Evaluation of mitigation strategies to improve pedestrian comfort in a typical Mediterranean city

Riccardo Buccolieri[1], Giuseppe Maggiotto[1], Francesca Di Nicola[1], Silvana Di Sabatino[2]

[1]Dipartimento di Scienze e Tecnologie Biologiche ed Ambientali, University of Salento, S.P. 6 Lecce-Monteroni, 73100, Lecce, Italy
[2]Department of Physics and Astronomy, ALMA MATER STUDIORUM - University of Bologna, Viale Berti Pichat 6/2, 40127, Bologna, Italy

UNIVERSITÀ DEL SALENTO
ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA

ICUC9
20th-24th July 2015 Toulouse France
9th International Conference on Urban Climate jointly with 12th Symposium on the Urban Environment
CIC meetings

Introduction

Thermal comfort in urban spaces is known to be an important contributor to people's health. One of the most widespread interventions to improve thermal comfort is incorporating green infrastructure (trees) into the urban built-space.
In this work, the **CFD-based ENVI-met** (v3.1) is employed and is evaluated against field measurements held during summer 2012 in Lecce, a medium size city in south Italy.
Some thermal comfort indices (**Mean Radiant Temperature MRT and the Predicted Mean Vote PMV**) are evaluated.

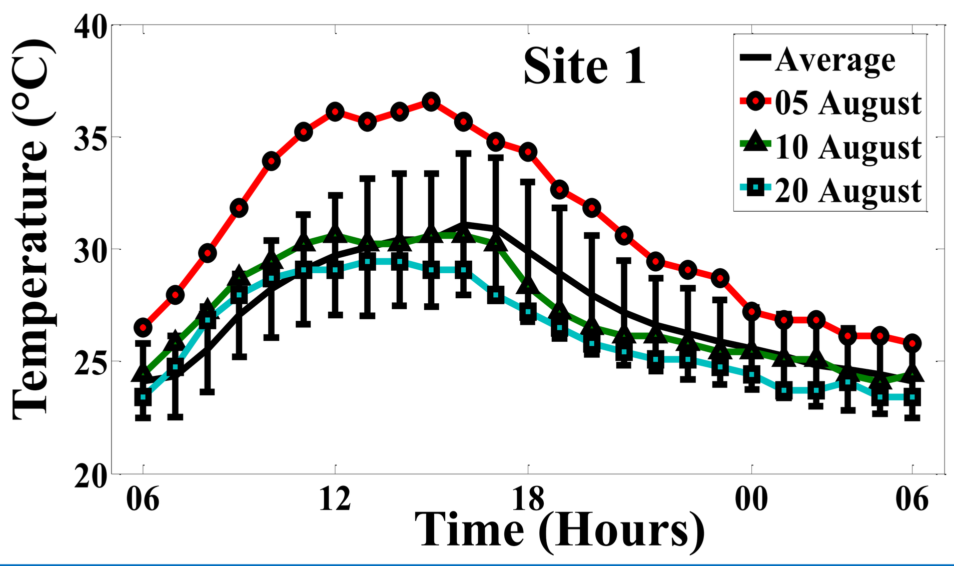
MRT is defined as the uniform temperature of an imaginary enclosure in which the radiant heat transfer from the human body is equal to the radiant heat transfer in the actual non-uniform enclosure. It has a strong influence on thermophysiological comfort indexes such as Predicted Mean Vote (PMV).
The **PMV** relates the energy balance of the human body with the humans thermal impression. PMV scale is defined between -4 (very cold) and +4 (very hot) where 0 is the thermal neutral (the most comfortable condition) value (Fanger, 1982)[1].

