Urban impact of a medium size city
an overview of Porto century climatological data (1900-2005):

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INTRODUCTION

GEOGRAPHY Object

spatial organization models

success failure

biogeophysical balance (air, water, fauna, flora)

evaluate rehabilitate

effectiveness

Irreversible loss admission

well being & life quality expectations

convince

transform costs into benefits
Porto is a north-west coast Portuguese city

an enormous economic growth during the last 3 decades

Porto's industrial and commercial location patterns and accessibility → changed

and were closely followed by the already expected reflexes in behavior and mentalities
Population
Human density
Impermeable area
increase
Porto

2nd most important Portuguese city

250,000 inhab.
(inside a 1 million metropolitan area)

600 vehicles/1000 inab.

>300,000 vehicles/day
Urbanization stress

More people
More buildings
More traffic
More activities
Less visible water
Less green areas
Air Quality $\rightarrow$ Atmospheric filter properties change

<table>
<thead>
<tr>
<th>City</th>
<th>Nº Vehicles/day</th>
<th>Speed (km/h)</th>
<th>CO</th>
<th>CxHy</th>
<th>NOx</th>
<th>SO₂</th>
<th>Emissions Estimation (kg/km done)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PORTO</td>
<td>300 000</td>
<td>35</td>
<td>6 300</td>
<td>780</td>
<td>540</td>
<td>9.900</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>100</td>
<td>4 800</td>
<td>540</td>
<td>1 140</td>
<td>9.300</td>
<td></td>
</tr>
</tbody>
</table>

Traffic fluidity
green areas loss
green areas loss
green areas loss

- Agriculture: 1801 ha in 1892, 143 ha in 1995
- Trees: 693 ha in 1892, 334 ha in 1995
- Private green: 503 ha in 1892, 417 ha in 1995
- Parks & public gardens: 28 ha in 1892, 171 ha in 1995

Madureira, H, 2001
Have we good reasons to expect evidences of Porto’s impact on climate?
Urban energy budgets

\[ \text{Qs} + \text{Qf} + \text{Qi} = \text{Ql} + \text{Qg} + \text{Qe} \]

- \( \text{Qs} \): rate of radiant energy from sun
- \( \text{Qf} \): rate of generation of heat due to combustion, metabolism and dissipation machinery
- \( \text{Qi} \): rate of heat arrival from the earth’s interior
- \( \text{Ql} \): rate of loss of heat by evaporation
- \( \text{Qg} \): rate of loss of heat by conduction to soil, buildings, roads, etc.
- \( \text{Qe} \): rate of loss of heat by radiation
Landsberg, 1979

Reason for doing this
Porto's geographical context is very complex.

Confined by the Atlantic Ocean on the west
and to the south by the Douro's River
and with some important orographic barriers on the east,
and the climate?.....
evidences of urbanization impacts on climate?
RESULTS

Minimum and maximum temperature at Porto (1900-2005)

upward trend especially evident in the minimum temperatures and during the colder season.
Minimum Temperature Porto-SP (1901-2005)

\[ y = 0.0031x + 9.9807 \]
RESULTS

Maximum Temperature Porto-SP (1901-2005)

- Temperatura Máxima
- Linear (Temperatura Máxima)

$y = 0.0152x + 18.152$
We conclude that exists a steady increase especially in the winter minimum temperatures, that can not be merely interpreted as the result of intrinsic climatic variability.

It should be viewed as a short-term temporary answer to the uncountable human interferences in the climatic system.
Nº of days with Tmax ≥ 35°C at Porto SP (1901-2005)

Number of days

\[ y = 0.0098x + 0.9172 \]

\[ R^2 = 0.0241 \]
RESULTS

Nº of days with Tmin ≥ 20ºC at Porto SP (1901-2005)
RESULTS

Nº of days with Tmin ≤ 0ºC at Porto SP (1901-2005)

\[ y = -0.0126x + 5.4009 \]

\[ R^2 = 0.0064 \]
RESULTS

We conclude that exists a **steady increase**

of

*tropical nights and very hot days*

We conclude that exists a **steady decrease**

of

*frost during nights*
RESULTS

Rainfall at Porto-SP (1900-2005)

\[ y = 1.2168x + 1136.4 \]

\[ R^2 = 0.0196 \]
Accumulated rainfall from October till March at Porto-SP (1900-2005)

$y = 0.8614x + 816.81$

$R^2 = 0.0091$
Rainfall data shows a seasonal disorganization.
DISCUSSION

Why?

Local?  Regional?  Global?

