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Toward advanced representations of the urban microclimate in building performance simulation

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ABSTRACT

The present contribution is concerned with the potential of empirically-based methods to capture the microclimate variance across a city and its implications for the performance of buildings. We explore the possibility to explain microclimatic variance across an urban area based on geometric and semantic attributes of specific locations. We use high-resolution and dynamic weather data streams across numerous urban locations in the city of Vienna, Austria. Using advanced data extraction methods, the values of a number of urban attributes that are hypothesized to contribute to the urban microclimate variance (e.g. morphological factors, semantic properties of urban surfaces) are derived for these locations. The results point to possible correlations between location-based climatic conditions and distinct urban attributes that could be harnessed to formulate empirically-based algorithms for generating customized microclimatic boundary conditions.

1. Introduction

The energy and thermal performance of individual buildings is affected in part by their specific urban settings (morphology, street canyons, urban surfaces, etc.) as well as the immediate urban microclimate (de la Flor & Dominguez, 2004; Erell, Pearlmutter, & Williamson, 2011; Yang, Zhao, Bruse, & Meng, 2012). As discussed by de la Flor and Dominguez (2004), the energy consumption of buildings was found to be directly related to external air temperature, solar loads, and wind flow patterns. For instance, they reported on the proportional relationship between building's cooling demand savings and the decrease of outdoor mean air temperature. This circumstance is specifically relevant to the deployment of highly sophisticated numerical modelling to predict the thermal performance of buildings. Typically, building performance simulation is undertaken with standardized weather files which are based on long term observations (weather records) from reference weather stations (typically located in the proximity of airports). Thus, such files provide a rather general perspective on the weather conditions in the city and do not necessarily represent in a detailed manner the dynamics and variability of microclimatic conditions around the existing or designated location of a building (Barnaby & Crawley, 2011; Hensen, 1999; Pernigotto, Prada, Cóstola, Gasparella, & Hensen, 2014). Pernigotto et al. (2014) stressed that the representativeness of a typical reference year can vary significantly when building's thermal performance evaluation is undertaken in different locations in the city.

In this context, the present paper is concerned with the potential of empirically-based methods to capture the microclimate variance across a city and to further outline the implications of this variance for the performance of buildings. Specifically, we explore the possibility to explain and approximately predict microclimatic variance across an urban area based on geometric and semantic attributes of specific locations (Mahdavi, Kiesel, & Vuckovic, 2013; Mahdavi, Kiesel, & Vuckovic, 2014a; Mahdavi, Kiesel, & Vuckovic, 2014b). Toward this end, we use high-resolution and dynamic weather data streams across numerous urban locations (referred here to as Urban Units of Observation or U2Os) in the city of Vienna, Austria. This facilitated the search for spatio-temporal microclimatic variation across distinct low-density suburban and high-density urban typologies in Vienna. Using automated and semi-automated data extraction methods, the values of a number of U2O variables that are hypothesized to contribute to the urban microclimate variance (e.g. topographic and morphological factors, semantic properties of urban surfaces) are derived for these locations (Glawischnig, Kiesel, & Mahdavi, 2014; Glawischnig, Hammerberg, Vuckovic, Kiesel, & Mahdavi, 2014). Hence, the existence and extent of the possible correlations between location-based climatic conditions and distinct aggregate morphological and physical attributes of urban domains (U2O variable values) are assessed (Mahdavi, Kiesel, & Vuckovic, 2015). The results obtained thus far point to the likelihood that such correlations exist and could be potentially harnessed to for-