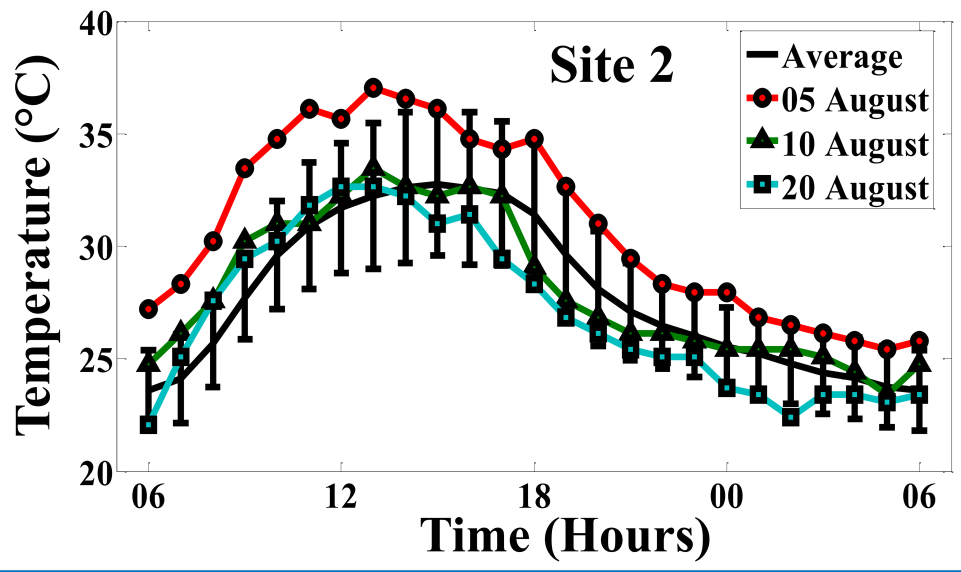
[1]Fanger P.O., 1982: Thermal Comfort. Analysis and Application in Environment Engineering. McGraw Hill Book Company, New York.

Methodology

Meteorological measurements

- **Air temperature** was measured in the study sites (51-day: from July 21 to September 9 2012), using standard thermistor probes PB-5001 assembled with Tinytag TGP-0073 by Gemini data loggers.
- **Thermal sensors** were mounted at 4-6m height above ground level to be representative of the urban canyon conditions
- From the profiles it can be noted that **5 August** was the hottest day, while **20 August** experienced the lowest temperatures (and high humidity); **10 August** was representative of the temperature averaged over the whole meteorological campaign.





Numerical modelling

	5 August	10 August	20 August
Wind speed (m/s) at 10m	1.0	1.5	1.0
Wind direction (°) at 10m	118	300	238
Initial air temperature (°C)	27	24	23
Relative humidity at 2 m (%)	57	67	83
Soil data: initial temperature (°C) and relative humidity (%) of upper layer 0-0.2m	35 40	29 40	29 40
Soil data: initial temperature (°C) and relative humidity (%) of middle layer 0.2-0.5m	35 50	29 50	29 50
Soil data: initial temperature (°C) and relative humidity (%) of deep layer below 0.5m	33 50	27 50	27 50
Walking speed (m/s)	0.8		
Energy-exchange	0.93		
Clothes thermal resistance (clo)	0.5		

Initial and boundary conditions.

Thermal comfort indices (**MRT and PMV**) were calculated based on three parameters:

- walking speed,
- energy exchange
- clothes thermal resistance

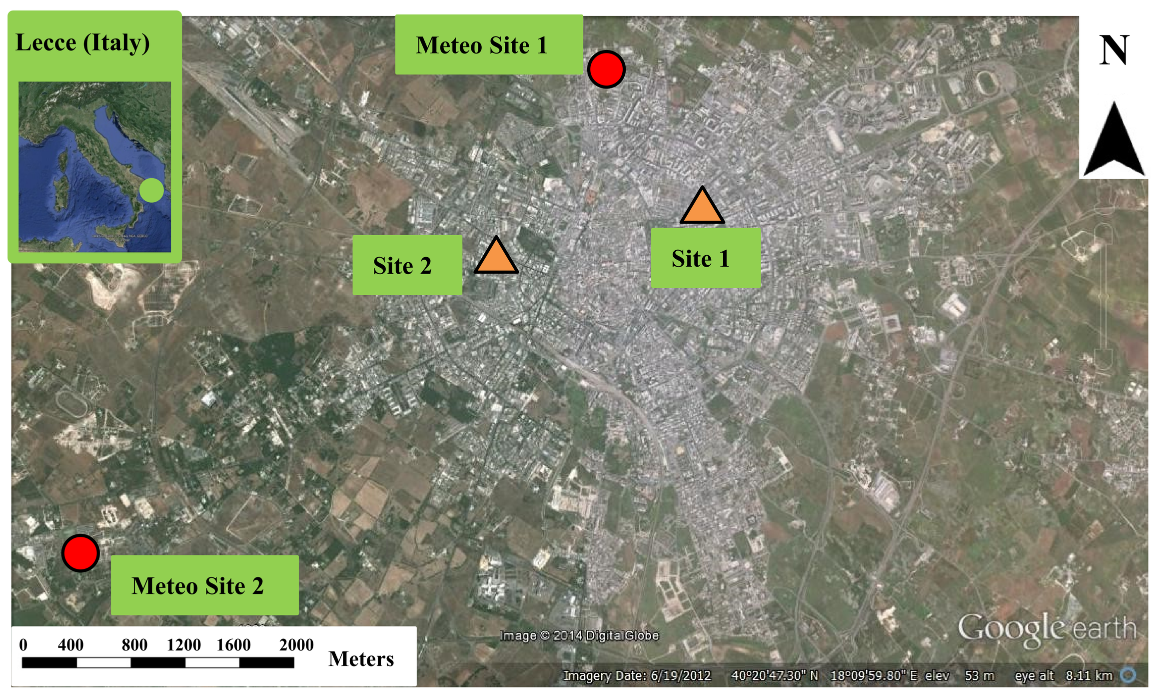
The mitigation strategy consisted of planting trees within street canyons:

- 417 trees have been added in Site 1 with an increase of 32%
- 497 in Site 2, with an increase of 49%

ENVI-met areas input: domain size of 494m x 494m for each site, which was meshed by 247 x 247 square cells of 2m x 2m. Within the domain, the nested study site occupied an area of 350m x 350m meshed by 175 x 175 square cells. Red circles identify areas were trees have been added for mitigation purposes. The study site was nested in a chessboard patterned computational domain which allowed the selection of two types of soil surfaces (loamy soil and asphalt).

Study area

- According to their different morphological characteristics and location, **two sites** were selected in **Lecce**, where temperature measurements were taken.
- Two meteorological stations (**Meteo Site 1 and 2**) were selected in order to collect the upwind data necessary for the CFD modelling simulations.



Location of study area and two selected sites

Photographs of the street canyons and DEMs with position of the temperature sensors (red point) at (a) Site 1, (b) Site 2.

Results

ENVI-met profiles of MRT

❑ **Site 1**:

