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Extending Martilli's urban boundary layer scheme: off-line validation over different urban surfaces

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FUMAPEX

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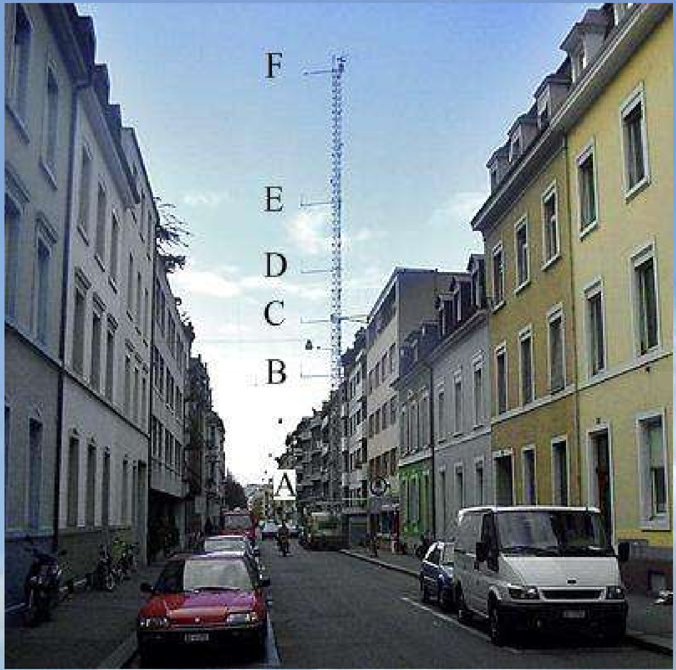
- Overview of the campaign BUBBLE (**B**asel **U**r**B**an **B**oundary **L**ayer **E**xperiment)
- Extending the parameterization of Martilli

  → Introduction of the fraction of vegetation

  → New lateral friction

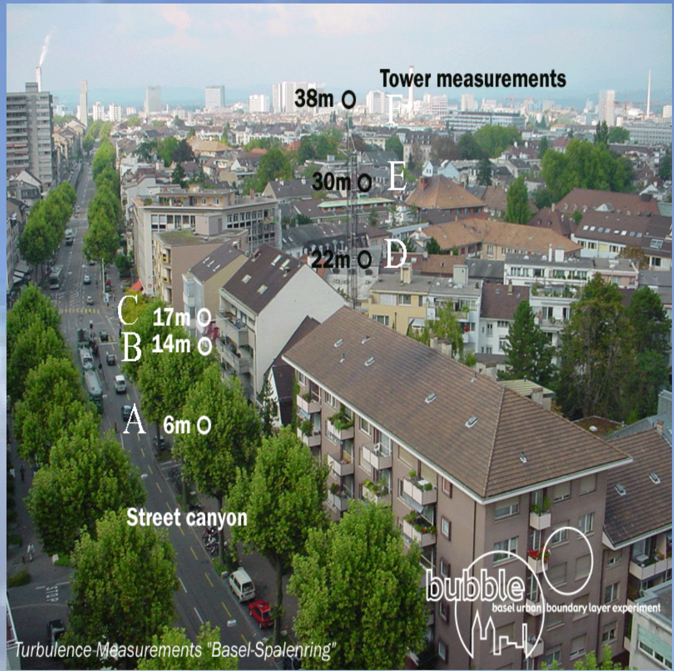
  → New drag formulation
- Results and discussions
- Conclusions

Basel-Sperrstrasse (Ue1)



Urban

Basel-Spalenring (Ue2)



Urban

Allschwil-Rämelstrasse (S1)

Suburban

	Basel-Sperrstrasse (Ue1)	Basel-Spalenring (Ue2)	Allschwil-Rämelstrasse (S1)
Height of tower :	32 m	38 m	16 m
Building height :	14.6 m	18 m	7.5 m
Height/Width (H/W) :	1	0.55	1
Vegetation fraction :	16 %	31%	53 %
Net radiation :	31.5 m	32.9 m	15.1 m
Lat. and Sens. heat :	31.7 m	29.9 m	15.8 m

A, B, C, D, E, F ： Ultrasonic anemometer-thermometers

Topographic Vorticity-Mode Mesoscale Model (TVM)

- The TVM numerical model is non-hydrostatic, Boussinesq, anelastic and expressed in vorticity.
- TVM contains a constant flux surface boundary layer (SBL) ⇐ MOST
- Surface temperature and moisture values ⇐ Surface energy and moisture balance equations.
- The turbulence scheme is 1.5-order closure. (Therry and Lacarrère, 1983)
- The model is used in 1D and forced by the upper level measurements

1- Implementation of the Martilli's urban module in TVM

The prognostic vorticity equation is: $\frac{\partial \vec{\xi}_H}{\partial t} = -\vec{\nabla}(\vec{U}\,\vec{\xi}_H) + \ldots + \vec{D}_H$

Here $\vec{\xi}_H(\xi_1, \xi_2)$ is the horizontal vorticity vector, $\vec{U}(u, v, w)$ the wind vector and $\vec{D}_H(D_x, D_y)$ the horizontal drag term.

