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TRACK T4. SpSe5 - Intersecting the Multiple Scales of Climate Justice: Mapping Inclusive Adaptation and Just Fossil Fuel Transitions

Climate justice in warming cities: mapping ten years of climate extremes and their potential impacts in Padua (Italy)

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UNIVERSITÀ
DEGLI STUDI
DI PADOVA



Climate risk in Italy

Risk Analysis

Climate Change in Italy

Executive Summary

- Climate change in Italy is linked to increases in temperature, **changes in rainfall patterns and increased frequency and duration of extreme weather events.**
- The climate scenarios analyzed in this report show a **generalized +5°C increase** in average temperature **in 2100 compared** to the beginning of the century (worst case scenario, RCP8.5).
- The precipitation regime shows significant differences throughout the region.
- **All the scenarios considered show an increase in the number of hot and dry days during the year.**



Heatwaves

Heat wave (also referred to as extreme heat event)

A period of abnormally hot weather. Heat waves and warm spells have **various and in some cases overlapping** definitions (IPCC, SR Glossary of terms in Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation, **2012**)

A UK heatwave threshold is met when a location records a **period of at least three consecutive days with daily maximum temperatures meeting or exceeding the heatwave temperature threshold.**

The threshold varies by UK county (Met Office)

A heatwave occurs when the maximum and the minimum temperatures are unusually hot over a three-day period at a location. **This is considered in relation to the local climate and past weather at the location** (Australina Bureau of Meteorology)

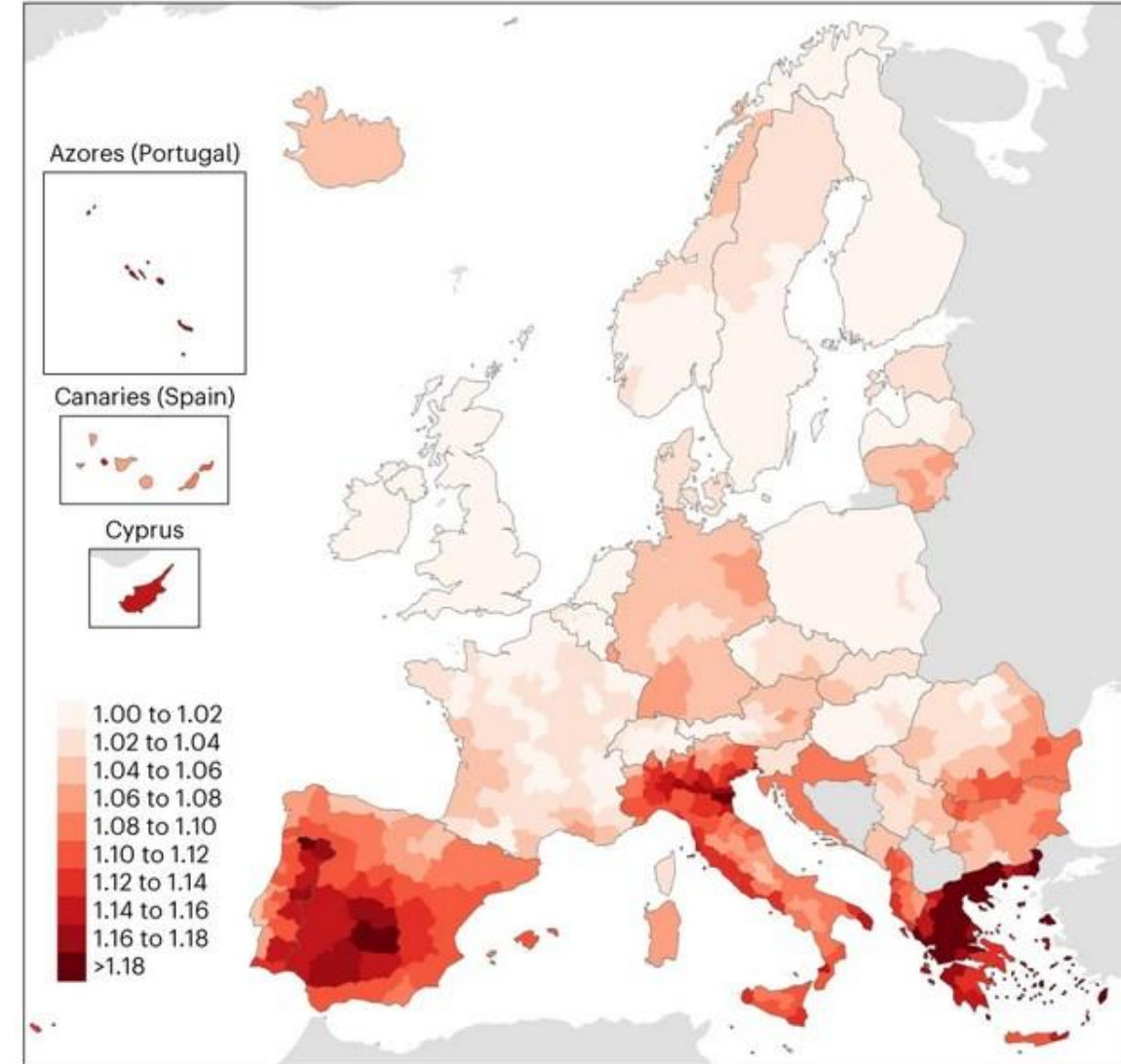
A heat wave as a period during which the daily maximum temperature exceeds for more than five consecutive days the maximum normal temperature by 5 degrees Celsius, the normal period being defined as 1961–1990 (WMO 2021)

