

Monitoring and evaluation of thermal comfort in urban areas: application to Valencia city

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Abstract

In this paper, it is presented preliminary results of a methodology for thermal comfort monitoring and evaluation in urban areas based on local metering of ambient conditions and Rayman model application. In the framework of GROWGREEN European project it was installed six monitoring stations for data acquisition of air temperature, relative humidity, wind speed, solar radiation and black globe temperature. Data of first 5 months of monitoring and modelling of one location with Rayman model to calculate PET (physiological equivalent temperature) is presented. Based on PET it was calculated the percentage of hours with thermal comfort per month, and it was made a comparison between PET and black globe temperature (GT) in order to evaluate the suitability of GT as a single, low cost and robust indicator of thermal comfort in urban areas.

Keywords: *thermal comfort; monitoring; Rayman model; black globe temperature*

1. Introduction

Climate change provides that heat stress periods frequency and intensity progressively increase, especially in warm climates as Mediterranean one. Additionally, big cities present the urban heat island effect so that built areas absorb more heat than natural areas (agricultural or forest areas) (Oke, 1982). These facts provide a significant health risk for the population (Rosenzweig *et al* , 2017) and comfort in outdoor areas is being reduced progressively and so, specific criteria and detailed information about urban thermal behaviour should be provided to urban management organizations (Blumberg, 2014 ; European Environment Agency, 2012). Urban planning, maintenance and refurbishment should use this information and focus on mitigating heat stress in warm climates cities.

GROW GREEN project through the delivery of four demonstration projects in a wide range of different geographical, climatic, political, governance, societal and financial scenarios, will establish the evidence that NBS¹ (Nature-based solutions) in cities provide a cost-effective, sustainable and replicable alternative to improve urban climate and water resilience, and deliver social, environmental and economic benefits.

Valencia city, in the framework of GROW GREEN project², will demonstrate, through specific pilot actions, the feasibility, multi-benefits and effectiveness of NBS for urban heat management.

In this work it is presented preliminary result of heat stress monitoring and modelling results for two locations. Specific climatic parameters (Temperature, humidity, solar radiation, wind speed, black globe temperature) metering results (since January 2019), and PET (Physiological Equivalent Temperature) modelling through RAYMAN model will be compared.

2. Methodology

For outdoor comfort evaluation, in two different urban locations in Valencia (Spain) city, it will be used PET (Physiologically Equivalent Temperature). The PET index has been used

¹ According to European Commission (EC) definition , Nature-based solutions are actions inspired by, supported by or copied from nature and which aim to help societies address a variety of environmental, social and economic challenges in sustainable ways.

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Figure 2. Location B: partial shadowing with trees (Andreu Alfaro street, Valencia, Spain)

For heat stress monitoring purposes it has been used a HSM (heat stress monitoring box), see Figure 3, with acquisition of data about black globe (BG) temperature, air temperature, humidity, wind speed and solar radiation. HSM boxes are attached to urban street lights posts and, always, south oriented.



Figure 3. HSM - Heat stress monitoring box.

In location A it has been checked that in Winter (January 2019) this box is metering undisturbed solar radiation from 9:00 in the morning to 18:00 in the afternoon, and so in summer (really may 2019) from 8:00 to 20:00.

Black globe³ temperature consists of a hollow copper sphere (90 mm diameter) painted matt black, to absorb radiant heat, with a temperature sensor at its centre.

2.2. PET and Black globe evaluation and comparison

Both locations will be modelled with RAYMAN model software to evaluate PET in each hour during 6 months (from January to June 2019), and direct metering of black globe temperature is provided by HSM boxes (also hourly). With PET hourly values it will be calculated thermal comfort hours according to the following reference table (Matzarakis et al., 1999):

Table 1. Thermal perception PET ranges.

Max.	Min.	Thermal perception
	>41	Extreme heat stress
41	35	Strong heat stress
35	29	Moderate heat stress
29	23	Slight heat stress
23	18	No thermal stress
18	13	Slight cold stress
13	8	Moderate cold stress
8	4	Strong cold stress
	<4	Extreme cold stress

³ For further information please see ISO 7726. Ergonomics of the thermal environment - Instrument for measuring physical quantities". Geneva, Switzerland: International Organization for Standardization. November 1998.

It will be compared, hour by hour, PET values with black globe (BG) temperature in order to evaluate the possibility of using BG as a single, simple and low cost indicator to monitor heat stress.

