Analysis of the impact of different temporal aggregation techniques of land surface temperature on SUHI indicators and the relationship of surface temperature with population density and night lighting

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Outline

- Motivation and aim
- Data and methodology
- Study site
- SUHI indicators
- Results
- Conclusions

MOTIVATION

- Ph.D. thesis : *"Anthropogenic heat flux estimation method by means of satellite data and spatial GIS data"*

- Current work is the last one devoted for LST and SUHI

- Next step: Sensible heat flux – from satellite and scintillometer (with University of Łódź, Poland)

MOTIVATION

- In Poland during transitional seasons the synoptic conditions may be very different from year to year
  - question arises: what is a mean SUHI in transitional seasons ?
- **AIM:** to find an long-term average LST image and SUHI intensity for transitional seasons in Warsaw, Poland
  - Season =~ at least 30 days
- However, in terms of high amount of data accumulation (15 years):
  - low quality observation ≠ high quality observation !
  - mean LST from 2 days ≠ mean LST from 7 days !

Methodology

- **Weighted arithmetic mean** was applied in order to obtain **the most representative** long-term mean LST image (15 years)

- Weights were based on MODIS Quality Control metadata
  - Clear-sky days (1-8)
  - LST retrieval errors (1-5)
  - combined

LST retrieval errors	**weight**
good quality…	**5**
average LST error <= 1K	**4**
average LST error <= 2K	**3**
average LST error <= 3K	**2**
average LST error > 3K	**1**
LST not available	**0**

Moderate Resolution Imaging Spectroradiometer (MODIS)

- **<u>MODIS level 3 products (MOD11A2) – 8 day mean LST</u>**
  - Spring and Autumn equinox , day and night
  - 15 years (2000 – 2014) - Terra satellite only!
  - For each month 4 products (consecutive 32 days of observation)
  - Result : 15 years x 4 products z 2 seasons x 2 cases (d/n) = 240 rasters (1920 satellite acquisitions)

- **Night-time lights –** NPP VIIRS DNB Cloud Free Composites
  - Two Months Composite (2012/4/18-26 and 2012/10/11-23)
  - ~0.33 km resolution, 14 bit

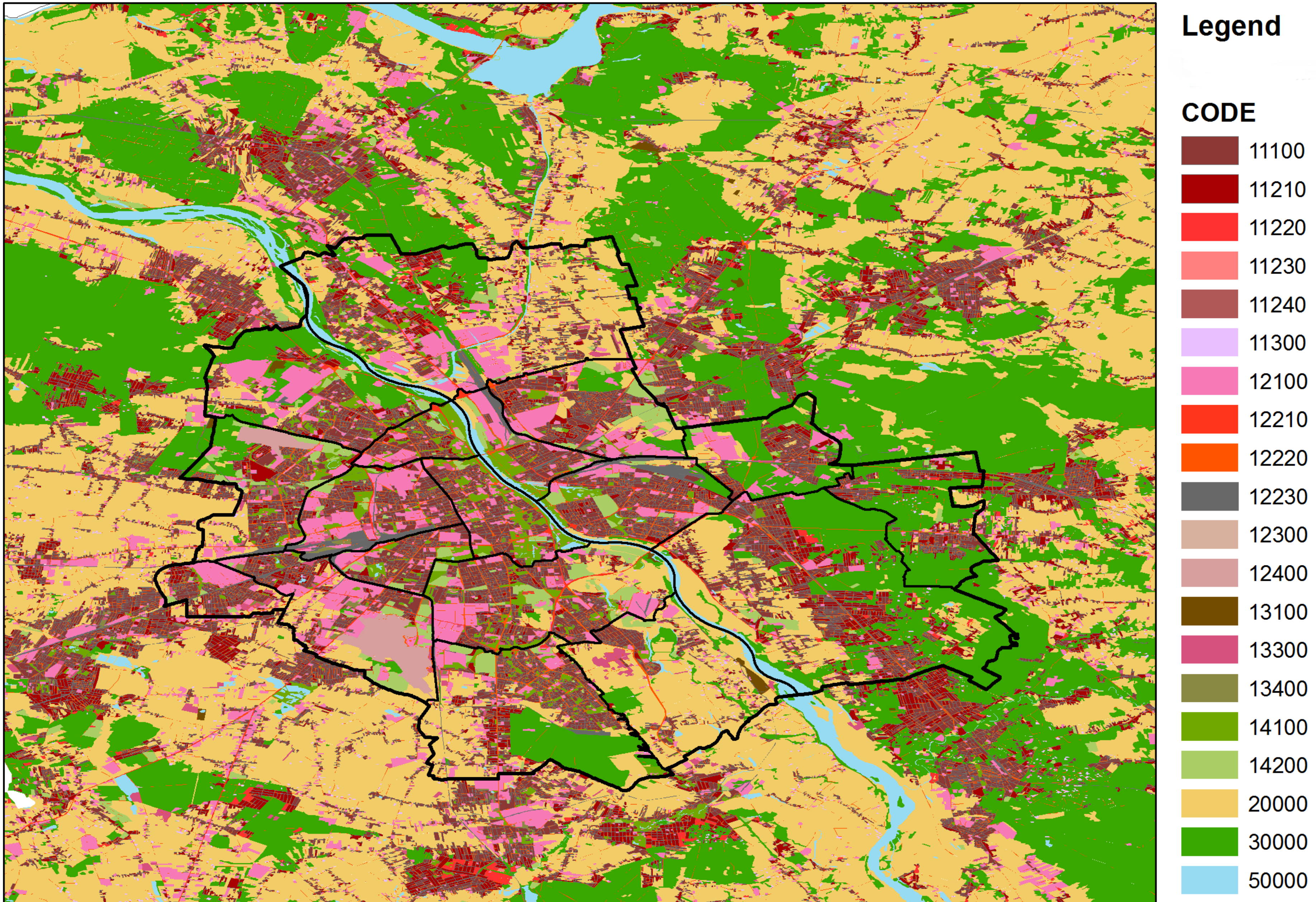
- **Population density** – 1km, Geostat, GEOSTAT_Grid_POP_1K_2011_V1_0

