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Distribution of Aerodynamic Roughness Based on Land Cover and DEM-A Case Study in Shanghai, China

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1. Introduction

Estimating the urban surface wind speed effectively is useful for a number of applications such as wind energy resource development, wind disaster prevention and so on. The aerodynamic characteristics which are typically described by the aerodynamic roughness length (Z_0) and zero-plane displacement (Z_d) can be used to describe the vertical variation of the horizontal mean wind speed using the standard logarithmic profile. In the absence of direct wind measurements, Z_0 and Zd can be estimated via the use of morphometric models, which relate these aerodynamic parameters to various geometric properties of the urban surface (Raupach 1992, 1994, 1995; MacDonald et al. 1998; Jia et al.1998; Kastner-Klein and Rotach 2004; Shao and Yang 2005).Most of the models were developed that attempt to relate Z_0/H_m (mean height of the roughness elements) and Z_d/H_m to the simplified geometrical parameters of the underlying surface.In this paper, the spatial distribution map of aerodynamic roughness length (Z_0) and zero-plane displacement (Z_d) of Shanghai are derived from the DEM and land Cover data.

2. Data and methods

2.1 data

ASTER GDEM (version 2) data was gotten as the original surface height of Shanghai city. The ASTER GDEM was developed jointly by the Ministry of Economy, Trade, and Industry (METI) of Japan and the United States National Aeronautics and Space Administration (NASA). The ASTER GDEM contributes to the Global Earth Observation System of Systems (GEOSS) and is available at no charge to users via electronic download servers at the Earth Remote Sensing Data Analysis Center (ERSDAC) of Japan and NASA's Land Processes Distributed Active Archive Center (LP DAAC). It covers land surfaces between 83°N~83°S and it is composed of 22,600 tiles that are squared off with one degree by one degree. The GDEM is in GeoTIFF format with geographic lat/lon coordinates and one arc-second (arc sec) grid. A 2-byte digital number indicates the elevation above the WGS84/EGM96 geoid.

Predominantly cloud-free images of Landsat ETM+ that captured in 2010 were acquired mainly from USGS EROS Data Center (http://eros.usgs.gov/) and GLCF Data Center (http://glcf.umiacs.umd.edu/). And the land use maps were created by visual interpretation method based on these images and a variety of ancillary data, such as topographical maps, existing land use/cover maps, road network maps, river maps, settlement maps and GPS data collected during field surveys. The hierarchy of land use was established based on image capabilities, research goals and regional land use characters, which include 7 main types (agriculture, forest, grass/pasture, water body, urban, rural, and independent industrial-mining) and several subtypes.

2.2 Derivation of aerodynamic roughness length

The aerodynamic roughness length for momentum (Z_0) and Zero-plane displacement length (Z_d) were derived using morphometric methods in the support of GIS technique. In the central urban area, Z_0 and Z_d were calculated with the DEM data given the significant variations in building height while in the suburban area, Z_0 and Z_d were determined according using assumptions linked to land cover types as shown in table 1 (Delage and Verseghy, 1995). In the central urban area, we use the most common morphometric approach which is a simple rule of thumb (RT): Zo and Zd are simply related to the height of the elements (Grimmond and Oke 1999):

$$Z_d = f_d * Z_h \qquad (1)$$

$$Z_0 = f_o * Z_h \qquad (2)$$

In which, Z_h is the height of the elements, and f_d and f_o are empirical coefficients. In this paper, we assign 0.67 and 0.1 to f_d and f_o respectively (Garratt, 1992).

Table1. The aerodynamic roughness length (Zo) for different land use types

ID	Land use type	Zo	ID	Land use type	Zo
11	Paddy field	0.08	51	Graff	0.005
12	Dry land	0.2	52	Lakes	0.005
21	Forest land	3.5	53	Reservoir pits	0.005
22	Open forest land	2	54	Bottomland	0.05
23	Scrub woodland	0.5	61	Intertidal zone	0.05

24	Other woodland	0.1	62	Estuarine waters	0.005
31	High coverage grassland	0.03	63	River delta wetland	0.05
32	Moderate coverage grasslands	0.02	64	Coastal lagoon/lagoon	0.005
33	Low coverage grassland	0.01	65	Shallow waters	0.005
42	Rural residential land	0.7	71	Salt fields	0.04
43	Industrial and mining area	0.5	72	Aquiculture area	0.04

3 Result

As shown in the fig.1, overall, the Z_0 values became increasingly high from the edge of the city to the central area. High values are concentrated in the central downtown areas with Z_0 values all larger than 1 meter while in the surrounding water area; the values are all very low and less than 0.1 meters. For some suburban area, the Z_0 values are ranging from 0.1 to 1 according to the different land use types. The spatial distribution map of the zero-plane displacement (Z_d) of Shanghai is similar to that of the Z_0 map while the values is 6.7 times of the Z_0 values in each grid.

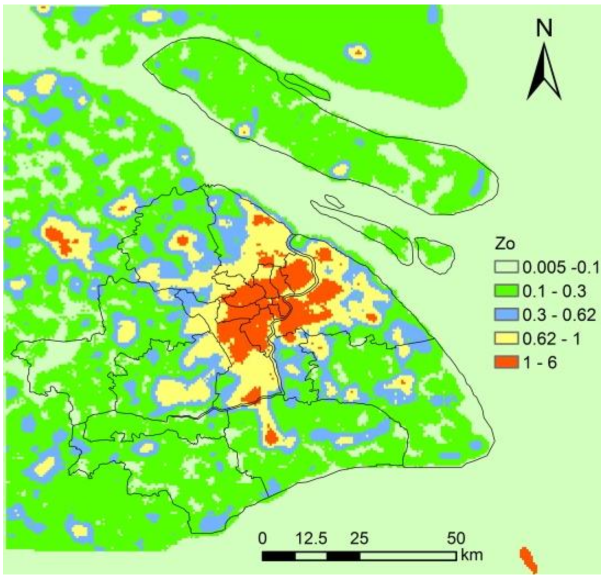

Fig. 1 Spatial distribution map of the aerodynamic roughness length (Z_0) of Shanghai

4 Conclusion and Discussion

Aerodynamic roughness length (Z_0) and zero-plane displacement (Z_d) are two of the most important parameters to describe turbulent exchange processes between the surface and atmosphere. ASTER GDEM data, Landsat ETM+ data were used to obtain the surface height and land use type for the entire Shanghai city. The aerodynamic roughness length for momentum (Z_0) and Zero-plane displacement length (Z_d) were derived using morphometric methods with GIS databases. In the central urban area, *Zo* and *Zd* were calculated with the DEM data given the significant variations in building height. While in the suburban area, *Zo* and *Zd* were determined according using assumptions linked to land use types.

Under gale force winds, which are likely to be associated with neutral stability, we can use the logarithmic wind profile model to assess the influence of the surroundings on the wind parameters. We use an analytical down-scaling method to estimate the surface wind speed as a function of height for Shanghai in the support of the aerodynamic characteristics.

The spatial distribution of aerodynamic roughness(Z_0, Z_d) can significantly affect the material and energy exchange between the surface airflow and the underlying surface especially for mega cities such as Shanghai, and the application of aerodynamic roughness to derive wind speed under neutral weather conditions is very useful for strong wind forecasts and wind disaster prevention.

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