Proceedings of the 2nd ICAUD International Conference in Architecture and Urban Design
Epoka University, Tirana, Albania, 08-10 May 2014
Paper No. 259

The Variance of the Urban Microclimate in the City of Vienna, Austria

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ABSTRACT

Metropolitan areas worldwide display highly diverse microclimatic conditions that are believed to be influenced by a variety of parameters: morphologies, structures, materials (particularly urban surface properties), and processes (mobility, industry, etc.). The density of urban structures and sealing of urban areas may lead to higher heat storage, thus increasing the daily urban air temperatures. In order to understand some of the relationships between the microclimates of urban neighborhoods, human activity and thermal environments that regulate microclimates, this paper investigates the intra-city microclimatic variance in several locations in the city of Vienna, Austria, which effectively portray urban and suburban climatic conditions. Specifically, we explore possible deviations of local (site-specific) microclimatic conditions from those captured by near-by stationary weather stations.

KEYWORDS: microclimate variance, Vienna, air temperature, urban canyon

1 INTRODUCTION

In the course of urbanization, substantial changes were introduced to land cover, building density, and total amount of impervious and heat-absorbing materials, etc. (Johnson et al. 1991, Oke et al. 1991, Ali-Toudert and Mayer 2006). These changes can generate a significant variation in microclimatic conditions (i.e., air temperature, relative humidity, wind velocity) between urban centers and surrounding suburban areas, also affecting the total energy balance of the urban domain (Grimmond and Oke 1999). Recently, extensive efforts have been undertaken to understand the street-scale climate variability and associated influencing factors (Mayer et al. 2008, Kiesel et al. 2012, Maleki et al. 2012, Mahdavi et al. 2013). Dense urban geometry presents one of the key factors contributing to the overall increase in air temperatures (Oke 1992, Lindberg et al. 2003, Giannopoulou et al. 2010). Complex urban domains have a large potential to absorb, store and exchange heat. Other factors that may lead to higher heat storage are sealing of building and street surfaces, material properties, and absence of vegetated areas (Bouyer et al. 2009, Hebbert et al. 2011, Groleau and Mestayer 2012).

In this context, the present paper specifically addresses the following question: Are there systematic differences between data obtained from standard (stationary) weather stations and those located within the urban canyon (e.g., at the very location of planned interventions such as building construction)? To answer this question, we compared in five locations across Vienna temperature data from mobile monitoring stations located in the urban canyon with simultaneously monitored data from nearby standard (stationary) weather stations. Such differences would suggest that stationary weather station data could not be used without the consideration of specific urban conditions such as morphology, property of the surfaces in the surroundings, and sky view factor at the selected site of an intervention such as a building construction project.

2 METHODOLOGY

The study is carried out for selected locations in the city of Vienna, Austria (48.21°N, 16.37°E). The five selected study areas were Innere Stadt, Gaudenzdorf, Allgemeines Krankenhaus der Stadt Wien (AKH, Vienna General Hospital), Hohe Warte, and Donaufeld (Figure 1).

