Evaluation of building energy use: from the urban to the building scale

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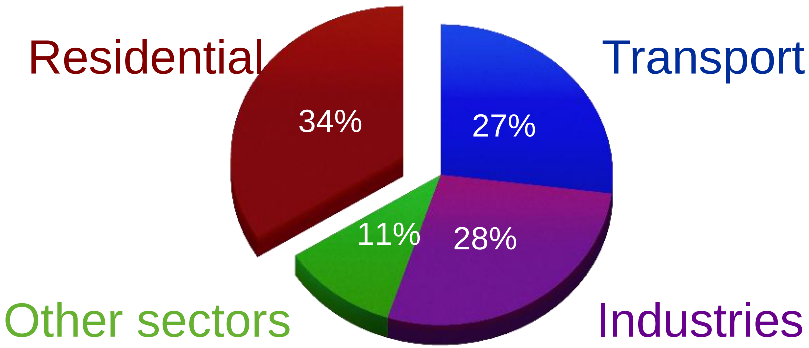
ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

future energy efficient buildings & districts

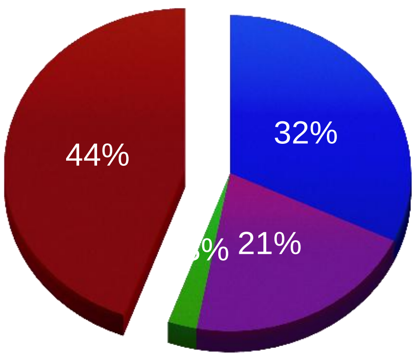
- Introduction
- Objectives
- Methodology
- Results
- Conclusions and future works

Buildings and energy use

Energy consumption by sectors

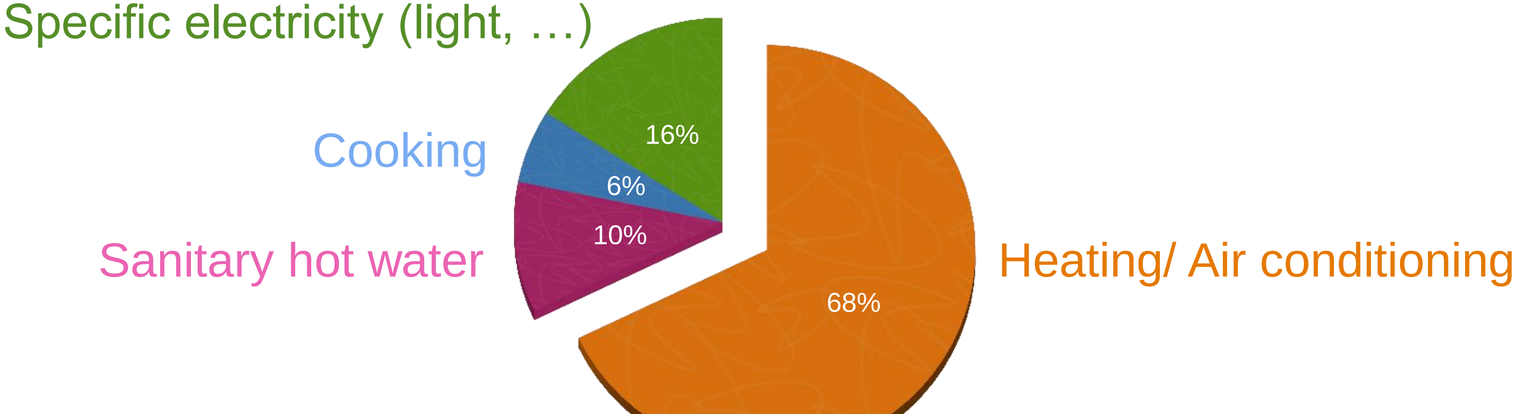


World (IEA, 2012)



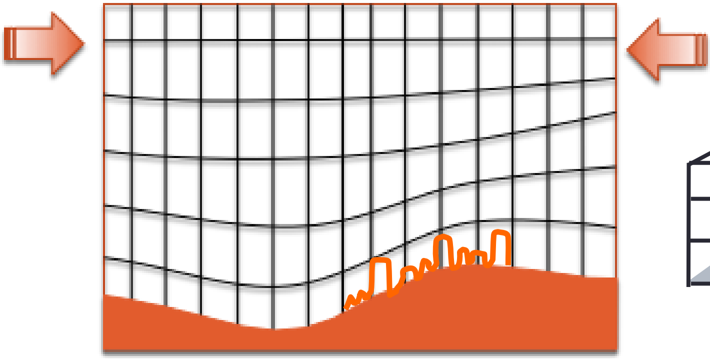
France (ADEME, 2013)

Energy use inside buildings



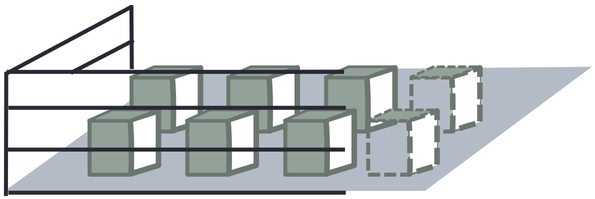
France (ADEME, 2013)

Meso-scale models



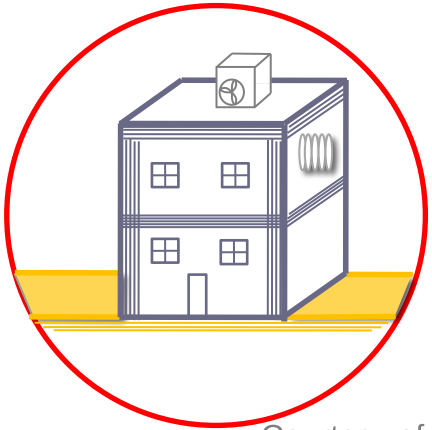
WRF (Skamarock et al., 2008)
Meso-NH (Lafore et al., 1997)
FVM (Clappier et al., 1996)

Rugosity
Influence of obstacles
 - Additional term in equations



BEP (Martilli et al., 2002)
UCM (Kusaka et al, 2001)
TEB (Masson, 2000)

