ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

Local heat transfer coefficients in a multiscale framework for dynamic simulation of buildings

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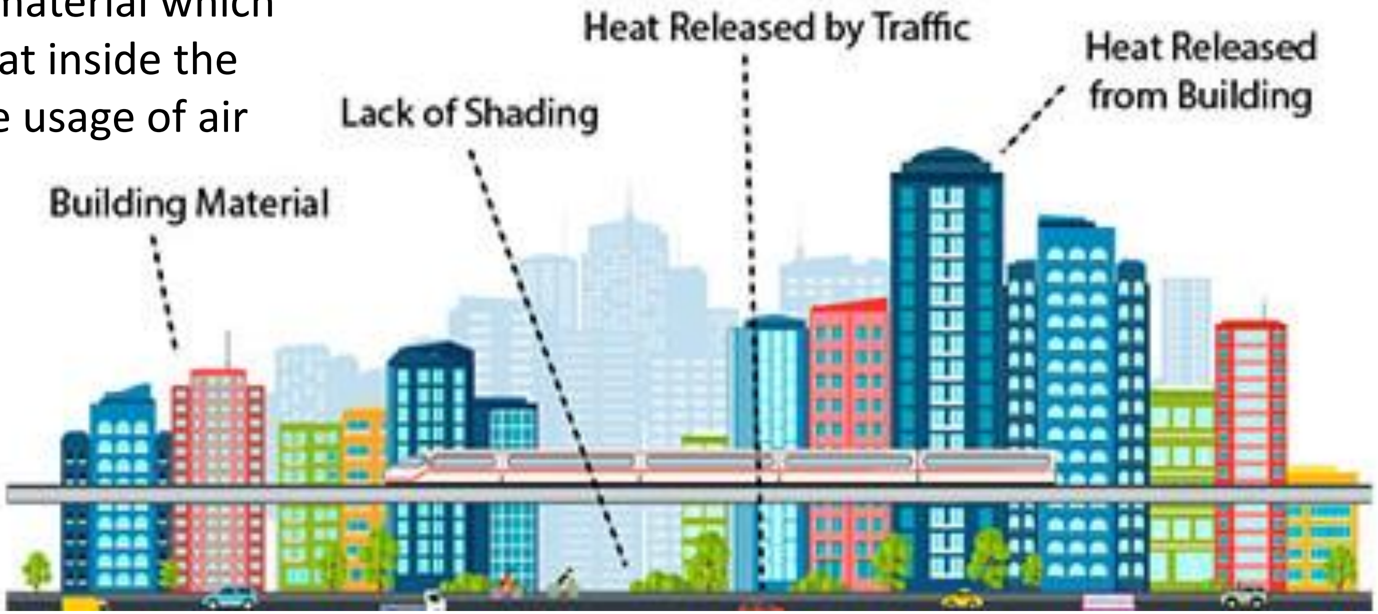
Carnot user meeting – Bologna, 22-23 June 2023

Introduction and motivation

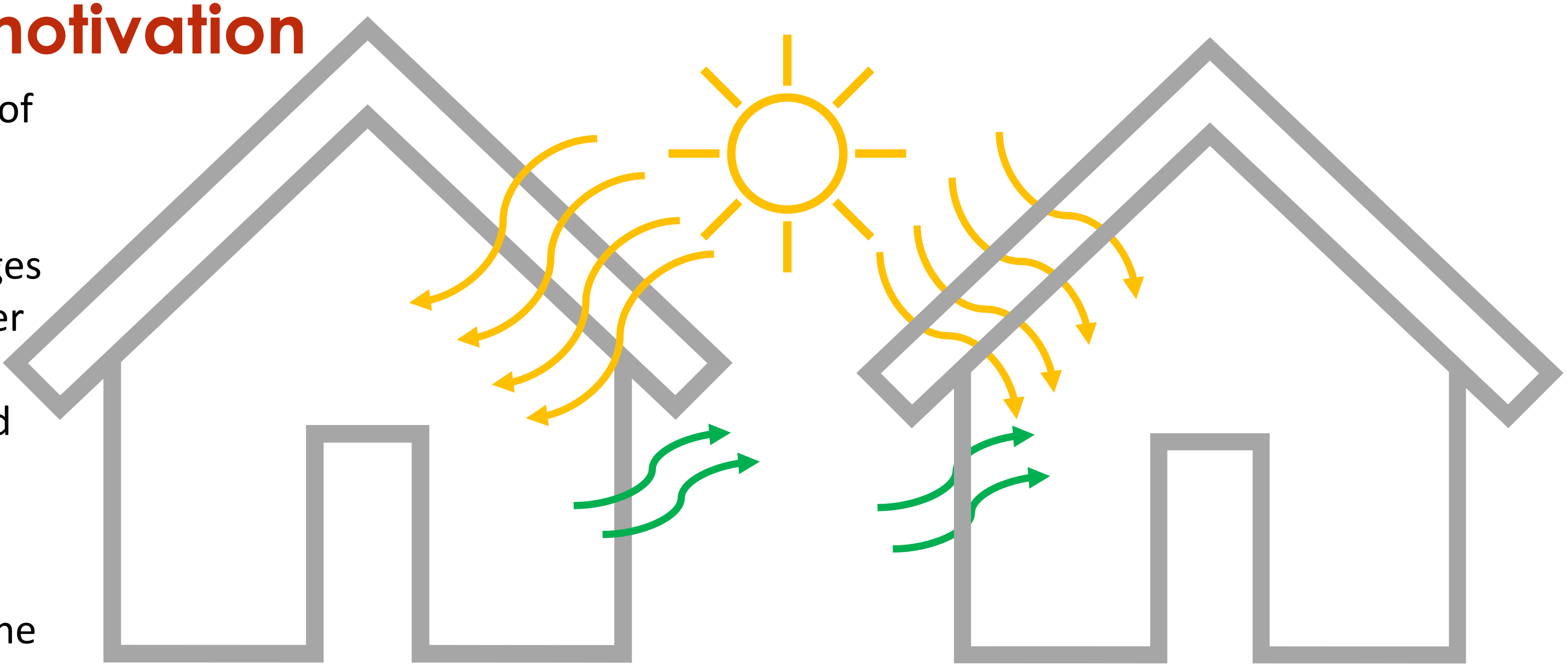
The street canyons trap the heat between the walls and lead to warming up of the buildings.
A vicious cycle is created in the cities, where the use of air conditioning adds up to the heat waves and pollutants, leading to heat-emissions. Many commercial complex and corporate offices use glass as a facade material which adds on to the heat inside the building and more usage of air conditioning.



Improved building and city-scale thermal simulations are required to allow modelling of the effects of climate change and urban heat islands.
These are also required to assess the effectiveness of the possible amelioration measures which could be used to improve the climate of our towns and cities.

Introduction and motivation

In the literature, a large number of investigations are available to determine the role of the convective and radiative exchanges separately, especially on the outer side of the building components. Conversely, few studies are found for the heat exchanges on the inner side that influence the enclosure mean radiant temperature and consequently the thermal comfort conditions.