Heat-related mortality in Europe during the summer of 2022

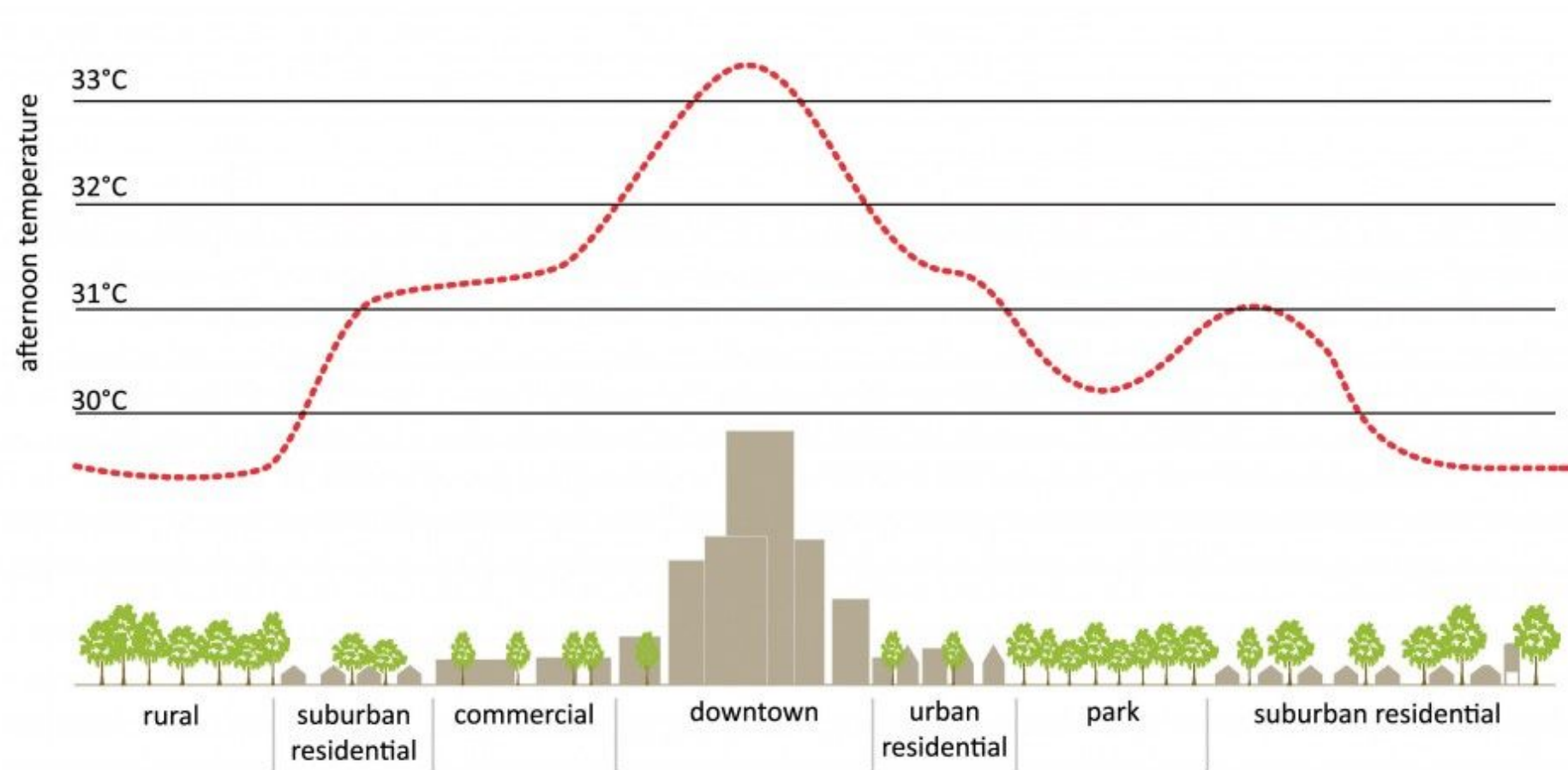
- The number of hot days (LST > 90° percentile) was **>40 days across most of the west-central Europe**, topping >50 days in several hotspots
- Over **61,000 deaths** in Europe
- countries most exposed to climate risk are those bordering the Mediterranean basin
- **Italy**, with a total of **18,000 deaths** and 295 deaths per million inhabitants, was the most affected country

c

All ages, both sexes



Urban Heat Island (UHI)



UHIs are ***spatially non-homogenous*** (landcover, urban fabrique, urban morphology, meteorological dynamics)

Monitoring Urban Heat Islands

UHIs can be generally assessed and monitored by three main approaches:

- 1) **Remote sensing platforms** (satellite, aircraft, drones) equipped with thermal infrared sensors to derive LST as proxy parameter for UHI/SUHI (mainly Landsat 8-9, 100 m pixel⁻¹ spatial resolution of TIRS bands)
- 2) Networks of **ground meteorological stations** for direct measures of air temperature
- 3) **High-resolution reanalysis climate models** (100 m pixel⁻¹)

Monitoring hourly-based meteorological parameters is crucial to **identify urban hotspots for heat-related risk, thermal stress and climate index analyses**

Aims of the study

General aim

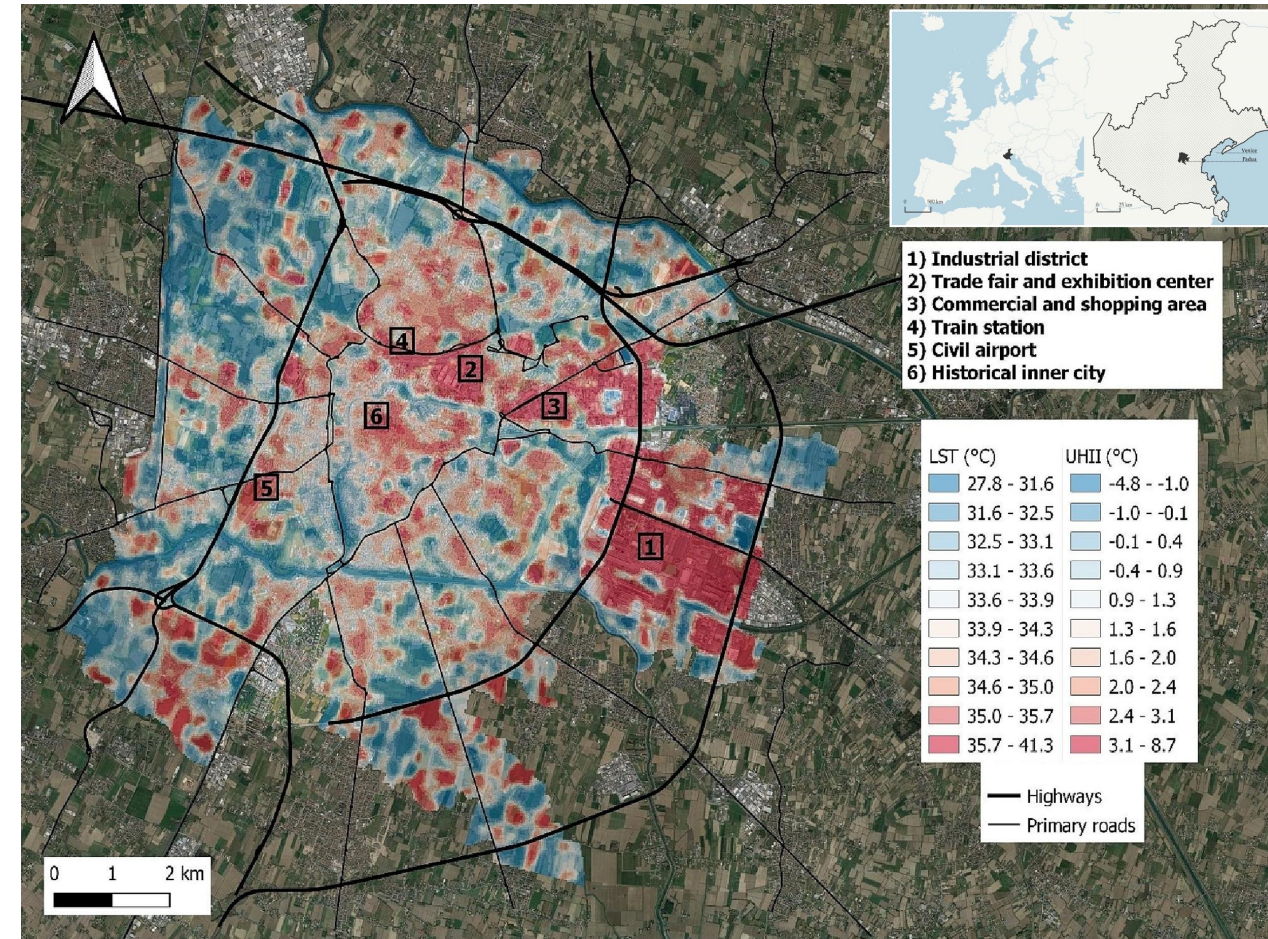
Mapping and assessing, during heatwaves, **critical hotspots of climate extremes** in the **city of Padua**, by integrating regional climate models and 'citizen climate sentinels', to address climate justice in adaptation planning

Specific objectives

- i) by validating the UrbClim model, mapping UHIs, HD, TN during 10-years (2008-2017);
- ii) mapping the climate risk for climate extremes (HD, TN);
- iii) by using citizen science weather stations, assessing HD and TN during the exceptional Summer 2022

Study case: the city of Padua (NE Italy)

