

URBAN CLIMATE MAPPING IN BRAGANÇA (PORTUGAL)

Preliminary results



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Urban climate mapping (UCMap) is a complex yet necessary activity that should be considered in the urban planning process. Although there has been a wide development of UCMap across different countries, mapping methods must be further improved and cover a wider diversity of geographic locations (Ren, 2010). As part of the transnational BIOURB project, an UCMap of Bragança (Portugal) is being developed aiming at informing the local Planning Authorities, while establishing a basic methodology that can be used as a reference for the Northern Portuguese and Castilla-León (Spain) cities. The methodology can be described by the implementation of two combined approaches: a urban climate monitoring and a climate model.

Urban climate is being studied by means of meteorological monitoring, combining the use of temperature and relative humidity sensors (23), wind anemometers (5) and weather stations (3). The location of these equipments was established to equally address seven different Local Climate Zones (LCZ) (based on Stewart and Oke, 2009) and to express the eventual gradient from rural to urban. The Poster presents the preliminary results focusing on the initial findings concerning temperature differences across LCZ, the effects of wind speed on such processes and amplitude of the Urban Heat Island (UHI).

METHODS

Bragança is located in the north-east of Portugal. Local climate (Fig. 1 and 2) is characterised by the contrast between a cold rainy winter and a hot and dry summer (Csb cat. - Köppen). This major variability generates a wide range of climate conditions throughout the year.

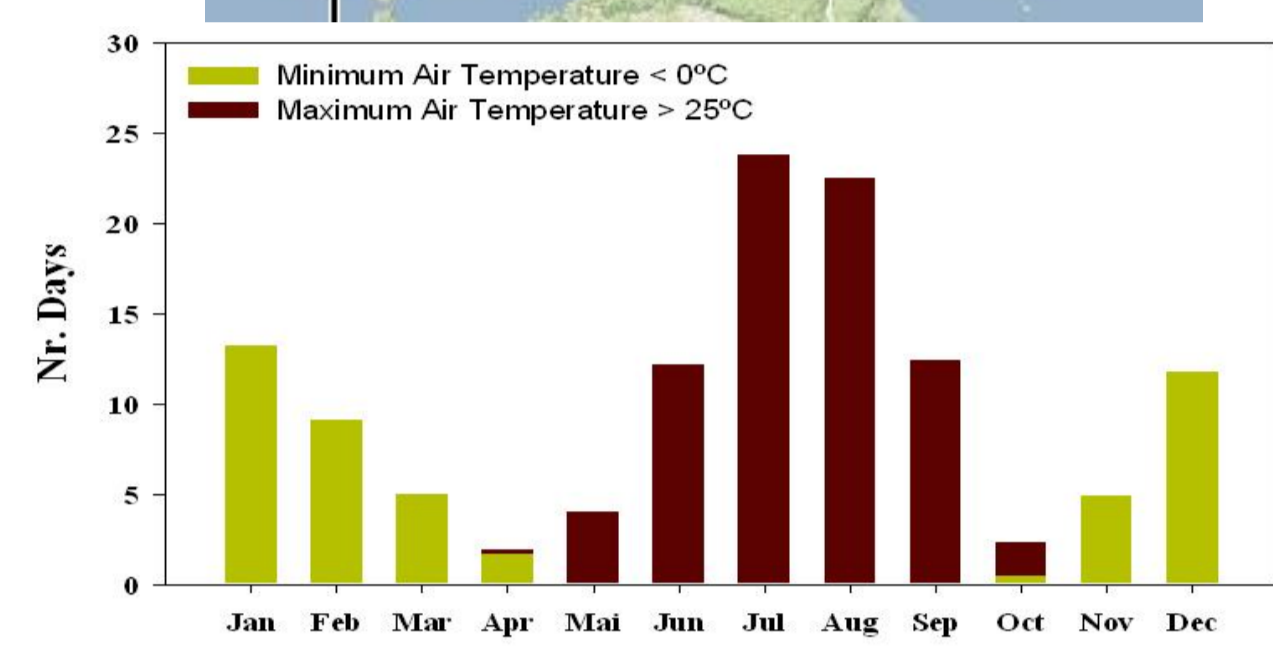


Figure 1: Monthly variation of aggregate average number of days over 25°C and under 0°C