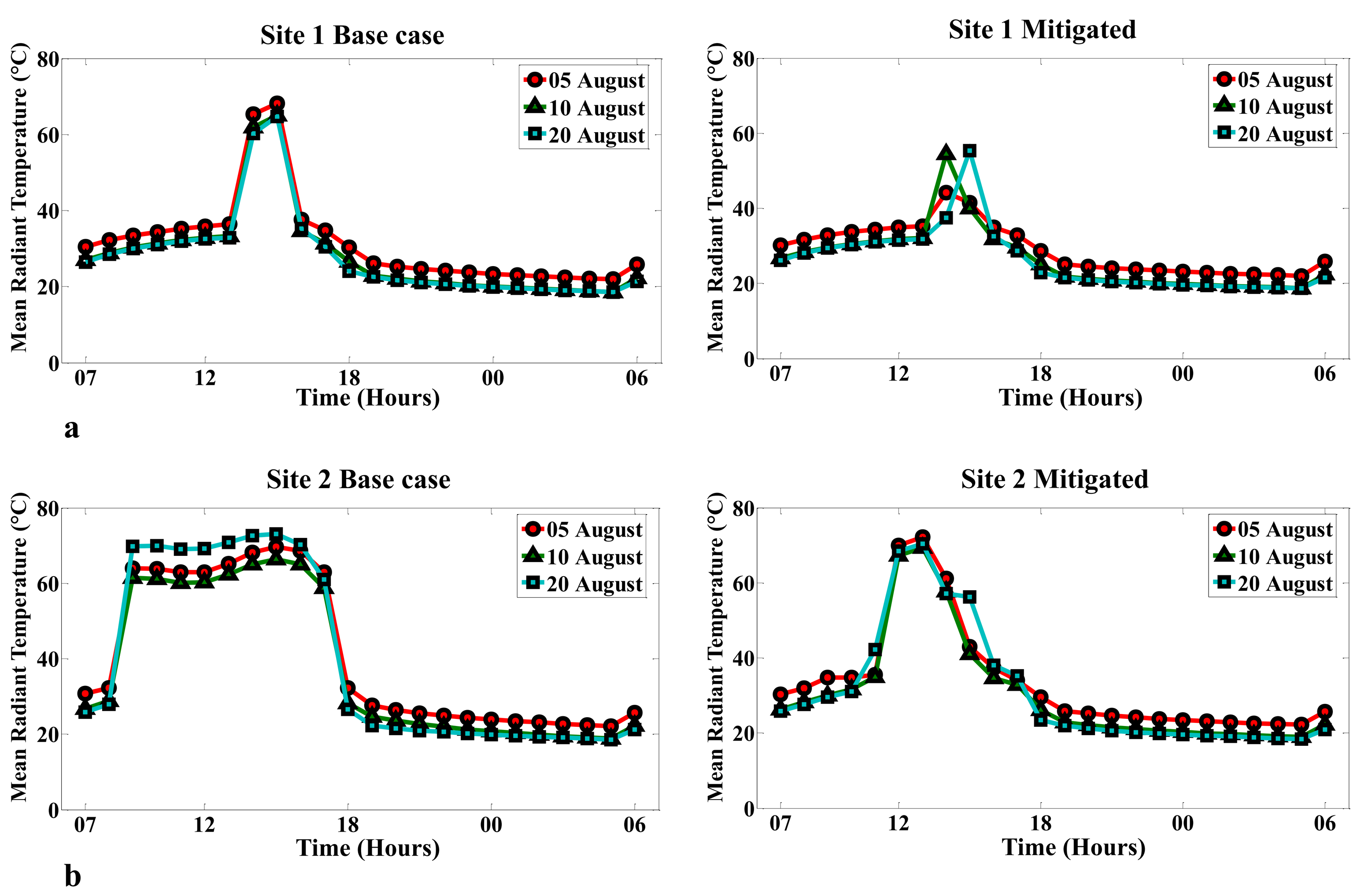
- In the base case a peak of MRT occurred during the hottest hour up to 70°C.
- In the mitigated case, MRT values decreased during the hottest hours.

✓ **The mitigation strategy was thus more effective in decreasing the MRT during the warmer and drier day.**

❑ **Site 2**:

- In the base case MRT peaks occurred from 9:00 to 17:00, this was due to long exposure to direct solar radiation.
- In the mitigated case, MRT values decreased during the hottest hours.

✓ **Overall, due to the street orientation, the most significant contribution of the mitigation strategy was that of decreasing the number of hours showing MRT peaks, which were however similar to those found in the base case.**

