THE INFLUENCE of WEATHER TYPES on the URBAN HEAT ISLAND'S MAGNITUDE and PATTERNS at PARANHOS, OPORTO – a case study from November 2003 to January 2005

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Oporto is a medium size city on the NW coast of Portugal with approximately 300 000 inhabitants that has experienced an intense urbanization process especially after 1970.

Results from daily field work from November 2003 to January 2005 show several different thermal nocturnal pattern in Paranhos, Oporto, some of which we conclude can easily be related to different weather types.

Our main purpose is to demonstrate the diversity of Oporto's climatic subsystem resolution processes under generically similar weather types, as found during our period of itinerant measurements.

Our research underlines the idea that the latitude, the strength of the winds from west, the Douro's river presence and the altimetric diversity are not sufficient to erase the influence of urban metabolism on the energy city balance.

From the analysis of the various examples selected, it is possible to state that there is a significant relationship between the weather type and the magnitude and pattern of the "urban heat islands".

The "urban heat-island" was specially evident on days of strong stability, weak barometric gradient, weak wind and frequent periods of calm, conditions normally associated with the presence of anticyclonic situations, but which we have found also under the influence of cyclonic weather types.

We conclude however that it is not absolutely true that the "urban heat-island" is weaker under cyclonic than anticyclonic weather types. On the majority of the days with cyclonic weather and good mixing conditions we frequently verified a disturbance in the explicatory capacity of the two geographic factors considered - distance from the sea and altitude.

Nevertheless, these two geographic factors proved decisive in explaining Oporto's thermal nocturnal pattern on days under the effect of dry and very hot or very cold air masses.

It is also significant that there was no particular intensification in the "heat-island" during the coldest time of the year. In our opinion, this did not occur because, on the one hand, the annual thermal amplitude is quite weak and, on the other, because the state of Portugal's economic development is not compatible with the generalised use of equipment (eg. central heating of buildings) which can create a more comfortable ambience in the interior of buildings.

We conclude that the energetic excesses which sustain Oporto's climatic subsystem and the positive thermal anomalies particularly significant in some points of the city are above all associated with intense traffic, great compactness of the constructed area and irregular topography in these areas.

Although our analyses of some climatic elements clearly show several examples of what we call the new balances of *Oporto's Climatic Subsystem*, they also reveal the difficulties concerning the distinction between the intrinsic climatological variability and effects induced by anthropogenic processes.

Keywords: Urban Environment, Weather Types, Urban Heat Island.

1.Introduction

Oporto is a medium-sized city on the NW coast of Portugal with approximately 300 000 inhabitants that has experienced an intense urbanization process especially after 1970.

Oporto is integrated in the northwestern Atlantic façade of the Iberian Peninsula, in the occidental extremity of Europe, enclosed therefore in the zone of the mid-latitudes alternatingly swept by the subpolar and subtropical pressure belts of the north hemisphere, what clearly places it in the temperate latitudes. From the river Douro, the Oporto territory is located on a platform that goes up until the alignment of the Rotunda of Boavista (129 m), Lapa (122 m) and Mount of Congregados (157 m), going down then softly towards North; it also goes down almost imperceptible to the West, towards the sea. Together, the Mankind and the hydrographic nets of the Douro/Leça rivers have shaped the physical substratum where the city is implanted and the majority of the tributaries of those two water courses "had been reoriented" by the increasing necessities of space. It is from the division zone of the two basins of the Douro/Leça rivers, with orientation NE/SW, around the 100/150 m, that a great part of Paranhos municipality is located.

2.Methodology

2.1. Direct acquisition of the information

After some experimental passages, daily field work from November 2003 to January 2005 was made with an itinerary where direct information has been obtained, according to the proceeding: itinerant measurements of temperature and relative humidity were made in a passengers vehicle, during which a digital termohygrometer was used. The Estação Meteorológica Automática (EMA) of Porto-Pedras Rubras was chosen as the reference station.