Which is of the form following Martilli et al (2002): $\vec{D}_H = \vec{\nabla} \wedge (-\rho_0 C_D a(z) \|\vec{U}_{ort}\| \vec{U}_{ort})$

And following the coordinate transformation:

$$\begin{cases} D_x = \frac{-1}{f_{zg}} C_D \frac{\partial}{\partial \sigma}(-\rho_0 a(\sigma) \|\vec{U}_{ort}\| V_{ort}) \\ D_y = \frac{+1}{f_{zg}} C_D \frac{\partial}{\partial \sigma}(-\rho_0 a(\sigma) \|\vec{U}_{ort}\| U_{ort}) \end{cases}$$

where $f_{zg} = \frac{Z_t - Z_g}{Z_t}$

2- Extending the parameterization of Martilli

- Introduction of the fraction of vegetation
- New lateral friction term

$$\vec{F}_{drag} = \rho_0 C_D a(z) \|\vec{U}_{ort}\| \vec{U}_{ort} + \rho_0 C_{ch} a(z) \|\vec{U}_{par}\| \vec{U}_{par}$$ ←

- New drag formulation

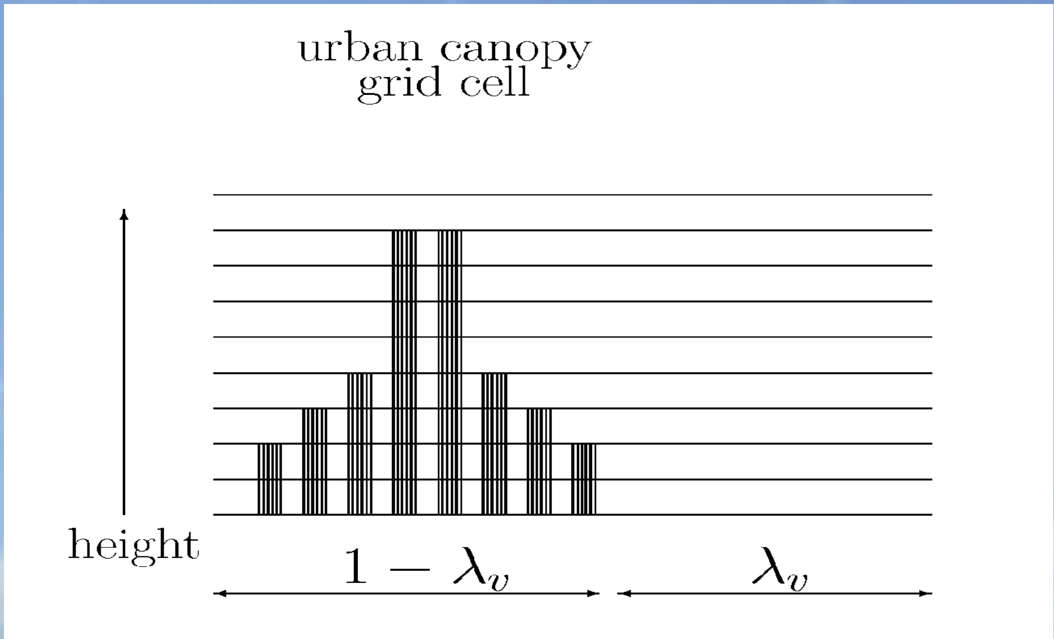
Measured drag coefficient at (Ue1) for cross canyon flow.

$$C_D = \left(\frac{u_{st}}{u}\right)^2$$

Z (m)	Z/H	C_D
3.6	0.25	0.11
11.3	0.77	0.15
14.7	1.01	0.2
17.9	1.23	0.08
22.4	1.53	0.05
31.7	2.17	0.02

Cumulated surface

Set-up of the simulation

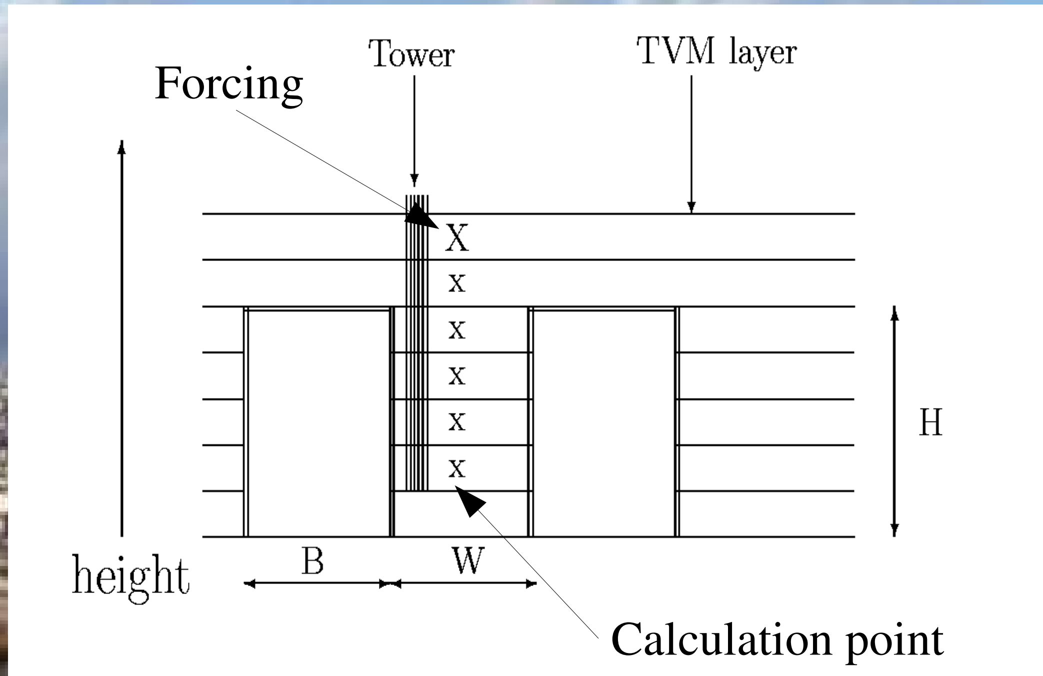


The orientations of the street are deduced from a Basel city map. This input is crucial for the incoming solar radiation on the walls and, hence, for the energy balance.

Sites	*Wall*	*Roof(1)*	*Street (length)*	*H/W*	*Street (Direction)(1)*	λ_v
Ue1	*14.6 m*	*15 m*	*14.6 m*	*1*	*67 °*	*16,00%*
Ue2	*18 m*	*15 m*	*32.4 m*	*0.5*	*160°*	*31,00%*
S1	*7.5 m*	*15 m*	*7.5 m*	*1*	*120°*	*53,00%*

The period of the simulation extends from
2002/06/16 to 2002/06/30

Forcing is applied to wind, temperature, humidity, turbulent kinetic energy and downward global short- and long-wave radiation.