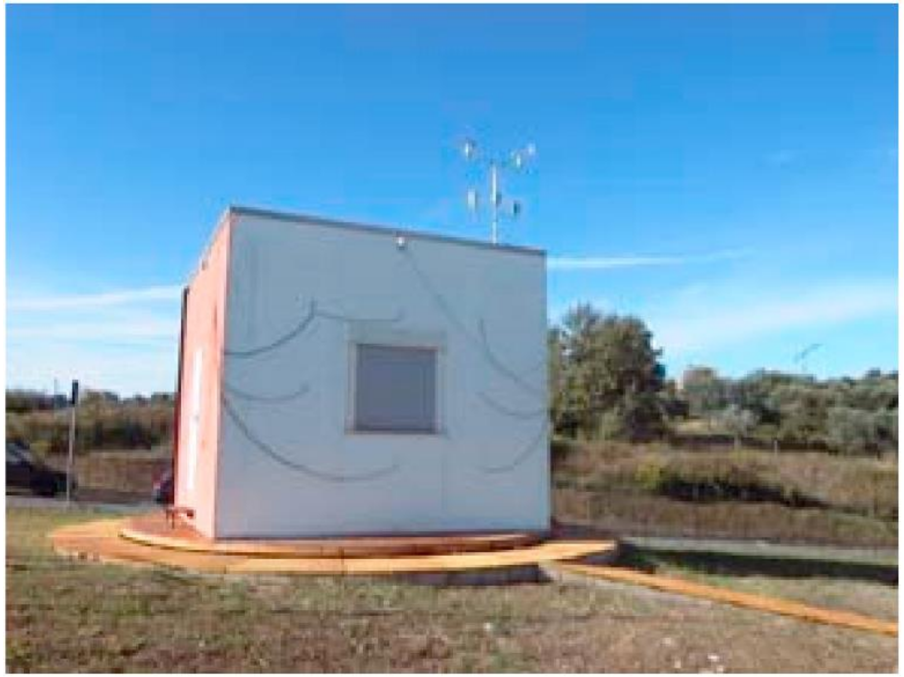


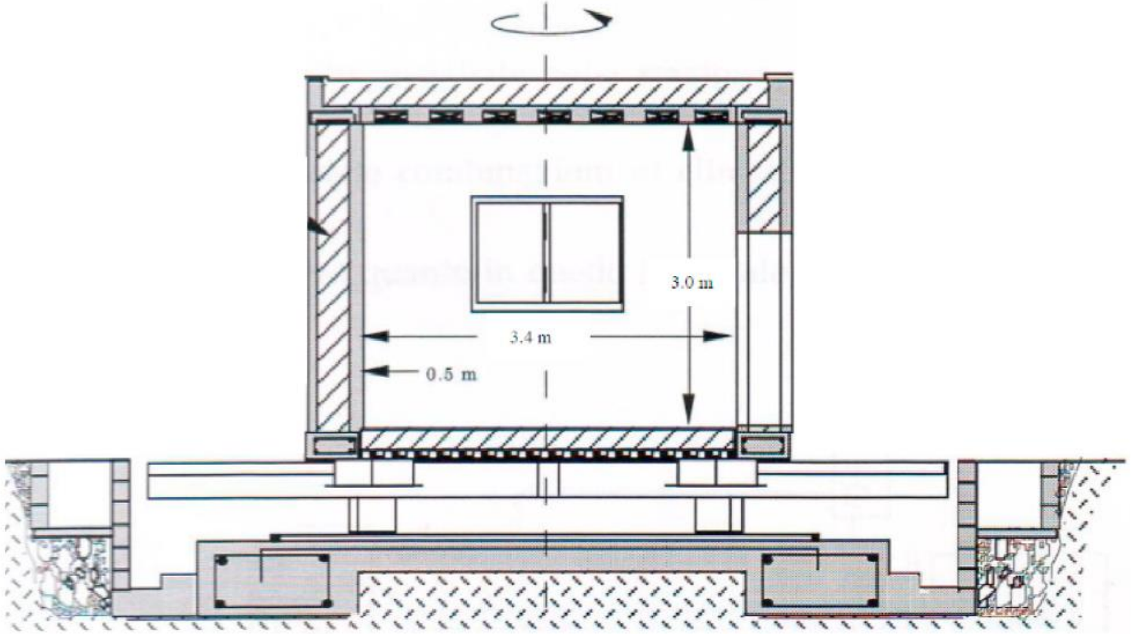
It was proved **that a wide uncertainty range could be observed when heat transfer coefficients vary dynamically**, especially for the convective exchange viewpoint.
Wind direction has a noticeable influence on vertical walls and tilted roofs, whereas the temperature difference between air and wall surface has a negligible effect when the wind velocity is greater than 2 m/s.

Regarding the surfaces of the inner components, the conditioned space as well as of the air-conditioning system produce **great fluctuations in the convective heat transfer coefficients**, such as the non-uniformity of the indoor air temperature, the simplification to use a characteristic dimension for the enclosure, and the impact of airflow disturbances.

Dynamic heat transfer coefficient

Steady and dynamic heat transfer coefficients acting on different building components affect energy and thermal comfort evaluations.





ELSEVIER

Building and Environment

journal homepage: www.elsevier.com/locate/buildenv

On the assessment of the heat transfer coefficients on building components: A comparison between modeled and experimental data

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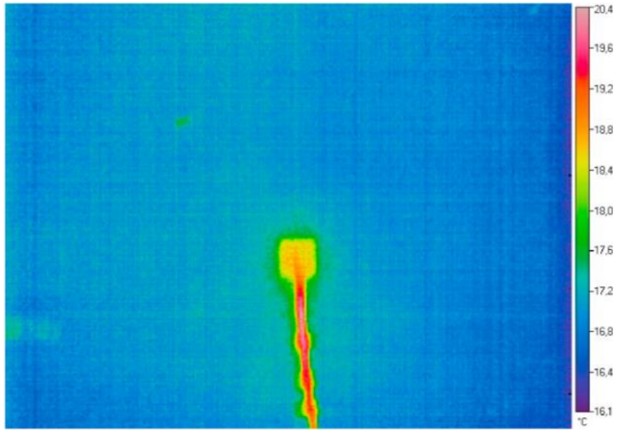
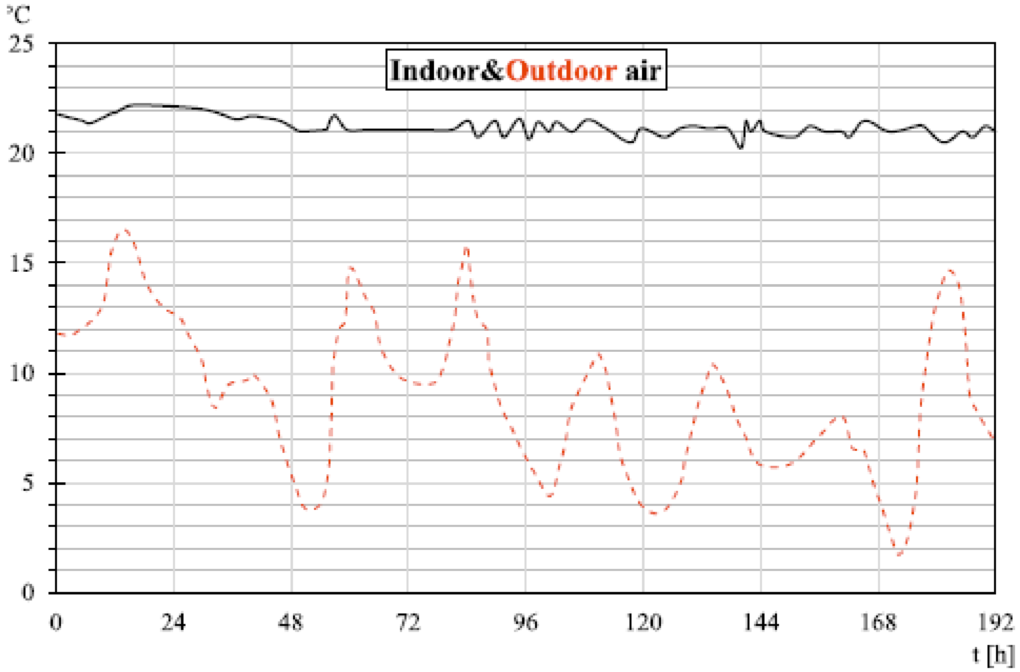
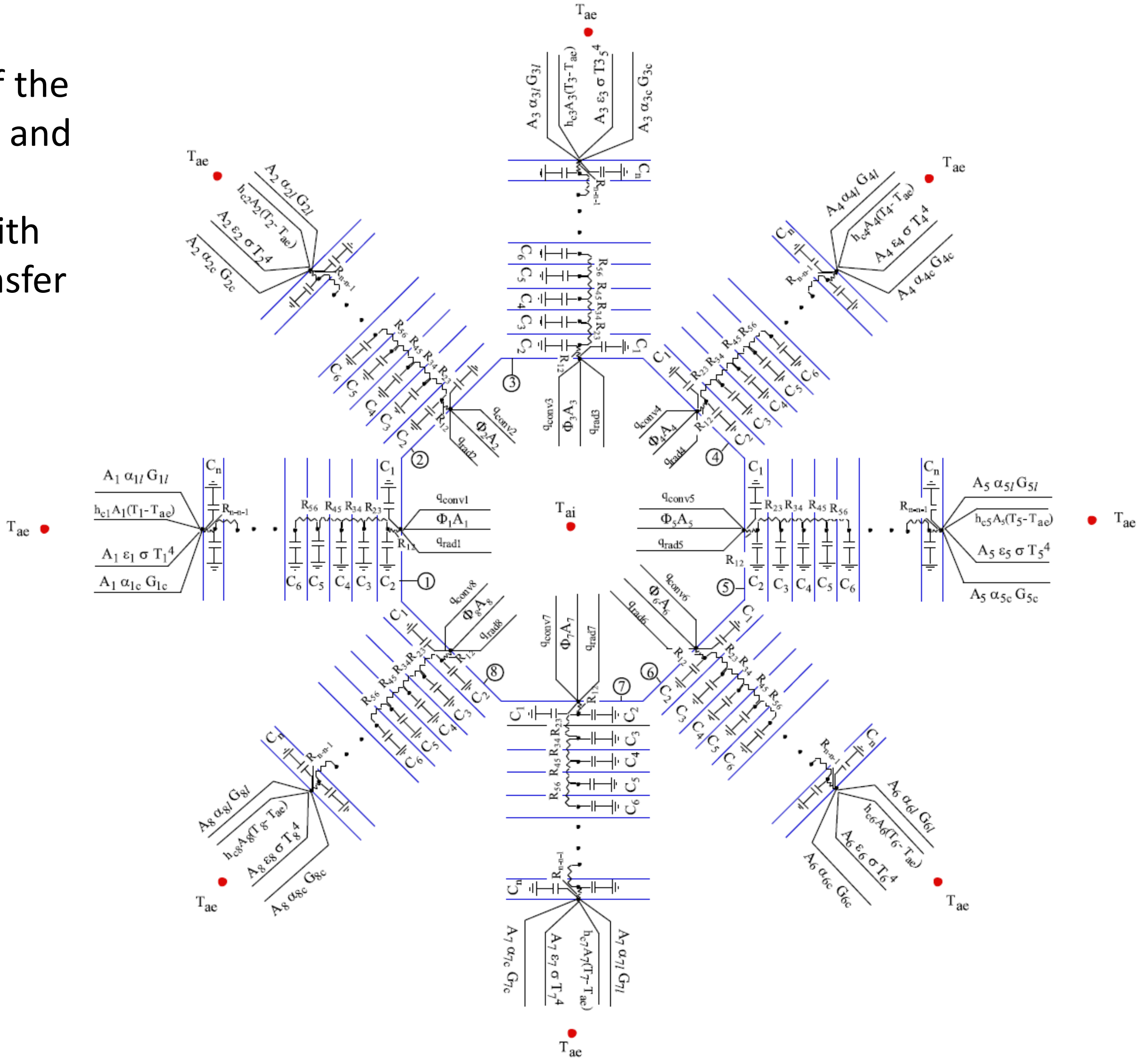