2.2. Non direct acquisition of the information

To study the weather and the atmospheric conditions under the measurement moments, synoptic charts hasve been saved/analysed (UKMO, 00h00 and 18h00). Satellite NOAA 17 photos have also been saved/analysed as complement to the synoptic charts.

2.3. Data handling

A model of data treatment was defined, for posterior cartography, according to following process:

i) the temperature of the station of reference (Porto-Pedras Rubras) was defined at the beginning of each measurment round;

ii) The data (measured temperatures) had been inserted in a model of linear regression and, through analysis of trend, the foreseen values of temperature and the value of Δ T were calculated:

$$T\ prev\ i = a\ 0 + a\ 1 * n\ i$$

iii) From the measured real data temperature (Tm) and the value of Δ T, we proceeded the simplified thermal variation correction, with the purpose of getting the corrected values (Tcorr):

$$Tcorr_i = Tm_i - \frac{\Delta T}{N}\left(n_i - \frac{N}{2}\right)$$

iv) The thermal anomalies relatively to the reference station were calculated:

$$T\ desv\ i = T\ corr\ i - T\ aerop$$

Because the information we got is discrete and it is possible to georeferenciate, intending to convert it into continuous information - and in the perspective of the existence of preferential directions of variability of the phenomen in study, that made to foresee of the existence of anisotropies – we opted for the classic methodology proposed by geostatístics, previously used in simmilar cases (J. Góis, 2004; A. Monteiro, e A. Fernandes, 2004): structural analysis, estimate with kriging and cartographic representation. The estimate of unknown values from known data, with kriging, implies the construction of variograms.

3. Results

The observation moments first had been divided in synoptic situations of clear stability and unstable/transient situations. Afterwards we considered the wind direction and speed and only after that had approached other factors.

3.1. Stability

3.1.1. AC, Continental (centered in the Iberian Peninsula and surrounded in N and W by fronts; or centered in the NE of the Iberian Peninsula):

In the days 17, 18 and 19/11-2003; 10, 16 and 25/12-2003 (00:15); 04/01-2004; 3 and 4/02-2004; 3 and 4/4-2004, with wind of quadrant N and E, equal or less than 3m/s, during all the day or part of the day, it was verified that the urban heat island in the study area exists, varying of magnitude between 0,05ºC and 3,42ºC.

In the days 12/11-2003; 11 and 14/12-2003, with wind of NW, W and S, equal or less than 3m/s, it was verified the inexistence of the phenomen of the urban heat island.

In the same way, the urban heat island also does not exist or is insignificant, considering the magnitude, in days of wind speed higher than 3m/s (days 17, 20, 21, and 25/12-2003 (23:56); 05 and 06/01-2004; 02 and 9/02-2004; 3/3-2004; 24/11-2004). However, although the urban heat island do not exists compared with the reference station, cases of "relative island" in the interior of the urban perimeter are verified, with clear meaningfullness of the geographic localization (example of day 21/12-2003)

3.1.2. AC, Atlantic

Centered N and NW of the Iberian Peninsula: In the days 24/11-2003; 22 and 24/12-2003; 8, 10, 11, 17 and 18/2-2004; 1/3-2004; 05 and 25/04-2004 (Fig. 1); 15,17 and 18/5-2004; 13/6-2004; 24/07-2004; 26/08-2004; 21, 23 and 24/09-2004, in situation of calm or wind equal or inferior to 3m/s, during the day or part of the day, it was verified the occurrence of heat island, varying its magnitude from 0,33ºC to 7,31ºC. This is also true even when the wind is higher than 3m/s – but never from W – under a large period of the day, when usually those anticyclones have a very high atmospheric pressure and there is a relative low pressure in the Iberian Peninsula (15, 16, 17 and 28/6-2004; 14, 23 and 24/7-2004; 26/8-2004).

Centered W of the Iberian Peninsula: In the days 16/11 and 23/12-2003; 1 and 3/01-2004; 27/12-2004, with wind of equal or higher speed than 3m/s, the urban heat island does not occur or it is extremely feeble.