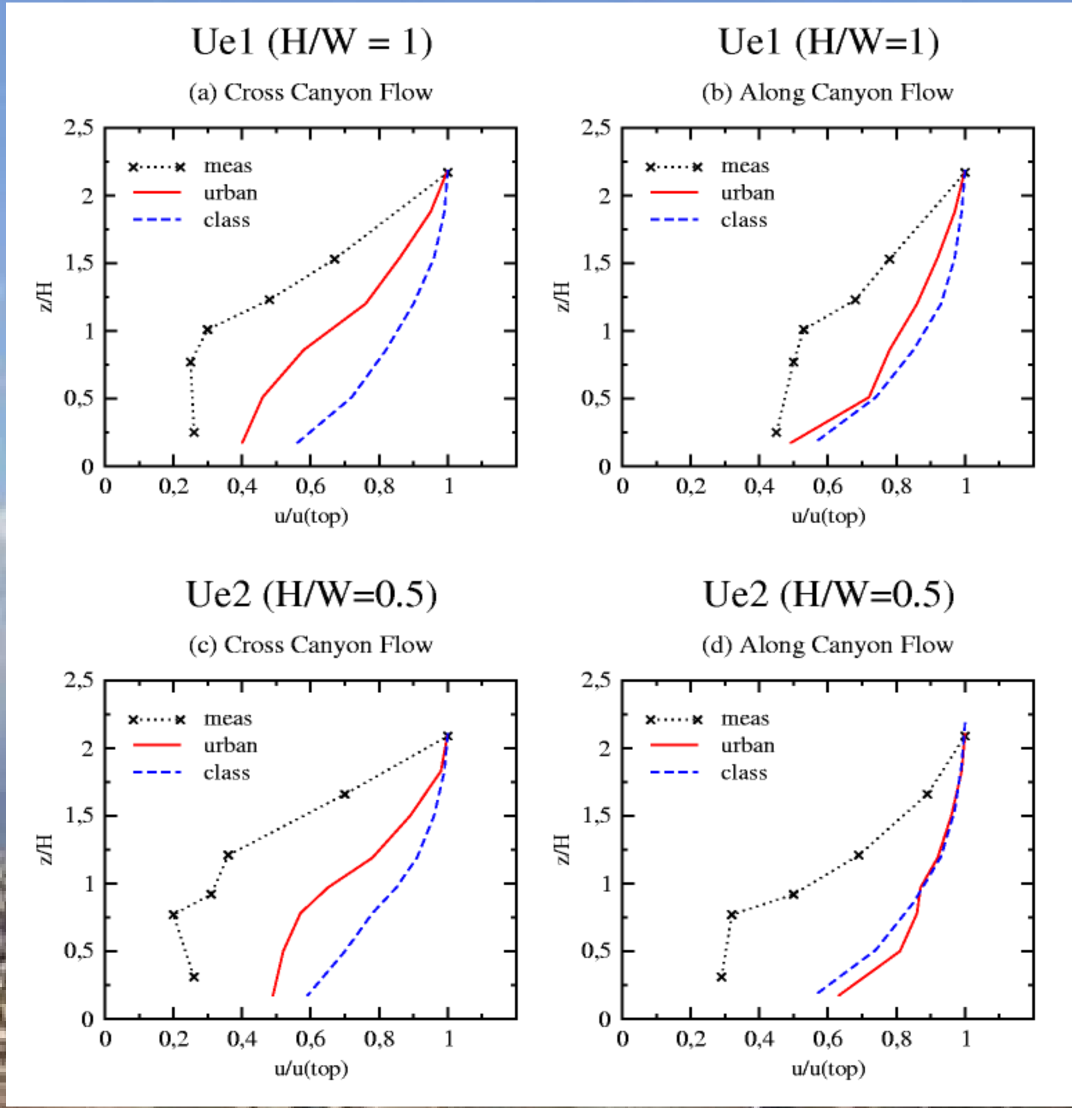
Results and discussions

1- Profile of Wind speed

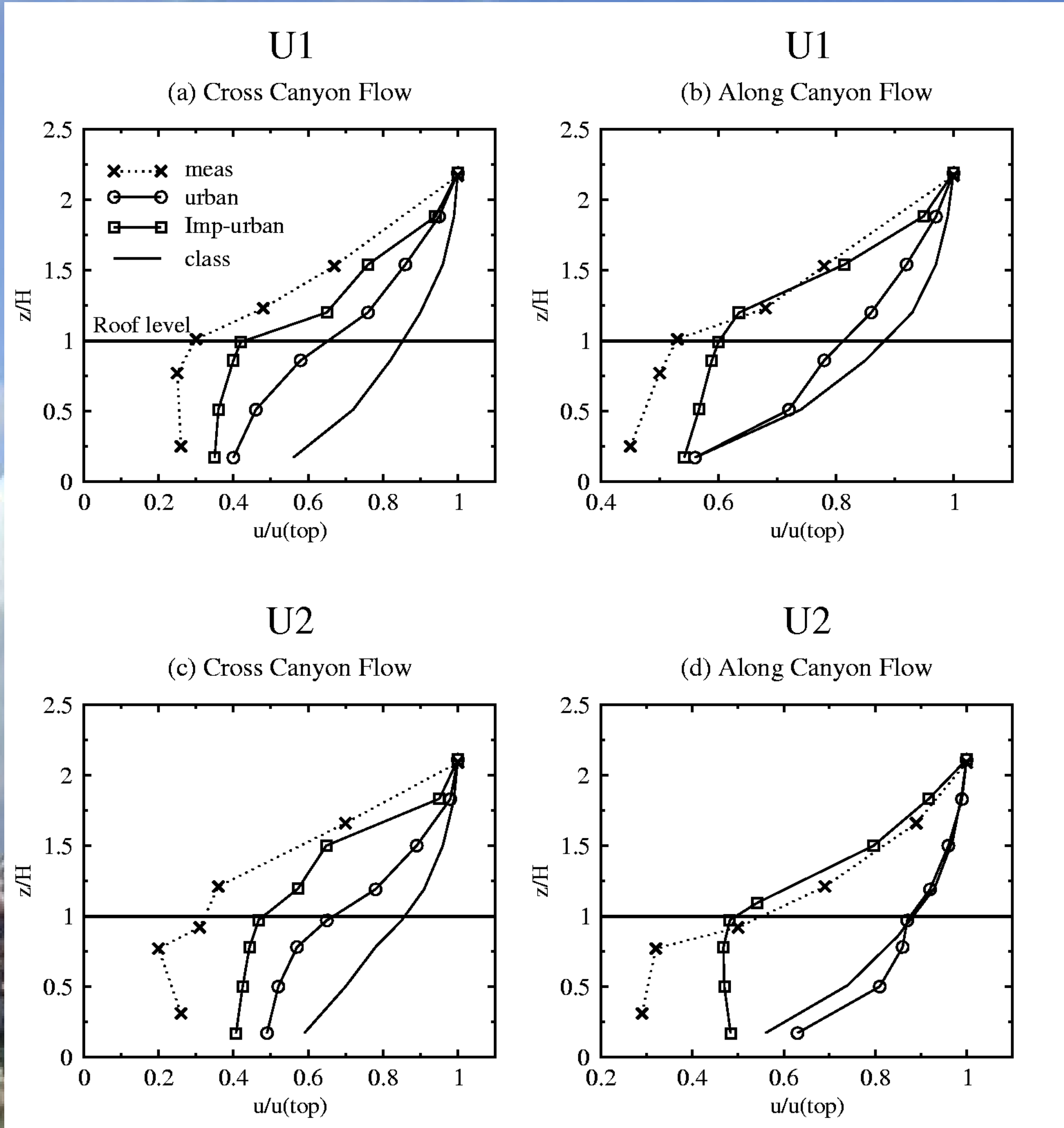
The original Martilli's version

- Along canyon flow with the mean wind within $\neq 10°$ of the canyon direction.
