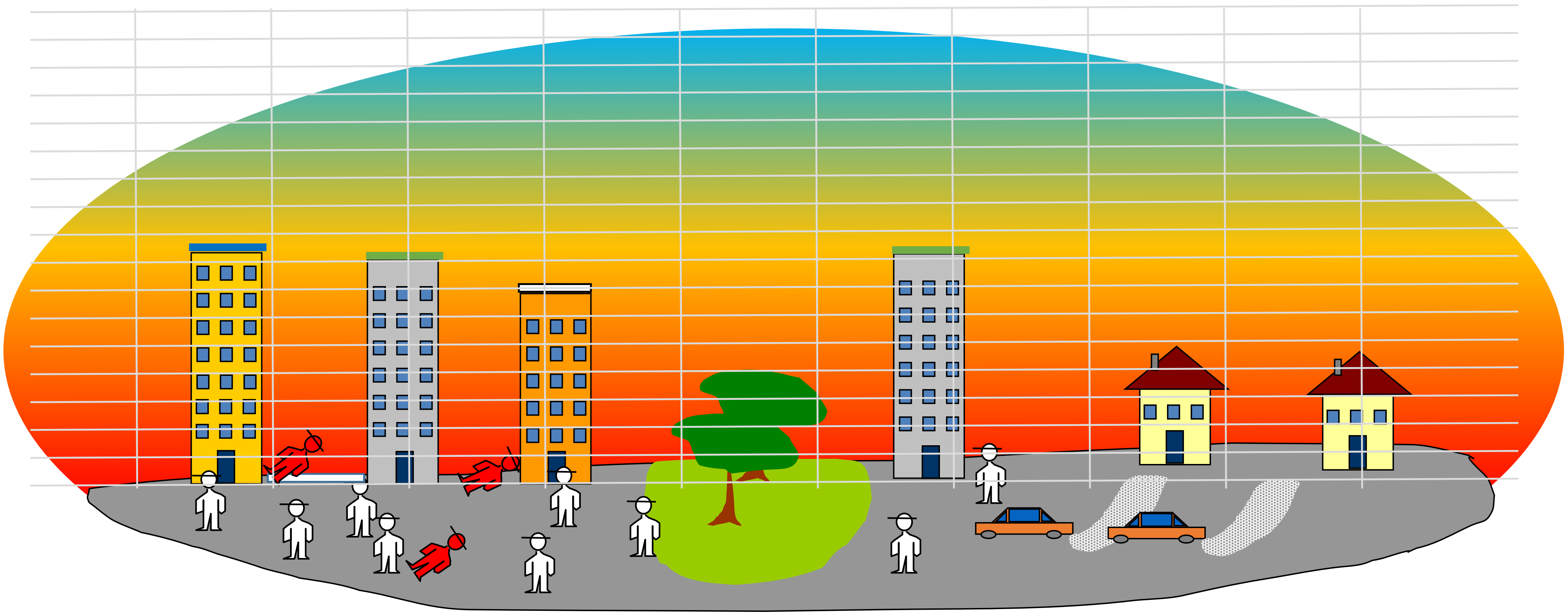
BEP-BEM

Alberto Martilli

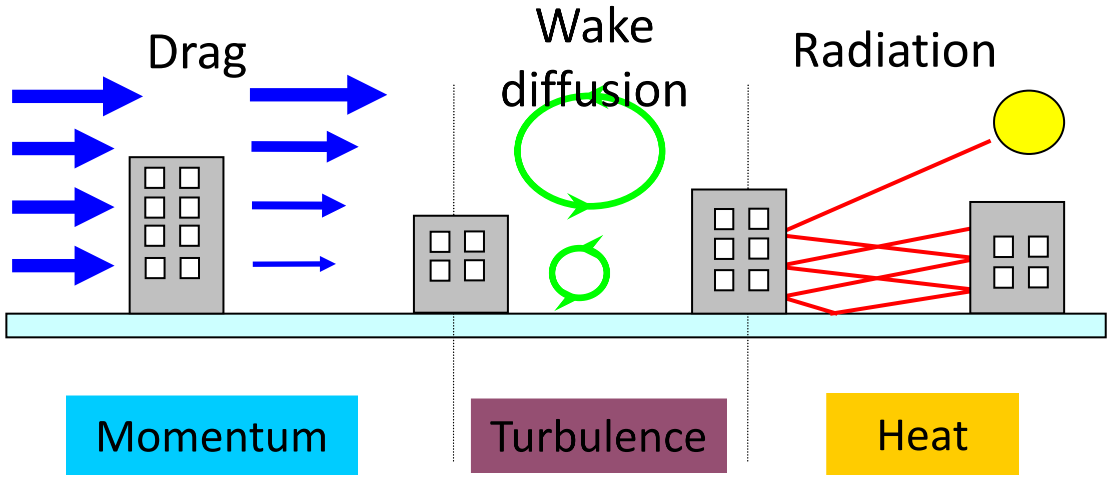


GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA, INNOVACIÓN Y UNIVERSIDADES
Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

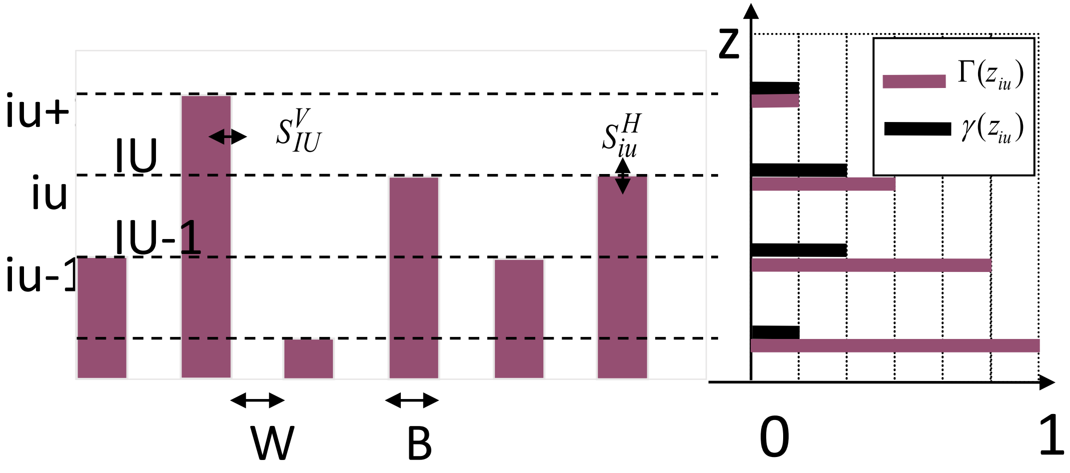
BEP (Building Effect Parameterization, Martilli et al. BLM 2002)

AN URBAN SURFACE EXCHANGE PARAMETERISATION FOR MESOSCALE MODELS

ALBERTO MARTILLI[1,*], ALAIN CLAPPIER[1] and MATHIAS W. ROTACH[2]
[1] *Swiss Federal Institute of Technology, Lausanne (EPFL), Air and Soil Pollution Laboratory, 1015-Lausanne, Switzerland;* [2] *Swiss Federal Institute of Technology, Zurich (ETHZ), Institute for Climate Research, 8057-Zurich, Switzerland*



BEP is implemented in FVM (swiss model), ***WRF*** , LM (Lokal Model), UK model.



