Roughness Length Characterization for Urban Climate Maps in the City of São Paulo – SP, Brazil

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1. Introduction

• The densely compacted (tropical) megacities - thermal component and air circulation are constantly changed;

• UHI (urban heat island) and SUHI (surface urban heat island)
Urban Heat Island and balance energy

- Lack of vegetation, lack of evaporative cooling, shading
- Anthropogenic heat released from heated or cooled buildings
- Heat released by traffic
- Tall buildings trap air in to the street canyons and reduce wind speed within the city
- Building materials store solar heat and release it at night
- Long-wave radiation is reflected from walls back to street level

Due to the UHI a city centre can be over 10 degrees warmer than the surrounding countryside

Source: www.climateandus.com
The growth and density urban:

Aerodynamic Roughness

Wind Speed and Ventilation of cities

Change in heat transfer advection

(Alcoforado et al., 2005).

turbulences increase (50 to 100%); wind speed reduction (20 to 30%)

Source: Voogt (2000)
Aerodynamic Roughness length (z₀)

- z₀ is the height where neutral wind profile reaches zero
- Height, shape, topography, density, and spacing of roughness elements in the upwind area (Lopes, 2003; Prata, 2005; Oke, 2006; Fariña, 2009).
- Allows to infer about the changes in the velocity and flow of the winds;

Why we study the roughness length in urban spaces?

- Hamper the formation of UHI;
- Potential ventilation paths (pollutants dispersion);
- Conditions of thermal comfort to the population;
- Urban Climatic Maps (UCMaps)

Source: Burghardt et al., 2010.

Edward Ng, 2015
Selection and Delineation of Study Area

- São Paulo - 462 years
- Population: 11.9 million (IBGE, 2014)
- Metropolitan population: 22 million (39 cities)

- Elevation - 750 m
- Relative Humidity: 78% (annual average)
- Climate: humid subtropical (22ºC to 27ºC in summer - 15ºC to 21ºC in winter)

Source: www.prefeitura.sp.gov.br
<table>
<thead>
<tr>
<th>Year</th>
<th>Population</th>
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<td>1872</td>
<td>31,385</td>
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<td>2010</td>
<td>11,244,369</td>
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<td>2014</td>
<td>11,967,825</td>
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</table>

Source: IBGE
How to calculate morphological indexes to a megacity like São Paulo with huge heterogeneity of geometry and land/land cover?
The methodology developed with a GIS environment is presented, applied to Lisbon (Correia et al., 2015) and Cascais (Lopes & Correia, 2012).
Vector-based buildings database

Data/Shapefiles: System of Buildings

Source: Municipality of São Paulo

2,817,744 polygons
Generalization

2.817.744

Tool- Dissolve / Spatial Join

1.500.800 vector-based block buildings database
Create units of analysis
CELLS 100x100 m (dimensions of a city block) - Create Fishnet

Create lines to calculate
Windward Frontal Area - 20 m 20 m parallel lines perpendicular to the prevailing wind SE – NW

Cels - These data were divided into cells, together with the height of the buildings, footprint area and volume.
Calculate Windward Frontal Area

Block buildings

Regular block buildings

∩ with lines and grid

Windward Frontal Area
Aerodynamic Roughness length ($z_0$)

Roughness length ($z_0$) = $0.5h \times \frac{s}{S}$ (Lettau, 1969)

\[
(z_0) = 0.5h \times \frac{s}{S}
\]

- $s$ - frontal area
- Windward Frontal Area
- $S$ – cell area
- Height Buildings in each cell
Results

Roughness Length in the City of São Paulo – SP, Brazil

Legend
- No data
- 0.01 - 0.05
- 0.06 - 0.10
- 0.11 - 0.20
- 0.21 - 0.30
- 0.31 - 0.50
- 0.51 - 0.75
- 0.76 - 1.00
- 1.01 - 1.50
- 1.51 - 2.50

Fig 14. 1. São Paulo; 2. Sé.
Conclusions

The model can be envisaged as a good tool for calculate indexes urban to megacities – simple and quick way.

Further variables can to be incorporated in the model to account for urban density and morphology, UCMaps and Thermal Comfort.

The results promoting the maintenance and management of potential ventilation paths in the megacity of São Paulo and other cities in Brazil.

Contribute to urban planning for estimate futures scenarios for tropical cities.
References


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