Revisiting the Seasonality of Surface Urban Heat Islands

Panagiotis Sismanidis[1], Benjamin Bechtel[1], Mike Perry[2], Darren Ghent[2]

1. Institute of Geography, Ruhr University Bochum, Germany
2. National Centre for Earth Observation, Department of Physics and Astronomy, University of Leicester, UK

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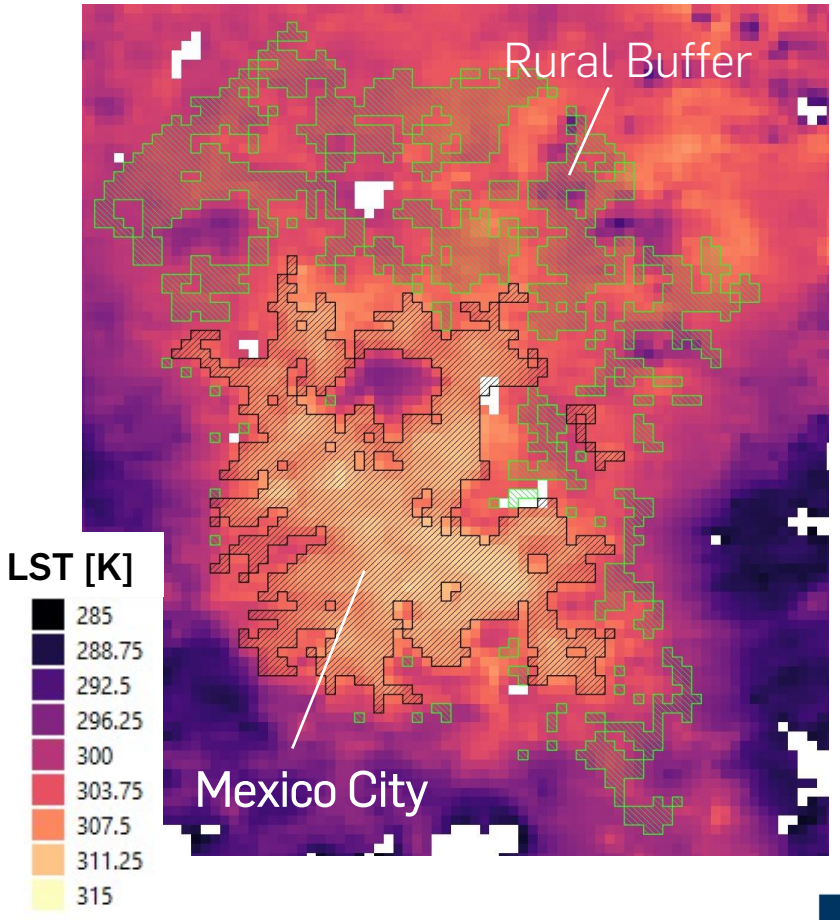
Surface Urban Heat Islands

- Cities are warmer than their surroundings.
- The difference between urban and rural LST is known as SUHI Intensity (SUHII):

$$\mathrm{SUHII} = \overline{\mathrm{LST}}_{\mathrm{urban}} - \overline{\mathrm{LST}}_{\mathrm{rural}}$$

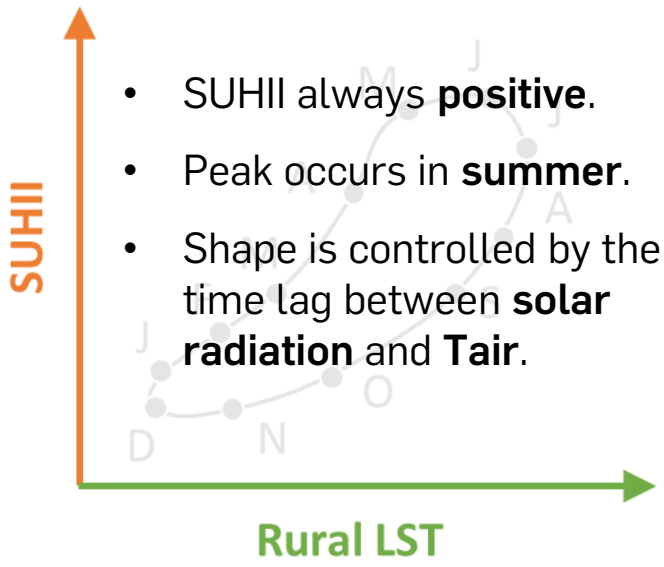
- SUHII is a function of both urban and rural features.



SUHII Seasonal Hysteresis

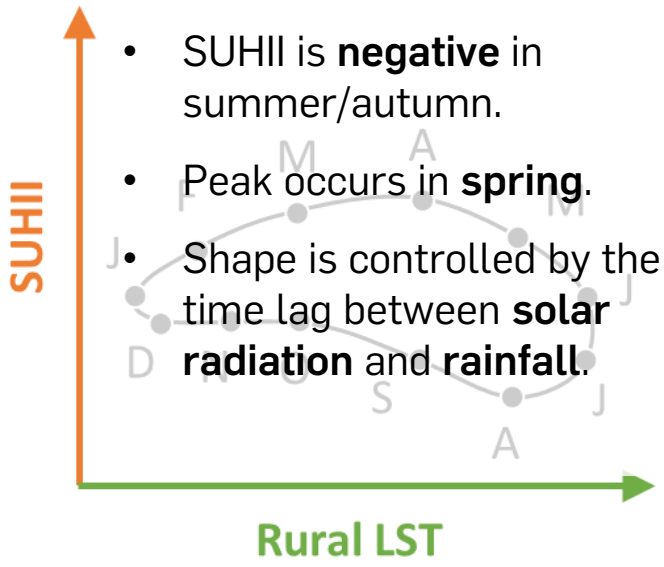
- The seasonal variation of SUHII exhibits a rate dependent hysteresis that strongly depends on local climate conditions.

Wet Climates: Concave-Up Loop



- SUHII always **positive**.
- Peak occurs in **summer**.
- Shape is controlled by the time lag between **solar radiation** and **Tair**.

