Evaporation from urban areas: model sensitivity and results with TERRA-ML(U) standalone

Hendrik Wouters, Matthias Demuzere, Koen De Ridder, Gerd Vogel, Nicole van Lipzig

vito
vision on technology

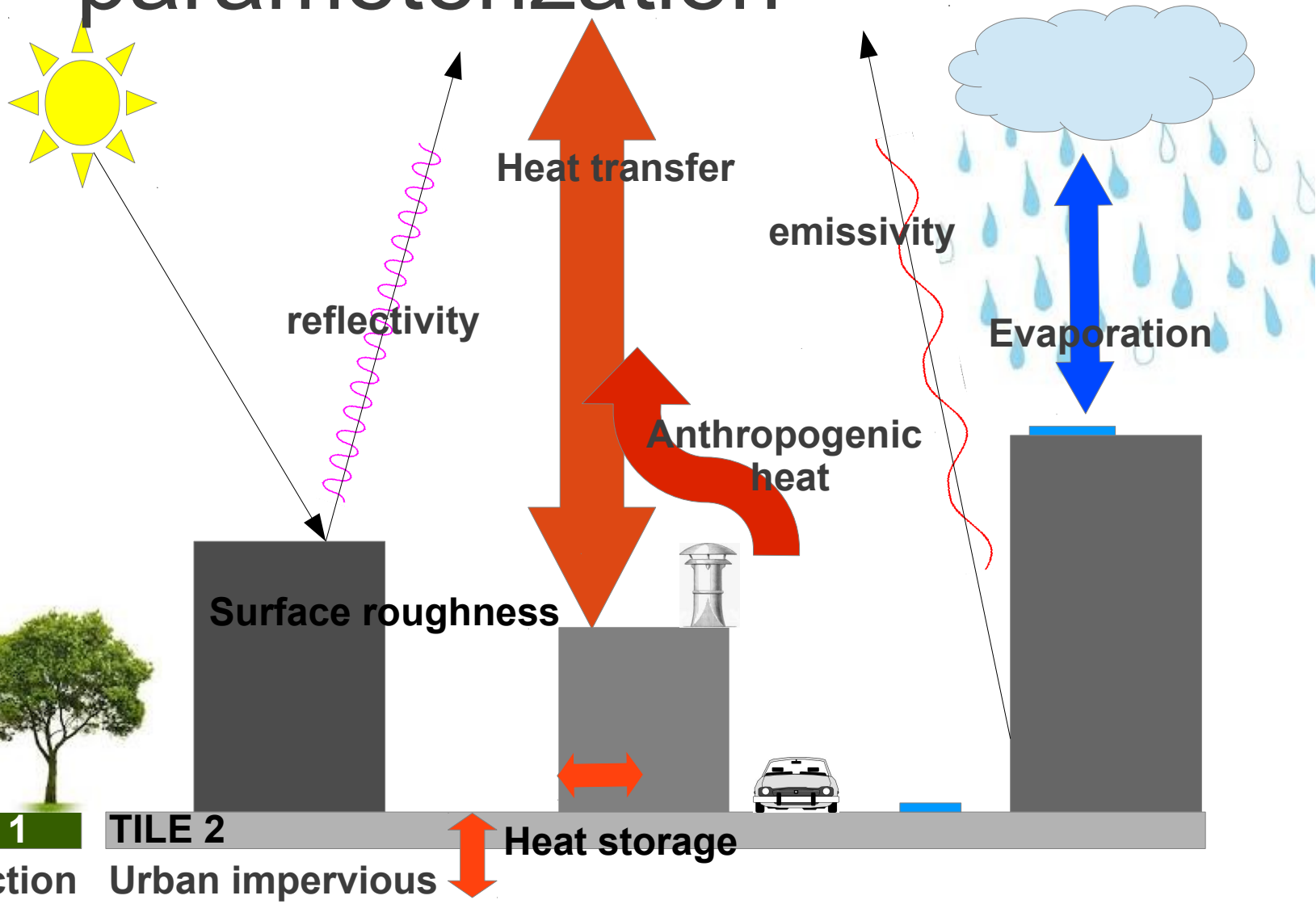
KATHOLIEKE UNIVERSITEIT
LEUVEN

Motivation

“To assess the impact of urbanization on the surface water balance”

- What are the different contributions to evapotranspiration inside cities?
- How much rain can be stored on urban impervious surfaces?
- What is the fraction of the rain falling on the impervious surface that is evaporated back to the atmosphere?

How? Using TERRA_ML with urban parameterization



An urban geometric impervious water storage (UGIWS)

- Rain and Runoff: $\frac{dw}{dt} = R_f = R_0 \left[1 - e^{-\left(1 - \frac{w}{w_m}\right)}\right]$

$$w(t+\Delta t) = (w_m - w_m \ln\left[1 - \left(1 - e^{c_f\left(1-\frac{w(t)}{w_m}\right)}\right) e^{-c_f \frac{R\Delta t}{w_m}}\right]$$

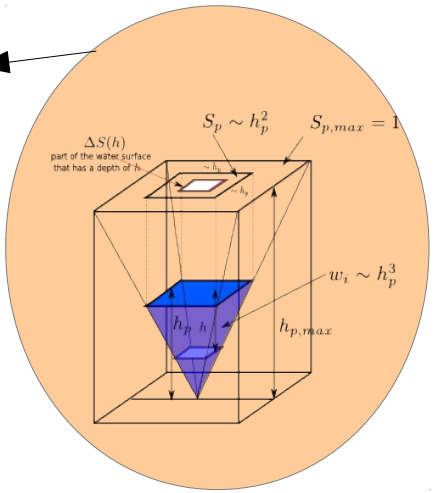
- Current urban models assume full potential evaporation (PE) from impervious surfac, or neglect evaporation (NE)
- New →UGIWS: evaporative surface fraction depends on the amount of water on the impervious surface

$$\frac{dw}{dt} = -E_p S_w = -E_p \left(\frac{w}{c_{p,m} w_m}\right)^{\frac{2}{3}}$$

$$w(t+\Delta t) = \left(w(t)^{\frac{1}{3}} - \frac{E_p \Delta t}{3(c_{p,m} w_m)^{2/3}}\right)^3$$