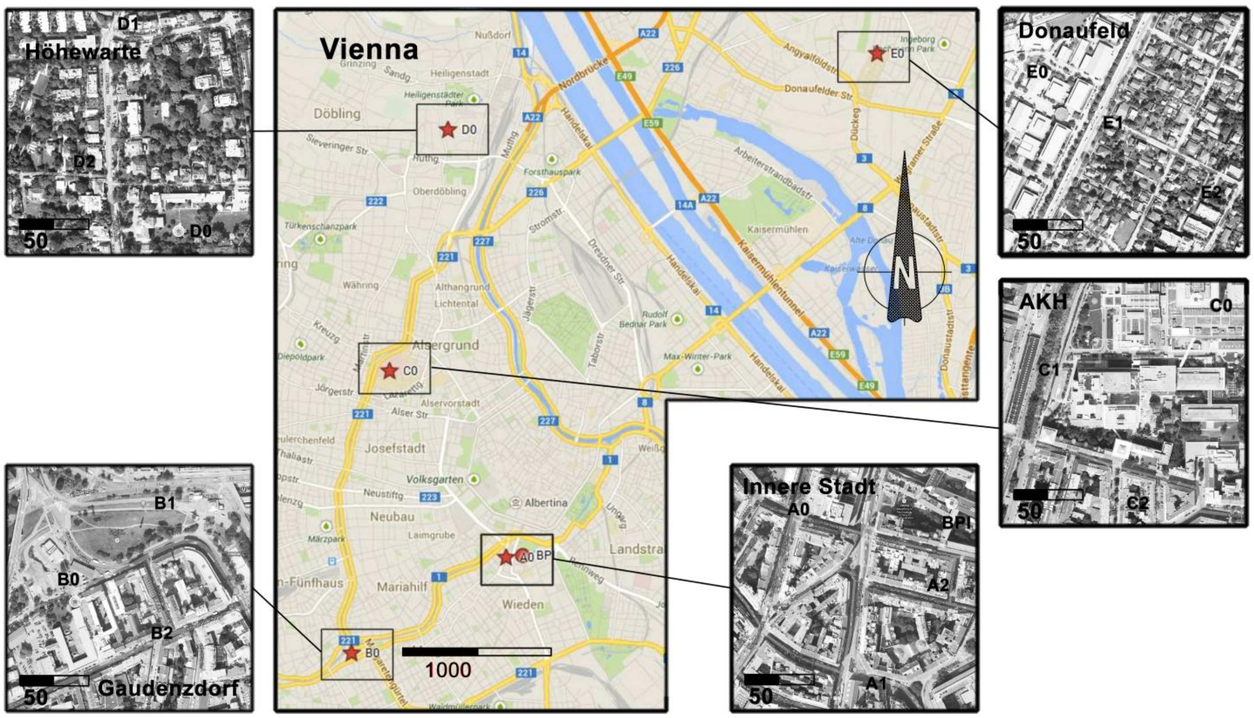

Figure 1: Overview map of the selected areas in Vienna, each with one stationary weather station and two nearby locations for short-term mobile microclimate monitoring

2.1 Investigated areas

The selected five locations represent different zones with varying geometries and local conditions. To capture the specific characteristics of each area, two locations for mobile monitoring and one stationary weather station were selected (

Figure 1). Selected spot locations were positioned to capture the variety of microclimate conditions in terms of air temperature, relative humidity, wind velocity, etc. Within each area, location 0 represents the stationary weather stations, whereas mobile monitoring units were positioned in locations 1 (open field) and 2 (urban canyon). Data from both stationary and mobile weather stations was obtained for these study areas. The stationary weather stations are operated by the Central Institute for Meteorology and Geodynamics (ZAMG) and the City of Vienna, Municipal Department of Environmental Protection Agency (SW). Mobile weather station equipment was provided by our Department of Building Physics and Building Ecology, Vienna University of Technology. In case of location Innere Stadt (area A), our Department provided an additional stationary weather station (BPI) located above the urban canopy. Table 1 entails some general information about the selected areas.

Table 1 General information about the selected locations

	Study area	Type	Stationary stations	Mobile stations
A	Innere Stadt	Urban (central)	A0 (ZAMG); BPI (TU)	A1, A2
B	Gaudenzdorf	Urban (peripheral)	B0 (SW)	B1, B2
C	AKH	Urban (peripheral)	C0 (SW)	C1, C2
D	Hohe Warte	Suburban	D0 (ZAMG)	D1, D2
E	Donaufeld	Suburban	E0 (ZAMG)	E1, E2

2.2 Data collection

The mobile weather stations used to monitor microclimatic conditions in area A (Figure 2) were equipped with sensors mounted at 1.5 meters above the ground to monitor air temperature and relative humidity, wind speed, global solar radiation, and CO_2. Mobile weather stations for areas B through E, as presented in Figure 2, were similarly equipped with sensors to monitor air temperature and relative humidity data, mounted on a tripod at 1.5 meters above the ground. Mobile measurements were conducted within two periods: one week in May and one week in June 2013 (see Table 2). Each measurement session lasted a total of four hours, once in the morning and once in the afternoon, allowing each area to be monitored twice daily. Mobile and BPI weather stations were set to record data on five-minute intervals; ZAMG data was recorded on an hourly basis, and SW data was recorded every half-hour. Given the uncertainty of mobile measurements, two methods were used to remove statistical outliers (Moore et al. 2009, Cimbala 2011).