Dynamic heat transfer coefficients

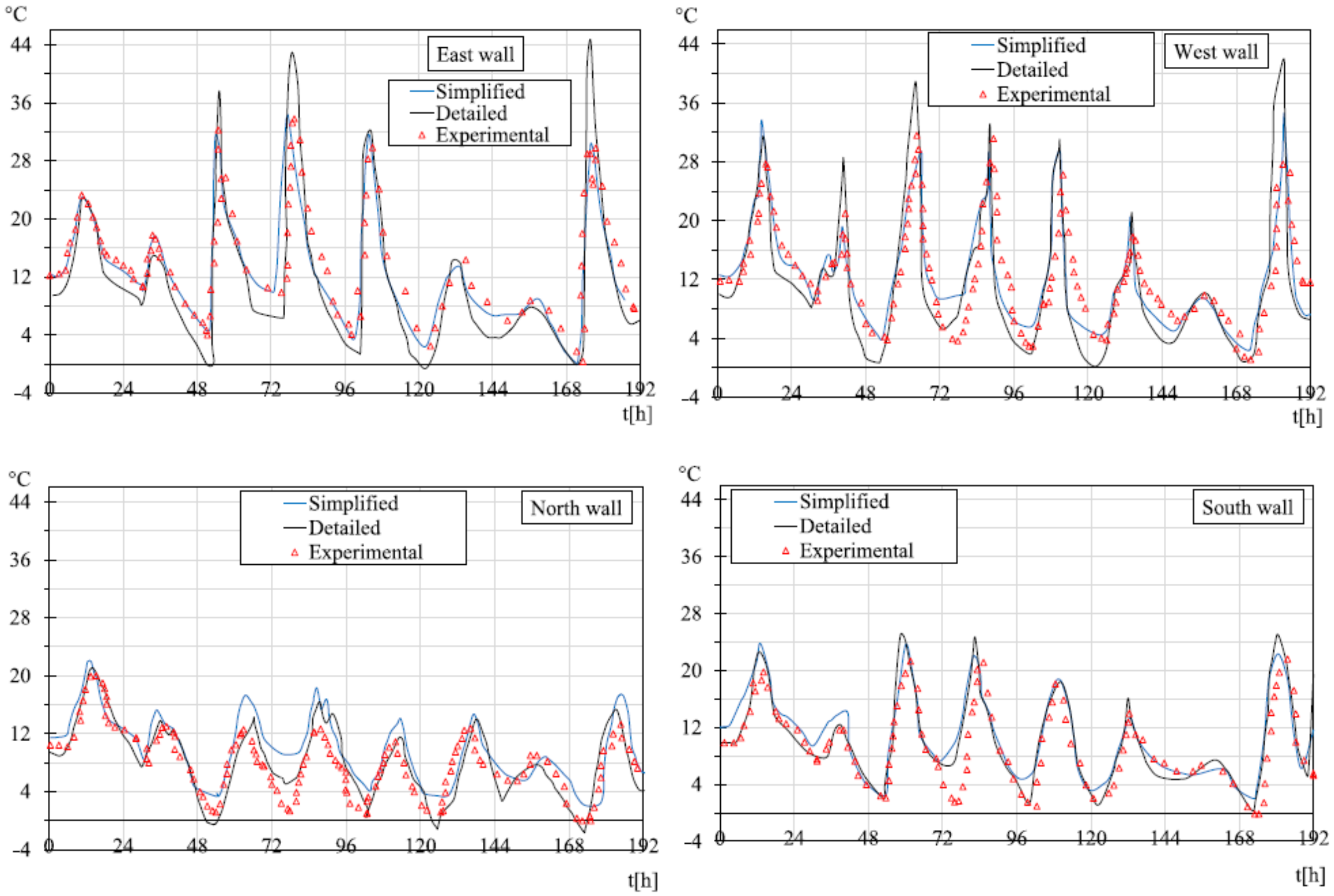
the two scenarios considered to investigate the role of the heat transfer coefficients on the surface temperatures and thermal fluxes have been defined as **“detailed” and “simplified”** approaches, corresponding to the case with **dynamic/separated** and **constant/combined** heat transfer coefficients respectively





Dynamic heat transfer coefficients

The simplified procedure on the inner side provides underestimated temperature for every component suggesting that **the adoption of constant thermal resistances produces an underestimation of the convective and radiative exchanges**.
Conversely, the employment of dynamic and separated heat transfer coefficients can provide appreciable results.

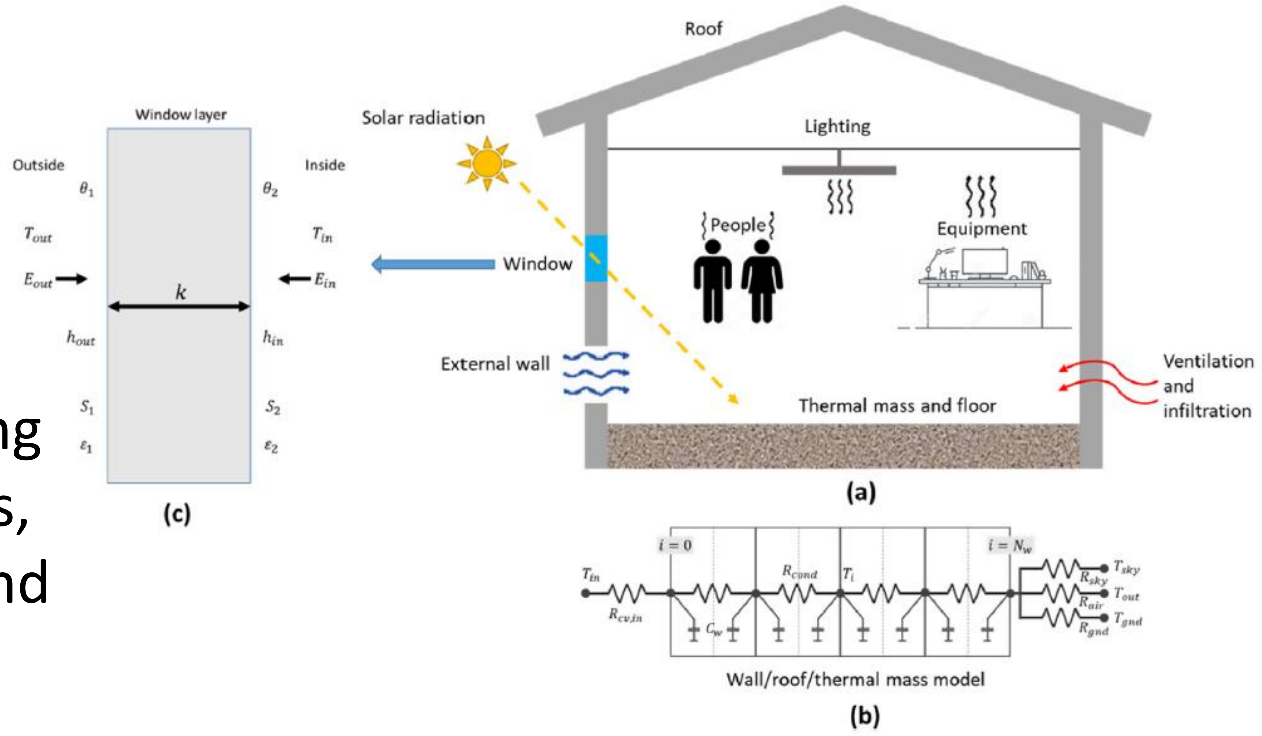


	TRNSYS Steady values	TRNSYS Dynamic values
Maximum heat load [W]	548.87	454.33
Energy need in the considered period [kWh]	42.63	31.82

The use of constant convective heat transfer coefficients on the building component surfaces produces an increase in the maximum heating load and of the thermal energy need equal to 20% and 34% respectively.

City neighborhood scale

The model gives the dynamic integration of urban microclimate and building thermal/energy models.
The dynamic simulations were achieved using weather station data as boundary conditions, including air temperature, solar radiation, and wind speed and direction, instead of typical meteorological year data.



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Energy

journal homepage: www.elsevier.com/locate/energy

Urban building energy and microclimate modeling – From 3D city generation to dynamic simulations