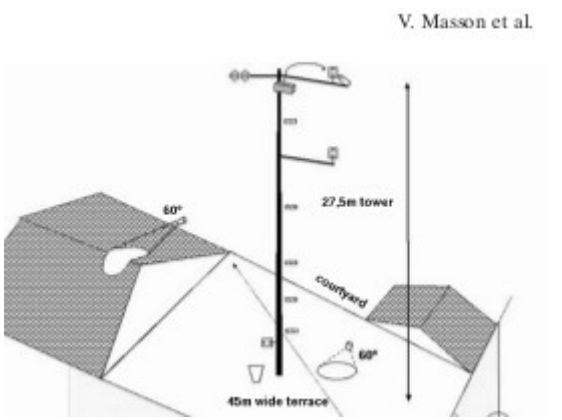
w_m : maximum water storage

$c_{p,m}$: shape parameter

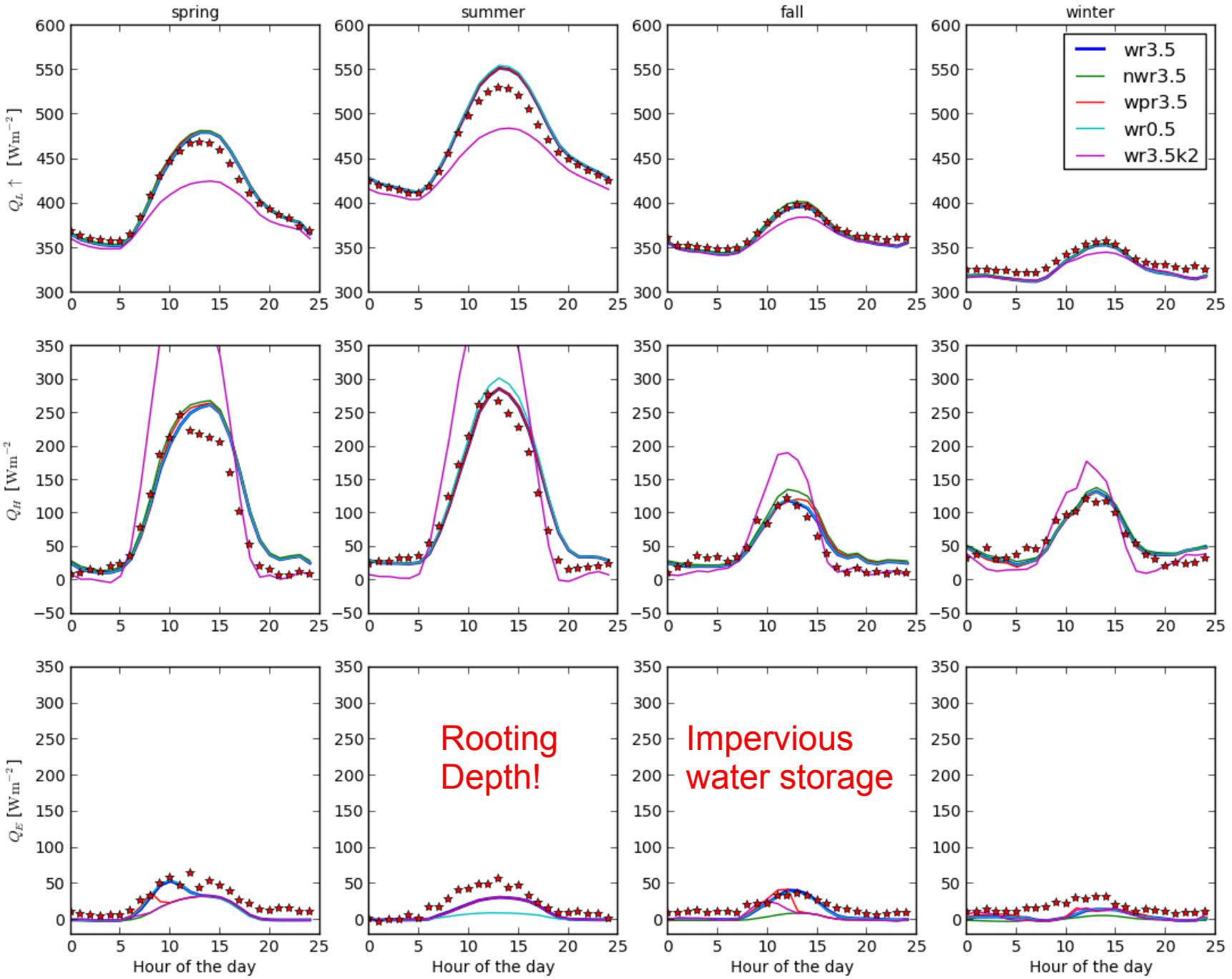


Offline runs for Toulouse

- **CAPITOUL:** *Masson et al., 2008. The Canopy and Aerosol Particles Interactions in TOulouse Urban Layer experiment*
- 1-year offline runs with TERRA-ML!

