

# Urban Heat Island: Processes, effects and potential mitigating options

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Cagliari



Urban Heat  
Island

Active and  
participatory  
governance

Municipality of  
Cagliari

Reliefs

Results

Data  
processing

Mitigation



# Urban Heat Island



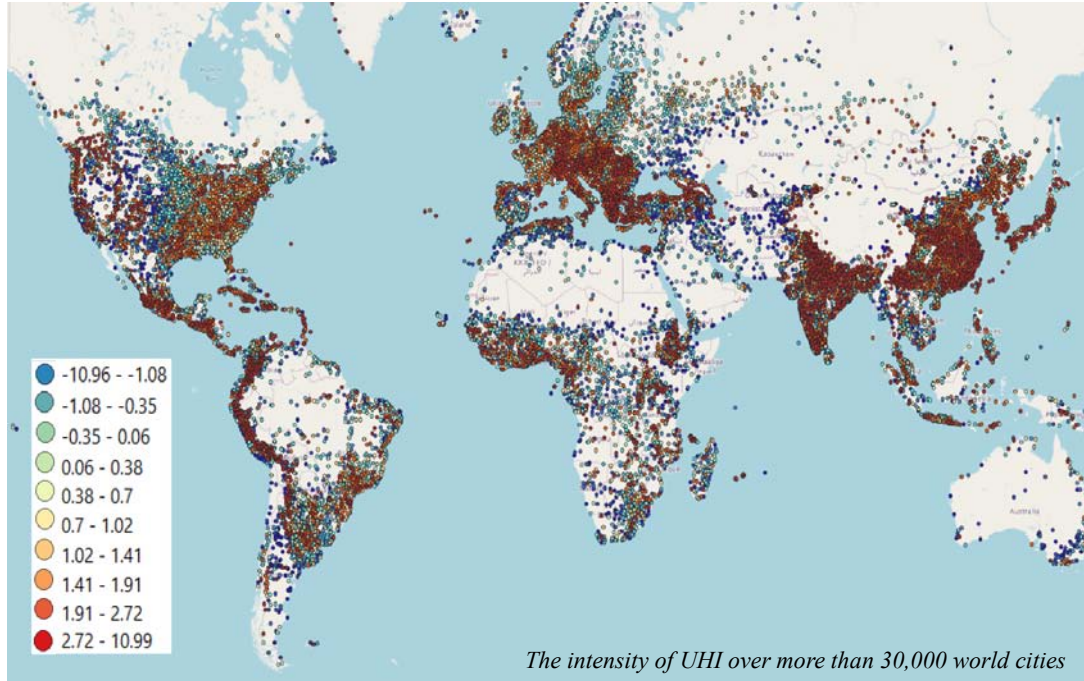
An urban heat island (UHI) is an urban area or metropolitan area that is significantly warmer than its surrounding rural areas due to human activities

$DT > 0.50 \rightarrow 5.0 \text{ } ^\circ\text{C}$

What is an urban heat island?



<https://www.youtube.com/watch?v=0Wevbkcg43g>



# Why?

Widespread overbuilding

Bituminous surfaces

Reduced green areas

Vehicle emissions

Heating and air conditioning systems

The building reduces the dispersive effect of the wind

The vertical surfaces reduce the dispersion due to radiation



# And..

**Urban morphology:  
the characteristics of the contemporary city**

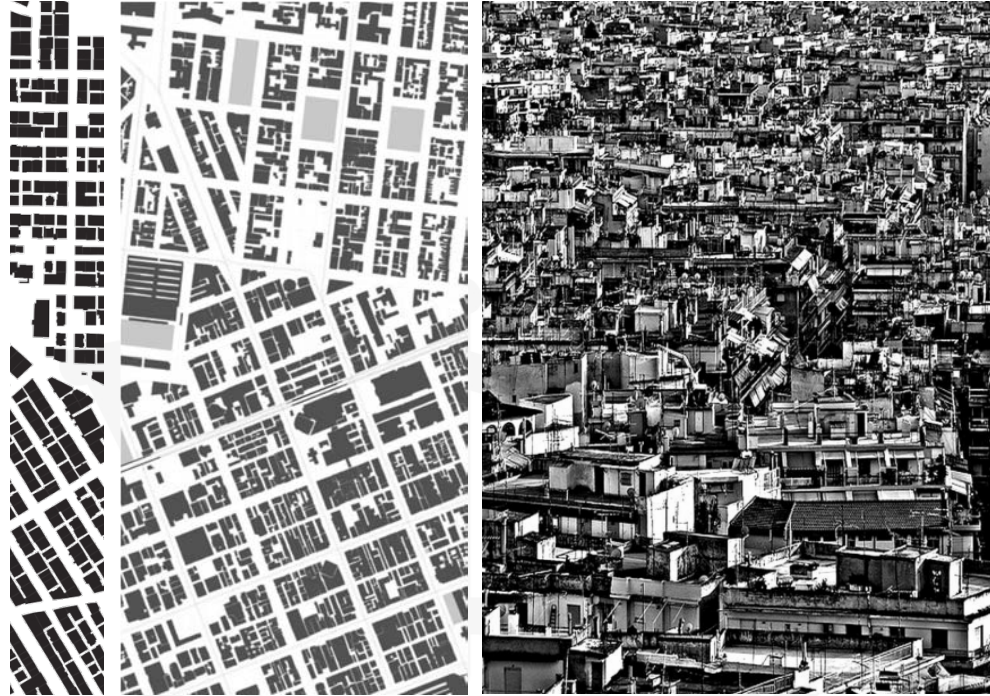
High density

High rise buildings

Lack of open spaces

Lack of green areas

Pavements and roads that can not absorb rain water







The higher temperatures of urban heat islands can be attributed to human activity, particularly changes in land surfaces

Urban development requires the use of significant amounts of concrete and asphalt for roofing purposes and for paving sidewalks and roads

These materials have bulk thermal properties that absorb more solar radiation than surfaces found in rural areas

These materials have different surface radiative properties, which means that they emit energy such as thermal radiation or heat



## Urban Heat Island

Superficial  
Atmospheric

High temperatures of urban surfaces compared to rural areas, evidenced by thermographs

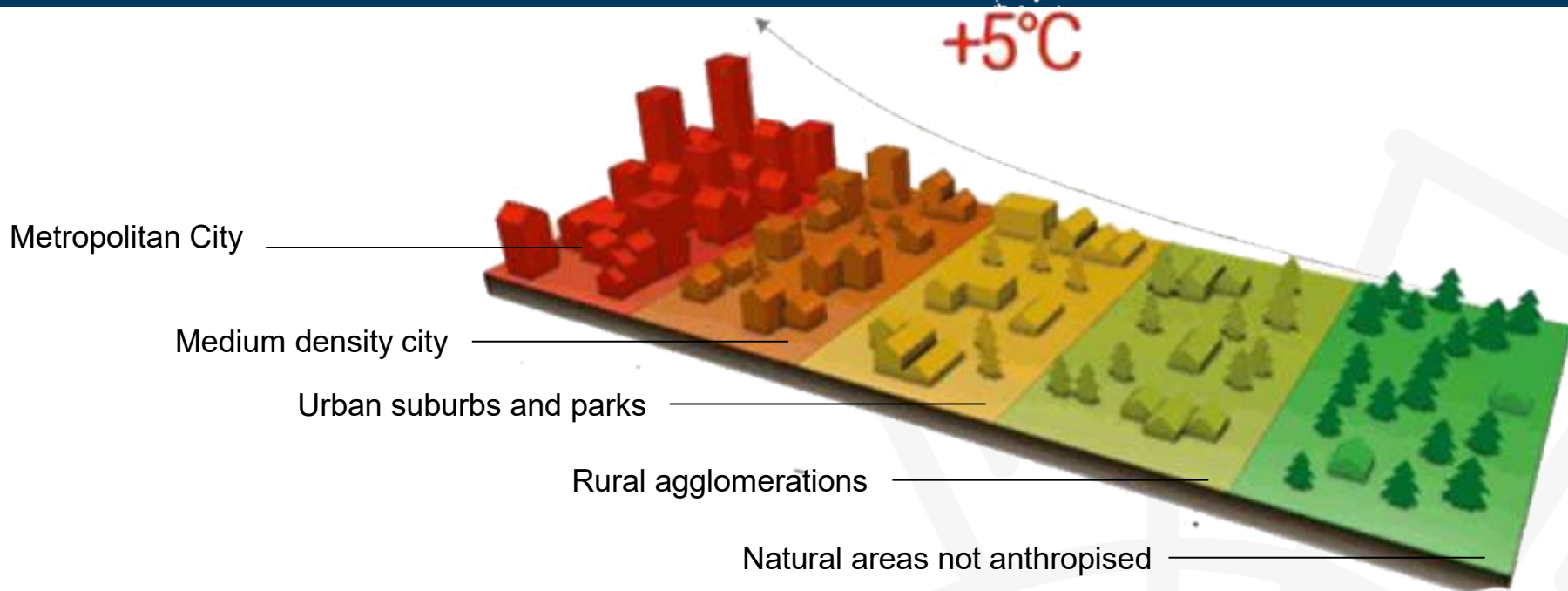
Warmer air in the urban context than in rural areas, highlighted by isothermal maps