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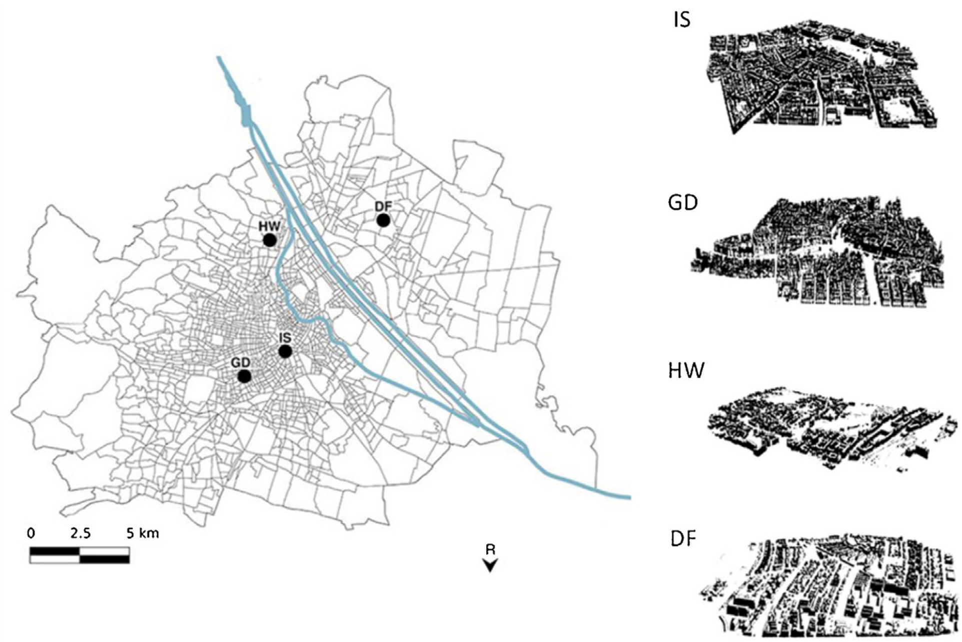

Fig. 1. The general location of the selected U2Os in the city of Vienna with 3D visualisation (height maps derived from 2.5D shape files).

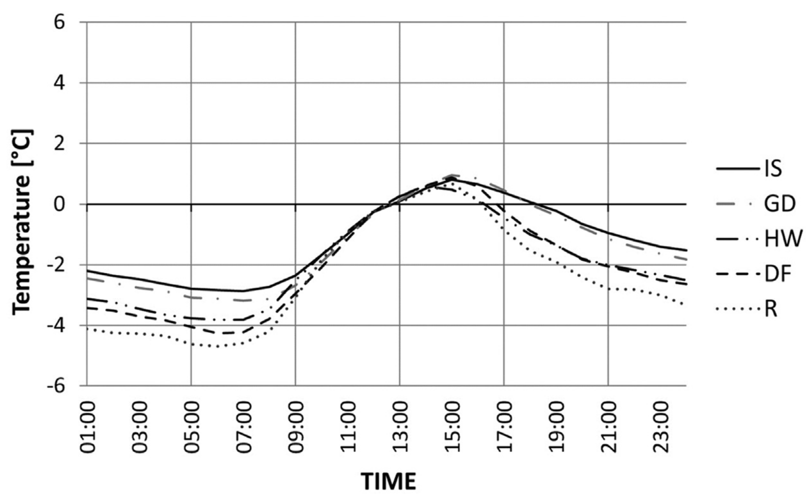

Fig. 2. Mean hourly temperature (reference day, February 2012).

mulate empirically-based algorithms for generating customized (i.e. location-specific) microclimatic boundary conditions. The corresponding documents could replace the conventional weather files in building simulation applications, such that a more detailed and realistic description of the microclimatic boundary conditions of individual buildings can be achieved. The research results are thus expected to contribute to the efforts targeted at more reliable simulation-supported analyses of the consequences of microclimate variance for the thermal performance of buildings.

2. Urban climate variation

There is ample evidence of the variation of the microclimatic conditions within cities (Arnfield, 2003; Broto & Bulkeley, 2013; Eliasson & Svensson, 2003; Erell et al., 2011). Hence, the resulting implications of urban microclimate in general and its spatio-temporal variations should be addressed. To illustrate this point, we conducted a systematic study for the city of Vienna, Austria. Specifically, high-resolution weather datasets were collected at four distinct urban domains (low-density suburban and high-density urban typologies) and one reference rural domain (see Table 1, as well as Fig. 1). For this purpose, the notion of "Urban Unit of Observation" (U2O) is introduced to define these suitably bounded areas within an urban setting (Mahdavi et al., 2013, 2014a, 2014b). The extent and characteristics of an U2O were based on the insights formulated in previous research (Stewart & Oke, 2012). As discussed by Stewart and Oke (2012), for measured climatic variables (e.g., air temperature, wind speed, humidity) to be spatially representative, the size of a sample area should not exceed a few hundred meters in radius. Thereby, a spatial dimension (radius) of approximately 400 m was targeted for this study. The microclimatic data was collected from the stationary weather station centrally positioned within the observed domain. Four stations (IS, HW, DF, R) are operated by the Central Institution for Meteorology and Geodynamics (Zentralanstalt für Meteorologie und Geodynamik, ZAMG), whereas the station called Gaudenzdorf (GD) is operated by the Municipal Department of Environmental Protection in Vienna (MA22). Weather station R represents the rural conditions.