Buildings / Streets
Solar radiation

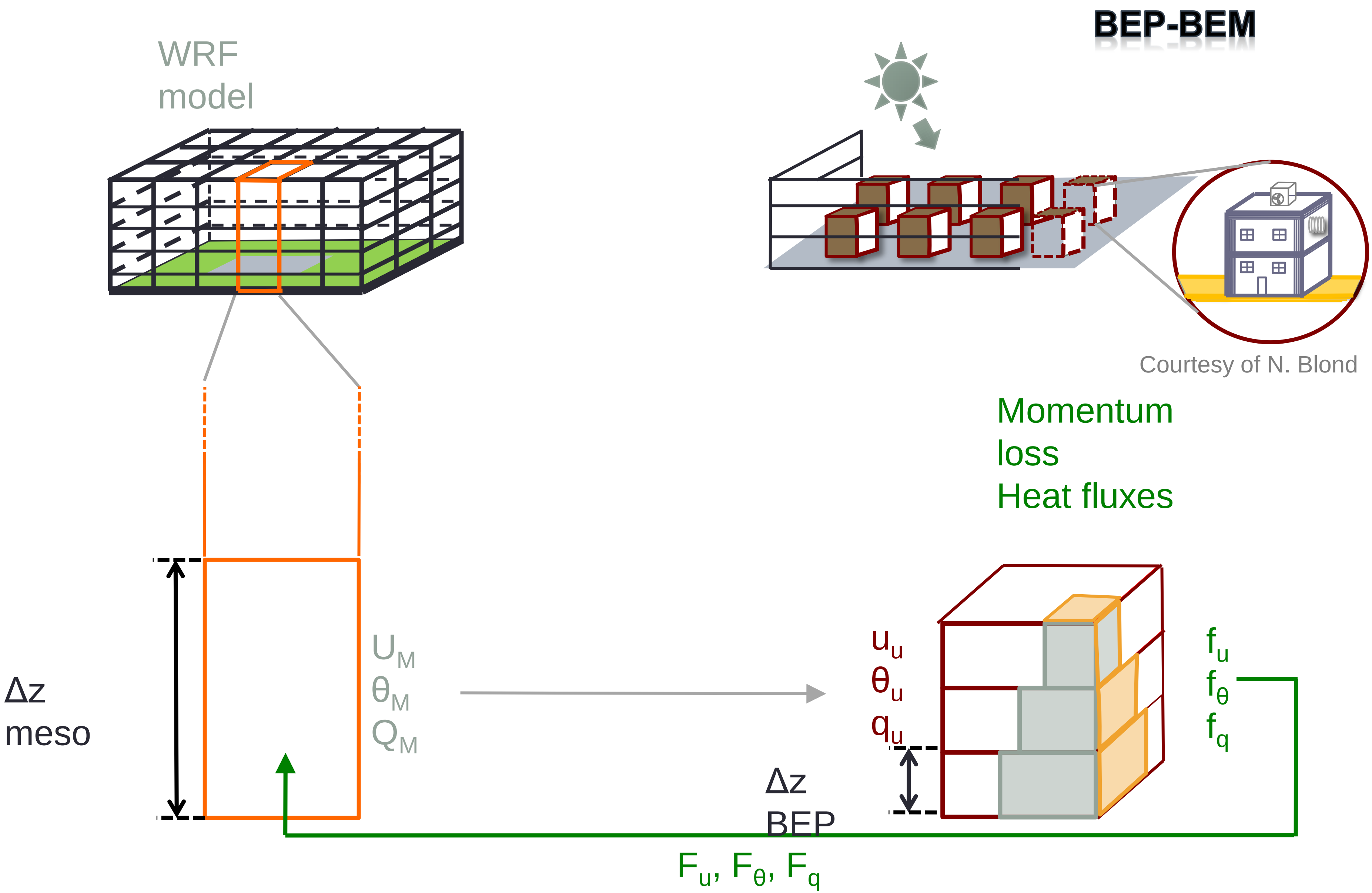


Courtesy of N. Blond

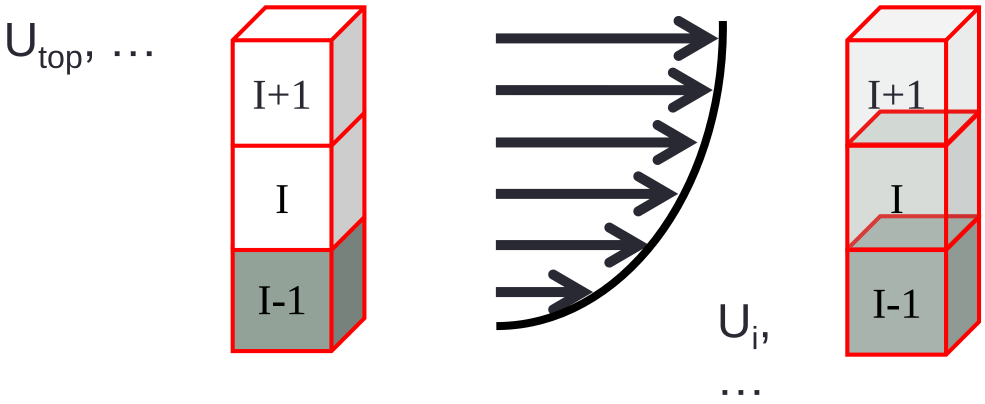
BEM (Krpo et al., 2010)
(Kikegawa et al. 2003)

Walls, roofs & streets
Window
Cooling/ Heating

Meso-scale – coupling with BEP-BEM



Governing Equations



'*M*' – meso-scale value
'*c*' – canopy value
'I' – variable at centre
'*U*' – wind speed (ms^{-1})

MOMENTUM

$$\frac{\partial U}{\partial t} = \frac{\partial}{dz}\left(\mu_t \frac{\partial U}{\partial z}\right) + f_u^s$$