Dry Climates: Concave-Down Loop



- SUHII is **negative** in summer/autumn.
- Peak occurs in **spring**.
- Shape is controlled by the time lag between **solar radiation** and **rainfall**.

$$\mathrm{SUHII} = \overline{\mathrm{LST}}_{\mathrm{urban}} - \overline{\mathrm{LST}}_{\mathrm{rural}}$$

Manoli et al. (2020); Bechtel et al. (2019); Zhou et al. (2013)

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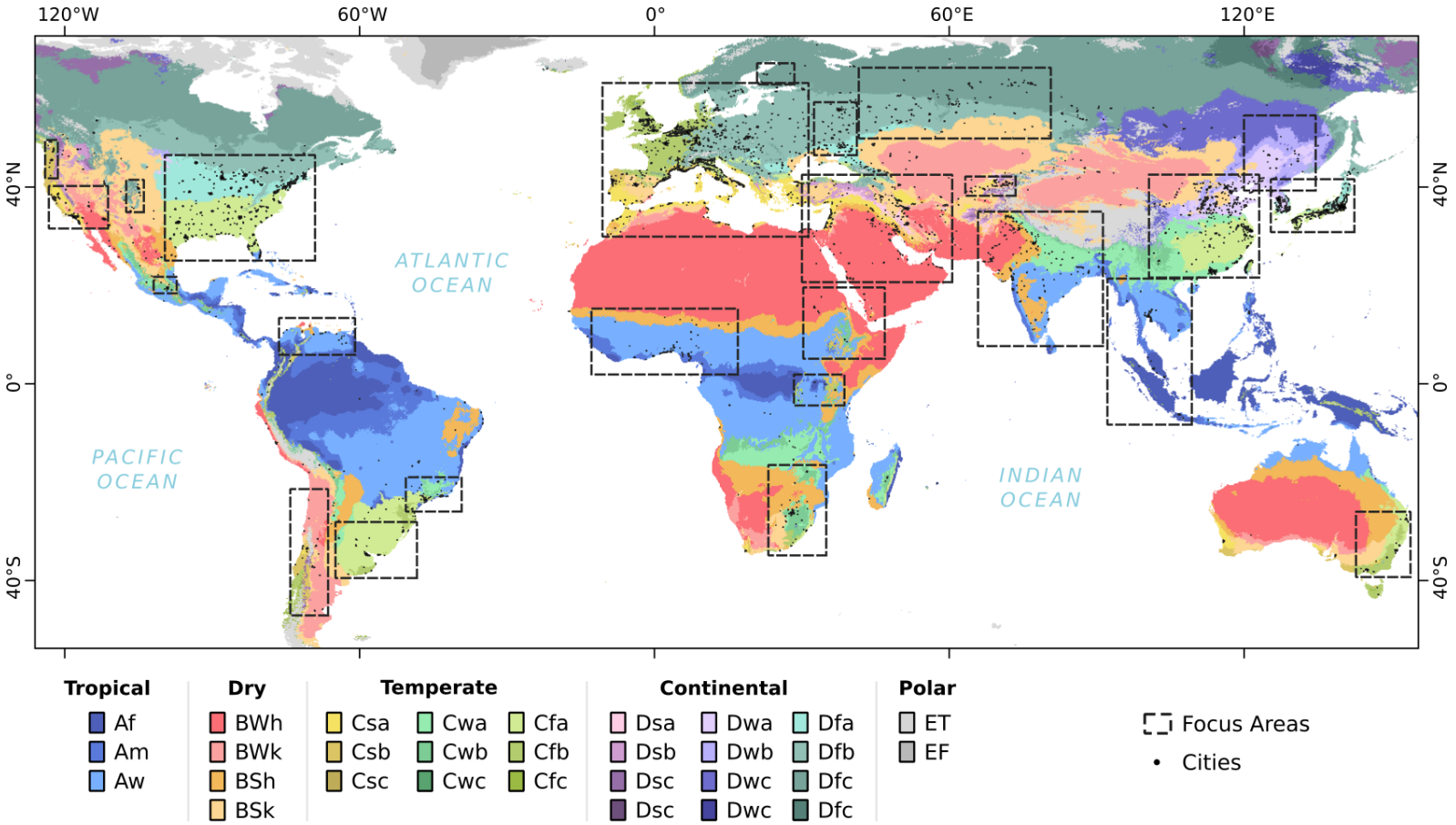
Research Question

Original model development and testing is based on these cities:

- What is the shape of the SUHII hysteresis loops in every densely populated climate?

Study Areas



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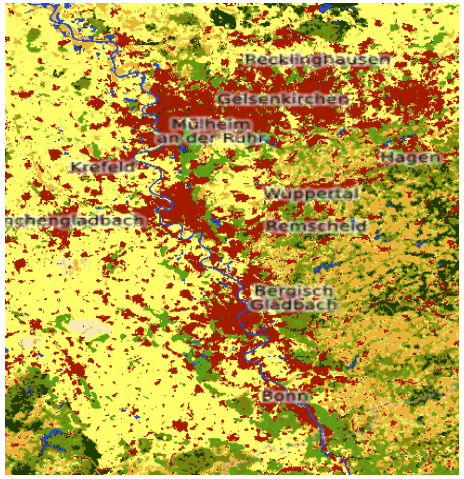
City Delineation (1/3)

- We use a custom implementation of the **City Clustering Algorithm**.

300 m Land Cover



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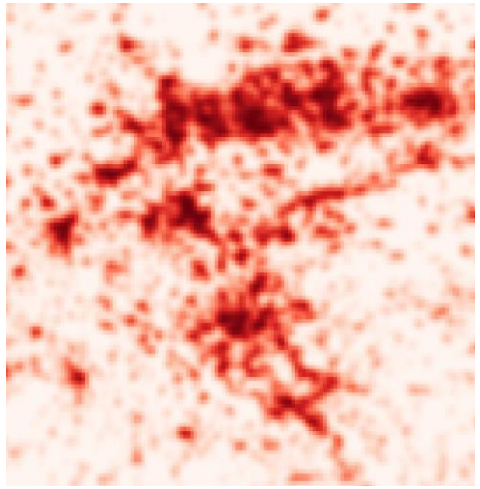
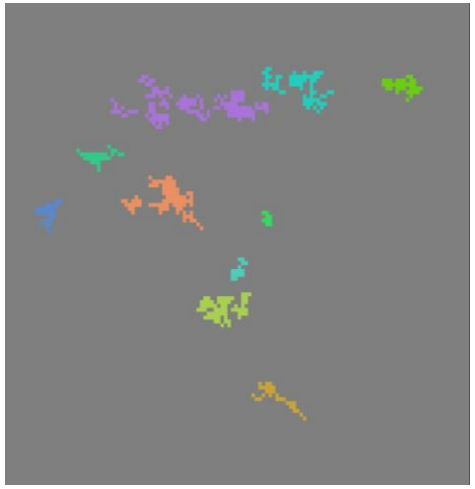
1 km Urban Fraction