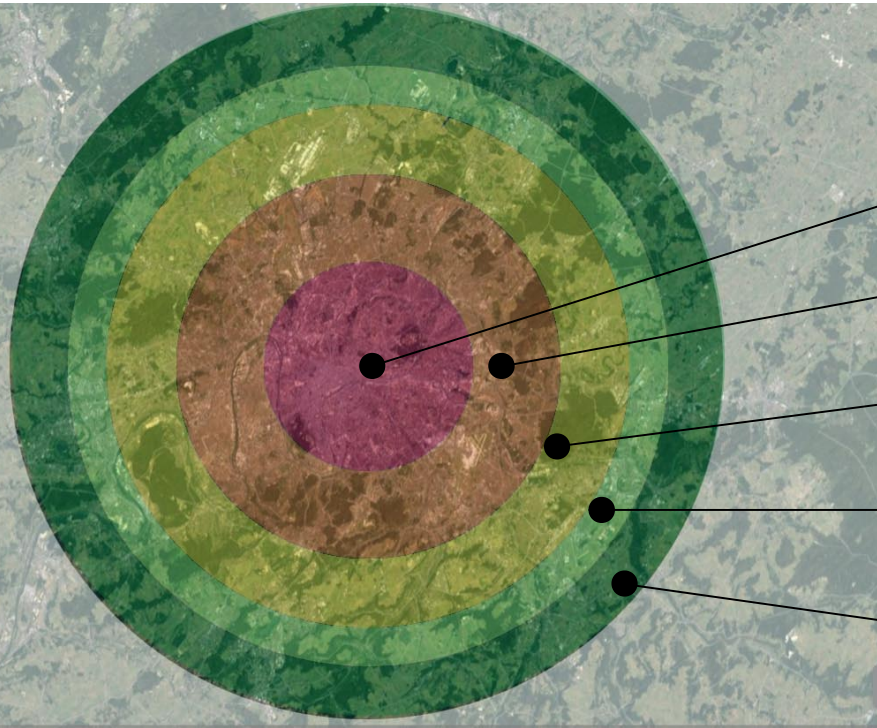
Layer of low air and warmer than the inhabited area between the ground and the top of the buildings

High air cover above the highest roofs, extended for 1-2 km





+ 5°C



Metropolitan City

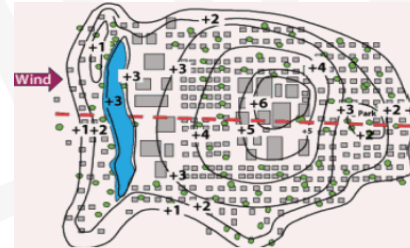
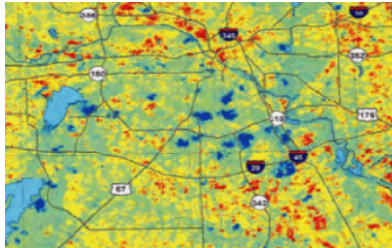
Medium density city

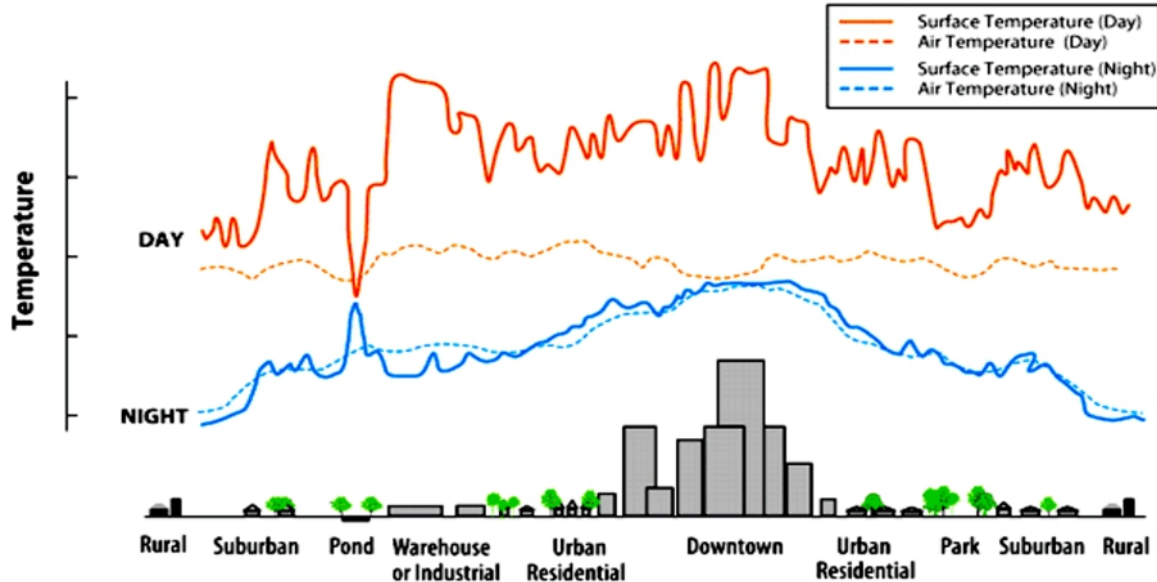
Urban suburbs and parks

Rural agglomerations

Natural areas not anthropised

<b>Andamento</b>	Always present day and night More intense during the day and in summer	Almost absent during the day More intense at night and in winter
<b>Trend</b>	It varies a lot in space and time Day: 10 - 15 ° C Night: 5 - 10 ° C	It varies little Day: 1 - 3 ° C Night: 7 - 12 ° C
<b>Detection</b>	Remote sensing indirect measurement	Direct measurement of weather and mobile stations
<b>Results</b>	Thermal images	Isothermal maps, temperature graphs

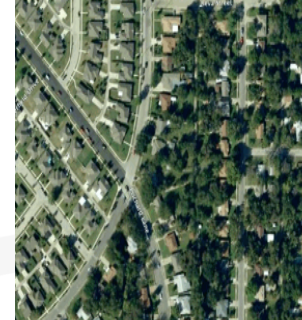
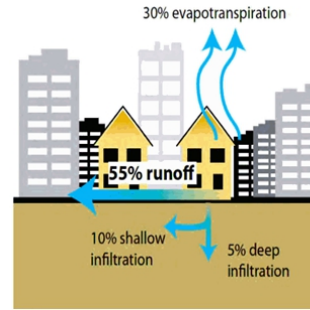
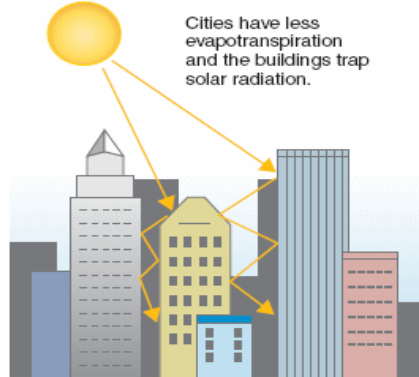
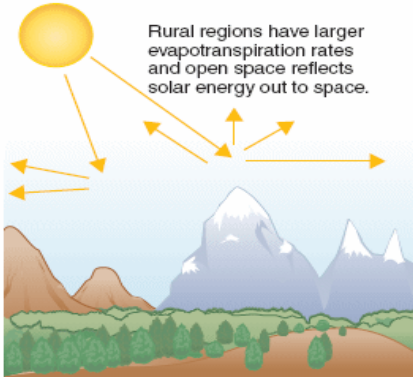
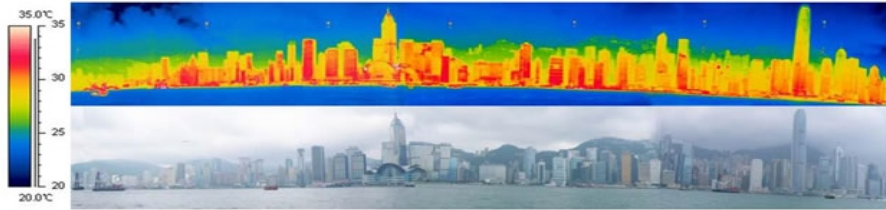