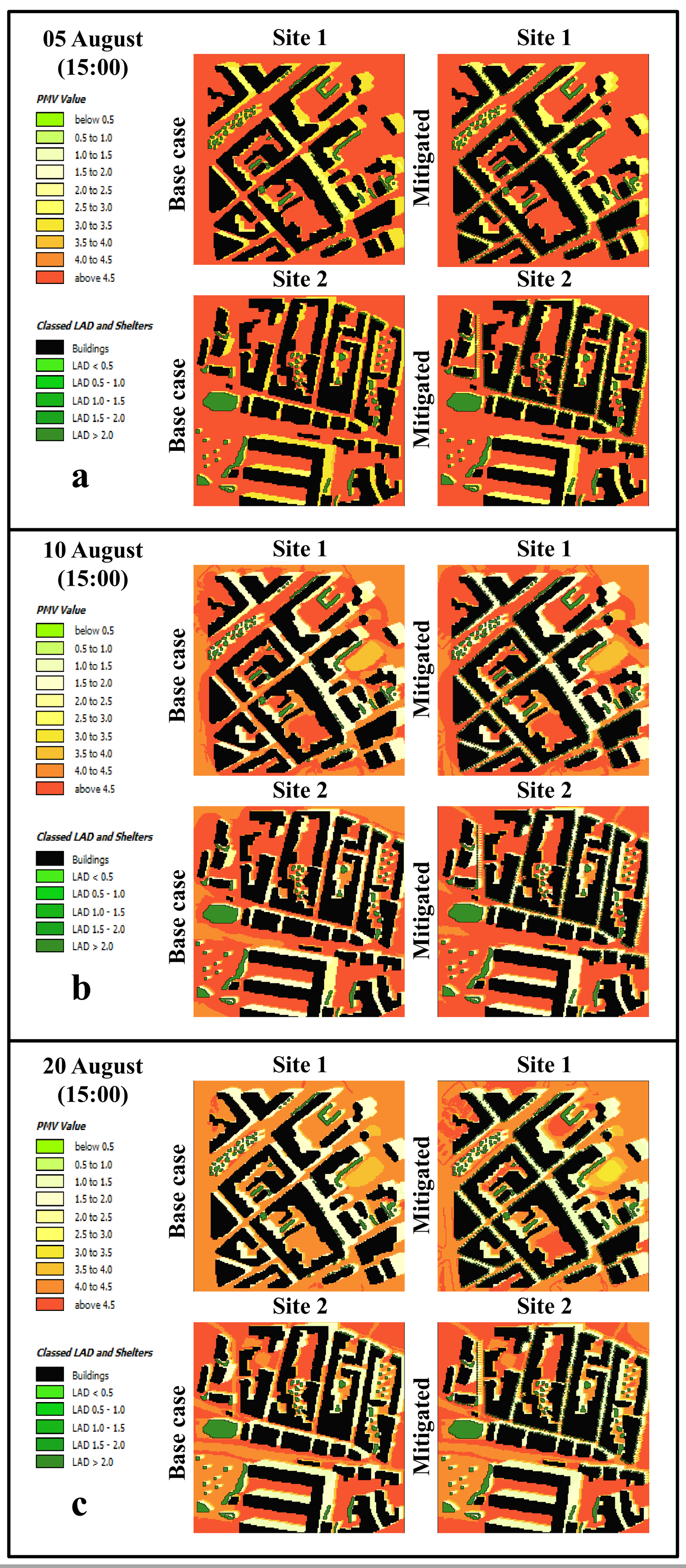


ENVI-met maps (at 2m) of PMV

As expected from the MRT analysis, the influence of trees was to lower PMV, even though the effect was confined to the streets subjected to the mitigation strategy.

- **Site 1:** PMV values decreased of maximum 3.42 on 5 August (-42%), 2.99 on 10 August (-67%) and 2.94 on 20 August (-70%).
- **Site 2**: PMV values decreased of maximum 1.61 on 5 August (-27%), 1.4 on 10 August (-30%) and 1.57 on 20 August (-34%).

✓ **The mitigation strategy was thus more effective in decreasing the PMV during the humid day.**



Conclusions

Once validated, ENVI-met results were used to estimate the **Mean Radiant Temperatur**e (MRT) and the **Predicted Mean Vote** (PMV) to assess the influence of trees on thermal comfort at the investigated sites.
The **efficiency of trees** in improving thermal comfort is mostly confined to the streets with trees and strictly depends on the street orientation which affects direct solar radiation and/or the presence of building shadows. **Planting trees for mitigation purposes should thus be carefully evaluated though a comprehensive analysis which involves the influence of the street geometry and position as well as meteorological factors.**