Land Surface Temperature derivation using Landsat 8 Data: a case-study of Surface Urban Heat Island [UHI] in 5 Mediterranean Cities

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3 Professor and Researcher, IGOT - Universidade de Lisboa
1. Introduction
   a) Definition, Causes and Consequences
   b) Why Mediterranean Cities?
   c) Research Question

2. Methodology

3. Results
   a) Overview
   b) Marseilles, France
   c) Barcelona, Spain
   d) Statistical Analysis

4. Conclusions
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Urban Heat Island
[UHI]
The air temperature difference between urban centers and their non-urban surroundings.
(Oke, 1978)
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I. Changes in Land Surface

II. Anthropogenic Activities
I. Changes in Land Surface
   I. Artificial materials
   II. High level of soil sealing
   III. High built mass/high roughness
   IV. Reduced vegetation/water surfaces

II. Anthropogenic Activities
I. Changes in Land Surface

I. Artificial materials
II. High level of soil sealing
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IV. Reduced vegetation / water surfaces

II. Anthropogenic Activities

i. Heat discharges from human activities
ii. Air pollution
I. Artificial materials
II. High level of soil sealing
III. High built mass/high roughness
IV. Reduced vegetation / water surfaces

I. Health (e.g. morbidity, mortality)
II. Economical (e.g. energy demand and peak power)
III. Environmental (e.g. CO$_2$ concentration, air quality loss)

Increasing heat absorption and discharges
Reducing natural cooling

i. Heat discharges from human activities
ii. Air pollution

Consequences:

I. Changes in Land Surface
II. Anthropogenic Activities

Land Surface Temperature derivation using Landsat 8 Data: a case-study of **Surface Urban Heat Island [UHI]** in Mediterranean Cities
<table>
<thead>
<tr>
<th>Feature</th>
<th>Atmospheric UHI</th>
<th>Surface UHI [sUHI]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temporal Development</td>
<td>Small or non-existent during the day</td>
<td>Present at all times day and night</td>
</tr>
<tr>
<td></td>
<td>Intense at night and winter</td>
<td>Intense during the day and summer</td>
</tr>
<tr>
<td>Peak Intensity</td>
<td>Day: -1 to 3°C</td>
<td>Day: 10 to 15°C</td>
</tr>
<tr>
<td></td>
<td>Night: 7 to 12°C</td>
<td>Night: 5 to 10°C</td>
</tr>
<tr>
<td>Typical identification</td>
<td>Direct measurement</td>
<td>Indirect measurement</td>
</tr>
<tr>
<td>method</td>
<td>Fixed weather stations</td>
<td>Remote sensing</td>
</tr>
<tr>
<td></td>
<td>Mobile traverses</td>
<td></td>
</tr>
<tr>
<td>Typical depiction</td>
<td>Isotherm map</td>
<td>Thermal image</td>
</tr>
<tr>
<td></td>
<td>Temperature graph</td>
<td></td>
</tr>
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</tr>
<tr>
<td>-----------------------------</td>
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</tr>
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I. Causal factors relation is less well understood
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II. Most studies focus on singular case studies
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III. Micro-scale modelling prevails
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III. Micro-scale modelling prevails
IV. Further investigation is needed
I. Causal factors relation is less well understood
II. Most studies focus on singular case studies
III. Micro-scale modelling prevails
IV. Further investigation is needed
   i. Building scenarios for the future:
      a. Urban development prospects
      b. Climate change forecasts
      c. Countermeasures efficiency
Global

I. Urban Population Growth Prospects
II. Climate Change Forecasts

Why the Mediterranean bioregion?
I. Urban Population Growth Prospects

II. Climate Change Forecasts

i. Local Impacts and Adaptation needs

ii. Urban Sprawl and "Coastalisation"

iii. Social/economical vulnerability
Research Question?
I. Using Land Surface Temperature [LST] as dependent variable, what urban surface indicators can predict it the most?