Filtered Urban Mask

Labelled Urban Clusters



- Urban Fraction >95%
- Water fraction 0%
- Distance from coastline > ~2 km
- 9 or more connected pixels

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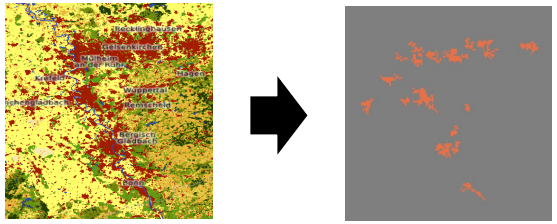
City Delineation (2/3)



- Urban Fraction >95%
- Water fraction 0%
- Distance from coastline > ~2 km
- 9 or more connected pixels

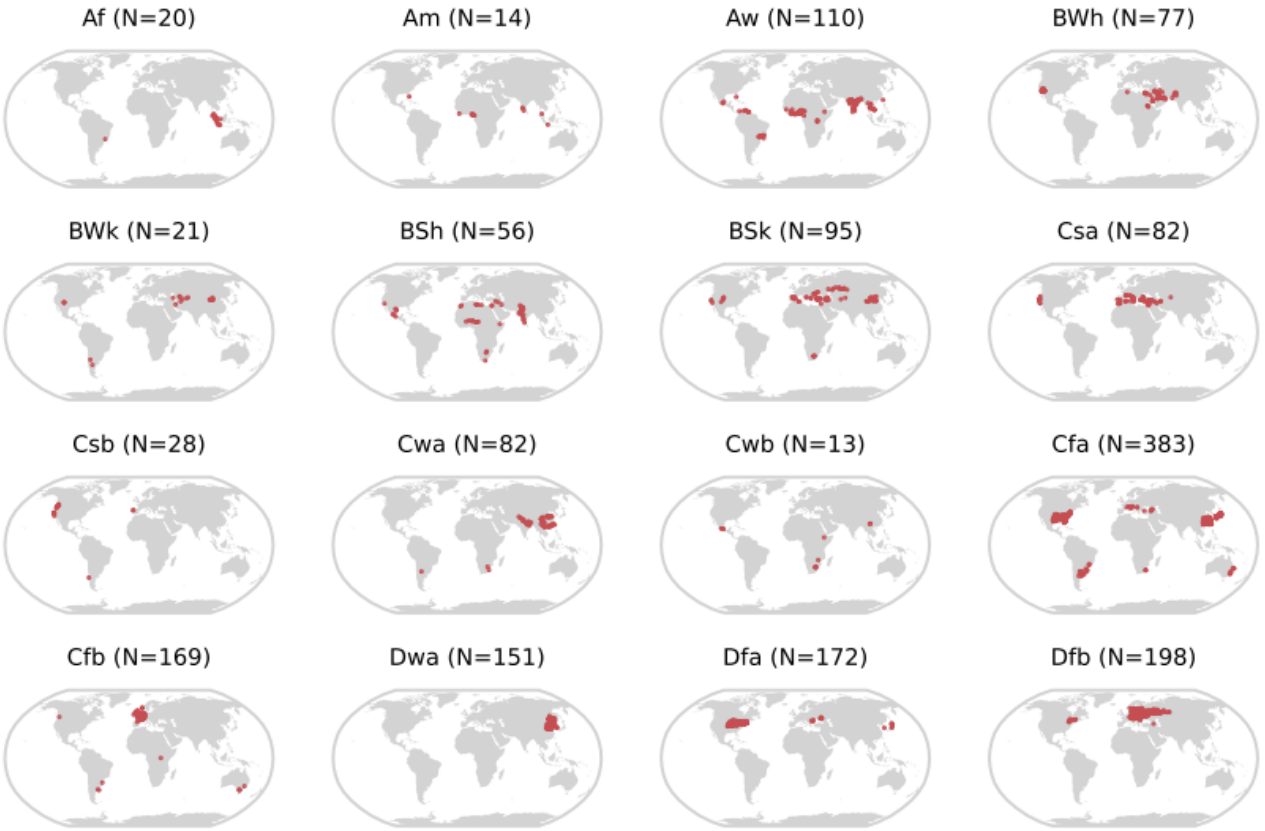
Why these configuration?

Make sure each city polygon includes almost no vegetation or water surfaces.

The emissivity of coastline pixels is not well-defined, and it is generally associated with high errors.

The GSD of the satellite should be able to resolve the minimum city size.

City Delineation (2/3)



(Only the zones with 10 or more cities are shown here)

