19th International Conference on
Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes
3-6 June 2019, Bruges, Belgium

SIMILAR URBANISTIC TYPOLOGIES AND MORPHO-METRIC PARAMETRIZATION: ANALYSIS OF A POSSIBLE DATE OF CONSTRUCTION BASED CLASSIFICATION

Luca Salvadori[1], Maria Grazia Badas[1], Michela Garau[1], Annalisa Di Bernardino[2], Agnese Pini[2], Giorgio Querzoli[1], Simone Ferrari[1]

[1]DICAAR – Dipartimento di Ingegneria Civile, Ambientale e Architettura, Università degli Studi di Cagliari, via Marengo 2, 09123 Cagliari, Italy

[2]DICEA – Dipartimento di Ingegneria Civile, Edile e Ambientale, Università di Roma La Sapienza - via Eudossiana, 18 - 00184 Roma, Italy

Abstract: Many applications in *Urban Boundary Layer* (*UBL*) air quality studies, e.g. using mesoscale and air quality simulation models, require an urban area characterization. This can be based on morpho-metric parameters calculation, used to compute fluid dynamic parameters on the basis of empirical equations derived in laboratory. When used in a real context, mean representative morphometric values have to be computed. We here show how adaptive grids can better represent roughness elements with respect to regular ones, which are often used in literature. We considered here a street graph derived grid, in order to isolate single buildings or, at least, a small group of buildings. Through a *Digital Surface Model* analysis, it is possible to get a statistic of main morpho-metrics, such as the mean height, *Plan Area Index* (λ_p), *Frontal Area Index* (λ_f) and various types of *Aspect Ratio* for canyon characterization (*AR*). Once the elementary components of urban texture has been marked, they can be grouped together following a spatial-nearness criterion, based on similar values of the parameters or on the date of construction of the buildings. In this paper, the target is to study if homogeneous date of construction and/or architectural type of buildings correspond to similar values for the above-mentioned parameters. As a case study, we considered two areas in the Italian towns of Rome and Cagliari, areas with similar characteristics in this sense, both being included in second post-war period typology. In other words, we investigate the possibility to associate typical values for morpho-metric parameters to buildings of the same historical period and with similar architectural characteristics.

INTRODUCTION

Air quality and city breathability are an important and current topic (e.g., Mi et al. 2019 and Miao and Liu 2019) and, as it is well known, a poor environmental air state has damaging effects on human health and well-being (Dockery et al. 1993). Moreover, it is important to mention potential architectural heritage damages caused by a pollutant stressful environment (Striegel et al. 2003).

As a consequence, the scientific community has recently developed methods and practices to analyse urban air quality (Chen et al. 2011, Soulhac et al. 2017, Blocken 2015). The direct monitoring of pollutant levels in cities can be difficult, expensive and, in any case, able to show only a partial information with respect to the whole extension of an urban texture. Because of those disadvantages, a modelling approach has been established in order to predict aerodynamic quantities and pollutant concentrations also where pollution is not monitored, or measurement cannot be achieved due to technical and practical reasons (Soulhac et al. 2017).

With the aim to characterize in depth the surrounding area of a specific site under investigation, reliable and detailed description and parameterisation are essential. Modelling the average effect of urban canopy in large-meso-scale problems is a critical issue, and it should be treated carefully especially in case of unstable and convective boundary layers, in which more complex spatial structures may arise even in the case of flat terrain (Badas and Querzoli 2011). Eventually, the positive effect of an adequate characterization for these purposes has been widely demonstrated (Salamanca et al., 2010; Chen et al., 2011). Moreover, a detailed characterisation of the urban areas is fundamental for microscale models too. Here the proper description of the urban context is still necessary for setting the urban roughness length in the larger area surrounding the target one, which are not explicitly modelled although included in the simulation domain, as well as to define appropriate approaching wind boundary condition (Gousseau et al. 2011; Petenko et al. 2011; Pellliccioni et al. 2015; Blocken 2015).