II. Considering cities within the same regional climate, do this indicators show similar behaviour among them?
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Data Selection

- Warmer Season
- Warmest Day
- Low Wind
- Low Cloud Cover
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Data Selection
- Warmer Season
- Warmest Day
- Low Cloud Cover
- Low Wind

Data Processing
- Digital Elevation Model (DEM)
- Shadows
- Albedo (ALB)
- Emissivity Band 10 (EM)
- Norm. Diff. Vegetation Index (NDVI)
- Norm. Diff. Moisture Index (NDMI)

Statistical Analysis
- Single and Multiple Regression
- + Cluster Analysis per city
Pre-Processing
(DOS-1; DN Conversion; Water/Cloud Masks)

Landsat 8\(^1\) - Operational Land Imager (OLI) + Thermal Infrared Sensor (TIRS)

- **OLI Bands 2, 3, 4, 5**
  - NDVI (NASA, 2015)
  - FVC (Xiaolei et al., 2014)
  - Land Surface Emissivity (LSE) – NDVI Threshold Method (Xiaolei et al., 2014)

- **TIRS Bands 10, 11**
  - Bands 10 and 11 TOA Brightness Temperature (BT\(_{10}\), BT\(_{11}\))
  - (NASA, 2015)

- **OLI Bands 1, 3, 4, 5, 6, 7**
  - ALB (Smith, 2010)
  - EM (Xiaolei et al., 2014)
  - NDVI (NASA, 2015)
  - NDMI (NASA, 2015)

ASTER - GDEM\(^2\)

- **DEM SHADOWS**

**Water Vapour content**
(AERONET)

Atmospheric Transmittance Coefficients (Rozenstein, et al. 2014)

**Statistical Analysis**

\[
\text{LST}^* = A_0 + A_1.BT_{10} - A_2.BT_{11}
\]

\(\textit{S}^{\text{Split-Window Algorithm (Rozenstein et al., 2014)}}\)

1"Landsat imagery courtesy of NASA Goddard Space Flight Center and U.S. Geological Survey"
2"ASTER GDEM is a product of METI and NASA".
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"ASTER DEM is a product of METI and NASA".
"Map data: Google"
"Landsat imagery courtesy of NASA Goddard Space Flight Center and U.S. Geological Survey"
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ATHENS (Air temp.: 27°C)
BARCELONA (Air temp.: 27°C)
LISBON (Air temp.: 30°C)
MARSEILLES (Air temp.: 30°C)
NAPLES (Air temp.: 29°C)

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Map data: Google
Land Surface Temperature derivation using Landsat 8 Data: a case-study of **Surface Urban Heat Island [UHI]** in **5 Mediterranean Cities**

3rd Landsat imagery courtesy of NASA Goddard Space Flight Center and U.S. Geological Survey
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<table>
<thead>
<tr>
<th>City</th>
<th>ALB r2</th>
<th>ALB P-value</th>
<th>EMISSIVITY 10 r2</th>
<th>EMISSIVITY 10 P-value</th>
<th>NDVI r2</th>
<th>NDVI P-value</th>
<th>NDMI r2</th>
<th>NDMI P-value</th>
<th>DEM r2</th>
<th>DEM P-value</th>
<th>SHADOWS r2</th>
<th>SHADOWS P-value</th>
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<tbody>
<tr>
<td>Athens</td>
<td>0.09</td>
<td>&gt; 0.00</td>
<td>0.05</td>
<td>&gt; 0.00</td>
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<td>Barcelona</td>
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<td>&gt; 0.00</td>
<td>0.02</td>
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Athens

Barcelona

Lisbon

Marseilles

Naples

<table>
<thead>
<tr>
<th>City</th>
<th>MULTIPLE REGRESSION</th>
<th>r²</th>
<th>p-VALUE</th>
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</thead>
<tbody>
<tr>
<td>Athens</td>
<td>0,50</td>
<td>&gt; 0,00</td>
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<tr>
<td>Barcelona</td>
<td>0,53</td>
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<tr>
<td>Marseilles</td>
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<tr>
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<td>&gt; 0,00</td>
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**ALBEDO (Average per LST category)**

- ALB T1 - Low
- ALB T2 - Med
- ALB T3 - High

**NDVI (Average per LST category)**

- NDVI T1 - Low
- NDVI T2 - Med
- NDVI T3 - High

**NDMI (Average per LST category)**

- NDMI T1 - Low
- NDMI T2 - Med
- NDMI T3 - High
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4. Conclusions
I. Causal factors did not predict the LST adequately

II. However, Albedo, NDVI and NDMI seem more significant

III. Regression results are similar among cities

IV. Cluster Analysis showed a clearer relations between variables
I. The need to better understand the complexity of relations at stake;
II. Further variables have to be incorporated in the model to account for urban parameters
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Work in progress, to be continued...
Thank you!
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