Diffusion Fluxes

$$\mu_t = C_\mu \sqrt{E} l$$

HEAT

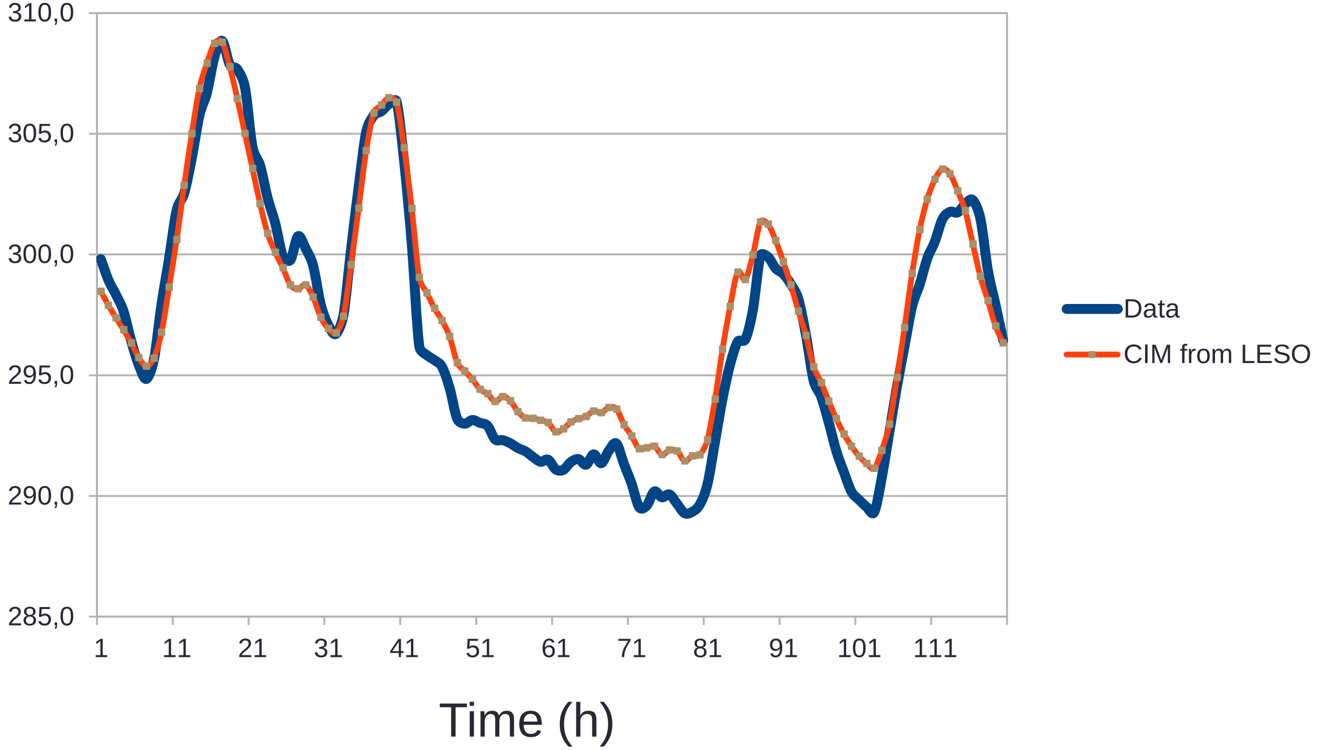
$$\frac{\partial \theta}{\partial t} = \frac{\partial}{dz}\left(\kappa_t \frac{\partial \theta}{\partial z}\right) + f_\vartheta^s$$

Diffusion Fluxes

$$\kappa_t = \frac{C_\mu \sqrt{E} l}{\Pr}$$

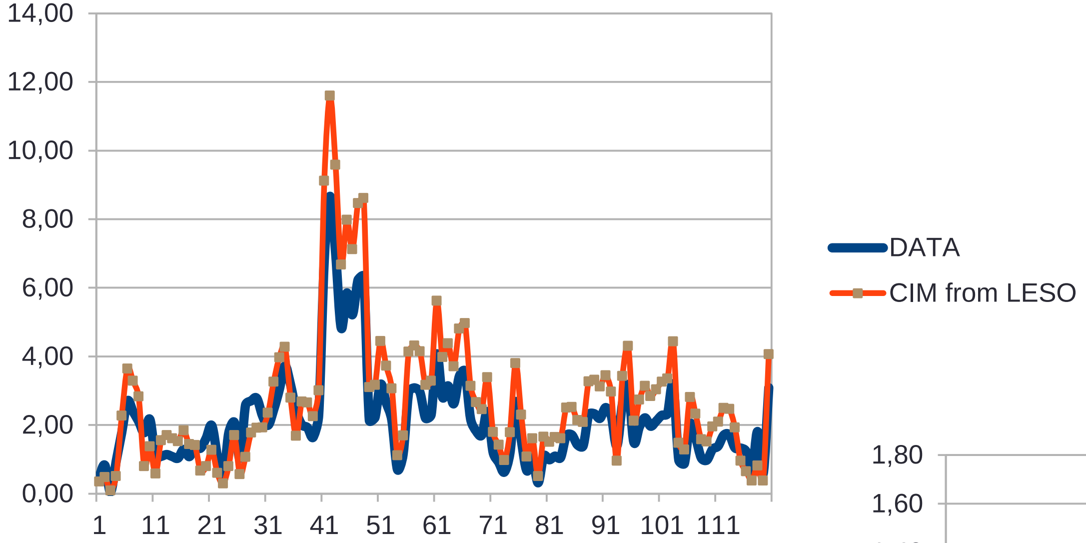
$$\frac{\partial E}{\partial t} = \frac{\partial}{\partial z}\left(\lambda_t \frac{\partial E}{\partial z}\right) + P\left(1 - C_G Ri_f\right) - \varepsilon + f_e^s$$