- Southern Europe, Eastern area of the Po Valley
- Medium-size compact city (92 km²)
- 208,000 inhabitants
- Climate: subcontinental temperate (annual T 13.7 °C), (Csa Köppen)
- Very high urbanization processes
- Complex mixed urban fabrique
- Soil sealing >50% of the municipal territory
- High frequency and duration of HW
- High values of Surface Urban Heat Island intensity



Land Surface Temperature (LST) and Urban Heat Island (UHI) by Pappalardo et al., 2023

A representative case for assessing urban heating and climate extremes

Data and methods

Meteorological observations

- Official reference station Arpa Veneto (Legnaro) for climatological indexes calculation
- 3 Citizen Science stations from Meteonek association (www.meteonek.it)
- 10-year dataset of climate variables at 100 m pixel⁻¹ spatial resolution and 1 hour temporal resolution (period: 2007-2018)
(Copernicus Climate Change Service, UrbClim model by VITO, see De Ridder et al., 2015; Lauwaet et al., 2024)

Climate extremes metrics and climatological indexes

- Hot days: $T_{max} > 90^{\circ}$ percentile $\sim 32^{\circ}\text{C}$
- Tropical nights: $T_{min} < 10^{\circ}\text{C}$
- Group-specific risk:
$$R_{h,i,j} = 0.25V_{i,j} + 0.25E_j + 0.5H_i$$
- Groups considered: urban, suburban, rural, peri-urban
- Global risk index:
$$UHRI_j = 0.125\sum V_{k,j} + 0.125E_j + 0.5H_j$$

Territorial data

- Administrative limits for the municipality and urban units (City of Padova)

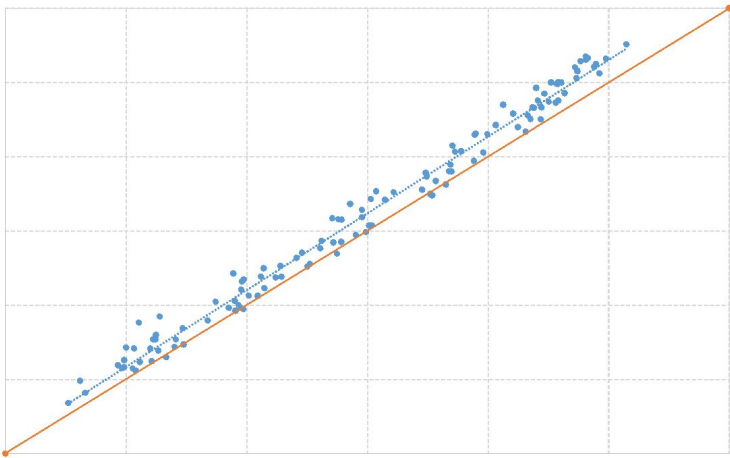
Results - UrbClim model assesement

- From UrbClim model to mapping UHI and climate extremes
- Validation of UrbClim through the Legnaro reference station

	Tmin	Tmean	Tmax
ARPAV	9.8	14.0	18.5
UrbClim	11.0	14.6	18.6

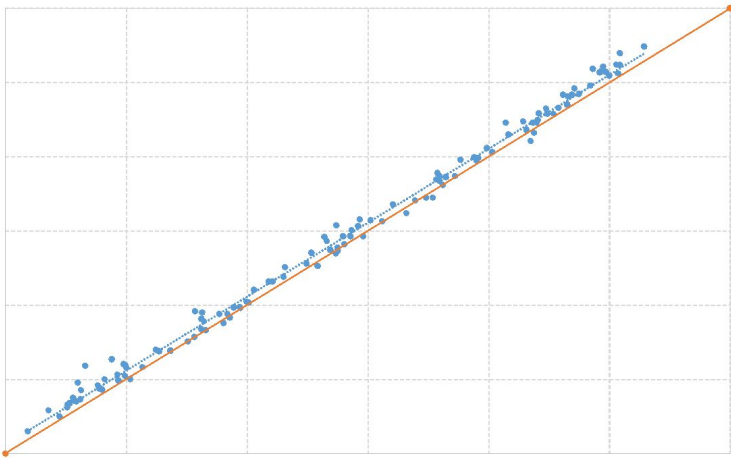
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Tmin