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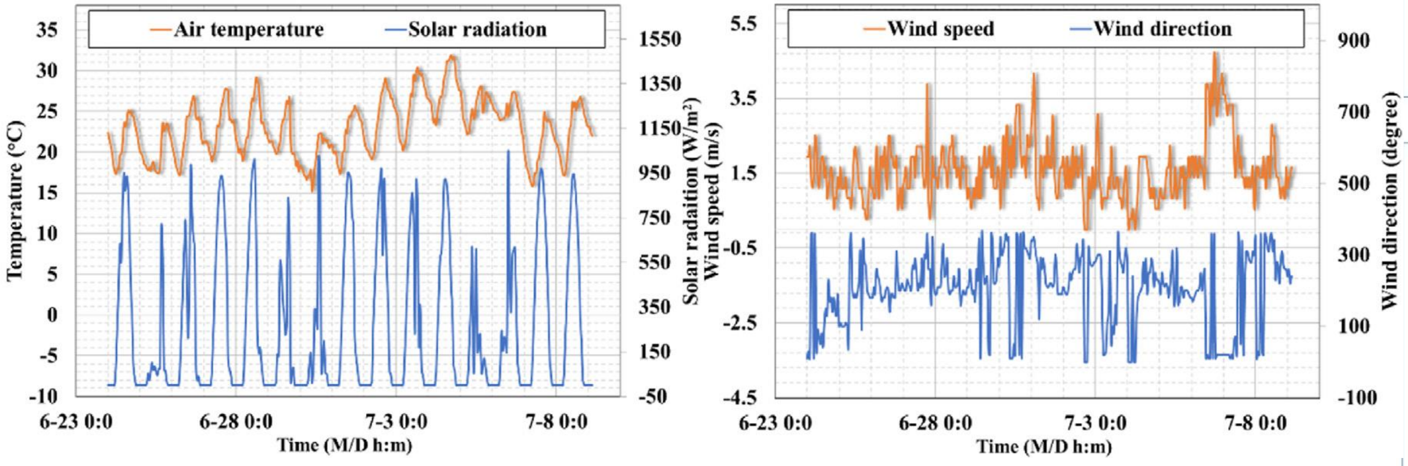
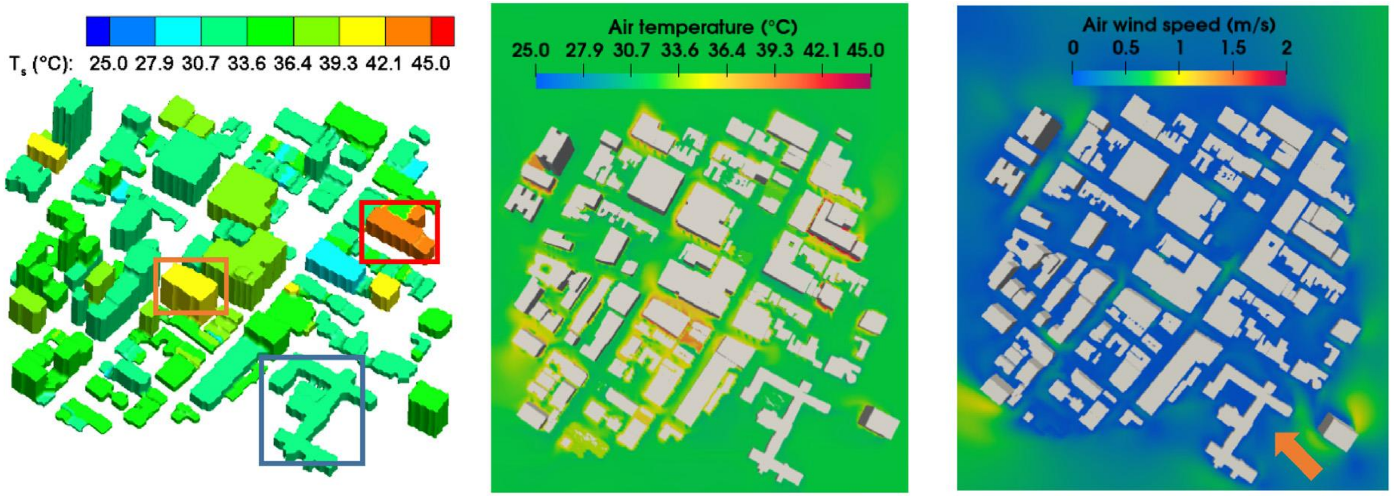
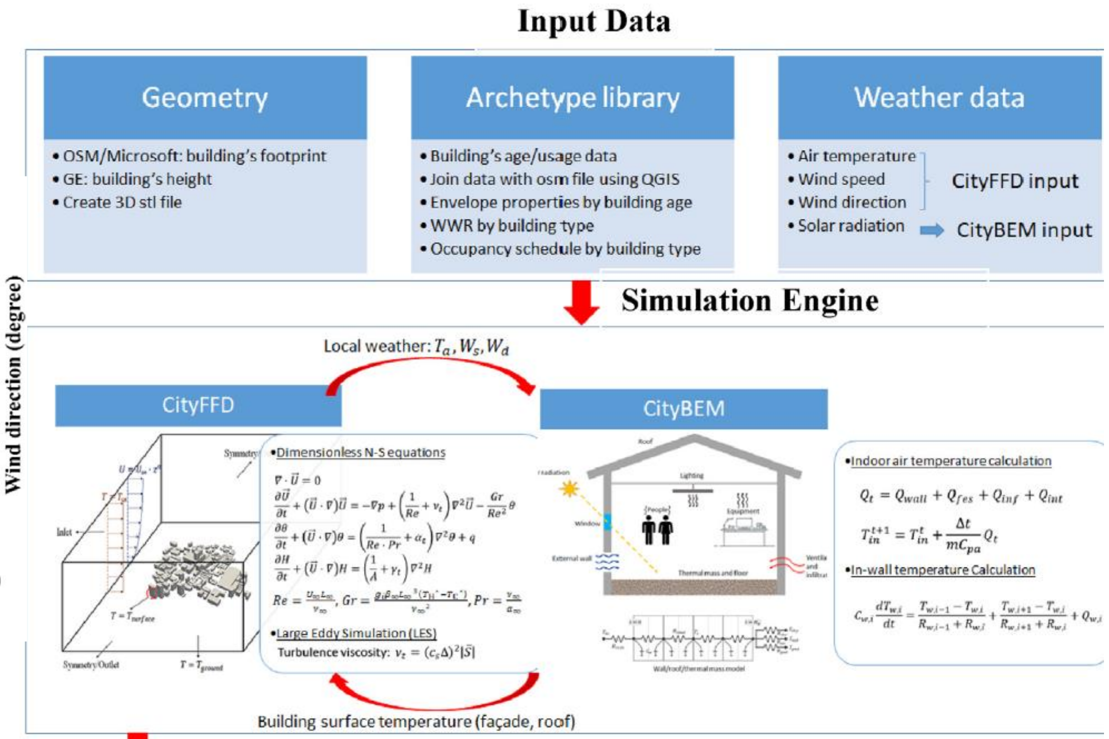
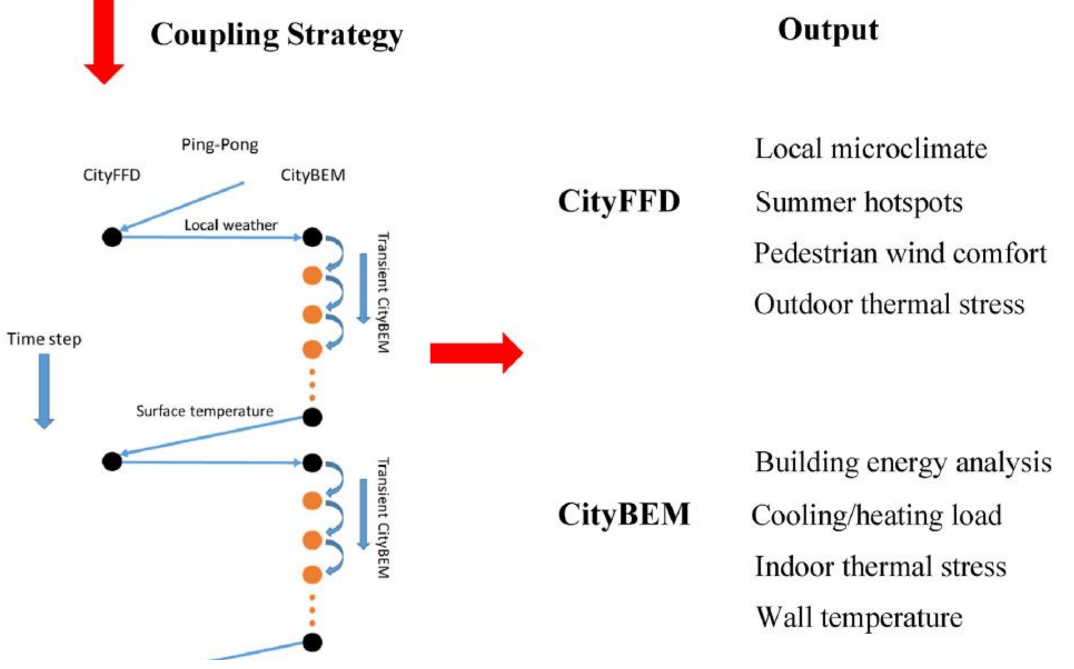
The building are a single zones, within which the air is well mixed, i.e., internal flows between spaces are ignored.
The total thermal load of the building is composed of convective heat transfer from indoor surfaces (walls, floor, roof, windows, and internal thermal mass), infiltration heat transfer, and internal heat gains.

Multi-domain approach







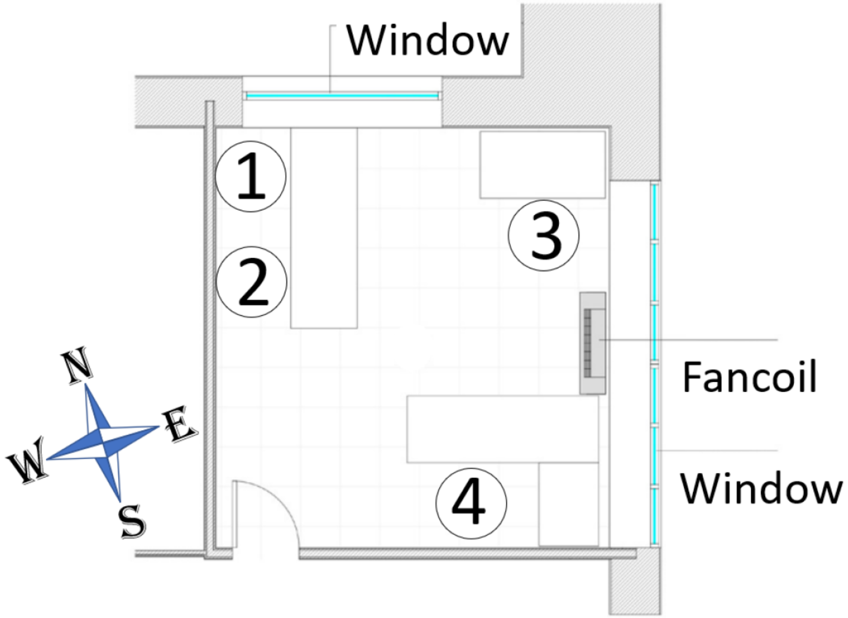


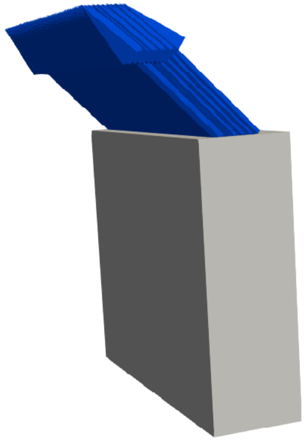
Historical buildings

Article

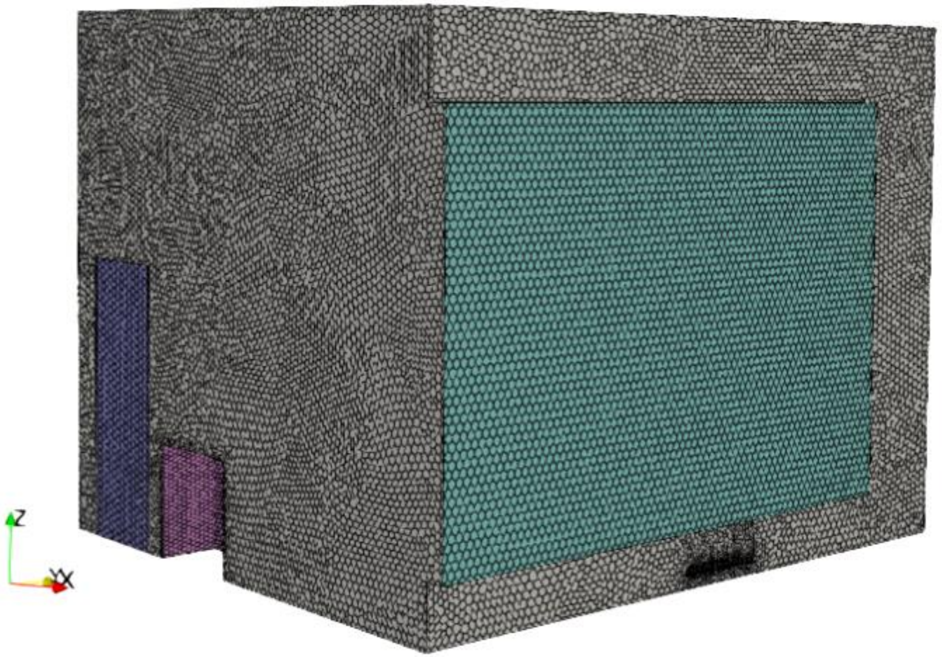
Numerical Analysis on the Optimisation of Thermal Comfort Levels in an Office Located inside a Historical Building

