Urban Heat Island:
Processes, effects and potential mitigating options

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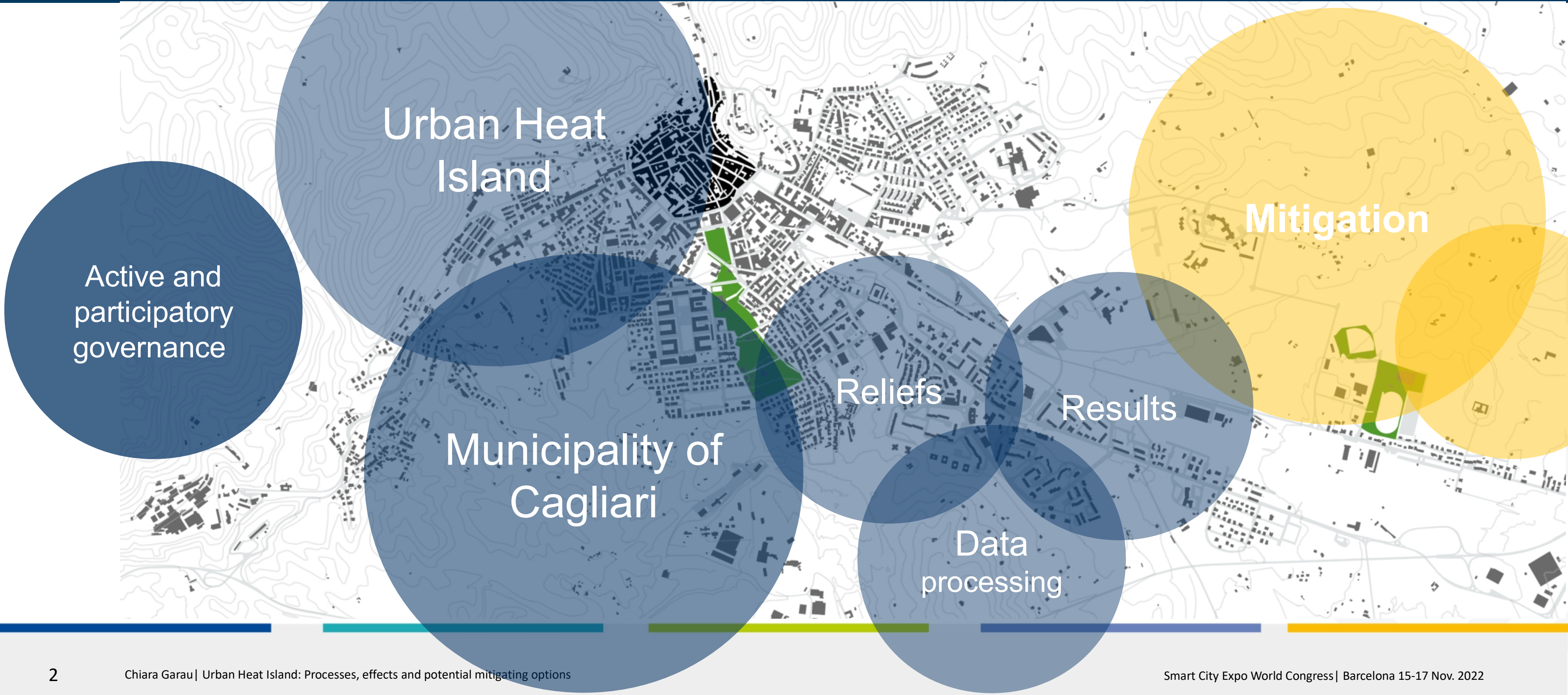
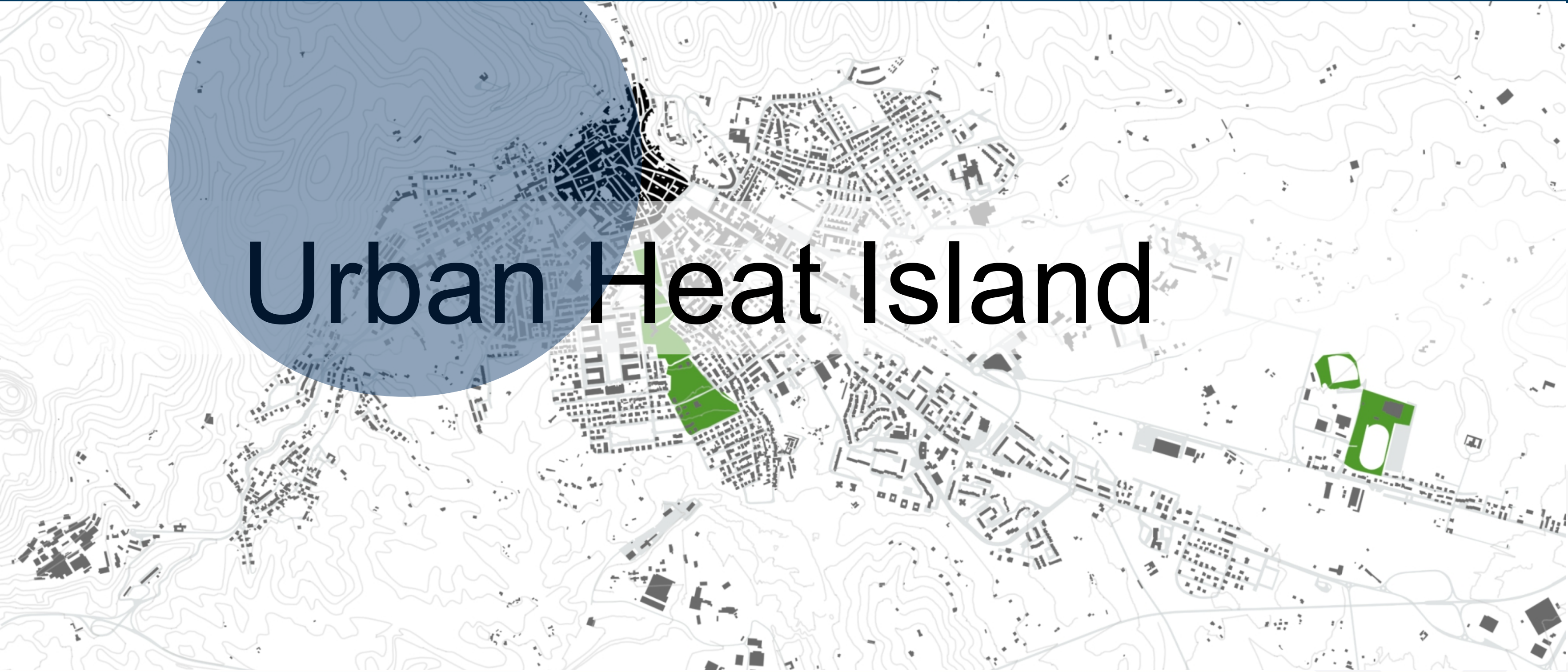
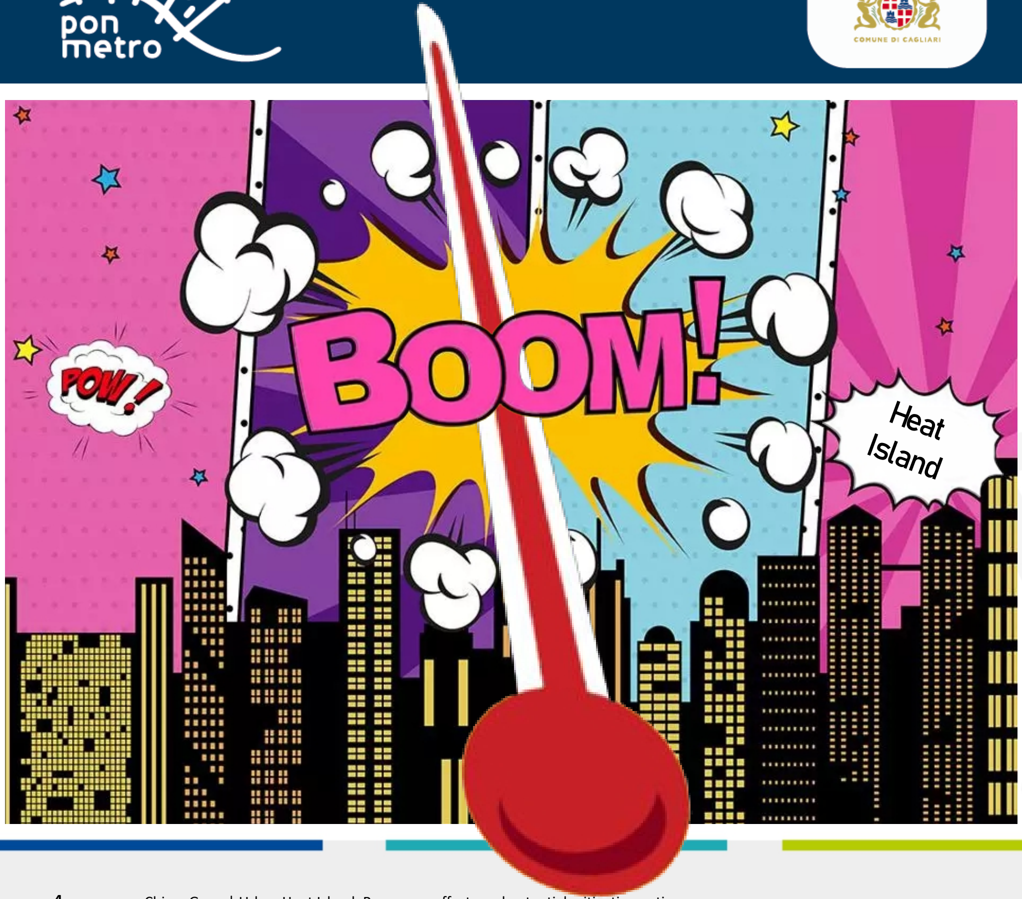
SmartCity Expo World Congress| Barcelona 15-17 Nov. 2022