3.1.3. AC prolongated in direction W-E, sqeezed between fronts in the N and the S (generally after cF):

In the days 15/12-2003; 28/01 and 7/2-2004, with weak wind, the heat island phenomena occurs.

3.2. Unstable/transient

3.2.1. In days 20 and 25/11-2003; 3/12-2003; 7, 22 and 27/1-2004, independently of the wind speed being low, the unstable/transient synoptic situation, associated with winds of W and S, inhibit the formation of the urban heat island. In days 22, 23 and 24/11; 4 and 9/12-2003, although the unstable/transient synoptic situation, with winds of low speed blowing from N and NNE, the heat island is promoted, with magnitude relatively low (0,10ºC to 2,28ºC) but clear.

Thermal Anomalies Table

Weather situation	Date	Temp.	Thermal Anomalies			Weather situation	Date	Temp.	Thermal Anomalies		
St = stable		(airport ºC)				St = stable		(airport ºC)			
It = unstable						It = unstable					
Tr = transient			Average	Max	Min	Tr = transient			Average	Max	Min
St	031112	22:53 - 12ºC	-0,23	0,58	-1,54	St	040425	21:44 - 14ºC	5,33	6,65	2,89
St	031116	22:02 -11ºC	-0,98	-0,62	-1,34	St	040515	22:54 - 16ºC	3,83	4,49	2,84
St	031117	22:20 -11ºC	1,44	2,13	0,56	St	040517	23:05 - 16ºC	3,67	5,64	2,17
St	031118	23:01 -14ºC	1,88	2,53	1,01	St	040518	23:05 - 18ºC	3,81	5,38	1,56
St	031119	22:56 -12ºC	0,30	1,27	-0,73	St	040613	23:28 - 19ºC	6,46	7,31	3,63
Tr(Ac)	031124	23:10 - 7ºC	1,60	2,28	1,07	St	040615	23:15 - 21ºC	2,28	3,47	0,70
St	031210	23:05 -7ºC	0,97	1,69	0,05	St	040616	23:29 - 19ºC	3,77	5,39	0,60
St	031211	23:08 - 12ºC	-0,02	0,44	-0,33	StTr	040617	23:32 - 16ºC	1,79	2,55	1,26
St	031214	00:02 - 10ºC	-1,08	-0,53	-1,74	St Tr	040628	22:50 - 18ºC	5,36	6,95	4,11
St	031215	00:01 - 10ºC	0,60	1,03	-0,30	St	040714	23:02 - 21ºC	5,78	7,57	2,56
St	031216	00:02 - 8ºC	2,11	3,42	1,04	Tr	040723	23:35 - 19ºC	3,97	5,53	2,46
St	031217	00:01 - 11ºC	-1,28	-0,69	-1,67	St	040724	23:13 - 19ºC	4,83	6,19	3,28
St	031220	00:14 - 13ºC	-1,64	-1,01	-2,44	St	040826	22:52 - 16ºC	3,90	4,76	2,17
St	031221	00:14 - 12ºC	-1,31	-0,63	-2,05	St	040921	22:58 - 17ºC	4,88	5,98	2,96
St	031222	00:05 - 7ºC	1,57	2,43	0,33	St	040923	23:00 - 21ºC	3,57	5,24	0,57
St	031223	00:05 - 8ºC	-1,71	-0,50	-2,79	St	040924	01:03 - 20ºC	2,44	4,13	-0,91