Figure 2: Mobile weather station: location A1 (left); A2 (middle); and B through E (right)

Table 2 Overview of the measurement sessions for the five study areas

Date	Time
May 13^{th} – 17^{th}, 2014 (spring)	07:00 – 11:00; 17:00 – 20:00
June 10^{th} – 14^{th}, 2014 (summer)	07:00 – 11:00; 17:00 – 20:00

2.3 Data analysis and quality check

Collected data was subjected to a quality check to remove questionable data. The following Figure (Figure 3) illustrates hourly diurnal temperature distribution for each measurement week (mobile weather stations and BPI).

As stationary weather station data was considered to be reliable (Böhm, 1998), only mobile weather stations were subjected to quality check. In order to identify and remove potential outliers, i.e., data points that are statistically inconsistent with the rest of the dataset (Moore et al. 2009), two statistical methods were employed:

1 Formulation of statistical upper and lower limits within a dataset (Moore et al. 2009)

2 Modified Thompson's tau technique (Cimbala, 2011)

According to Method 1, any number outside the interquartile range, or 1.5 times the length away from difference of the first and third quartiles, can be considered an outlier. In method 2, only one suspected outlier was considered at a time – namely, the data point with the largest value of absolute deviation. If that data point was determined to be an outlier, it was removed and the procedure was repeated with the remaining data points until no more outliers were found.

Application of Method 1, which involved the determination of the upper and lower limits of the data, resulted in Figure 4.

Method 2 retained the upper and lower limits lines, as defined in the previous method for comparison purposes between the two methods. After several iterations based on Method 2 application, several data points remained, which had been previously removed by Method 1 (Figure 5). The procedure was repeated multiple times to remove any further remaining outliers. The second iteration found one additional outlier while the third iteration did not find any further outliers in the dataset. The resulting data from this method was used for further analysis.

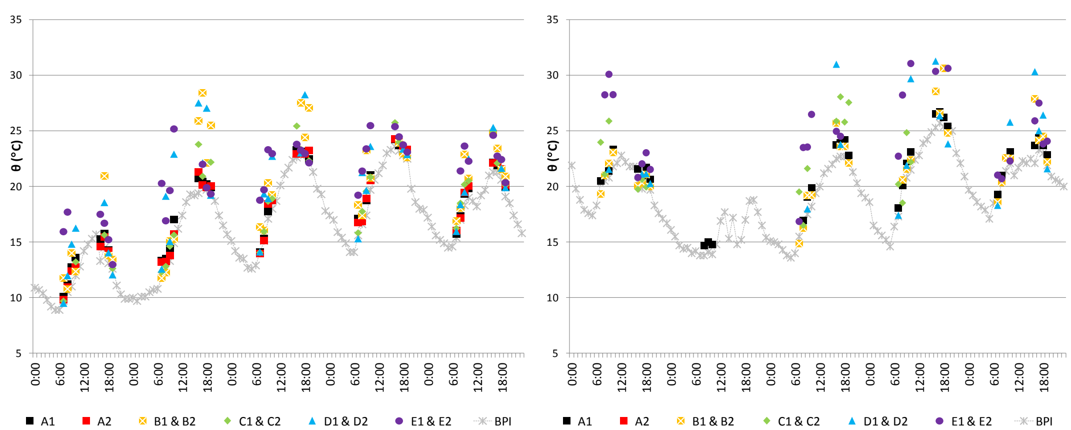

Figure 3: Monitored temperatures (left: May; right: June) with mobile stations together with BPI data as reference.