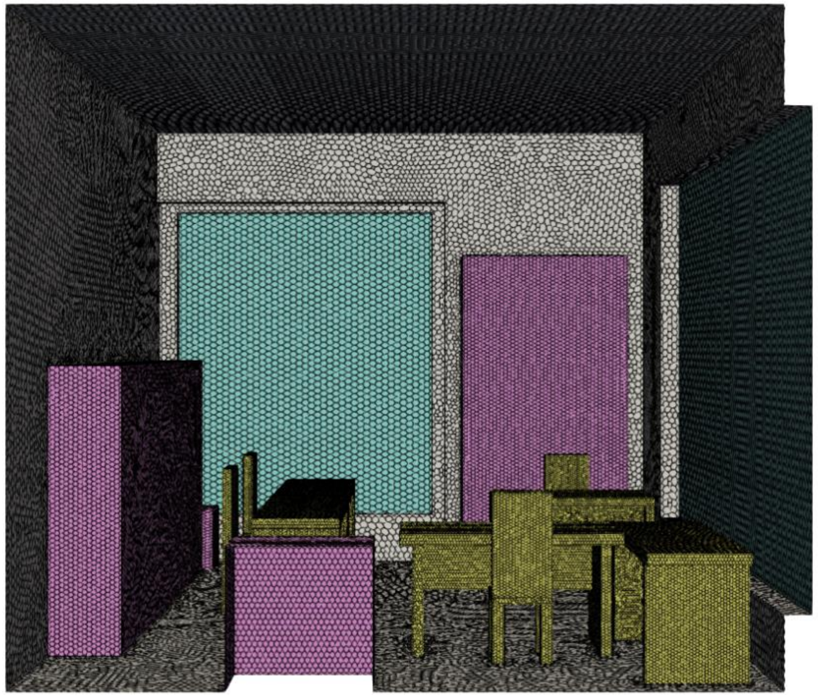
Eleonora Palka Bayard de Volo *, Beatrice Pulvirenti *, Aminhossein Jahanbin, Paolo Guidorzi and Giovanni Semprini

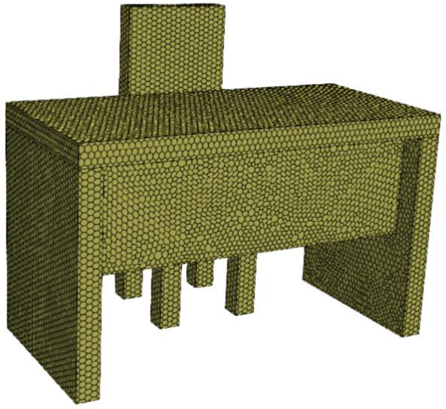




Grid and boundary conditions



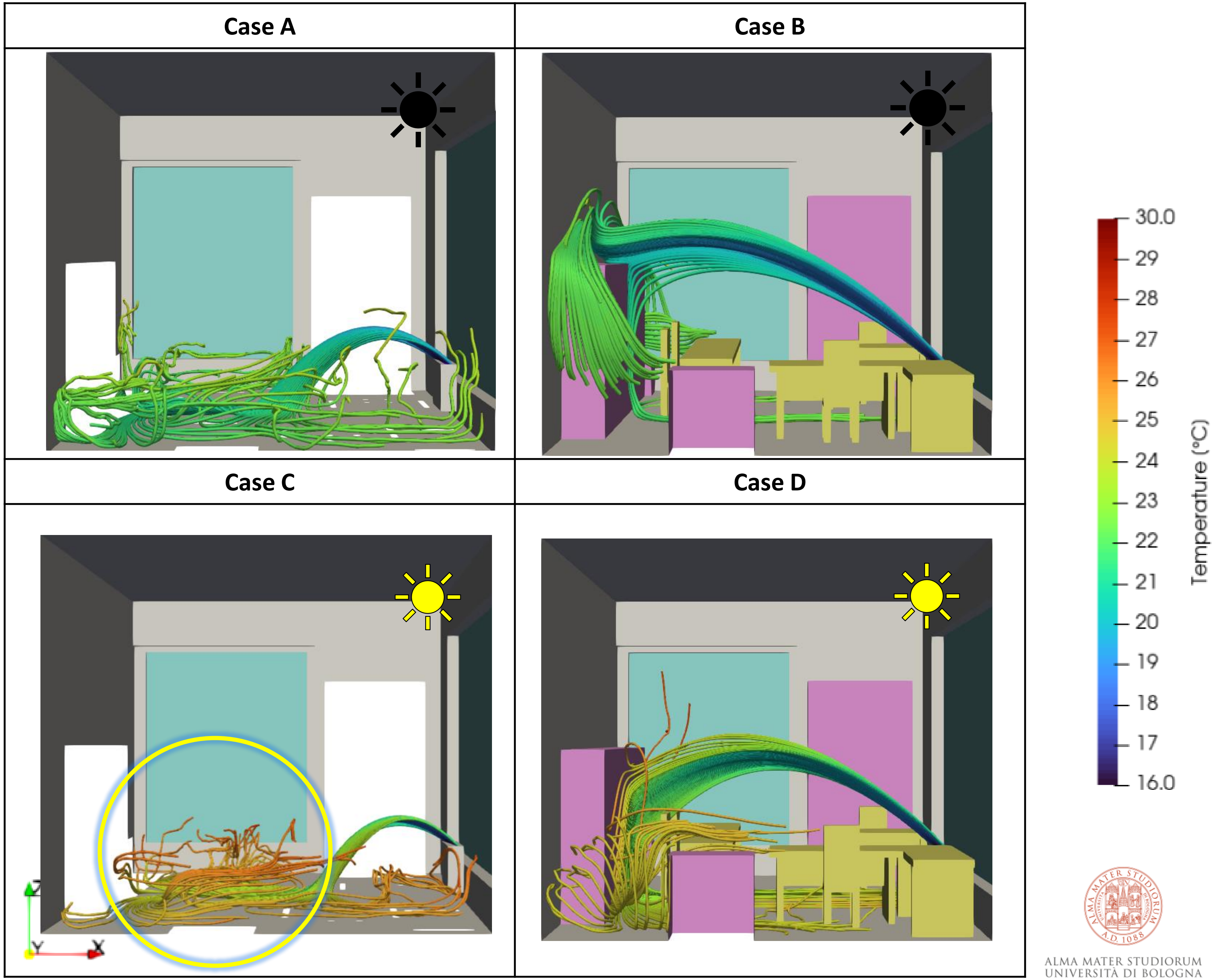




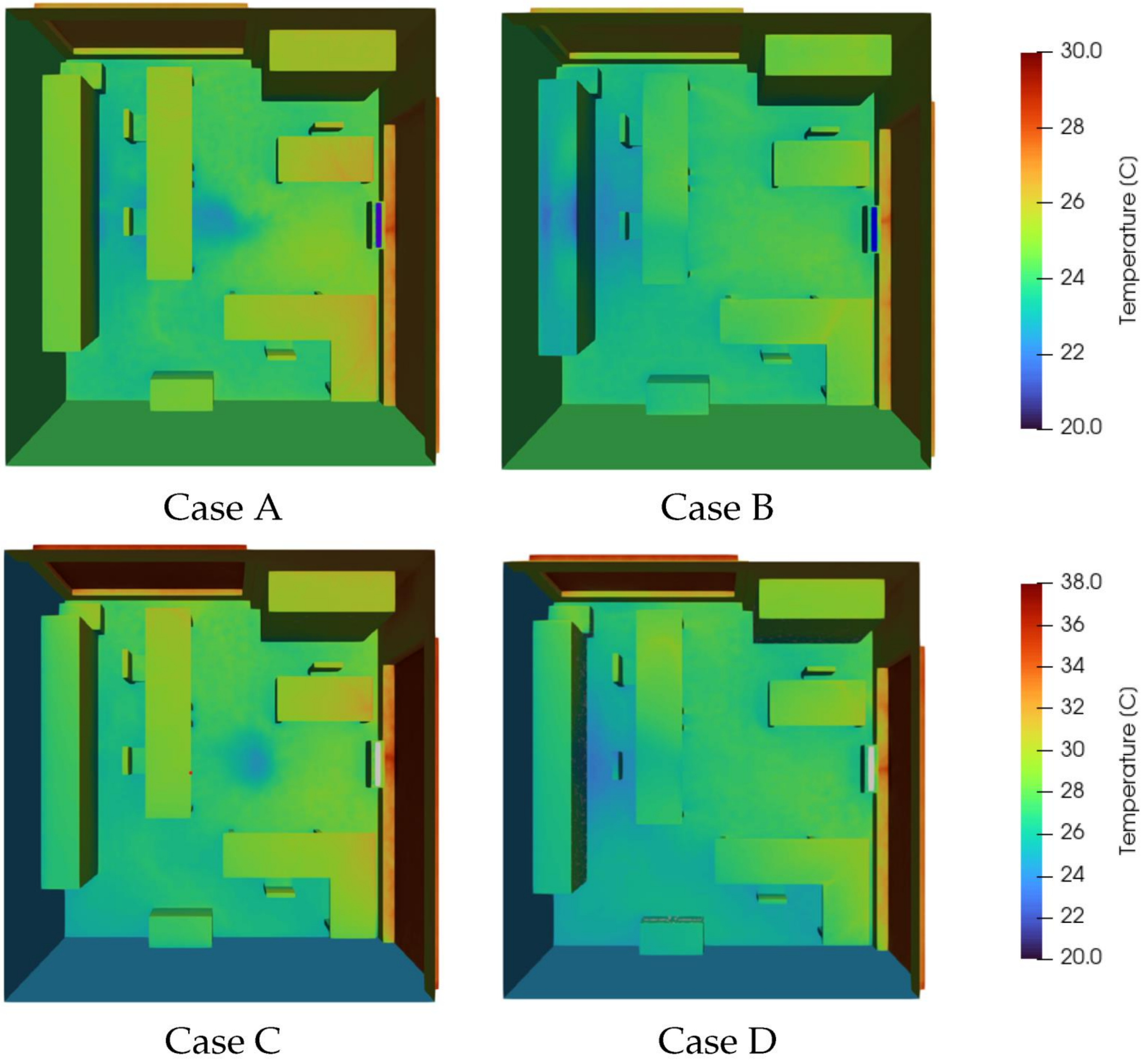
Configurations	Inlet air velocity $[\frac{m}{s}]$	Solar Load $[\frac{W}{m^2}]$	
		Direct radiation(1)	Diffuse radiation(2)
Case A	1	0	10
Case B	2	0	10
Case C	1	597.6	597.6
Case D	2	597.6	597.6