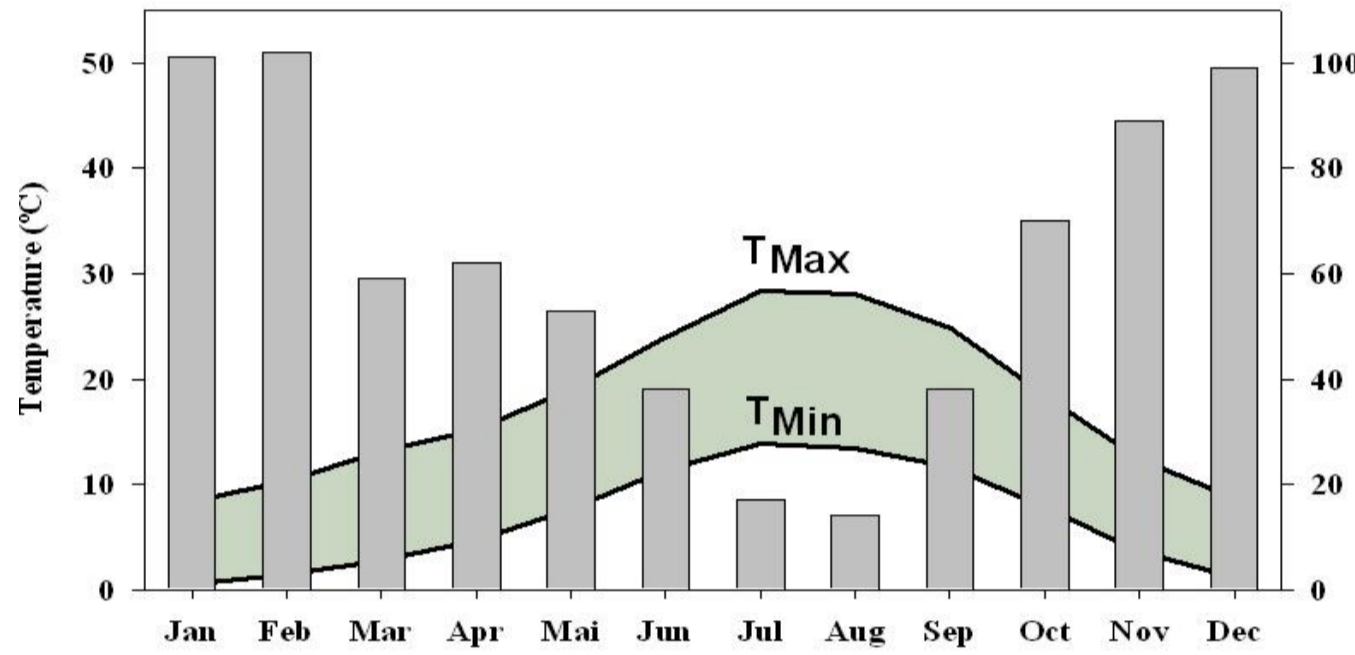


Figure 2: Monthly variation for the average minimum to maximum temperature range and accumulated precipitation