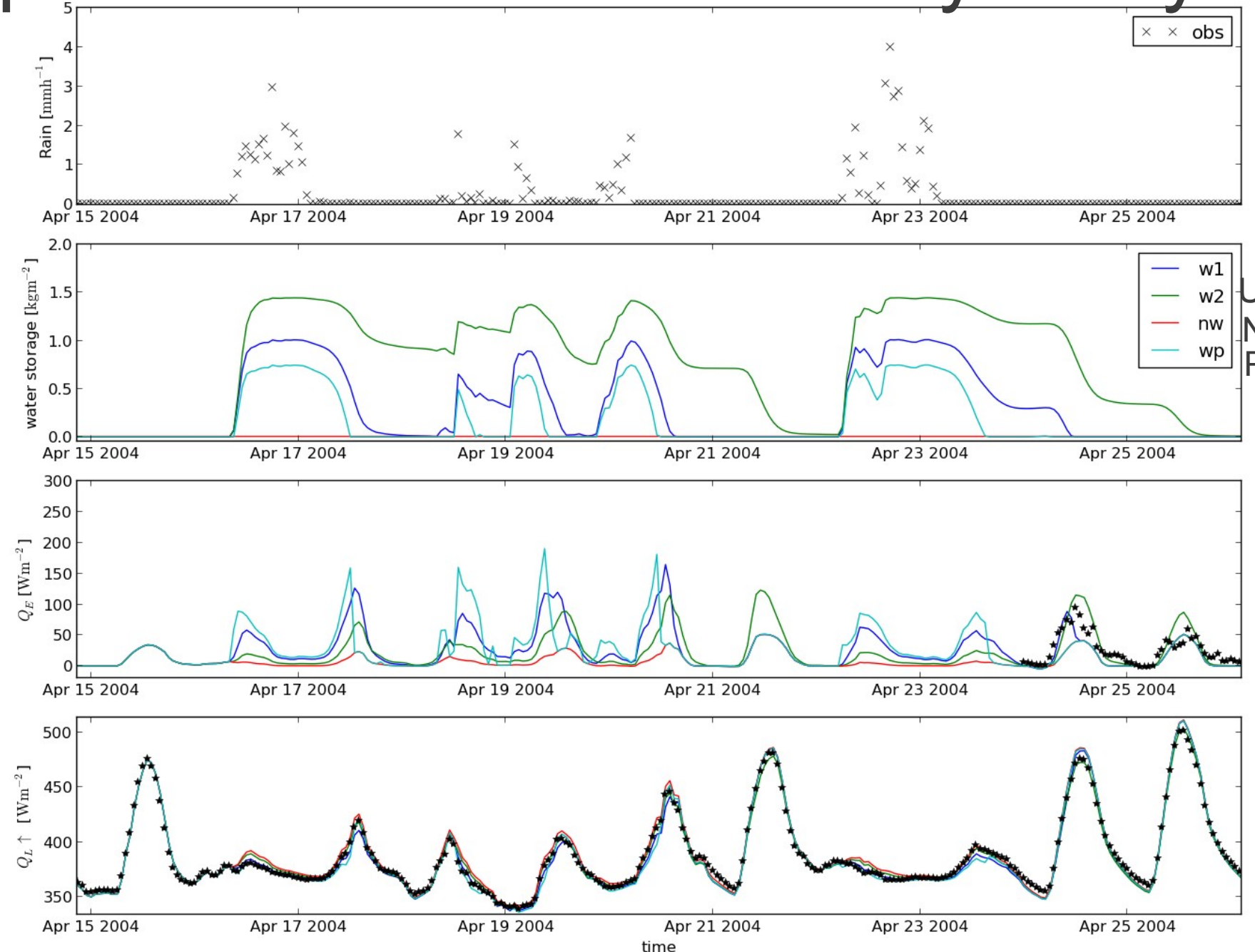


Overall performance for rain-free days



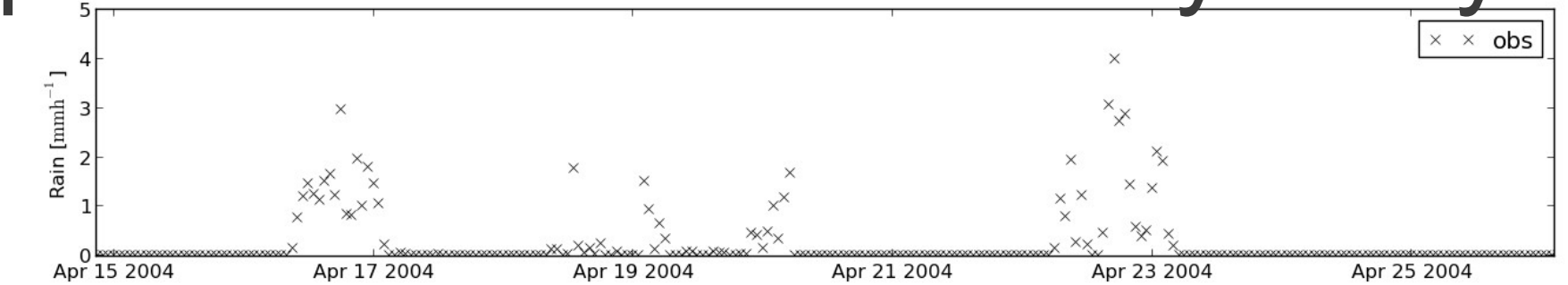
Determine water-storage parameters with sensitivity study

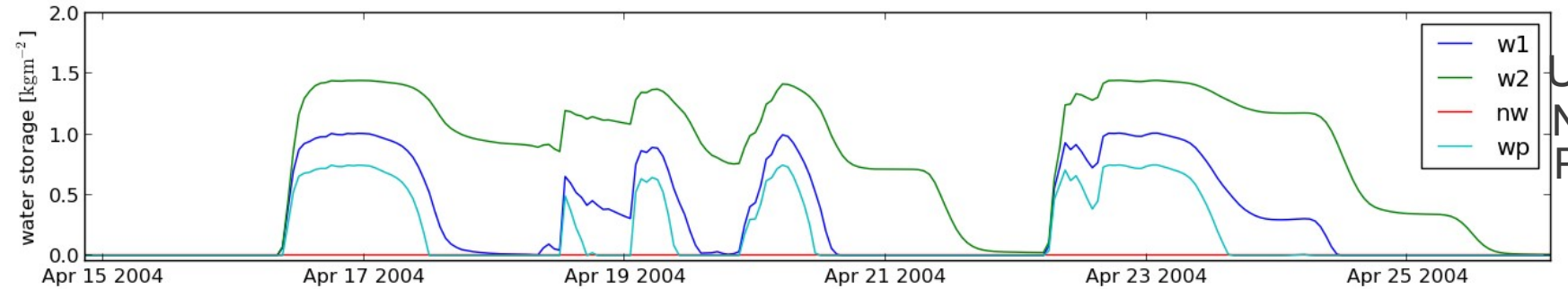
Determine impervious water-storage parameters with sensitivity study