**Daytime temperatures:** they vary greatly with the type of surface. The air temperature varies little

**Night temperatures:** they are higher on urban surfaces, the air temperatures follow their trend

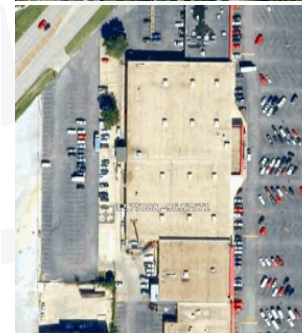
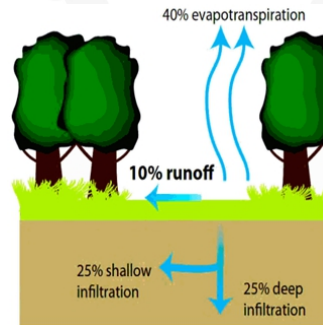
## Main aspects



**Vegetation**  
The shading of the vegetation keeps the surfaces cool

**Shading**  
Evapotranspiration helps refreshment

**Evapotranspiration**  
Paved urban areas are drier



**Territory coverage**

**Urban geometry**

**Size and shape of buildings**

**Dimensions and spacing of buildings affect the phenomenon:**  
Wind speed  
Incident solar radiation  
Reflected solar radiation



## Main aspects

### Urban surfaces

#### Thermal properties of materials

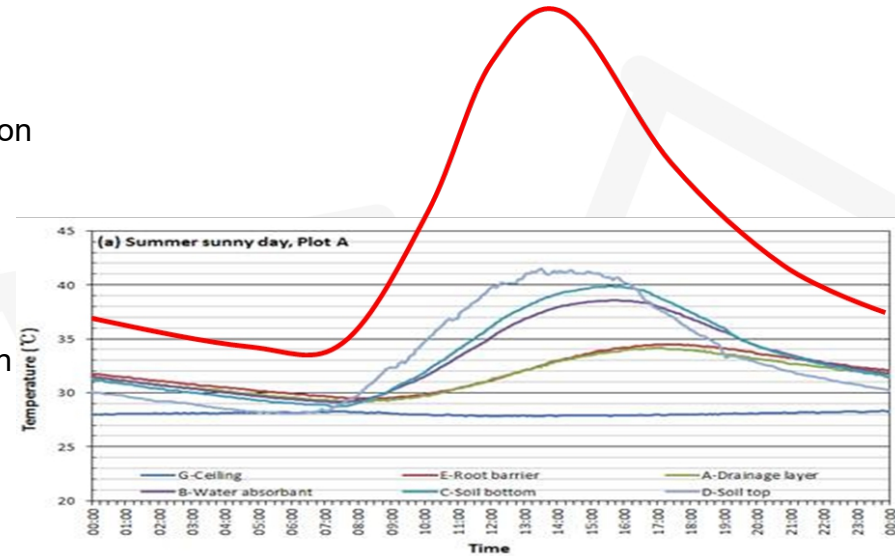
Reflectivity (Albedo) ability of the material to reflect solar radiation

Thermal emissivity: ability of the material to emit heat

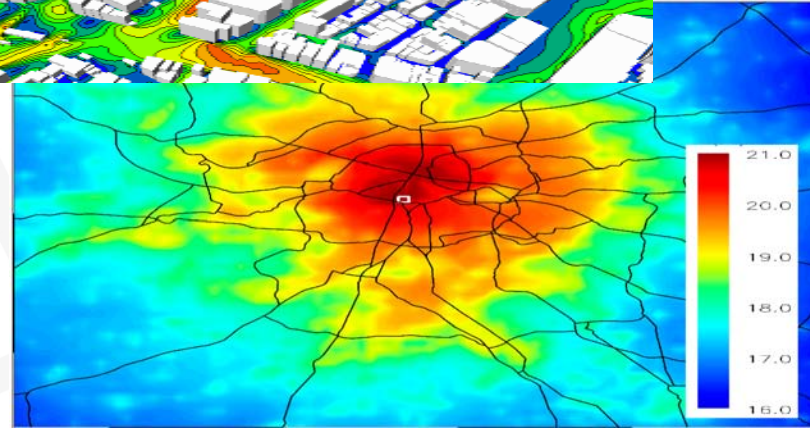
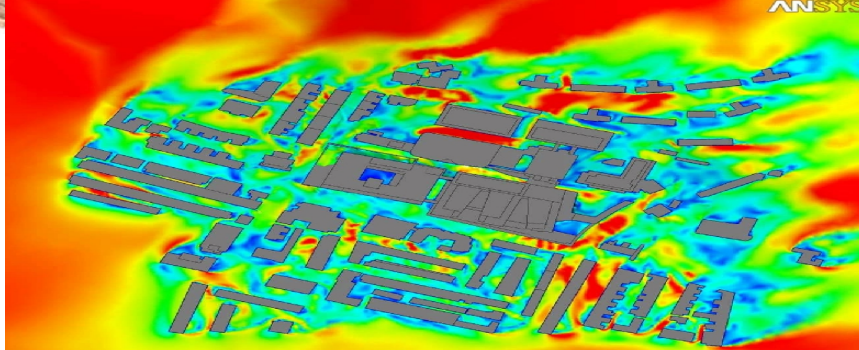
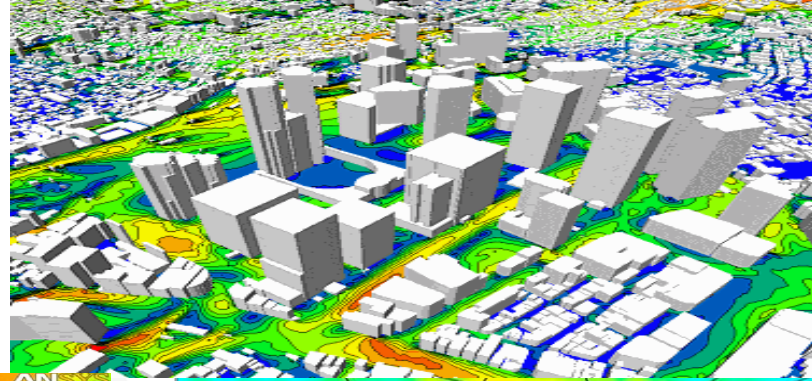
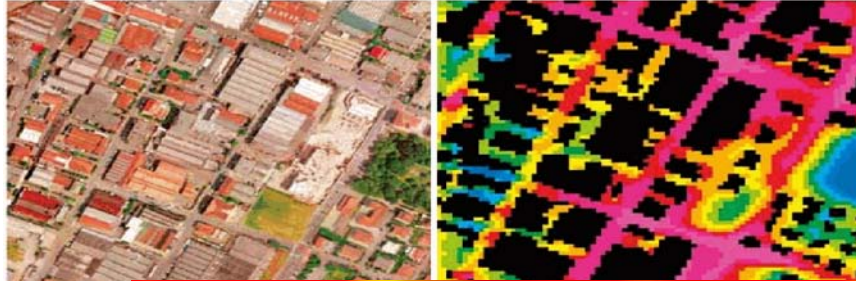
Thermal capacity: ability of a material to store heat