- **Impervious surface area** – 1km, NOAA (Elvidge et al., 2007)

Methodology

- Promotion of the best quality and a number of cloudless observations
  - 5 exponential powers applied to each weight
- Analysis of MODIS QC impact on urban LST pattern
  - Simple arithmetic mean without accounting for MODIS QC minus weighted mean with accounting for MODIS QC
- ISA, population density and night-time lights have a clear pattern in urban areas (analogical to LST)
  - How does temporal aggregation with growing exponential power changes the relationship with LST? (LST & ISA, POP, NLT)

STUDY SITE


Legend
CODE
11100
11210
11220
11230
11240
11300
12100
12210
12220
12230
12300
12400
13100
13300
13400
14100
14200
20000
30000
50000

SUHI indicators

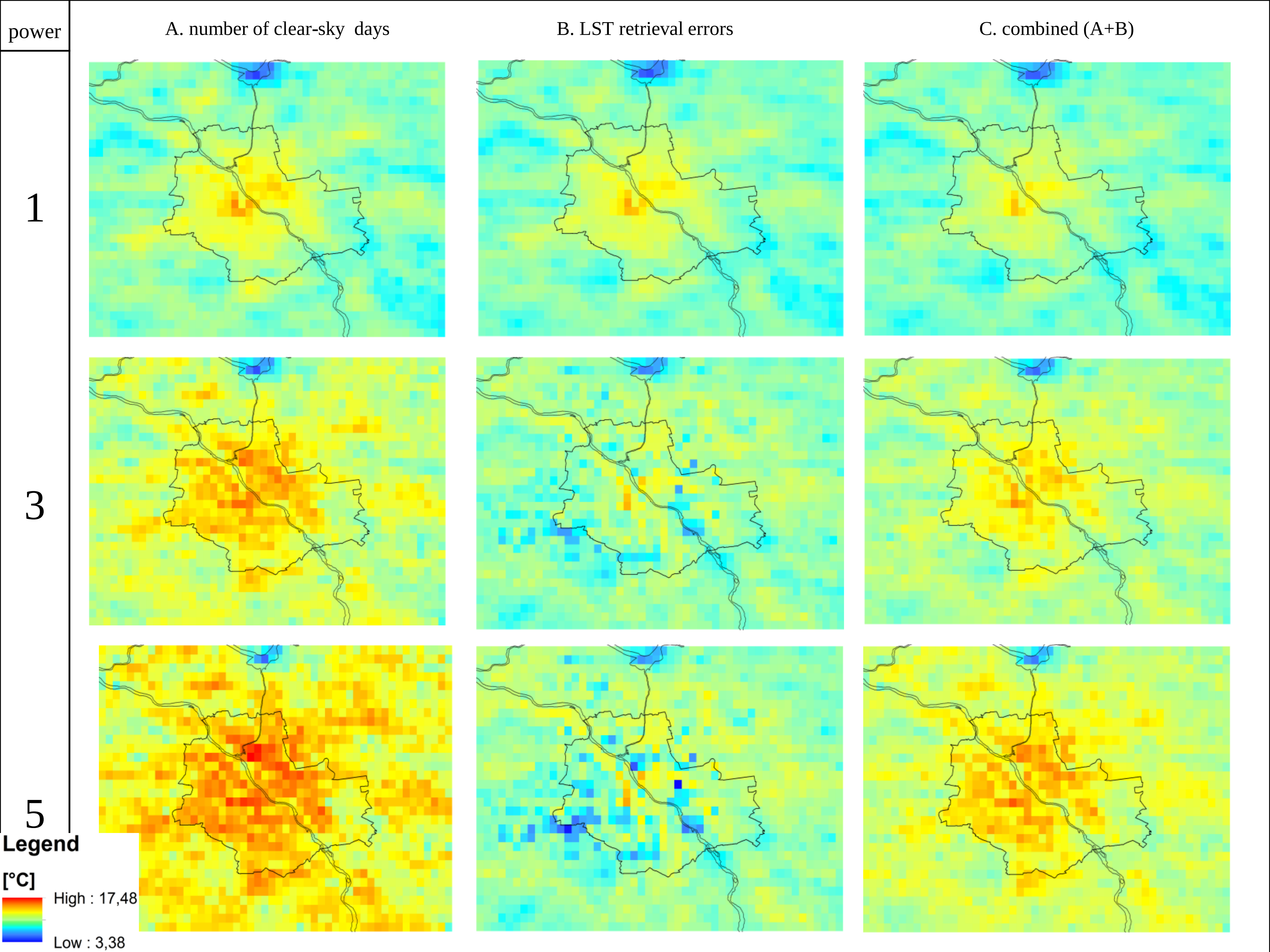
- According to the remarks given by Schwarz et al., 2011, 2012 we used several indicators in parallel