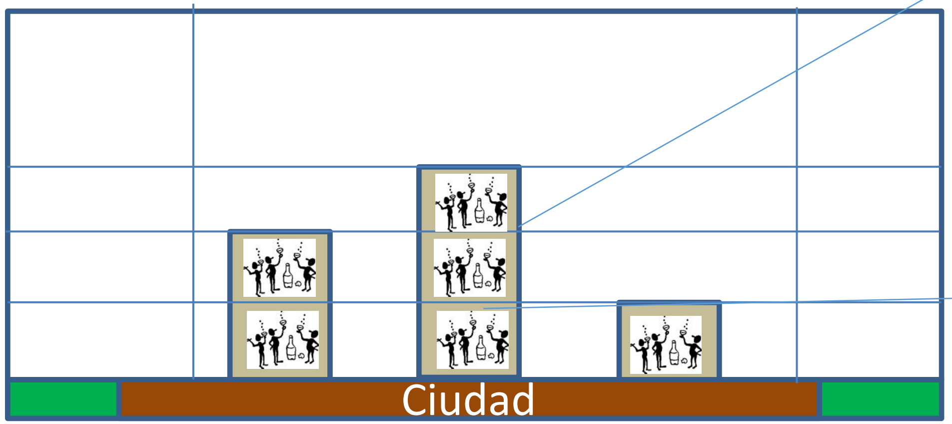
Turbulent scheme of Bougeault and Lacarrere, (1989)

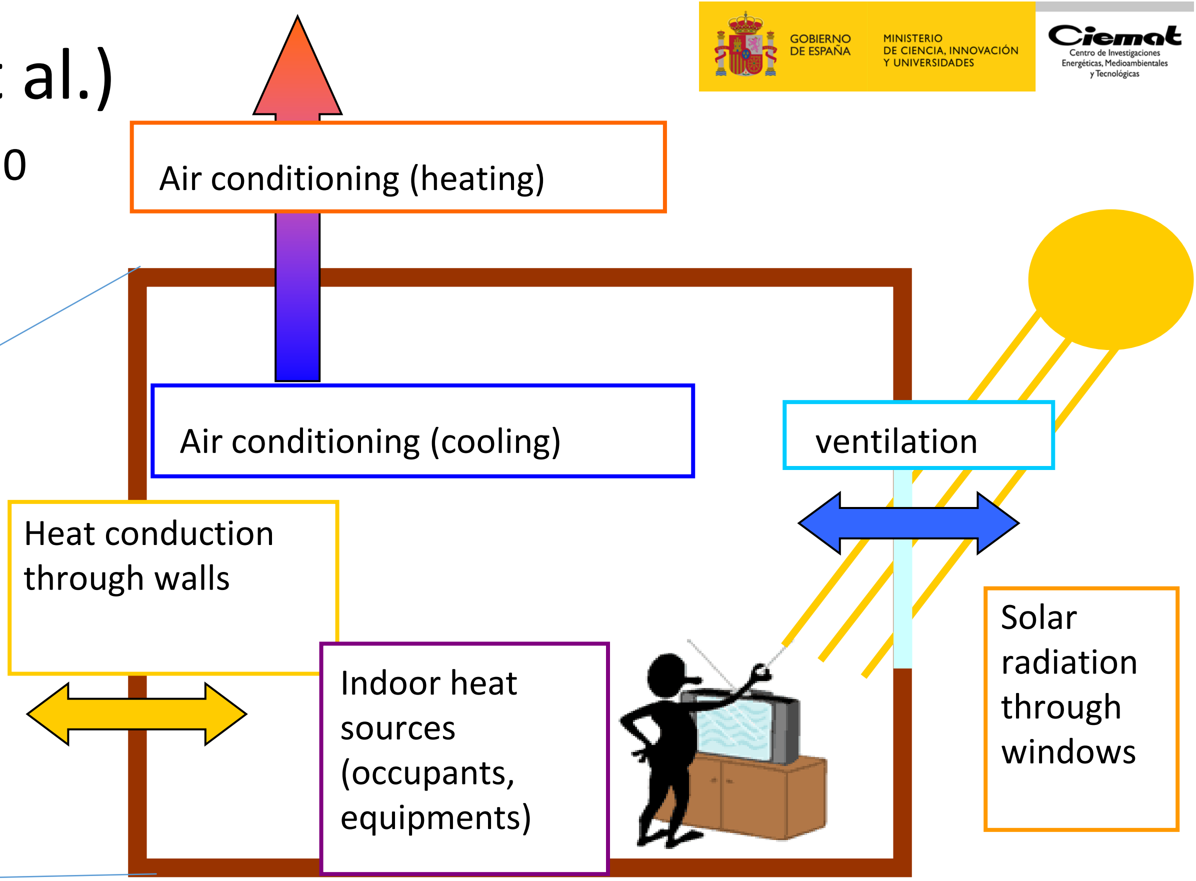
BEM (Building Energy Model, Salamanca et al.)

Theor Appl Climatol 2010

A new building energy model coupled with an urban canopy parameterization for urban climate simulations—part I. formulation, verification, and sensitivity analysis of the model

Francisco Salamanca · Andrea Krpo · Alberto Martilli · Alain Clappier





$$\rho C_p Vol \frac{\partial T_{indoor}}{\partial t} = H_{people} + H_{equip} + H_{walls} + H_{vent} + H_{windows} + H_{need}$$

Recently added features
(*already in the official release*)

JGR Atmospheres

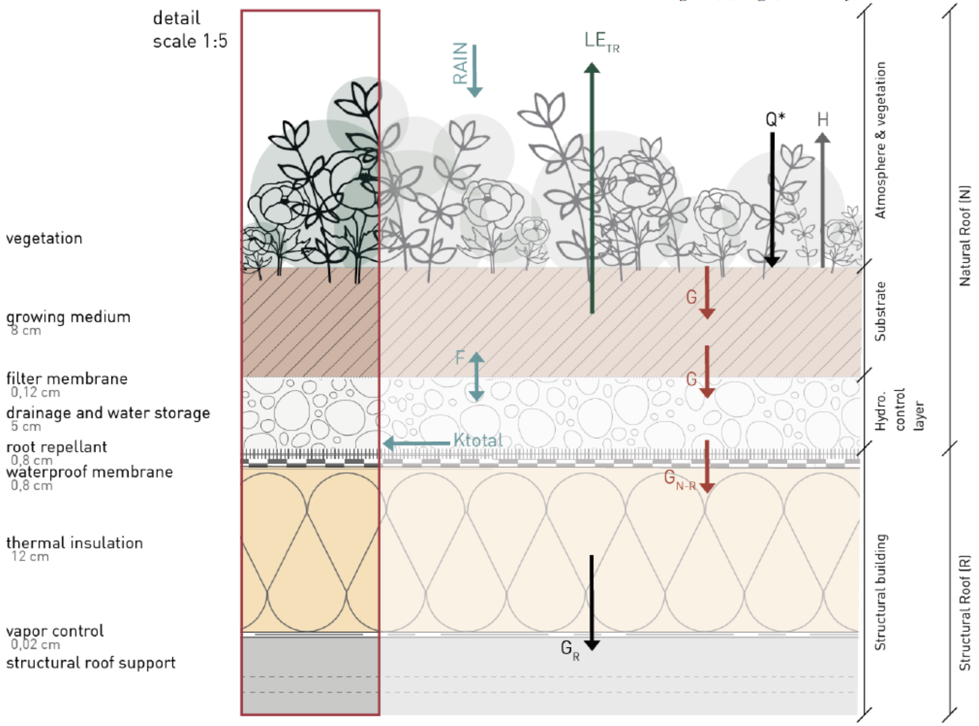
RESEARCH ARTICLE
10.1029/2021JD035002

Key Points:
- New parameterizations of rooftop mitigations strategies are developed