Permeability: porous materials cool when the air passes through

Solar reflectance index ASTM E1980-01



There are many simulation tools, some integrate the thermal response of materials





## U.H.I Mitigation Project Athens.2

### A 3 stage STUDY APPROACH

- Field Survey Summer Period
- Microclimate Project
- Evaluation of the proposals



## U.H.I Mitigation Project A

**Microclimatic Parameters:**  
 (Ta) > 33 °C - High temperatures  
 (WS) < 2.0m/sec - Low wind speeds  
 (RH) < 55% - Low relative humidity

### Buildings

Remarks-Infrared Thermography

- Temperature range building's facades, 43.0°C - 52.0°C
- Min mean daily  $T_{surf}$ , 30.0°C
- white coatings
- Max mean daily  $T_{surf}$ , 45.0°C
- dark colored coating

### Streets

- Min dia (for v/s)
- Max dia (for dia)

## U.H.I Mitigation Project Ath



Grass temperature under shade: 26 °C  
 Road temperature under shade: 42 °C  
 Road temperature unshaded: 56 °C

The grass area has a lower surface temperature with 10-20 degrees of difference.  
 The grass under shade presents about

## U.H.I Mitigation Project Athens.12

### Techniques of microclimatic modifications:

#### Radiation modification:

- Reduce solar radiation using shading
- Increase reflected radiation using light colors
- Use cool materials with high reflectivity and emissivity

#### Temperature-Humidity modification:

- Protection of the area from the prevailing atmospheric systems with the use of tall walls, dense vegetation, etc
- Creation of water elements → evaporation → increase humidity → reduction of air temperature
- Green planning (vegetation) → increase evapotranspiration → increase humidity
- Vegetation for shade → increase shading → reduction of air temperature

#### Wind modification:

Characteristics of landscape elements → modify wind speed and direction

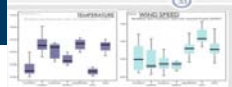
Depending on:

- Size of the study area
- Location of the area
- Orientation
- Proximity
- Proximity

### Final PROPOSALS

- NEW PEDESTRIAN TRACKS
- INCREASE VEGETATION
- USE OF COOL MATERIALS
- SHADED OPEN SPACES
- WATER ELEMENTS
- GREEN ROOFS
- LIGHT COLORS
- RENOVATION
- GREEN CARPETS

## U.H.I Mitigation Project Athens.7



In the 90% of the measurements, the maximum air temperature ( $T_a$ ) in the region fluctuated well above 33°C  
 This is on average, the highest price for Athens during July and August.

The spatial variation of the air temperature is low. The atmosphere is a "capable mixer" that any change in temperature or moisture can be smoothed relatively quickly.  
 The wind instead, is a microclimatic feature that can significantly influence / changed from buildings or other forms/structures/profiles in the terrain

## U.H.I Mitigation Project Athens.15

### NEW PLAN : RENOVATE SIGNIFICANT BUILDINGS



Preservation and restoration of individual historic monuments and buildings with a significant architectural and environmental qualities

Preservation and restoration with cool materials for roofs and walls and the surrounding open space.

## U.H.I Mitigation Project Athens.14

### PSIRI : FIELD MEASUREMENTS OF MICROCLIMATIC PARAMETERS



It is important to treat each space as an individual  
 Further research is required in order to evaluate suggested improvements through the CFD model simulation

### Before

The difference of surface temperatures is Remarkable  
 The minimum value  $T_s = 31.8$  °C noted in Liberty Square the maximum value  $T_s = 48.9$  °C Street Sarris

In terms of thermal comfort, the unfavorable climatic condition due to the lack of greenery and the use of conventional material consideration in the simulations of the existed situation)

## U.H.I Mitigation Project Athens.18

### Simulation Programs

Evaluation of proposed climate and architectural interventions to improve the microclimate performed with computational fluid dynamics (CFD) models: PHOENIX and TAPAS 3D

Using computer models provides valuable information especially for the urban areas, where the flow of the wind, characteristics of turbulence and the meteorological factors (Temperature, Humidity, etc.) affected by the existence of buildings in the area, after the application of techniques to improve microclimate.

### Surface temperature

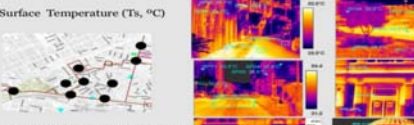


• Evaluation of proposals for improving the microclimate  
 Comparing the results of the new to the current situation there is a significant reduction in ambient temperature on average 2 °C  
 The improvement of the microclimatic characteristics it is worth mentioning Thermal comfort Improvement - Reduction of Energy consumption for cooling  
 There is a remarkable reduction of surface temperatures, after the application of architectural interventions, of about 10 °C on average.



## U.H.I Mitigation Project Athens.4

### Surface Temperature ( $T_s$ , °C)

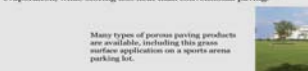


PERIPHERIC, WIDE MAIN STREETS OPEN SPACES PAVEMENT MATERIALS GREEN AND WATER ELEMENTS BUILDINGS

## 3.0 Water Effects of Urban Surfaces

Water evaporation from urban surfaces can also moderate temperatures.

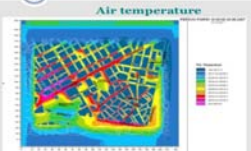
- Evaporation from green roofs releases moisture into the air, unlike hard surface rooftops.
- Porous paving allows moisture to stay near the surface and cool by evaporation, while storing less heat than conventional paving.



## U.H.I Mitigation Project Athens.17

### Before

The maximum air temperature is:  $T_a = 31.2$  °C and occurs in most streets of the historic center with bright red color, while the minimum is:  $T_a = 30.2$  °C and it is noted in the archaeological site and to green spaces with green hues.



The results are plotted in the form of spatial distributions  
 The color scale corresponds to a similar price range.

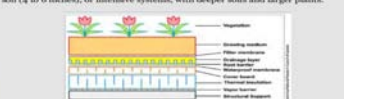
## U.H.I Mitigation Project Athens.21

### CONCLUSIONS

- From all the above, it was confirmed that:
  - the use of new suitable reflective MATERIALS
  - the use of suitable VEGETATION
  - and the reduction of anthropogenic heat
- Play a crucial role modifying significantly the microclimate and thus the thermal comfort conditions.

## 3.2 Porous Paving

- There are many types of porous or pervious paving, including pervious concrete and porous asphalt.
- These pavements cool by evaporation of water in the pavement, convective airflow, and reduced thermal storage.
- They are primarily used for non-road surfaces, although they are capable of higher traffic loads.
- Stormwater management and design features are key attributes for considering porous paving.



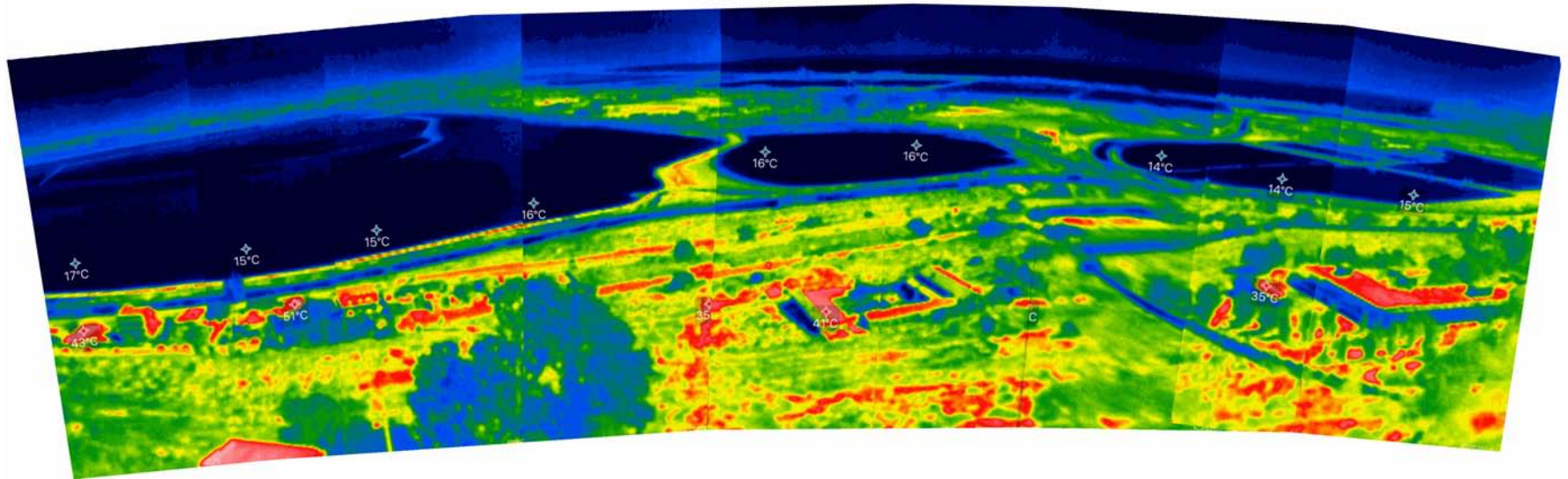
Porous paving has been used to replace conventional paving for improved stormwater management.



