P2.2 ROUGHNESS LENGTH AND DISPLACEMENT HEIGHT DERIVED FROM BUILDING DATABASES

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1. INTRODUCTION

In air quality and meteorological models, the bulk drag and turbulence enhancement due to cities is often parameterized through the roughness length (z_o) and displacement height (d). These log-law parameters have traditionally been derived from meteorological measurements and building morphological characteristics (e.g., see Grimmond and Oke, 1999).

We are in the midst of an effort to characterize the morphological properties of some of the major cities in the western U.S. At this time we have completed the analyses for Los Angeles, Phoenix, and Salt Lake City. We are currently working with datasets from Portland and Houston and anticipate analyzing more than five other cities in the near future. Morphological analysis of 3-D building databases produces a suite of urban canopy parameters that can be incorporated into mesoscale meteorological, surface energy budget, and pollutant dispersion models. Additional computations can be performed to derive roughness length and displacement height using several common morphological formulae described in the literature. This paper summarizes the derivation of roughness length and displacement height for a 12-km^2 section of downtown Los Angeles, 16-km^2 section of downtown Phoenix, and 6-km^2 section of downtown Salt Lake City. We correlate the computed roughness length and displacement height to underlying land use type.

2. BUILDING DATABASES

3-D building datasets were obtained from commercial vendors for downtown areas of Los Angeles, Phoenix, and Salt Lake City. Table 1 shows several characteristics of the three databases. The GIS databases are in vector format with polygons representing building footprints and rooftop elevation as an attribute. The Salt Lake City building database contains additional information about rooftop color and pitch. Rooftop structures (e.g., elevator shafts and air conditioning units) were not included in the GIS databases. The Salt Lake City database, however, was accompanied by a detailed AutoCAD drawing that did include representations of the rooftop structures.

We obtained land use datasets for Los Angeles, Phoenix, and Salt Lake City from the Southern California Association of Governments (SCAG), the Maricopa Association of Governments (MAG), and the U.S. Geological Survey (USGS), respectively. The USGS dataset for Salt Lake City was updated using a high-resolution (~6-inch pixel size) digital orthophoto. Information about the base land use datasets are contained in Table 1. Burian et al. (2002) give a detailed description of the land use categories for the Los Angeles land use dataset. Similar reports for Phoenix and Salt Lake City are currently being compiled.

3. MORPHOLOGICAL ANALYSIS

3.1 *Morphological Equations*

We used three sets of morphological equations to compute the roughness length and displacement height for the three case study cities. We also computed the parameters as a function of land use type. The first set of morphological equations is simple rules-of-thumb relating the roughness length and displacement height with the average building height:

$$z_o = f_o \overline{z_H} \quad (1)$$

$$d = f_d \overline{z_H} \quad (2)$$

where $\overline{z_H}$ is the average building height and f_d and f_o are empirical coefficients. Approximations for urban values are 0.5 for f_d and 0.1 for f_o (Hanna and Chang 1992). The second set of morphological equations were those presented by Raupach (1994), and the third set were those presented by Macdonald et al. (1988). The Raupach (1994) equations relate roughness length and displacement height to average height and frontal area index, while the Macdonald et al. (1988) set of equations uses average height, plan area fraction, and frontal area index to compute z_o and d. Limitations of these equations applied to urban areas are described elsewhere (e.g., Grimmond and Oke 1999).

3.2 *Roughness Length and Displacement Height*

Table 1 shows the roughness length and displacement height computed for Los Angeles, Phoenix, and Salt Lake City using the three sets of morphological equations described above. Fair consistency is observed between the rules-of-thumb, the Raupach (1994), and the Macdonald et al. (1988) equations. Since the equations are based on average height the computed values for Los Angeles and Salt Lake City are similar.

Tables 2 and 3 show the roughness length and displacement height, respectively, as a function of land use for the three cities. We only present the results for the Raupach (1994) equations in Tables 2 and 3. The roughness length and displacement height are significantly larger in the downtown core areas for all

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three cities compared to the individual land use types. However, in dense built-up areas with significant height variability, similarity theory may not be valid.

Figures 1 and 2 show the spatial distribution of the roughness length and displacement height, respectively, for downtown Los Angeles. The highest values correspond to the location of the downtown core area. The values gradually decrease moving radially outward from the city center.

Table 1. Roughness length and displacement height computed from 3-D databases.

	Los Angeles	Phoenix	Salt Lake City
Rules-of-thumb:			
z_o (m)	1.20	0.56	1.20
d (m)	5.98	2.80	6.00
Raupach:			
z_o (m)	1.27	0.32	1.43
d (m)	5.93	2.10	6.38
Macdonald et al:			
z_o (m)	0.80	0.34	1.42
d (m)	6.60	1.89	5.46

Table 2. Roughness length (m) as a function of land use type.

Land Use	Los Angeles	Phoenix	Salt Lake City
Residential	0.71	0.16	1.14
Commercial and Services	3.12	0.71	2.24
Industrial	0.47	0.21	1.07
Mixed Industrial and Commercial	0.81	---	---
Transportation	0.05	0	---
Mixed Urban or Built-up	1.47	---	1.17
Downtown Core Area	5.46	2.13	2.72

Table 3. Displacement height (m) as a function of land use type.

Land Use	Los Angeles	Phoenix	Salt Lake City
Residential	3.24	1.26	5.08
Commercial and Services	13.61	3.71	9.82
Industrial	2.62	1.69	5.15
Mixed Industrial and Commercial	4.97	---	---
Transportation	1.41	0	---
Mixed Urban or Built-up	6.47	---	5.49
Downtown Core Area	27.93	9.39	12.25

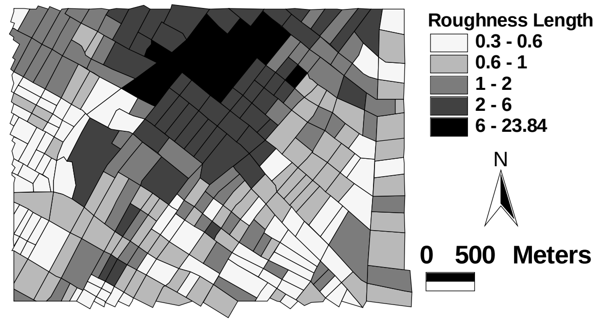

Figure 1. Spatial distribution of roughness length in downtown Los Angeles. Roughness length computed using rule-of-thumb (eq. 1).

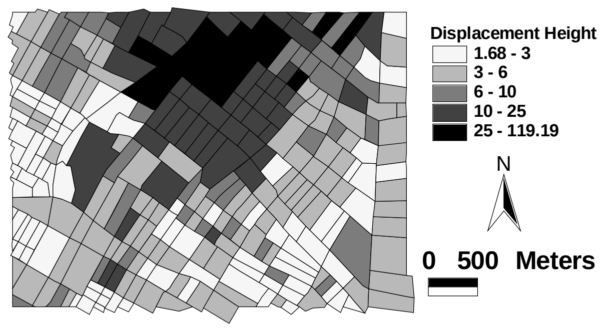

Figure 2. Spatial distribution of displacement height in downtown Los Angeles. Displacement height computed using rule-of-thumb (eq. 2).

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