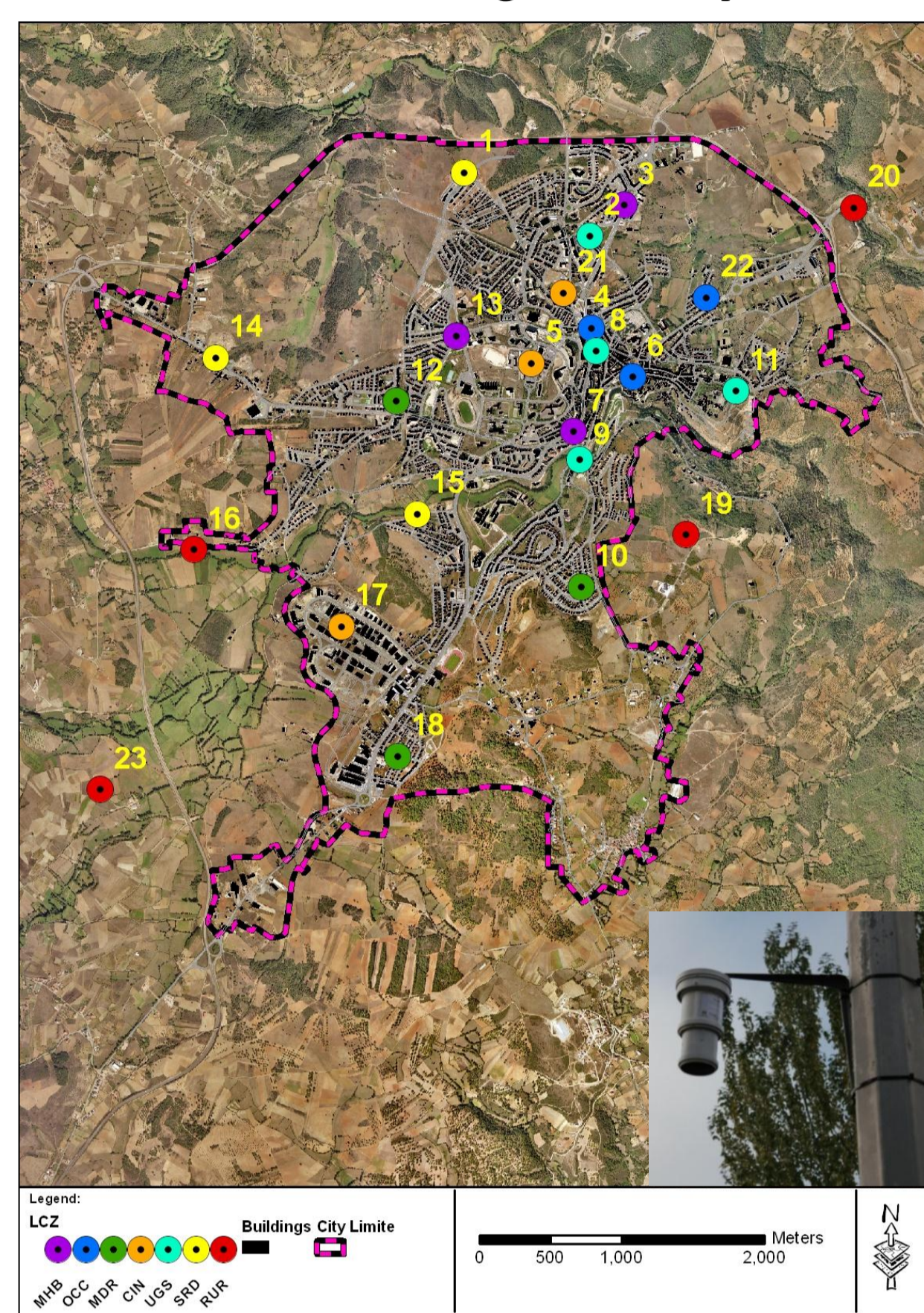


Figure 3: Stations localization Map

Urban climate characterization started in November 2011 after the installation of 23 temperature and relative humidity sensors (TinyTag TGP-4500), encapsulated in white cases and placed 3 meters above ground level, semidetached from existent street lights. Wind speed is measured with three weather stations used for data control (R.M. Young, 05103). Measurements were logged every ten minutes and converted into hour means.

Sensors have been placed considering (Table 1; Fig. 3): at least three sensors for each of the seven Local Climate Zones (LCZ); spread points across the study area; and to cover an urban to rural gradient.

Data analysis considers winter (DJF) and Spring (MAM) (2011-2012) temperature variation across both inter and intra LCZ classes using SPSS 17 Software.

Local Climate Zone ¹	Sky View Factor ²	Roughness ³	% Impervious ⁴
MHB - Modern Mid to high-rise buildings, high density and paved surfaces	0.59 - 0.81	1.54 - 2.5	94 - 99
OCC - Old city core, low to medium-rise buildings, high density - 2 - 5 storey, attached or very close-set buildings often of brick or stone	0.69 - 0.92	0.93 - 1.07	88 - 99
MDR - Medium density, low rise residential quarters with row or detached but close-set houses	0.74 - 0.76	0.74 - 0.76	90 - 99
CIN - Commercial and industrial - Highly developed, low or medium density with large low buildings & paved parking	0.82 - 0.99	0.82 - 0.99	99
UGS - Urban Green spaces - Small to Medium-sized Gardens or parks, predominantly green cover with both trees and ground vegetation	0.91 - 0.99	0.08 - 2.00	2 - 81
SRD - Semi-rural development - scattered houses with agricultural fields in its surroundings	0.97 - 1.00	0.00 - 0.15	23 - 57
RUR - Isolated rural areas in the outskirts of the city representative of local landscape characteristics.	1	0	0 - 20

1 - Adapted from Stewart and Oke, 2009 considering local urban and rural conditions and addressing local green spaces as an autonomous category.
 2 - Fisheye-photos taken with Nikon EOS 550D equipped with SIGMA 4.5 mm F2.8 Fisheye.
 3 - Calculated with ArcView 3.2 Extension (Gál and Unger, 2009).
 4 - Considering a 50 meters radius buffer.

