Universität Bremen

Space-ST M. Sc.

Institut für Umweltphysik IUP

Faculty 1

Physics / Electrical Engineering

Impact of LU/LC and Climate Change on Urban Heat Islands

Analysis of Bremen using Landsat 8 and 9 Remote Sensing Data

Linus Andrae

21. June 2024

Structure of the Presentation

- Urban Heat Islands basics and problem description
- Presentation of my work
- Conclusion and further research
- Time for questions and discussion

Urban Heat Islands

Urban Heat Islands (UHIs) are heat anomalies within urban areas.
Caused by surface material properties, lower evapotranspiration and lack of surface water availability.

An SUHI is an area with increased surface temperature within an urban space.
It is defined as having a temperature at least 3 standard deviations above the average temperature of the adjacent rural buffer zone. The rural buffer zone measurement is corrected for temperature influence of larger settlements.

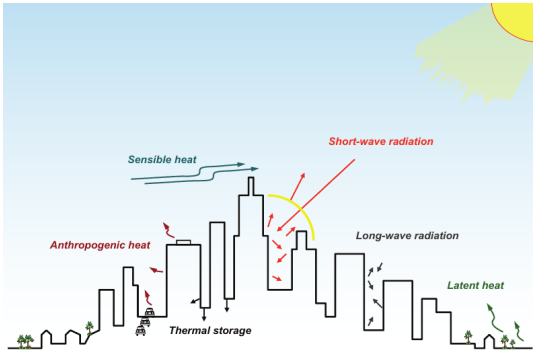
Why are UHIs an important research topic

- Heat is one severe stressor on human, animal and plant health
- Pollution: Tropospheric ozone creation is increased by higher temperatures
- Global warming increases severity of temperature related effects
- From the news:
  - At least 922 heat deaths in Mecca during 2024 Hajj [2]
  - Dangerous levels of Heat forecasts for the continental US for up to 52 °C

Physical mechanisms behind UHIs

Land cover changes alter the energy flux.

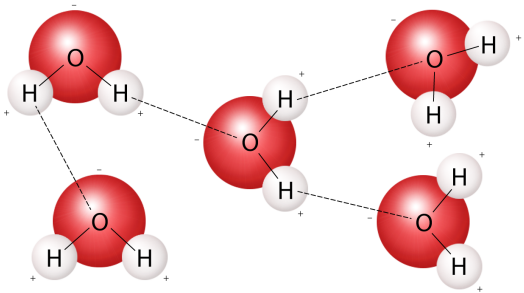
- Materials absorbing solar energy during day time
- Lower latent heat transfer within urban areas due to less vegetation and lower surface water availability
- LW radiation, heating the boundary layer of the atmosphere at night
- Increased anthropogenic heat emission



Urban-Atmosphere-Energy System
[3, Fig. 7 p. 11]

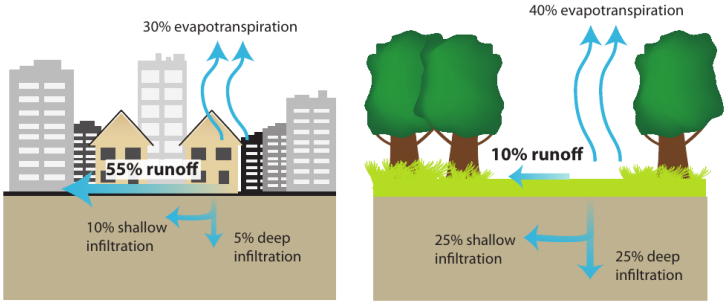
Water as an heat transport mechanism (1/2)

- Latent Heat of Evaporation
- Low density of water vapor
- Updraft and thermal wind



Water molecules [1]

Water as an heat transport mechanism (2/2)



Change of water availability in urban areas
[3, Fig. 5 p. 7]

Effect of Vegetation on Temperature

- Transpiration as part of photosynthetic respiration
- Absorption (PAR) and reflection (NIR) by leaf surfaces
- Resulting shading

Surface Urban Heat Islands

- Parameter: Surface temperature
- Area within city with higher surface temperatures
- Temperature of surface materials according to Planck's law

