Software, Data and Modelling News

Urban boundary layer wind speed reduction in summer due to urban growth and environmental consequences in Lisbon

A. Lopes a,*, J. Saraiva b, M.J. Alcoforado a

a Centre for Geographical Studies and Institute of Geography and Spatial Planning, University of Lisbon, Alameda da Universidade, Lisboa, Portugal
b Portuguese National Laboratory of Civil Engineering (LENCE), Av. do Brasil 101, Lisboa, Portugal

A R T I C L E   I N F O

Article history:
Received 9 March 2010
Received in revised form 6 May 2010
Accepted 26 May 2010

Keywords:
Mesoscale wind
Urban growth
Urban environmental modelling
Urban climate modifications
Lisbon

A B S T R A C T

Knowledge of the mesoscale wind systems is very important to understand the dispersion of pollutants, thermal regulation and human comfort in the city. Wind field modifications brought about by the growth of the city of Lisbon and the possible urban environmental impacts are presented. In the last years the city of Lisbon has been growing towards the northern districts and the city center looses an efficient way to remove pollutants and effective way to control thermal comfort because of the consequent reduction in the wind speed average. It was concluded that until the eighties of the 20th century, there was a 30% reduction of the surface summer wind speed over Lisbon and that in the near future the increase of the aerodynamic roughness (z0) from 0.02 m to 1.5 m windward of the city will cause a 40% reduction of the wind speed above the buildings. This information can be very important to help urban planners to plan ventilation paths for the prevailing north winds towards the city center.

© 2010 Elsevier Ltd. All rights reserved.

1. Introduction

Wind flow around buildings is a well-known subject. Several wind tunnel experiments (Lopes, 2003) and environmental software (especially based on CFD) have been recently produced and improved to solve ventilation problems in urban areas (Baklanov et al., 2009). Most of the models provide solutions to the problem of air pollution dispersion inside urban canyons (Chu et al., 2005; Yang and Shao, 2008) or in large cities (Rebolj and Sturm, 1999; Thacher and Hurley, 2010). But wind field modifications above the urban envelope (in the urban boundary layer) due to the growth of the city have not yet been fully understood in a mesoscale perspective. City roughness diminishes the air flow and therefore the urban wind profile is different from that of open areas (Oke, 1987). On a regional scale, environmental disadvantages of the wind speed reduction could be related to a decrease in the thermal regulation (Lopes et al., 2010) and more frequent pollutant concentrations (San José et al., 2005; Pisoni et al., 2010). To understand the wind field modifications and to estimate future modifications of the wind speed in the next decades were the main objectives of this research.

The summer wind regime in the city of Lisbon is dominated by a relatively strong north wind (the Nortada) that occurs in 45% of the days (Alcoforado, 1987). This wind promotes pollutant dispersion and removes natural and anthropogenic heat loads. Lisbon has been growing towards the north making an enormous barrier to the north wind, leading to an environmental problem as the city center looses an efficient way to remove pollutants and an effective system to control thermal comfort.

2. Methods and data

The influence of the city growth and aerodynamic roughness on wind profiles was analyzed considering: i) the situation prior to the establishment of the city (only topography was taken into account); ii) the eighties of the 20th century (an important decade of growth in the northern part of Lisbon), when the roughness length (z0) increased to its actual value in the north (≈1 m); iii) in the future, where the volumetry and spatial arrangement of buildings, can lead to z0 = 1.5 m. Hourly average wind speeds and directions for the period from 1971 to 1980 of Lisbon/Airport meteorological station were used. The diagnosis BZ-model (Troen, 1990) based in the logarithmic wind law was used. z0 values were assigned according to Mortensen et al. (1993) and the Daweport–Wieiringa classification (Lopes, 2003).

3. Results

It was estimated that the growth of the city in the last years forced a decrease in the wind speed of about 30% at 10 m height. Considering only the summer Nortada conditions (wind speed...
above 5 m/s and directions from 45° to 315°) and assuming that \( z_0 \) will change from 0.01 to 0.03 m; “Future” refers to the wind speed estimations if the \( z_0 \) in the north of the city increases to 1.5 m.

Evidence of wind speed reduction obtained from observed wind data is shown in Fig. 3. Lisboa/Portela (PA) is a meteorological station operating since 1947 on the runway of the Airport, well exposed to the prevailing winds. In 1982 a new observatory (Gago Coutinho — GC), was set out 1 km south-eastwards near the airport buildings. Since the 1998 Lisbon Expo the airport expanded in volume and extension in response to the flux of visitors. The “Lisboa/Geofísico” (LG) station was the first meteorological facility in Portugal (city centre). As can be seen from 1984 to 1997 the two airport stations had similar annual wind speed values. After the urban expansion period (1998) an increase of the differences between the two stations is observed. After 1997 a growth of annual wind speed of Lisboa/Portela is observed not followed by the wind measured at Gago/Coutinho station that shows a similar behaviour to the Lisboa/Geofísico urban station. This can be due to the expansion of the airport that amplified the obstacle effect to the dominant north wind.
4. Conclusions and applications

Increasing the roughness of the surface modifies wind climate in cities. On a regional scale this research confirmed that until the 1980s the summer wind speed in Lisbon suffered a 30% reduction near the ground. In the future, an increase of $z_0$ from 0.02 m to 1.5 m windward of the city will cause a 40% wind speed reduction above the buildings at 25 m height. Ventilation along the valley beds must absolutely not be hindered because they are north wind paths along which the winds are channeled (Alcoforado et al., 2009). Growth in the northern area of Lisbon should therefore be guided by measures that will mitigate and prevent future implications to the south.

References


Lopes, A., 2003. Local wind changes with different roughness simulated in a wind tunnel: an example of application to a city district in the north of Lisbon. Proceedings of the 5th International Conference on Urban Climate (ICUC5), Lodz.