RESULTS

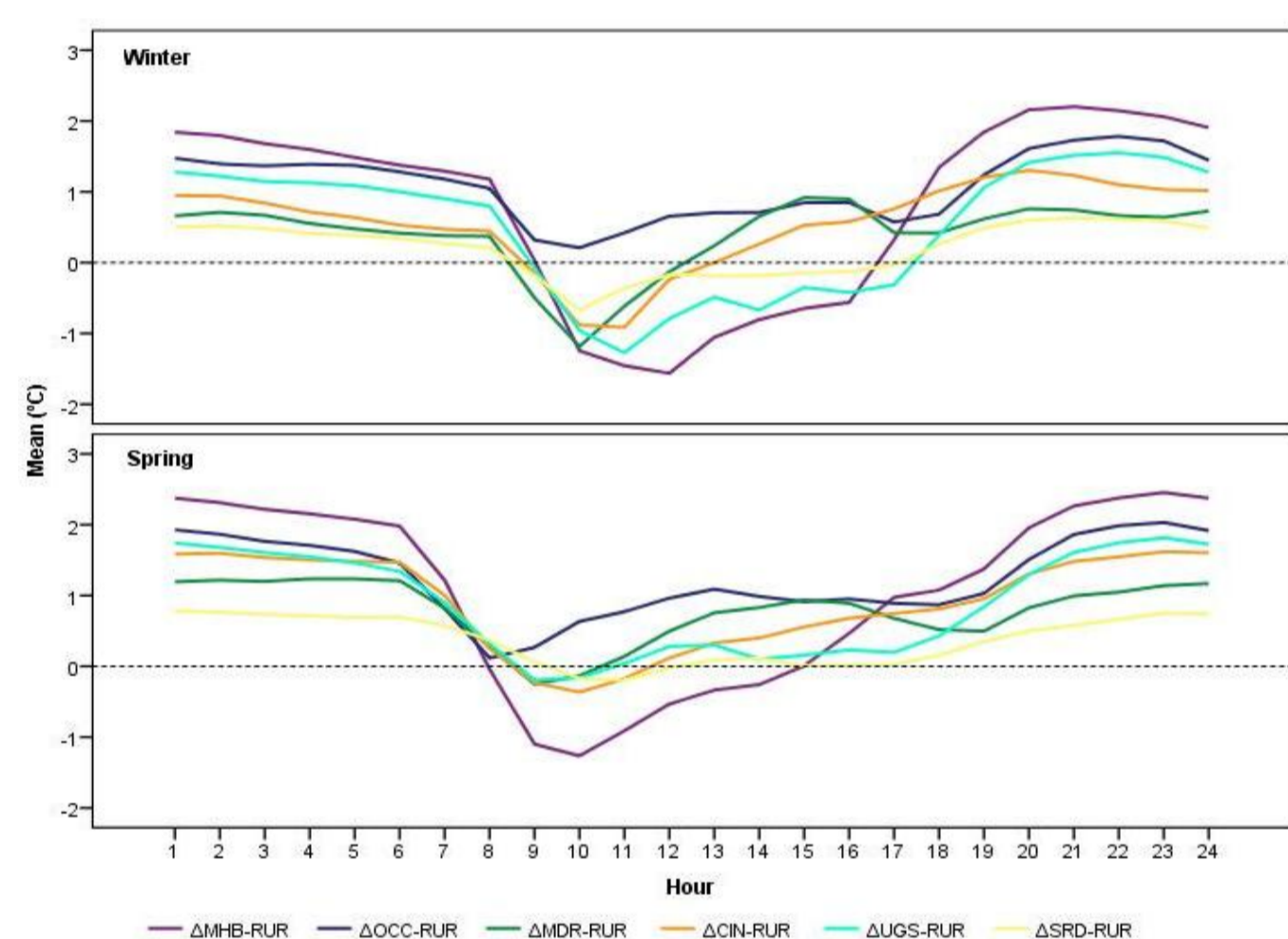


Figure 4 - Daily variation of the UHI intensity at urban stations considering both Winter and Spring