Cagliari


Urban Heat Island
Active and participatory governance
Municipality of Cagliari
Reliefs
Results
Data processing
Mitigation



Urban Heat Island

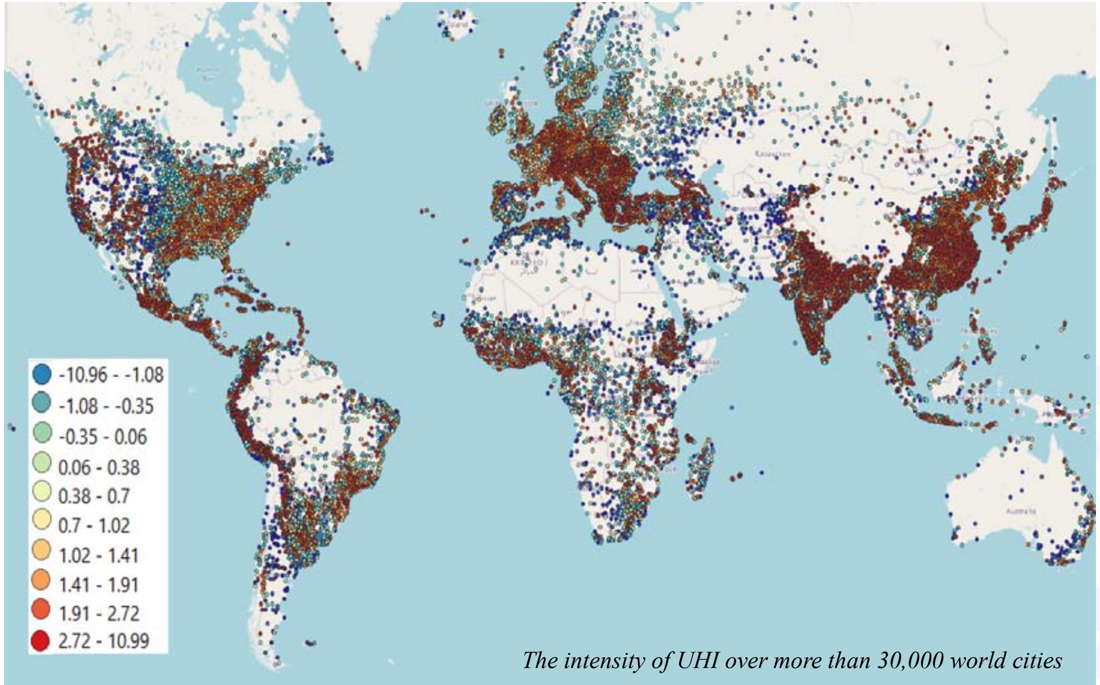


An urban heat island (UHI) is an urban area or metropolitan area that is significantly warmer than its surrounding rural areas due to human activities

DT > 0.50 → 5.0 °C

What is an urban heat island?

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



The intensity of UHI over more than 30,000 world cities

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

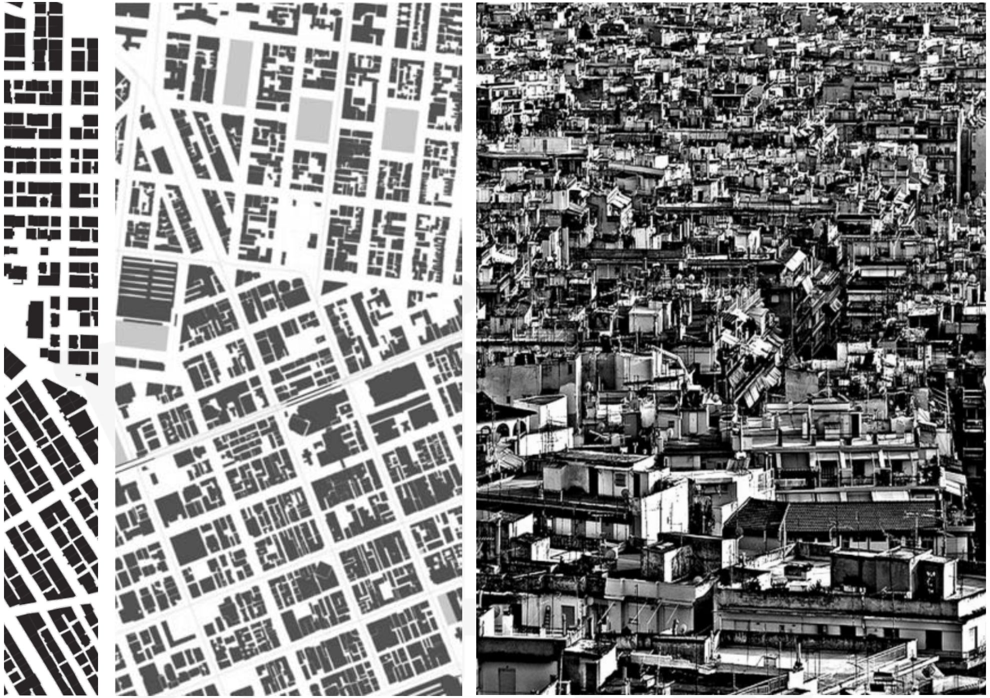
High density

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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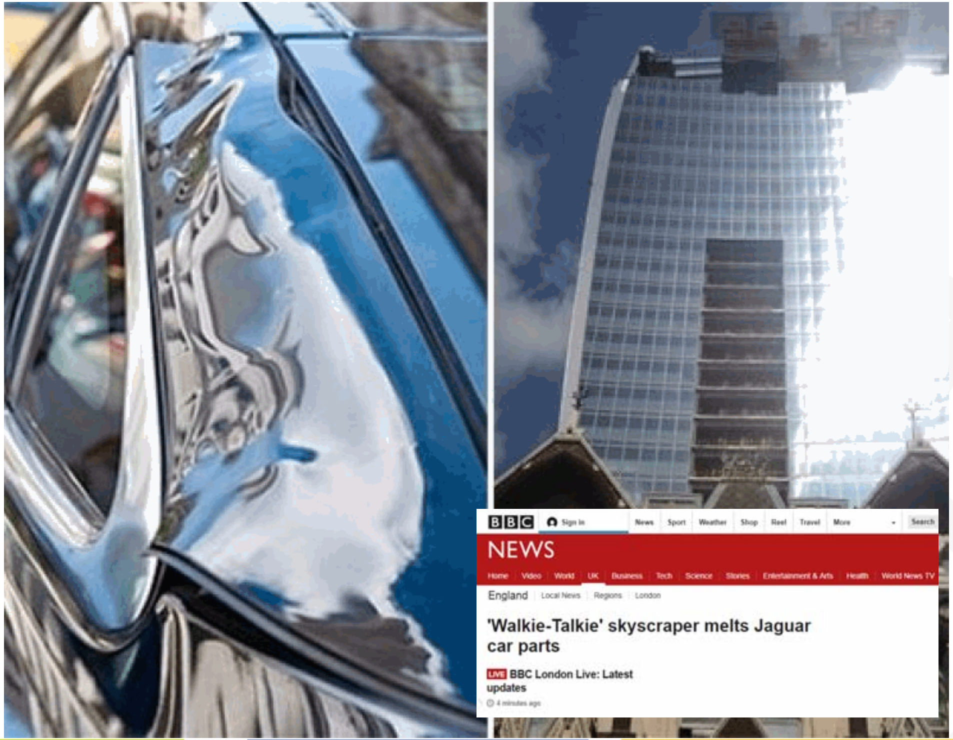
India, caldo killer: sale il numero delle vittime e si scioglie l'asfalto

Si è superata la quota 1400 vittime e le temperature hanno raggiunto i 50 gradi. Anche il manto stradale è liquefatto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'Walkie-Talkie' skyscraper melts Jaguar car parts

LIVE BBC London Live: Latest updates

Urban Heat Island

Superficial

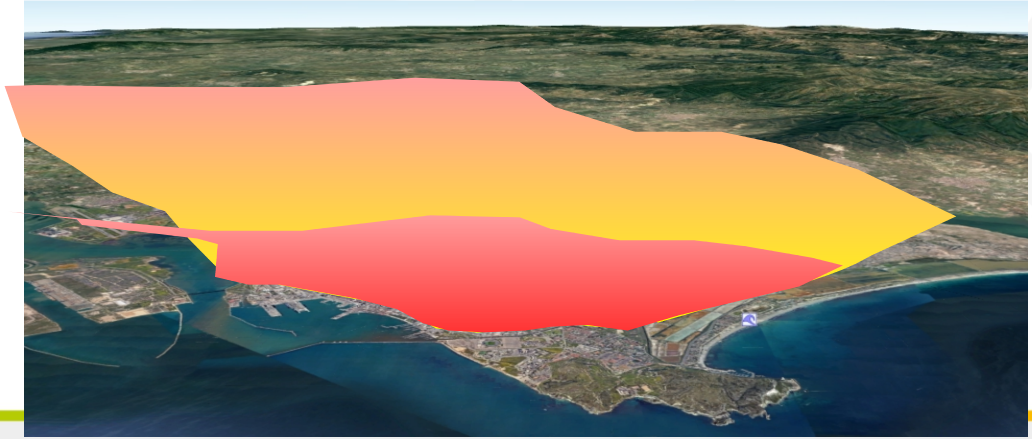
High temperatures of urban surfaces compared to rural areas, evidenced by thermographs

