Yuqi TANG

Estimation of Aerodynamic Parameters for a High Rise Area of Shanghai

Yuqi TANG[1], Jianguo TAN[1], C.S.B. GRIMMOND[2], Yuanyong CHANG[1], Xiangyu AO[1],

1 Shanghai Institute of Meteorological Science, 166 Puxi Road, Shanghai 200030, China, kate_086@163.com

2 Department of Meteorology, University of Reading, Earley Gate, PO Box 243, Reading, RG6 6BB, UK, c.s.grimmond@reading.ac.uk

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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 (z_0) and zero-plane displacement length (z_d) 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:

$$Uz = (u_*/k)* \ln [(z-z_d) / z_0]$$

where Uz is mean wind speed at a height (z), u_* 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_* with sonic measurement directly. Both the two methods require a value of z_d 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 (z_d) 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 (z_0) with wind direction were obtained. These were inversely proportional to zero-plane displacement (z_d) 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.

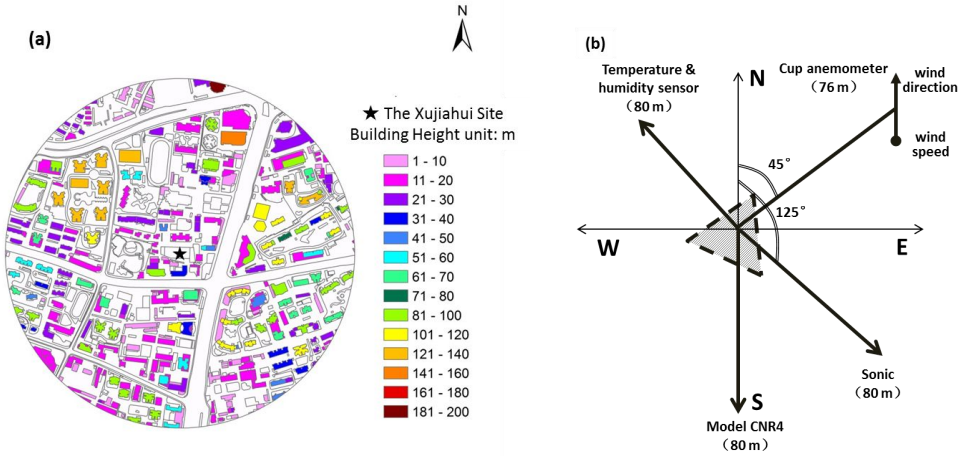


Fig. 1 (a) Distribution of building heights within a 500 m radius of the Xujiahui tower, (b) Orientation of installed instruments (the thick black arrows) with measure height on the Xujiahui tower (the dotted line triangle).

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 z_0 respectively); and the two anemometric methods, Es and Su exhibit similar performance (R^2 value 0.91 for z0) through all approaches have some differences. The distribution of z_d by TVM method might fit the building density and arrangement better.