	Name	Brief definition
1.	**Standard Deviation**	Standard deviation of LST values within city's administrative borders
2.	**Magnitude**	Maximum LST – mean LST (within city borders)
3.	**Range**	Maximum LST – lowest LST (within city borders)
4.	**Urban mean – other**	Mean LST (within city borders) – mean LST (areas outside borders within a buffer)
5.	**Urban mean – water**	Mean LST (within city borders) – LST of Zalew Zegrzyński Lake
6.	**Urban mean - agriculture**	Mean LST (within city borders) – LST of cropland pixel
7.	**Inside urban – inside rural**	within city borders: mean LST of artificial areas – mean LST of natural areas
8.	**Urban core – rural ring**	mean LST of artificial areas within city borders – mean temperature in ring of pixels outside the city
9.	**Urban core – deep forest**	mean LST of artificial areas within city borders – pixel covered with dense forest (Kampinos National Forest)
10.	**Hot island**	Area (px) with LST higher than mean + one std
11.	**Micro UHI**	Percentage of area (without water surfaces) with LST higher than warmest LST associated with tree canopies

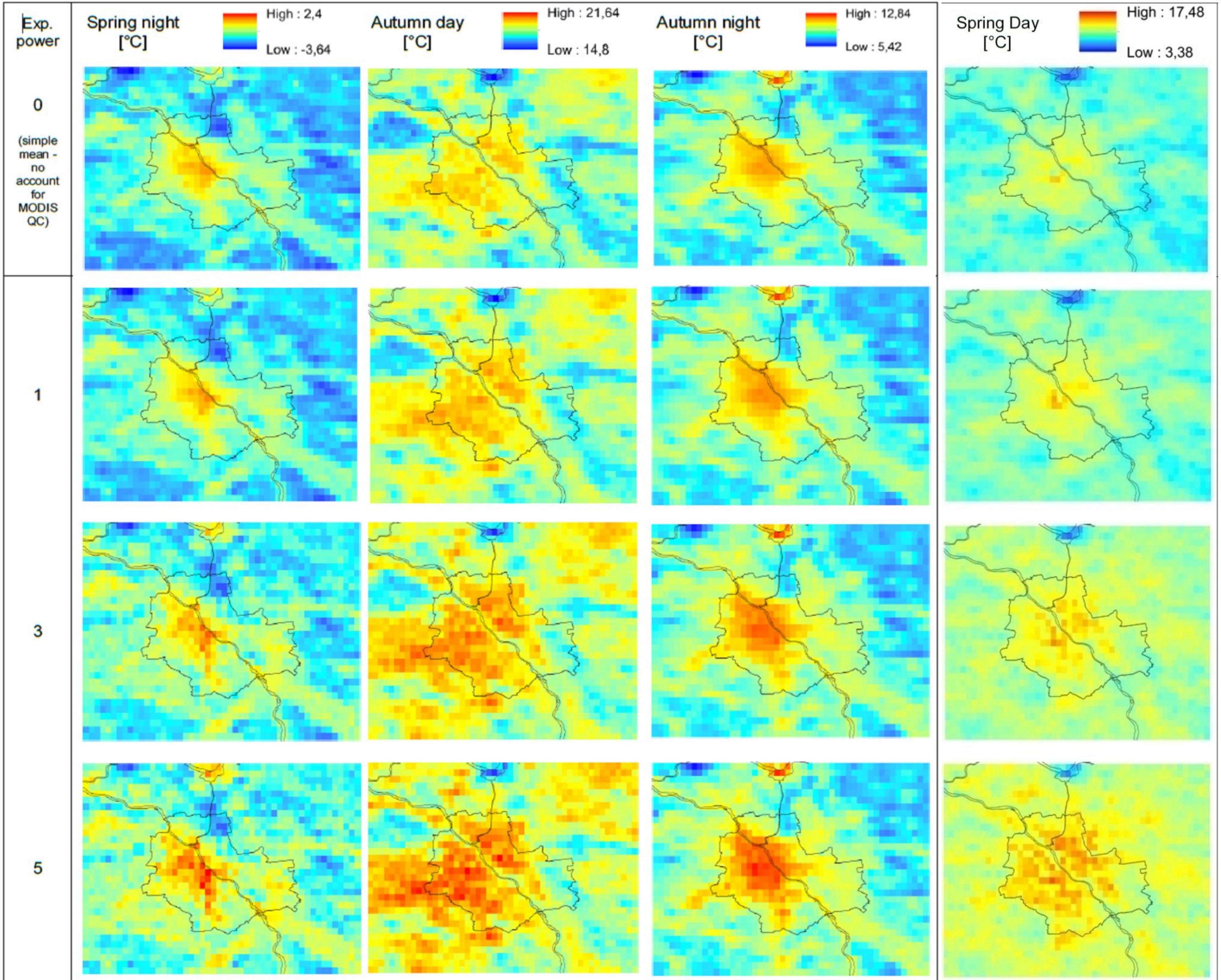
- RESULTS

3 types of weights – which is the best?

- Spring day case


power
A. number of clear-sky days
B. LST retrieval errors
C. combined (A+B)
1
3
5
Legend
[°C]
High : 17,48
Low : 3,38

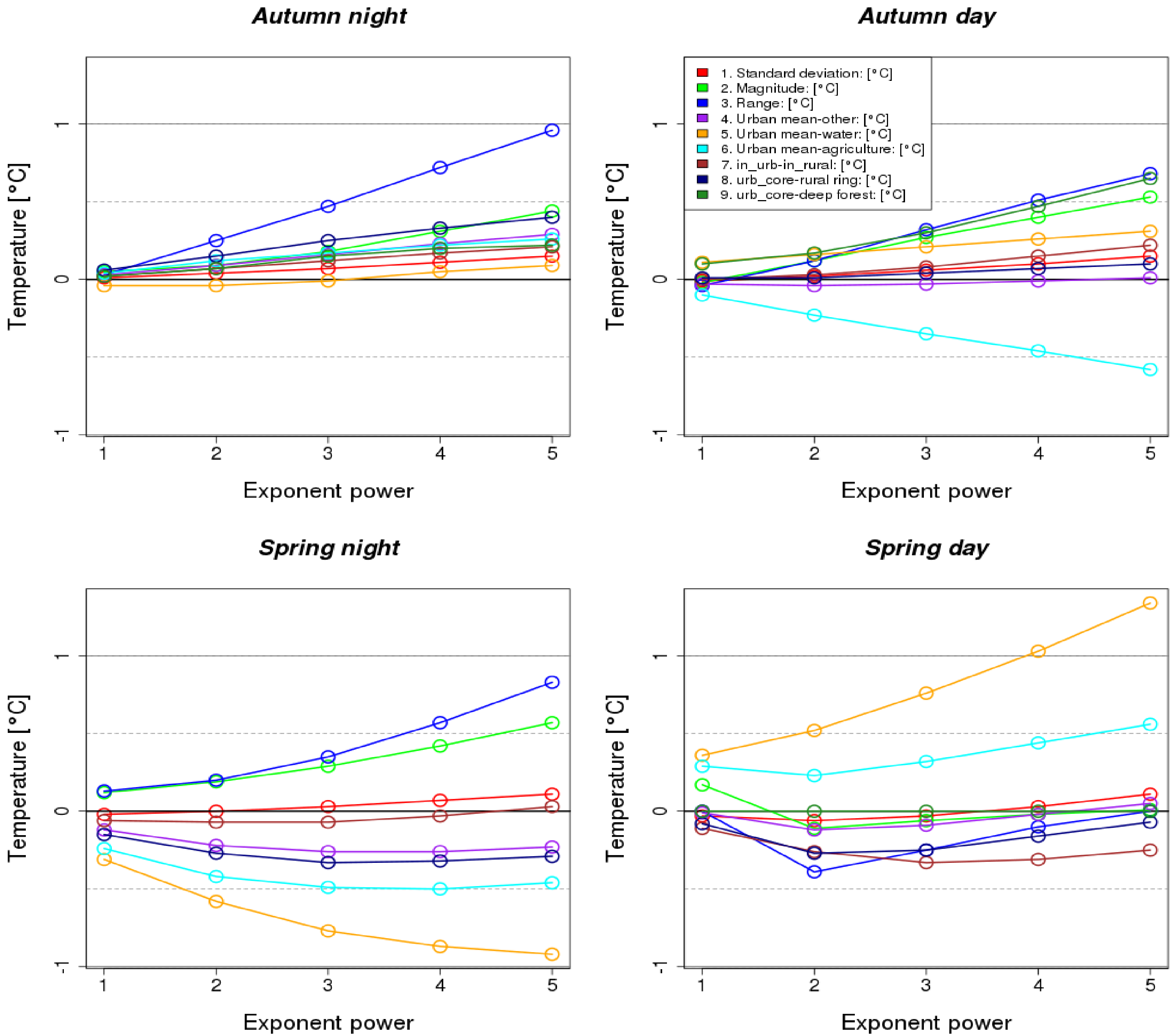
LST spatial distribution in different seasons