- Cross canyon flow with the mean wind within $\neq 10°$ perpendicular to the canyon direction.

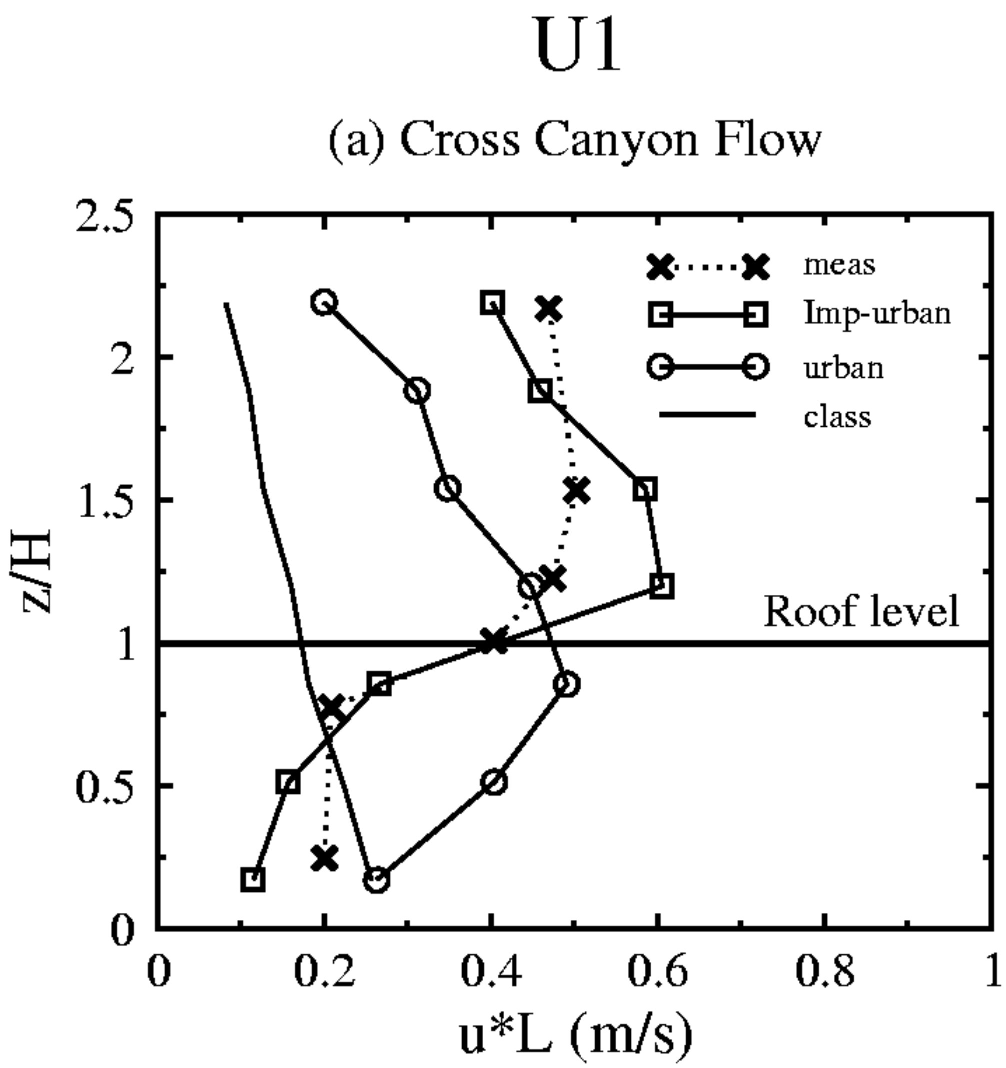
Site	*Cross Canyon Flow*	*Along Canyon Flow*
Ue1	*34*	*23*
Ue2	*24*	*25*