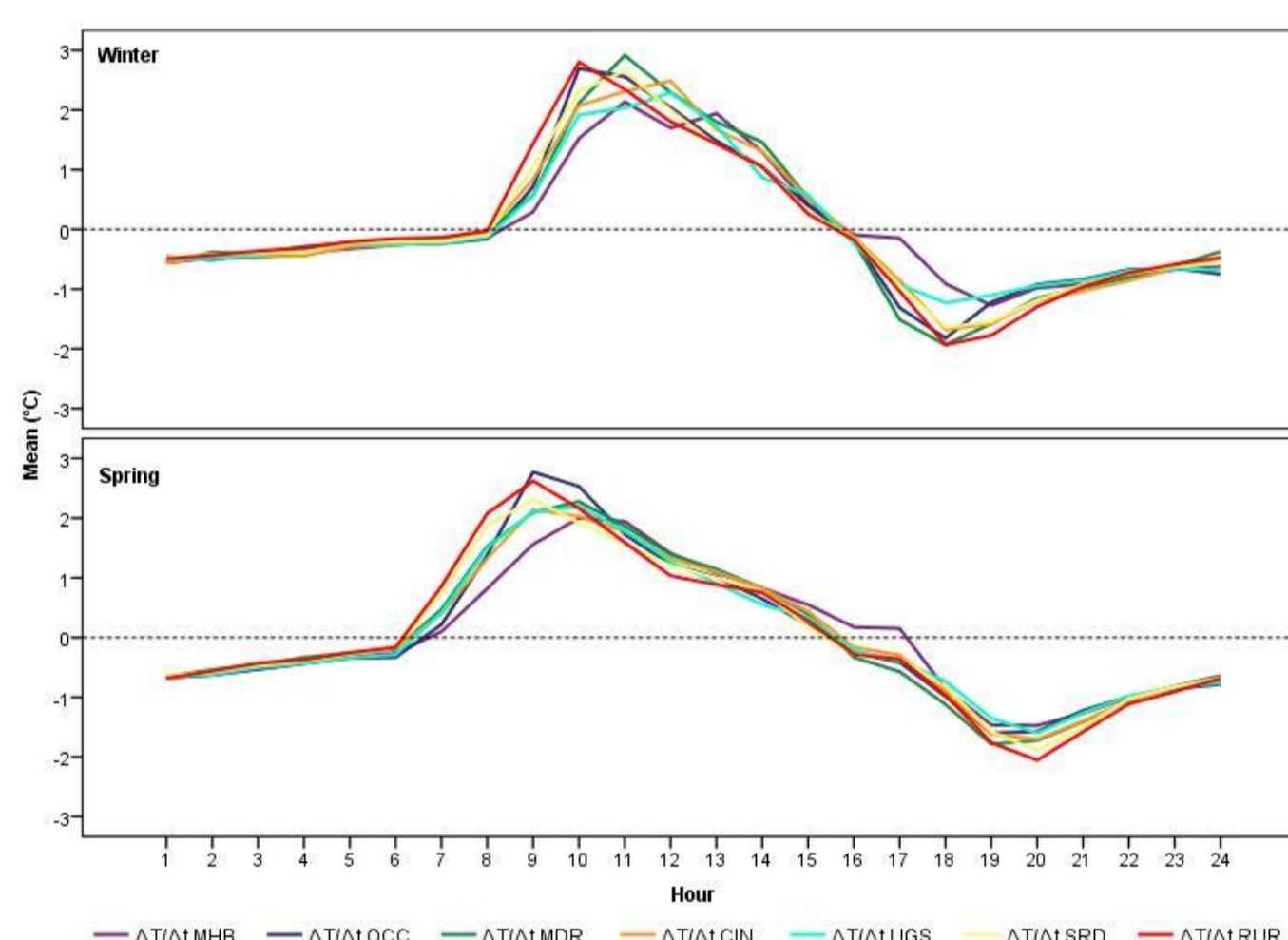


Figure 5 - Daily variation of the warming/cooling rates (ΔT/Δt) at LCZ classes

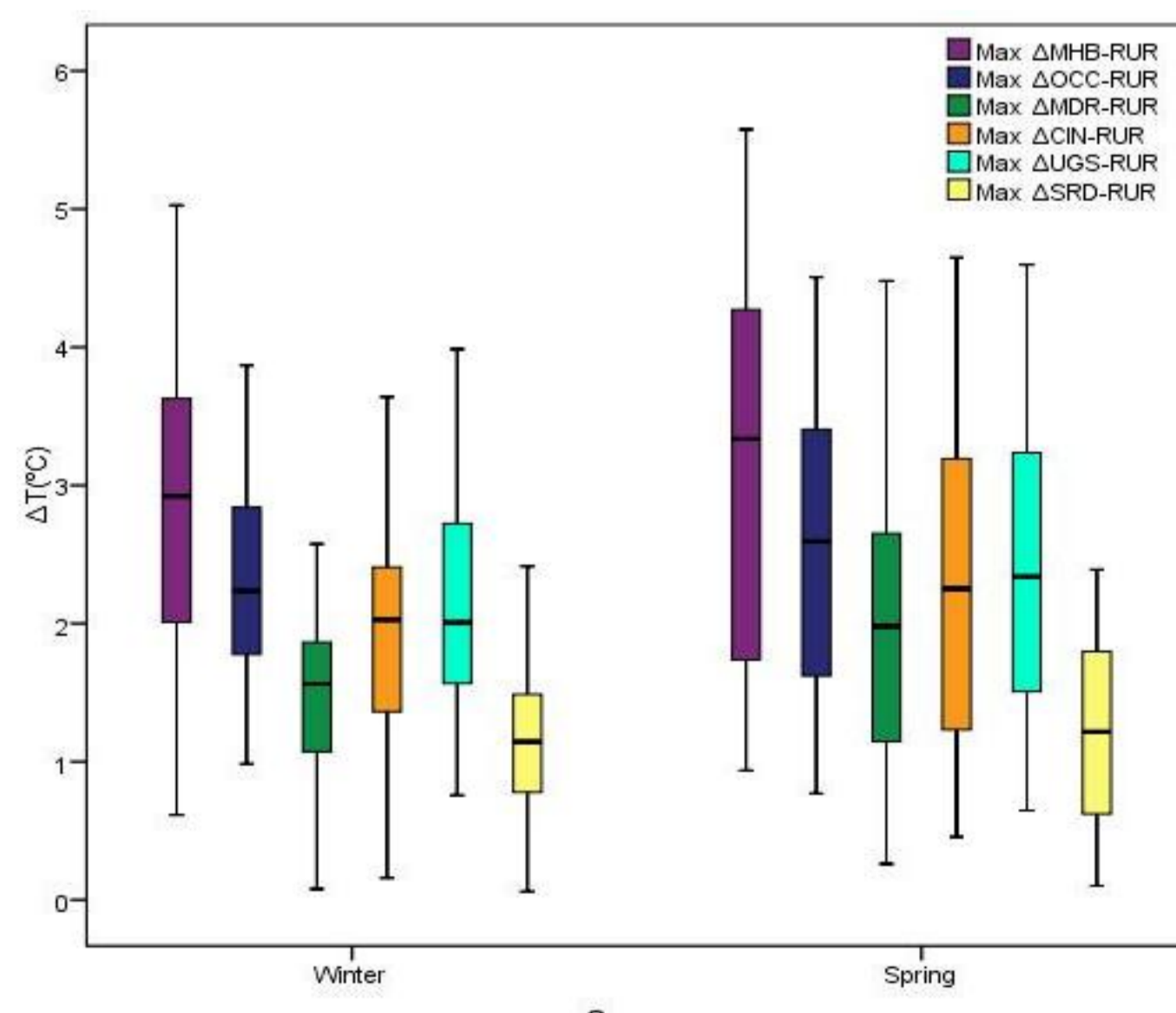


Figure 6: Differences between daily average maximum temperatures on diverse Urban LCZ with Rural LCZ

The definition of different Climate Zones ranging from Urban to Rural locations allows for a more diverse evaluation of the effects of urban structures on local meteorological conditions, that can be expressed in both intra and inter-classes evaluation.