2085 Cities

in 20 Köppen-Geiger classes

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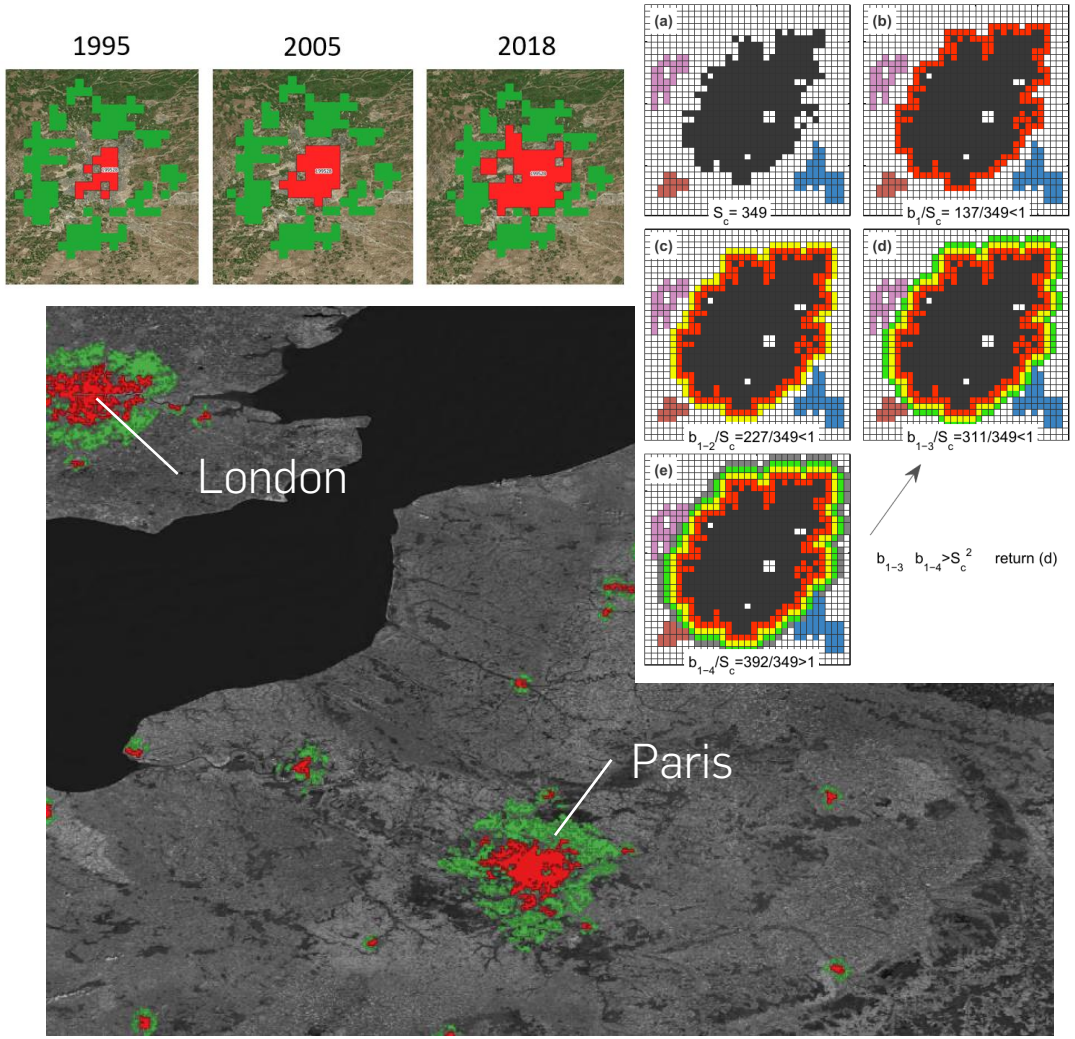
Natural Buffer (1/2)

- We iteratively expand a buffer around each city until they have approx. the same city.
- One per city
- Same for all years
- Natural LC fraction is ≥95% for each year.
- Urban & water fractions are 0%.
- The elevation must not differ by more than ±200 m from the median elevation of the urban area.
- Maximum width is 30 pixels



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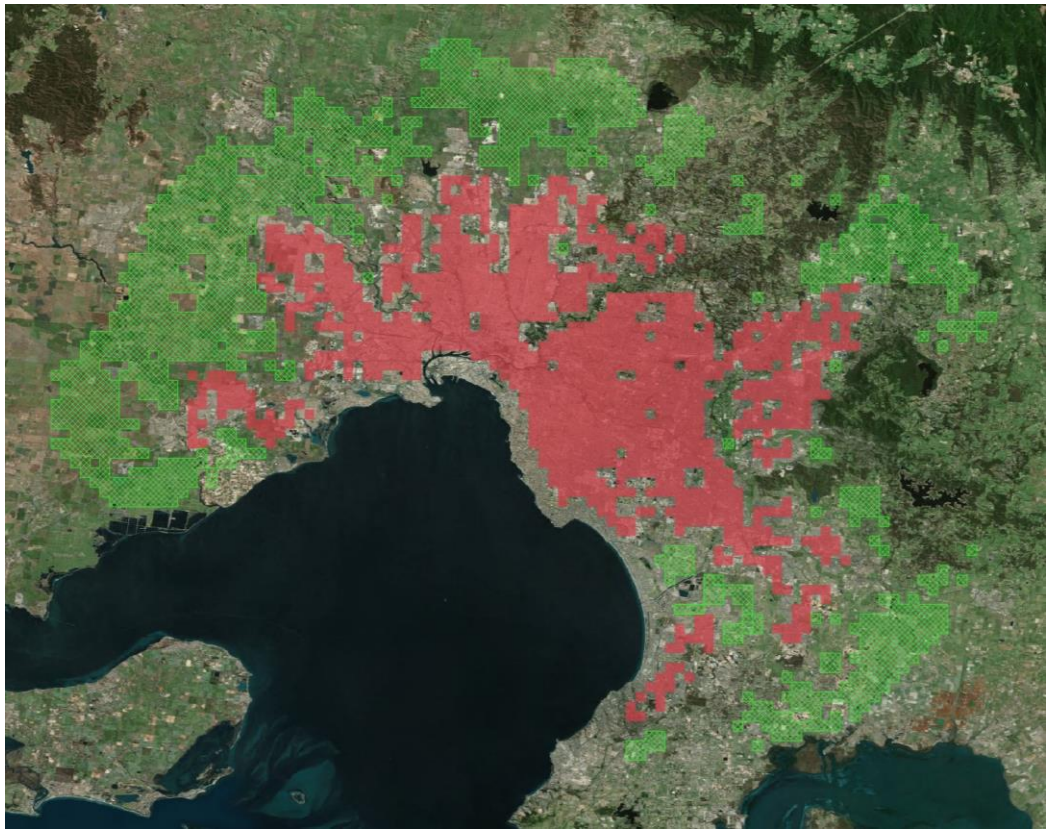
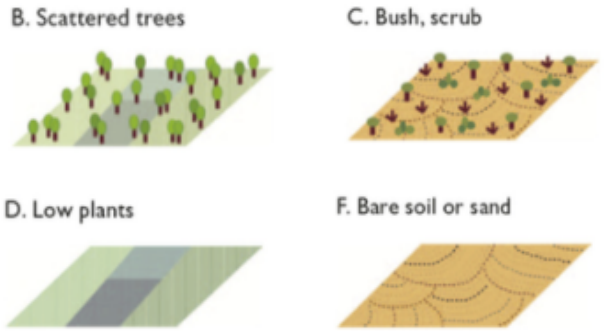
Natural Buffer (2/2)