Appropriate parametrization are also necessary to set an averaged effect of urban canopy on air flow turbulent structures in pollutant dispersion on urban scale modelling (Chen et al. 2011b), which can be very complex, due to the nonlinear processes involved as well as to land heterogeneities, especially in urban context (Arnfield 2003; Pelliccioni et al. 2016). The study of appropriate parametrization and their implications on the urban ventilation and pollutant dispersion is useful to define better urbanistic protocols and practices, and it might help to shape the built environment considering aerodynamic and air quality topics (Shen et al. 2017; Salvati et al. 2019).

Urban canopy parameterization and fluid dynamic parameters are generally developed on the basis of simple urban configurations, considering the urban canyon as fundamental unit. The broad division of urban canopy models, used in large scale numerical simulations, into single-layer (e.g., Masson, 2000) and multi-layer (e.g. Martilli et al., 2002) models, leads to the conclusion that studies performed on simple configurations, including two-dimensional urban canyons, are valuable (Ferrari et al., 2016; Badas et al., 2017; Garau et al., 2017; Ferrari et al., 2017; Garau et al., 2018; Badas et al., 2018, Garau et al., 2019).

It is possible to derive fluid-dynamics parameters, necessary for the above discussed applications, through empirical equations which involve morpho-metric ones (Grimmond and Oke 1999). We show here a summary of the main parameters defined for urban characterization, which completely describe an urban texture:

- Mean buildings height (H) is the average of the discretized height data within a polygon which defines building boundaries;
- Plan area index (λ_p) is the built to total area ratio in a planar projection, within a certain extension;
- Frontal area index (λ_f) is the ratio between the frontal building area referring to a specific wind direction and the total planar projection of a defined extension;
- Canyon Aspect Ratio (ARc) is the ratio between canyon width and building height;
- Building Aspect Ratio (ARb) is the ratio between canyon building width and building height.

We investigated if it is possible to associate a certain set of parameters values to a specific building period and/or architectonical style.

CASE STUDY

As a comparative case study, the choice of two zones with similar construction date is necessary. With this purpose, we have considered two areas in two Italian cities: an area in Cagliari, slightly further north than "San Benedetto" neighbourhood (hereinafter A1), and an area in Rome, nearby "Piazza dei Re di Roma" and between "Tuscolana" street and "Appia" street (hereinafter A2). Both these areas are characterized by modern-regular architectonical buildings, dated second post-war years (according to available data on "UrbisMap").

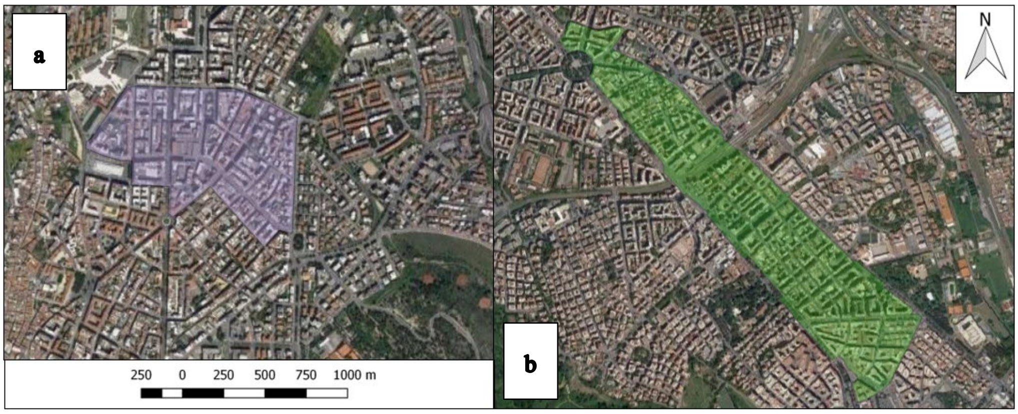

Figure 1. The two areas chosen for comparison. (a): Cagliari study area A1; (b): Rome study area A2.