For inter-classes evaluation, mean hour values from the same LCZ stations were first computed. This data was then used for UHI evaluation assessing the differences between urban LCZ and the rural LCZ. The resulting data was considered in the evaluation of the UHI intensity during a 24-h, as shown in Figure 4.

The maximum intensity of the UHI for every urban LCZ takes place during the night, two to three hours after sunset, simultaneously with the maximum range across classes. The highest values are reached in more artificial Urban LCZ (MHB and OCC), reaching up to approximately 2.5 °C. Conversely, the lowest UHI intensity is reached 2 to 3 hours after sunrise, as several LCZ exhibit 'cool islands', i.e. negative UHI. The OCC has a rather different behavior as mean temperatures are consistently higher than RUR.

These results can also be interpreted considering the daily variation of the warming/cooling rates for each LCZ (fig. 5). MHB, despite having the largest UHI intensity, has the smallest hour temperature variations, suggesting that the determinant factor in such effect is the fluctuation in RUR temperature. Moreover, just after sunrise and sunset, as we move from artificial to natural LCZ, there is an increase in the rate at which temperatures change (heating or cooling), fact that can mainly be attributed to the differences in surfaces behavior.

UHI can also be evaluated considering the daily maximum intensity. Figure 6 presents the data variation across LCZ classes, showing that the highest values are reached for the most densely developed urban classes. As values reach over 5 °C even under winter conditions, it is clear that the UHI effect can be quite relevant, despite the relatively small size of this city.

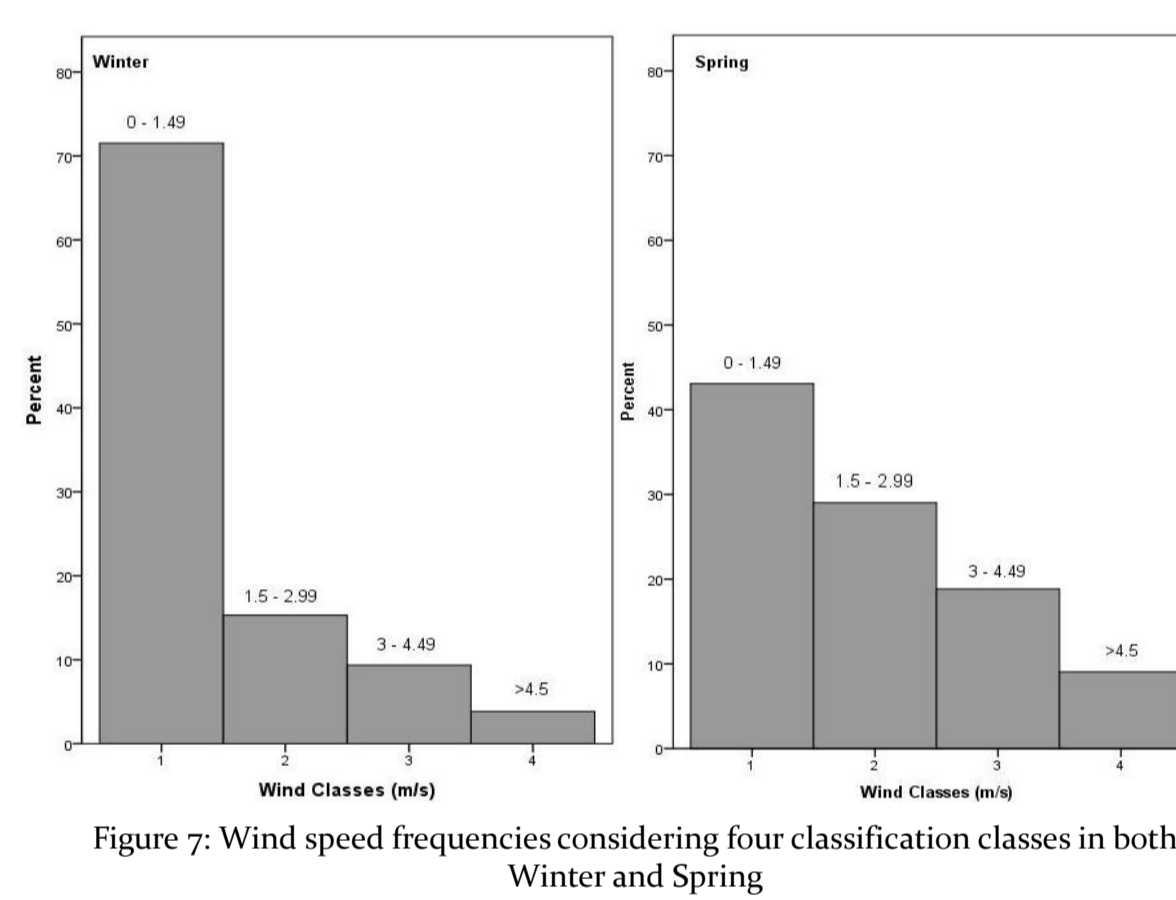


Figure 7: Wind speed frequencies considering four classification classes in both Winter and Spring