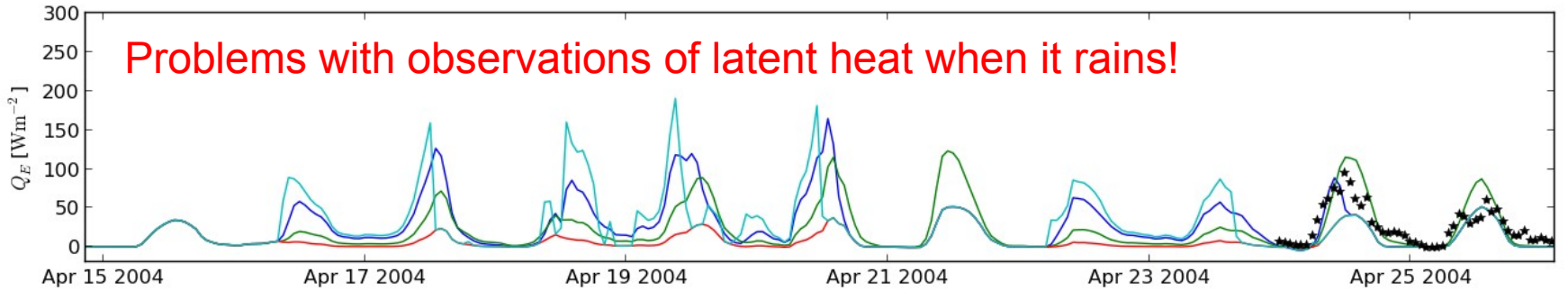
UGIWS
NE
PE

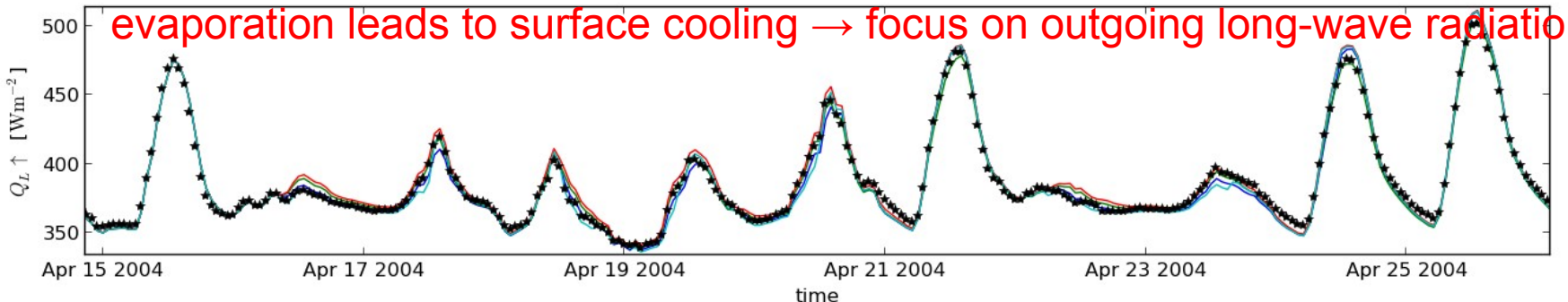
Determine impervious water-storage parameters with sensitivity study