3. Results and discussion

In Table 2 it is included thermal perception hours evaluation in locations A and B (according to PET results):

Table 2 . Thermal perception hours

Thermal perception	LOCATION A		LOCATION B	
	Time(h)	%	Time(h)	%
Extreme heat stress	32	0,74	51	1,2
Strong heat stress	187	4,34	144	3,3
Moderate heat stress	426	9,86	192	4,4
Slight heat stress	580	13,42	277	6,4
No thermal stress	529	12,23	438	10,1
Slight cold stress	744	17,23	838	19,4
Moderate cold stress	636	14,73	992	23,0
Strong cold stress	574	13,30	800	18,5
Extreme cold stress	612	14,16	589	13,6

Considering HEAT STRESS as the addition of (Extreme heat stress) + (Strong heat stress) + (Moderate heat stress), it was concluded that there was HEAT STRESS 15% of the time in location A (where no shadowing is available) and only 9% of the time in location B. However it is interesting to notice that extreme heat stress hours are very low in both locations but slightly higher in location B. Looking at specific simulation results it was concluded that this is due to the fact that, as shadowing is only partial, when solar radiation was not blocked and temperature was high (aprox. in the mornings from 11:00 to 15:00, during may and june.)

PET was, sometimes, higher because wind speed (that usually improves thermal comfort in hot periods) was partially reduced by the trees.

In Figure 4 it has been included the comparison of PET and black globe temperature (January – June 2019, hourly values):

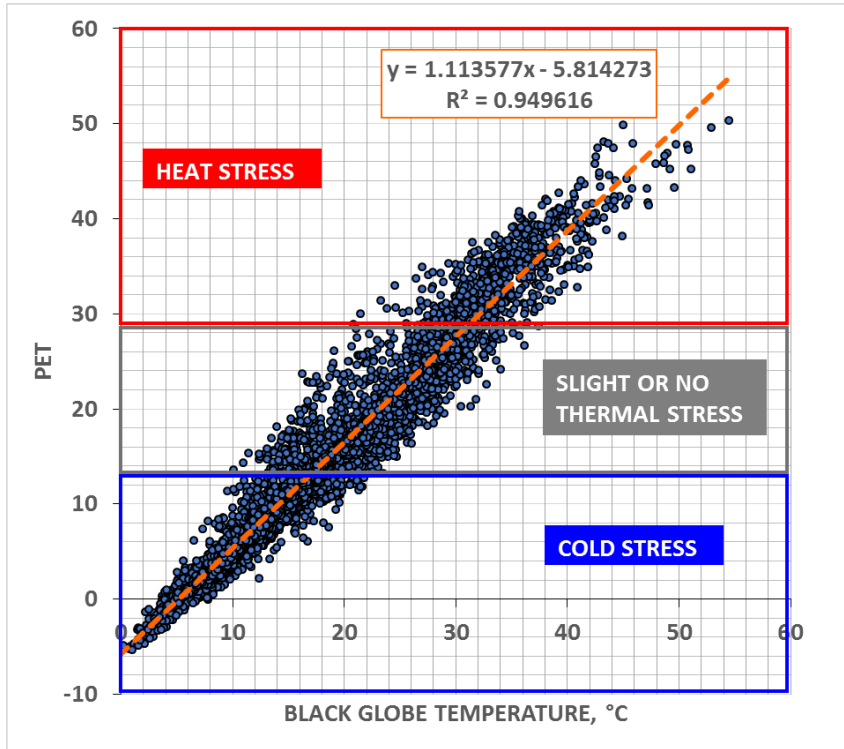


Figure 4. PET and Black globe temperature comparison

It can be concluded that there is an strong relationship and using linear approximation (other equations where tested but fitting was no improved significantly), it was observed an average error of 1.7 degree (with standard deviations of about 1.5 degrees, so most values with an error lower than 3.2 degrees) when calculating PET only with black globe temperature.

4. Conclusions

Monitoring of heat stress was performed in Valencia from January to June 2019 in two different urban locations. RAYMAN simulations provided PET values and it was concluded that 9-15% of the time there was heat stress. For accurate PET modelling it was necessary many outdoor conditions parameters (temperature, wind,

humidity, solar radiation) however, based on preliminary results, acceptable approximations (average error or 1.7 PET degrees for absolute values in the range 20 – 50 PET degrees) can be done using just one metering variable, which is black globe temperature. However, more different locations and longer monitoring periods will be necessary to confirm these results.

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