ENVI-MET
principi fisici della modellazione del comfort outdoor

Kristian Fabbri - 29 Settembre 2017
Headquarter
Accesso veloce alla homepage del software e cabina di pilotaggio della modellazione

Leonardo 2014
Analizza i tuoi risultati e crea una mappa 2D e 3D

Spaces
Disegna il tuo progetto e l’ambiente

BioMet
Sistema di processo per i file di output per calcolare PMV/PPD, PET o UTCI
Comfort: Modellazione e progetto architettonico-urbanistico
Struttura del software

<table>
<thead>
<tr>
<th>INPUT</th>
<th>SIMULAZIONE</th>
<th>OUTPUT</th>
<th>LETTURA OUTPUT</th>
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<tbody>
<tr>
<td>AREA</td>
<td>ENVI-MET</td>
<td>FILE DATI IN USCITA</td>
<td>LETTURA GRAFICA</td>
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<td>DATABASE</td>
<td>ENVI-MET</td>
<td>FILE DATI IN USCITA</td>
<td></td>
</tr>
</tbody>
</table>
Boundary conditions: A no-slip condition is used for all solid surfaces. The inflow profile is obtained from the one-dimensional reference model and a zero-gradient Neumann condition is used at the outflow and lateral boundaries. At the top boundary all vertical motions are assumed to be zero. Special boundary conditions are used for the pressure perturbation on all outflow boundaries to keep the model mass conserving.

Temperature and Humidity
The distribution of the air temperature $\theta$ and specific humidity $q$ is given by the combined advection diffusion equation with internal source/sinks

Atmospheric turbulence
Turbulence is produced when the air flow is sheared at building walls or vegetation elements. Under windy conditions, the magnitude of local turbulence production normally surpasses its dissipation, so that turbulent eddies are transported by the mean air flow. Depending on the structure of the flow, this leads to an increased turbulence away from the original source of disturbance. To simulate this effect, a so-called 1.5 order turbulence closure model is used in ENVI-met. Based on the work of Mellor and Yamada (1975) two additional prognostic variables, the local turbulence $(E)$ and its dissipation rate $(\Sigma)$ are added to the model.
La modellazione della vegetazione

La vegetazione viene trattata come una colonna mono dimensionale con altezza Zp nella La vegetazione è trattata come una colonna monodimensionale di altezza zp in cui il profilo della densità d’area delle foglie (LAD) è usato per descrivere la densità e la distribuzione delle foglie. Lo stesso concetto è usato, all’interno del suolo, fino ad una profondità –zr, per descrivere la distribuzione delle radici, attraverso il RAD (Root Area Density). Questo schema universale può essere applicato sia alle piante ad alto fusto, sia ai cespugli, sia all’erba, semplicemente associando ad ogni tipo di pianta i propri valori di zp e zr.

Dominio computazionale e la struttura della griglia
A seconda del problema, la dimensione totale del modello tridimensionale X, Y e Z, nonché la risoluzione della griglia può essere selezionata entro un ampio intervallo. Per impostazione predefinita, la spaziatura $\theta x$, $\theta y$ e $\theta z$ è equidistante in ogni direzione (solo la cella più bassa al di sopra del suolo è normalmente suddivisa in 5 sotto-cellule con il formato $\Delta zg = 0.2\Delta z$ per aumentare la precisione nel processo di calcolo della superficie). Il modello tridimensionale è annidato in un modello unidimensionale che si estende fino a 2500 m altezza. I valori di un modello tridimensionale sono utilizzati come valori di riferimento come anche i profili di afflusso e le condizioni al contorno per il modello tridimensionale.
Rotazione del modello
Nei modelli 3D completi la griglia verticale è fissata una volta creato il modello. L’unico modo per cambiarla è di convertire il modello verso il basso per un modello 2.5D (e perdere tutte le informazioni del 3D), modificare le impostazioni di rete e poi ri-convertirlo in 3D. In breve, quando si crea un modello 3D si dovrebbe pensare alla messa a punto della griglia verticale in dettaglio PRIMA di iniziare a modificare il modello.
La modellazione della turbolenza

Si basa su due variabili: la turbolenza locale ($E$) e il suo tasso di dissipazione ($\varepsilon$).
L’energia cinetica in questo caso rappresenta una misura dell’intensità delle turbolenze dell’aria; essa risulta direttamente legata al trasporto locale di calore e umidità.