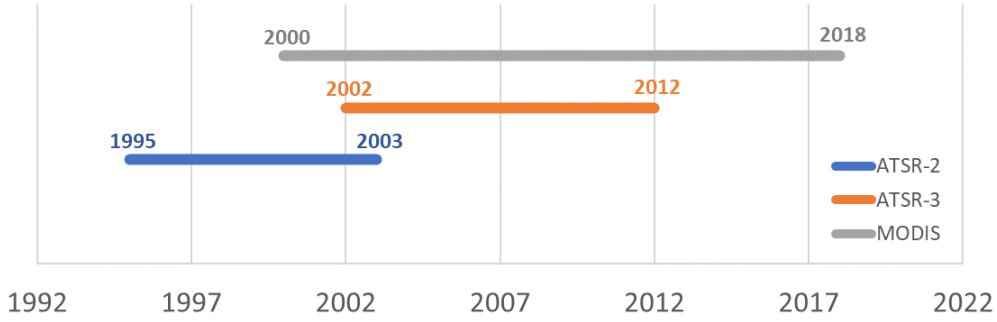


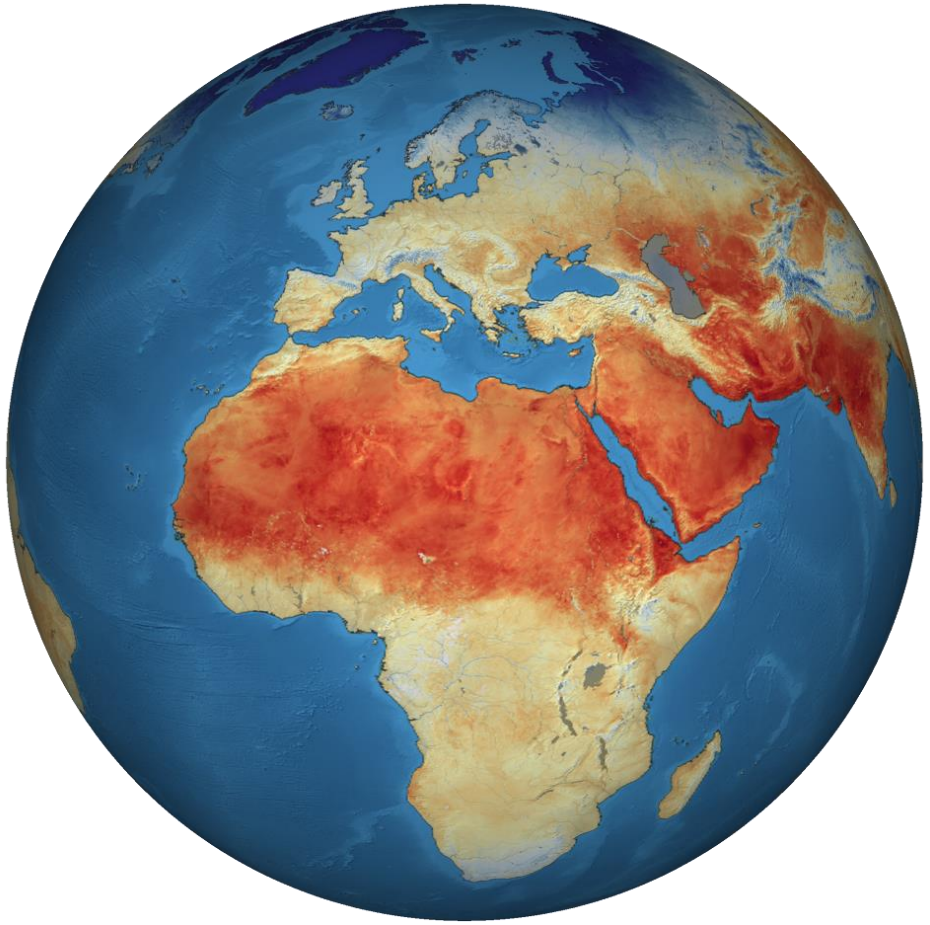
The resulting class closely resembles Local Climate Zones B, C, D, and F:



ESA-CCI LST Data

- Datasets:
  - ATSR-2 (1995-2003)
  - ATSR-3 (2002-2012)
  - Terra MODIS (2000-2018)
- Daytime and Nighttime





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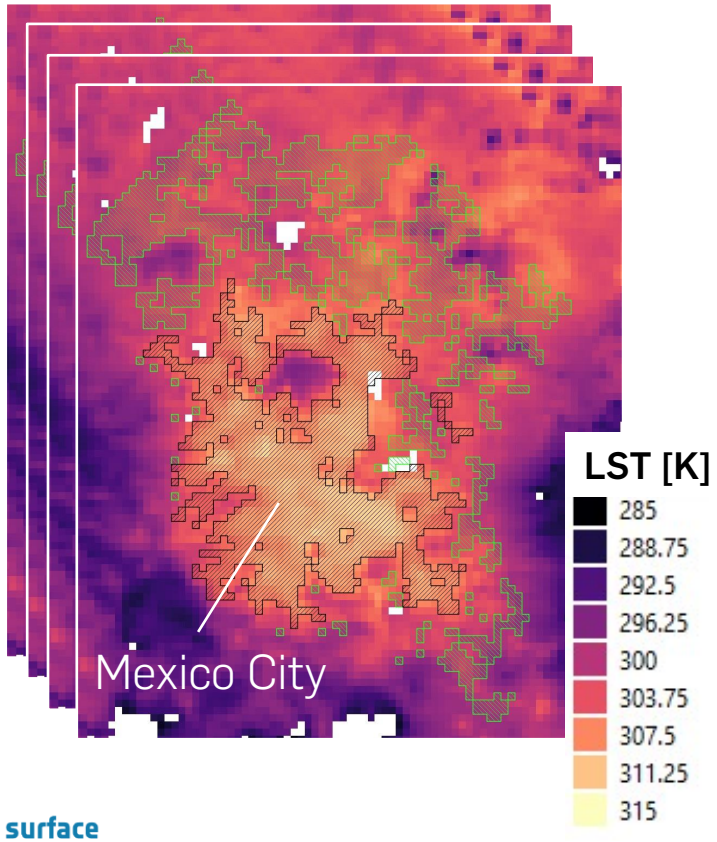
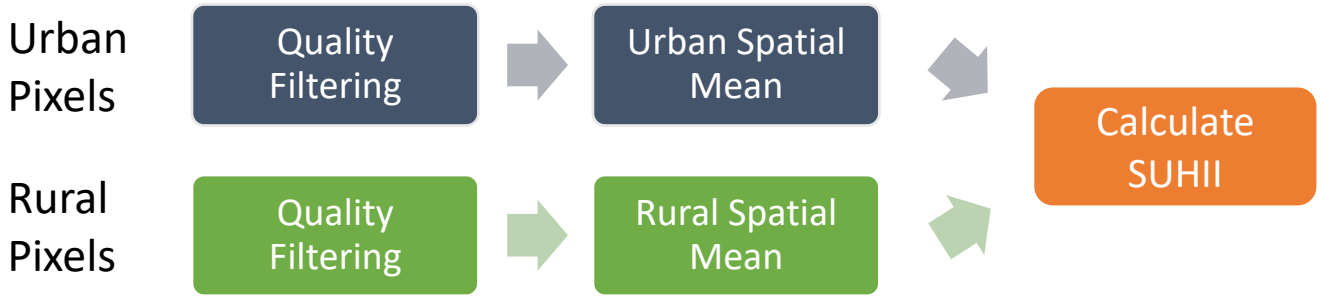
LST Means & SUHI Intensity