Validation of CIM



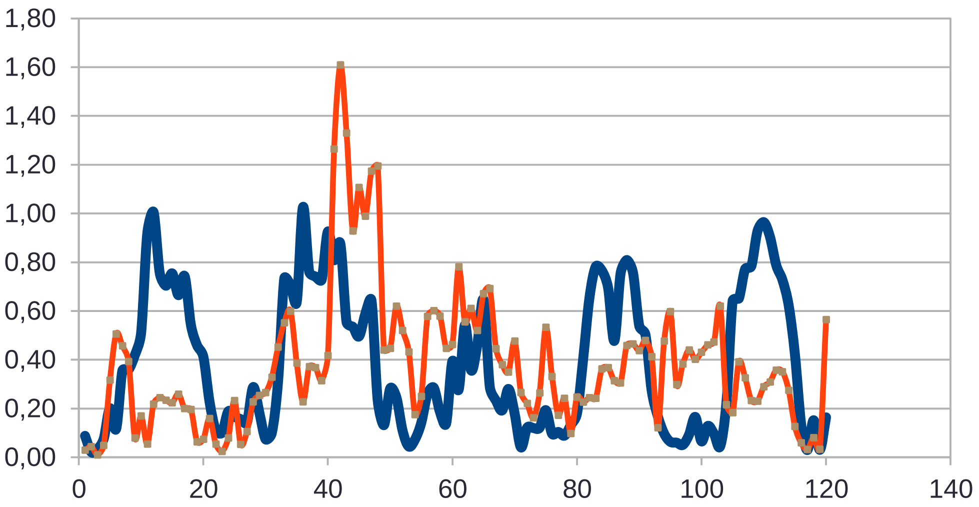
Potential temperature (K) at 2m

Validation of CIM – Wind speed



Time (h)

Wind speed (ms^{-1}) at 10m



Time (h)

Wind speed (ms^{-1}) at 2m

Mauree et al., 2015

Coupling with citysim

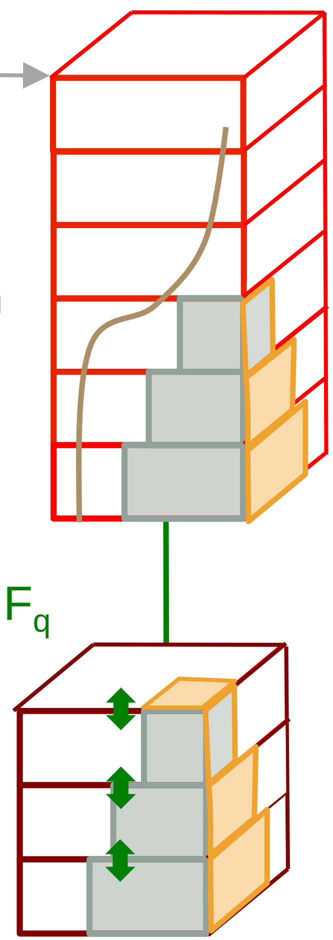
Canopy Interface Model

CITYSIM

Init.

Occ. Vol. & Surf., height ← Average geometrical characteristics of buildings

Meteonorm data
Model data …



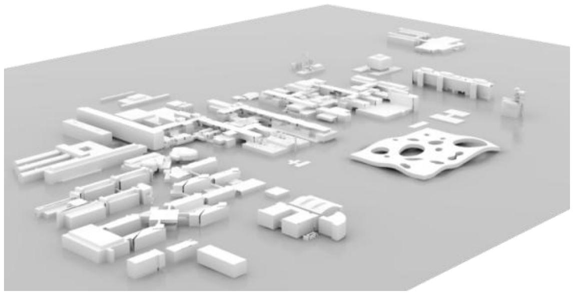
U_u
θ_u
q_u

F_u, F_θ, F_q

Momentum
loss
Heat fluxes

θ_s

Convection
coefficient /
Wind speed &
Air temperature



EPFL- Courtesy of S. Coccolo

Calculation of h_c

McAdams coefficient

$$h_c = 2.8 + 3U$$

Mirsadeghi et al. 2013

U – wind calculated w.r.t. to attack angle

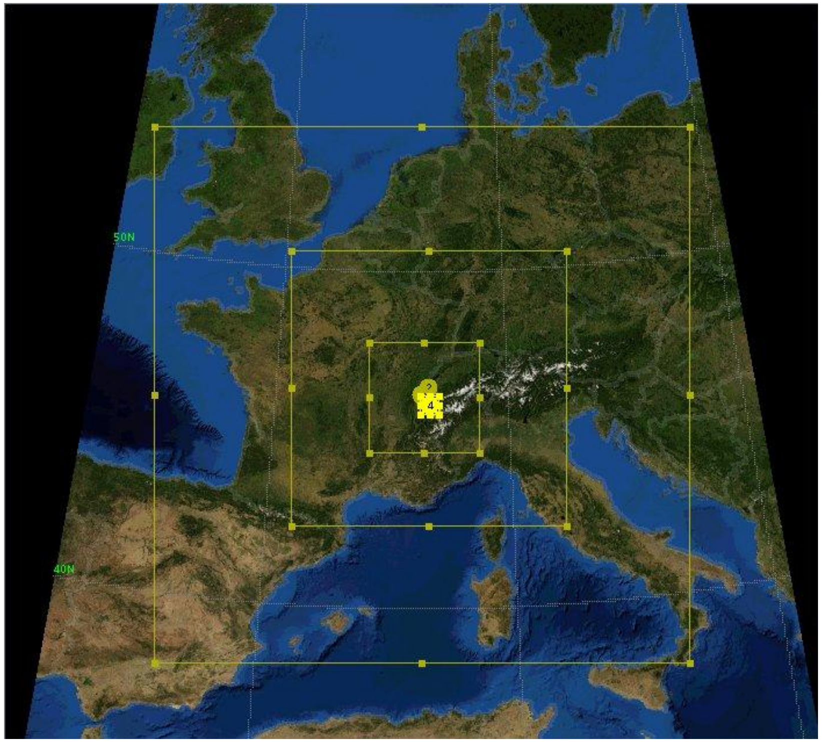
Then calculate a «*pseudo*» h_c^* for CitySim that accounts for a more precise wind profile