Il sistema implementato è di due equazioni di cui la prima descrive la distribuzione di energia cinetica nell’aria in funzione della produzione dei moti convettivi e la seconda esprime la dissipazione dell’energia stessa.
The Role of Nesting Grids

The only difference between example A and B is that in (A) we have used only 3 nesting grid cells around the core domain whereas in (B) 5 of them are used. As the grid size of the nesting grids is increasing with each grid, the area is extending very fast with each extra Nesting Grid. The Remember: The Gesting Grids are not included in the Output Files by default, so you will not be able to see troubles there. To see the complete model area, you must include the nesting grids in the Output Files.
**Basic Layout of ENVI-met**

The sketch above aims to give you an impression over the very basic structure of a microclimate model like ENVI-met. The general design is not only specific to ENVI-met but is used by almost all 3D numerical models.

The Main Model is designed in 3D with 2 horizontal dimensions (x and y) and one vertical dimension (z). Inside this main model, the typical elements that represent the area of interest are placed: buildings, vegetation, different types of surfaces. To use a numerical model, the area of interest must be reduced into grid cells. The smaller one single grid cell is, the finer the resolution of the model is. On the other hand, making the grid cells small means that more cells are needed to cover a certain area.

For example, a 100 x 100 m area can be organised in 100 x 100 grid cells of 1 x 1 m each or it can be organised in 20 x 20 grid cells with 5 x 5 m each. For each simulation, a compromise has to be found between the accuracy and resolution of the model and the number of treatable grid cells. As a rule of thumb, reaching 250 x 250 x 30 grid cells (or any other combination such as 120 x 80 x 30,..) **can be considered as a large model needing a good amount of CPU time.**
Total Model Height
What is the Minimum Model Height?
Selecting the correct size of the model domain is a central aspect in successful numerical modelling.
Whereas the horizontal dimension is more or less given by the dimension of your subject of interest, the vertical height of the model is less obvious and can - if not selected properly - cause major problems.

The height of the 3D model is a result of the number of vertical grid points used as defined in the Area Input File and grid size plus the method of grid creation (see also Model Layout).

A simple Example: If you have a 30 m building in your model and you choose to have 10 grids with a grid size of 2 m each, the total model height will be 20 m, or, in other words, your building will look 10 m out of the model domain. This is, of course, not acceptable.
From Version 4 on, it is recommended to use at least the “Simple Forcing” option for temperature and humidity. This overcomes almost all problems that have been observed with the lateral boundaries in the former versions.
The problem...

In complex Model Areas (and sometimes even in configurations you consider as being “simple”) you might experience numerical instabilities from time to time. **These instabilities appear as “PANIC Dumps”** (if ENVI-met has detected that something went wrong) or simply as error messages or crashes of the model. The most frequent error message are “Division by Zero” or “Floating Point Error”.

These messages do not contain any useful information except of the general message, that something went wrong. In fact, **“Division by Zero” is most of the times only the end point of a long chain of problems producing very high or very low (and very wrong) numbers.**

Why is it like that...

**First of all, remember that you are working with a very complex numerical model.**

There is a conceptual difference between error messages you might get from, say, a text-processing program, and those you get from ENVI-met. Error messages (and the numerical problems which cause these messages) are inseperably connected with the whole process of numerical modelling.

If it would be possible to construct any Model Area and get guaranteed results, numerical modelling would no longer be an advanced technology ;). In other words: **When you decide to use non-liner models like ENVI-met, you must be prepared that things are not always running as you would like them to run.** Sometimes models run on the edge of numerical stability and a complex configuration might cause that they fall over this edge and send you an error message.
Running ENVI-met
The user friendly interface of ENVI-met sometimes makes people forget that they work with a sophisticated climate simulation system. Normally, these kind of numerical models can only be run on complex and extremely expensive supercomputers.

In more than 20 years of ENVI-met development, we have invented various technologies to bring the scientific power of physical climate simulation models to your desktop. ENVI-met uses a complex system of optimized algorithms and intelligent troubleshooting allowing you to run dynamical 3D microclimate simulations on an arbitrary standard PC bought anywhere on the world running MS WINDOWS.