2000-2018 Daily LST
(Daytime or Nighttime)



$$\mathrm{SUHII} = \overline{\mathrm{LST}}_{\mathrm{urban}} - \overline{\mathrm{LST}}_{\mathrm{rural}}$$

For each day:



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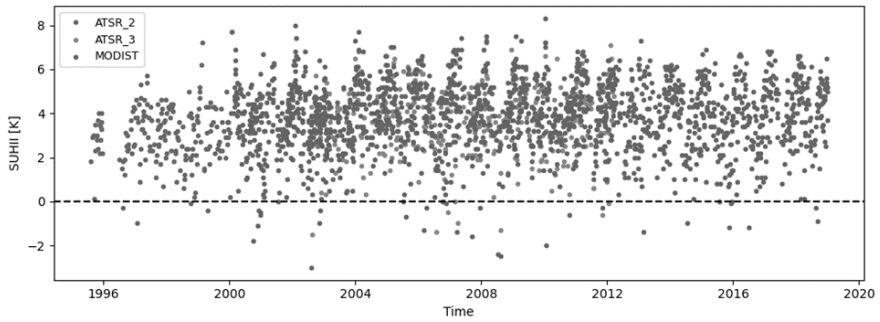
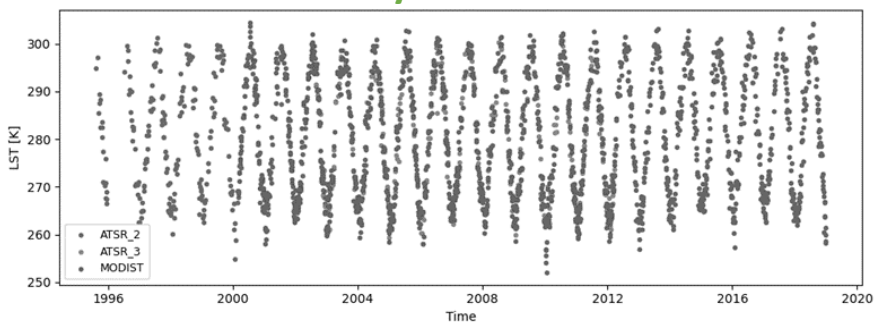
Data Analysis

For each City:

Daily SUHII



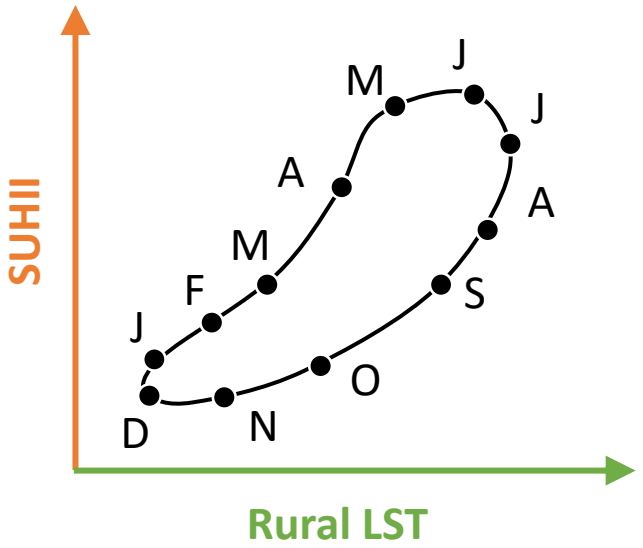
Daily Rural LST



Calculate Monthly Means for all years

Calculate Monthly Means for all years

Hysteresis Loop



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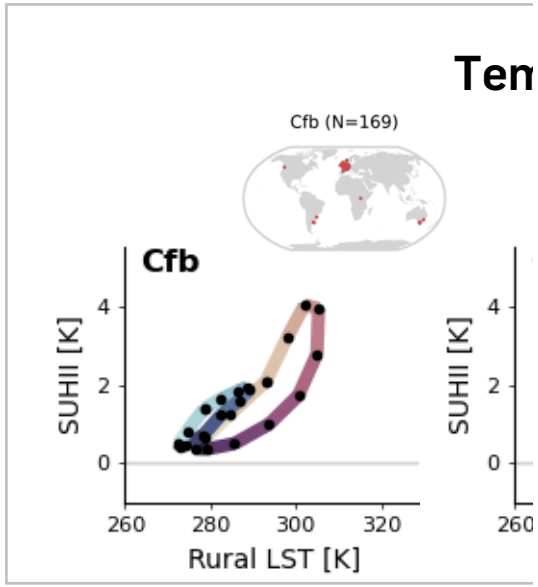
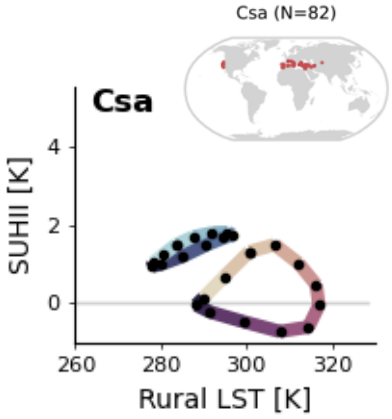
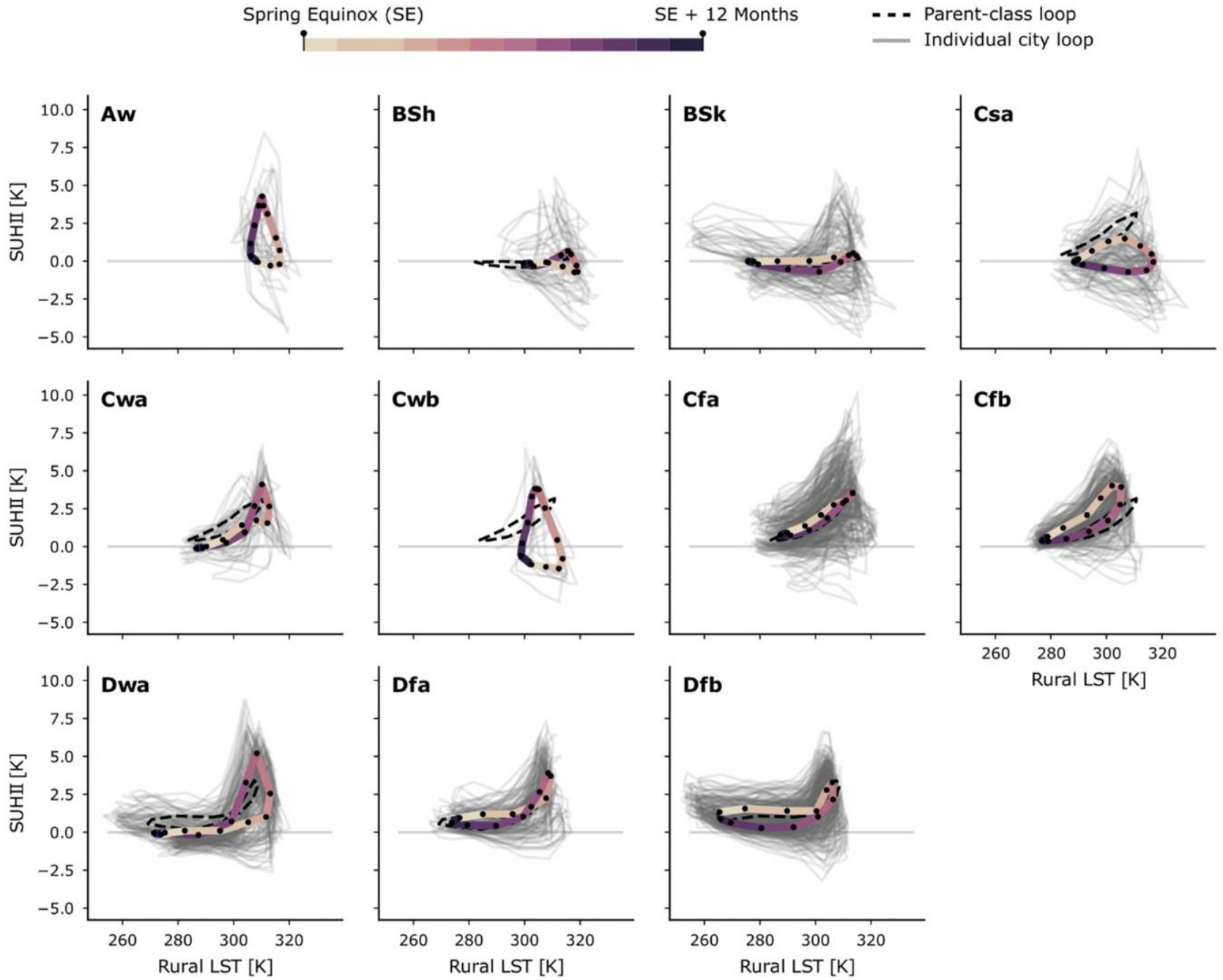
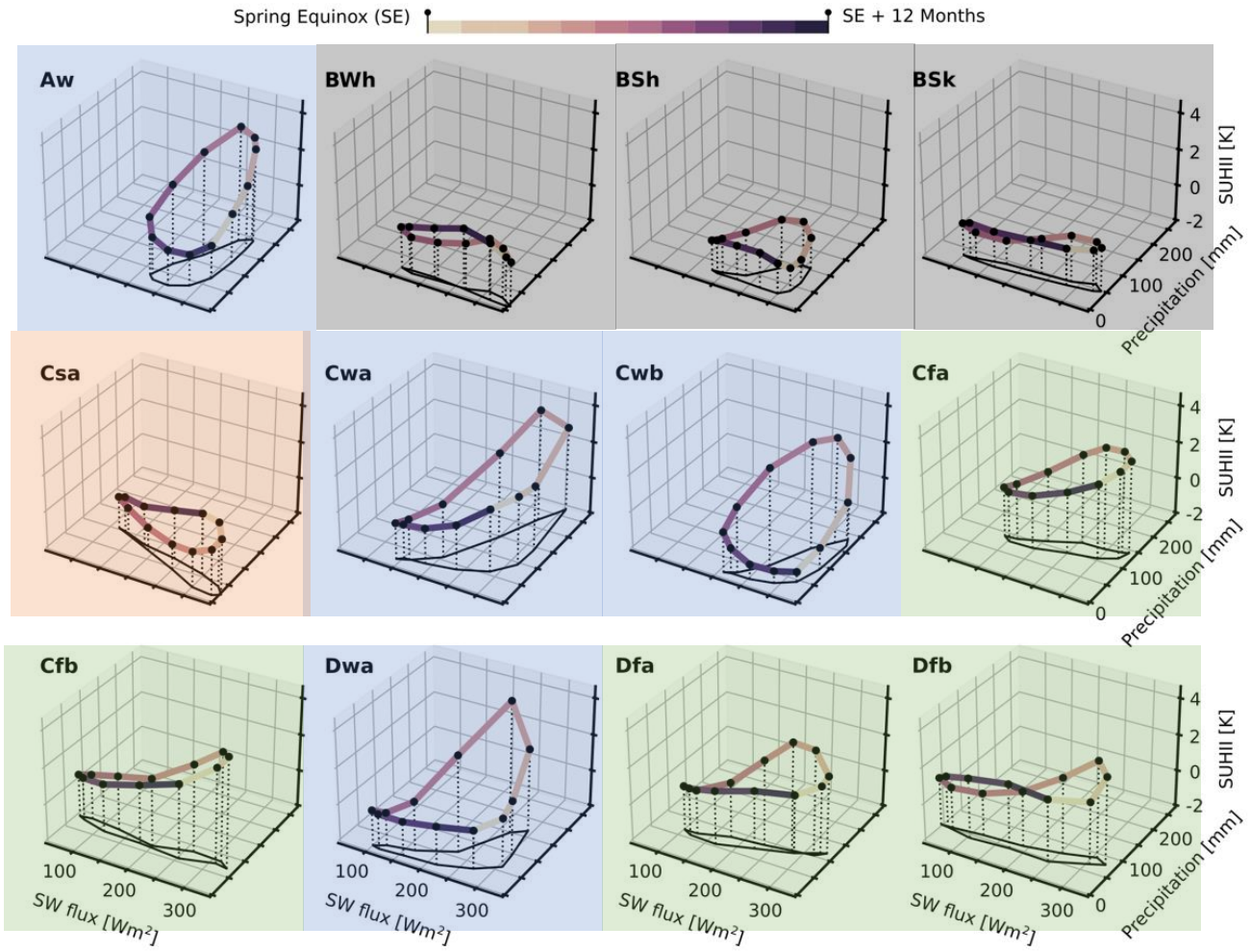
Results