$$h_c^* = \frac{h_c(\theta_i - \theta_S)}{\theta_n - \theta_S}$$

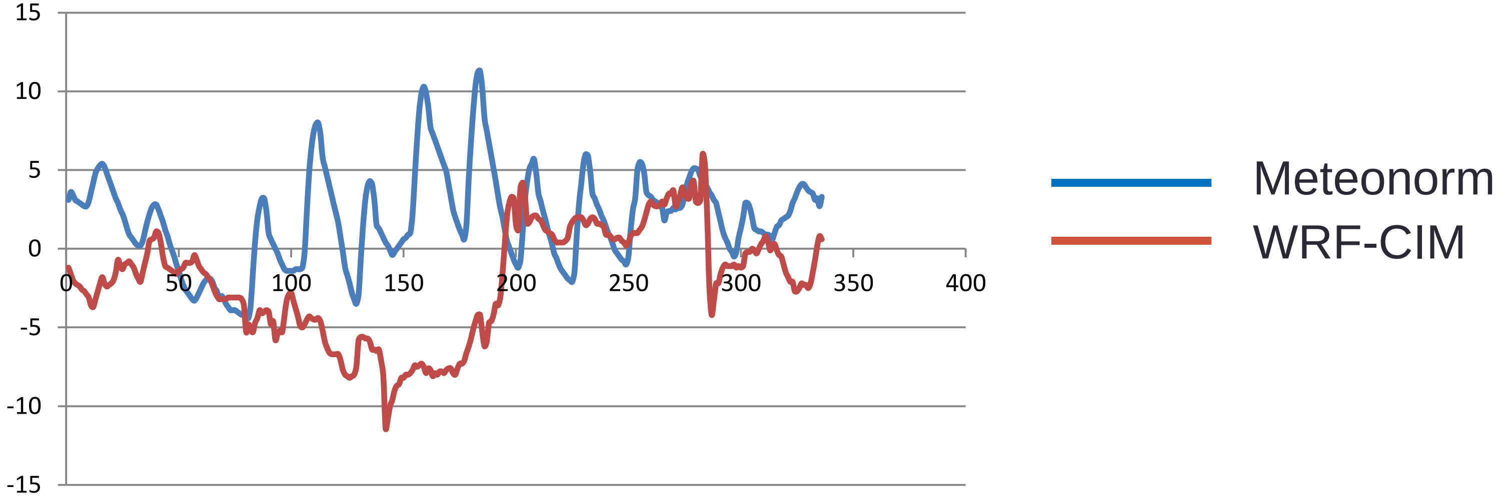
Experiment

Simulation using a nested domain over Lausanne

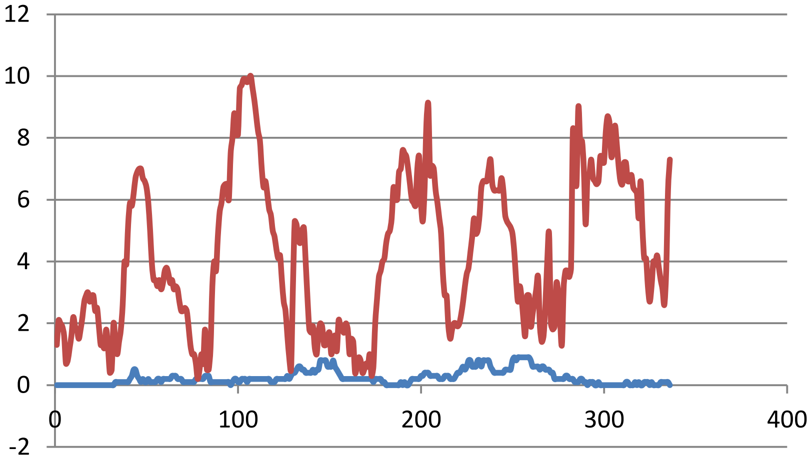
Resolution : 45km – 15km – 3km – 1km
Duration : 14 days December 2010



C.f. WRF-CIM and Meteonorm



Temperature (^{o}C)



Wind speed (ms^{-1})

Energy consumption

- Significant difference in evaluation of energy use

	Energy consumption (kWh/m^2)
Meteonorm	19
WRF+CIM	25
Difference (%)	30

Conclusions

- Proper evaluation of energy use needed to define more precise development / planning scenarios
- Enhance capability of existing tools to give enhance estimation at the neighborhood scale
- Evaluation of building energy use with real meteorological data could help understand processes regulating the energy consumption from the building to urban scale

Future work

- Two-way coupling with feedback to meso-scale model
- Full year analysis of energy consumption
- Increase from one building to whole neighbourhood
  - Implementation of methodology to account for varying building height
- Evaluate the possibility of Renewable Energy integration in urban areas

Thank you!
Questions?

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cisbat.org 9 - 11 SEPTEMBER 2015 EPFL - Lausanne, Switzerland