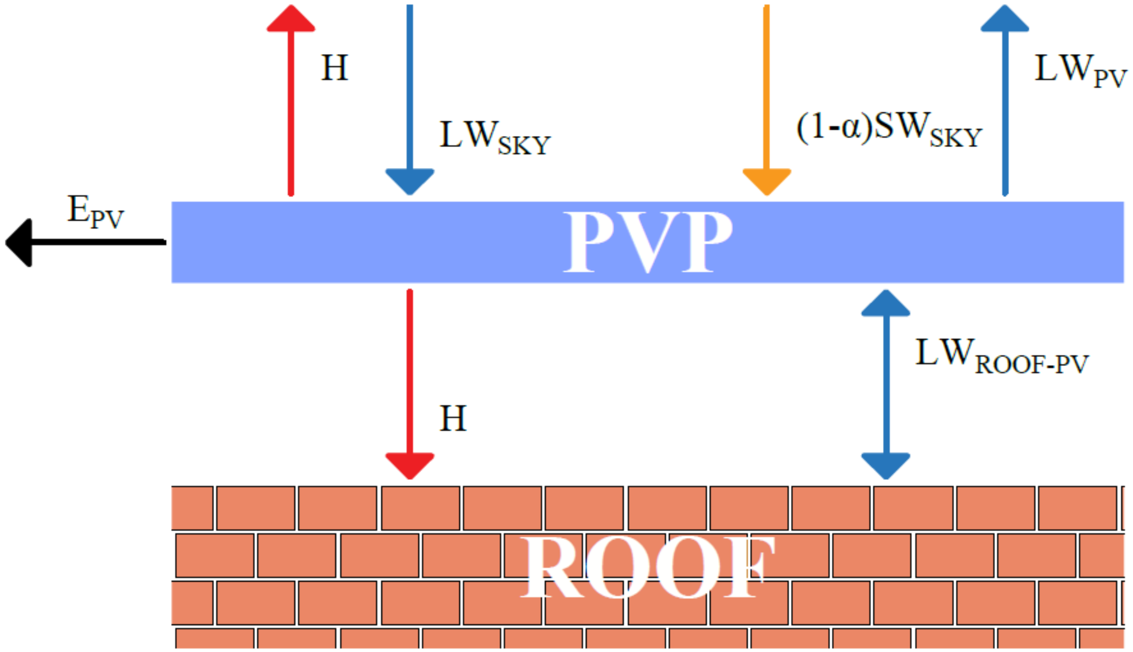
Exploring the Effects of Rooftop Mitigation Strategies on Urban Temperatures and Energy Consumption

A. Zonato[1], A. Martilli[2], E. Gutierrez[3], F. Chen[4], C. He[4], M. Barlage[4], D. Zardi[1], and L. Giovannini[1]

Green roofs



Roof top solar panels

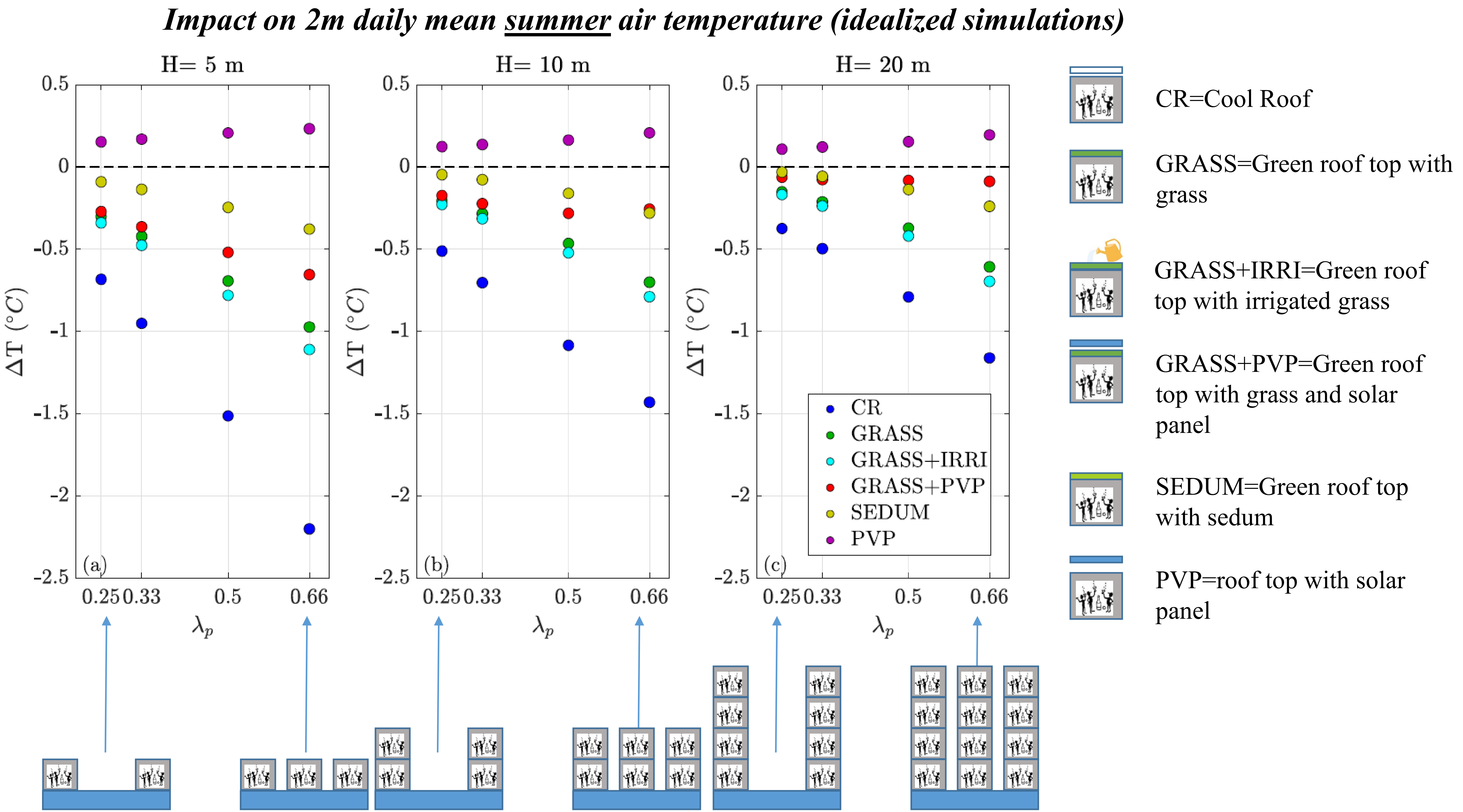


The City College of New York

PhD of Estatio Gutierrez (2015)