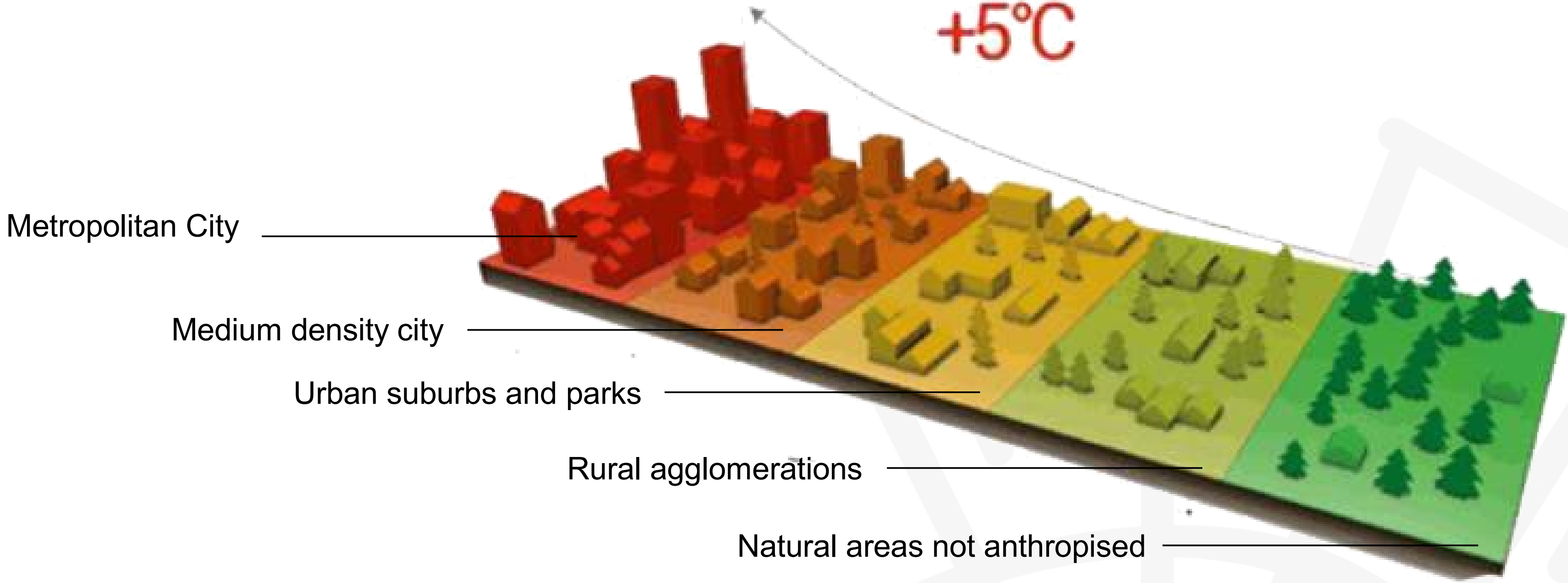
Atmospheric

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

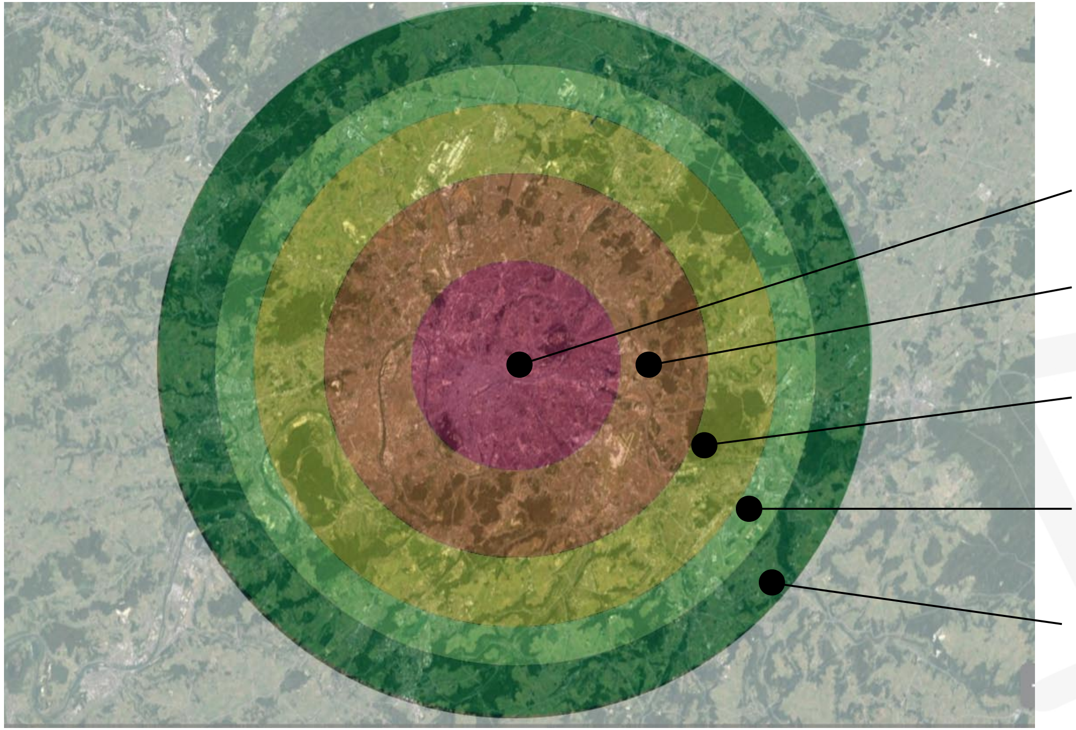
Layer of low air and warmer than the inhabited area between the ground and the top of the buildings

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



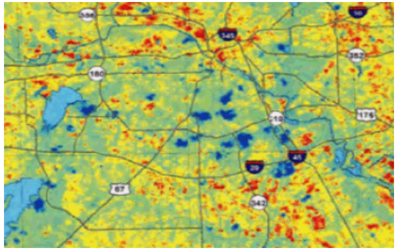

+5°C
Metropolitan City
Medium density city
Urban suburbs and parks
Rural agglomerations
Natural areas not anthropised

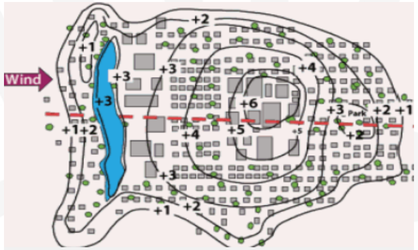
+ 5°C

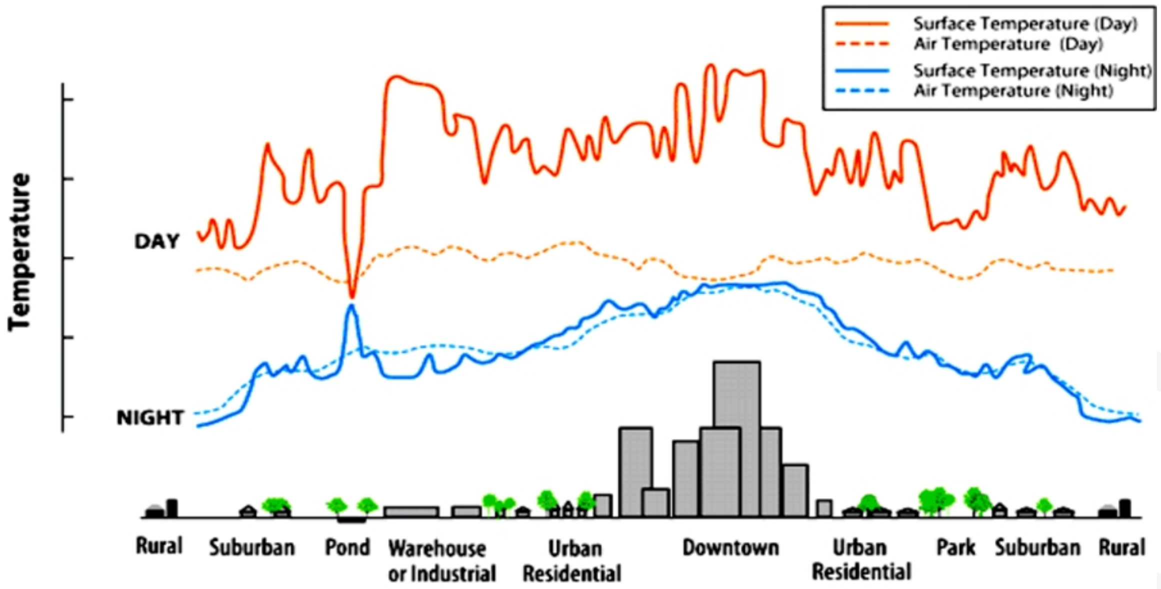


Metropolitan City
Medium density city
Urban suburbs and parks
Rural agglomerations
Natural areas not anthropised

Andamento	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
Trend	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
Detection	Remote sensing indirect measurement	Direct measurement of weather and mobile stations
Results	Thermal images	Isothermal maps, temperature graphs