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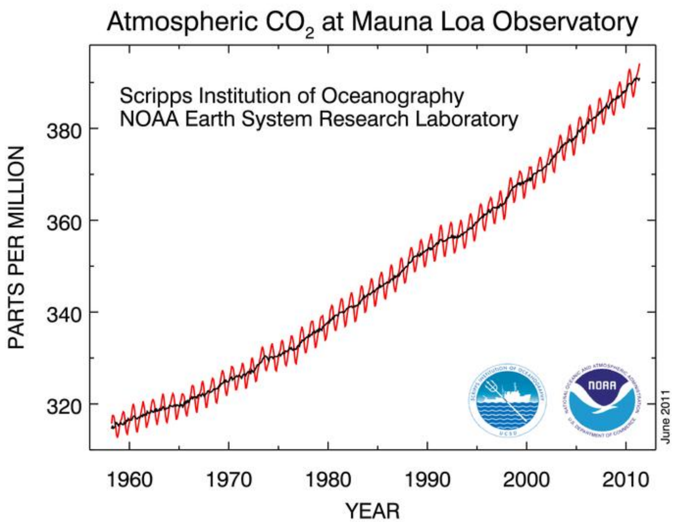
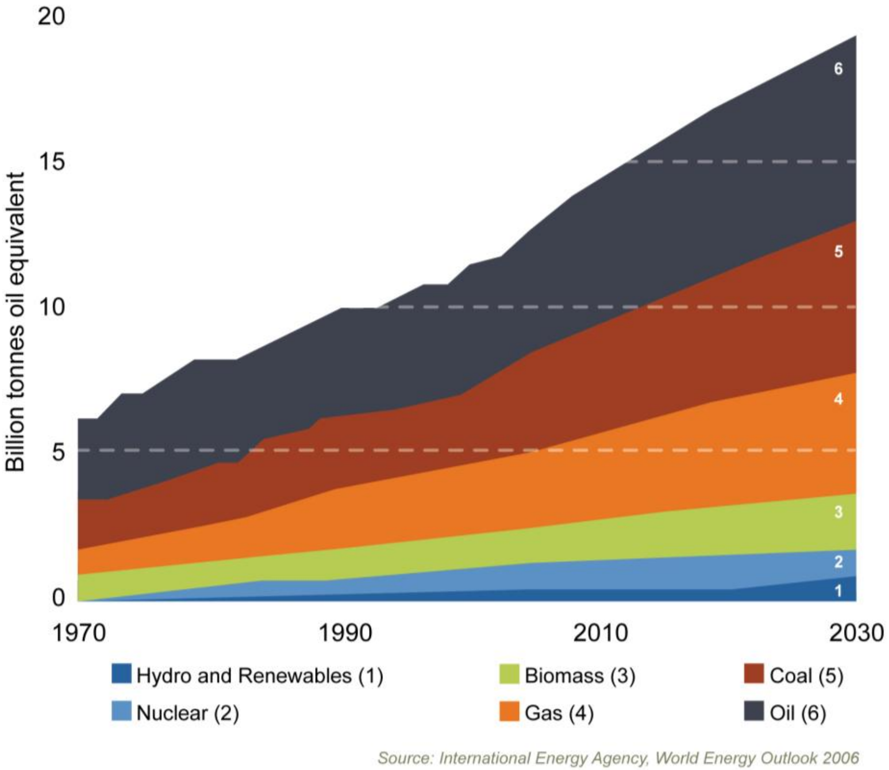
Climate change



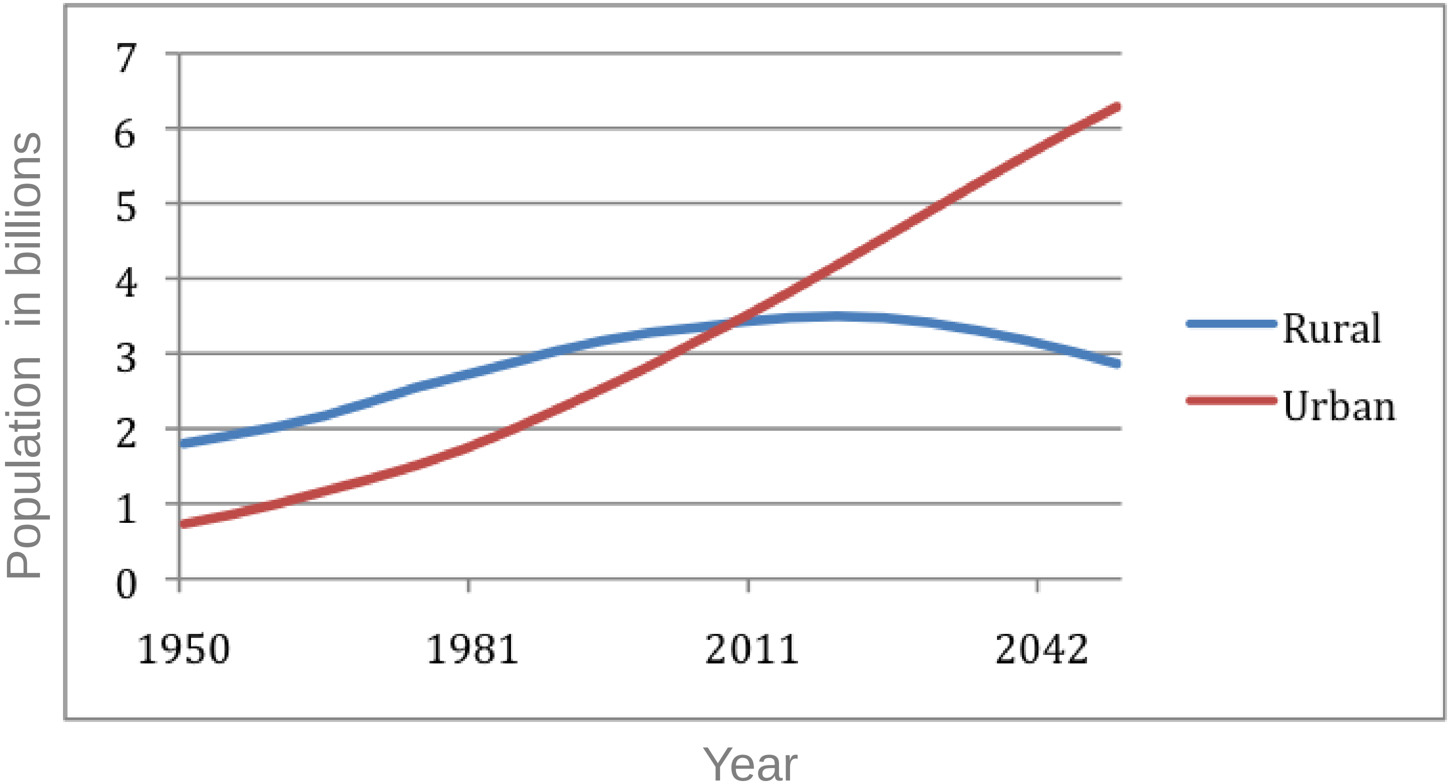
Carbon dioxide concentration at Mauna Loa Observatory from 1960 to 2011



Year

Evolution of the world energy production (IEA, 2010)

