Identifying Hot Spots in Urban Areas in support of Microclimatic Studies in the City of Athens, including its Historic Centre

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This study was done in the framework of the MONITOR project which deals with such urban issues as expansion/sprawl, thermal stress, flooding and geological hazards. The study concentrates on the assessment of the thermal environment in the city, through a specific (qualitative and quantitative) indicator termed as “hot spots”.

1. Urbanization affects dramatically the thermal environment of cities.

2. The recognition of the pattern of hot spots (areas where maximum (surface and air) temperature areas are observed) is needed.

3. The recognition of such areas is important as they reflect areas where immediate interventions are necessary to ameliorate the thermal environment.

4. In addition, the knowledge of their spatial distribution and temporal variation is needed when drafting an adaptation and mitigation city plan for climate change.
Urban Indicator (1): Urban fabric and sprawl
An assessment of Land Use/Land Cover Changes (LULCC) for the wider agglomeration of Athens for the period 1994-2010 has been done using the index based built up index (IBI) proposed by Xu (2008) and the Normalized Difference Built-up Index (NDBI) proposed by Zha et al. (2003). Results demonstrated a significant increase of built-up areas. In Fig. 1 the results from the IBI index methodology are demonstrated.

Fig. 1. Greater Athens area
**Urban Indicator (2): Urban microclimate**

Land surface temperature (LST) is a key parameter for mapping surface urban heat islands (SUHIs).

An assessment of the urban thermal environment in the city of Athens is attempted with the use of Landsat 8 images during summer. In order to study the urban microclimate, the adopted methodology consists of the following:

- Classification of the greater Athens area in eleven classes
- Calculation of an average LST image from summer days
- LST zone statistics analysis for six of the eleven classes
In Fig. 2 the study area and the spatial distribution of the meteorological stations used in this study are illustrated.

Several stations (Seven urban stations, three suburban stations and eleven rural stations) were selected so as to depict the thermal characteristics.

Fig. 2. Greater Athens area
Surface and air temperature of Athens

- In Fig. 3 a map of land surface temperatures of the greater Athens area is presented. LSTs were derived from Landsat 8 data for the summer period.

- LST reaches 50 °C in bare soil areas.

- Air temperatures from the meteorological stations network are presented as a second layer, measured at the same acquisition time with the Landsat images.
Through the supervised classification of the greater Athens area (Fig. 4), eleven land cover and three water classes have been depicted. The main classes that were further studied as they consist the majority of human related land cover are: Urban, suburban, industrial, bare soil, ports/airports and roads.
Analysis is concentrated in the historic Centre of Athens.

The historic centre of Athens (Fig. 5) can be divided into three areas:

1) The archaeological area, the green belt of the city, is a concentration of monuments of classical Greece situated inside an extended pedestrian area which links parks, green areas and archaeological sites.

2) The ancient quarters, nearly all pedestrianized, have been well preserved and are full of exceptional samples of Greek, Roman, Byzantine and Neoclassical architecture.

3) The modern Area of the historical centre has been the institutional, commercial and vital centre of the capital for the last two centuries.
Fig. 6. Characteristic images for six classes (urban, suburban, industrial, bare soil, roads, ports-airports)
The maximum, minimum and mean LST values for the urban, suburban and industrial classes are depicted in Fig. 7. The suburban class has the lowest values.

Fig. 7. Land surface temperature for three classes.
The maximum, minimum and mean LST values for bare Soil, roads and ports-airports classes are depicted in Fig. 8. The Suburban class has the lowest values.
Identification of hot spots in the City of Athens:

Hot Spots: urban areas which systematically present higher LSTs as compared to the average one.

Hot spots were clearly identified through:

- An average LST image of several summer days
- Manual interpretation of the LST image, taking in account both the highest temperature and the land cover, lead to a local threshold of 44°C over which the area is considered as urban hot spot.

As expected hot spots were found in areas with land covers such as urban, industrial and bare soil. Vegetated areas such as urban parks were found with lower temperatures, although they are located near the aforementioned areas.
The enlarged area in Fig. 9 shows several hot spots within the city of Athens and particularly within the historical centre and the Industrial zone of Athens. On the contrary, LST in several green areas in the centre of Athens and in the northern suburbs is much lower.
Fig. 10. Land surface temperature for the Industrial zone of Athens.
Most of the hot spots appear in areas of great interest for the citizens of Athens such as commercial and cultural sites.

Fig. 11. Land surface temperature of the historical centre of Athens.
Fig. 11. Land surface temperature of the historical centre of Athens.
Conclusions

Results allow a detailed look in the thermal characteristics of an urban area in conjunction with the specific land cover classes. They also support the design of *focused and differentiated* interventions in the city so as to ameliorate the heat stress.

Major potential exists to define and set a threshold value for LST as an indicator for the need for resilience planning.

On the basis of the results, consultations have been promoted with stakeholders and in particular with the Municipality of Athens (M.A.) so as to develop a plan for the thermal resilience of the city centre (in light of the participation of the M.A. to the Resilient Cities initiative of the Rockefeller Foundation).