	Summer	Winter
Outside temperature	30 °C	6 °C
Inlet temperature	16 °C	33 °C

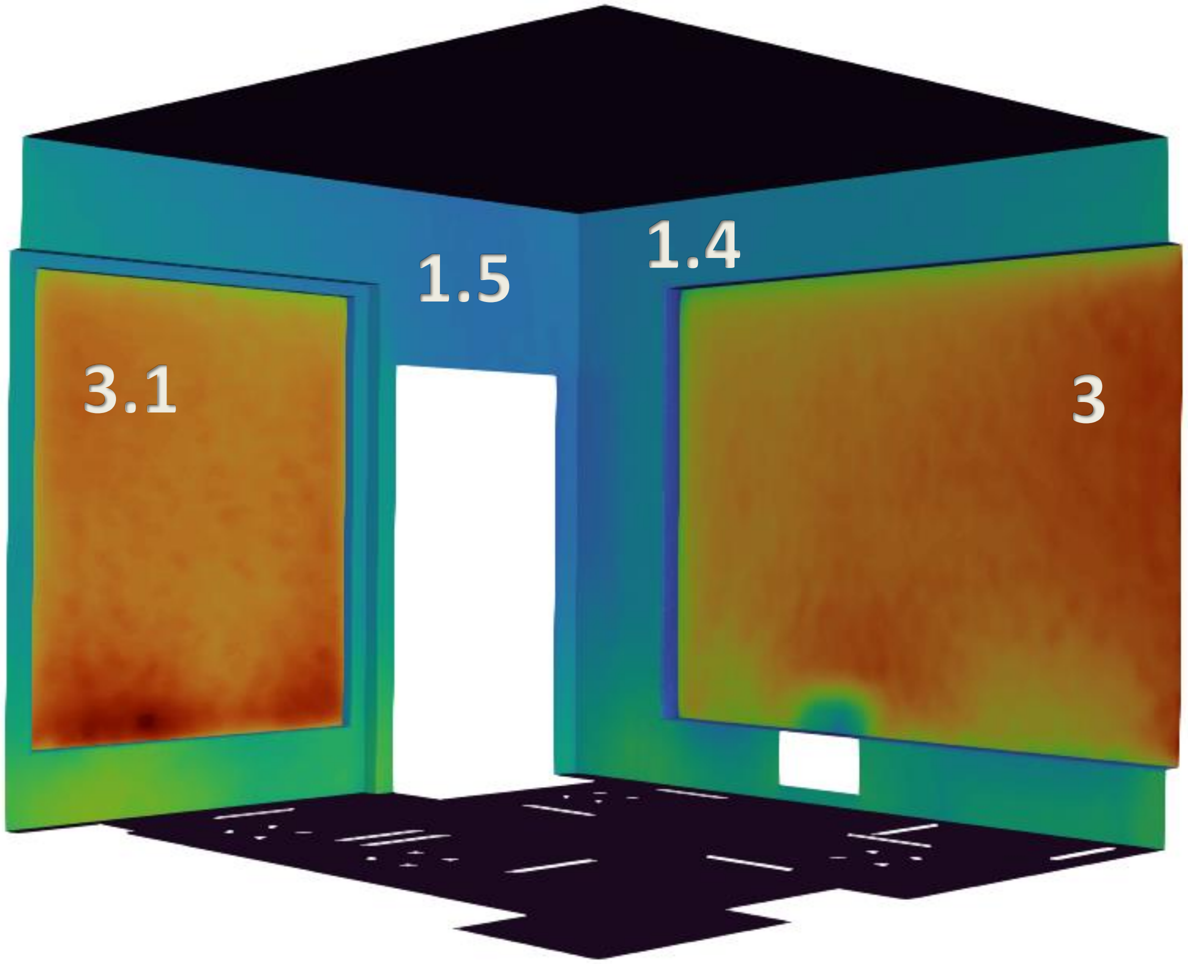
Summer

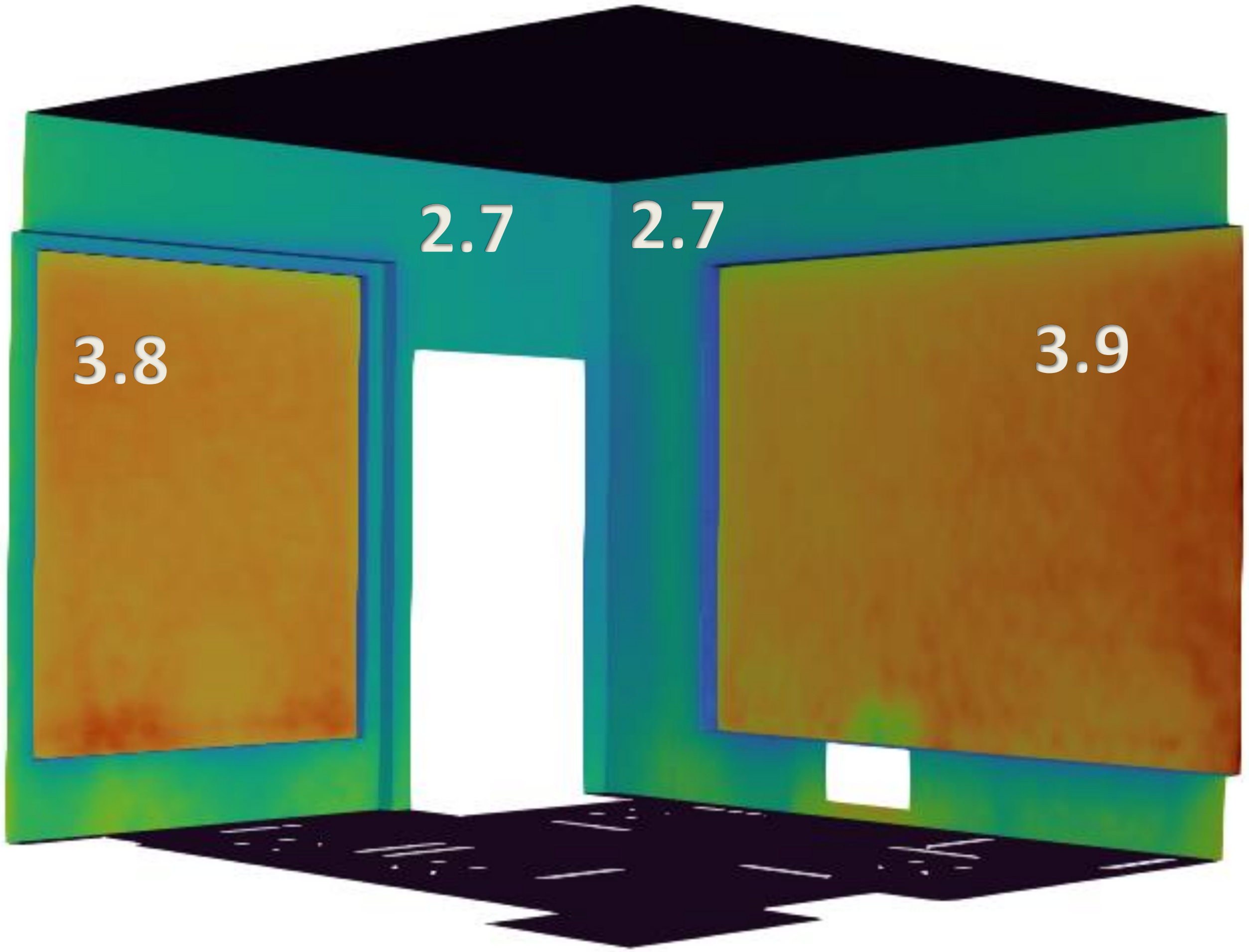

Case A
Case B
Case C
Case D
30.0
29
28
27
26
25
24
23
22
21
20
19
18
17
16.0
Temperature (°C)