Urbanization



World urban and rural population evolution

Urban energy use:
70% of world energy consumption

INTERACTIONS AT DIFFERENT SCALES

GLOBAL

Seasonal variations

MESO

Topography, Land uses
Urban-Rural Interaction

NEIGHBORHOOD

Obstacle effects
Urban canopy – atmosphere interaction

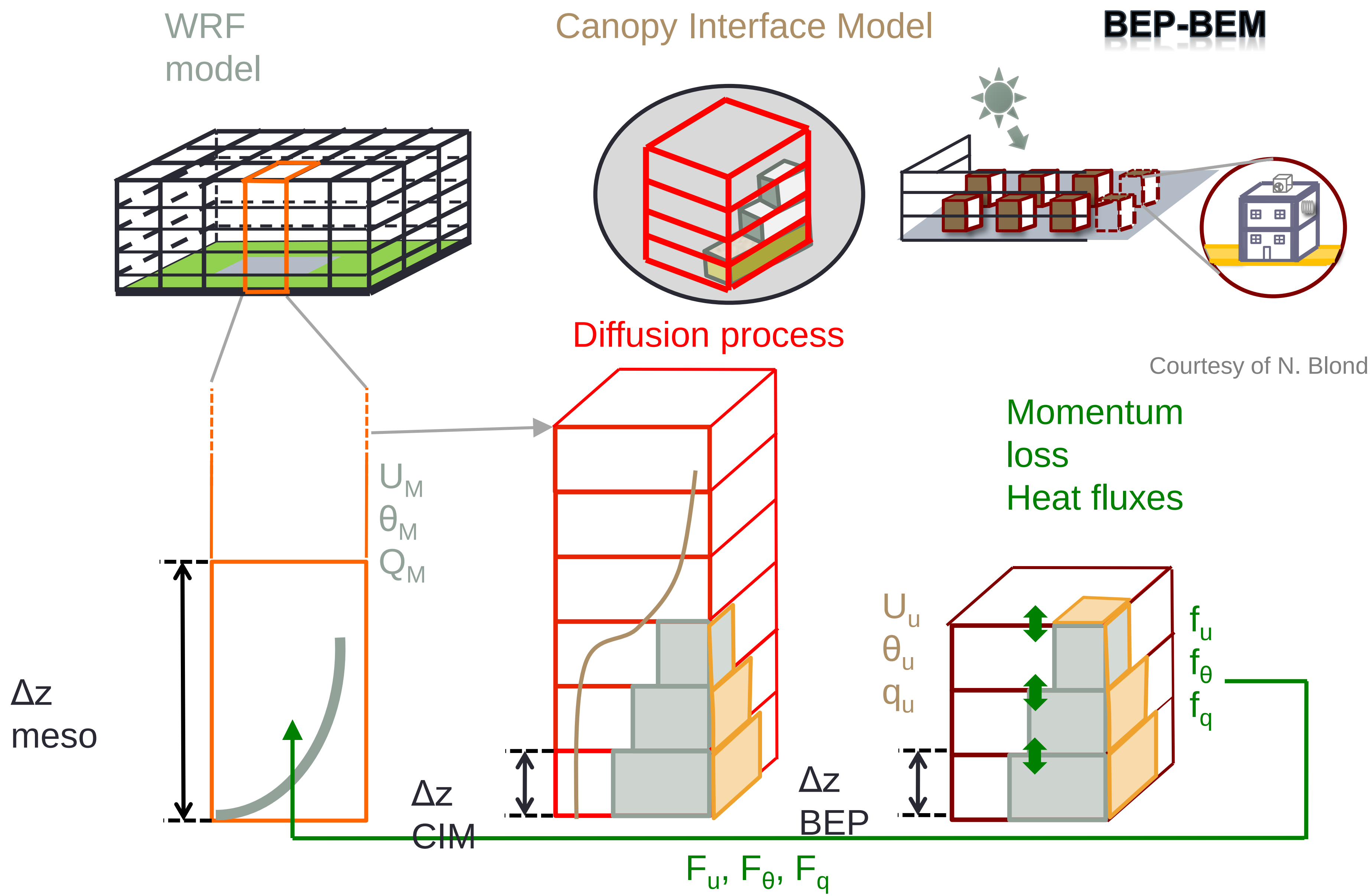