Atmospheric Urban Heat Islands

- Parameter: Air temperature
- Temperature of air in the urban canopy layer
- Affecting well-being of inhabitants of the area

Measurement techniques

Atmospheric heat islands:

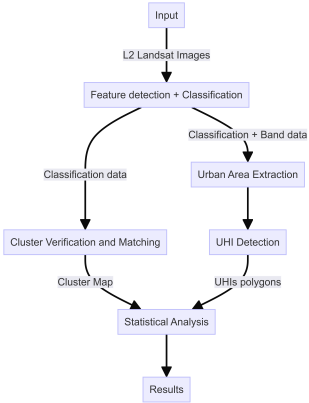
- Weather stations
- mobile measurement campaigns

Surface heat islands:

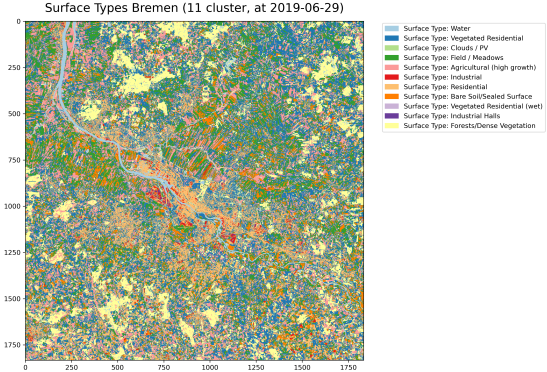
- Remote observation of surface temperature (corrected TOA temperature)
- Surface temperature probes

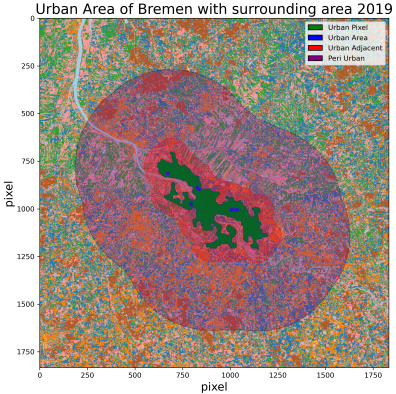
Approach within my thesis

- Single data product classification and UHI detection
- Landsat 8 & 9 L2 product
- Using statistical definition for detection of UHIs