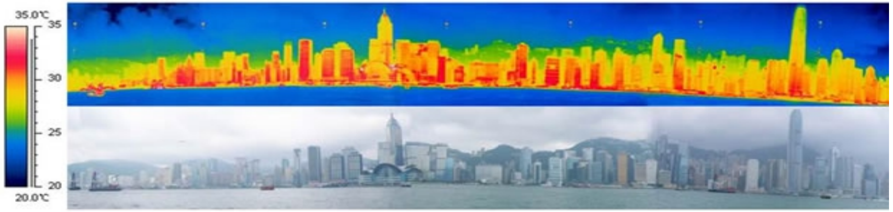


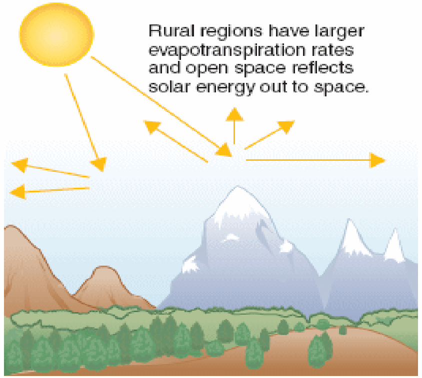


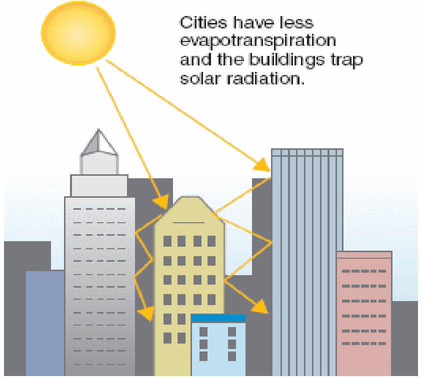
Daytime temperatures: they vary greatly with the type of surface. The air temperature varies little

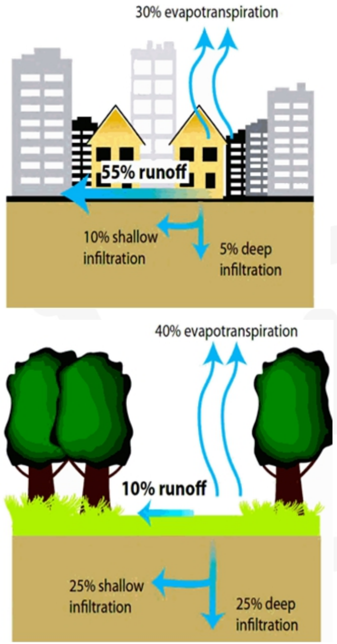
Night temperatures: they are higher on urban surfaces, the air temperatures follow their trend

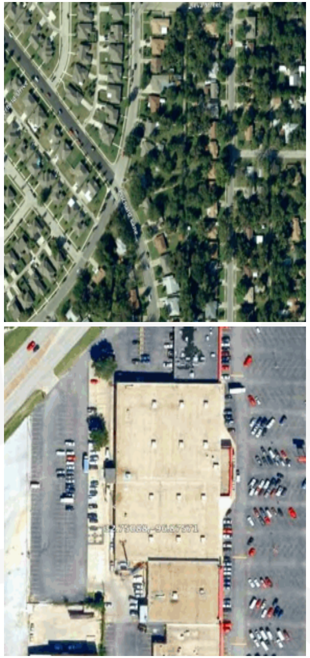
Main aspects











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

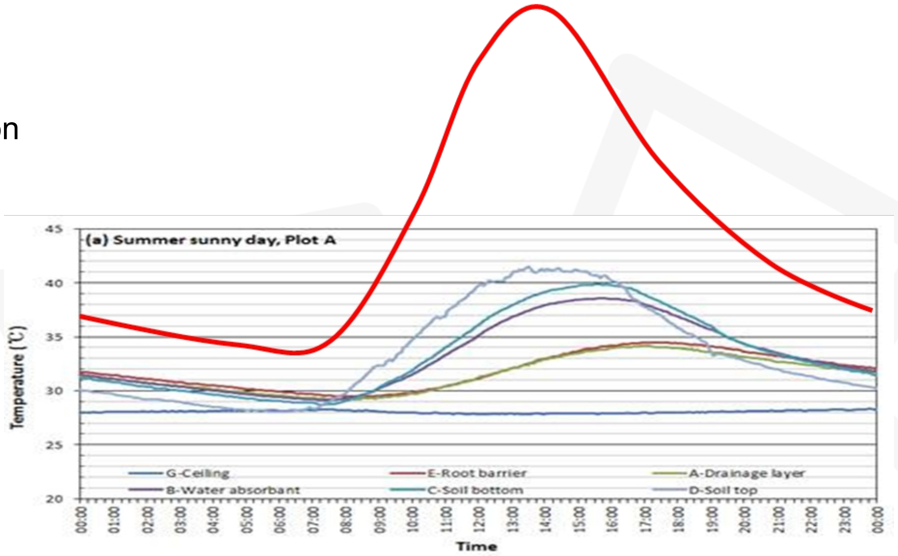
Reflectivity (Albedo) ability of the material to reflect solar radiation

Thermal emissivity: ability of the material to emit heat

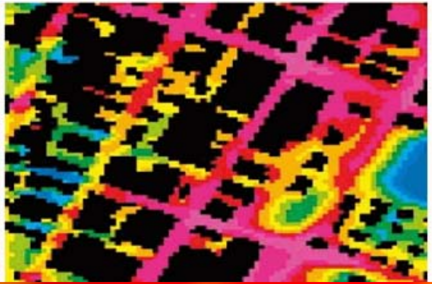
Thermal capacity: ability of a material to store heat

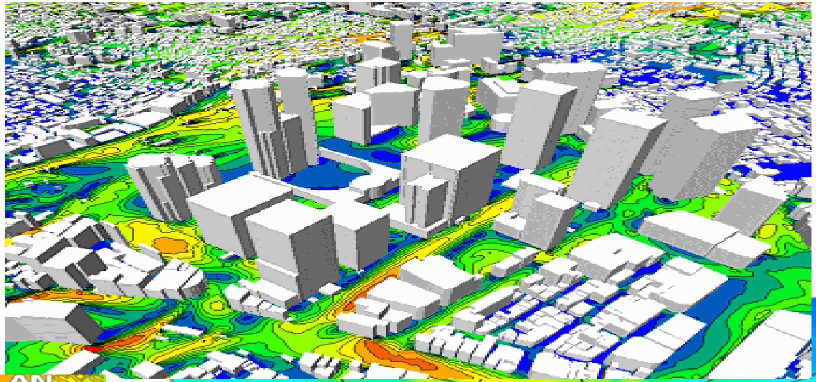
Permeability: porous materials cool when the air passes through

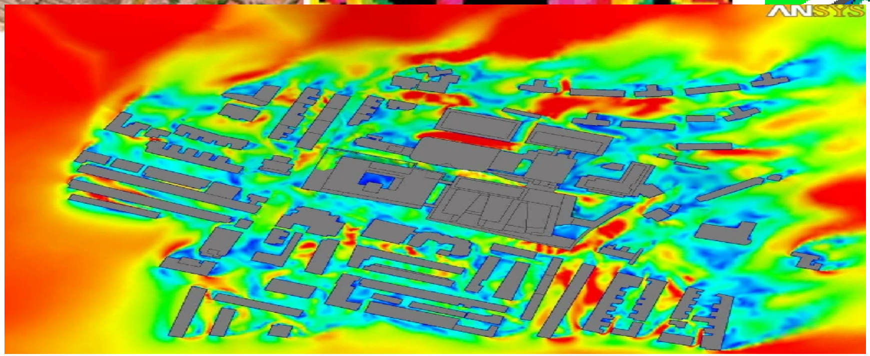
Solar reflectance index ASTM E1980-01

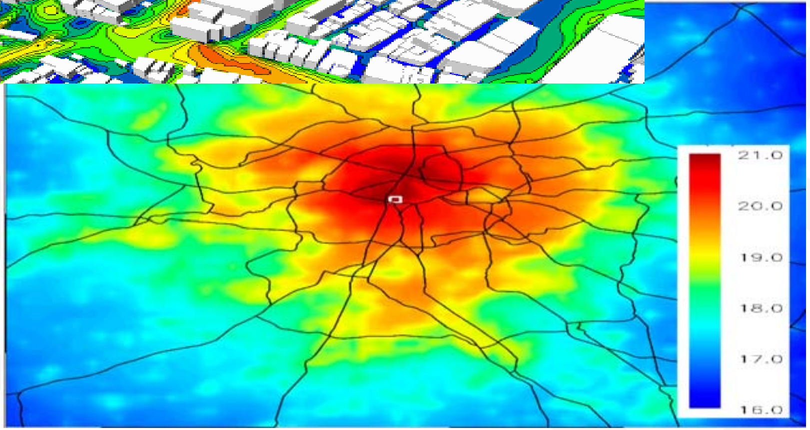


There are many simulation tools, some integrate the thermal response of materials










1 No poverty
2 Zero hunger
3 Good health and well-being
4 Quality education
5 Gender equality
6 Clean water and sanitation
7 Affordable and clean energy
8 Decent work and economic growth
9 Industry, innovation and infrastructure
10 Reduced inequalities
11 Sustainable cities and communities
12 Responsible consumption and production
13 Climate action
14 Life below water
15 Life on land
16 Peace, justice and strong institutions
17 Partnerships for the goals
SDG
SDG 17
SDG