Summer

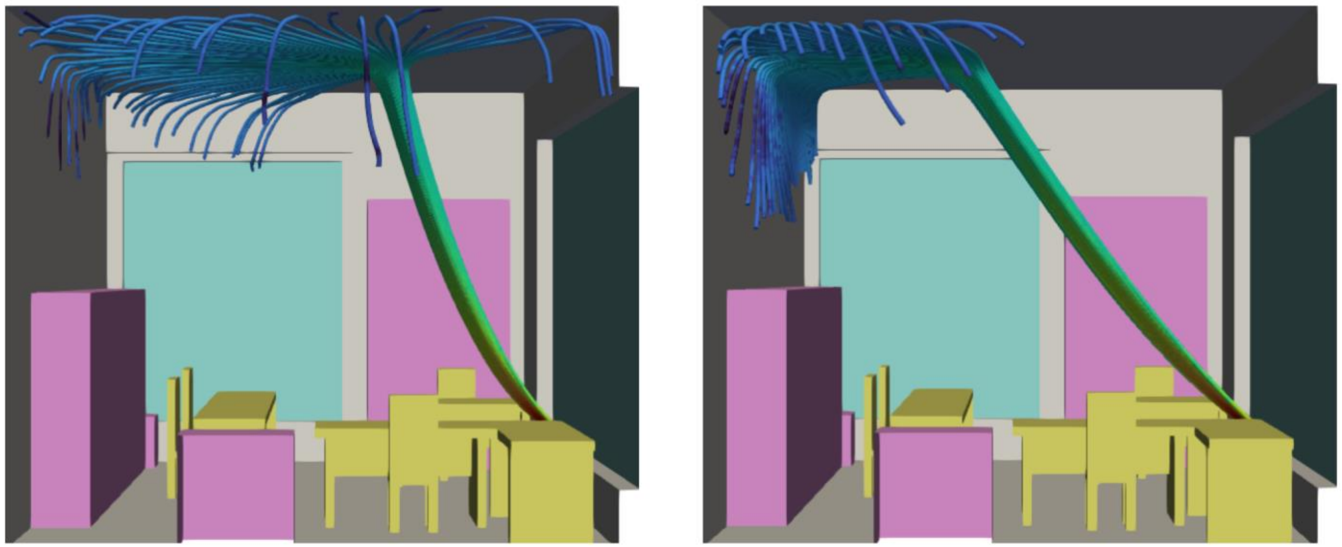

Case A
Case B
Case C
Case D
30.0
28
26
24
22
20.0
Temperature (C)
38.0
36
34
32
30
28
26
24
22
20.0
Temperature (C)