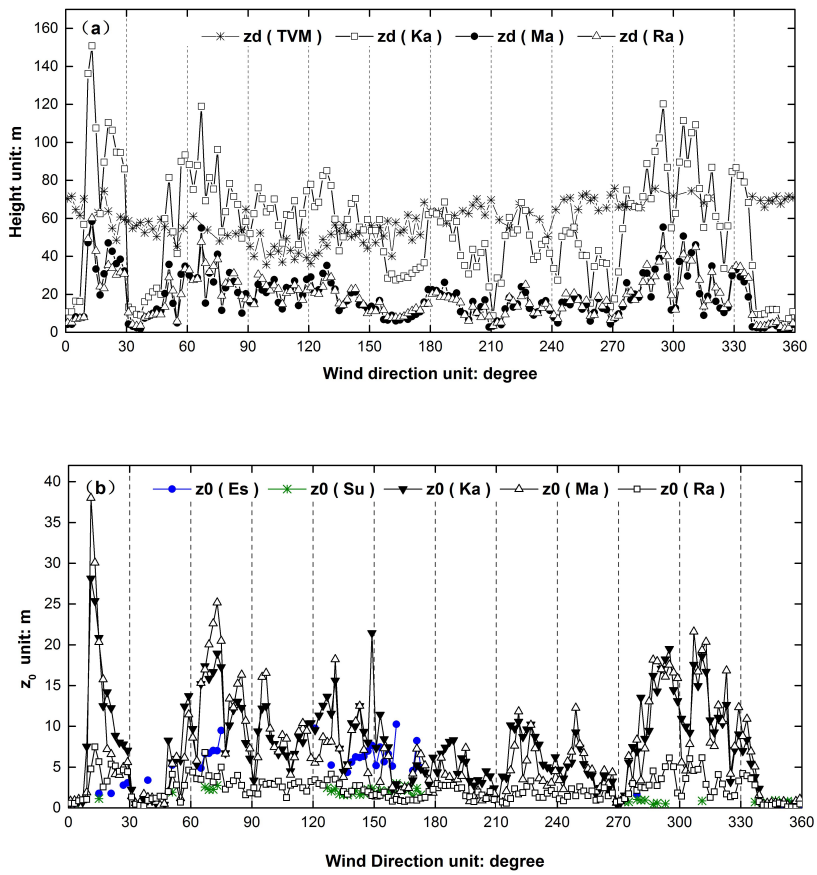


Fig. 2 (a) Zero-plane displacement lengths(z_d) calculated by TVM, Ka, Ma and Ra method, (b) aerodynamic roughness lengths(z_0) calculated by Es, Su, Ka, Ma and Ra method.

The values of z_d determined by the TVM method are proportional to parameter C_1 (Fig. 3 a), inversely proportional to the parameter C_3 (Fig. 3 b) and affected by wind speed. The z_d values increase by 9.1% on average with a 28.6% increment in C_1; and decrease by 14.7% on average with a 10.5% increment in C_3. 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).

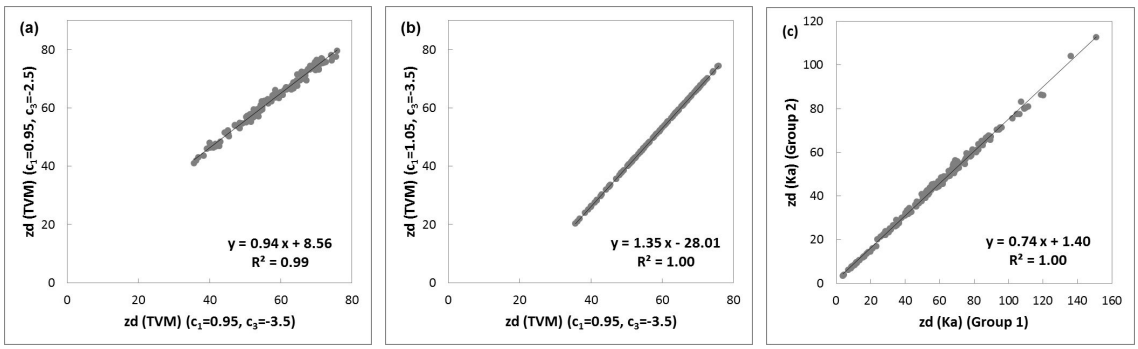
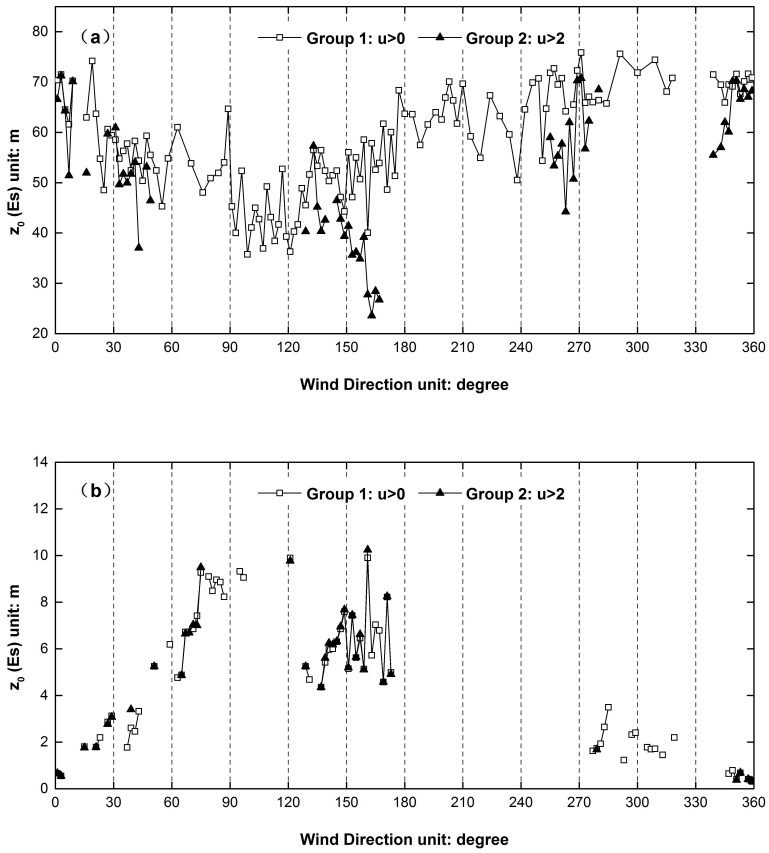