9 INDUSTRY, INNOVAT
AND INFRASTRUCT
11 SUSTAINABLE CITIES AND COMMUNITIES
13 CLIMATE ACTION

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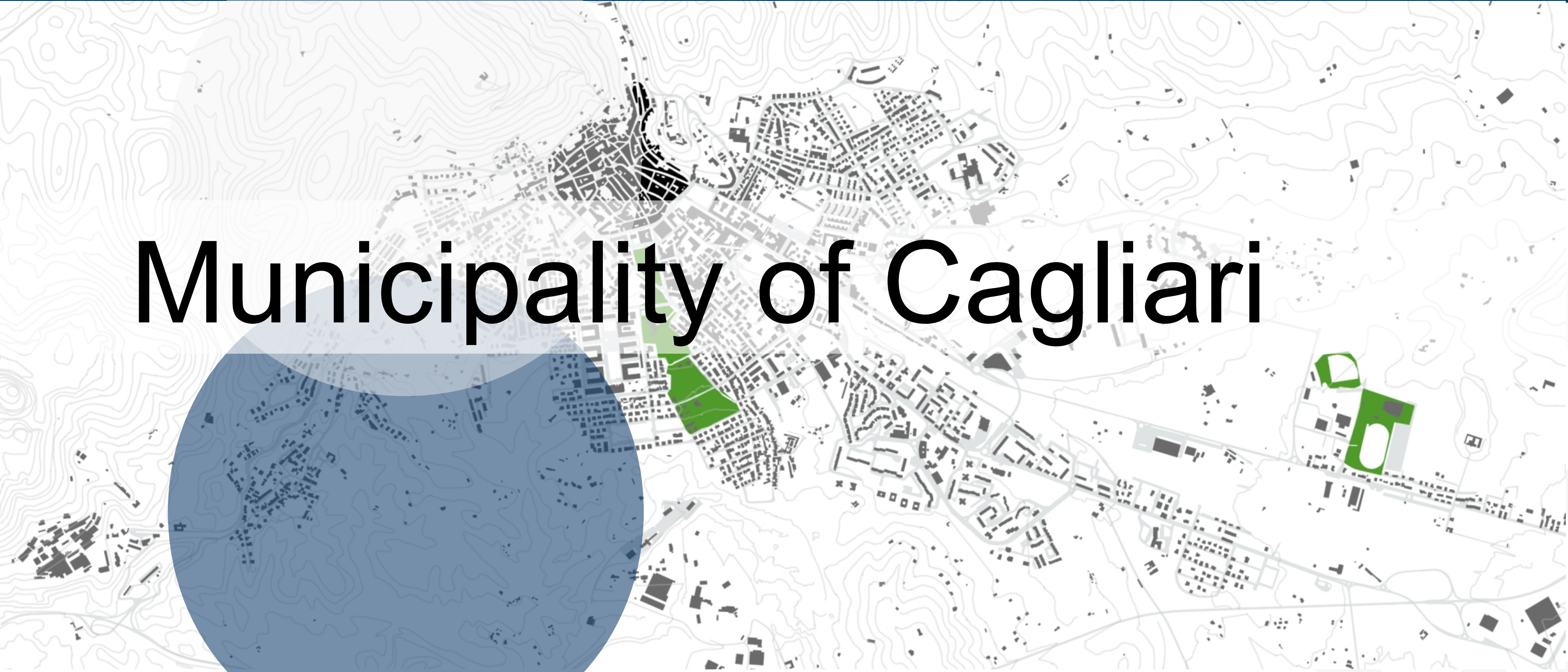
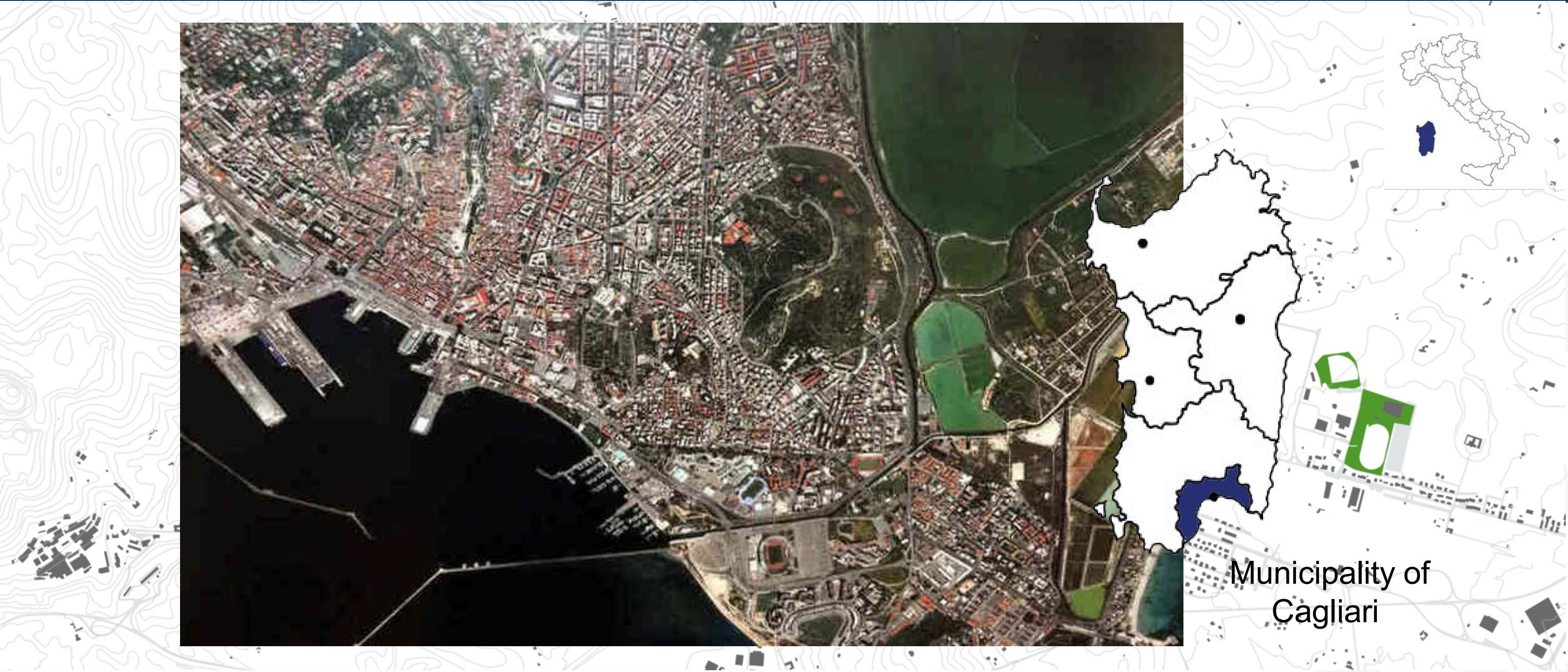
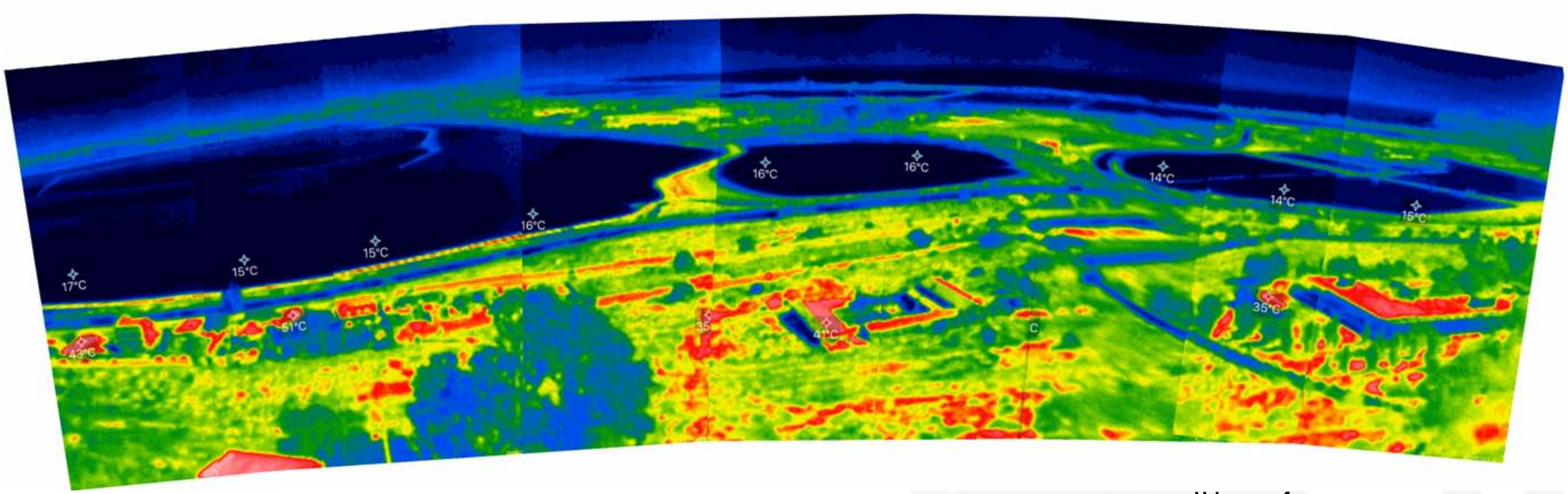
Municipality of Cagliari




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 ° C ÷ 330 ° C.