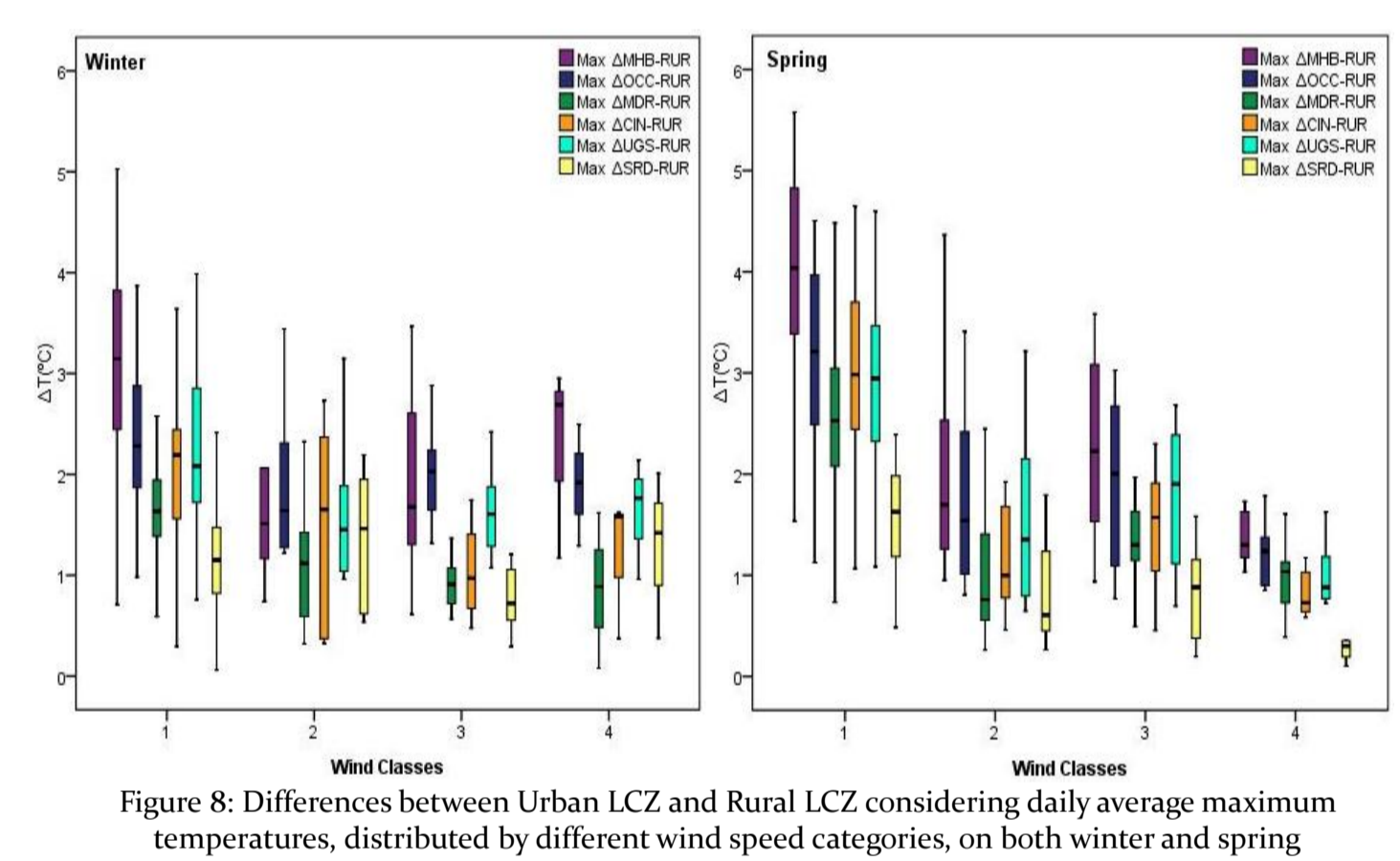


Figure 8: Differences between Urban LCZ and Rural LCZ considering daily average maximum temperatures, distributed by different wind speed categories, on both winter and spring

Several studies suggest that wind speed affects the Urban Heat Island (Morris et al., 2001; Zhang et al., 2011), therefore data sets were established considering four wind categories (Chow and Roth, 2006). Frequency distribution among classes is presented in Figure 7. Wind speeds were mostly below 3 m/s, however spring data shows greater variation. Figure 8 shows that higher UHI intensities are generally associated with lower wind speeds, however results show fluctuations across some classes.