# Municipality of Cagliari



Municipality of  
Cagliari



Urban surfaces  
Thermal properties of materials

**Cagliari:**  
thermal imaging camera (Seek Pro 640 x 480, aperture 32 °) mounted above the wing of a small plane flew over the city of Cagliari, continuously capturing the temperature of the areas crossed (each frame frames 180 x 130 m)







Survey date: 17.10.2017 at 16.00

Duration: 33 '42' ' Aircraft 'Seek Pro' thermal camera

Temperature range  $-40^{\circ}\text{C} \div 330^{\circ}\text{C}$ .

Anti-vibration rubber layer

640 x 480 pixel matrix

$32^{\circ}$  opening

Size of the framed area per frame approximately 180m x 130m

About 250 elementary areas analyzed



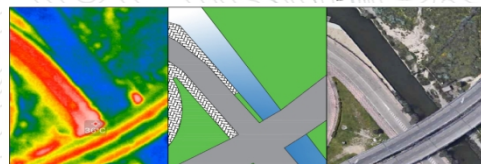
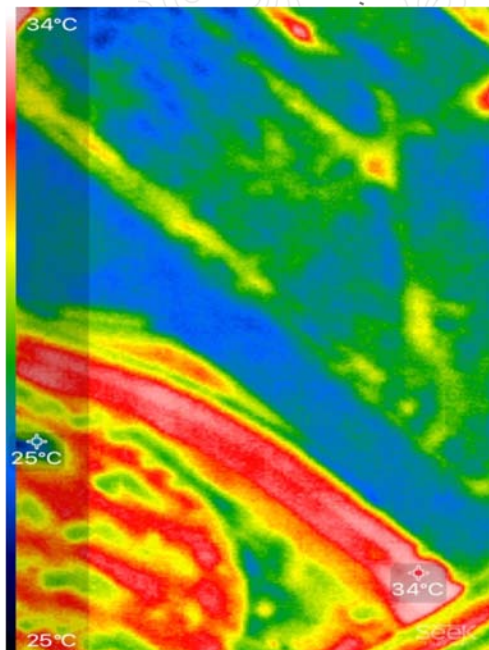
Route length of about 70 km

Altitude of about 300 s.l.m.

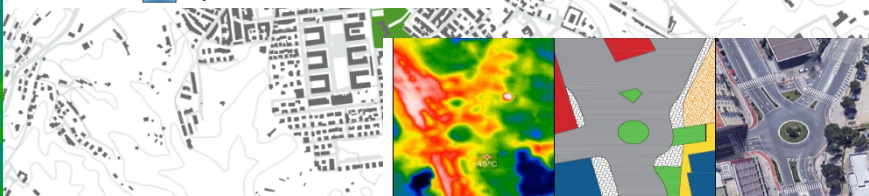
Speed of 80 knots (148 km / h)

Air temperature about 20 °C

### Zone 03\_ Sant'Elia Stadium

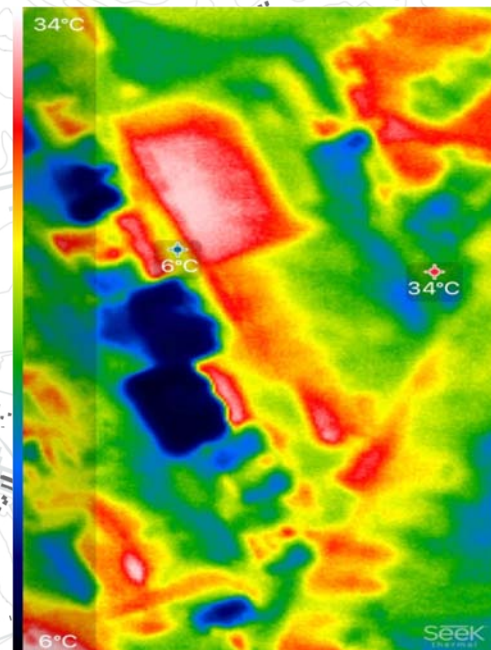


- Pavimentazione stradale - conglomerato bituminoso
- Elementi lapidei - colorazione chiara
- Vegetazione
- Corpo idrico - canale



- Pavimentazione stradale - conglomerato bituminoso
- Elementi lapidei - colorazione chiara
- Calcestruzzo
- Non Pavimentata
- Tetti di copertura - colorazioni scure
- Tetti di copertura - colorazioni chiare
- Vegetazione

### Zone 20\_ Is Mirrionis roundabout



## Data processing

### Phase 1

Reading of the  
image to be  
analyzed

### Phase 2

Calculation of  
intermediate  
temperatures

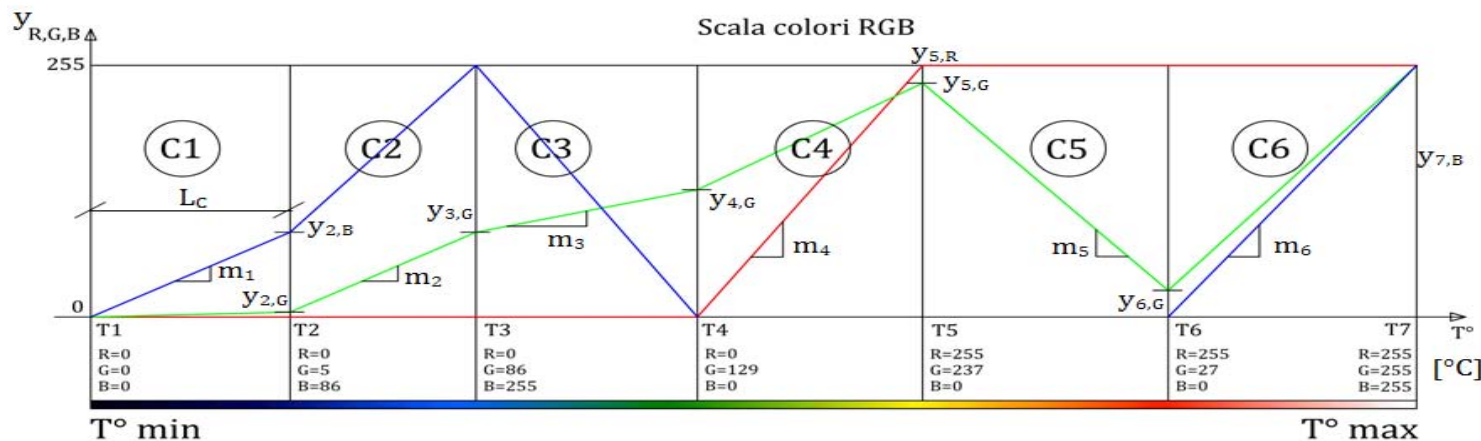
### Phase 3

Reading of the  
RGB values of  
each pixel,  
selection of field  
C in the color  
scale and  
calculation of the  
temperature value

### Phase 4

Calculation of  
image  
temperature  
values

## Data processing



The weighted average of the respective temperature values in the different areas was calculated for each type of surface:

$T^{\circ}pj$  [°C] =

$$A_{i,j} [m^2] = \frac{\sigma_{T_{i,j}} \cdot T_{i,j}}{\sum_{j=1}^m A_{i,j}}$$

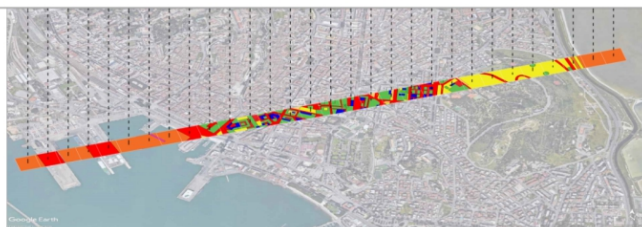
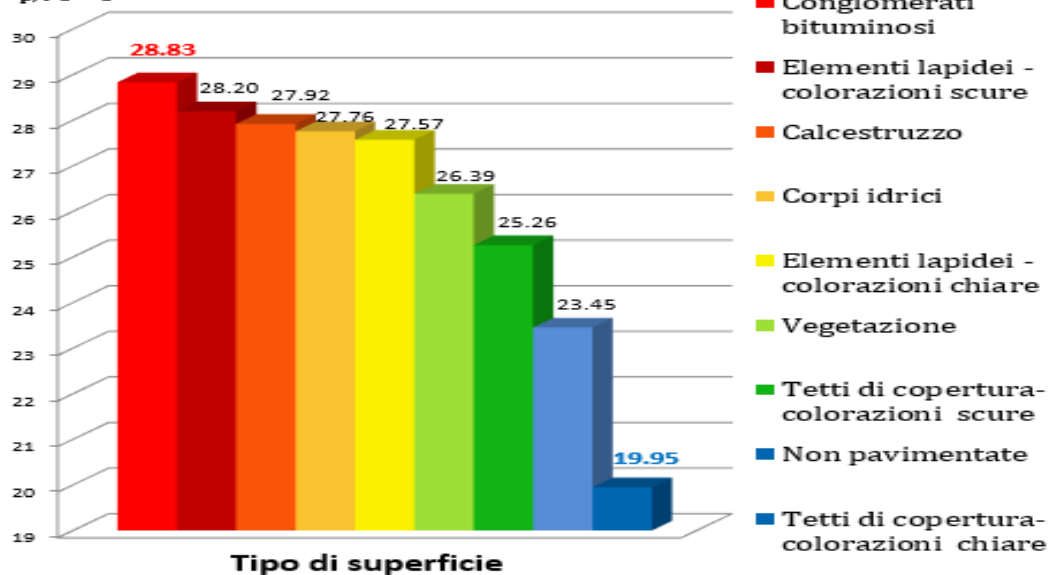
$T_{i,j}$  [°C] = surface temperature i-th, zone j-th  
 $m$  = number of j-th study areas

### Weighted average temperature [° C] - October 2017



Tmax = 29

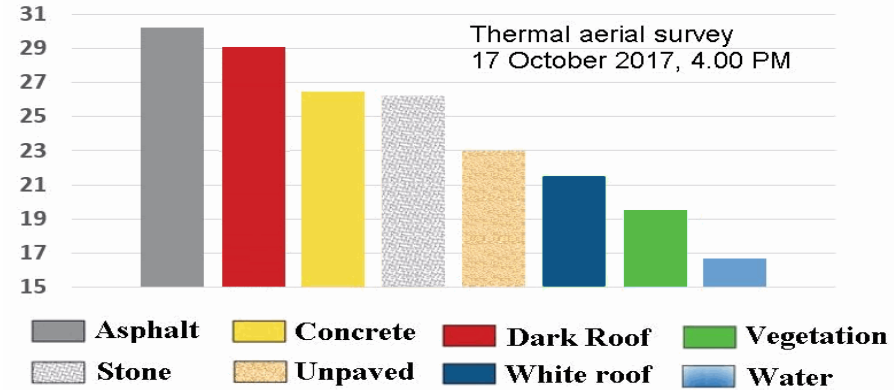
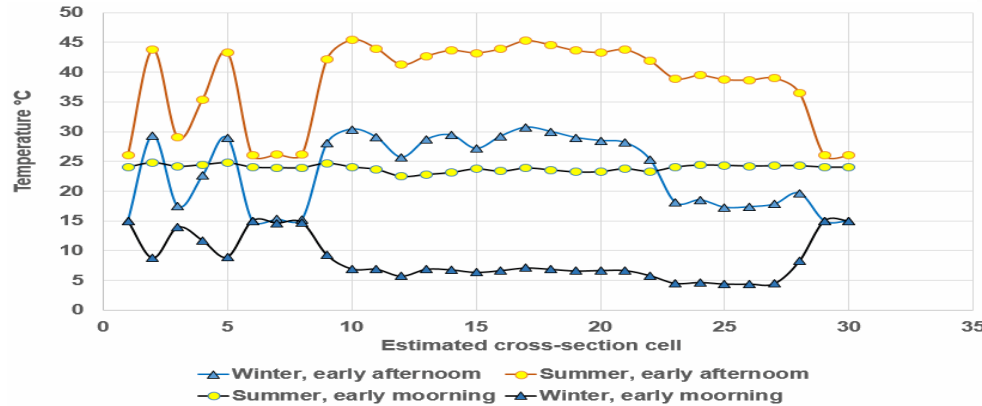
T° p. i [°C]



- |  |  |
|--|--|
| <span style="color: red;">■</span> Pavimentazione stradale - conglomerato bituminoso | <span style="color: yellow;">■</span> Vegetazione                                |
| <span style="color: orange;">■</span> Calcestruzzo                                   | <span style="color: green;">■</span> Tetti di copertura - colorazioni scure      |
| <span style="color: blue;">■</span> Corpo idrico                                     | <span style="color: lightblue;">■</span> Tetti di copertura - colorazioni chiare |
| <span style="color: lightorange;">■</span> Elementi lapidei - colorazione chiara     | <span style="color: pink;">■</span> Molo - legno                                 |

Zone 02

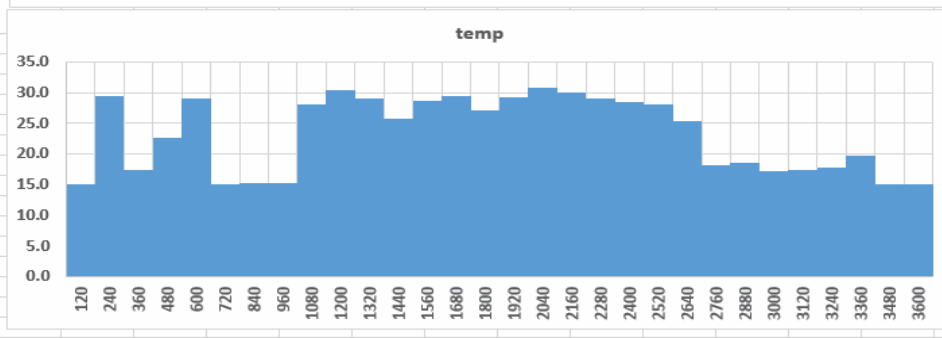
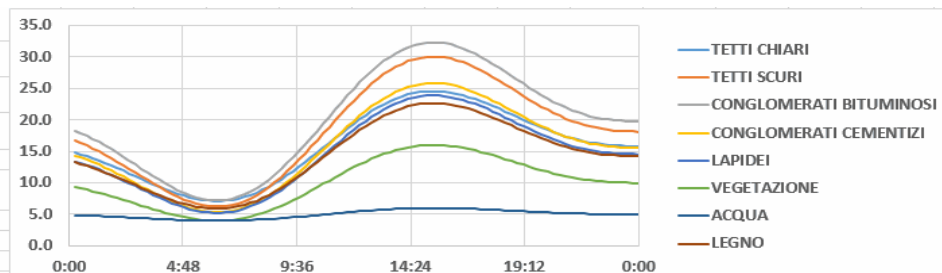
Zona 13