**However, installing the software on your PC is the smallest step in using ENVI-met for microclimate analysis...**
Besides the two basic files needed for each simulation, the Area Input File .INX and the Simulation file .SIMX, ENVI-met needs to know a lot of additional information about different items used in your model such as surfaces types, soils, plants or emission sources in the model. These data are not stored in the Area Input file themself (exception: Packages), but in a database system.

Each database entry is defined by a unique key, which has to be a two-sign alphanumerical ID in ENVI-met (e.g. "a0"). Any reference to a database entry, may it be in an Area Input file or some other table of the database is given by using this ID.
The energy balance of the outer façade surface can be written as

\[ Q_{sw,net}^{abs} + Q_{lw,net}^{abs} = \varepsilon \sigma T_{1,2}^4 + h_{c,o} (T_{air} - T_1^*) + \frac{\lambda}{\Delta x} (T_2^* - T_1^*) = \frac{c_{wall} \rho \Delta x}{2 \Delta t} (T_1^* - T_1) \]

with \( Q_{sw,net}^{abs} \) and \( Q_{lw,net}^{abs} \) being the absorbed incoming short wave and long wave radiation [W], \( \varepsilon \) the emissivity [%], \( \sigma \) the Stefan-Boltzman constant, \( h_{c,o} \) is the convection coefficient for the outside wall [W/(m²K)], \( \lambda \) the heat transfer coefficient [W/(mK)], \( \Delta x \) the distance between two nodes [m], \( c_{wall} \) heat capacity of the wall [J/(kgK)], \( T_1^* \) the temperature at node 1 at present \( T_{n-1} \) or future \( T_{n}^* \) time step.
Il modello numerico 3D

With the Fourier Equation

\[
\frac{\delta T}{\delta t} = \frac{\lambda}{c_{\text{wall}} \rho} \frac{\delta^2 T}{\delta x^2}
\]

the energy fluxes at the node in the center of the wall can be summed up as

\[
(P + 2)T_2^* - T_3^* = PT_2 + T_1^*
\]

with \( P = \frac{\Delta x^2 c_{\text{wall}} \rho}{\lambda \Delta t} \).

For the node at the inside of the wall the energy balance sums up to

\[
-T_2^* + \left( \frac{P}{2} + \frac{h_{c,d} \Delta x}{\lambda} + 1 \right)T_3^* = \frac{P}{2} T_3 + \frac{h_{c,d} \Delta x}{\lambda} T_1
\]

with \( h_{c,d} \) as the heat convection coefficient at the inside \( (7.7 \text{W/(m}^2\text{K)} \)).
**3D Plant Geometry**
ENVImet supports simple vertical plants such as grass or corn, but also allows complex 3D vegetation geometries like large trees. All plants are treated as individual species with an integrated water balance control and heat and water stress reaction concept.

**Vegetation water supply**
Plants are living organisms and will only contribute in a positive way to the local microclimate, if enough water is available in the soil within the root zone. Together with the simulation of the soil water content and the new sophisticated 3D root model, the dynamic water supply of the plant and the resulting water extraction from the soil can be calculated.

**Foliage temperature**
The temperature of the leaves is calculated by solving the energy balance of the leaf surface with respect to the actual meteorological and plant physiological conditions for each grid box of the plant canopy. The health status of the plant and the water supply by the soil regulate, beside other factors, the plants transpiration rate and thereby the leaf temperature. ENVImet uses a sophisticated model to simulate the stomata behaviour of the vegetation in response to microclimate, CO2 availability and water stress level.
Surface and soil temperature

The surface temperature and the distribution of soil temperature is calculated for natural soils and for artificial seal materials down to a depth of -4m. For each vertical grid layer a different soil or sealing material can be chosen in order to simulate different soils structures. The heat conductivity of natural soils is calculated with respect to the actual soil water content.

Detailed building materials

In Detailed Design Mode, ENVI-met allows to assign individual wall types to each wall and roof surface. The wall types can be composed out of 3 layers of different materials with individual physical properties such as solar radiation transmission, heat capacity or heat conductivity. The different wall and roof materials can be designed graphically using the Database Manager.