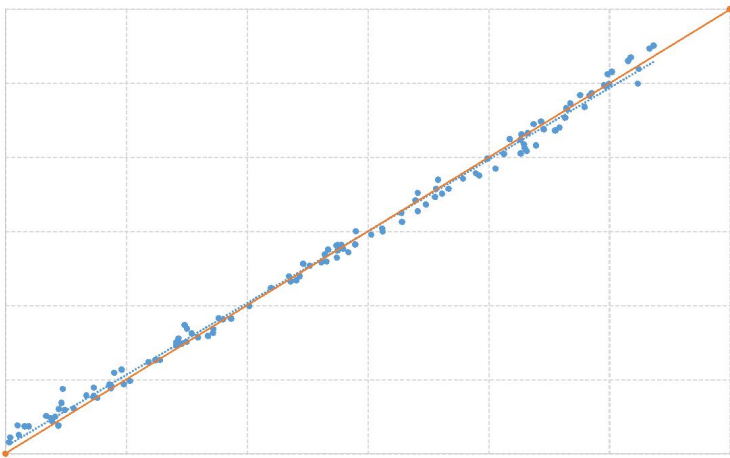
RMSE = 1.45°C

Tmean



RMSE = 0.78°C

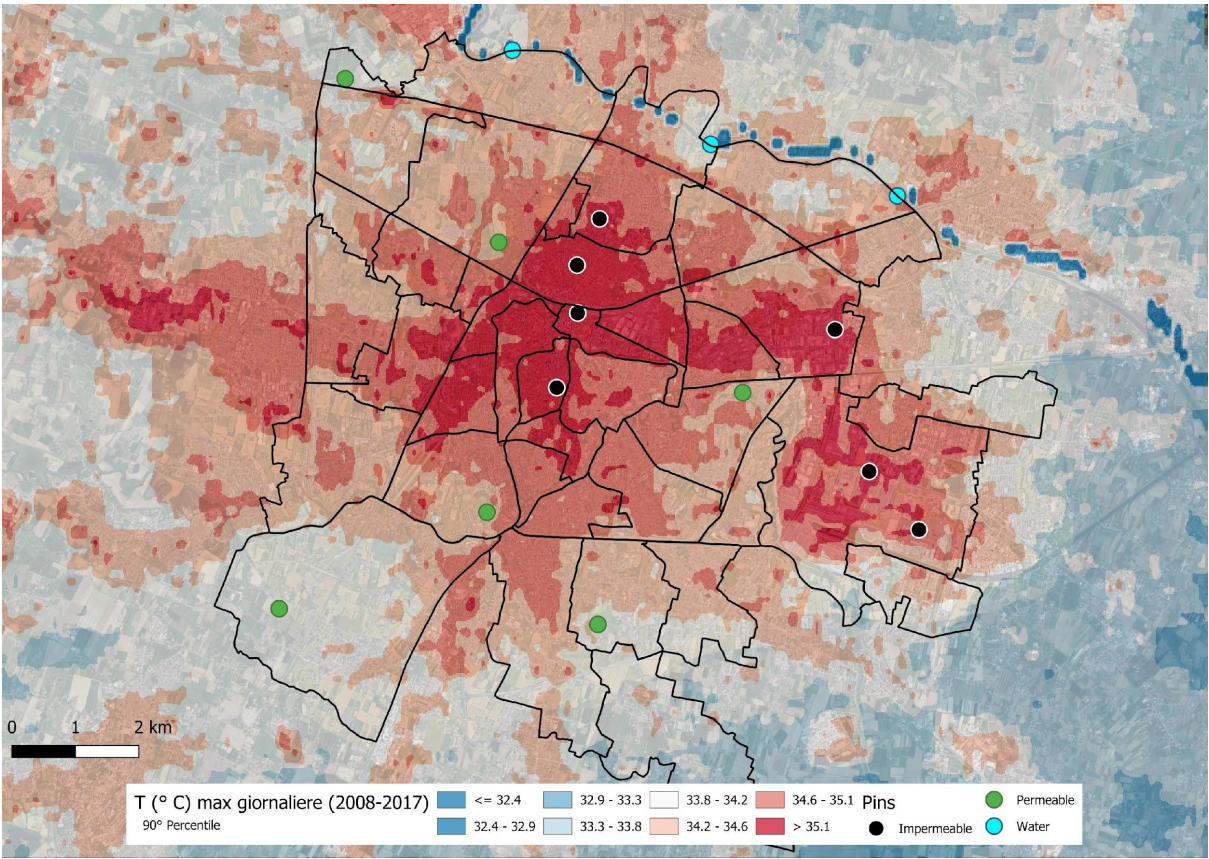
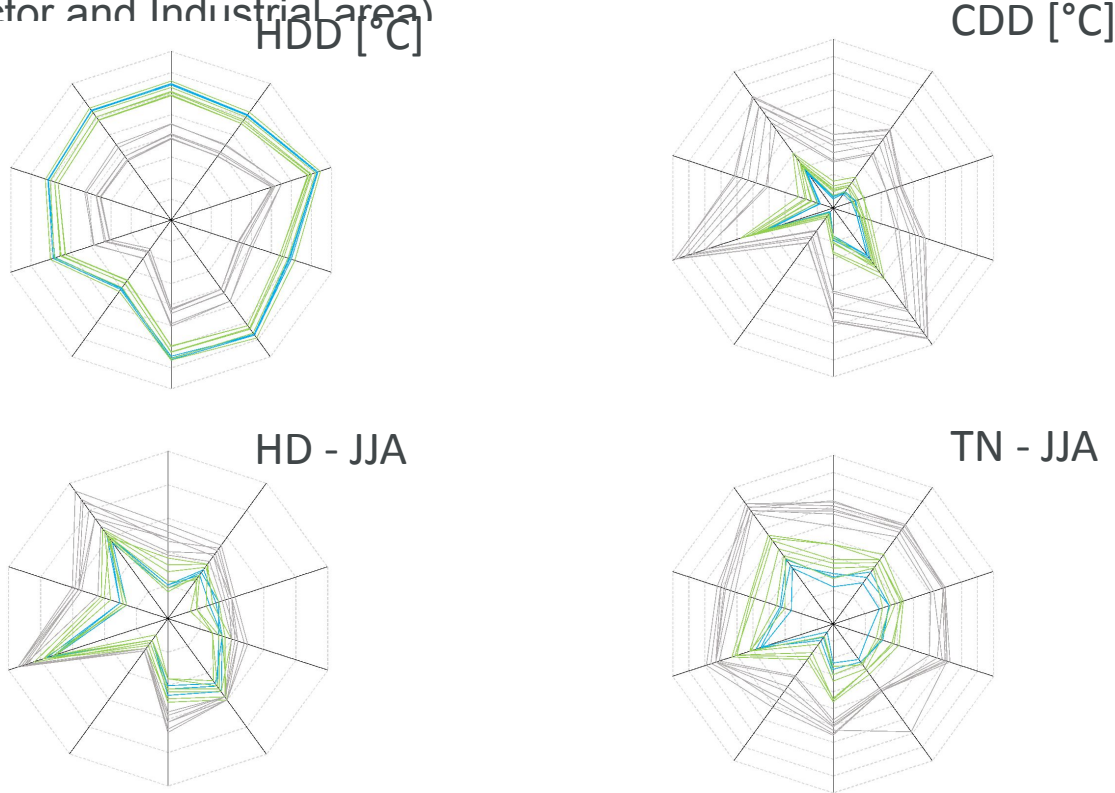
Tmax



RMSE = 0.58°C

Results – Padua Urban Heat Island

- Urban Heat Island pattern (2007-2018)
- 90° percentile T_{max} daily ($T \sim 32^{\circ}\text{C}$)
- UHI mainly shaped by sealed surfaces (inner city, northern sector and Industrial area)