Global Warming effect?  Urbanization effect?
Urbanization effects on regional climate

with the predicted formula of Oke, T.R. (1973)

relating population size and urban heat island intensity

<table>
<thead>
<tr>
<th>CITY</th>
<th>INHABITANTS</th>
<th>T(u-r)measured</th>
<th>PREDICTED</th>
<th>AUTOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>LONDON</td>
<td>8500000</td>
<td>10°C</td>
<td>9.9°C</td>
<td>CHANDLER, 1965</td>
</tr>
<tr>
<td>BERLIM</td>
<td>4200000</td>
<td>10°C</td>
<td>9.3°C</td>
<td>GRUNOW, 1936</td>
</tr>
<tr>
<td>VIENA</td>
<td>1870000</td>
<td>8°C</td>
<td>8.5°C</td>
<td>SCHMIDT, 1927</td>
</tr>
<tr>
<td>SHEFFIELD</td>
<td>500000</td>
<td>8°C</td>
<td>11.5°C</td>
<td>GARNETT, 1966</td>
</tr>
<tr>
<td>MALMO</td>
<td>275000</td>
<td>7.4°C</td>
<td>7.4°C</td>
<td>LINDQVIST, 1972</td>
</tr>
<tr>
<td>LISBON</td>
<td>830000</td>
<td>4°C-5°C</td>
<td>7.8°C</td>
<td>ALCOFORADO,1988</td>
</tr>
<tr>
<td>COIMBRA</td>
<td>98000</td>
<td>5°C</td>
<td>6.0°C</td>
<td>GANHO, 1992</td>
</tr>
<tr>
<td>PORTO</td>
<td>300000</td>
<td>6.0°C</td>
<td>6.9°C</td>
<td>MONTEIRO, 1993</td>
</tr>
</tbody>
</table>

Oke, T.R. formula: \( DT_{u-r} \text{ (max.)} = 2.01 \log \text{ pop.} - 4.06 \)
Urban climate monitoring
PORTO
Dimension - 42 km$^2$
Population - 270 060
Motorisation rate - 596 vehic. /1000hab
Vehicles/day - > 300 000

Urban heat island 6 a 8°C
Dia: 10 de Janeiro de 1998
Início: 00h19m19s
Temperatura média itinerante: 13.9 ºC
Temperatura HSJ: 14.2 a 14.9 ºC
Vento:
- velocidade: 1.9 m/s
- rumo (HSJ): N/NE (Aeroporto): E
Humidade Relativa HSJ: 53.3%
Sit. Sinóptica à superfície: Margem Anticiclónica

Mapa elaborado pelo método de Kriging
Dia: 22 de Janeiro de 1998 (2º percurso)  
Início: 00h43m38s  
Temperatura med. itinerantes: 5.3 a 12.6ºC  
Temperatura HSJ: 11.1 a 12.1ºC  
Vento: - velocidade: 1,4 m/s  
- rumo (HSJ): NW  
(aeroporto): E  
Humidade Relativa HSJ: 44.4%  
Sit. Sinóptica à superfície: Margem Anticiclônica  

Mapa elaborado pelo método de Kriging
Dia: 22 de Janeiro de 1998
Início: 00h21m00s
Temperatura med. itinerantes: 6.3 a 14.0ºC
Temperatura HSJ: 11.0 a 12.1ºC
Vento: - velocidade: 1,2 m/s
- rumo (HSJ): NW
  (aeroporto): E
Humidade Relativa HSJ: 44.4%
Sit. Sinóptica à superfície: Margem Anticiclônica

Mapa elaborado e ilho método de Kriging
Dia: 19 de Junho de 1998
Início: 00h08m03s
Temperatura med. itinerantes: 19.9 a 27.3°C
Temperatura HSJ: 24.0 a 25.2°C
Vento: - velocidade: 0.4 m/s
- rumo (HSJ): E (aeroporto): E
Humidade Relativa HSJ: 53.1%
Sit. Sinóptica à superfície: Anticiclone Atlântico Subtropical

Mapa elaborado pelo método de kriging
The resolution process in *Oporto’s climatic subsystem* under generically similar synoptic situations were *quite diverse*.

The Oporto’s thermal nocturnal pattern denoted great vulnerability,

in relation to the different types of synoptic situation,

as well as

in relation to small *nuances* within the same type of synoptic situation.
“heat-island” was specially evident on days of great stability, weak barometric gradient, weak wind and frequent periods of calm.

Conditions normally associated with the presence of anticyclonic situations, but which, as we saw, can arise under the influence of situations of depression, when the ascendant movement of the air is conditioned by the presence, in altitude, of a “cold drop”, or when caused by a strong base heating.
The shape and intensity of the Porto urban heat island changed a lot from one day to another according with the weather type prevalent.

The wind velocity and direction, the type and the vertical structure of the atmosphere have an effective control upon the thermal pattern within the city favourable to some factors more than others.

The thermal pattern of Porto is the instantaneous result of 3 main vectors: the distance to the atlantic ocean and/or to the Douro's river, the altitude and the intensity of the site urbanization phenomena.
Neither the E-W topographic differentiation, nor the proximity of two important mosaics of water (the ocean and the Douro River),

nor, much less,

the repercussions in terms of the diversity of area occupation, inherent to its more than eight centuries of history,

are sufficient
to dissimulate the impacts of the **urban metabolism**, at least, at the level of its **energetic balance**
So,

We should **downscale** our speech about climate change.

It is very easy to demonstrate the mechanics involved in:

- the human performances $\rightarrow$ urban climate
  (local and regional scale)

It is very difficult to demonstrate and convince people of:

- the human performance $\rightarrow$ global warming
  (zonal and global scale)
Thank you