Exp. power
Spring night [°C]
High : 2,4
Low : -3,64
Autumn day [°C]
High : 21,64
Low : 14,8
Autumn night [°C]
High : 12,84
Low : 5,42
Spring Day [°C]
High : 17,48
Low : 3,38
0
(simple mean - no account for MODIS QC)
1
3
5

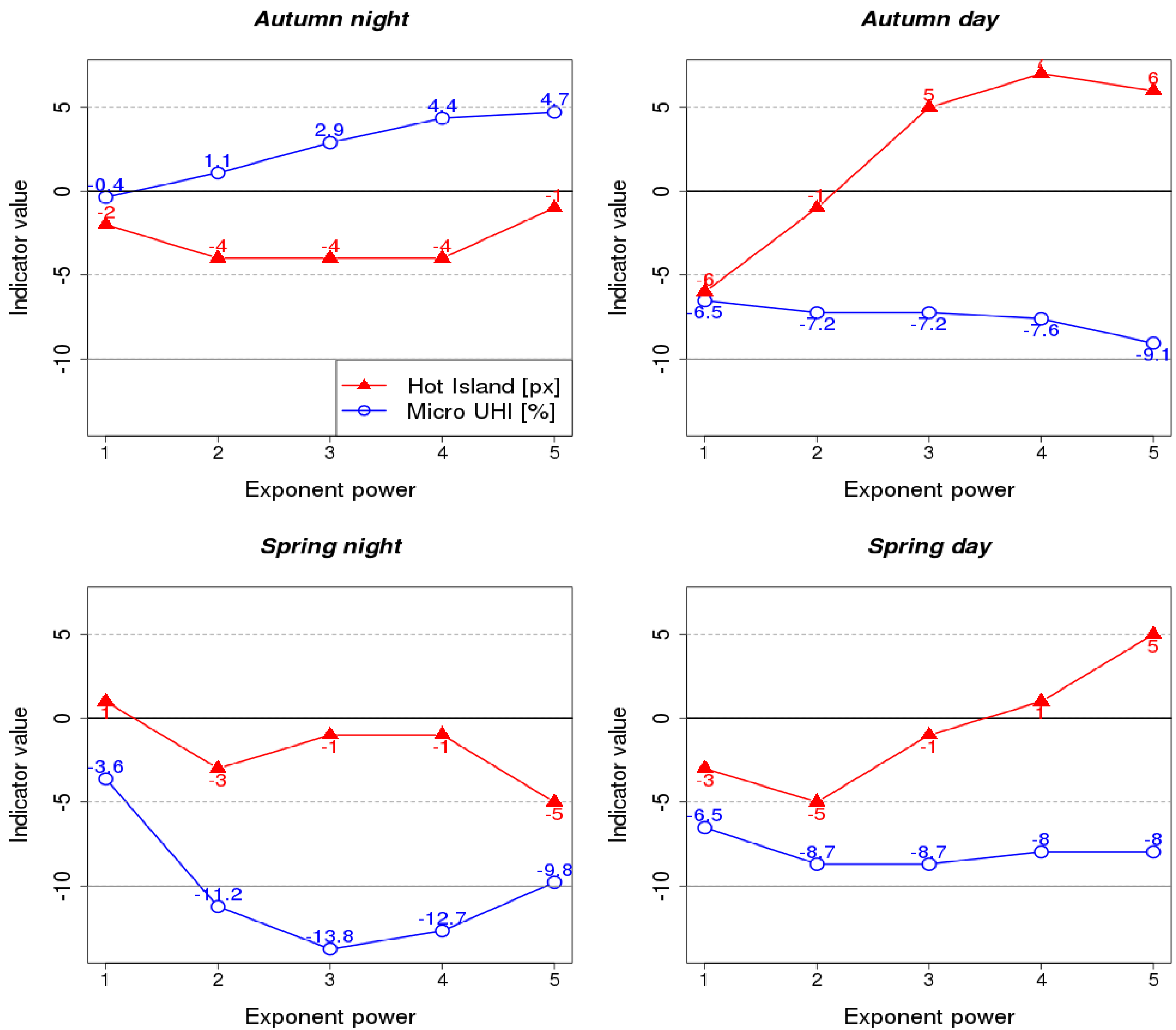
SUHI intensity

	[°C]	Autumn day	Autumn night	Spring day	Spring night
1.	**Standard Deviation**	0,86	0,97	1,15	0,83
2.	**Magnitude**	1,39	1,88	3,55	1,9
3.	**Range**	3,92	4,56	6,75	4,51
4.	**Urban mean - other**	0,85	1,49	1,5	1,15
5.	**Urban mean - water**	4,26	-1,71	5,93	-0,02
6.	**Urban mean - agriculture**	-0,04	1,4	1,64	1,05
7.	**Inside urban – inside rural**	1,08	1,28	1,57	1,01