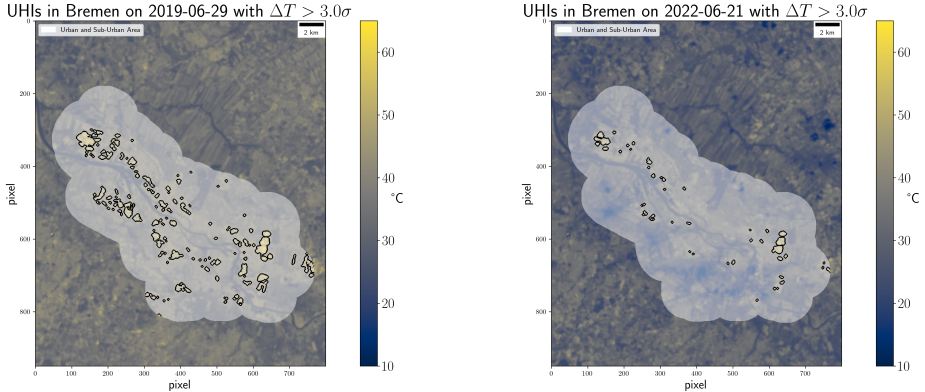


Classification and Urban Area Extraction



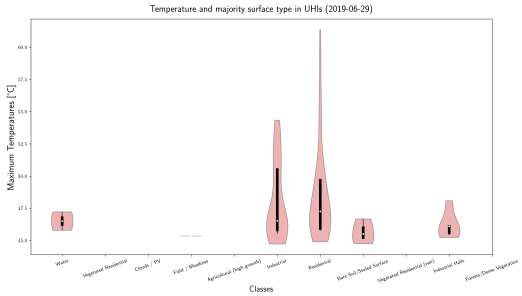


UHI detection in Bremen

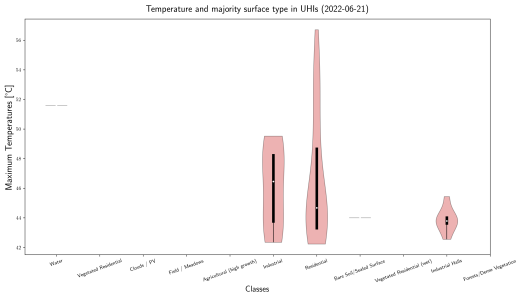


UHIs in Bremen

LULC Statistics



(a) 2019



(b) 2022

LULC Bremen

What worked well

- Consistent detection of UHIs independent of average temperature
- Clear correlation between surface materials and UHIs
- No UHIs with predominantly vegetation pixels
- Increase in number and size of UHIs with rising daily temperatures

What worked well

- Statistical significant offset between urban and rural weather station in Bremen suggesting atmospheric heat island all year round
- Upsides of classification and UHI detection using a single data product:
  - Same georeference and pixel sizes
  - No averaging of classification over the seasons
  - Fast change detection possible

Challenges

- Low data availability made significant statistical analysis impossible
- Lack of significant land cover changes in study area, did not allow to analyse impact of LU/LC on UHIs
- Climate change statistic needs additional past data of different satellites (e.g. Landsat 7)
- Include more factors in UHI analysis

Suggested improvements

- Use of additional satellites to increase data availability and elongate timeline
- Analyse current and future building projects
  - Leipzig 416
  - Effectiveness of heat mitigation projects
- Apply in different cities and temperature regions to verify approach
- Enrich with other data sources
- Create risk index/ forecasts based on surface temperatures and weather models

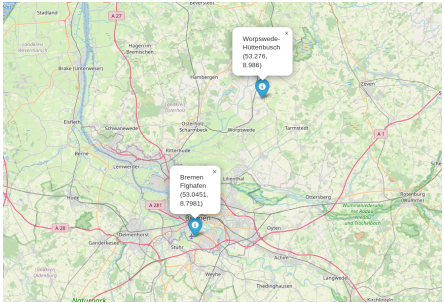
Sources

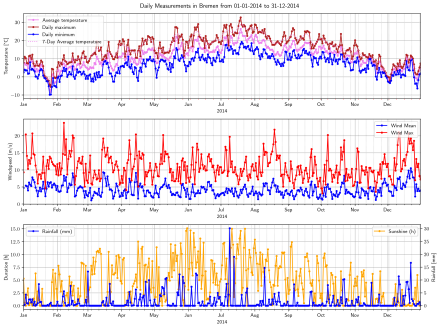
[1] Tara A. Gross. URL: https://www.usgs.gov/media/images/strong-polar-bond-between-water-molecules-creates-water-cohesion-0.

[2] *Loved ones search for missing as hajj death toll passes 900*. en. June 2024. URL: https://www.france24.com/en/live-news/20240619-loved-ones-search-for-missing-pilgrims-after-hajj-heat-deaths (visited on 06/20/2024).

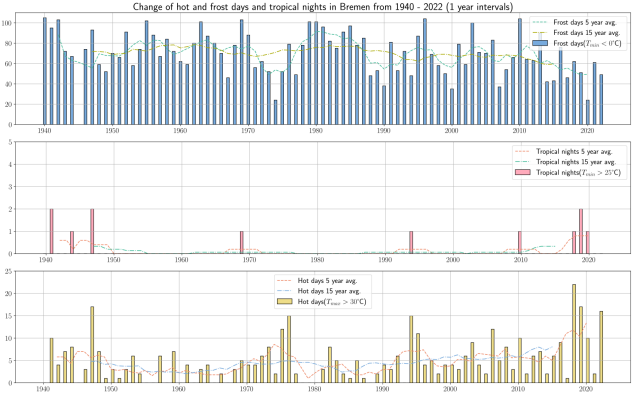
[3] U.S. Environmental Protection Agency (EPA). "Reducing urban heat islands: Compendium of strategies". In: (2008). URL: https://www.epa.gov/heatislands/heat-island-compendium.