Each wall and roof segment in ENVI-met is represented by its own thermodynamical model consisting of 7 prognostic calculation nodes. The temperature of the outside node is updated continuously with respect to the meteorological variables at the facade and the thermal state of the buildings and other objects within the view range of the facade/roof element considered. The thermal state of the inner wall nodes is calculated from the physical properties assigned to the wall/roof based on Fourier’s law of heat conduction.

Full 3D building geometry & Single walls

Complex buildings and other structures can be constructed in full 3D with no limitations in complexity as far as the cubic base structure allows. This allows the simulation of semi-open spaces such as the soccer stadium shown in the icon and in this example. Moreover, ENVI-met Professional allows the usage of single thin walls that can be applied to any grid which can be used to represent spaces which are enclosed by walls but do not behave like a building e.g. bus stop shelters, shading structures...
Cosa si può modellare con ENVI-MET – Situazioni specifiche

**Turbulence**
Turbulence is calculated using the E-epsilon 1.5 order closure ("E-epsilon" or "k-epsilon" model). Two prognostic equations for turbulent energy production ($E$) and its dissipation ($\epsilon$) are used to simulate the distribution of turbulent energy. Exchange coefficients ($K_x$) in the air are calculated using the Prandtl-Kolmogorov relation. For low wind situations, the 1st order mixing length model can be used instead of the E-epsilon model (which often fails in this situations).

**Soil water content**
Simulating the water balance of the surface and the soil is a crucial aspect in urban microclimatology. While humid soils can act as cooling devices, dry soils are often hotter than asphalt. In addition, the cooling effect, and - on a longer time perspective - the vitality of vegetation depends on available soil water. ENVI-met dynamically solves the soil hydraulic state of the soil based on Darcy's law.

**Water bodies and ponds**
Water bodies are represented as a special type of soil. The calculated processes inside the water include the transmission and absorption of shortwave radiation inside the water. No second energy balance is used for the ground surface of the water pool, so that heating of shallow systems is lower than under real conditions where the main source of energy is the convection from the water ground surface rather than the absorption of radiation. In addition, no turbulent mixing is included in the model so that the use is restricted to still waters (e.g. lakes).
Modellazione del Comfort Outdoor
Interpretare i risultati: rassegna scientific literature
Kristian Fabbri - 29 Settembre 2017

Valutazione e proprietà dei materiali e morfologia urbana
Valutazione e proprietà dei materiali e morfologia urbana

Microclimate development in open urban spaces: The influence of form and materials

Angeliki Chatzidimitriou, Simos Yannas

Table 1
Sky view factors at the locations of monitoring points in each site at 1 m above ground level and indicative values of solar radiation (direct and diffuse) and long-wave radiation at summer noon (calculated by ENVI-met v3 on specific days at 14:00).