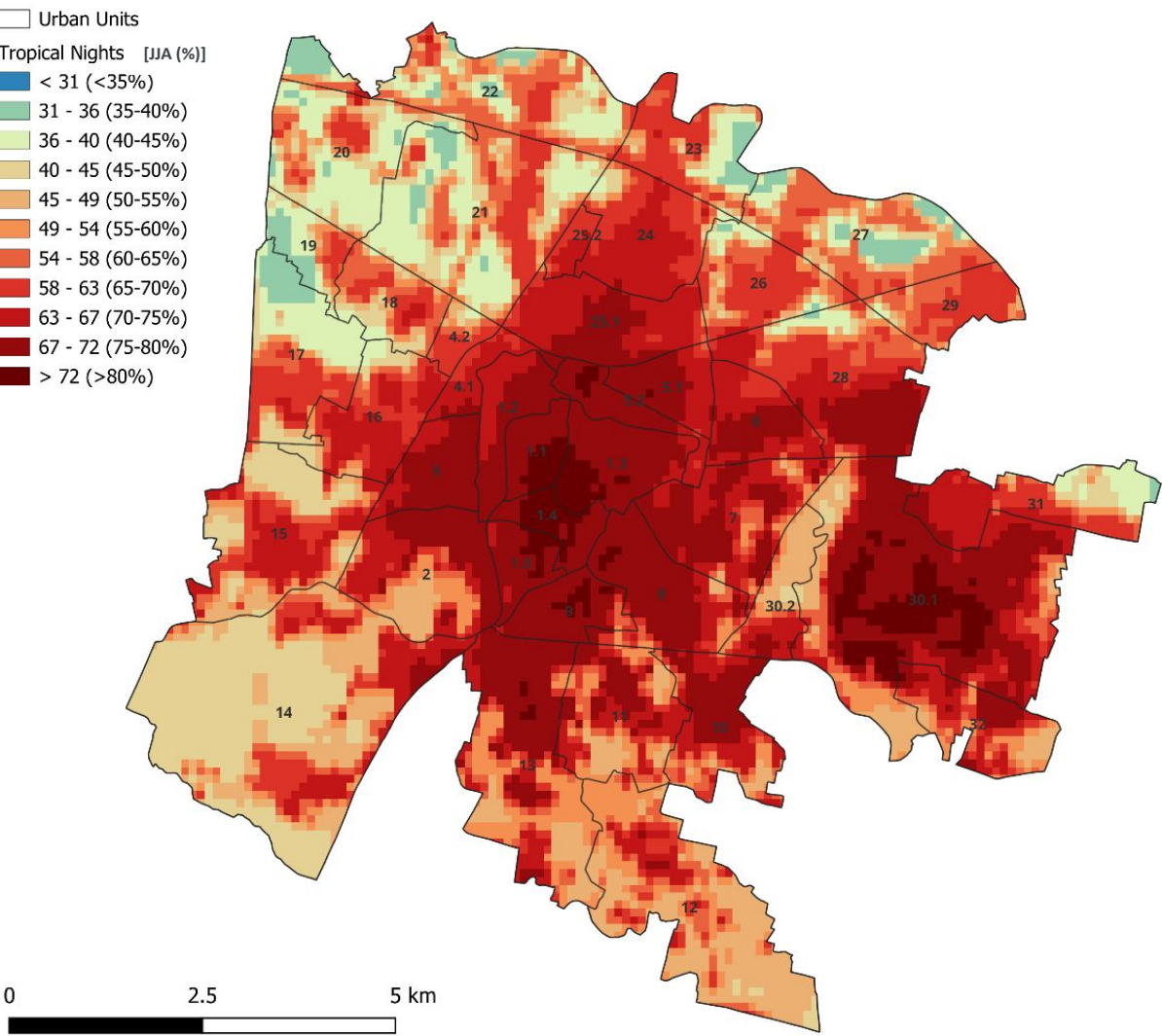
water

impermeable

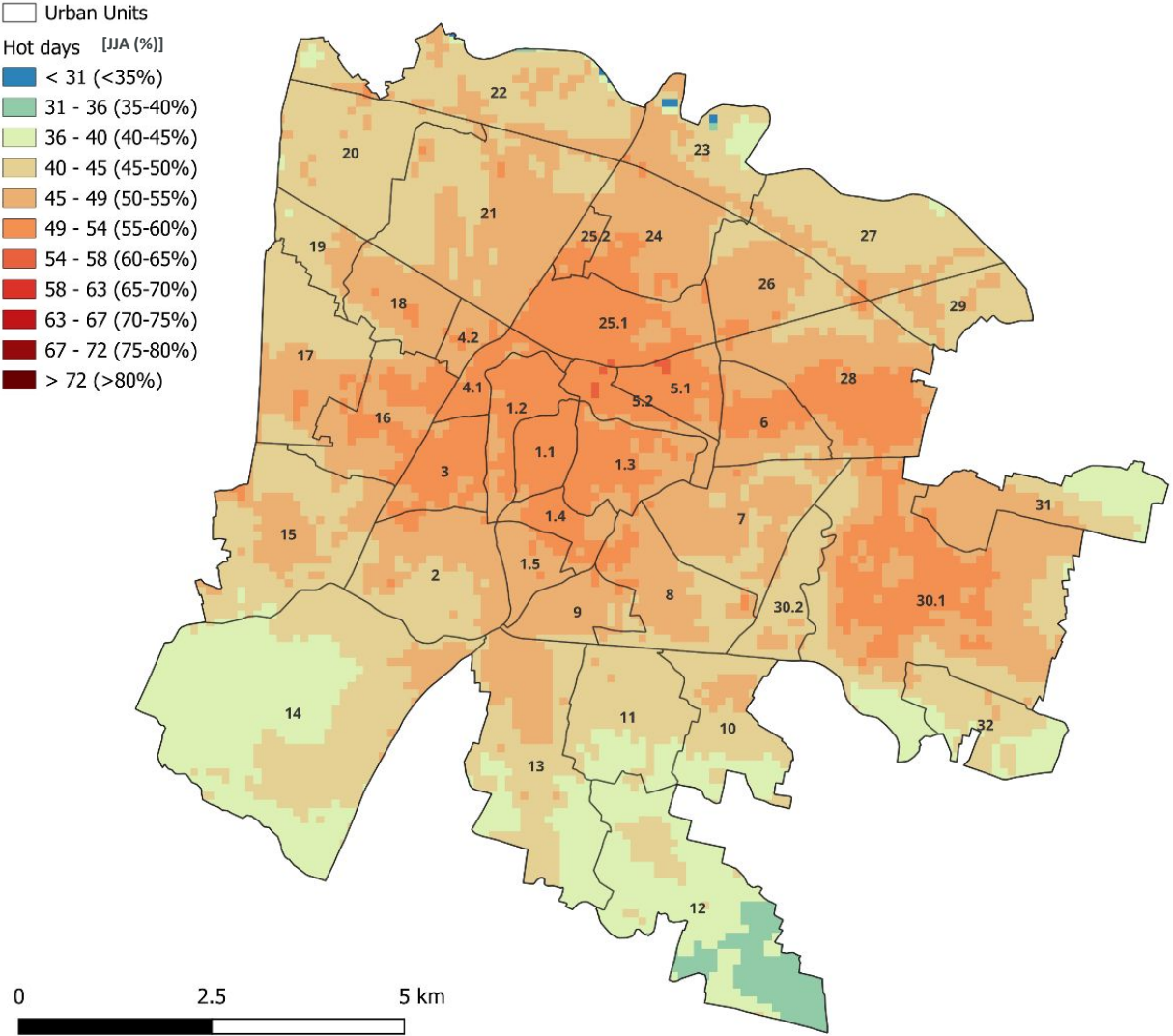
permeable

Results - climate extremes

Tropical Nights ($T_{min} > 20\text{ }^{\circ}\text{C}$)



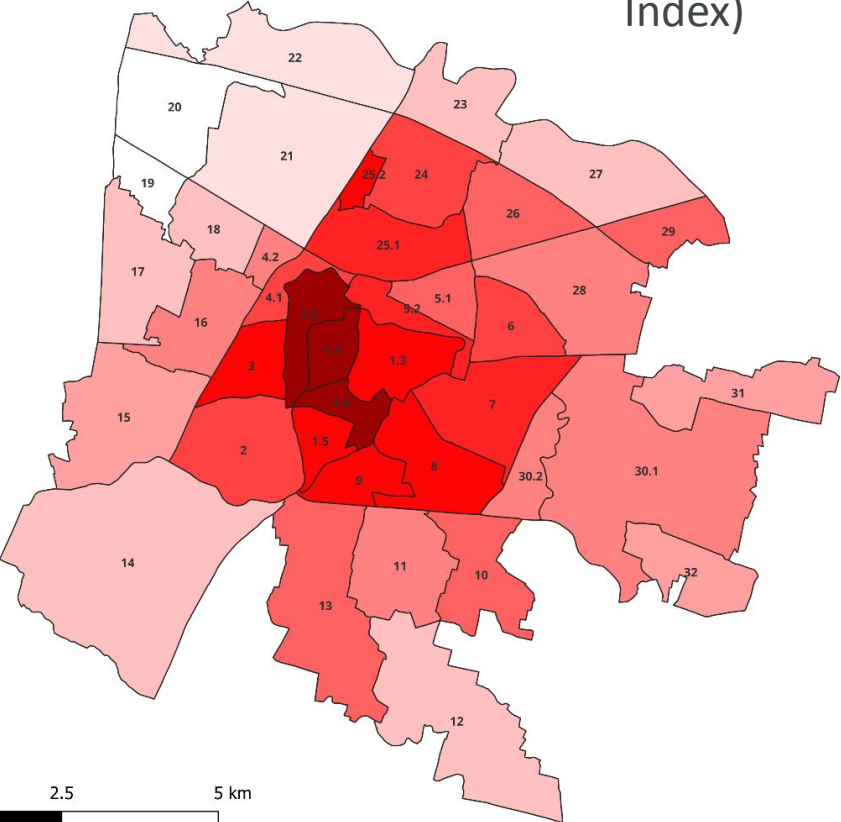
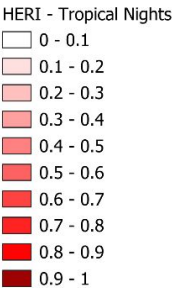
Results – Hot days ($T_{max} > 32\text{ }^{\circ}\text{C}$)



