Estimation of Aerodynamic Parameters for a High Rise Area of Shanghai

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1. Introduction

Aerodynamic parameters play an important role in parameterizations of land-atmosphere interactions in numerical models. Methods to determine the aerodynamic roughness length for momentum (z₀) and zero-plane displacement length (zd) can be grouped into those that require atmospheric observations (Grimmond et al. 1998) and morphometric methods based on the spatial arrangement of surface roughness elements (Grimmond et al. 1999; Kanda et al. 2013).

The need for the aerodynamic parameters comes about from the use of the logarithmic law to describe the wind profile. For neutral conditions, this is:

\[ U_z = \frac{u_0}{k} \ln \left( \frac{z}{z_0} \right) \]

where \( U_z \) is mean wind speed at a height (z), \( u_0 \) is the friction velocity and k is the Von Karman constant. The two logarithmic wind profile approaches, Su and Es methods (Grimmond et al.1998), can reduce the effects of multiple source areas inherent in to multiple level observations. The Es method also has the advantage of being able to determine \( u_0 \) with sonic measurement directly. Both the two methods require a value of zd which could be determined by temperature variance method (TVM, Rotach 1994) using sonic data, or morphometric methods using roughness element characteristics.

Using observations in the real world and wind tunnel a wide range of methods have been developed to express this behaviour in response to changes in characteristics of the spatial arrangement of the surface roughness elements, e.g. Ra (Raupach 1994), Ma (Macdonald et al. 1998) and Ka (Kanda et al. 2013) method. This needs to take into account porous, bluff, arrangement, density or consistency of the building heights.

The objective of this study is to assess the size of aerodynamic parameters for an area of Shanghai using a variety of methods based on both observations and morphometric characteristics. This type of high rise zone has been little studied because of the challenges of undertaking measurements in this type of area and because until recently the often relatively small spatial extent of such areas within cities making finding sufficient fetch difficult.

2. The abstract

With the accelerated urbanization process in numerous cities in China there is a need to obtain some of the fundamental parameters for modeling land-atmosphere conditions. Here the aerodynamic parameters for a site with tall buildings (> 35.9 m mean height) in Xujiahui, Shanghai are derived using meteorological and morphometric data. The temperature variance method (TVM) to determine zero-plane displacement (zd) provides results that reflect the influence of arrangement and density of buildings. The method is sensitive to wind speed. Using cup and sonic anemometers similar variations of roughness length for momentum (z0) with wind direction were obtained. These were inversely proportional to zero-plane displacement (zd) used. However, there are obvious differences both in values and spatial patterns between the aerodynamic and morphometric methods.

3. Meteorological Observations and Site Description

The study site located at Xujiahui (XJH, 31.19 °N, 121.43 °E), is a densely built-up commercial and residential area similar to large parts of central Shanghai. A fast response sensor and a slow response anemometer are mounted on a 25 m tower installed on the roof of the 55 m high building which locates in Shanghai Meteorological Service.
Fig. 1 (a) Distribution of building heights within a 500 m radius of the Xujiahui tower, (b) Orientation of installed instruments (the thick black arrows) with measure height on the Xujiahui tower (the dotted line triangle).

4. Results and analysis

In terms of the values calculated, the Three morphometric methods, Ra, Ka and Ma show similar variations (R² values between Ka and Ma, Ra and Ma, Ka and Ra are 0.90, 0.85, 0.87 for zd respectively, and 0.75, 0.48, 0.57 for z₀ respectively); and the two anemometric methods, Es and Su exhibit similar performance (R² value 0.91 for z₀) through all approaches have some differences. The distribution of zd by TVM method might fit the building density and arrangement better.

Fig. 2 (a) Zero-plane displacement lengths(zd) calculated by TVM, Ka, Ma and Ra method, (b) aerodynamic roughness lengths(z₀) calculated by Es, Su, Ka, Ma and Ra method.

The values of zd determined by the TVM method are proportional to parameter C₁ (Fig. 3 a), inversely proportional to the parameter C₃ (Fig. 3 b) and affected by wind speed. The zd values increase by 9.1% on average with a 28.6% increment in C₁; and decrease by 14.7% on average with a 10.5% increment in C₃. The zd
values calculated by Ka method with regressed constants Group 1 were larger by 11.96% - 28.34% than those using Group 2, and $R^2=1.00$ (Fig. 3 c).

The $z_d$ values by TVM method decrease as wind speed increases (Fig. 4 a), $z_0$ values by both Es and Su method did not show big differences between different wind speed range selections (Fig. 4 b, c). The $z_0$ values calculated by Es method and Su method are inversely proportional to $z_d$ (Fig. 5).
Fig. 4 Comparison of wind speed (m/s) sensitivity analysis for (a) TVM method, (b) Es method and (c) Su method.

Fig. 5 Comparison of $z_d$ value sensitivity analyses for (a) Es and (b) Su methods.

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References