8.	**Urban core – rural ring**	1,08	2,17	1,87	1,63
9.	**Urban core – deep forest**	3,03	1,45	4,21	0,6
10.	**Hot island [pixels]**	48	65	46	52
11.	**Micro UHI [%]**	88,77	52,9	80,8	42,75

SUHI intensity: difference simple mean – weighted mean



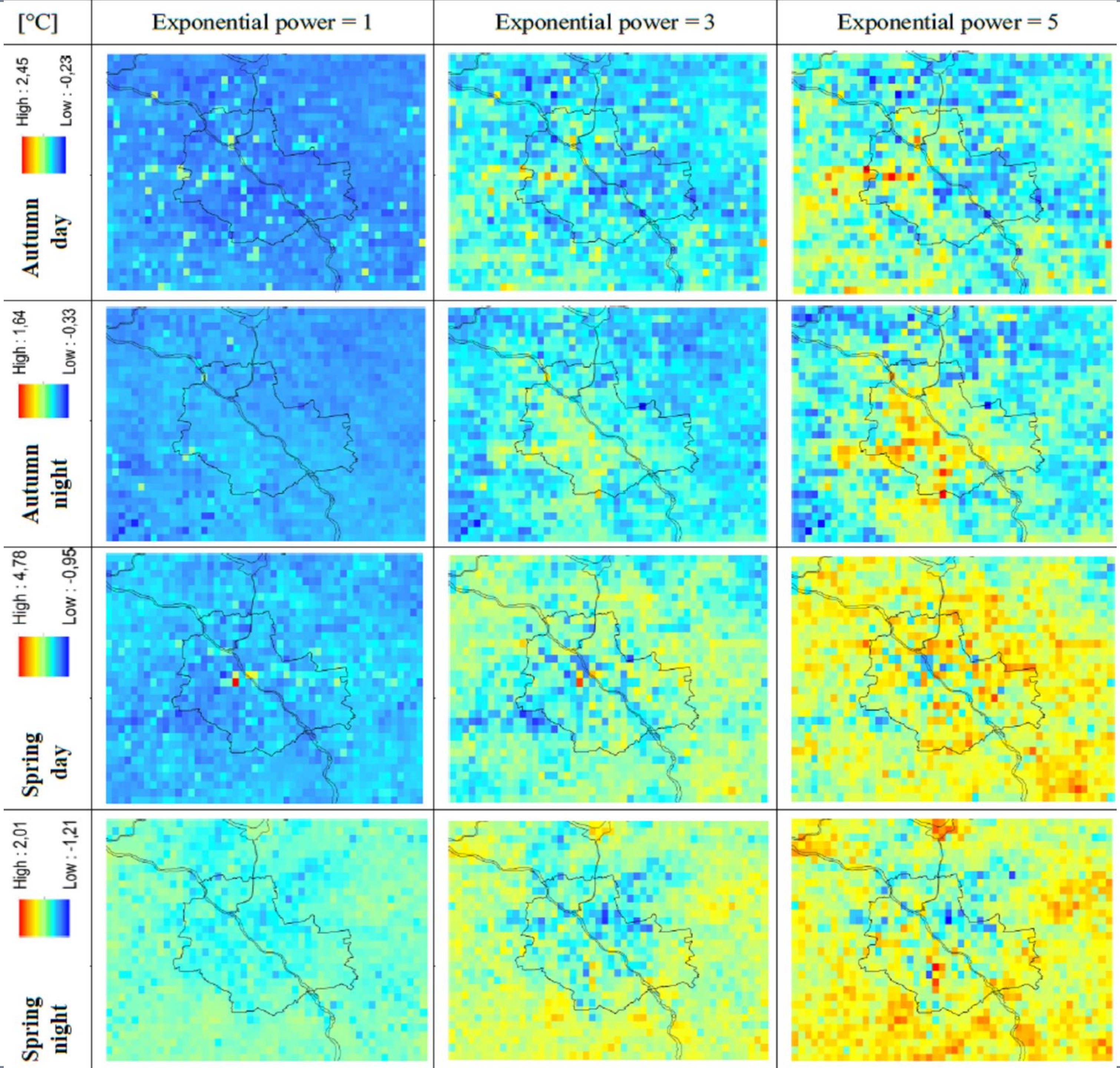
Autumn night
Autumn day
Spring night
Spring day
Temperature [°C]
Exponent power
1. Standard deviation: [°C]
2. Magnitude: [°C]
3. Range: [°C]
4. Urban mean-other: [°C]
5. Urban mean-water: [°C]
6. Urban mean-agriculture: [°C]
7. in_urb-in_rural: [°C]
8. urb_core-rural ring: [°C]
9. urb_core-deep forest: [°C]