Anti-vibration rubber layer

640 x 480 pixel matrix

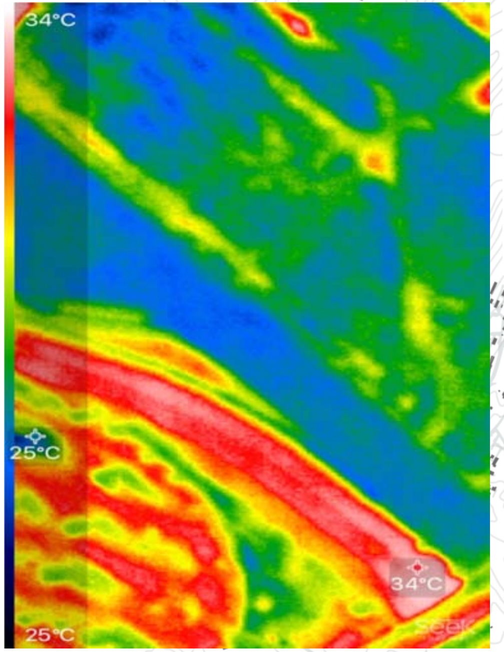
32 ° opening

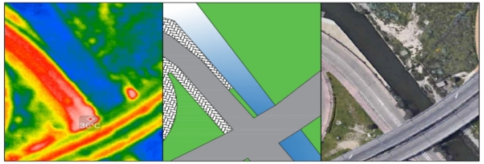
Size of the framed area per frame approximately 180m x 130m

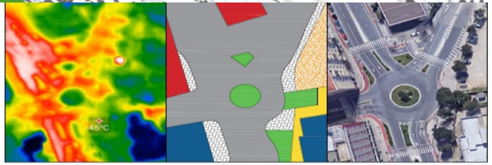
About 250 elementary areas analyzed

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**

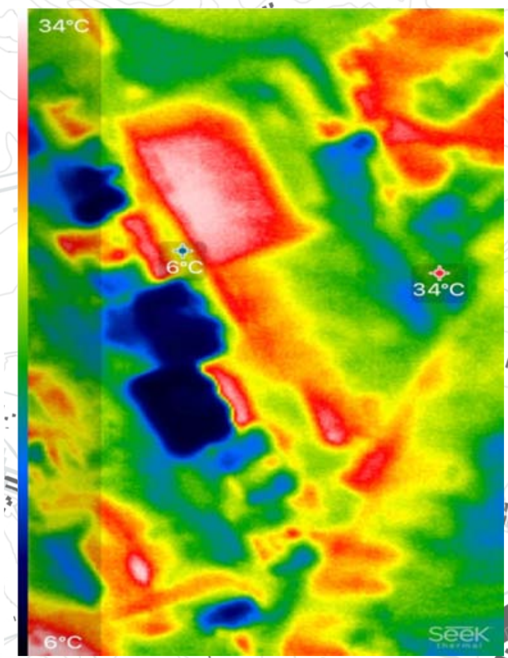
Zone 03_ Sant'Elia Stadium







Zone 20_ Is Mirrionis roundabout



Data processing

Phase 1

Reading of the image to be analyzed

Phase 2

Calculation of intermediate temperatures

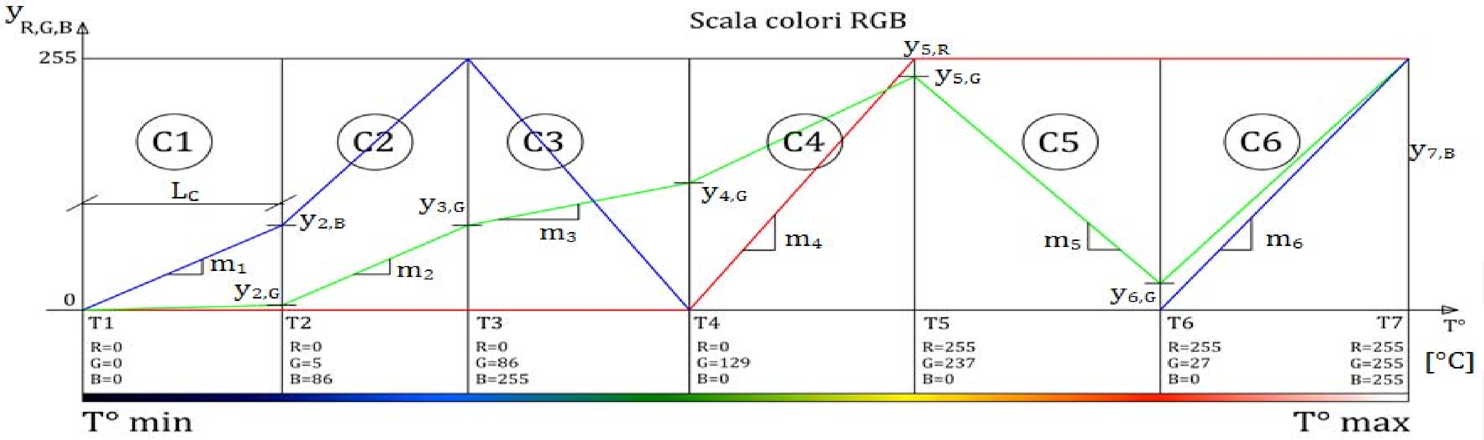
Phase 3

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



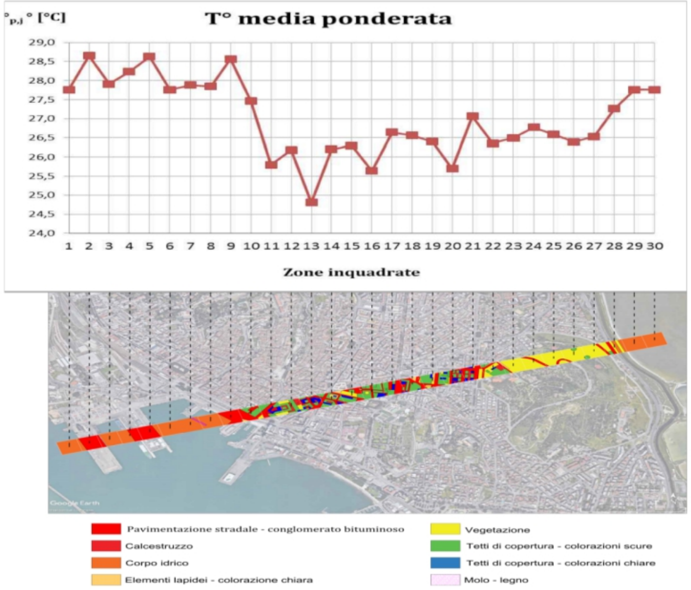
The weighted average of the respective temperature values in the different areas was calculated for each type of surface:

T°pj [°C] =

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

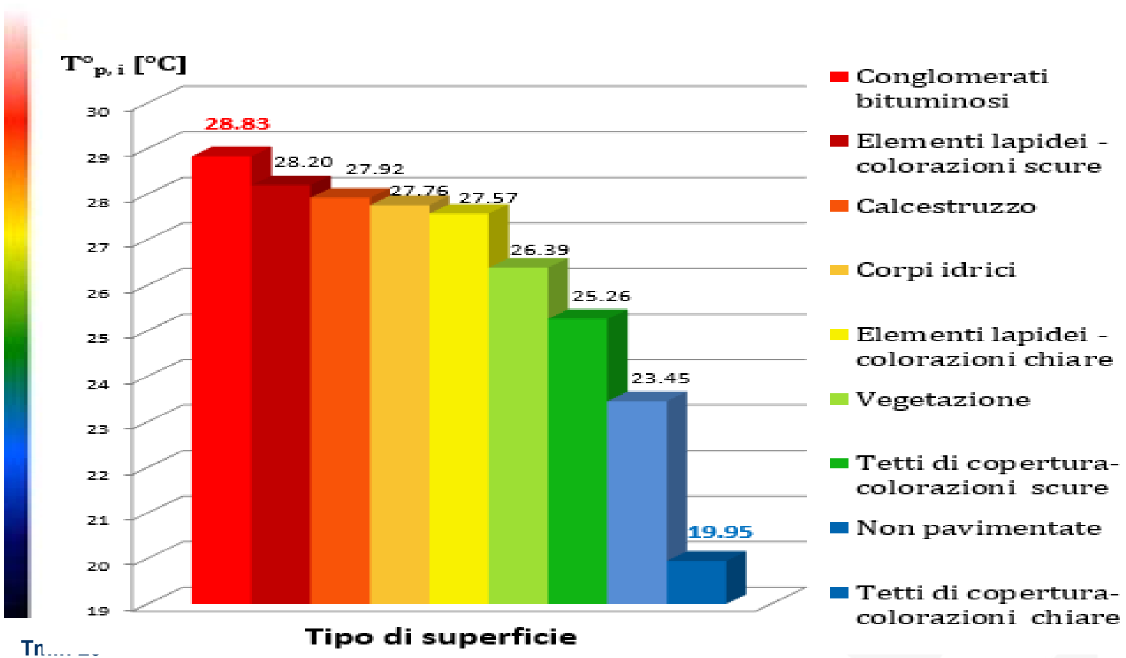
$A_{i,j}$ [m2]= i-th s… area
$T_{i,j}$ [°C]= surface temperature i-th, zone j-th
m= number of j-th study areas