Analysis and statistics of the temperature influence of UHIs



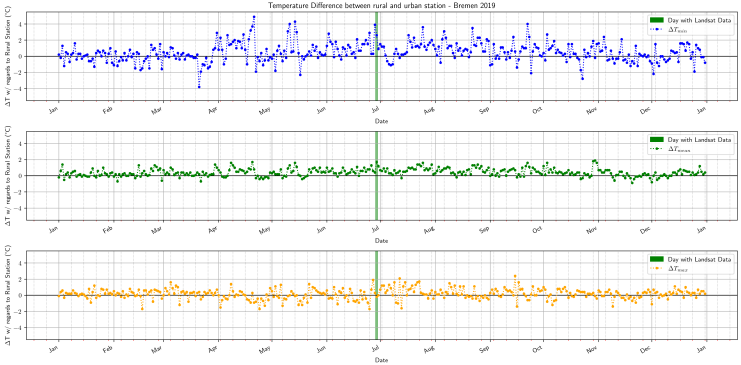


Weather Statistics



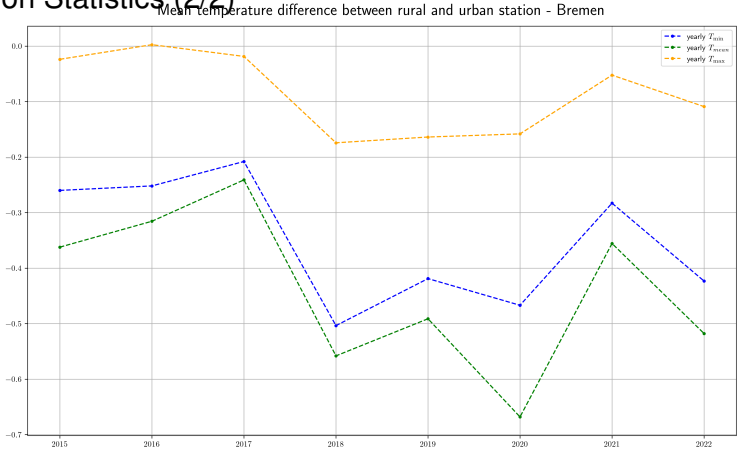
Hot Days, Summer Days, Tropical Nights

Weather Station Statistics (1/2)



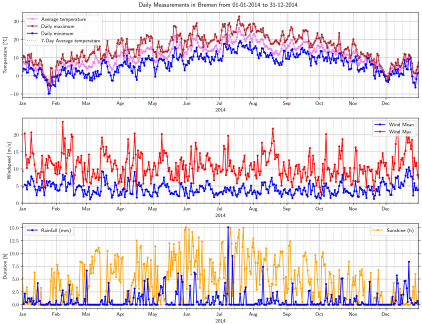
Rural urban offset

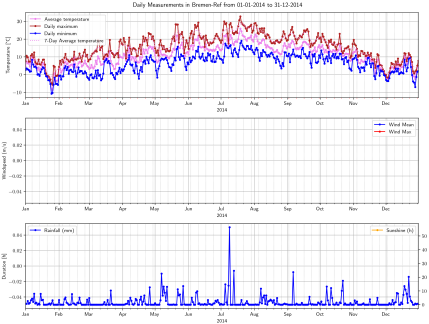
Weather Station Statistics (2/2)