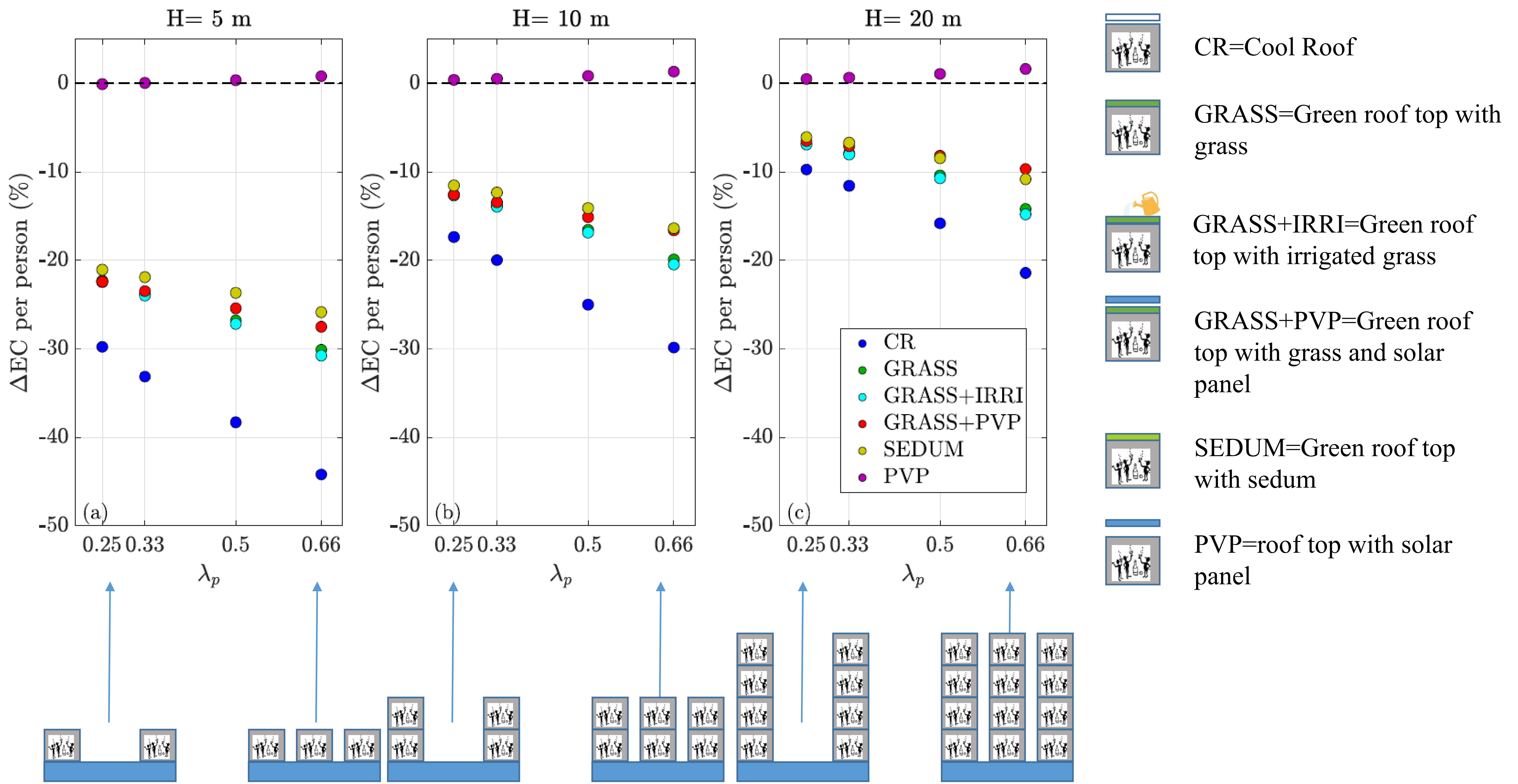
UNIVERSITÀ DI TRENTO

PhD of Andrea Zonato (2021)



Impact on 2m daily mean summer air temperature (idealized simulations)
H= 5 m
H= 10 m
H= 20 m
ΔT (°C)
λp
0.5
0
-0.5
-1
-1.5
-2
-2.5
0.25
0.33
0.5
0.66
(a)
(b)
(c)
CR
GRASS
GRASS+IRRI
GRASS+PVP
SEDUM
PVP
CR=Cool Roof
GRASS=Green roof top with grass
GRASS+IRRI=Green roof top with irrigated grass
GRASS+PVP=Green roof top with grass and solar panel
SEDUM=Green roof top with sedum
PVP=roof top with solar panel

Impact on daily summer energy consumption (idealized simulations)



Impact on daily summer energy consumption (idealized simulations)

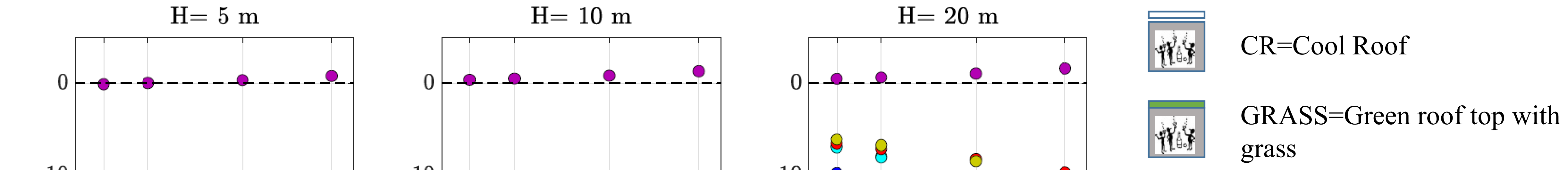
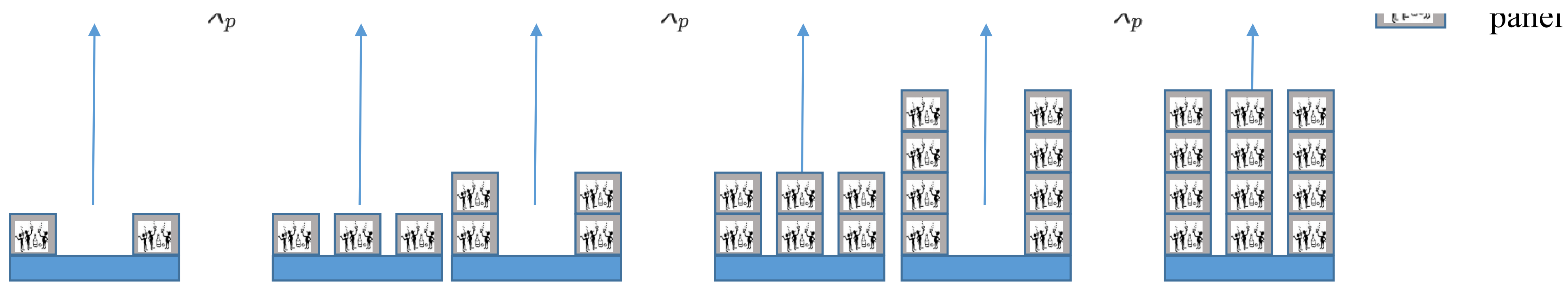


Table 2

Energy Saving Per Person (kWh/Person) During Summertime in the Photovoltaic Panel Cases in Absolute Values and in Percentage (in Brackets) With Respect to the Air Conditioning Systems Consumption