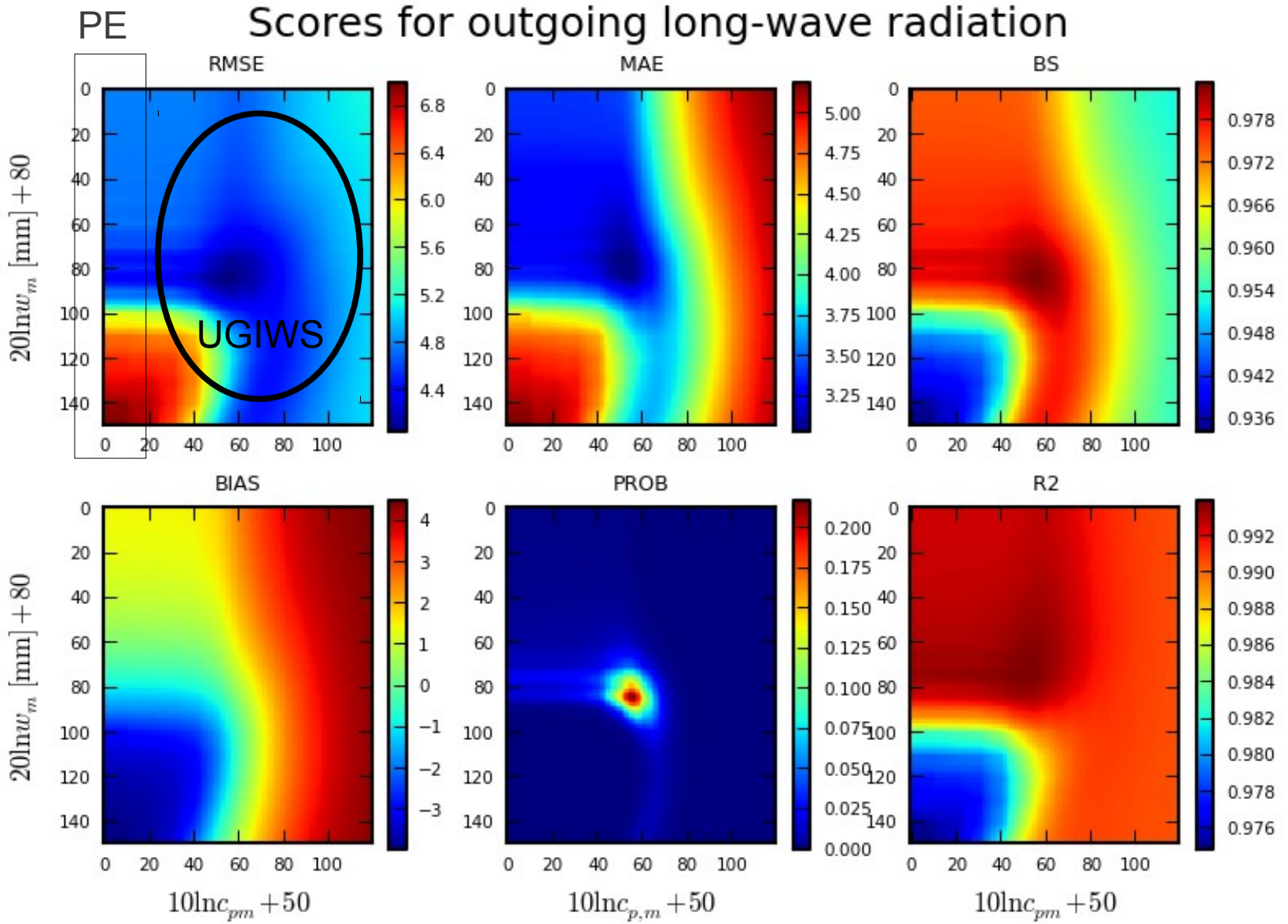


UGIWS
NE
PE





Results of the sensitivity study

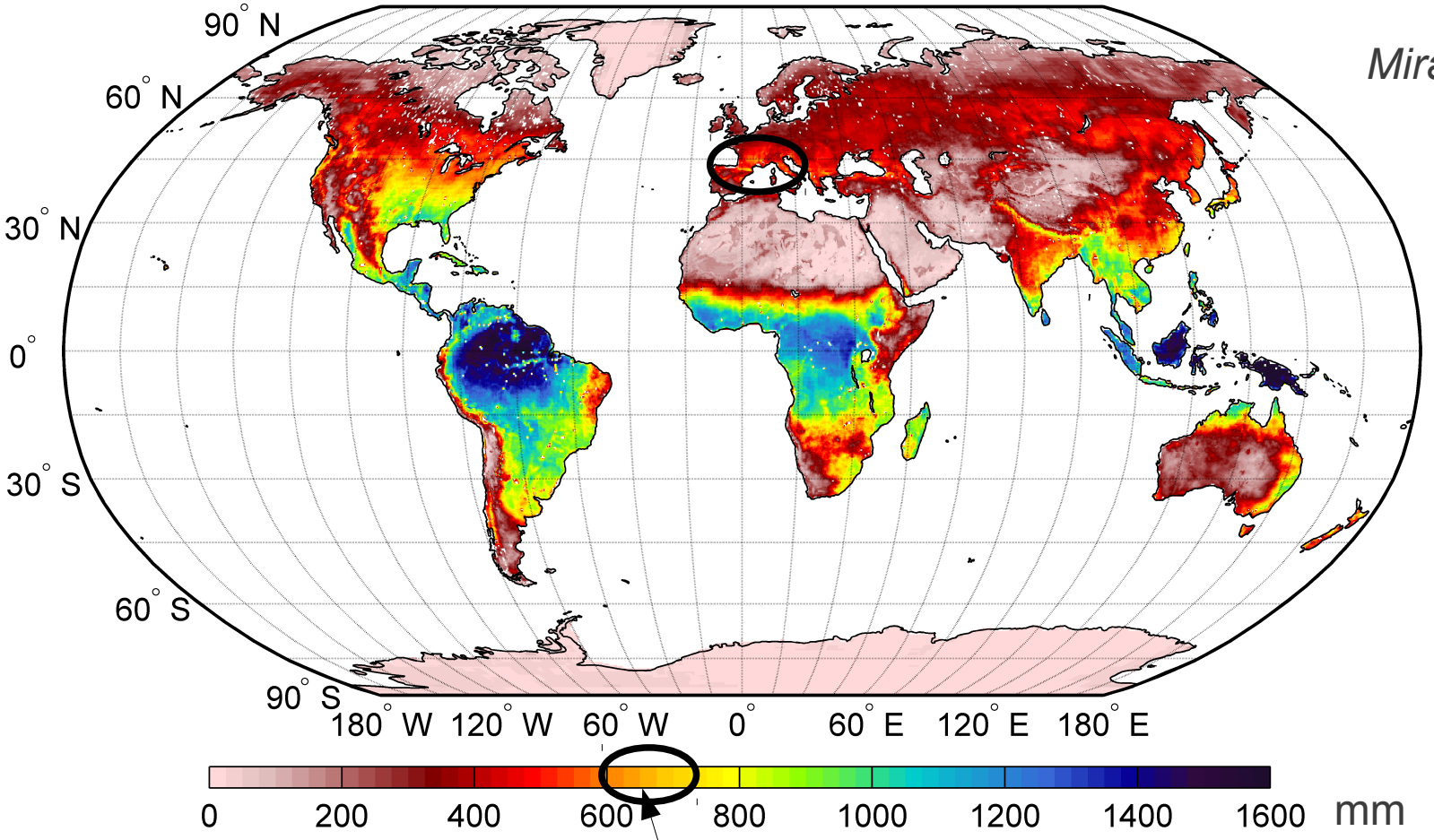


$$PROB(w_m, c_{p,m}) = \frac{\exp\left[\sum_i -0.5(Q_{L,o}(t_i)-Q_{L,m}(t_i))^2/\sigma^2\right]}{\exp\left[\sum_j \sum_i -0.5(Q_{L,o}(t_i)-Q_{L,j}(t_i))^2/\sigma^2\right]}$$

Estimates for Toulouse 2004

- Estimate of the maximum impervious water storage: $1.16 \pm 0.46 \mathrm{kg\ mm^{-2}}$
- Weighted annual-mean evaporation from the impervious surface (with UGIWS): $8.0 \pm 1.0 \mathrm{W m^{-2}}$
- This is comparable to the weighted evaporation from the vegetative fraction which was: $6.1\ \mathrm{W\ m^{-2}}$
- Fraction of precipitation on impervious surface evaporated back to the atmosphere: $19.5\% \pm 2\%$
- Assuming PE: 27.1% (excess 35%)