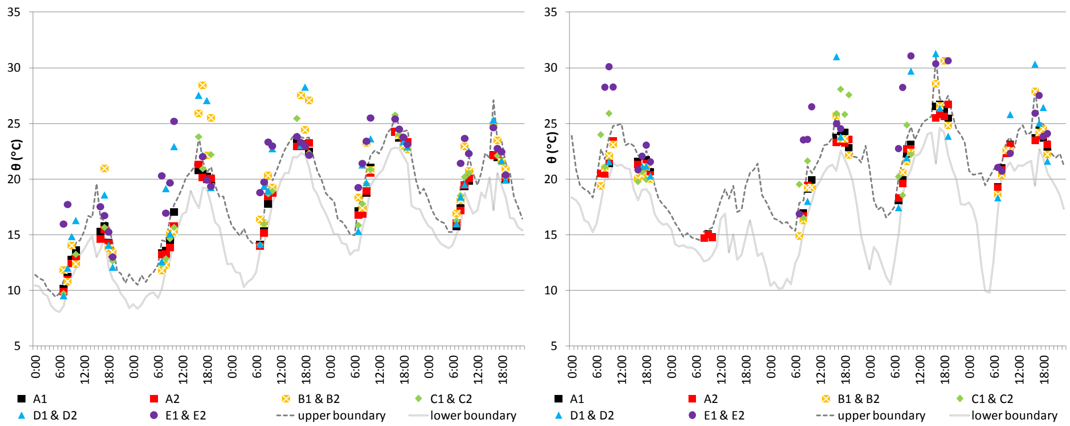

Figure 4: Statistical upper and lower limits of monitored temperatures (left: May; right: June), shown with outliers

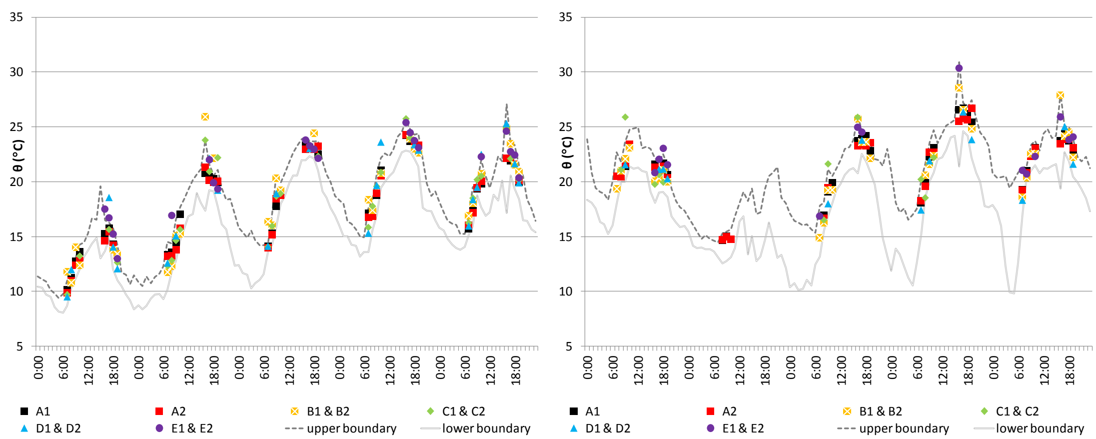

Figure 5: Reduced data set (left: May; right: June) after the application of Method 2, third iteration

3 RESULTS AND DISCUSSION

Figure 6 compares the mobile weather station temperature data ($\square_{M}$) with the simultaneously monitored data from the stationary weather stations ($\square_{S}$). These results suggest that temperature measurements obtained from the mobile monitoring stations within the urban fabric are systematically higher than stationary weather station data. This is indicated in the systematic shift of the regression line through all data (continuous line in Figure 6) relative to the theoretical line of perfect agreement (dotted line in Figure 6). Note that in area A the contextual setting around the stationary and mobile monitoring stations were rather similar (see Figure 1). Hence, if we separate the data pertaining to area A (Figure 7) from the rest of the locations (Figure 8), the aforementioned discrepancy between mobile and stationary monitoring locations becomes even more evident.

In Figures 7 and 8 white dots represent morning measurements and dark dots represent afternoon measurements. In area A (Figure 7), where the morphological surroundings of all three weather stations (stationary and mobile) were similar, stationary and mobile weather station results strongly agree (R^2 value of 0.97 and 0.98 for morning and afternoon data respectively). Mobile weather stations in areas B through E (Figure 8), on the other hand, reported consistently higher air temperatures (especially in the afternoon period).