Cfb (N=169)
Cfb
SUHII [K]
Rural LST [K]


Csa (N=82)
Csa
SUHII [K]
Rural LST [K]


Spring Equinox (SE)
SE + 12 Months
Parent-class loop
Individual city loop
Aw
BSh
BSk
Csa
Cwa
Cwb
Cfa
Cfb
Dwa
Dfa
Dfb
SUHII [K]
Rural LST [K]

Results



- SUHII increases with precipitation and solar radiation.
- SUHII increases with solar radiation.
- SUHII stops increases when precipitation drops.
- Cannot draw any conclusions.

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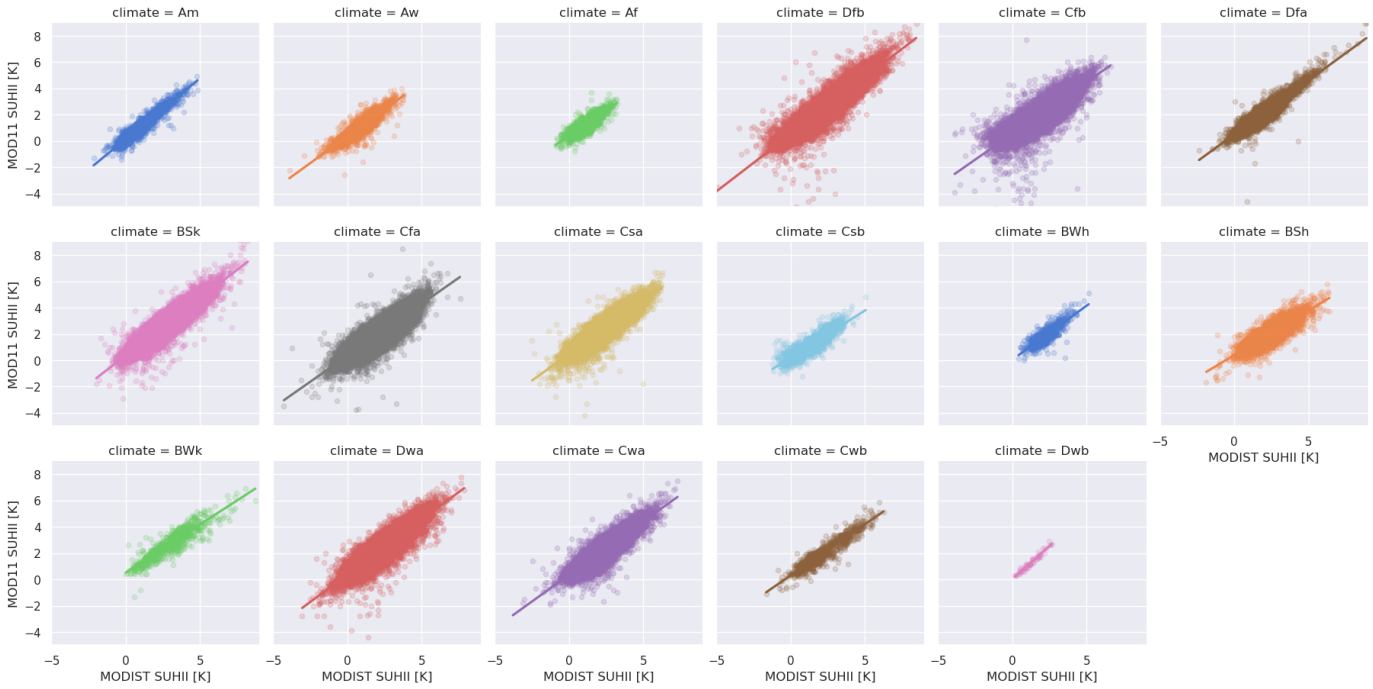
CCI MODIS vs. MOD11A1 v6

Table A1. The mean absolute difference (MAD) and the correlation coefficient between the 2000-2018 LST_cci and MOD11A1 (v.6.0) SUHII. D stands for daytime and N for nighttime.

Climate	MAD [K]		Correlation		Count	
	D	N	D	N	D	N
Af	1.0	0.3	0.87	0.84	903	2082
Am	0.5	0.3	0.97	0.95	1199	2144
Aw	0.7	0.3	0.94	0.89	1251	4069
BWh	0.8	0.5	0.80	0.84	2055	5101
BWk	0.5	0.3	0.94	0.92	12911	28920
BSh	0.6	0.5	0.93	0.83	239	626
BSk	0.6	0.5	0.97	0.91	536	762
Csa	0.6	0.4	0.91	0.88	19571	54352
Csb	0.5	0.4	0.90	0.88	26128	58994
Cwa	0.6	0.4	0.92	0.90	8221	19400
Cwb	0.5	0.4	0.91	0.88	1092	1709
Cfa	0.5	0.3	0.95	0.90	7395	29904
Cfb	0.6	0.4	0.90	0.94	253	1025
Dwa	0.7	0.4	0.90	0.92	2622	3729
Dfa	0.5	0.4	0.89	0.93	23760	45902
Dfb	0.5	0.3	0.96	0.90	25518	50369
All	0.5	0.4	0.93	0.90	133730	309152

Nighttime Comparison



Per Köppen-Geiger climate zone

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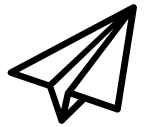
Conclusions

- LST_cci data can support the analysis of SUHIs.
- Our results for wet climate cities confirm the expected concave-up shape. However, for dry climate cities further investigations are required.
- SUHII is a function of both urban and rural features.

Thank you!



- Panagiotis.Sismanidis@rub.de

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