Annual mean: Comparison with environment 2005



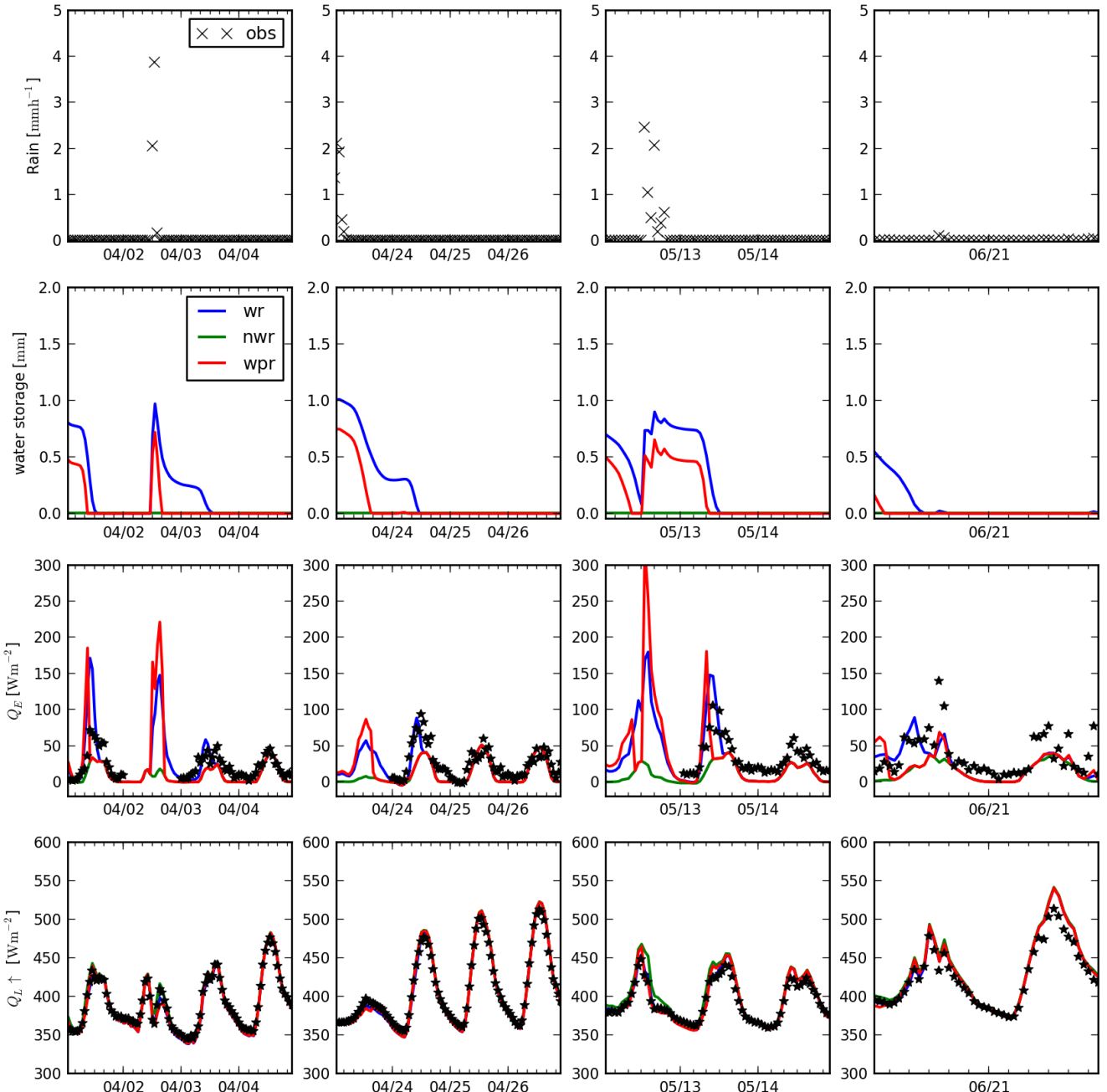
Miralles et al. 2011

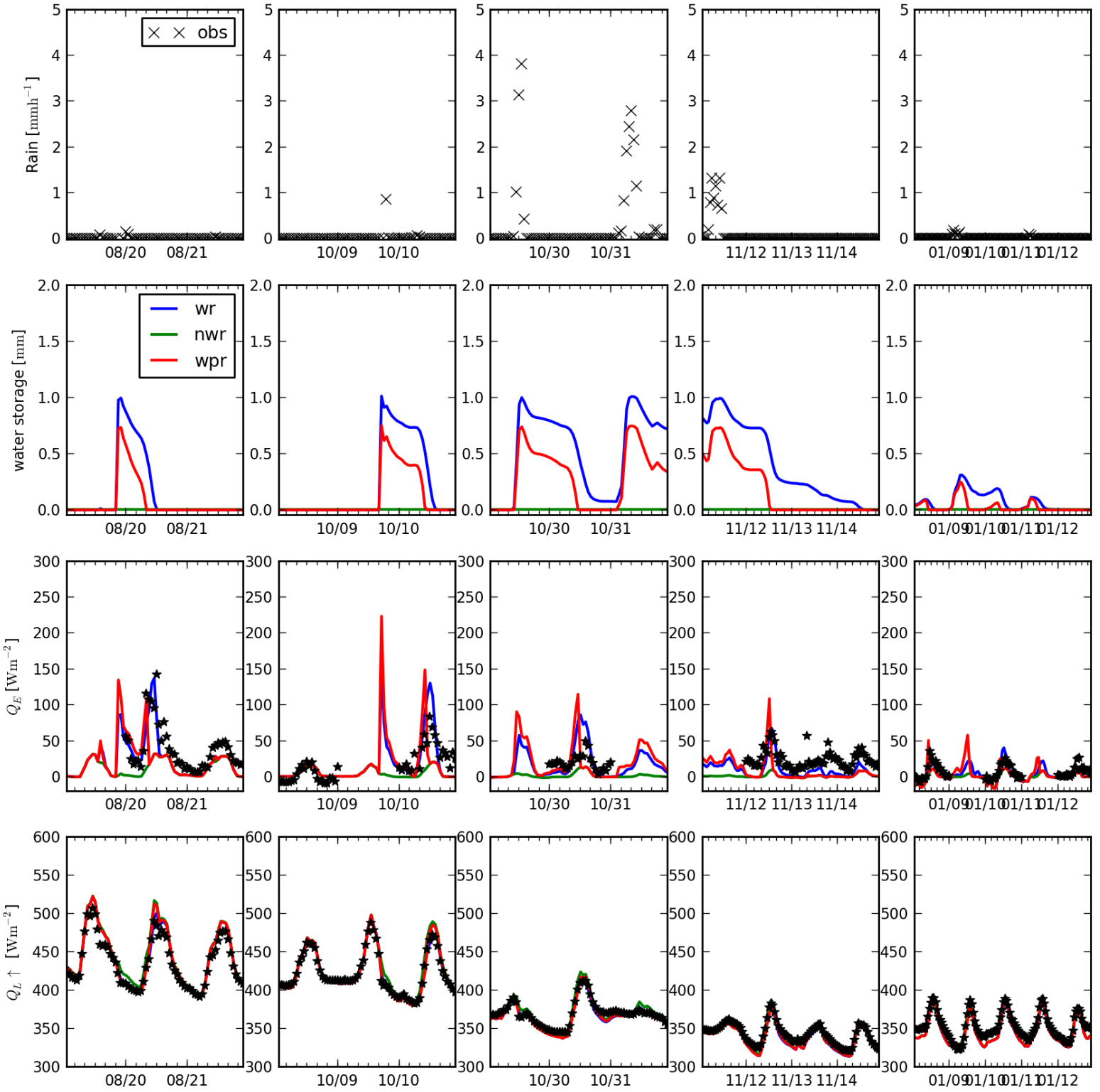
$8.9\ \mathrm{W\ m^{-2}}$ versus $\simeq 45\mathrm{Wm^{-2}}$

