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WUDAPT, an efficient land use producing data tool for mesoscale models? Integration of urban LCZ in WRF over Madrid

Oscar Brousse [a,b,*], Alberto Martilli [b], Michael Foley [c], Gerald Mills [c], Benjamin Bechtel [d]

[a] University of Strasbourg, France
[b] Research Center for Energy, Environment and Technology, CIEMAT, Spain
[c] School of Geography, UCD Dublin, Ireland
[d] Institute of Geography, University of Hamburg, Germany

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ABSTRACT

Nowadays, the absence of suitable data that describes the urban landscape in climate relevant terms for climatic models is a significant impediment to progress, even if the physics that underpins these models is universal. To address this data gap the World Urban Database and Access Portal Tools (WUDAPT) project focuses on creating a global database on cities suited for urban climate studies. The first phase of WUDAPT has established a protocol using the Local Climate Zones classification system to partition the urban landscape of cities into neighbourhood types that can inform parameter selection in model applications. In this paper, we explore the potential of these data for use in the application of the Weather Research Forecasting (WRF) model, which incorporates Building Effect Parameterization and Building Energy Model (BEP-BEM) schemes. The test is conducted for Madrid (Spain) during winter and summer and the results of using LCZ derived data are compared with those using CORINE land-cover data. The results are indicative but show that the LCZ scheme improves model performance. The paper emphasizes the need for further work to extend the value of these models for decisions on urban planning. However, such work will need useful urban data to make progress.

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* Corresponding author at: Calle Dos de Mayo 4, 3°B, Madrid 28004, Spain.
E-mail address: oscar.brousse@gmail.com (O. Brousse)

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1. Introduction

The Urban Heat Island (UHI) effect is a well-known phenomenon usually described as the difference of temperature between an urban area and a rural one. This urban land use impact has been studied for about 200 years (Howard, 1833) and is still a subject of interests. By 2050, the world's population is projected to be nearly 10 billion of which two-thirds will live in cities (United Nations. Department of Economic and Social Affairs. Population Division, 2015). In other words, the urban environment is fast becoming the norm for most on the planet. Cities have profound impacts on climate at a hierarchy of scales extending from the micro-scale (e.g. building and street) to mesoscale (city and surrounds) to the macro-scale (regional and global). These impacts include the urban heat island and air quality in cities, regional air pollution and global CO_2 emissions. Many of these changes have harmful direct and indirect effects on health (Tan et al., 2010; Watkins et al., 2007), water supply (Guhathakurta and Gober, 2007), and energy consumption (Salamanca et al., 2012). The processes that give rise to urban climate effects can be linked to aspects of their form and function. Urban form describes aspects of the surface cover (e.g. the impervious fraction), the construction materials used (e.g. thermal and radiative characteristics) and the three-dimensional morphology (e.g. building/tree heights and street width). Urban function describes the activities in cities that are sustained by the throughput of energy, materials and water, which generates waste as a consequence. Form and function are strongly correlated and produce a heterogeneous urban landscape that is often represented using maps of land-cover and land-use, respectively. However, there is a great deal of variation in the available information on cities (both in terms of coverage, scale and consistency) that presents an impediment to progress on urban climate studies.

Many of the consequences of urbanization (that is, the transformation of the natural landscape into anthropogenic urban landscapes) have been extensively studied over many decades (Oke, 1982; Arnfield, 2003) and much of the acquired understanding has been encoded into a variety of urban climate models. These models vary in their focus and sophistication but all require numerical descriptions (parameters) of the physical character of the urban landscape to simulate the urban effect. These parameters include the plan areas of buildings, paved and vegetated surface cover and the dimensions of buildings (including height), roads and other roughness elements. Many of these models can be nested within larger scale models that permit interactions between different atmospheric processes operating at different scales. For example, the *Building Effect Parameterization* (BEP) and *Building Energy Model* (BEM) (Martilli, 2002; Salamanca and Martilli, 2010; Salamanca et al., 2010) have been designed to include urban scale processes within the mesoscale Weather Research Forecasting model (WRF). BEP captures the spatial variations in form and function using urban canopy parameterizations (UCP) that capture aspects of morphology, material properties, etc. BEM links urban climate effects to building energy use and vice versa.

Acquiring UCP data for an urban landscape at a suitable scale for modeling is not a trivial task and may have to be assembled from numerous sources including: land-use/-cover maps, building databases and satellite/lidar data. For many cities much of this information is either non-existent or is unsuited to the task owing to inconsistent methodologies, poor spatial resolution and the absence of information critical to climate modeling (e.g. building height data). Information on urban morphology has been identified as critical to improving modeling capacity (Masson, 2006; Chen et al., 2011; Stewart et al., 2014). This data gap is greatest in the rapidly urbanizing parts of the world, where the need for modeling studies to guide urban development is the most important.

Recently, the World Urban Database Access Portal Tool (WUDAPT) has undertaken the task of creating a global database of cities for urban climate studies; it comprises information on urban form and function that has been gathered in a consistent manner and captures variation across the urbanized landscape (Ching et al., 2014; Ching et al., 2015; Mills et al., 2015). The database will be structured into levels, which indicate the level of detail available for a city. The lowest level data employs the *Local Climate Zone* (LCZ) typology to classify a city and its surrounding area into 17 types, ten of which are urban (Stewart and Oke, 2012). Each urban category has associated variables that describe aspects of urban morphology and material properties in terms of value ranges (Table 1). The LCZ map of a city shows the character of the urban surface and, by association, the distribution of typical parameter values. Higher levels of data in WUDAPT will have more detailed measures of the urban landscape that will be acquired through sampling or, where it is available, from existing data sources. This paper examines the value of the LCZ map in guiding parameter selection for running BEP-BEM within the WRF modeling environment. Our aim is to extract only the urban classes, which

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