Table 1. Comparison of the basic morpho-metric parameters of two areas under investigation (A1: Cagliari; A2: Rome)

Site	Mean Height [m]	Height standard deviation [m]	Plan Area Index [-]
A1	17,78	10.44	0,587
A2	21,47	10.02	0,613

The comparability of the two zones is highlighted also by the similarity of the basic morpho-metric parameters (such as H or λ_p), reported in Table 1. Figure 1 displays the planimetric views of the two areas.

METHODS

Getting information about urban textures implies to manage geographical data and often to pre-process them in order to achieve the right form of the dataset (depending on the investigated city, a different type of representation could be found). Moreover, this kind of data elaboration allows the definition of specific morpho-metric parameters, which are supposed to be representative for the urban environment in an aero-dynamic sense (Grimmond and Oke 1999). Starting from discretized information on building heights, it is possible to determine zonal statistics for some key parameters, as proportions and distances between buildings (Ratti and Richens 2004). This kind of information are available on national or local datasets, e.g. “Sardegna Geoportale” for the Cagliari case. When the street graph representation is available, it can be very useful especially to calculate λ_p on an arbitrary town-subpart, and to study λ_f as a function of the wind direction. As shown in previous studies, the use of the adaptive grid instead of the regular one, is better (Badas et al., 2019).

RESULTS AND DISCUSSION

Results show how parameters values in area A1 and A2 are comparable. Referring to λ_f, we obtained mean values (computed as averaged values on the whole extension and among all wind directions) of 0.210 [-] for A1 and 0.205 [-] for A2. Obviously, λ_f value for different directions is an important aspect, as well as the mean value. Figure 2 shows the polar diagram of frontal area index on the two zones: even if the principal direction is different in two cases, approximately the same trend can be detected. The difference between maximum and mean value is similar, too (9% for A1 and 12% for A2, normalized with respect to the mean value).

Figure 3 shows the probability density function for the two areas of two different types of aspect ratios, namely AR_c and AR_b: it can be noticed how the form of the two distributions is very similar, and the modal

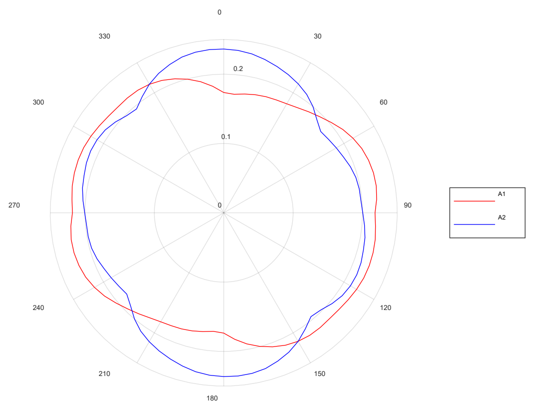

Figure 2. Polar graphic of λ_f vs wind direction for the two different investigated areas.

value can be detected in a short range for both of them. In particular, modal values are smaller than the unitary ratio, and for building aspect ratio it can be detected in proximity of 0.5).

CONCLUSIONS

This study is a first step to define and test possible methods to get morpho-metric parameters on a region of interest for aerodynamic, micro-climate and pollutant dispersion analyses. The adopted case studies show how it is possible to derive a characterization based on the knowledge of built date of the chosen urban zone. Main results show how, for the case study, the date of construction similarity is reflected into a morpho-metric parameters comparability too. Obviously, to achieve a precise correlation more efforts are necessary, but this two areas comparison highlights this feasibility. As a consequence, we are currently performing an extended study on the same parameters on various areas in the same two cities, in order to understand if a quick determination of values to use in studies and simulation, as above discussed, can be reached. The target would be to get an important simplification to the entire process, as well as a more detailed and pertinent results in simulations, based on more realistic input parameters, which better represent the larger area into the smaller one is included. This is important in order to improve our prediction capability, e.g. in the data extension process starting from a few monitored points, and our urban environment aerodynamic phenomena comprehension, allowing a better urbanistic practice in this sense.