Weighted average temperature [° C] - October 2017

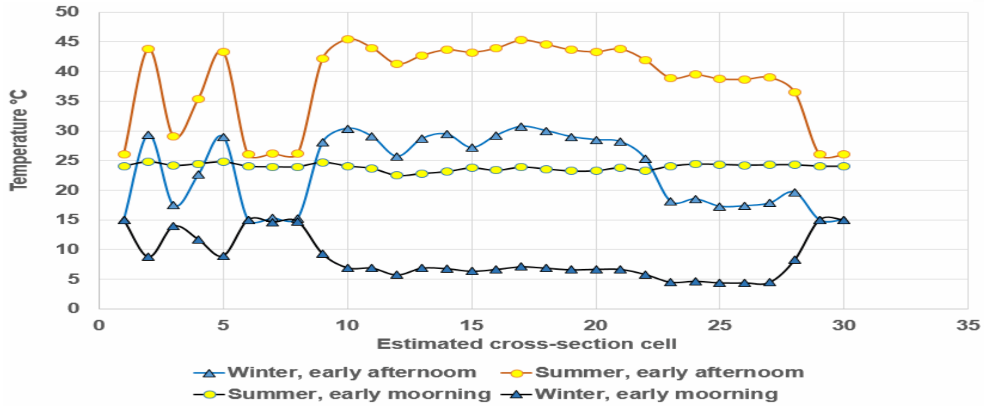


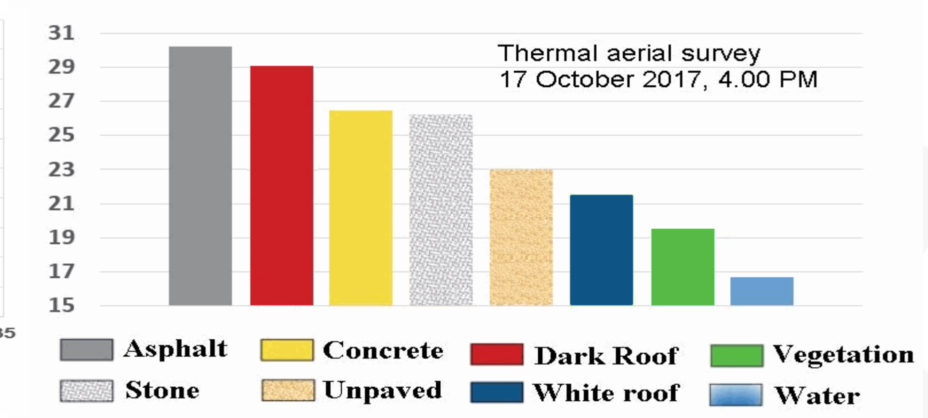
Zone 02 **Zona 13**

Tmax = 29



Results.


Temperature °C
Estimated cross-section cell
Winter, early afternoom
Summer, early afternoom
Summer, early moorning
Winter, early moorning

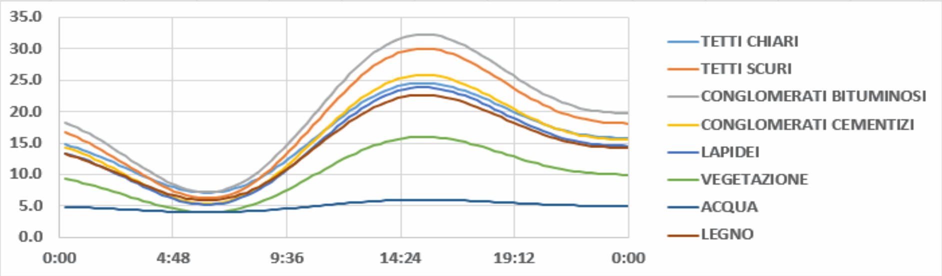

Thermal aerial survey
17 October 2017, 4.00 PM
Asphalt
Concrete
Dark Roof
Vegetation
Stone
Unpaved
White roof
Water

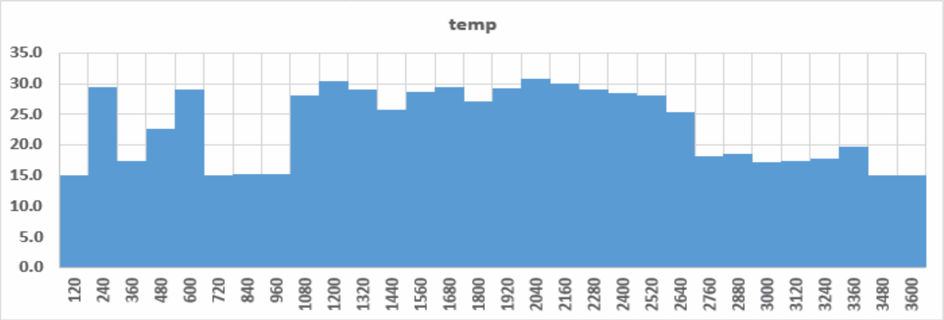
Results.

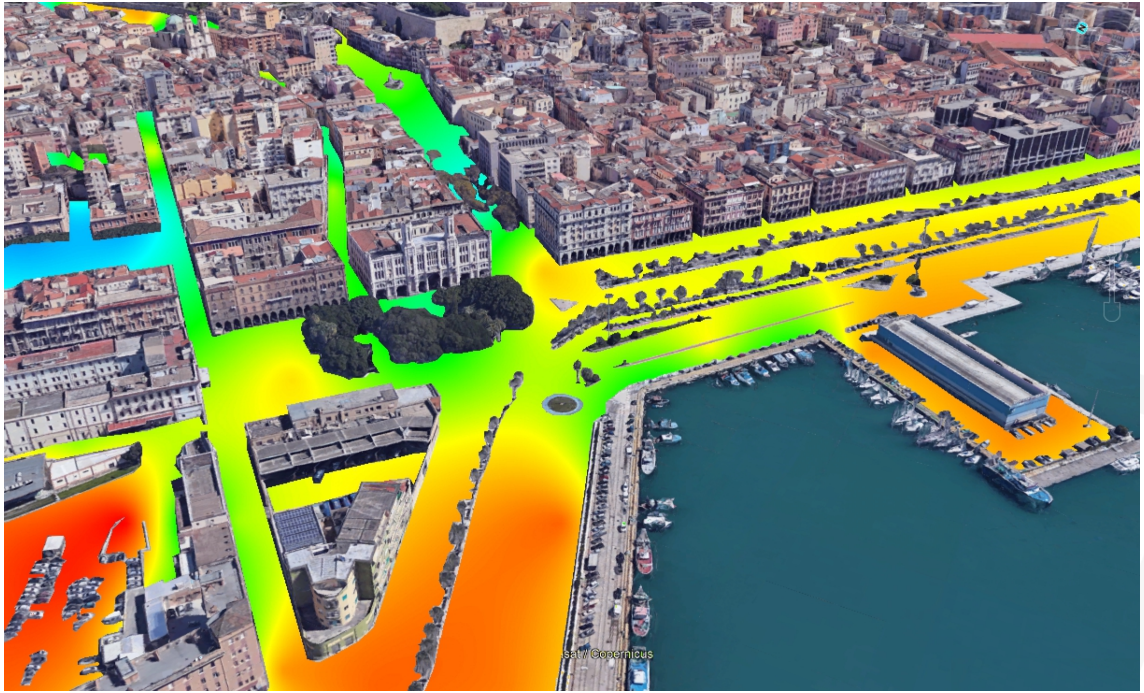
Temperatura massima aria	15
Temperatura minima aria	5
Radiazione solare	15
orario	15:36

	Tetti scuri	Tetti chiari	Congl. Bitum	Cls	lapidei chiari	Vegeta zione	Corpi idrici	legno
T° [°C]	30.0	24.5	32.3	25.8	23.8	16.0	15.0	22.6

Zona	Tetti scuri	Tetti chiari	Congl. Bitum	Cls	lapidei chiari	Vegeta zione	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**