λ_p				
H	0.25	0.33	0.50	0.66
5 m ()	– 2.78 (–211%)	– 2.77 (–212%)	– 2.77 (–213%)	– 2.76 (–218%)
10 m ()	– 0.23 (–107%)	– 1.38 (–109%)	– 1.38 (–113%)	– 1.37 (– 119%)
20 m ()	– 0.69 (–53%)	– 0.68 (–55%)	– 0.68 (–60%)	– 0.67 (–67%)



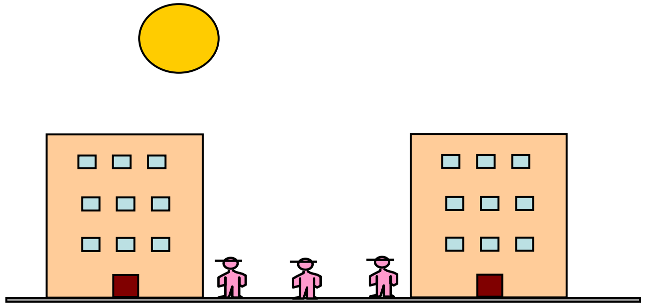
Recently added features
(not yet in the official release)

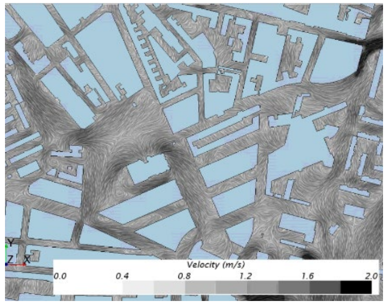
Methodology to compute heat stress, and its subgrid variability

https://doi.org/10.5194/egusphere-2023-1069
Preprint. Discussion started: 19 September 2023

WRF-Comfort: Simulating micro-scale variability of outdoor heat stress at the city scale with a mesoscale model

Alberto Martilli[1], Negin Nazarian[2,3], E. Scott Krayenhoff[4], Jacob Lachapelle[4], Jiachen Lu[2,3], Esther Rivas[1], Alejandro Rodriguez-Sanchez[1], Beatriz Sanchez[1], Jose Luis Santiago[1]





Starting from the two Street direction of BEP-BEM, computes ***6 values of mean radiant temperature***

+

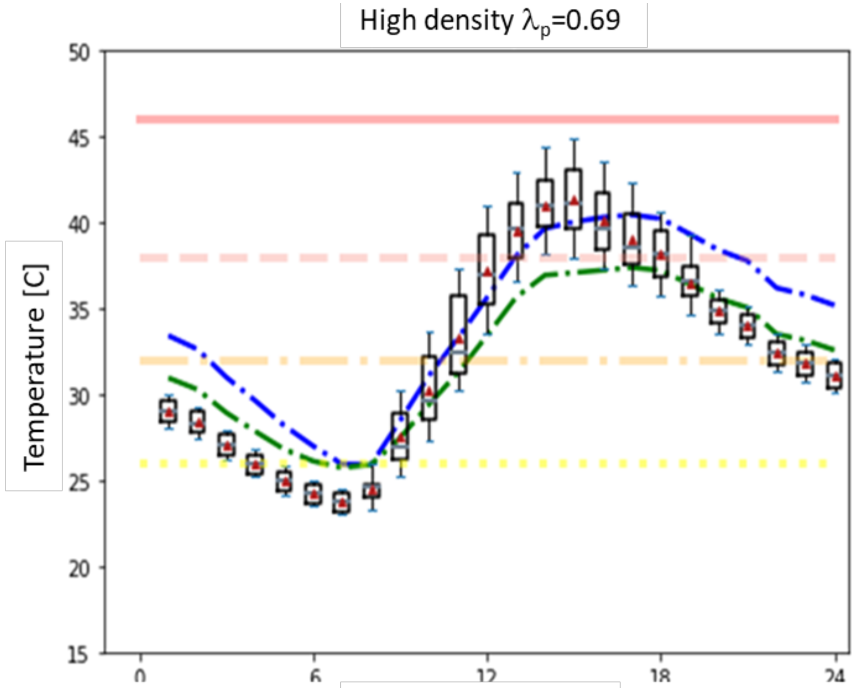
Starting from a database of CFD simulations, deduce a paramterization to estimate ***3 values of wind speed*** as function of urban morphology

+

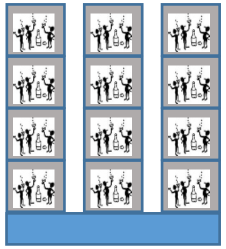
Starting from a typical subgrid variability (+/- 1C) ***3 values of air temperature***

54 possible values of heat stress index (UTCI)