<table>
<thead>
<tr>
<th>Site</th>
<th>Date</th>
<th>Monitoring point</th>
<th>SVF</th>
<th>Solar radiation (W/m²)</th>
<th>Longwave radiation (W/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site A – large square</td>
<td>29 July</td>
<td>Marble black and white</td>
<td>0.90</td>
<td>998</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Marble white and black</td>
<td>0.86</td>
<td>998</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cobble stone grey granite</td>
<td>0.89</td>
<td>998</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Porous stone beige</td>
<td>0.86</td>
<td>998</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Marble white</td>
<td>0.79</td>
<td>897</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Grass</td>
<td>0.79</td>
<td>918</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Grass (below tree shade)</td>
<td>0.20</td>
<td>109</td>
<td>4</td>
</tr>
<tr>
<td>Site B – coastal park</td>
<td>26 August</td>
<td>Concrete tiles</td>
<td>0.73</td>
<td>830</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Grass</td>
<td>0.71</td>
<td>826</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Concrete tiles (below tree)</td>
<td>0.32</td>
<td>561</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Grass (below tree)</td>
<td>0.31</td>
<td>576</td>
<td>13</td>
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<tr>
<td></td>
<td></td>
<td>Concrete tiles (below tent)</td>
<td>0.16</td>
<td>320</td>
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<tr>
<td></td>
<td></td>
<td>Concrete tiles (below canopy)</td>
<td>0.11</td>
<td>288</td>
<td>75</td>
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<tr>
<td>Site C – park with fountain</td>
<td>25 August</td>
<td>Asphalt</td>
<td>0.77</td>
<td>748</td>
<td>39</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Marble grey</td>
<td>0.87</td>
<td>779</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Grass</td>
<td>0.87</td>
<td>780</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Water</td>
<td>0.87</td>
<td>779</td>
<td>9</td>
</tr>
<tr>
<td>Site D – open square</td>
<td>29 June</td>
<td>Concrete and gravel white – grey</td>
<td>0.93</td>
<td>856</td>
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<tr>
<td>Site E – confined square</td>
<td>29 June</td>
<td>Ceramic tiles red</td>
<td>0.65</td>
<td>790</td>
<td>53</td>
</tr>
<tr>
<td>Site F – university campus</td>
<td>03 August</td>
<td>Asphalt</td>
<td>0.70</td>
<td>989</td>
<td>87</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Marble white and grey</td>
<td>0.65</td>
<td>986</td>
<td>106</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Concrete tiles</td>
<td>0.31</td>
<td>934</td>
<td>261</td>
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<tr>
<td></td>
<td></td>
<td>Brick red</td>
<td>0.30</td>
<td>933</td>
<td>265</td>
</tr>
</tbody>
</table>
Fig. 2. Ground surface materials at the examined urban sites: (a) marble white (and black), (b) marble black (and white), (c) porous stone, (d) cobble stone by grey granite, (e) marble white (plain), (f) marble dark grey, (g) water surface (fountain), (h) concrete with gravel, (i) red ceramic tiles, (j) red bricks, (k) concrete tiles, (l) marble white (and grey), (m) asphalt and (n) grass. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of the article.)
Fig. 25. Views of the monitoring points at the university campus (site F): (a) marble white and grey, (b) asphalt, (c) concrete tiles in NW courtyard, (d) red bricks in central courtyard.

Fig. 26. Ground surface temperatures at the university campus (site F) on 03-08-2007.
Valutazione e proprietà dei materiali e morfologia urbana

Fig. 12. Monitoring spots at the coastal park at site B: (a) concrete tiles exposed, (b) grass exposed, (c) grass below tree shade, (d) concrete tiles below tree shade, (e) fabric tent shading concrete tiles and (f) timber gallery shading concrete tiles.

Fig. 13. Ground surface temperatures at the coastal park (site B) on 27-07-2007.
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Fig. 6. Ground surface materials at site A: (a) marble black and white, (b) marble white and black, (c) granite cobble stones grey, (d) marble all-white, (e) porous stone beige and (f) Grass.

Fig. 7. Ground surface temperatures at the large square (site A) on 19-06-2005.

Fig. 8. Ground surface temperatures at the large square (site A) on 29-07-2007.
Morfologia urbana

Research Paper

Application of Universal Thermal Climate Index (UTCI) for microclimatic analysis in urban thermal environme

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2School of Geosciences, Victoria University, Victoria, BC, Canada

Fig. 1. Study locations: (a) Nanaimo location from Google map (http://maps.google.com), (b) street photographs of the Nanaimo sites (left, Nanaimo.1: right, Nanaimo.2 and 3), (c) fisheye lens photographs of the Nanaimo sites (left, Nanaimo.1, sky view factor (SVF) = 0.427; center, Nanaimo.2, SVF = 0.408; right, Nanaimo.3, SVF = 0.349) (Park, 2011, 2012), (d) Changwon location from Google map. Dots are site locations, (e) street photograph of the Changwon site, and (f) fisheye lens photograph of the Changwon site (SVF = 0.785) (Park, 2011, 2012). Fisheye lens photographs were taken using a Nikon Coolpix 8800 camera with Nikon FC-E9 fisheye converter lens and Nikon UB-E18 converter adapter. The collected \( \psi_{sky} \) values were determined using the BMSky-view computer program (Gáhi, Rzepa, Gromek, & Unger, 2007).
Fig. 5. ENVI-met wind speeds at (a) 11:30, (b) 14:00 and (c) 16:30 of Changwon and (d) 9:30, (e) 13:00 and (f) 16:30 of Nanaimo.

Table 4
Wind speed data at the Nanaimo sites.