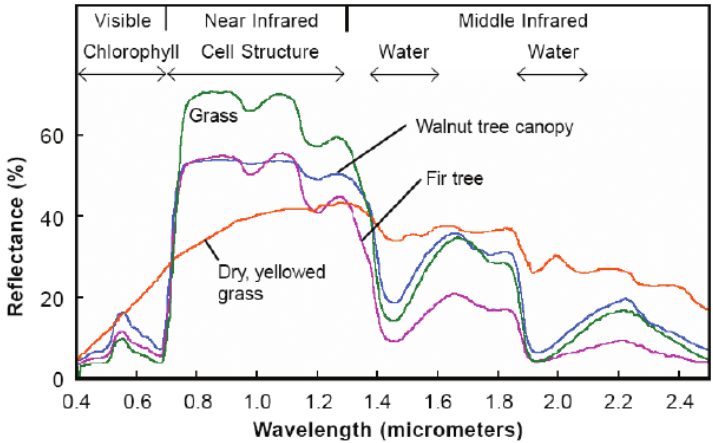
Rural urban offset

Measurement Stations

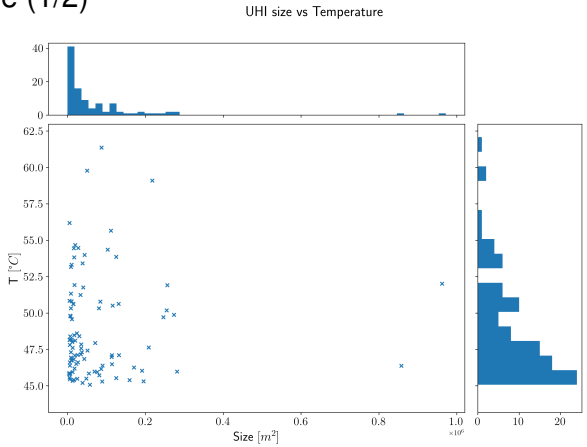




Reflectance

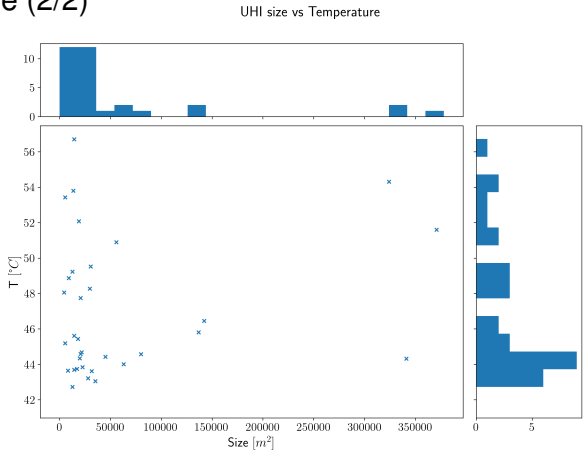


Size vs Temperature (1/2)



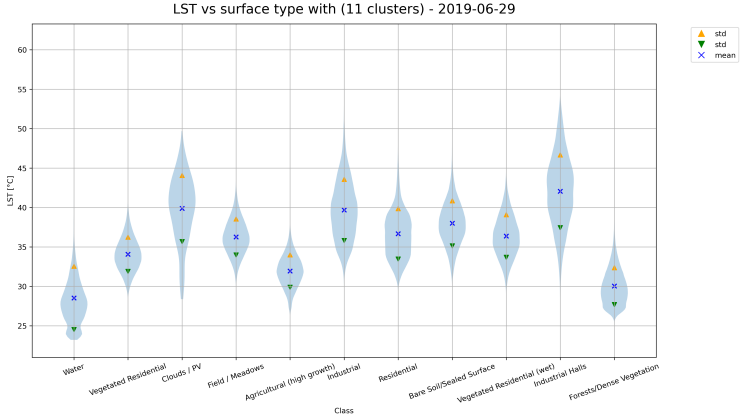
2019

Size vs Temperature (2/2)



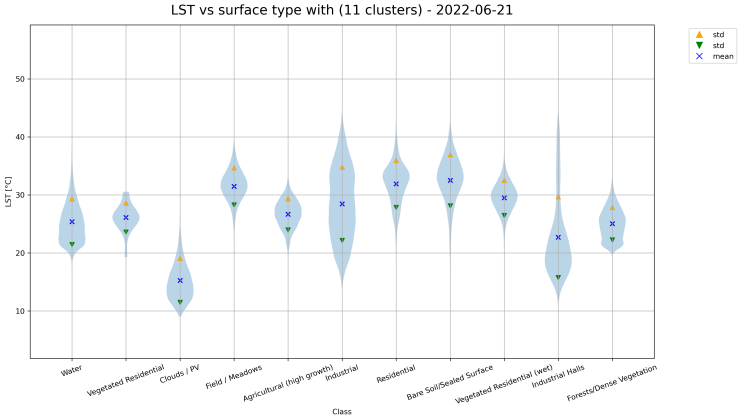
2022

LST vs Types (1/2)



2019

LST vs Types (2/2)



2022