Results – Group-specific risk map for tropical night

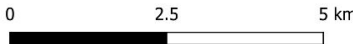
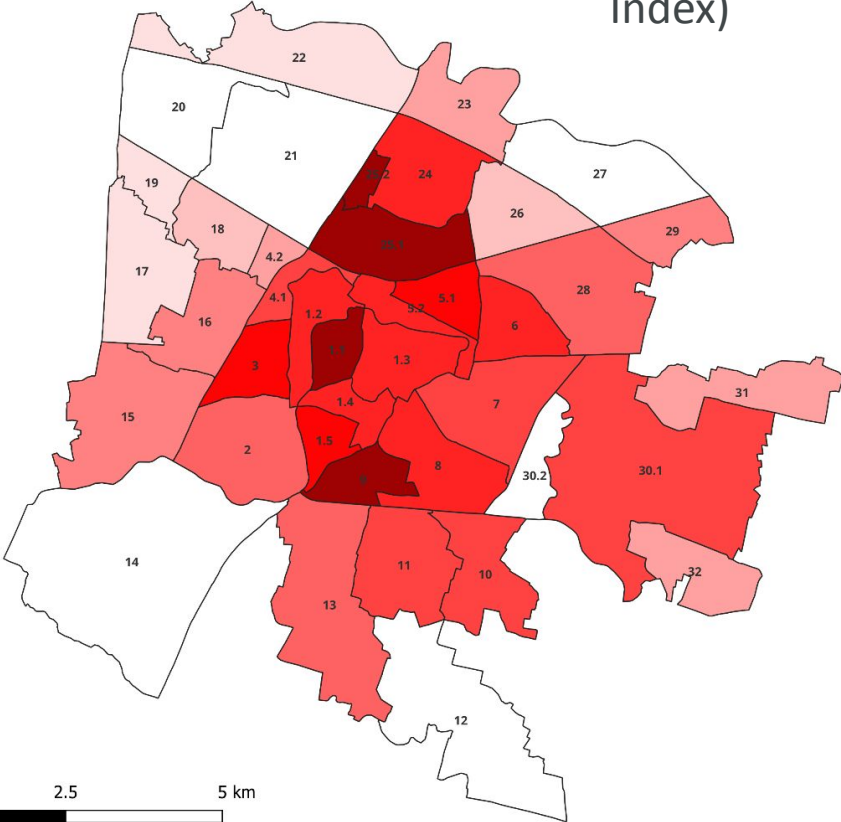
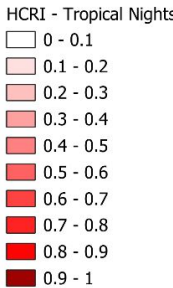
Elderly people (> 65 years old)

HERI (Heat Elderly Risk Index)



Children (< 5 years old)

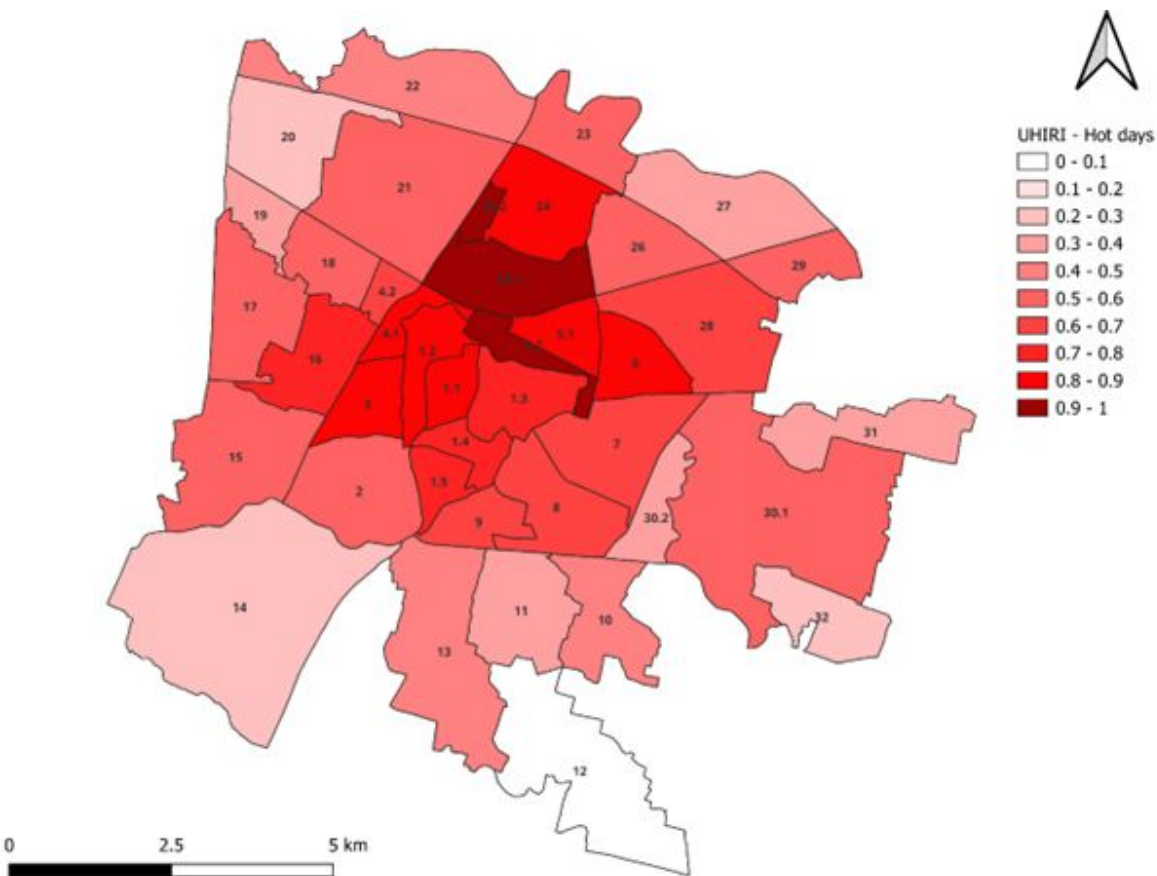
HCRI (Heat Children Risk Index)



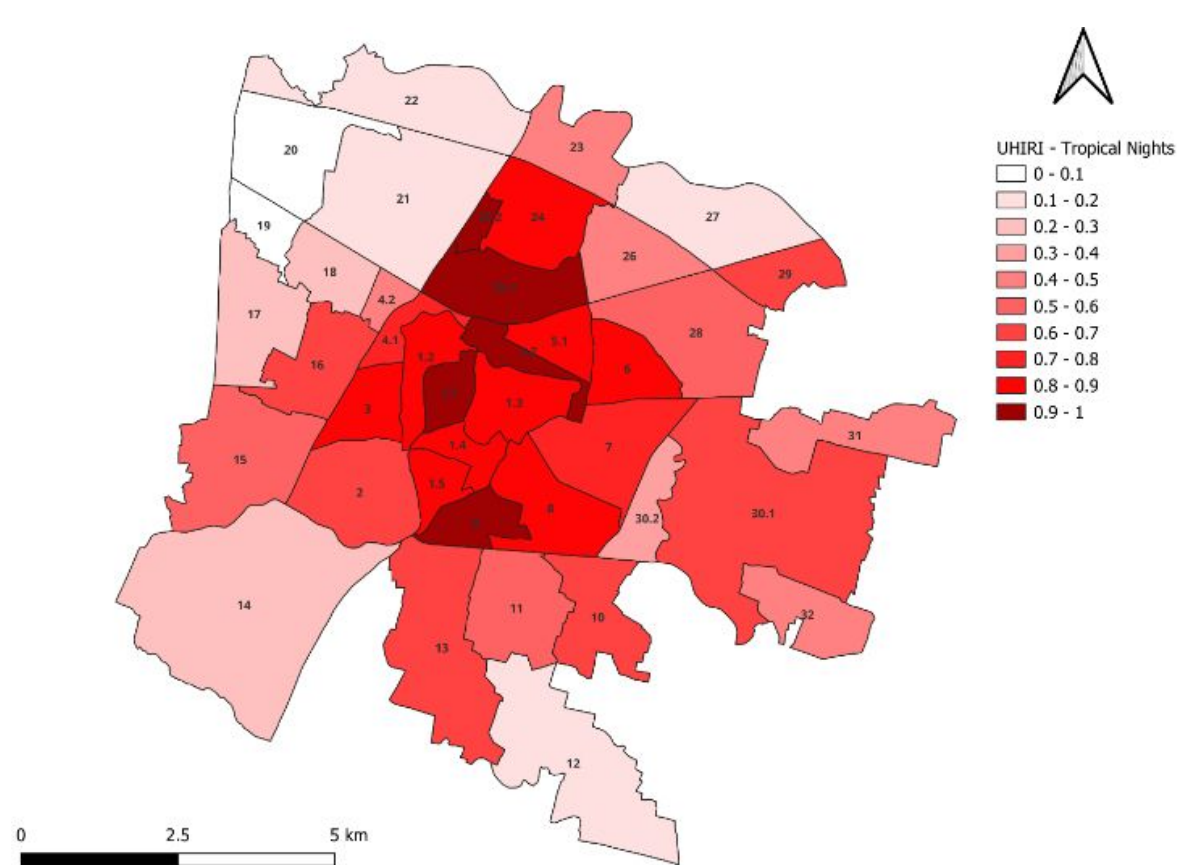
Number are refered to as metropolitan administrative units