St	031224	00:14 - 6ºC	2,46	3,06	1,74	St	040924	02:52 - 18ºC	2,64	4,07	0,00
St	031225	00:15 - 9ºC	2,41	2,70	2,00	St	040924	22:54 - 15ºC	4,63	6,99	2,33
St	031225	23:56 - 7ºC	0,24	0,77	-0,53	St	041124	22:01 - 9ºC	-2,10	-1,38	-2,92
St	040101	23:50 - 9ºC	-0,19	0,28	-0,68	St	041227	23:07 - 7ºC	-0,13	0,80	-1,04
St	040102	22:15 - 9ºC	0,45	1,28	-0,14	St	050104	22:04 - 6ºC	1,07	1,96	-0,04
St	040103	22:23 - 9ºC	0,04	0,57	-1,18	St	050104	23:03 - 6º C	0,24	1,10	-0,55
St	040104	22:20 - 8ºC	1,68	2,42	0,18	St	050105	00:14 - 7ºC	-1,50	-0,95	-2,49
St	040105	22:21 - 10ºC	-1,66	-0,96	-2,33	St	050105	01:17 - 6ºC	-0,97	-0,36	-1,67
St	040106	22:21 - 9ºC	-2,08	-1,66	-2,50	It Tr	031120	22:55 - 13ºC	-0,61	0,02	-1,07
St	040128	22:02 - 7ºC	0,23	1,39	-0,69	It	031122	22:59 - 10ºC	0,65	1,34	0,01
St	040202	22:11 - 14ºC	-0,84	-0,29	-2,03	It	031123	23:15 - 10ºC	0,48	1,16	0,13
St	040203	22:00 - 13ºC	2,08	2,77	1,29	Tr	031125	23:12 - 11ºC	-1,82	-1,25	-2,22
St	040204	21:57 - 13ºC	1,62	2,48	0,41	It	031203	23:07 - 9ºC	-0,17	0,32	-0,53
St	040207	22:04 - 9ºC	2,82	3,77	1,72	Tr	031204	23:04 - 8ºC	0,56	1,26	-0,79
St	040208	22:00 - 9ºC	4,06	4,61	3,11	Tr	031209	23:06 - 6ºC	0,90	2,00	0,10
St	040209	22:01 - 13ºC	0,07	0,63	-1,15	It	031226	23:49 -12ºC	-0,33	0,06	-0,56
St	040210	21:57 - 10ºC	2,69	3,51	0,44	Tr	040107	22:24 - 14ºC	-0,51	-0,25	-0,73
St	040211	21:58 - 8ºC	2,69	3,60	1,03	It Tr	040122	22:04 - 9ºC	-0,42	0,09	-0,87
St	040217	22:58 - 8ºC	2,96	3,75	2,01	Tr	040127	22:06 - 10ºC	0,63	0,98	0,40
St	040218	22:57 - 5ºC	5,23	5,81	4,80	It	040219	22:58 - 8ºC	0,36	1,34	-1,03
St	040301	21:57 - 3ºC	4,48	5,24	3,46	It Tr	040220	23:10 - 5ºC	0,47	1,64	-0,93
St	040303	21:57 - 12ºC	-1,07	-0,48	-1,45	It	040226	21:58 - 7ºC	0,22	1,69	-0,15
St	040316	22:03 - 12ºC	2,82	3,50	1,30	It Tr	040325	22:02 - 9ºC	0,26	1,38	-0,17
St	040321	21:59 - 10ºC	0,45	0,82	0,11	It	040326	23:11 - 10ºC	-0,50	-0,09	-0,89
St	040403	21:57 - 11ºC	1,10	1,59	0,31	It	040327	21:59 - 11ºC	0,09	0,41	-0,35
St	040404	21:56 - 11ºC	2,22	2,70	1,72	It	040328	21:00 - 8ºC	1,33	1,84	0,75
St	040405	21:58 - 12ºC	3,85	5,13	2,25	It	040520	23:04 - 20ºC	2,08	3,26	1,13
St	040413	22:00 - 12ºC	3,97	5,14	1,68	It	040602	23:07 - 18ºC	2,40	3,27	1,68
St	040424	22:58 - 12ºC	3,60	4,72	1,91	Tr	040611	23:18 - 17ºC	0,01	0,58	-0,36