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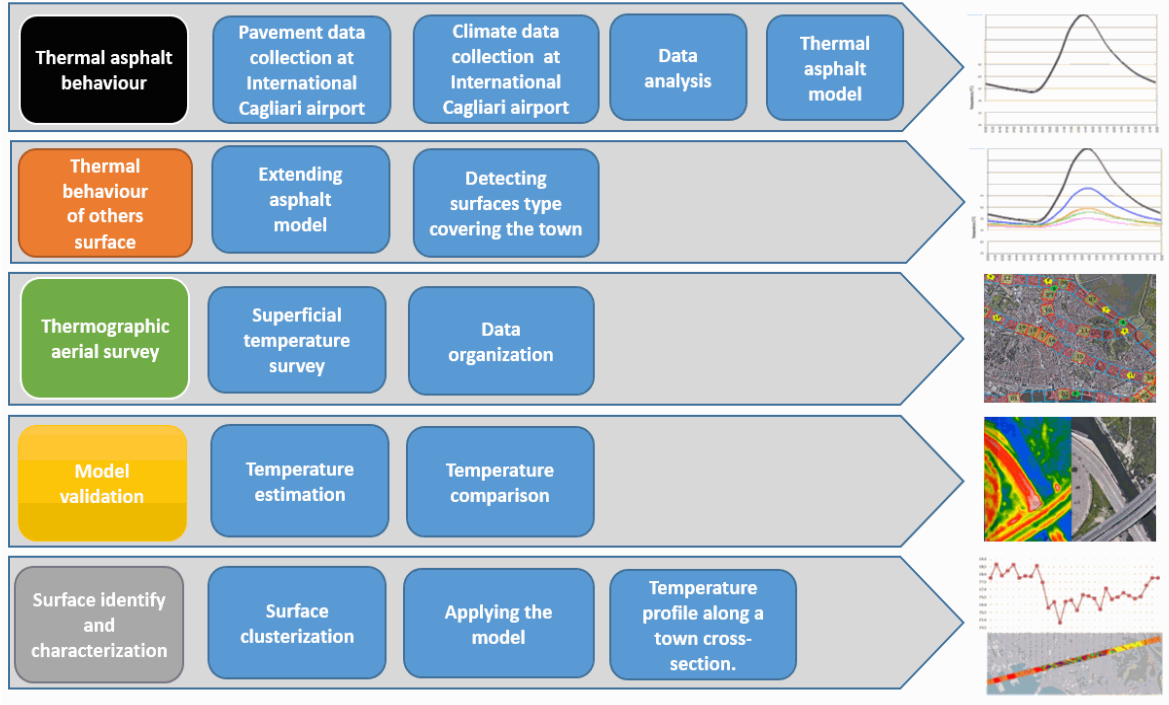
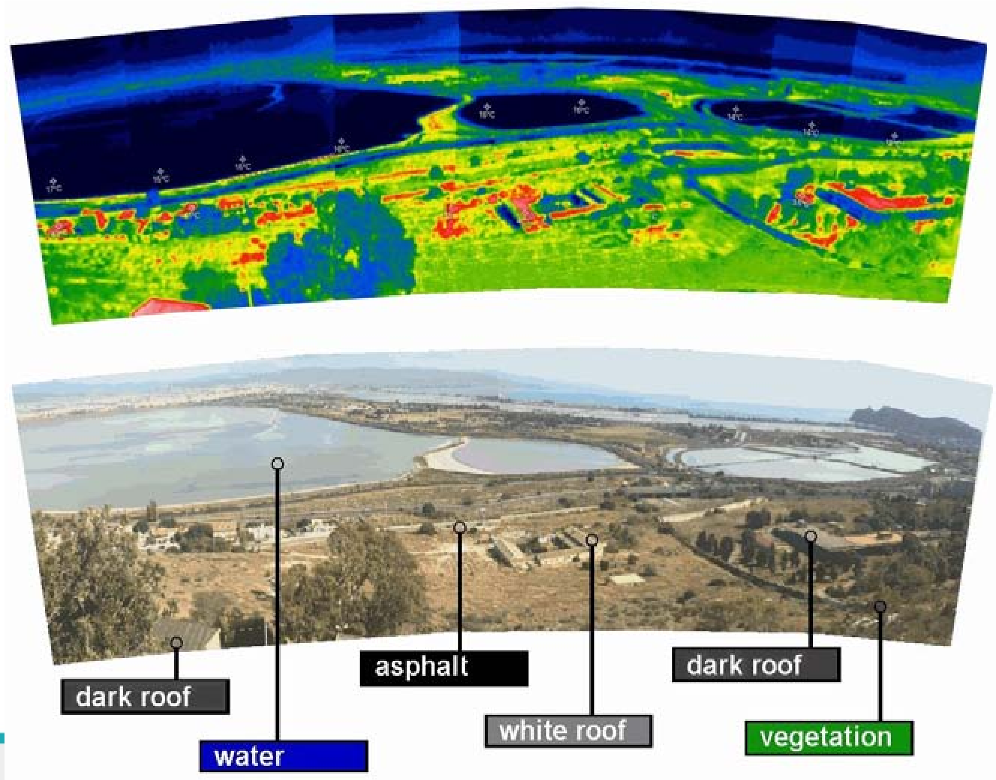

Thermal asphalt behaviour
Pavement data collection at International Cagliari airport
Climate data collection at International Cagliari airport
Data analysis
Thermal asphalt model
Thermal behaviour of others surface
Extending asphalt model
Detecting surfaces type covering the town
Thermographic aerial survey
Superficial temperature survey
Data organization
Model validation
Temperature estimation
Temperature comparison
Surface identify and characterization
Surface clusterization
Applying the model
Temperature profile along a town cross-section.


dark roof
water
asphalt
white roof
dark roof
vegetation

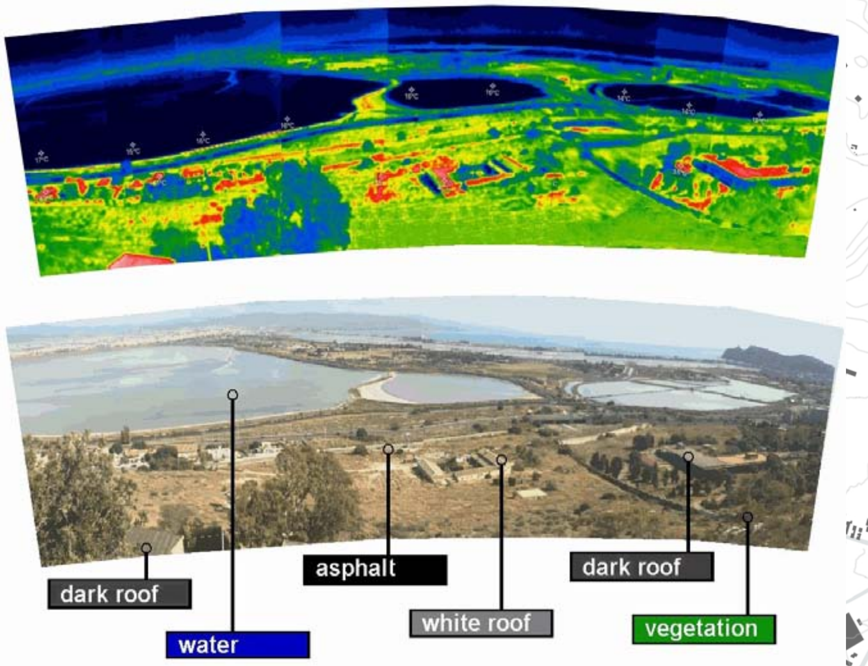
The research confirm the role of asphalt pavement increasing UHI

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

A thermal survey over Cagliari confirm the results

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



Mitigation

Various mitigation tools and Actions

Creation of urban green areas

Trees in the streets

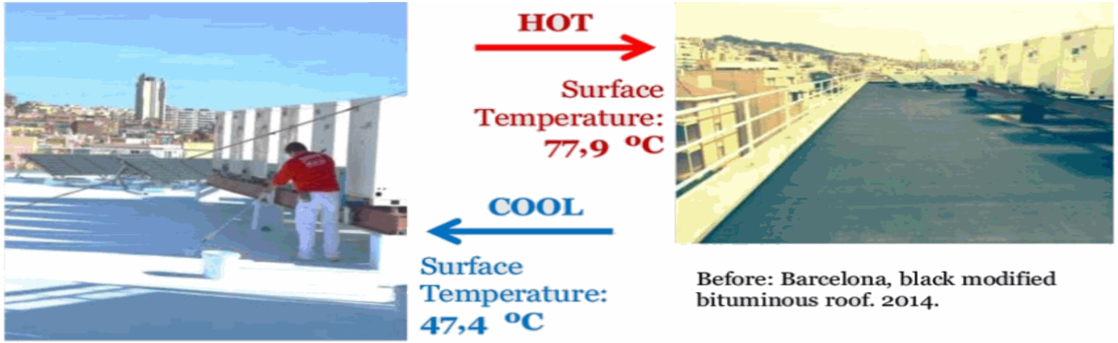
Energy efficiency improvement

Vehicular reduction

Green roofs

Clear coloring of the surfaces

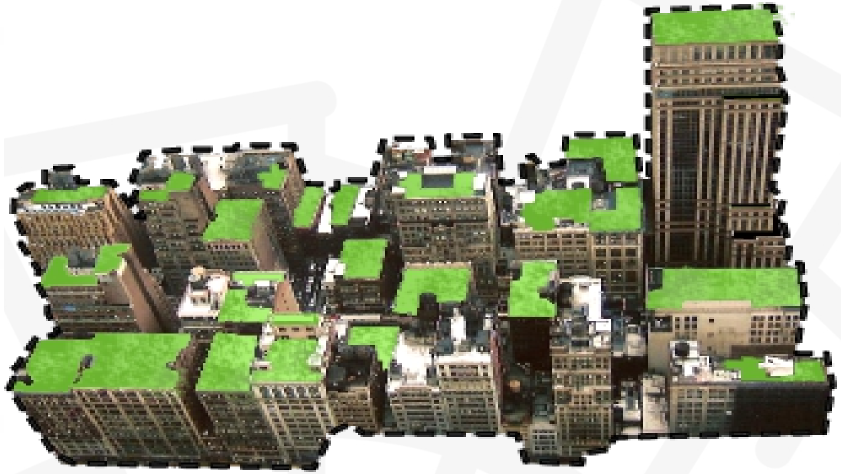
Reduction of bituminous surfaces



Before: Barcelona, black modified bituminous roof. 2014.

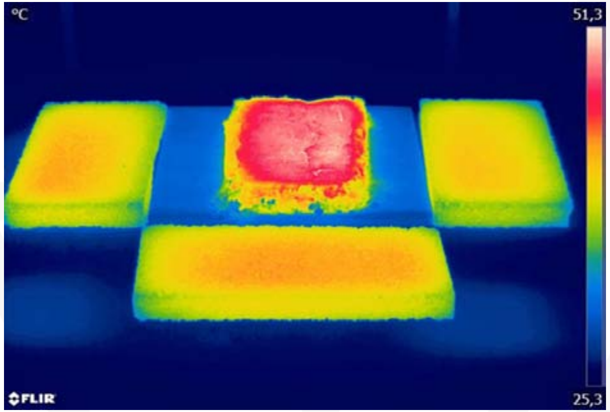
Barcelona, Colored COOL ROOF based on Abolin Co Coatings Tech. 2014.

Green roofs



Green roofs

Hydrodrain




WORK
IN PROGRESS

Thank you!

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