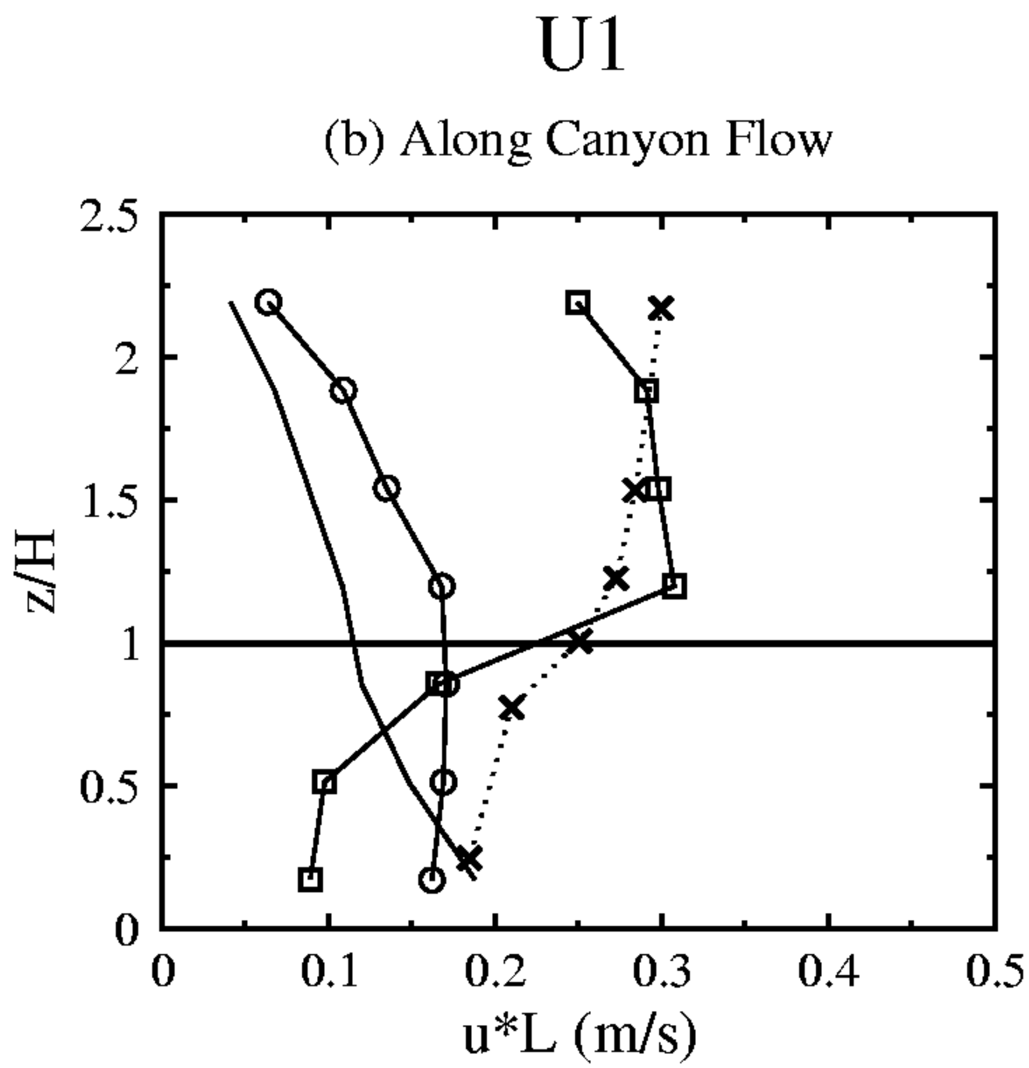


Expanded version

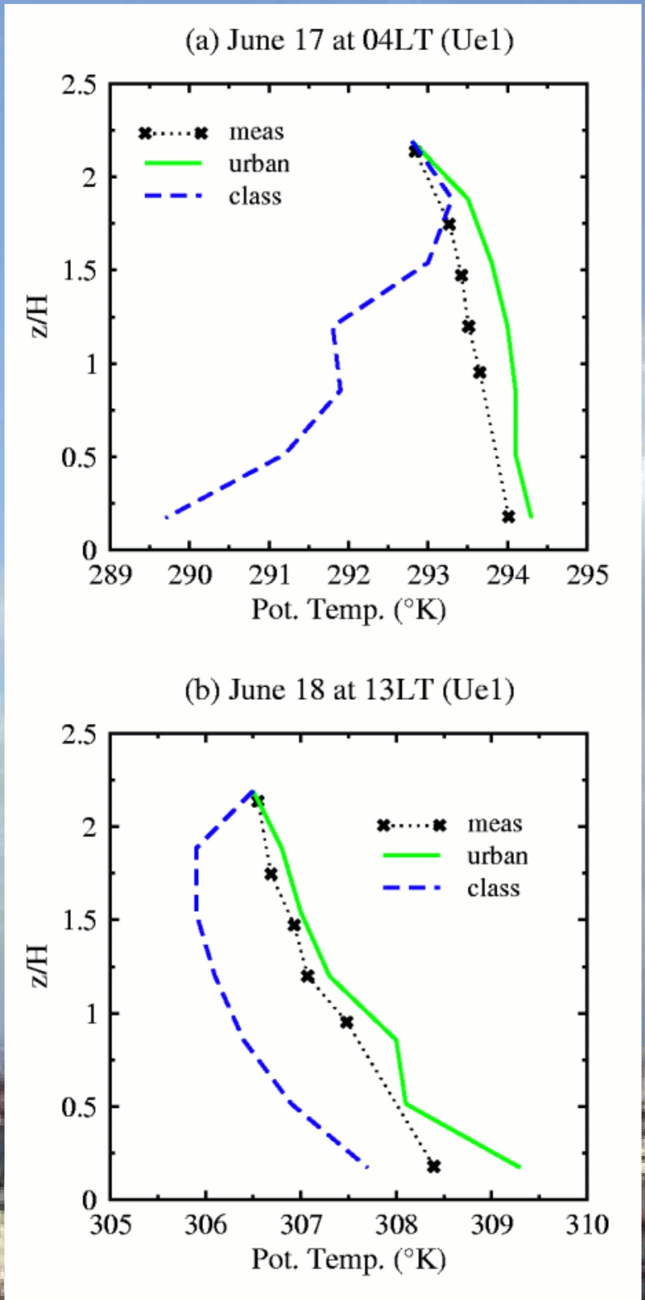


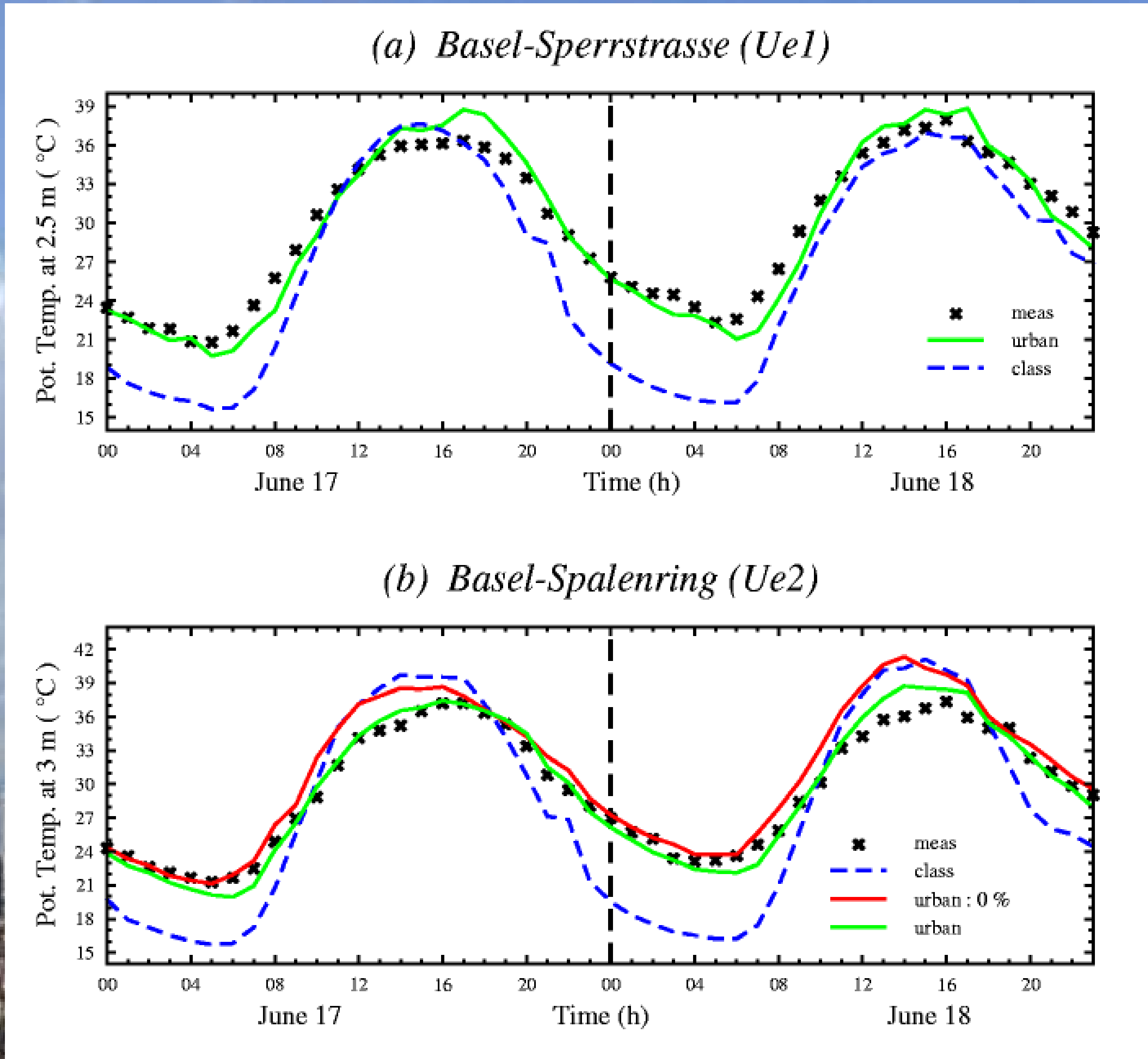
2- Stress profile





3- Potential temperature





4- Surface energy fluxes

The simulated surface fluxes are calculated in TVM as:

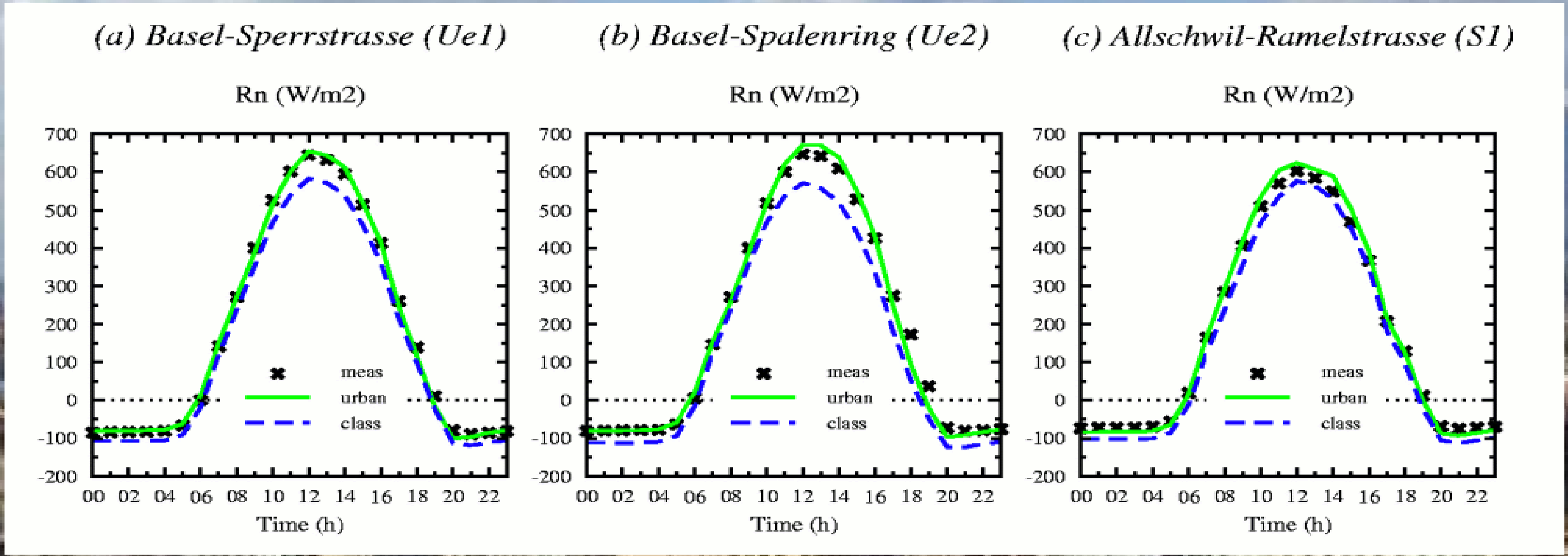
$$\phi_T = \phi_{floor} + \frac{1}{W} \sum \Delta Z_i (\phi_i^{West} + \phi_i^{East})$$

ΔZ_i is the vertical grid spacing in the urban grid.

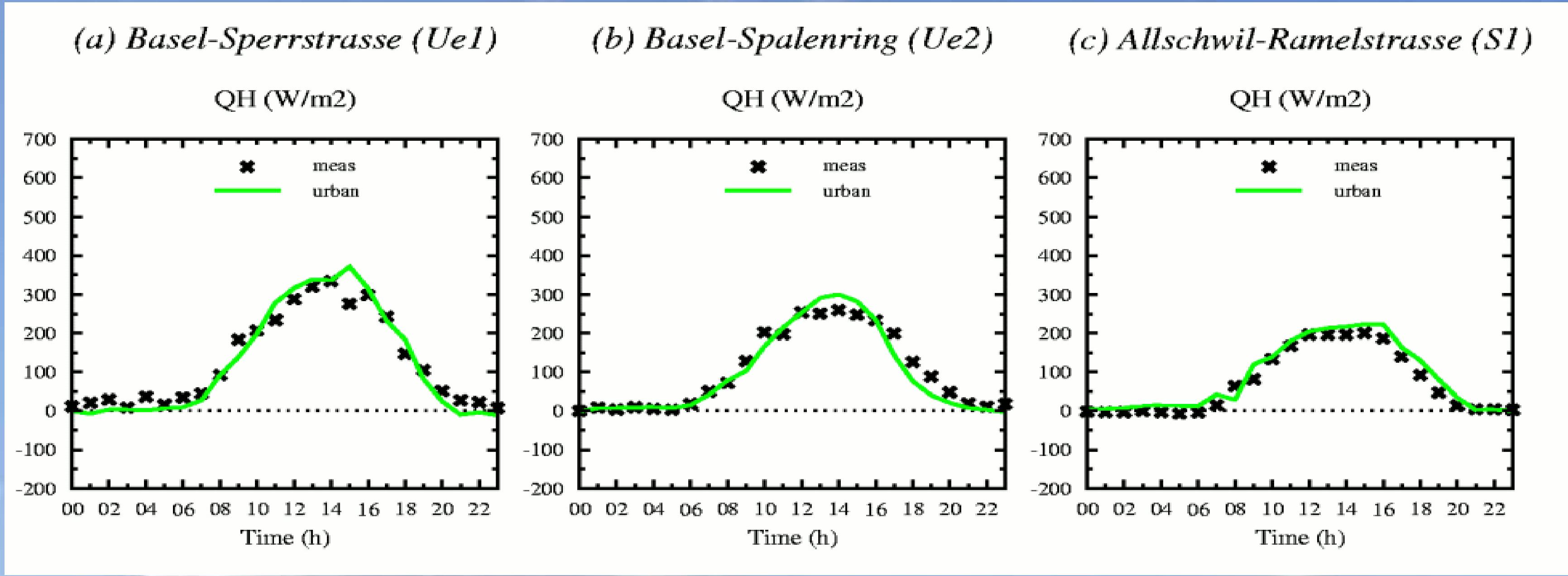
The sum is computed between the lowest and the highest urban grid level.

Five clear sky days are chosen (17, 18, 23, 26 and 30 June), the modeled and observed surface energy fluxes are then averaged over these 5 clear sky days.