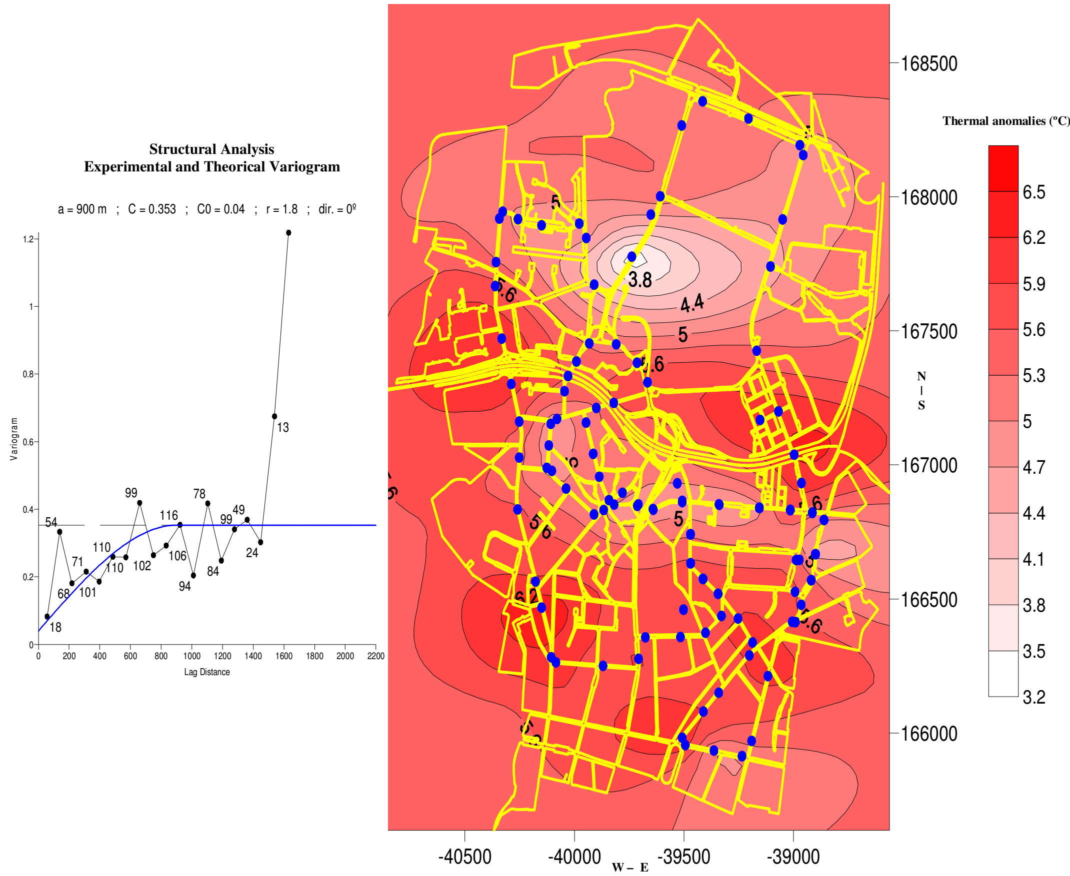

Fig. 1- Urban heat island pattern and magnitude (example)

4. Discussion

In situation of stability, with an anticyclone centered in the continent, the formation of urban heat island occurs in days of calm or weak wind (<3m/s) and if wind direction blows from N or E. In identically stable situations, with weak wind or calm, but with the wind direction from NW, W or S, the urban heat island is inhibited. Associated mist weather with changeable wind from S and W – even of low speed – generally inhibits the formation of the urban heat island. In stability situation, with an anticyclone centered in the Atlantic, in the N or the NW of the Iberian Peninsula, with wind equal or inferior to 3m/s, the heat island is formed, even after the cF passage. The localization of the Atlantic anticyclone in the W of the Iberian Peninsula causes winds of higher speed than 3m/s, therefore it does not promote the urban heat island.

There are cases of synoptic stability without urban heat island, or it is not significant, dependent on situations of the direction and speed of the wind.

The unstable/transient synoptic situations only favor the heat island if the wind will be weak and of quadrant N and NNE. There are cases of unstable/transient synoptic situation that shows urban heat island of bigger magnitude than synoptic situations of stability.

There are different urban heat island patterns depending on several factors but the highest magnitude occurs most around the points number 29/30.

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