<table>
<thead>
<tr>
<th>July 26, 2009</th>
<th>Sites</th>
<th>Time</th>
<th>Measured wind speed (m s⁻¹)</th>
<th>ENVI-met wind speed (m s⁻¹)</th>
<th>Difference (m s⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morning</td>
<td>2</td>
<td>9:37</td>
<td>0.40</td>
<td>0.01</td>
<td>−0.39</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>9:45</td>
<td>0.70</td>
<td>0.04</td>
<td>−0.66</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>10:12</td>
<td>0.60</td>
<td>0.04</td>
<td>−0.56</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>10:20</td>
<td>0.70</td>
<td>0.01</td>
<td>−0.69</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>10:44</td>
<td>1.00</td>
<td>0.48</td>
<td>−0.52</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>12:08</td>
<td>1.00</td>
<td>0.46</td>
<td>−0.56 ± 0.12</td>
</tr>
<tr>
<td>Noon</td>
<td>1</td>
<td>12:34</td>
<td>0.50</td>
<td>0.00</td>
<td>−0.54</td>
</tr>
<tr>
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<td>13:17</td>
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<td>0.03</td>
<td>−0.27</td>
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<td>13:23</td>
<td>0.60</td>
<td>0.00</td>
<td>−0.60</td>
</tr>
<tr>
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<td>1.00</td>
<td>0.41</td>
<td>−0.59</td>
</tr>
<tr>
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<td>Mean</td>
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<td>1.00</td>
<td>0.40</td>
<td>−0.60</td>
</tr>
<tr>
<td></td>
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<td>15:18</td>
<td>0.30</td>
<td>0.00</td>
<td>−0.30</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>15:28</td>
<td>0.40</td>
<td>0.03</td>
<td>−0.37</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>15:46</td>
<td>0.70</td>
<td>0.03</td>
<td>−0.67</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>15:53</td>
<td>0.80</td>
<td>0.00</td>
<td>−0.80</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>16:11</td>
<td>0.60</td>
<td>0.38</td>
<td>−0.22</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
<td>−0.49 ± 0.23</td>
</tr>
</tbody>
</table>
Urban gardens as a solution to energy poverty and urban heat island

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Fig. 3. Study area using Envi-met in each scenario.
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Fig. 4. Summer air temperature at 15 pm.

Fig. 5. Summer surface temperature at 15 pm.
Comparative analysis of green actions to improve outdoor thermal comfort inside typical urban street canyons

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Fig. 1. Analysis of the empty and built spaces of the selected urban areas. From the left: Casco Viejo, Abando/Indautxu and the Txurdinaga.
Morfologia urbana - Canyon

Fig. 3. The analyzed urban canyons with the position of the receptors, location of trees, distance between the trees ($D_1$), distance between the receptors ($D_2$) and foliage coverage of the trees. $H/W = 3.5$ Compact low-rise, $H/W = 1.5$ Compact mid-rise, $H/W = 1.3$ Open-set high-rise.

Fig. 4. The seven scenarios and the green actions analyzed in this work.
Morfologia urbana - Canyon

Fig. 4. The seven scenarios and the green actions analyzed in this work.

Fig. 5. The values of PET measured in all 14 receptors within the urban canyon in all the scenarios of open-set high-rise urban areas. Each box collects all the PET data recorded during the simulation day (7th of August); the bottom square, in dark blue, represents the 2nd or lower quartile (Q2) that is equal to 25% of the distribution of the all data under the average value of PET; the top square, in clear blue, is the 3rd or upper quartile (Q3) with the 25% of the data over the average value of PET; the average value marks the mid-point of the PET data and is shown by the line that divides the box into two parts. Half of the PET values, distributed in Q2, are greater than or equal to this value and half, distributed in Q3, are less. The upper (Q4) and lower (Q1) whiskers represent the distribution of the values outside the middle 50%. The whiskers also underline the outliers (extreme values). The upper whisker represents the peak of PET value recorded in each scenario. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)
**Morfologia urbana - Canyon**

Fig. 4. The seven scenarios and the green actions analyzed in this work.

Fig. 8. The hourly evolution of the average peak values of PET calculated from the peak values of PET recorded from all 14 receptors within the urban canyon for scenario S1. The hourly evolution of PET for the different ratio of height \( H \) and width \( W \) have been represented: \( H/W = 3.5 \) for compact low-rise, \( H/W = 1.5 \) for compact mid-rise and \( H/W = 1.3 \) for open-set high-rise.