Fig. 3 Linear relation of zero-plane displacement length between different parameters set (a) (b) by TVM and (c) by Ka in Xujiahui Site.

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).



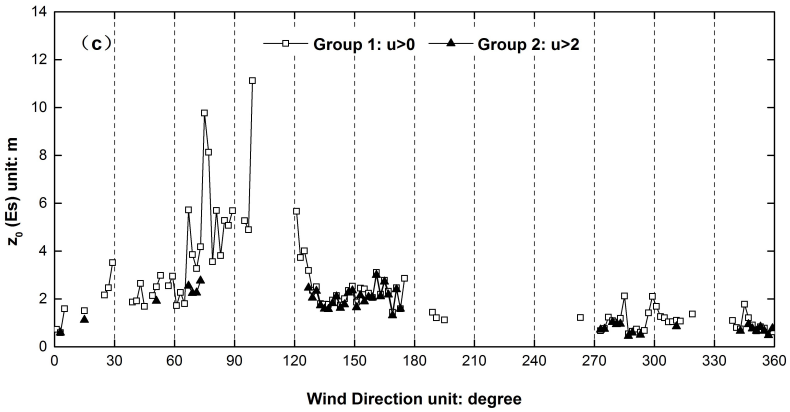


Fig. 4 Comparison of wind speed (m/s) sensitivity analysis for (a) TVM method, (b) Es method and (c) Su method.

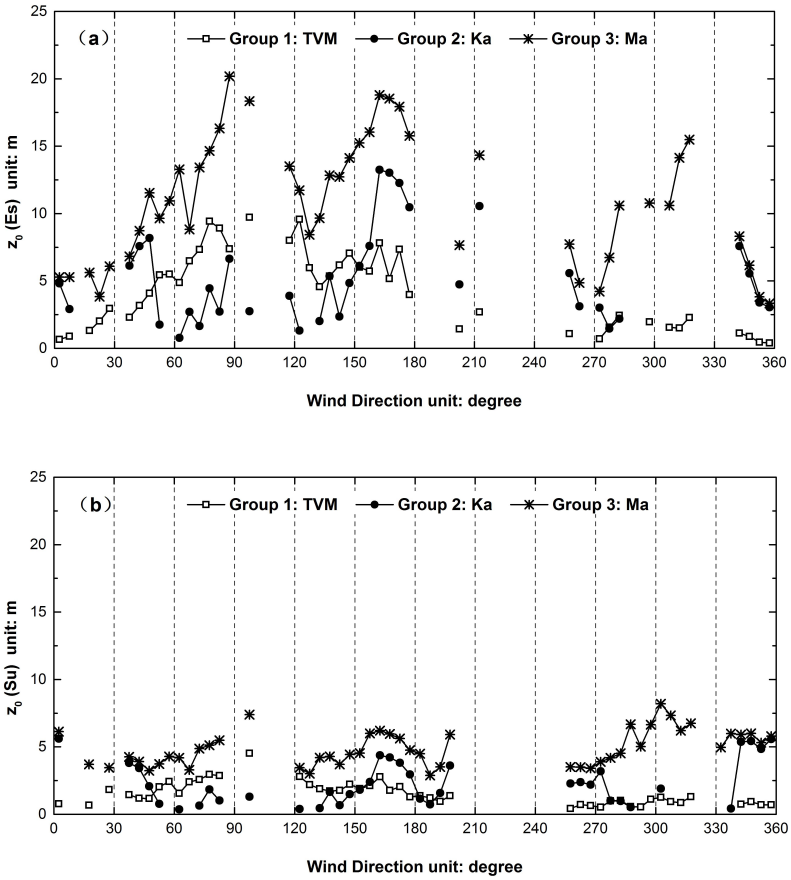


Fig. 5 Comparison of z_d value sensitivity analyses for (a) Es and (b) Su methods.

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