Autumn night
Autumn day
Spring night
Spring day
Indicator value
Exponent power
Hot Island [px]
Micro UHI [%]
5
0
-5
-10
1
2
3
4
5
-0.4
1.1
2.9
4.4
4.7
-2
-4
-4
-4
-1
-6
-1
5
6
-6.5
-7.2
-7.2
-7.6
-9.1
1
-3
-1
-1
-5
-3.6
-11.2
-13.8
-12.7
-9.8
-3
-5
-1
1
5
-6.5
-8.7
-8.7
-8
-8

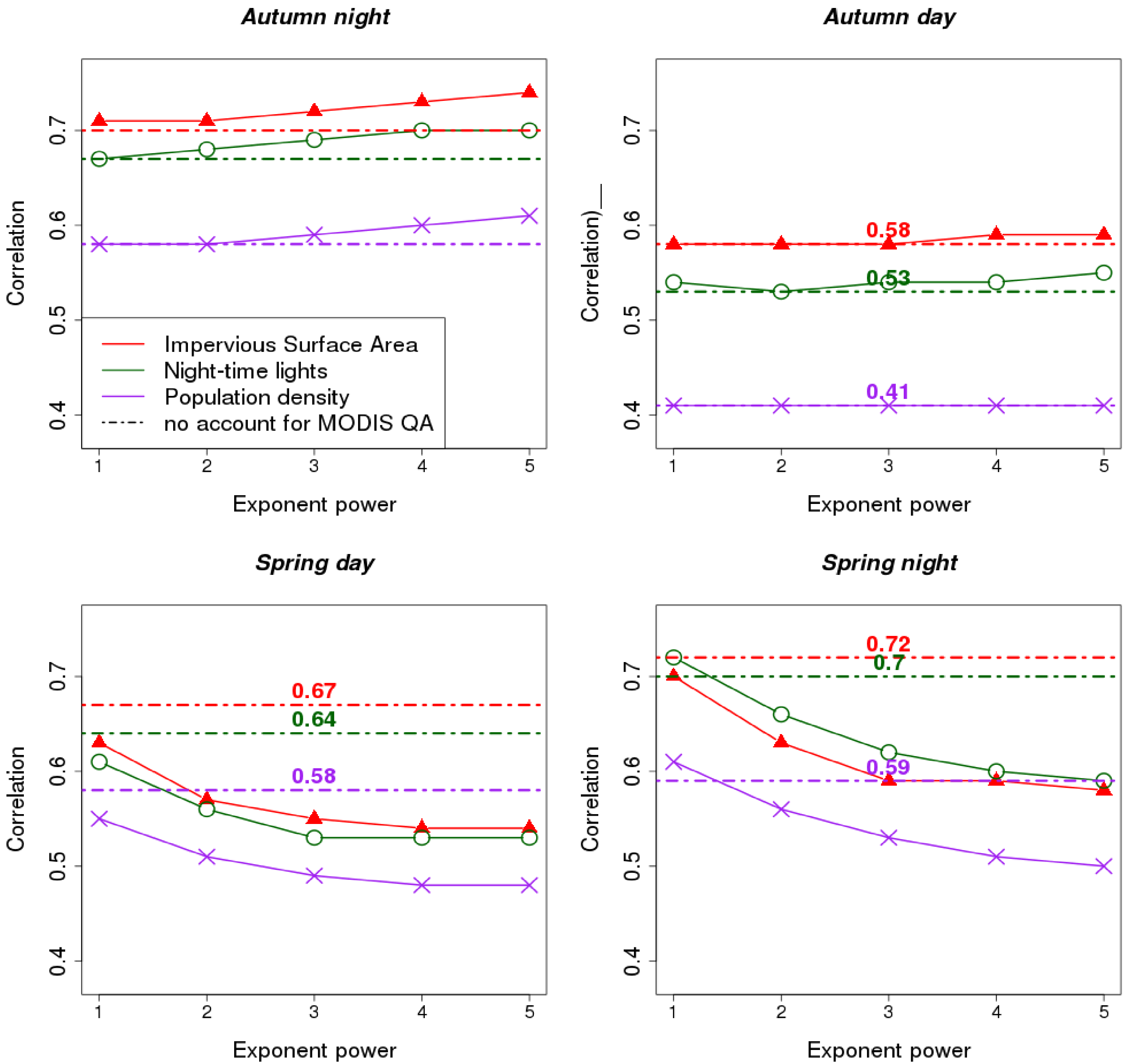
Impact of MODIS QC on urban LST pattern

Location and magnitude of differences:

Simple mean – weighted mean


[°C]
Exponential power = 1
Exponential power = 3
Exponential power = 5
High : 2,45
Low : -0,23
Autumn day
High : 1,64
Low : -0,33
Autumn night
High : 4,78
Low : -0,95
Spring day
High : 2,01
Low : -1,21
Spring night

Relationship: LST and ISA, population density, night-time lights


Autumn night
Autumn day
Spring day
Spring night
Correlation
Correlation)
Exponent power
Impervious Surface Area
Night-time lights
Population density
no account for MODIS QA
0.58
0.53
0.41
0.67
0.64
0.58
0.72
0.7
0.59
0.4
0.5
0.6
0.7
1
2
3
4
5

CONCLUSIONS

Conclusions – temporal aggregation and urban LST pattern

- Weighted mean based solely on LST retrieval errors gave **very unrealistic LST pattern**
  - The combination of weights based on LST retrieval errors and a number of clear-sky days gave the most realistic LST pattern

- The temporal aggregation process with accounting for MODIS QC metadata **has a significant impact on urban LST pattern**
  - Less significant on SUHI intensity

Conclusions – SUHI magnitude

- **Behaviour of SUHI indicators is inconsistent**, especially indicators expressed in area units
  - This reveals important inconsistencies, which may lead to discrepancies in other SUHI studies. This conclusion is consistent with the findings of Schwarz et al. 2011, where it is remarked that SUHI indicators reveal low correlations between each other

- In spite of the certainty that SUHI phenomenon does occur in the city of Warsaw in each case analysed, it is hard to conclude about its mean 15-year intensity. However, it might be stated that the mean **SUHI magnitude has at least 1 °C in each analysed season** and in specific cases might be much higher