Results – Global Risk Map

Hot days



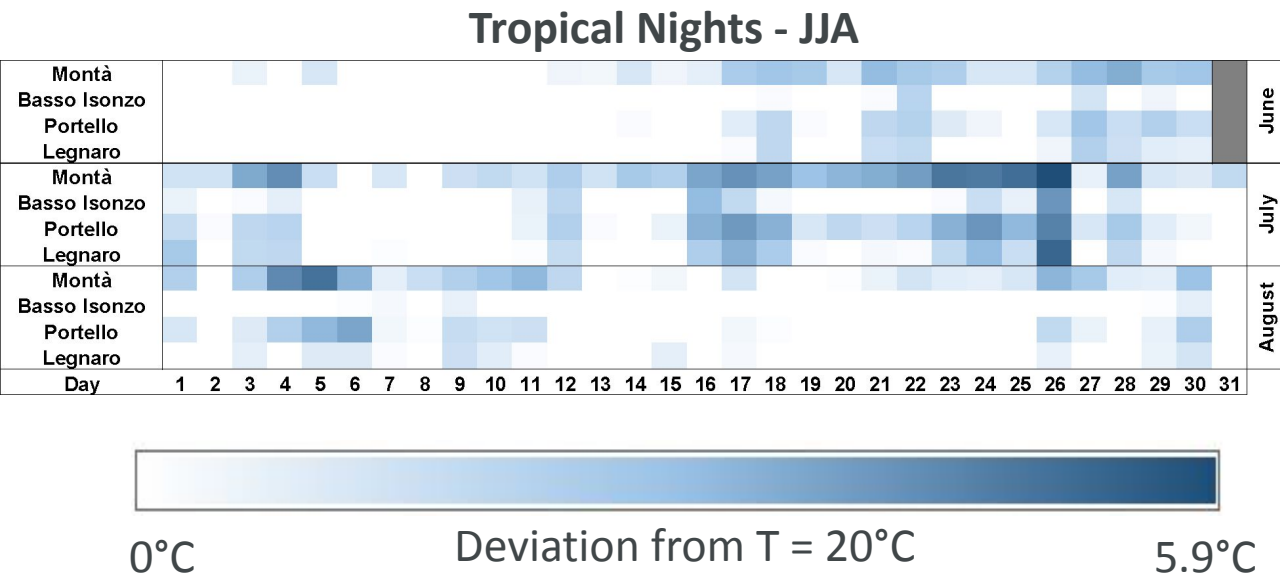
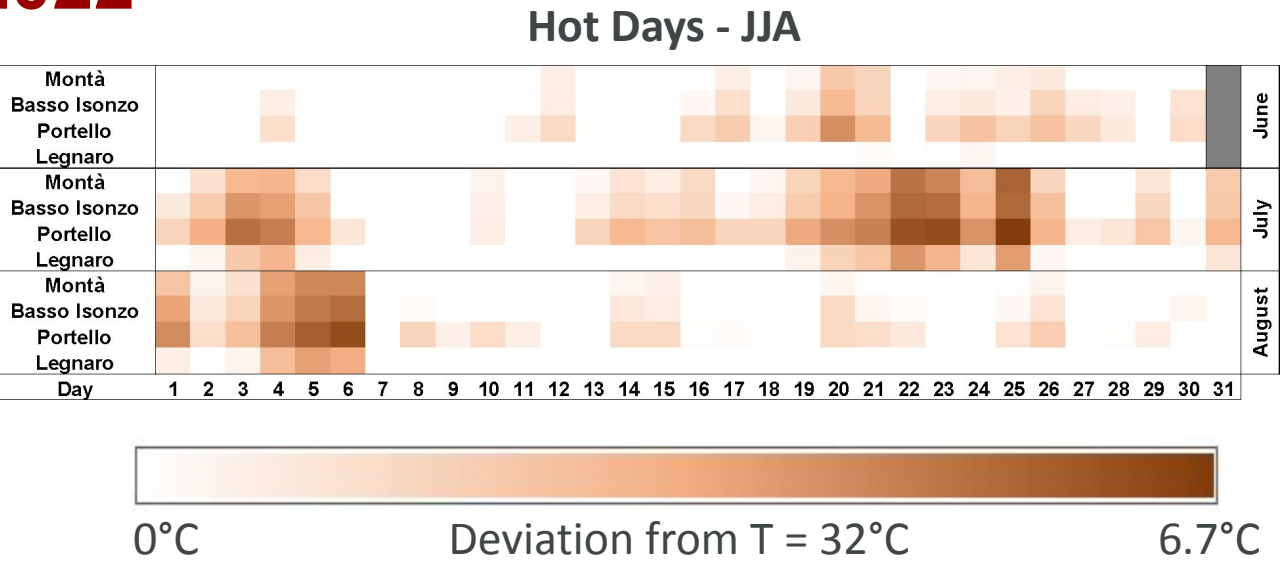
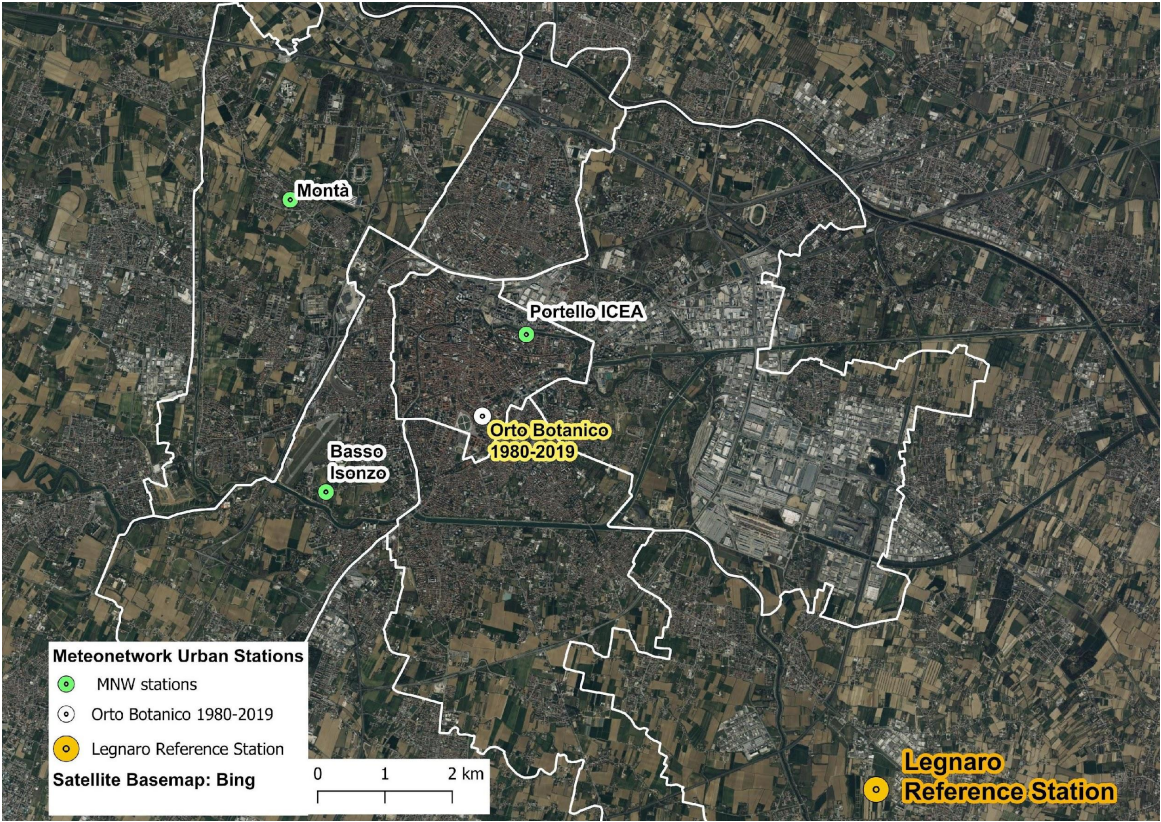
Tropical Nights