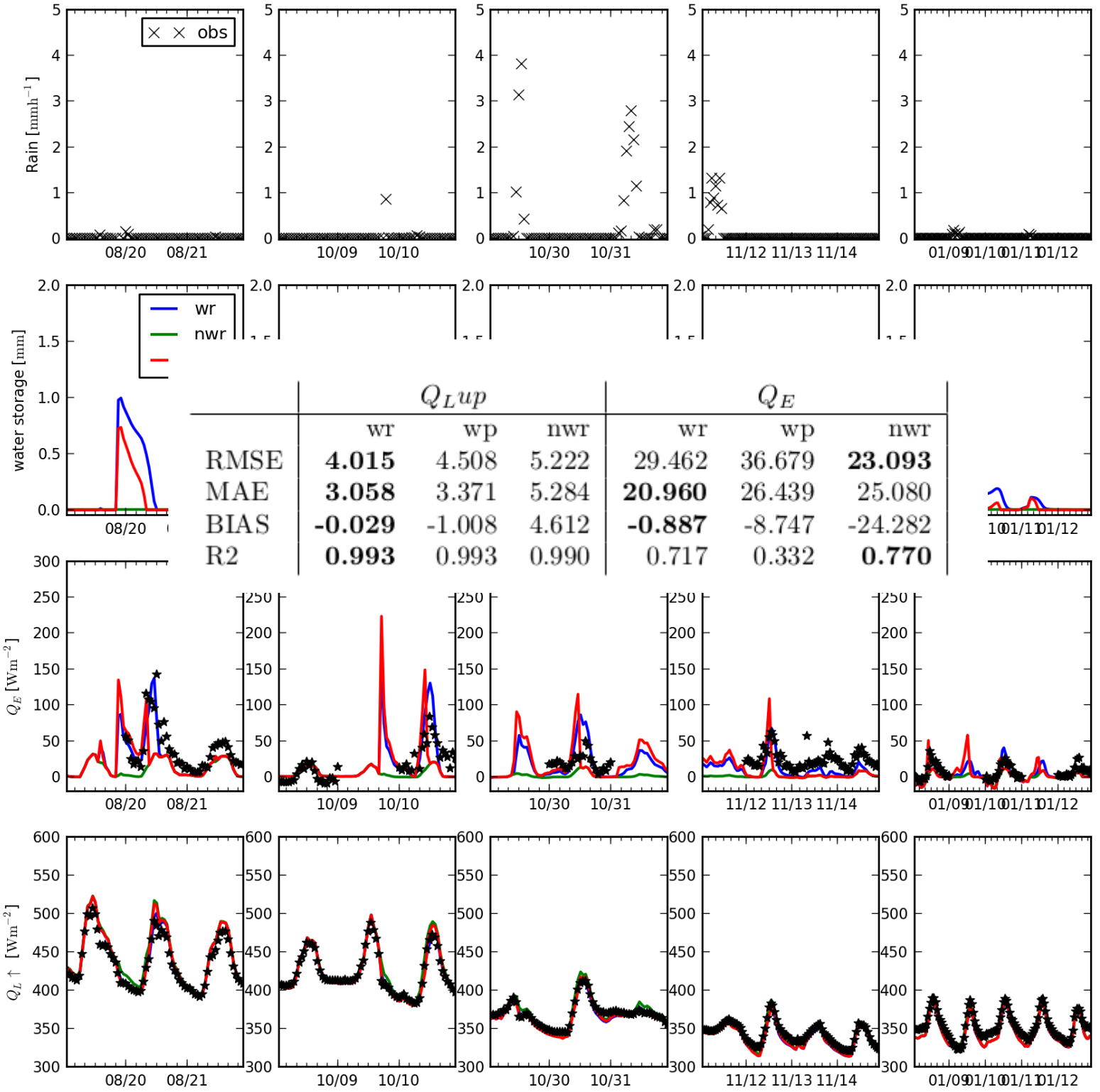
Non-weighted annual-mean evaporation from the impervious surface

