The URBKLIM Project
Climate and Urban Sustainability: Perception of comfort and climatic risks in Lisbon (Portugal)

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1. INTRODUCTION

Lisbon is located near the western coast of Portugal, at 38º43' latitude N and 9º9' longitude W. The city lies 30 km to the east of the Atlantic shore and right on the bank of the Tagus estuary, that is 15 km wide eastwards from Lisbon (fig.1). The studies on the urban climatology of Lisbon have begun three decades ago (Alcoforado, 1986). Three PhD thesis were devoted to this topic (Alcoforado, 1992; Andrade, 2003; Lopes, 2003). The results of the different studies have been presented in several conferences and papers such as Alcoforado and Vieira, 2004; Alcoforado and Andrade, 2006; Andrade and Vieira, 2005. The main climatic problems detected in the city are: urban heat island (UHI), changes in air circulation (or wind patterns), air pollution and urban floods. Lisbon's UHI has an average intensity of 3ºC and the nocturnal thermal pattern is frequently similar to the one shown in figure 2a (Andrade, 2003): the highest air temperatures occur mostly in the more densely constructed areas, both near the Tagus river bank and along the main circulation axis where construction has been in progress. Prevailing N and NW wind circulation is hindered by the densely built-up southern and central neighbourhoods. In the case of a strong north wind, the UHI is restricted to the southernmost city districts where not only topography but also built-up density creates sheltered conditions. By means of a numerical model, summer wind speed reduction until the 1980s (an important decade in Lisbon's urban expansion) was simulated (Lopes, 2003). The decrease in wind speed due to surface roughness was particularly important in the densely built-up southern city-districts and over the Monsanto hill (fig. 2b, Lopes, 2003). Nowadays, construction keeps on progressing north of the boundary between the well ventilated northern districts and the southern areas (with very restricted ventilation, fig. 2b). There are still open spaces in the northern city-districts, where ventilation paths for prevailing N winds must unquestionably be kept free. However, at the same time, there is also the risk of strong winds, that may cause trees uprooting and fall of branches and also damages and accidents (Lopes et al., 2007). The Tagus breeze does not always penetrate very far inland, but it is a very important source of cool air for the riverside neighbourhoods. Lisbon has not yet become a very polluted city, mainly on account of frequent winds and because the vertical temperature profiles that promote pollution concentration are not very frequent. However, legal thresholds are sometimes exceeded when anticyclonic calm conditions occur (Andrade, 1996). It is also clear that in order to promote air quality, air circulation should not be hindered.

Meanwhile, the results of our studies have been used to present climatic guidelines for urban planning in the frame of a project (CLIMLIS) and in collaboration with the Municipality (Alcoforado et al., 2005, Alcoforado, 2006). The climatic guidelines will be included in the Master Plan of Lisbon, which is now being developed. Afterwards, a detailed city district study (at the microscale) was carried out (Andrade and Alcoforado, online first).

The main purpose of the project "URBKLIM: Climate and Urban Sustainability. Perception of comfort and climatic risks"[2] is to contribute to increase urban sustainability. This implies the application of solutions to ameliorate the urban environment, either indoors or outdoors. We have focused on wind (Tasks I and III) and bioclimatic issues (Task II). The project is an example of interdisciplinary research, putting together the knowledge, methodologies and skills of climatologists, architects, engineers, landscape architects, sociologists, as well as members of the Lisbon Fire Brigade and Rescue Service (RSBL) and of the Municipality of Lisbon. The project begun early in 2006 and will end by December 2008.

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As the consequences of the frequent North winds had already been dealt with in former projects, in this project we have focused, on the one hand, on estimating the risks of strong winds and, on the other hand, on defining wind speed thresholds, adapted to Portuguese population, as wind influences thermal comfort as well as the individual's capacity for movement (mechanical comfort). Therefore, the main objective of Task I is to define wind speed thresholds applied to mechanical comfort ranges, as most of the existing ones date back to the 1970s and are not adapted to the Mediterranean climate and population; this task is based on wind tunnel experiments, which are still ongoing. The existence of trees in urban areas is mainly associated with a variety of benefits, both at an environmental level and at economical and social levels. However, under strong wind conditions (studied within Task III), trees can also be the source of damage and human injuries caused by the falling of branches, boughs and even the uprooting of the tree itself. Within Task II, bioclimatic issues were dealt with. Its main aims were to analyse the perception of the atmospheric conditions by users of open public spaces in Lisbon, in order, to define thresholds of bioclimatic comfort in relation to the atmospheric and personal conditions, as well as to analyse the usage of green areas in Lisbon, in relation to the weather types and the microclimatic conditions inside these green areas.