Fig. 14. Comparison of typical PET trends between scenario S1 and S3. Data related to receptor R04. The hourly evolution of PET for \( H/W = 3.5 \) for compact low-rise, \( H/W = 1.5 \) for compact mid-rise and \( H/W = 1.3 \) for open set high-rise have been represented.
Comparative analysis of green actions to improve outdoor thermal comfort inside typical urban street canyons

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**Fig. 16.** (From left) Visualization of the green action in compact low-rise, compact mid-rise and open-set high-rise urban areas. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)
Microclimate design for open spaces: Ranking urban design effects on pedestrian thermal comfort in summer
Angeliki Chatzidimitriou a, b, Simos Yannas c

Fig. 9. Simulation results for air temperature at noon (1200h), in the square, 1 m above ground level, in (a) the base case and (b) the case of 100% cover by trees (simulation results by ENVI-met).

Fig. 10. Simulation results for ground surface temperature in the afternoon (1500h), at the square, in (a) the base case and (b) the case of 100% cover by grass (simulation results by ENVI-met).

Fig. 11. Simulation results for ground surface temperature in the afternoon (1500h), at the courtyard, in (a) the base case and (b) the case of 100% cover by grass (simulation results by ENVI-met).
Fig. 18. PET values at noon in the square 1 m above ground level, in (a) the base case and (b) the case of 50% cover by trees.

Fig. 19. PET values at noon in the courtyard 1 m above ground level, in (a) the base case and (b) the case of 25% cover by trees.
Evaluation of a microclimate model for predicting the thermal behavior of different ground surfaces

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Fig. 1. Experimental area (image is from Google Earth), the layout of measurement points, and the features of the studied ground surfaces (right). For points 5, 6 and 7, both sub- and above-surface variables were measured. For point 9, only the above-surface variables were observed. For points 1, 2, 3, 4, 8 and 10, only air temperature and relative humidity at 0.2 m and 1.5 m above ground were measured. The anemometer sensor was located in the center of the square, 2 m above ground.
Effects of asymmetry, galleries, overhanging façades and vegetation on thermal comfort in urban street canyons

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Fig. 1. Urban canyon geometries used in the simulations with ENVI-met 3.0.

Fig. 2. Average air temperature $T_a$ at street level (1.2 m a.g.l.) for (a) asymmetrical urban canyons, (b) overhanging façades, and (c) urban canyons with trees, in comparison to symmetrical urban canyons of $H/W = 2$ and 1.
OMM Outdoor Microclimate Map
OMM Outdoor Microclimate Map


Outdoor Comfort: the ENVI-BUG tool to evaluate PMV values
Output Comfort point by point
Kristian Fabbri¹, Antonello Di Nunziò², Jacopo Gaspari², Ernesto Antonini³, Andrea Boe

Fig. 3. Comparison between (a) state of art (before) and (b): Relative Humidity distribution

Fig. 4. Comparison between (a) state of art (before) and (b): Wind Speed distribution

The data shows a significant variation in PMV values across different areas, highlighting the importance of understanding microclimate conditions. The maps provide a visual representation of how changes in environmental factors impact comfort levels. Further analysis is required to assess the effectiveness of albedo improvement strategies.
OMM Outdoor Microclimate Map

Fig. 2. The site layout before (a) and after (b) intervention (c, d) (credits: L. Ferrari, D. Galassi)
Fig. 6. Specific Humidity in g/kg (a) before; (b) after.

Fig. 7. Predicted Mean Vote (PMV) index (a) before; (b) after.
Il caso Piazza Bufalini a Cesena (referendum)

- **Stato di fatto**
- **Progetto con mantenimento lecci**
- **Progetto con nuovi alberi e abbattimento lecci**

Outdoor Microclimate Map to compare an open space design: the case study of Piazza Bufalini in Cesena.

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Il caso Piazza Bufalini a Cesena (referendum)
Il caso Piazza Bufalini a Cesena (referendum)

- Stato di fatto
- Progetto con mantenimento lecci
- Progetto con nuovi alberi e abbattimento lecci

Scenario (A)

Scenario (B)

Scenario (C)
Grazie