BUILDING

Building energy use

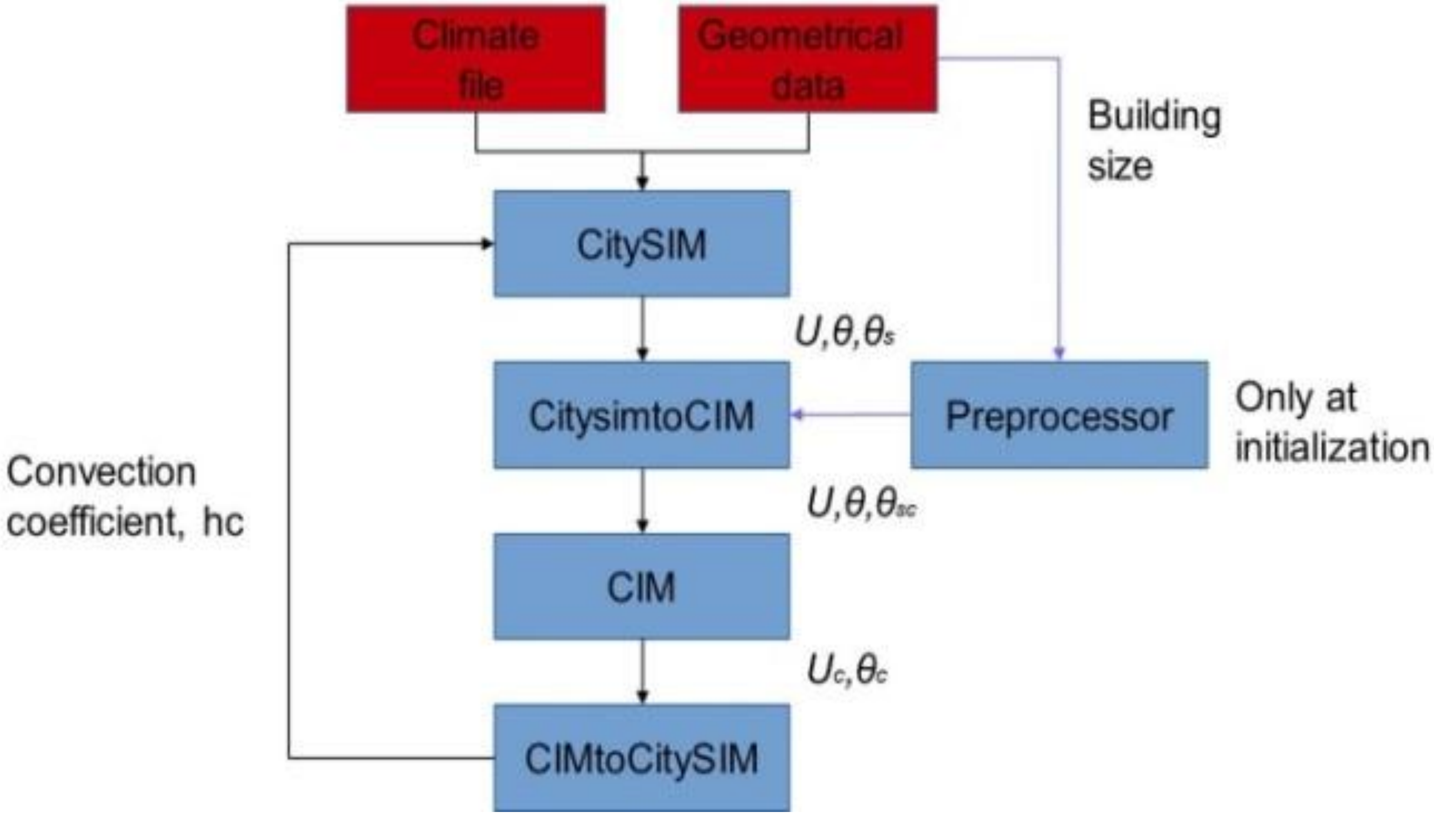
Domain size

+1000KM	+100KM	1KM	10M

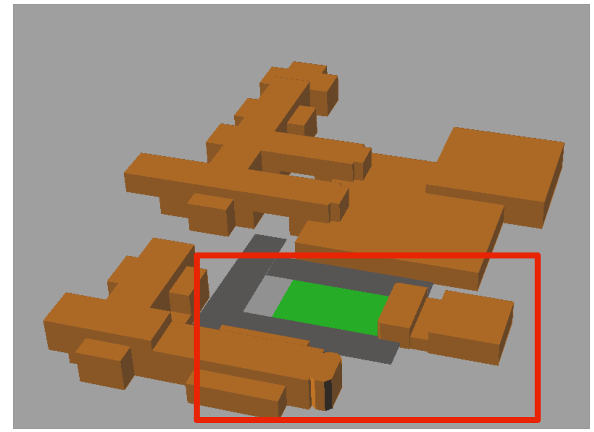
Meso-scale – coupling with CIM

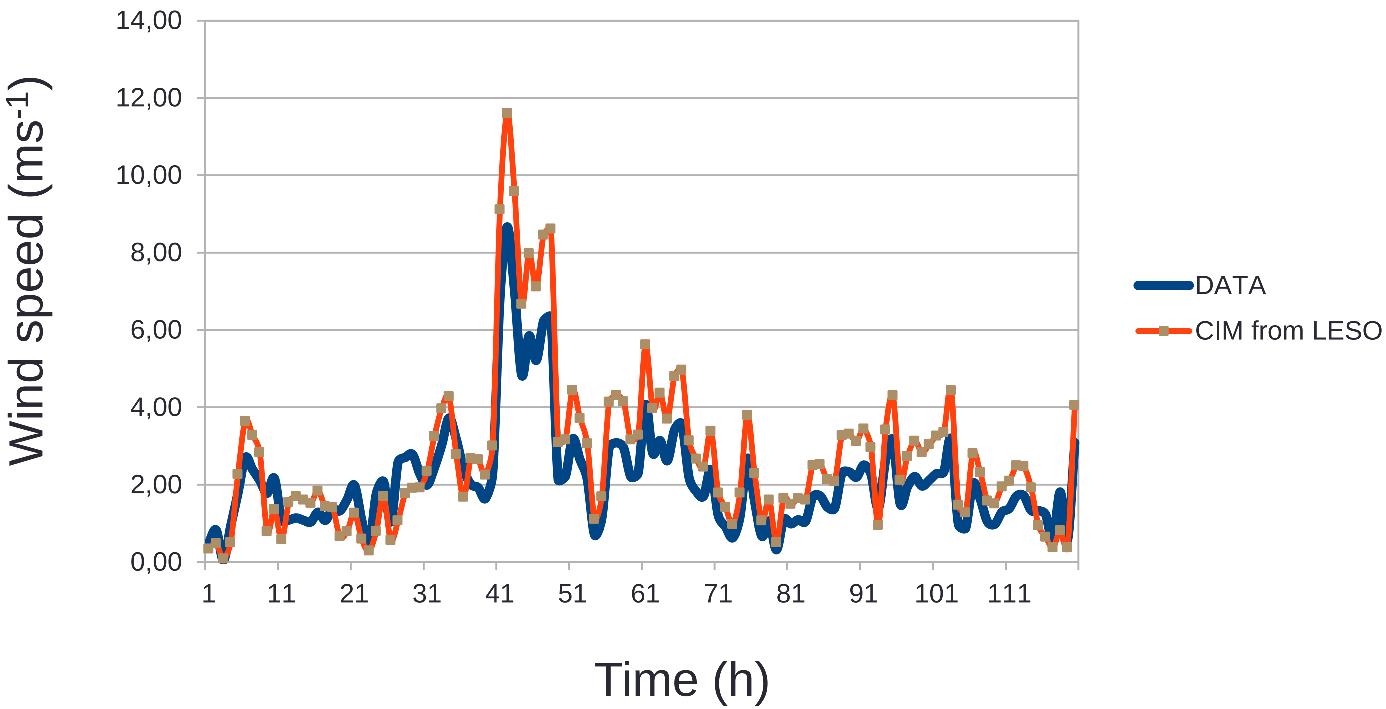


Coupling with CitySim



COUPLING WITH CITYSIM – WIND ON TOP





Coupling with Citysim – Wind / PT AT 2M