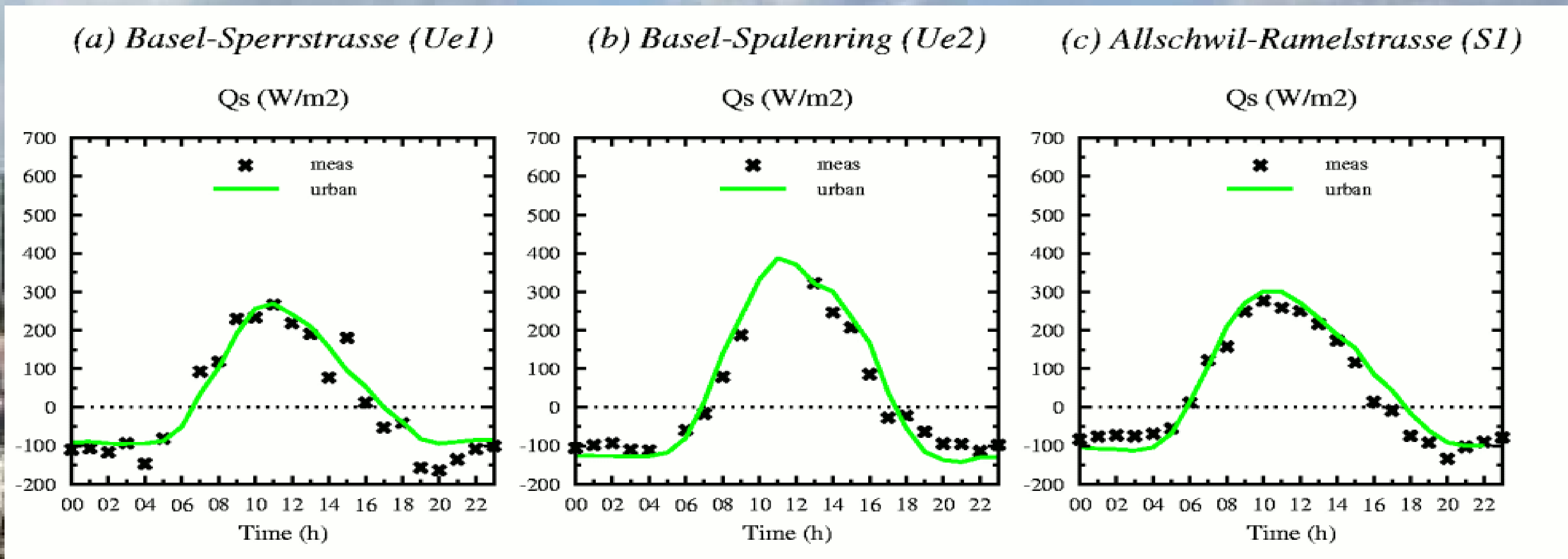
Net radiation



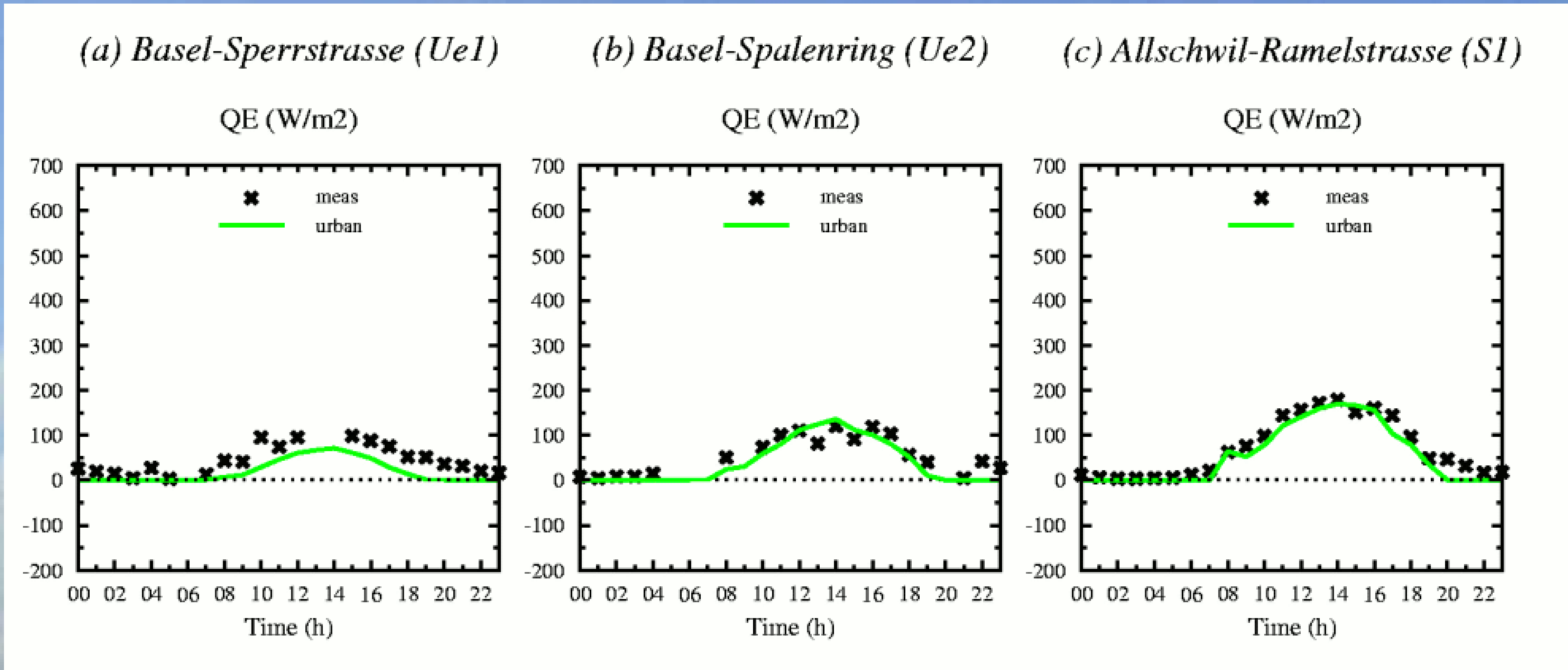
Sensible heat flux



Heat storage flux



Latent heat flux



Conclusions

The original Martilli urban module is able to represent the overall shape of the observed cross canyon wind speed profile. However, it appears that:

- For cross canyon flow, the simulated drag force is underestimated inside the street canyon, the urban module introduces too little shear.

- It fails completely in reproducing the along canyon wind profile.

  This version taking into account the **lateral drag** effect and a **new drag formulation** has been tested with the BUBBLE data. The results show that the new urban parameterization scheme is able to reproduce most of the typical processes induced by an urban surface near the ground.

- The original version of the Martilli urban module overestimates the average daily maximum temperature by 4°C for (Ue2). The simulated canyon air temperature is improved when the fraction of vegetation is taken into account .

  In the three urban sites, TVM partitions the surfaces energy fluxes appropriately.