Number are refered to as metropolitan
administrative units

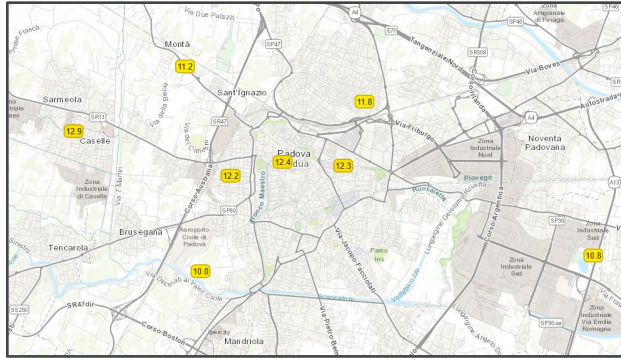
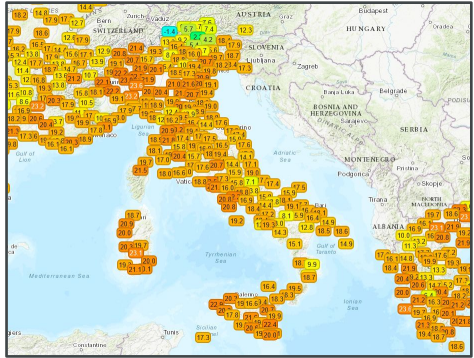
Results - The exceptional summer 2022

Since no reference stations within the municipality of Padua were available, we used the Citizen Scientist weather stations by Meteonetwork Association



Future perspectives

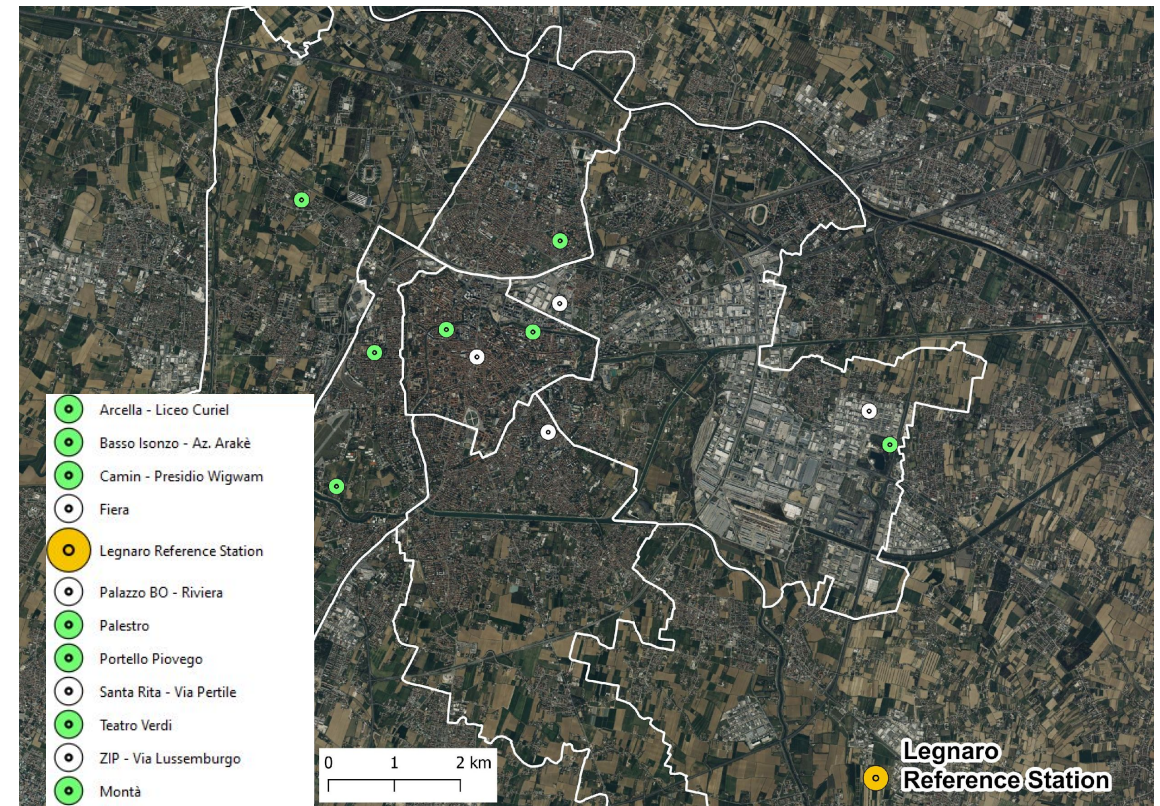
Meteonetwork stations (Giazzi et al., 2022)



Padua meteorological network

Implementation of a wider Citizen Science meteorological network for:

- assessing variability of the urban microclimate
- monitoring UHI
- calculating heat stress indices
- modelling Local Climate Zones (LCZs)



Conclusions

- **Climate change** is increasing frequency, magnitude and duration of Heatwaves (IPCC, 2023)
- Due to different factors (LULC, albedo, urban morphology) **HW-UHI** combined are “the perfect cocktail” for urban overheating
- Due to population density and economic activities **urban areas are the most vulnerable** to combined HWs-UHI, **jeopardizing health of city dwellers and infrastructures**
- In **2022, Europe experienced approximately 61,000 excess deaths** due heatwaves, particularly in the southern countries, with **Italy being the hardest hit, accounting for 18,000 deaths** (Ballester et al., 2023)
- Impacts of **HWs are not equally distributed on the urban territory**, affecting the most vulnerable people to heat (elderly, children, low-income families), raising issue of climate justice in cities

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