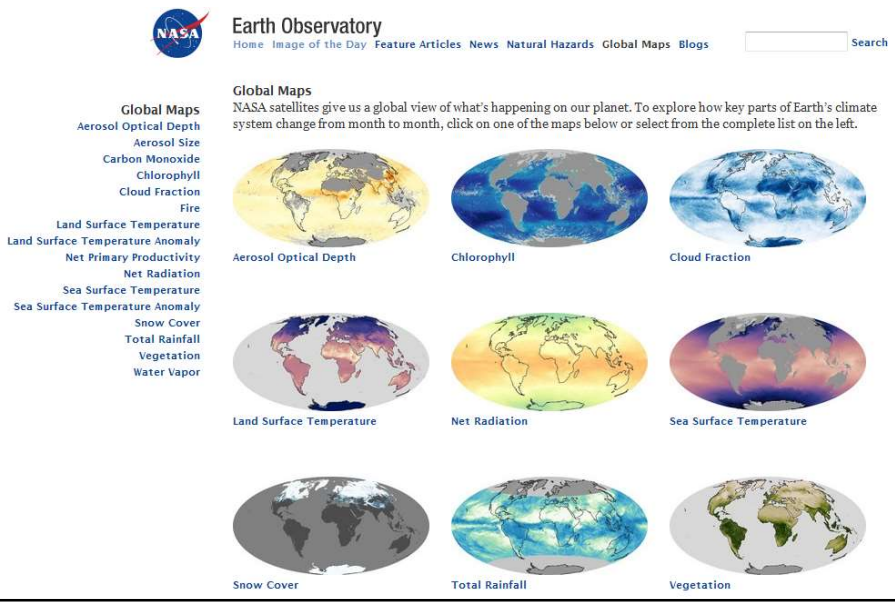
Cities from Space

https://sedac.ciesin.columbia.edu/data/set/ulandsat-cities-from-space



Satellite climatology

http://earthobservatory.nasa.gov/



5.5 Final remarks and questions

1. What are limitations of URS in terms of spectral, spatial and temporal resolution?
2. What are the main benefits of URS for heat wave studies compared to air temperature analysis?
3. How can be URS used for practical urban planning, regional development and for better adaptation to climate change?