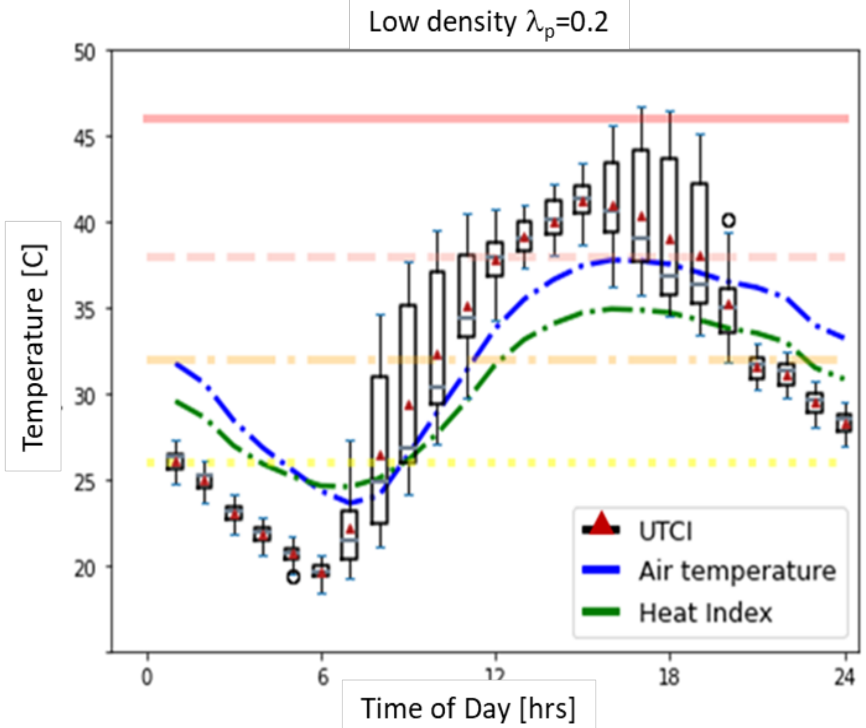
Example for Madrid during heat wave



Dense city center



H/W=1.6
Lambda_p=0.69

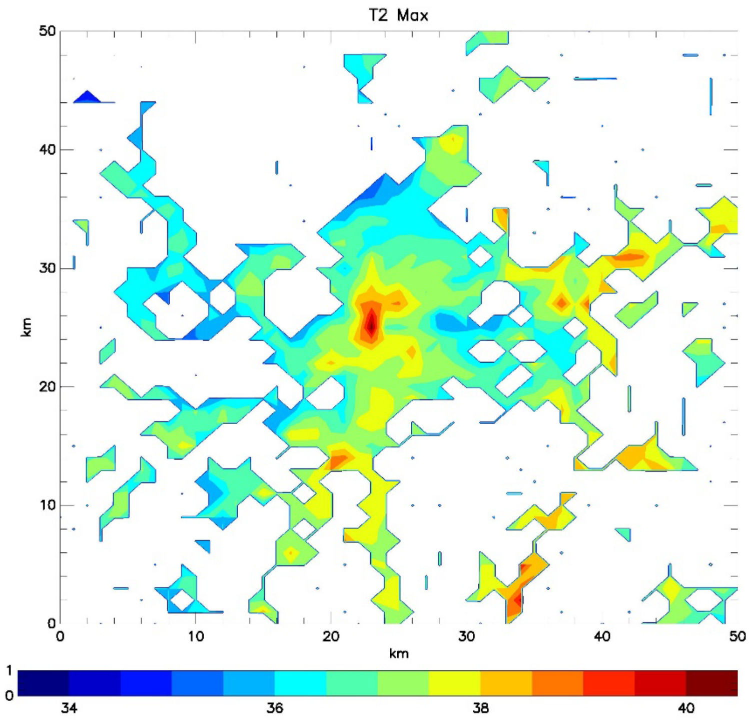


Low density region, south of the city center

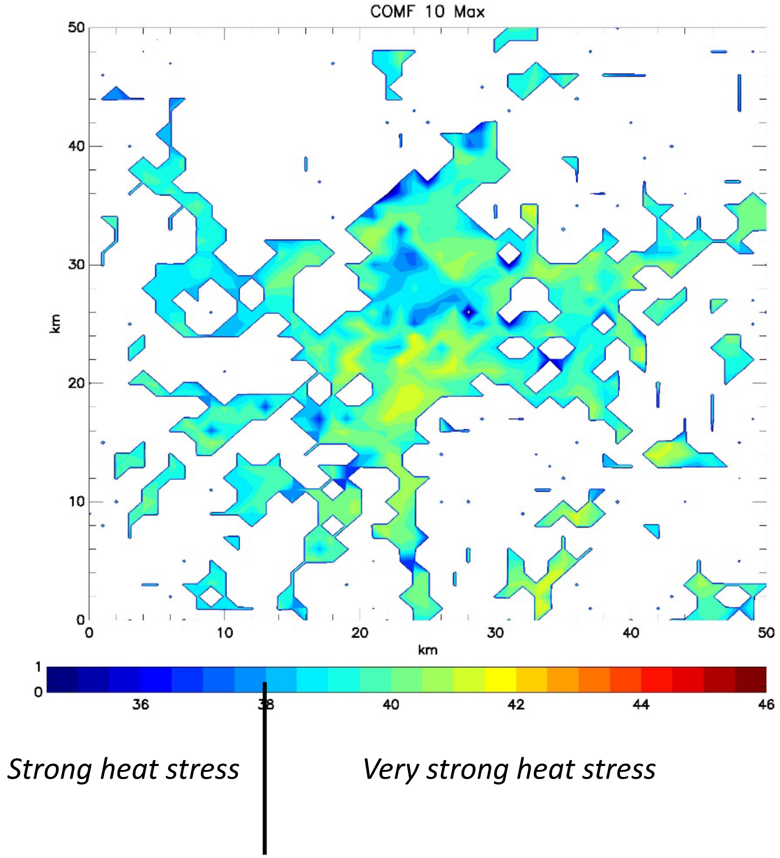
H/W=0.1
Lambda_p=0.2

Spatial distribution

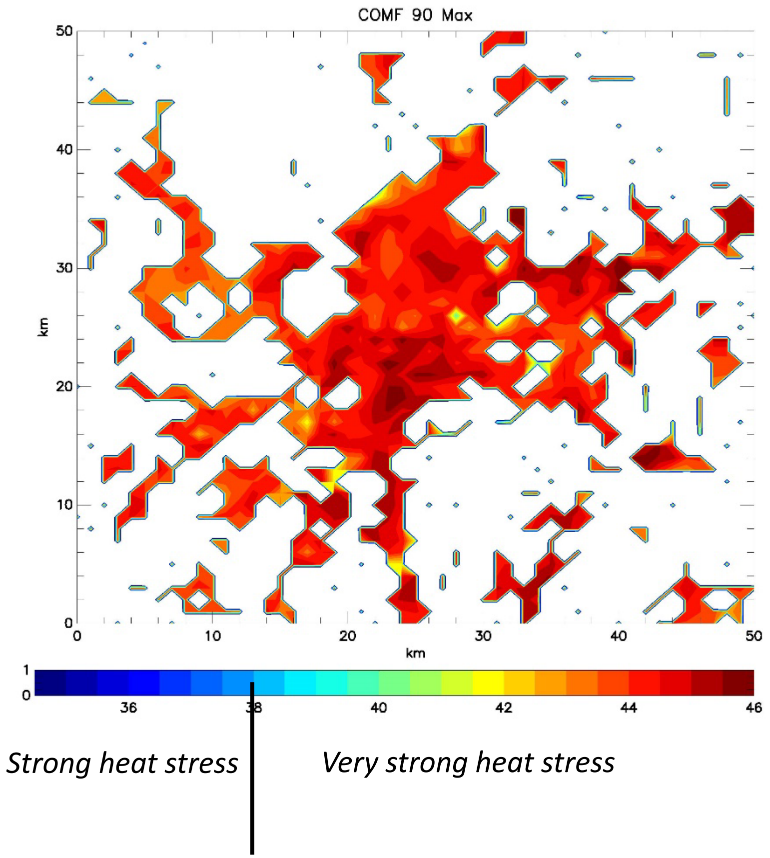
Maximum 2m Air temperature



Maximum 10 percentile UTCI



Maximum 90 percentile UTCI



How to activate it?

In namelist

sf_urban_physics = 3,

Currently coupled to PBL schemes Bougeault and Lacarrère (bl_physics=8), MYJ (bl_physisc=2), and YSU (bl_physics=1 – under testing)

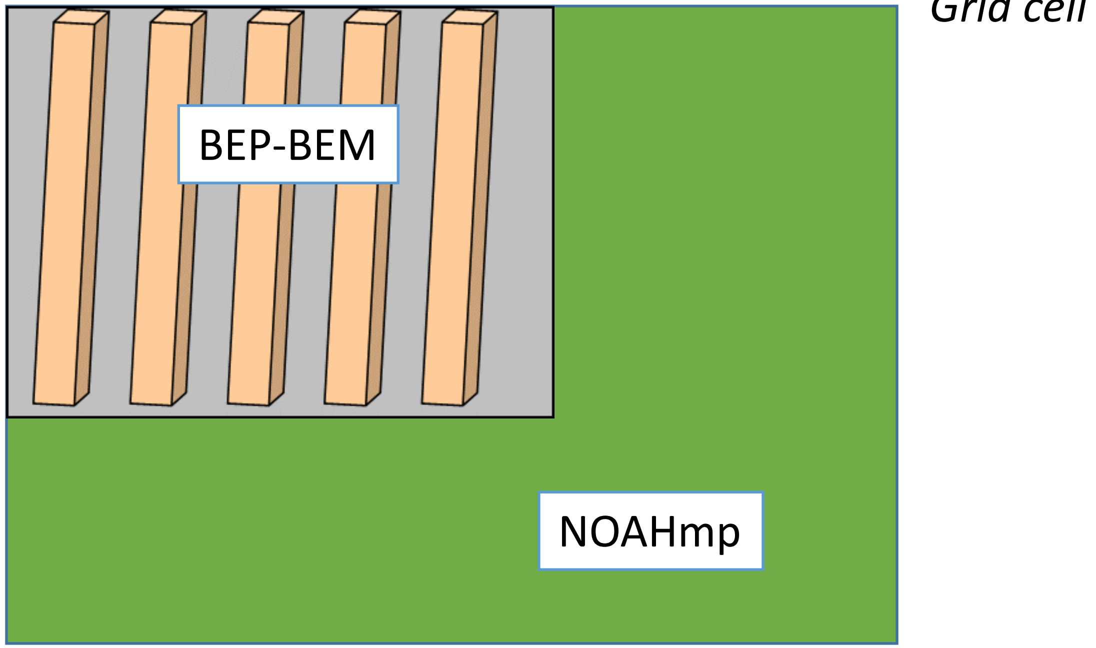
Set specific parameters in

URBPARM.TBL *if you use three urban clases*

or

URBPARM_LCZ.TBL *if you use 11 urban clases (LCZs)*

How does it work?