Heat transfer coefficient



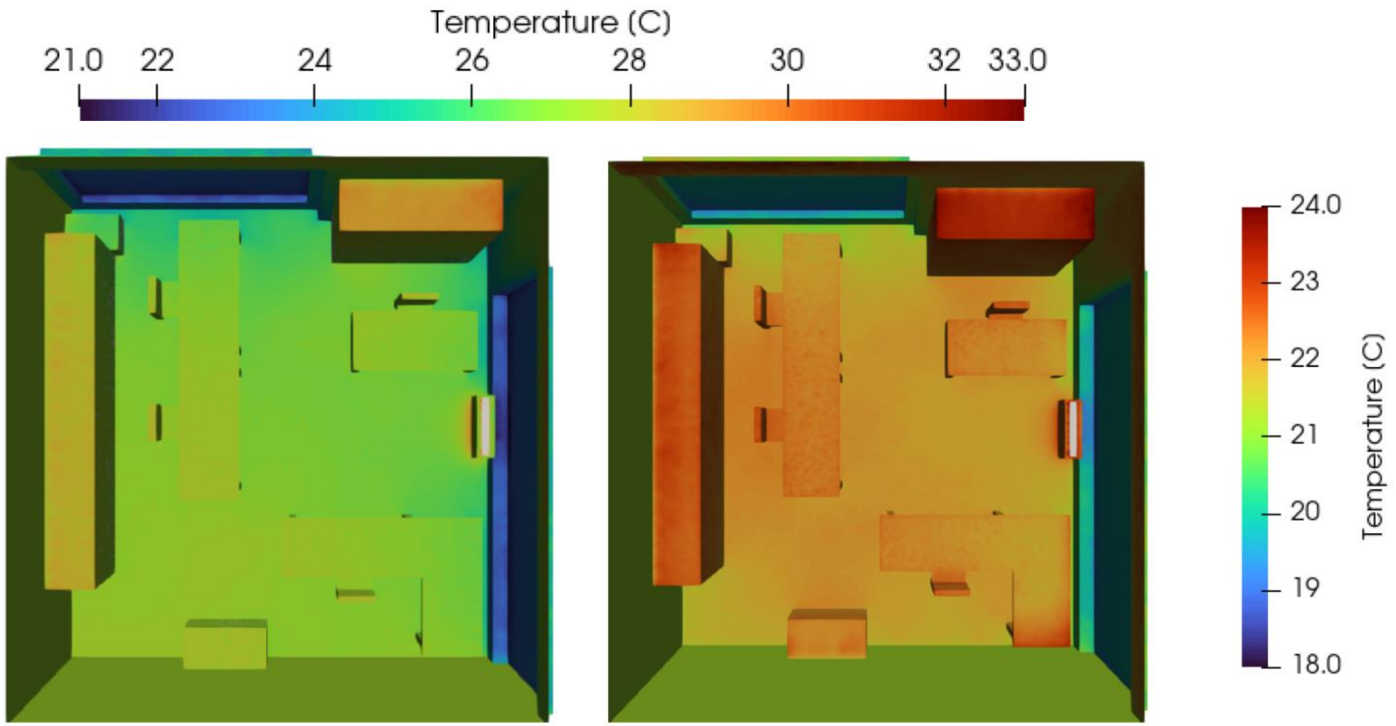


Winter

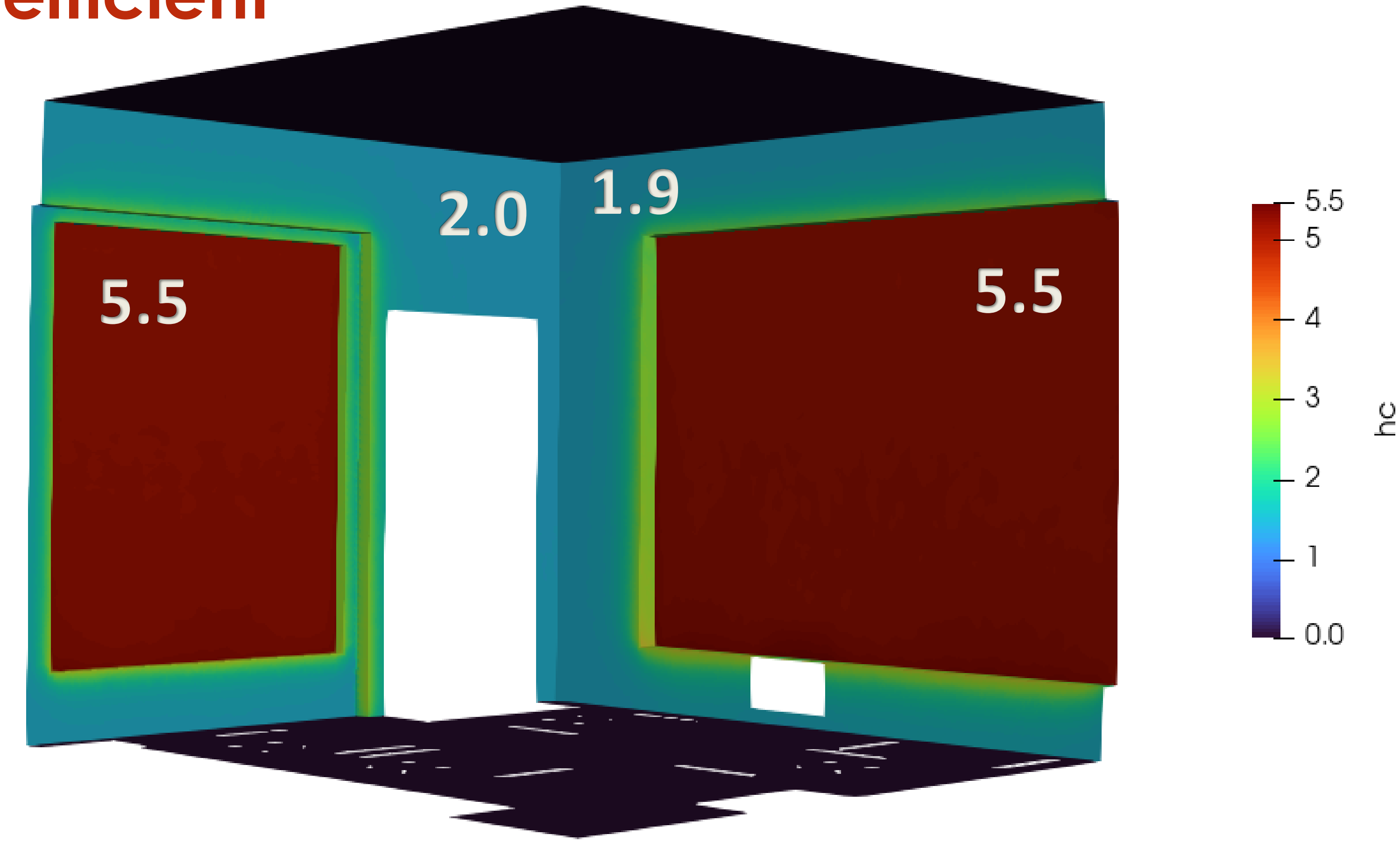


Case E

Case F



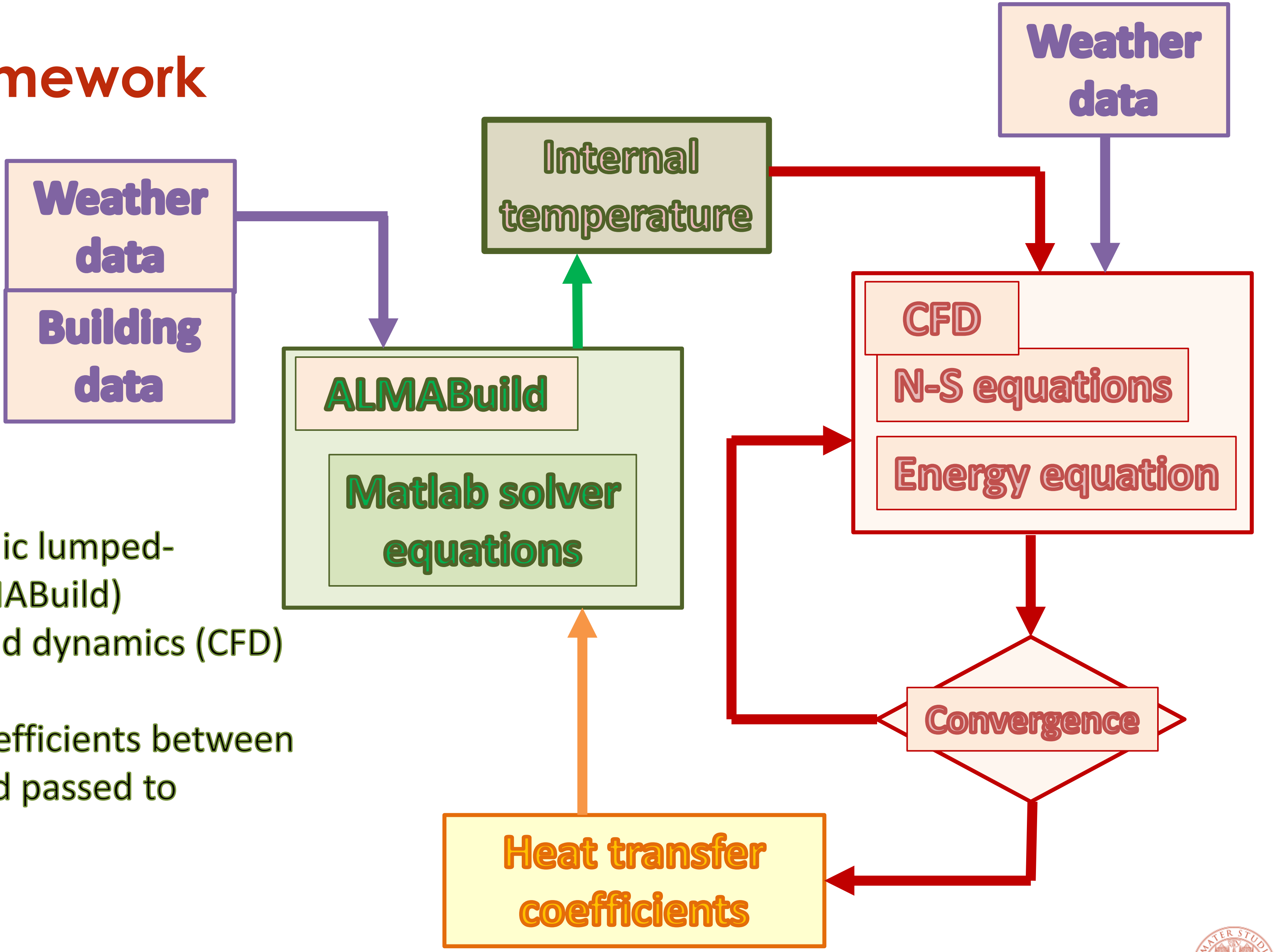
Winter – heat transfer coefficient



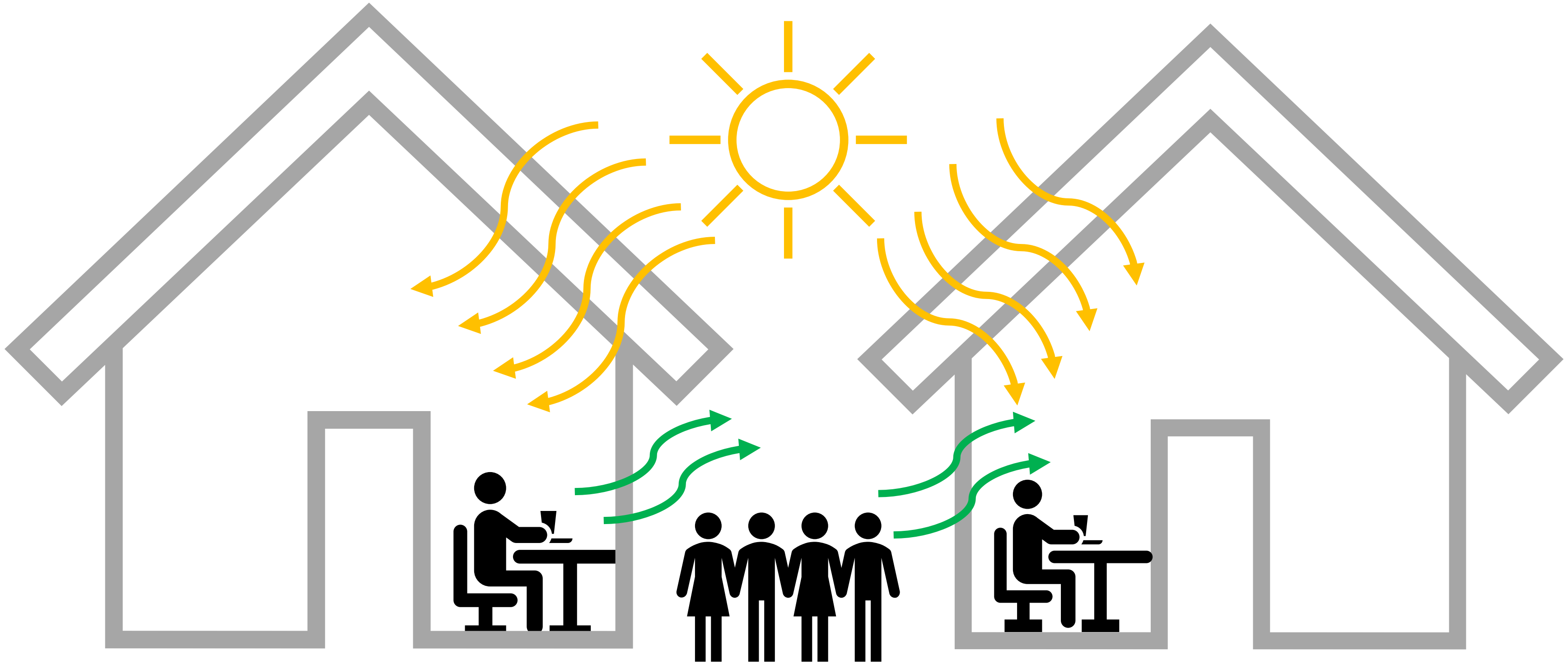
Developing a framework

A multi-domain simulation method is proposed for a structure with a thermally complex building envelope.

The method integrates a dynamic lumped-parameter simulation tool (ALMABuild) coupled with computational fluid dynamics (CFD) simulations.
The convective heat transfer coefficients between zones are calculated via CFD and passed to ALMABuild.



Conclusions

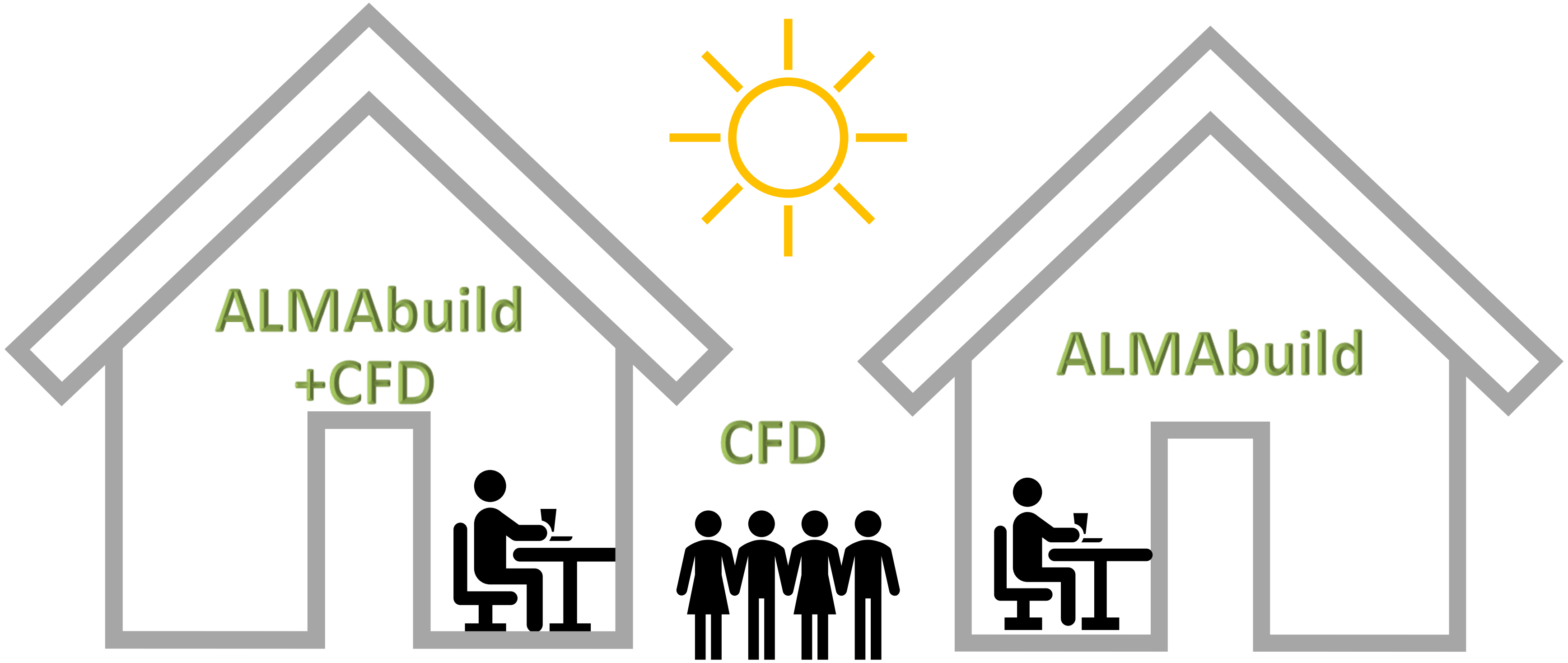


Through the multidomain modelling approach here presented it is possible:

- ➢ To establish the appropriateness of current convective heat transfer coefficient equations for the application to the surfaces of buildings.
- ➢ To take account of **realistic atmospheric conditions** in the boundary layer above urban areas, including the mean velocity profile and levels of turbulence.
- ➢ To determine the effect that the incident wind direction has upon the rate of convective transfer from the surfaces of buildings.

Conclusions

This integrated framework gives the following achievements:



- To determine the effect that various typical building spacings (street canyon widths) will have upon the rate of convective heat transfer coefficient.
- To determine the variation of the convective heat transfer coefficient across the various surfaces of a building, and to ascertain **the distribution of coefficients across each surface**.
- To present the results in a manner that permits incorporation into future urban climate and building thermal models.

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Thank you!

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