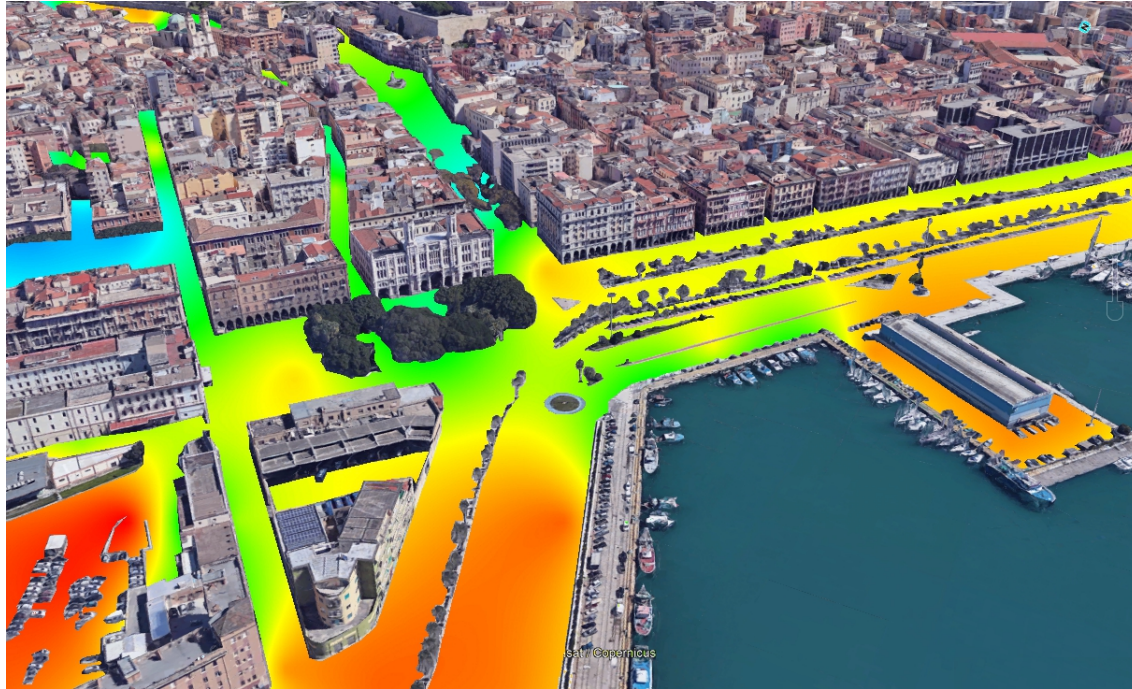
**Temperatura massima aria** 15  
**Temperatura minima aria** 5  
**Radiazione solare** 15  
**orario** 15:36

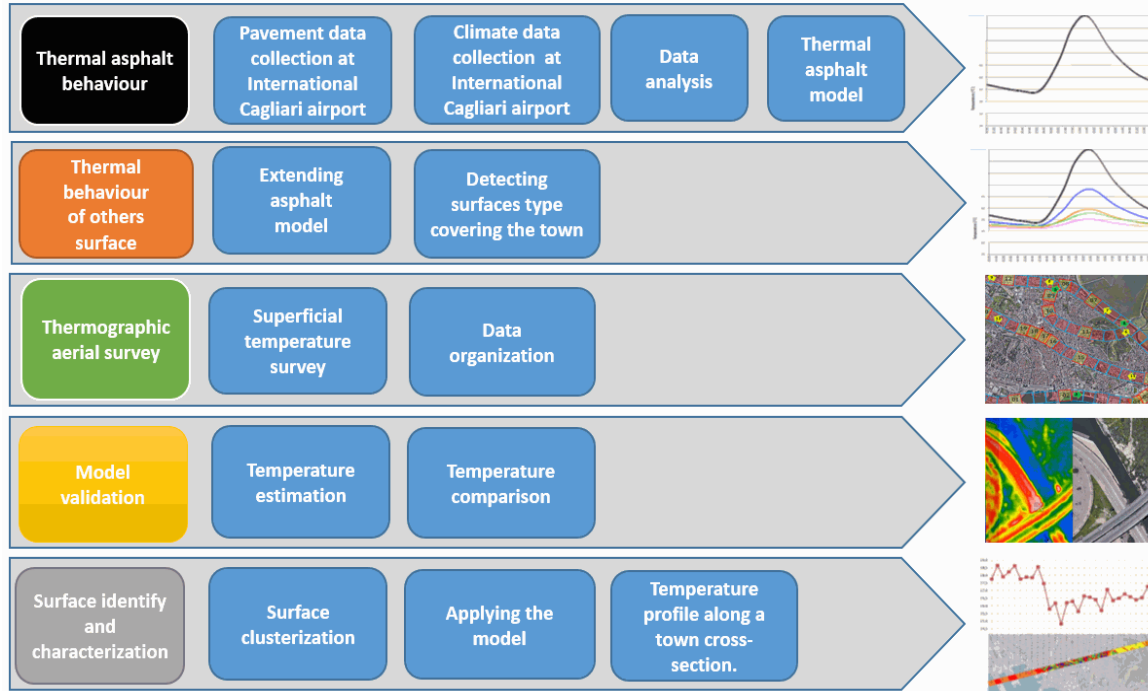
	Tetti scuri	Tetti chiari	Congl. Bitum.	Cls	lapidei chiari	Vegetazione	Corpi idrici	legno
T° [°C]	30.0	24.5	32.3	25.8	29.8	16.0	15.0	22.6

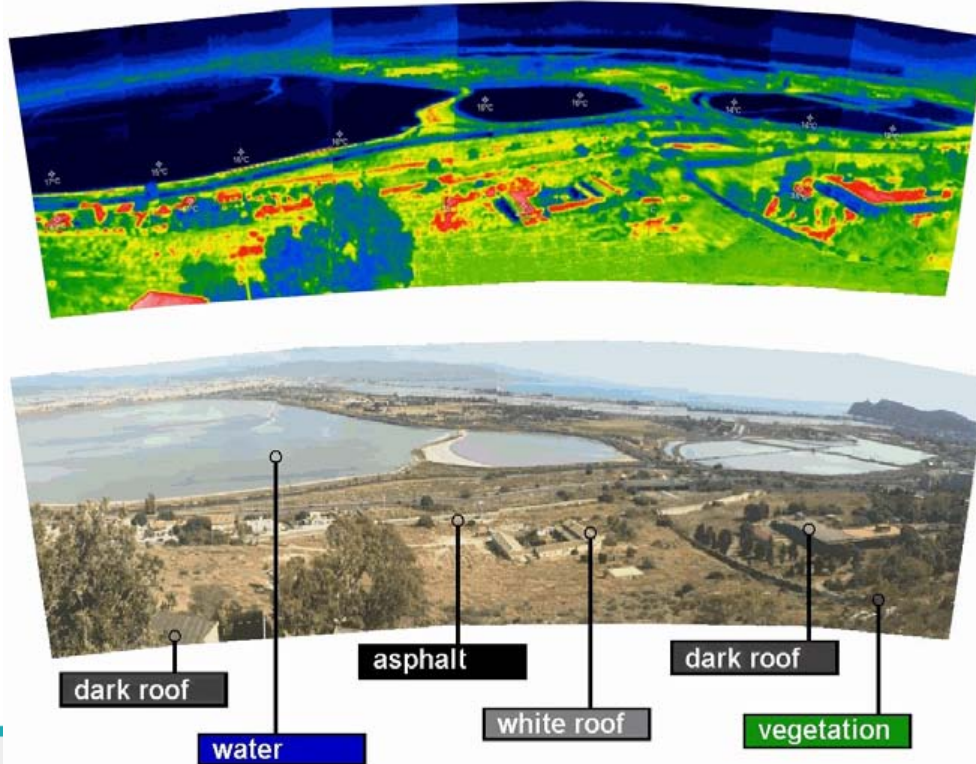
Zona	Tetti scuri	Tetti chiari	Congl. Bitum.	Cls	lapidei chiari	Vegetazione	Corpi idrici	legno	ascisse	temp
1	0	0	0	0	0	0	14400	0	120	15.0
2	0	0	11986	0	0	0	2414	0	240	29.4
3	0	0	2064	0	0	0	12336	0	360	17.5
4	0	0	6325	0	0	0	8075	0	480	22.6
5	0	0	11655	0	0	0	2745	0	600	29.0
6	0	0	0	0	0	0	14400	0	720	15.0
7	0	0	0	0	0	0	13822	578	840	15.3
8	0	0	0	0	0	0	13979	421	960	15.2
9	0	0	10815	0	131	0	3454	0	1080	28.0
10	4824	0	8378	0	424	774	0	0	1200	30.4
11	5608	2402	5425	0	0	965	0	0	1320	29.0
12	6823	272	0	4189	0	3116	0	0	1440	25.7
13	4732	3282	5551	435	0	0	0	0	1560	28.7
14	6400	1442	4622	420	1515	0	0	0	1680	29.4
15	5252	1095	4639	0	265	3150	0	0	1800	27.1