For each grid cell an urban fraction is defined.

- BEP-BEM computes fluxes of heat, momentum and source/sink terms for TKE for the urban fraction.
- NOAHmp (or NOAH) computes heat and momentum fluxes for the non-urban fraction, using the vegetation class indicated by NATURAL in VEGPARM.TBL *(alternatively it can be derived point by point based on LADUSEF – not in standard version yet).*
- Fluxes are weitghed averaged

How to give ***morphological parameters*** to BEP-BEM.

1) Via URBPARM.TBL

Section STREET PARAMETERS to provide street width, building width and distribution of building hieghts for each one of the three urban landuse classes (51,52,53).

Urban_fraction

2) Via URBPARM_LCZ.TBL

Activated with use_wudapt_lcz=1 in namelist.input

Section STREET PARAMETERS, to provide street width, building width and distribution of building heights for each one of the 11 urban landuse classes (51,52,53,54,55,56,57,58,59,60,61), corresponding to the urban LCZ of Stewart and Oke (2012). Typically these are mid-range values of those of S-O.

Urban_fraction

3) Via interpolation of CGLC_MODIS_LCZ_global from M. Demuzere, available in the WRF webpage (you need to download it and use as input in GEOGRID.TBL).

Activated with use_wudapt_lcz=1, and use_lcz_interpolation =1 in namelist.input

Starting from the LCZ data at 100m resolution, it averages the urban fraction, street width, building width and distribution of building heights provided for each LCZ in ***URBPARM_LCZ.TBL***

4) Gridded by modifying field URB_PARAM and FRC_URB2D in geo_em, files:

URB_PARAM(i,91,j)=lambda_p (plan area building density)

URB_PARAM(i,95,j)=lambda_b (density of building surfaces, vertical+horizontal)

URB_PARAM(i,94,j)= mean building height

URB_PARAM(i,118-132,j)=distributionmo f building heights (every 5m by default)

Sources of gridded data of *urban morphology* and *urban fraction*

Readily available in *WPS Geographical Input Data for Specific Applications* in WRF webpage:
NUDAPT= National Urban Data and Access Portal Tool (Ching et al. *BAMS*, 2009). Detailed of urban morphology for parts of some US cities.
nlcd= urban fraction fomr nlcd at 30m resolution for US

Soon to be available
GLOBUS: GLObal Building heights for Urban Studies
Data for over 1000 cities worldwide
Format ready to be used in geogrid.exe
Harsh G. Kamath and Dev Nyiogi (University of Austin)

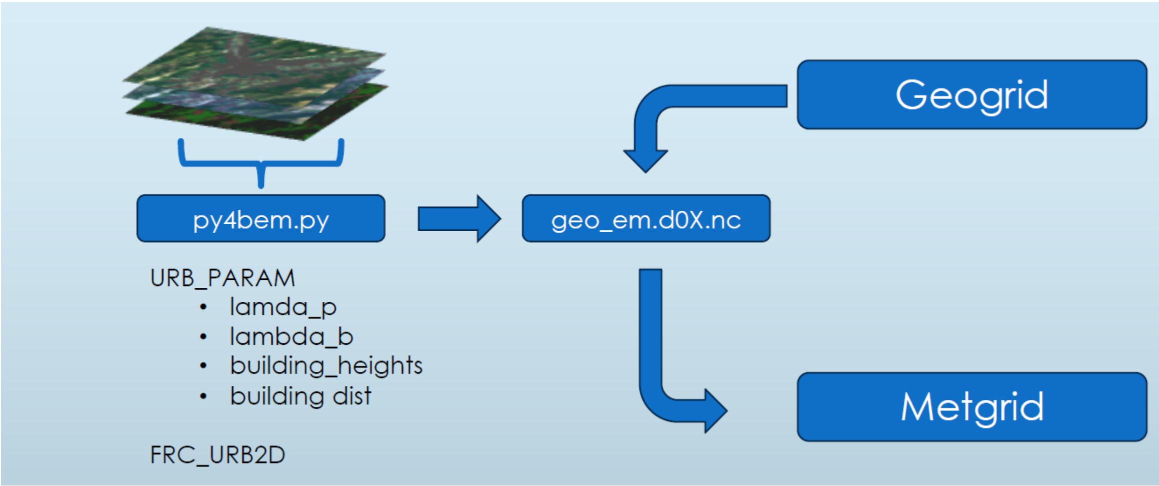
TEXAS
The University of Texas at Austin

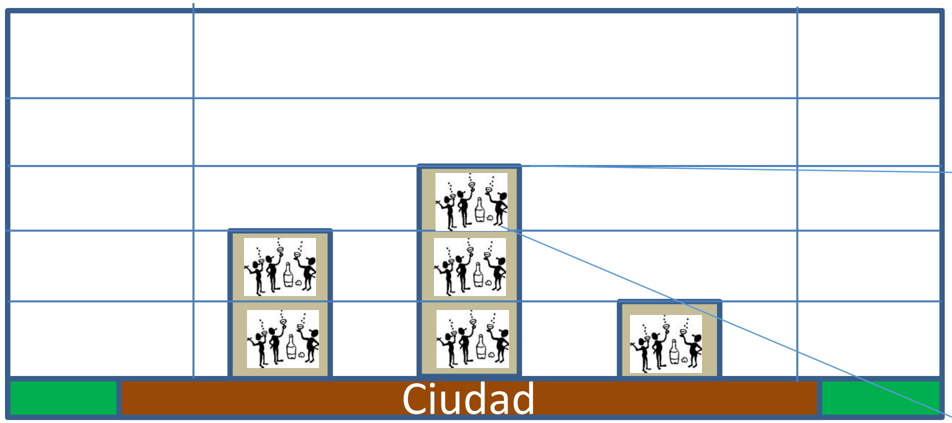
https://tinyurl.com/ut-globus-data

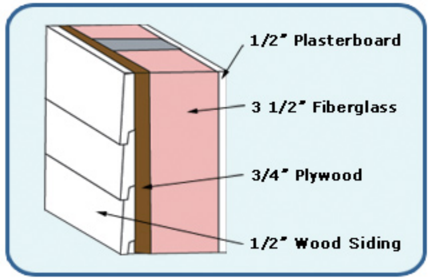
Building heights and urban canopy parameters for urban modeling
Harsh Kamath, Manmeet Singh, and Dev Niyogi