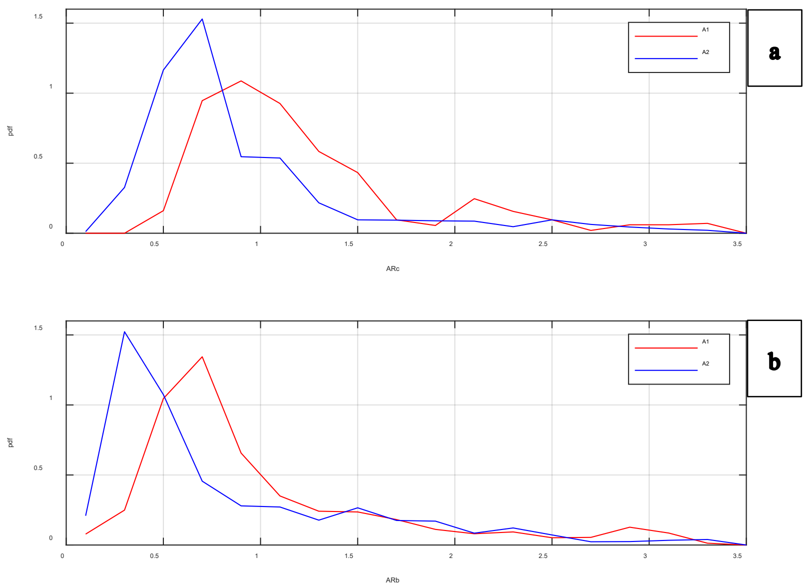

Figure 3. ARc (a) and ARb (b) probability density functions for the two different investigated areas.

REFERENCES

Arnfield JA (2003) Two decades of urban climate research: a review of turbulence, exchanges of energy and water, and the urban heat island - Arnfield - 2003 - International Journal of Climatology - Wiley Online Library. Int J Climatol 23:1–26

Badas MG, Ferrari S, Garau M, Querzoli G (2017) On the effect of gable roof on natural ventilation in two-dimensional urban canyons. J Wind Eng Ind Aerodyn 162:24–34. doi: 10.1016/j.jweia.2017.01.006

Badas MG, Querzoli G (2011) Spatial structures and scaling in the Convective Boundary Layer. Exp Fluids 50:1093–1107. doi: 10.1007/s00348-010-1020-z

Badas MG, Salvadori L, Garau M, Querzoli G, Ferrari S (2019, in press) Urban areas parametrisation for CFD simulations and cities air quality analysis. International Journal of Environment and Pollution.

Blocken B (2015) Computational Fluid Dynamics for urban physics: Importance, scales, possibilities, limitations and ten tips and tricks towards accurate and reliable simulations. Build Environ 91:219–245. doi: 10.1016/j.buildenv.2015.02.015

Cantelli A, Monti P, Leuzzi G (2015) Numerical study of the urban geometrical representation impact in a surface energy budget model. Environ Fluid Mech 15:251–273. doi: 10.1007/s10652-013-9309-0

Chen F, Kusaka H, Bornstein R, et al (2011) The integrated WRF/urban modelling system: Development, evaluation, and applications to urban environmental problems. Int J Climatol 31:273–288. doi: 10.1002/joc.2158

Dockery DW, Pope CA, xu X, et al (1993) An Association between Air Pollution and Mortality in Six U.S. Cities. N Engl J Med 329:1753–1759. doi: 10.1056/NEJM199312093292401

Ferrari S, Badas MG, Garau M, et al (2017) The air quality in narrow two-dimensional urban canyons with pitched and flat roof buildings