Conclusions – LST and ISA, population density, night-time lights

- In Autumn cases, temporal composition process with accounting for MODIS QC **brings out** the urban LST pattern more apparently (increases correlation) than without accounting for QC metadata

- In Spring cases temporal aggregation process **suppresses** the urban LST pattern (decreases correlation).
  - This is consistent with variability of SUHI indicators with growing exponential power applied to weights.

- **Thank you !**
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Shortcomings of the study

- **1) The length of the analysed period the and amount of data included;** it is found that temporal aggregation with accounting for MODIS QC significantly differs from the temporal aggregation without accounting for MODIS QC metadata. However, in this study the actual impact of the MODIS QC on the final LST patterns is increased by a long period of weights accumulation (15 years) and a number of utilized rasters (at least 54). In studies devoted to shorter periods with less data included such impact might be less apparent.

- **2) The strength of the best quality and a number of clear-sky days promotion**; the highest impact of temporal aggregation with accounting for MODIS QC is revealed when a high exponential power is applied to weights during the composition process. However, this study does not give an answer what is a proper exponential power applied to weights that should be applied in similar studies. It seems logical to promote pixels with the highest quality and a maximum number of clear-sky observations, but the appropriate strength of the promotion is unknown. It should be concluded that the choice must depend on a specific case.

- **3) Applicability to other satellite sensors;** the weights applied during the composition process were explicitly based on the quality thresholds and a number of clear-sky observations indicated by MODIS Quality Control SDS. However, applicability of the presented methodology for other satellite instruments is limited only to those products that contains appropriate metadata.