Fig. 1. The region of Lisbon

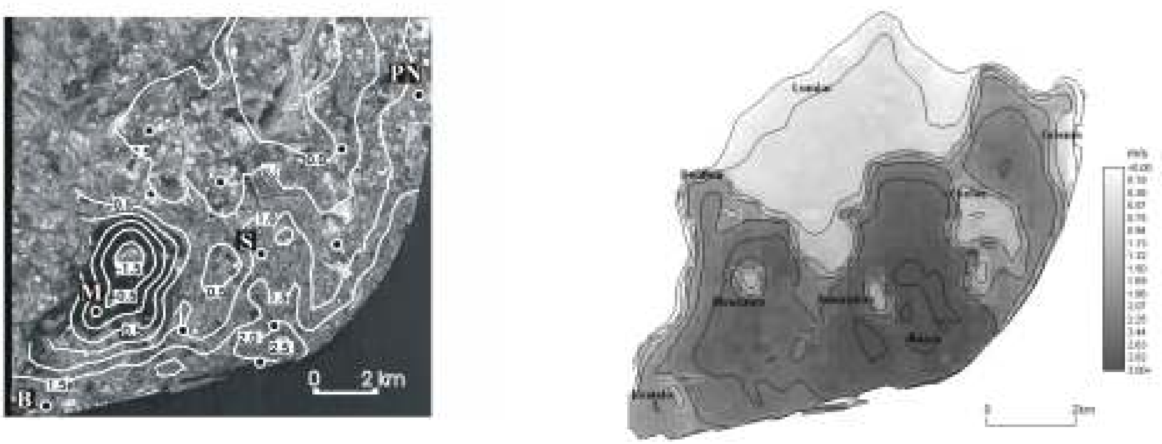

Fig. 2. Examples of previous work on Lisbon's urban climate.
a) Frequent nocturnal thermal pattern (standardized temperatures, ºC, Andrade, 2003).
b) Wind speed reduction until the 1980s (Lopes, 2003)

2. METHODS

In the frame of Task I and in order to evaluate wind influence on human comfort and movement, different tests were carried out inside a wind tunnel in order to establish the limits of thermal comfort, to determine the level of thermal response and to establish the individual's ability to move at moderate to strong wind speeds (between 7.5 and 18 m/s, divided into 6 increasing steps).

Within Task II, questionnaire surveys and measurements of weather parameters (air temperature, relative humidity, solar and long wave radiation and wind speed) were carried out in every season in two riverside areas of Lisbon during the years 2006 and 2007, in order to assess the relationships between these parameters, the individual characteristics of people (such as age, origin, clothing, activity and motivation, among others), their perception of the weather variables and their level of comfort. Nearly 1000 questionnaires were made. The analysis was carried out considering the preference votes of the interviewees, based on their answers concerning the desire to decrease, maintain or increase the values of the measured variables, in order to improve their level of comfort. Multiple logistic regression was used to model the relations between preference votes and the environmental and personal parameters. The climatic conditions of green spaces and of the surrounding area were analysed using measurements from thermohygrometers set around and inside the parks at approximately 3 meters above the ground, during the summer periods of 2006 and 2007. The usage of these parks was analysed from questionnaires that were filled out by the park visitors at the same time that temperature, relative humidity, wind speed and solar and infra-red radiation data were being collected through itinerant measurements.

In the frame of Task III, damages caused to trees by wind in the city of Lisbon and the potential causes for the uprooting of trees and the fall of boughs and branches are being studied. Up to date, 1241 tree falls (from a period of 17 years, between 1990 and 2006) were obtained from the archives of the RSBL and are being analysed along with weather data (wind speed and direction), information on the tree species, phyto-sanitary conditions, characteristics of the area and other urban parameters (such as street orientation, sky-view factor and the H/W relationship). Information on the synoptic situation associated to the events with the greatest number of occurrences has also been retrieved and instability indices are being computed.

3. RESULTS

Task 1 - Three different tests were performed and the preliminary results are the following: i) The thermal comfort limit was found to be situated between 2.5 and 4 m/s. At 4.5 m/s, only 20% of the participants declared not being cold. Above 6.5 m/s, all the people in the tunnel said they were feeling cold or very cold. As for wind speed perception, 90% of the individuals tested declared that they found it to be windy at the threshold of 3.5 m/s. At wind speeds of 6 m/s, all the participants stated the conditions as windy or very windy. When asked about the general comfort, 50% of the people tested declared to be uncomfortable at 3 m/s and 85% were uncomfortable or very uncomfortable at wind speeds of 7 m/s. ii) Thermal resistance tests revealed that at 4.5 m/s, 50% of the participants had already left the tunnel and after reaching 6,5 m/s only 8% of the participants were able to remain inside the tunnel. iii) As for the difficulty felt in moving, which was tested for wind speeds between 7.5 and 18 m/s, the results showed that for wind speeds of 7.5 m/s all participants felt no difficulty in moving, at 9.5 m/s 50% felt some difficulty in moving, at 14 m/s 60% found it difficult and 7% very difficult to move and at 18 m/s 70% of the tested individuals found it very difficult to move.