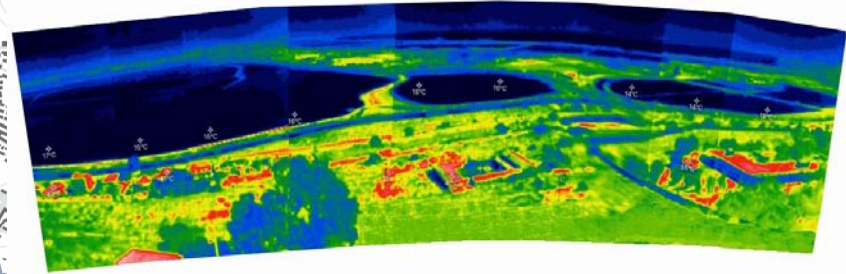
The research confirm the role of asphalt pavement increasing UHI

The contribution has been quantified based on the min and max daily temperature and solar radiation

Recognizing the materials covering the urban cell allow to evaluate a mean value of the cell temperature and draw a temperature profile of a town section for each daily hour

The methodology allow to forecast the mitigation actions and define strategies for their implementation

A thermal survey over Cagliari confirm the results



dark roof

asphalt

dark roof

water

white roof

vegetation



# Mitigation

## Various mitigation tools and Actions

- Creation of urban green areas
- Trees in the streets
- Energy efficiency improvement
- Vehicular reduction
- Green roofs
- Clear coloring of the surfaces
- Reduction of bituminous surfaces



Barcelona, Colored COOL ROOF based on Abolin Co Coatings Tech. 2014.

**HOT** →

Surface Temperature: 77,9 °C

← **COOL**

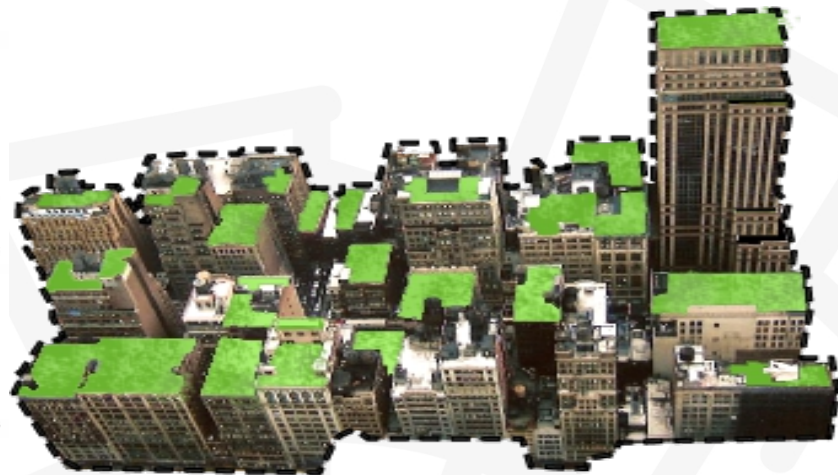
Surface Temperature: 47,4 °C



Before: Barcelona, black modified bituminous roof. 2014.



## Green roofs

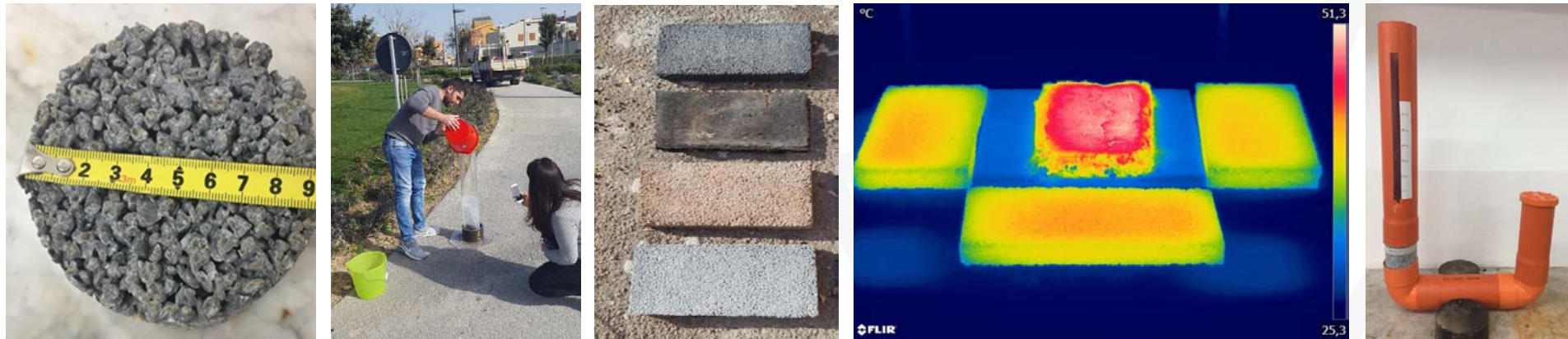


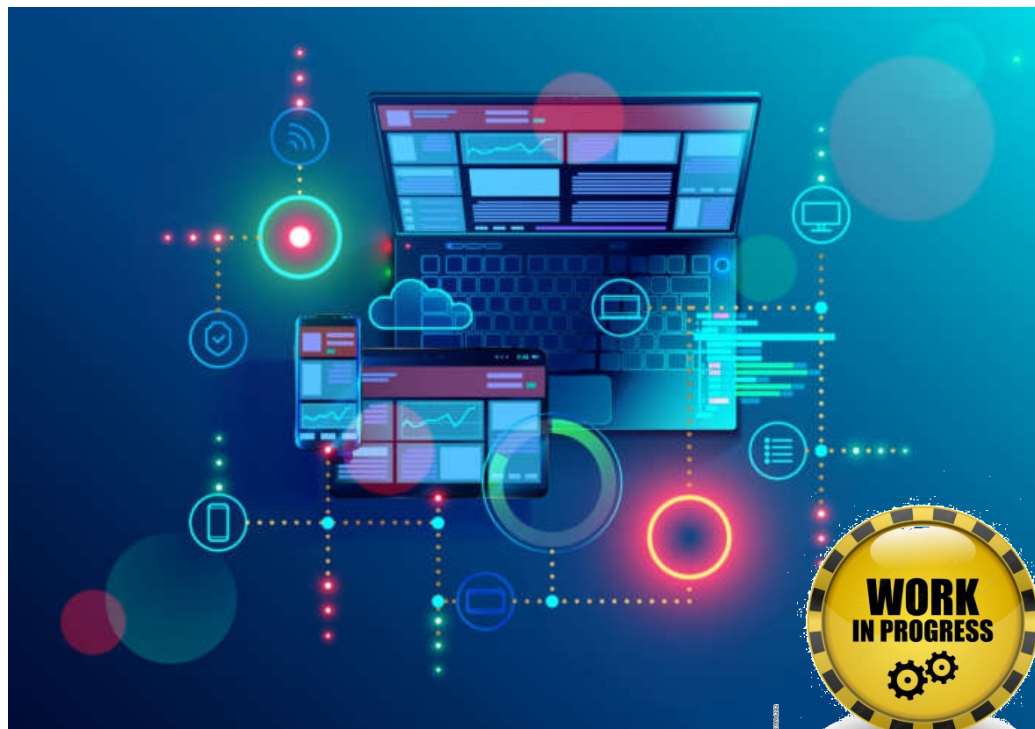
## Green roofs





## Hydrodrain





# Thank you!

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Cagliari