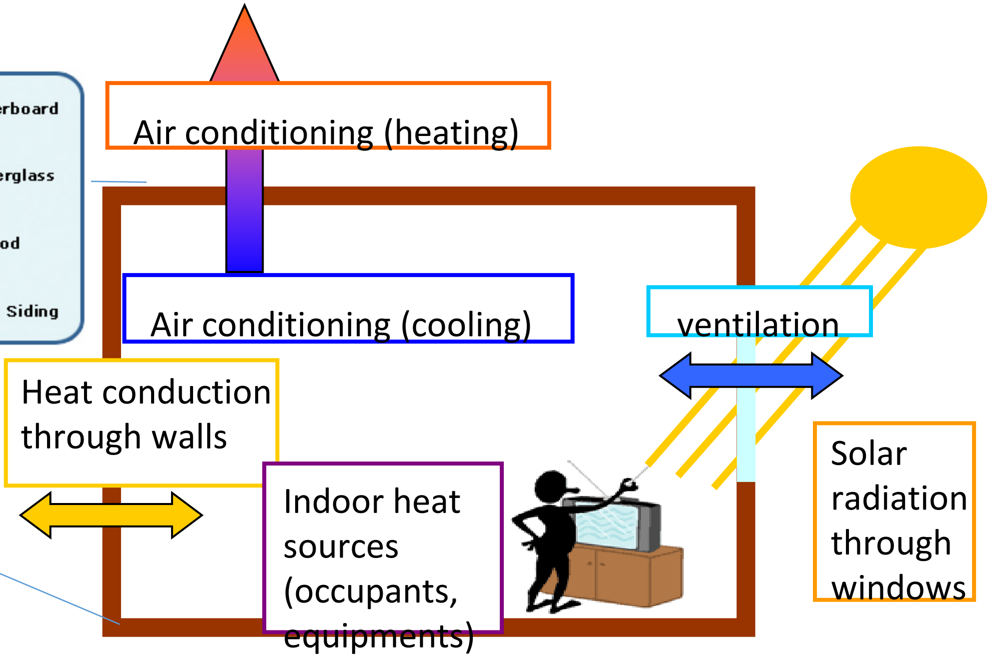
Do it yourself!

Many sources of data available (LIDAR, Openstreetmap, etc.)
Pyhton script to modify geo_em files
Thanks fo Jacobo Gabeiras (U. Grenoble)









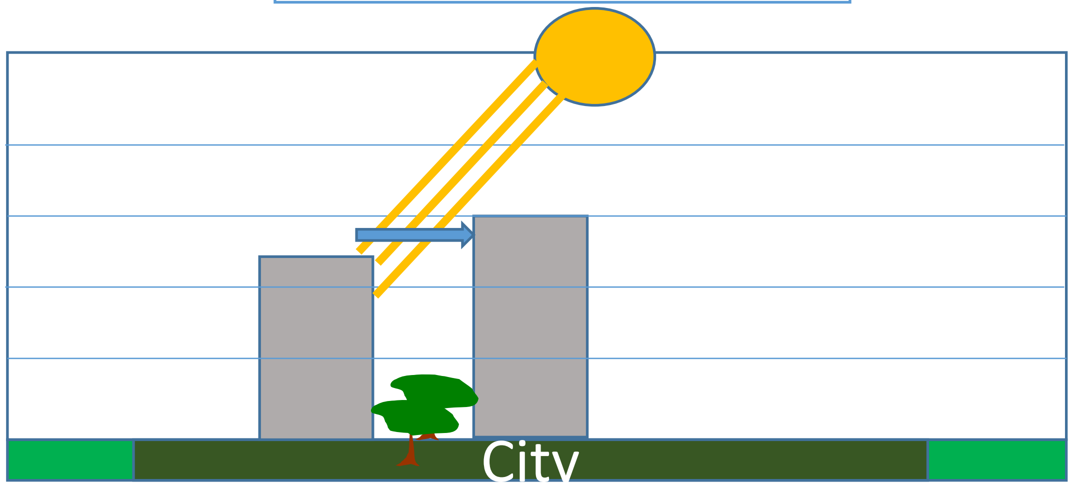
Currently the ***thermal and human properties*** are assgned per urban class (LCZ). ***Work in progress to give them gridded***.

Thermal properties:
CAPR: Heat capacity of roof [J m{-3} K{-1}]
CAPB: Heat capacity of building wall [J m{-3} K{-1}]
AKSR: Thermal conductivity of roof [J m{-1} s{-1} K{-1}]
AKSB: Thermal conductivity of building wall [J m{-1} s{-1} K{-1}]
ALBR: Surface albedo of roof [fraction]
ALBB: Surface albedo of building wall [fraction]
EPSR: Surface emissivity of roof [-]
EPSB: Surface emissivity of building wall [-]

Human properties
COP: Coefficient of performance of the A/C systems [-]
BLDAC_FRC: fraction of buildings installed with A/C systems [-]
COOLED_FRC: fraction of cooled floor area in buildings [-]
TIME_ON: Initial local time of A/C systems, [h]
TIME_OFF: End local time of A/C systems, [h]
TARGTEMP: Target Temperature of the A/C systems, [K]
GAPTEMP: Comfort Range of the indoor Temperature, [K]
TARGHUM: Target humidity of the A/C systems, [Kg/Kg]
GAPHUM: Comfort Range of the specific humidity, [Kg/Kg]
PERFLO: Peak number of occupants per unit floor area, [person/m^2]
HSEQUIP: Diurnal heating profile of heat generated by equipments
HSEQUIP_SCALE_FACTOR: Peak heat generated by equipments, [W/m^2]

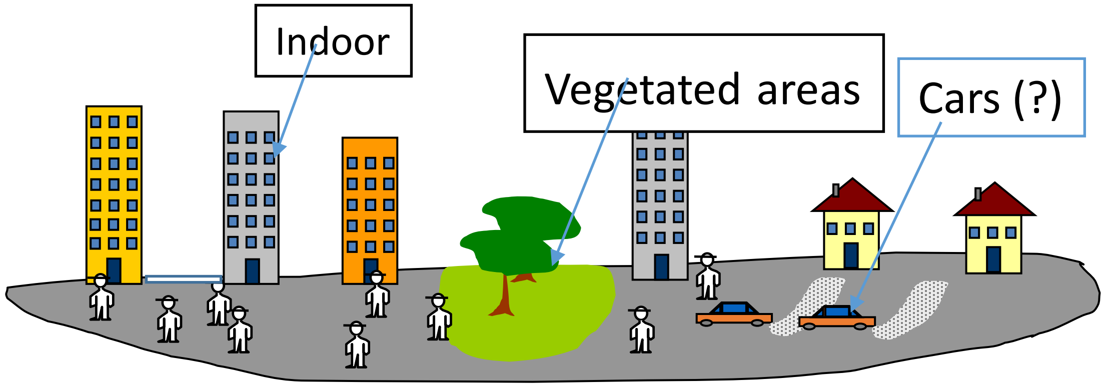
Ongoing/future work:

Introduction of Street trees



- Simplified version (only affecting shortwave radiation) - available
- BEP-tree (Krayehnhoff – work in progress)
- UT version (NOAHmp linked. By Kamath and Niyogi –work in progress)

Extend computation of heat stress to:



More on current and future plans about BEP-BEM can be seen here:

https://drive.google.com/drive/u/3/folders/1LoqAjRKpwqLPeh9rwXT4JPk0GLMg1ZNw

THANKS!