Task 2 - The thermal preferences depend largely on the season and are strongly associated with wind speed. Besides, a general decrease of discomfort with increasing age was also found, possibly due to higher clothing insulation and lower climatic sensitivity of older people. On the other hand, most people declared preference for lower wind speed in all seasons; the perception of wind shows significant differences depending on gender, with women declaring a lower level of comfort with higher wind speed than men. It was also found that the acceptability of warmer conditions is higher than for cooler conditions and that adaptive strategies are undertaken by people to improve their level of comfort outdoors, such as adjustments in clothing and the selection of shaded or sunny places.
In the two green spaces studied the registered temperature inside the parks was lower (between 3 and 8 ºC) than the surrounding areas, whilst relative humidity levels were higher (10 to 20%). Within the parks the microclimatic conditions varied considerably. This was due to the surrounding urban network, the park's equipment (benches, game-tables, play-parks), presence of water surfaces and structure and type of vegetation. These factors influence park activities and the preferences of its users, which also depend on the time of year and on daily weather conditions.

Task 3 – The highest percentage of falls occurred in the last 7 years and there are seasonal variations, in relation to the number of occurrences and the dominant wind direction. The majority of falls occur in autumn and winter, with S and SW winds, while in summertime the falls (mainly boughs and branches) are mostly due to north winds. In relation to the locations of the falls, it was verified that they concentrate in the central areas of the city, which may be dependent not only from the number and the species of existing trees and their phyto-sanitary conditions but also of the urban design of these areas. An analysis of radiosonde data of the days when tree-fall events were registered (2000-

2005) showed that the values of the SWEAT index might be the best to use in the prediction of strong wind events in the city.

4. CONCLUSION

At the end of the project (December 2008), we hope that this study will provide a framework to assess the influence of the atmospheric parameters and the subjective factors in the perception of the bioclimatic comfort, besides being a potential contribution to the design of more satisfying leisure areas in cities. We will present proposals for improving the microclimate in the chosen sites by modifying the urban design. This will be achieved by the introduction of new elements which increase the well-being of users both in the gardens themselves and in surrounding areas. Concerning strong wind risk, this study has the purpose to contribute to the definition of the areas most vulnerable to the fall of trees, boughs and branches in Lisbon, in order to establish a potential risk cartography, that can be the support to an alert system capable of preventing human and material damages. Further investigation on this topic is needed and is on-going. Furthermore, thresholds of wind speed influencing comfort and movement will be presented.

In conclusion, the main achievements expected from the project are the definition of guidelines to the planning and design of healthier, safer and more comfortable urban outdoor open and transitional spaces, in order to improve the general environmental performance of urban spaces, thus helping to reduce the energy consumption and the environmental impacts in the city. Further results of this project will be presented to this conference by Andrade, Lopes and Oliveira in two oral presentations and two posters. In this abstract, only references from previous work of the authors have been included.

REFERENCES

Alcoforado, M.J., 2006: Climatic Information for urban planning, in Climate as a Resource, WMO, Geneva: 176-188.

Alcoforado, M. J.,1992: The Climate of Lisbon's region. Thermal contrasts and rhythms (in Portuguese with an English summary). Memórias do Centro de Estudos Geográficos, n.º 15, Lisboa: 347.

Alcoforado, M. J., 1986: Contribution to the study of Lisbon's heat island, Analysis from an infra-red image. Freiburger Geographische Hefte, H.26 :165-176.

Alcoforado, M.J., Andrade, H., 2006: Nocturnal urban heat island in Lisbon (Portugal): main features and modelling attempts. Theor. Appl. Climatol. 84: 151–159 . DOI 10.1007/s00704-005-0152-1.

Alcoforado, M. J., Lopes, A., Andrade, H., Vasconcelos J., Vieira R., 2005: Climatic Guidelines for urban planning (in Portuguese with an English abstract). Geo-Ecologia, nº 4, CEG, Lisboa. http://pdm.cm-lisboa.pt/pdf/RPDMLisboa_avaliacao_climatica.pdf

Andrade, H.; Alcoforado, M.J.. 2007: Microclimatic variation of thermal comfort in a district of Lisbon (Telheiras) at night. Theor. Appl. Climatol on line first. DOI 10.1007/s00704-007-0321-5.

Alcoforado, M.J.; Vieira, H., 2004: Climate in Management Plans of urban areas (in Portuguese) Sociedade e Território, Lisboa, 37: 101-116.

Andrade H., 2003: Human bioclimate and air temperature in Lisbon (in Portuguese). PhD Thesis, University of Lisbon.

Andrade, H., 1996: Air quality in Lisbon. Average and extreme values (in Portuguese). Finisterra--Revista Portuguesa de Geografia, XXXI(61): 43-66.

Andrade, H., Alcoforado, M. J.: Microclimatic variation of thermal comfort in a district of Lisbon (Telheiras) at night. Theoretical and Applied Climatology (on line first).

Andrade, H., Vieira, R., 2005: The Climate of the Gulbenkian Park (Lisbon). Geo-Ecologia, n.º 5, Centro de Estudos Geográficos, Lisboa (in Portuguese with an English summary).

Lopes, A., 2003: Changes in Lisbon's urban climate as a consequence of urban growth. Wind, surface UHI and energy budget. (in Portuguese). PhD Thesis, University of Lisbon.

Lopes, A; S. Oliveira; M. Fragoso; J. Andrade; P. Pedro (2007) – Wind risk assessment in urban environments: the case of falling trees during windstorm events in Lisbon. In Střelcová, K. et al. (eds.): "Bioclimatology and Natural Hazards" International Conference, Zvolen Technical University: 11.