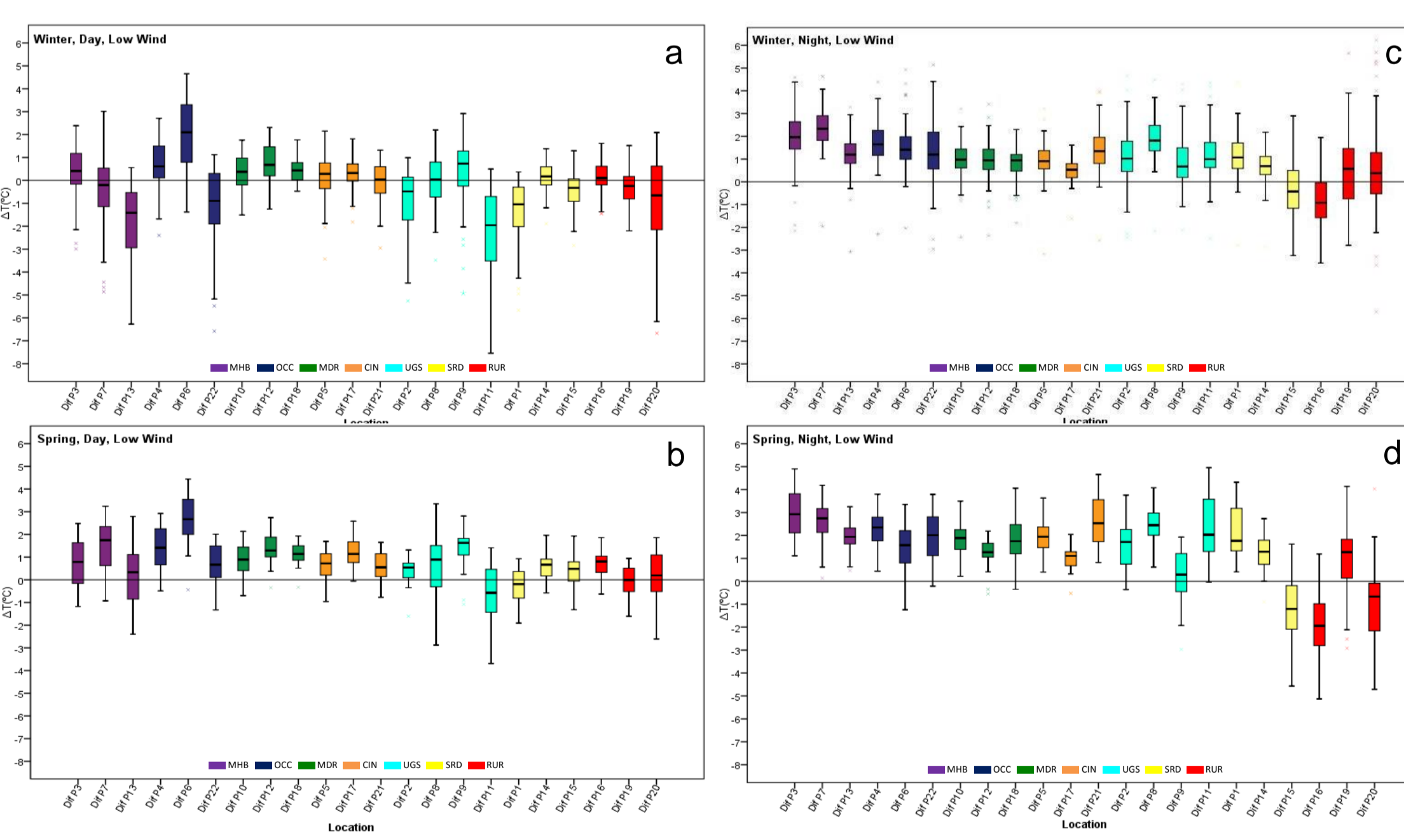


Figure 9: Differences of daily maximum temperature in (a) Winter and (b) Spring. Differences of daily minimum temperatures in (c) Winter and (d) Spring

Results are generally consistent with the previous analysis. However, intra-classes differences can be found and are more relevant for maximum temperatures (day) and under winter conditions. The most homogeneous data sets can be found amongst MDR and CIN, others classes present some variability: RUR - despite being evaluated against a similar point, differences can be found for night conditions, that can be related to the proximity to a river in P16 and P20; SRD - Similar differences for P15 can also be attributed to river proximity; UGS - Differences can be related to variations in both green spaces dimension and percentage of impervious surfaces within the assessment radius; OCC - P6 has considerably higher maximum temperatures which could be associated with on site impervious materials; MHB - P13 station is quite divergent from P3 and P7, however causes for these divergence are yet to be determined and may have had a determinant role in the previously identified cool island effect.

Final considerations

Urban climate evaluation demands for rather complex and data-demanding studies. This research addresses a small though complex urban reality. Under such urban context, and despite the proximity from the rural surroundings, preliminary results show that UHI values can reach over 5 °C under winter conditions, suggesting that the UHI effect can be quite relevant, as it is expected that the highest intensity will be reached throughout the summer.

As differences amongst stations are yet to be fully understood, additional characterization parameters should be added for greater depth in the analysis, and will include data from three additional wind speed and direction sensors that will be installed during the next months. Other relevant analysis adjustments may include the evaluation of topographic influence (ex. River influence).

References

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