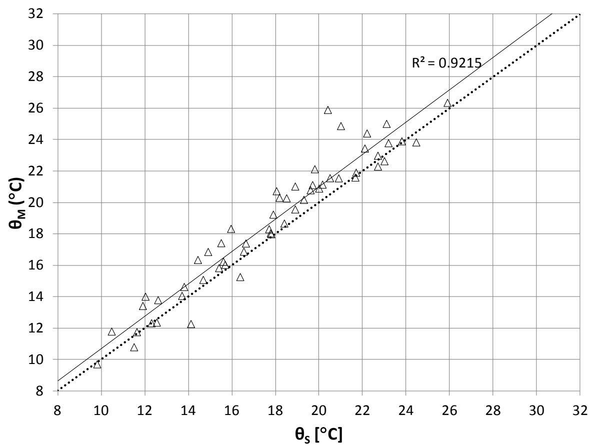

Figure 6: Mobile versus stationary temperature measurements in all areas

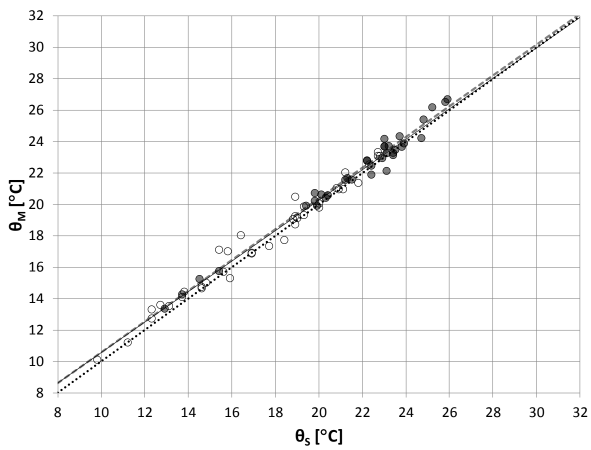

Figure 7: Mobile versus stationary temperature measurements, area A (white dots: morning measurements, dark dots: afternoon measurements)

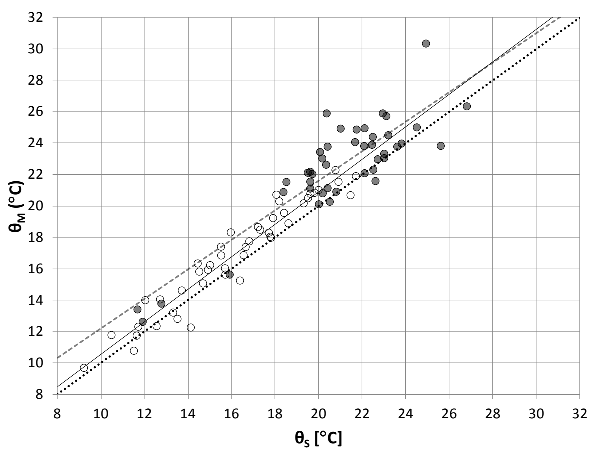

Figure 8: Mobile versus stationary temperature measurements, areas B through E (white dots + solid regression line: morning measurements, dark dots + dashed regression line: afternoon measurements)

4 CONCLUSION

Air temperature data was monitored for five locations in Vienna, Austria. One stationary and two mobile weather stations at each area provided microclimatic data. The main objective of the study was to ascertain if there are difference between data obtained from standard (stationary) weather stations and those located in the urban canyon. The results suggest that temperature data from mobile monitoring stations located in the urban canyon were generally higher than the simultaneously measured weather station data. Specifically, in our study the mean deviation of the mobile monitoring results from the stationary weather station data (areas B through E) was 5.9 ± 7.5%. This difference is arguably due to the specific urban conditions (morphology, property of the surfaces in the surroundings, fraction of visible sky, etc.). If a stationary weather station is located in a position highly representative of the nearby urban circumstance (in our case, area A), then the differences between stationary and mobile weather station data are rather small.

We thus conclude that when microclimatic data from stationary weather stations are used for decision making processes (e.g., building design and retrofit applications), potential differences between such data and actual conditions within the urban fabric (e.g., at the specific location of planned interventions) must be taken into consideration. In our future work, we plan to explore the utility of specific transfer functions that would allow for the derivation of site-specific microclimatic information from data provided by near-by stationary weather stations. Toward this end, such functions are envisioned to utilize the site-specific values of pertinent morphological and semantic variables.

5 ACKNOWLEDGEMENTS

The research work presented in this paper was supported in part within the framework of the EU-Project "Development and application of mitigation and adaptation strategies and measures for counteracting the global Urban Heat Island phenomenon" (Central Europe Program, No 3CE292P3).

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