Garau M, Badas MG, Ferrari S, et al (2018) Turbulence and Air Exchange in a Two-Dimensional Urban Street Canyon Between Gable Roof Buildings. Bound-Layer Meteorol 167:123–143. doi: 10.1007/s10546-017-0324-4

Gousseau P, Blocken B, Stathopoulos T, van Heijst GJF (2011) CFD simulation of near-field pollutant dispersion on a high-resolution grid: A case study by LES and RANS for a building group in downtown Montreal. Atmos Environ 45:428–438. doi: 10.1016/j.atmosenv.2010.09.065

Grimmond CSB, Oke TR (1999) Aerodynamic properties of urban areas derived from analysis of surface form. J Appl Meteorol 38:1262–1292. doi: 10.1175/1520-0450(1999)038<1262:APOUAD>2.0.CO;2

Martilli A, Clappier A, Rotach MW (2002) An Urban Surface Exchange Parameterisation for Mesoscale Models. Bound-Layer Meteorol 104:261–304. doi: 10.1023/A:1016099921195

Masson V (2000) A Physically-Based Scheme For The Urban Energy Budget In Atmospheric Models. Bound-Layer Meteorol 94:357–397. doi: 10.1023/A:1002463829265

Mi Z, Guan D, Liu Z, et al (2019) Cities: The core of climate change mitigation. J Clean Prod 207:582–589. doi: 10.1016/j.jclepro.2018.10.034

Miao Y, Liu S (2019) Linkages between aerosol pollution and planetary boundary layer structure in China. Sci Total Environ 650:288–296. doi: 10.1016/j.scitotenv.2018.09.032

Pelliccioni A, Monti P, Leuzzi G (2015) An alternative wind profile formulation for urban areas in neutral conditions. Environ Fluid Mech 15:135–146. doi: 10.1007/s10652-014-9364-1

Pelliccioni A, Monti P, Leuzzi G (2016) Wind-Speed Profile and Roughness Sublayer Depth Modelling in Urban Boundary Layers. Bound-Layer Meteorol 160:225–248. doi: 10.1007/s10546-016-0141-1

Petenko I, Mastrantonio G, Viola A, et al (2011) Local Circulation Diurnal Patterns and Their Relationship with Large-Scale Flows in a Coastal Area of the Tyrrhenian Sea. Bound-Layer Meteorol 139:353–366. doi: 10.1007/s10546-010-9577-x

Ratti C, Richens P (2004) Raster analysis of urban form. Environ Plan B Plan Des 31:297–309. doi: 10.1068/b2665

Salamanca F, Martilli A, Tewari M, Chen F (2010) A Study of the Urban Boundary Layer Using Different Urban Parameterizations and High-Resolution Urban Canopy Parameters with WRF. J Appl Meteorol Climatol 50:1107–1128. doi: 10.1175/2010JAMC2538.1

Salvati A, Monti P, Coch Roura H, Cecere C (2019) Climatic performance of urban textures: Analysis tools for a Mediterranean urban context. Energy Build 185:162–179. doi: 10.1016/j.enbuild.2018.12.024

Shen J, Gao Z, Ding W, Yu Y (2017) An investigation on the effect of street morphology to ambient air quality using six real-world cases. Atmos Environ 164:85–101. doi: 10.1016/j.atmosenv.2017.05.047

Soulhac L, Nguyen CV, Volta P, Salizzoni P (2017) The model SIRANE for atmospheric urban pollutant dispersion. PART III: Validation against NO2 yearly concentration measurements in a large urban agglomeration. Atmos Environ 167:377–388. doi: 10.1016/j.atmosenv.2017.08.034

Striegel MF, Guin EB, Hallett K, et al (2003) Air pollution, coatings, and cultural resources. Prog Org Coat 48:281–288. doi: 10.1016/j.porgcoat.2003.05.001

SITOGRAPHY

"UrbisMap": https://www.urbismap.com/

"Sardegna Geoportale": http://www.sardegnageoportale.it/