Evaluation for rainy periods

Evaluation for rainy periods

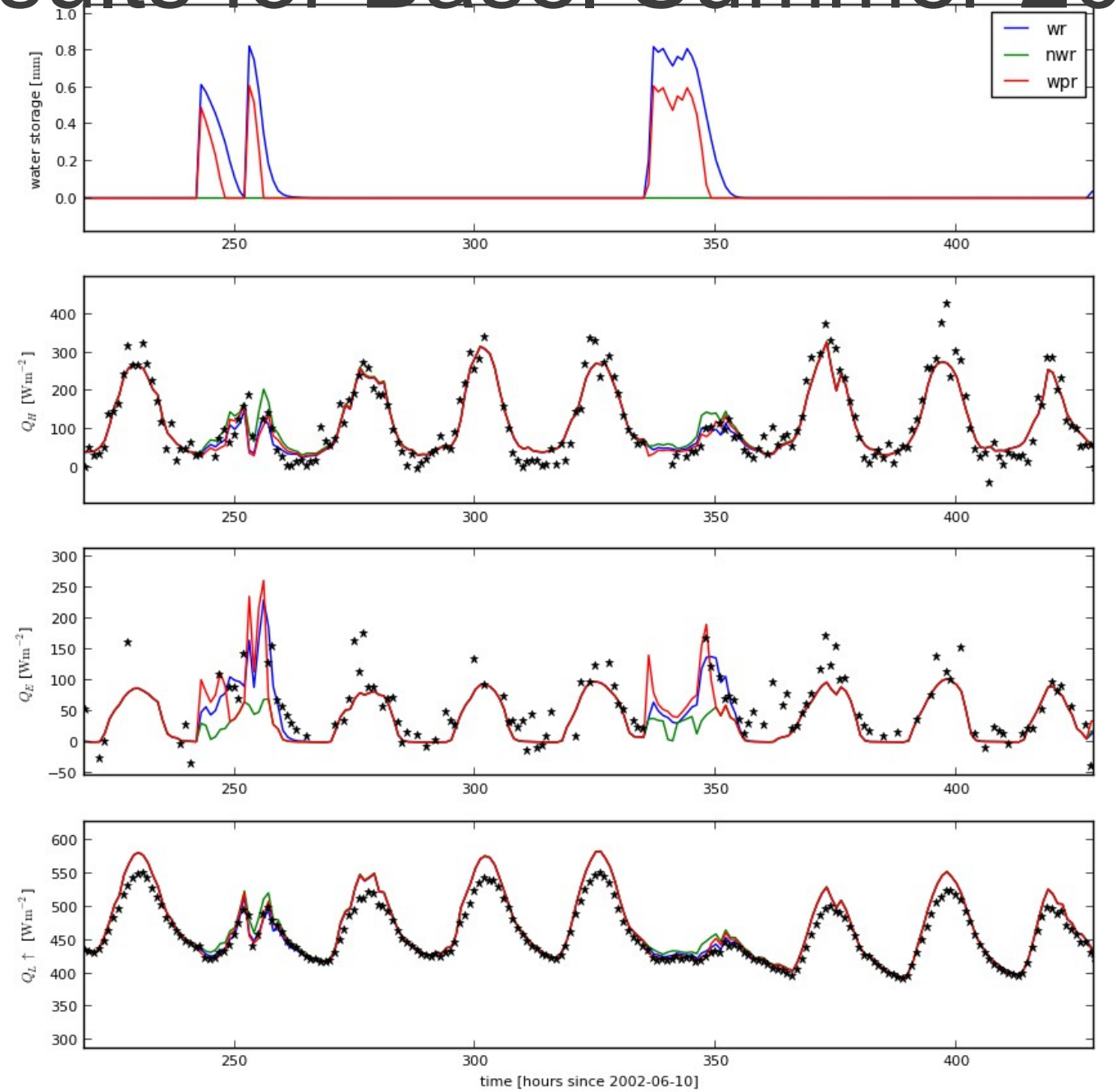



obs
Rain [mmh^{-1}]
wr
nwr
wpr
water storage [mm]
Q_E [Wm^{-2}]
$Q_L\uparrow$ [Wm^{-2}]
08/20 08/21
10/09 10/10
10/30 10/31
11/12 11/13 11/14
01/09 01/10 01/11 01/12

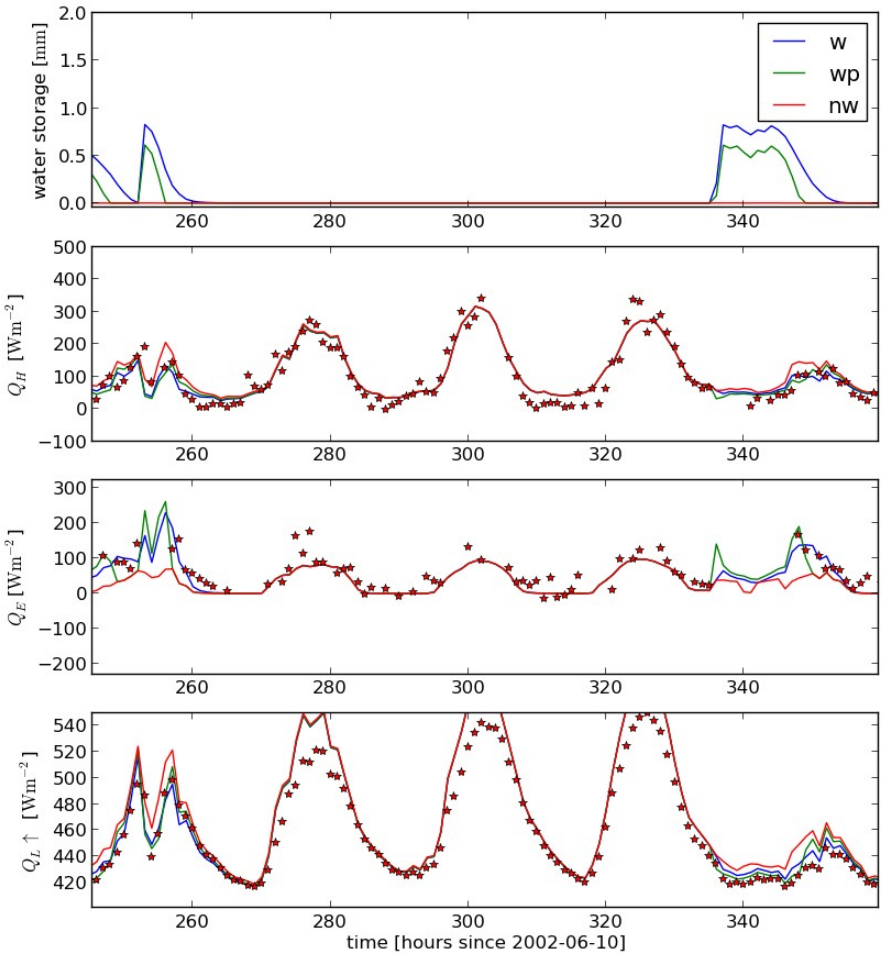


	$Q_L up$			Q_E		
	wr	wp	nwr	wr	wp	nwr
RMSE	**4.015**	4.508	5.222	29.462	36.679	**23.093**
MAE	**3.058**	3.371	5.284	**20.960**	26.439	25.080
BIAS	**-0.029**	-1.008	4.612	**-0.887**	-8.747	-24.282
R2	**0.993**	0.993	0.990	0.717	0.332	**0.770**

Results for Basel Summer 2002



Results for Basel Summer 2002



	$Q_L up$			Q_H			Q_E		
	wr	wp	wn	wr	wp	wn	wr	wp	wn
RMSE	**10.654**	10.930	10.900	**40.541**	40.630	41.305	**26.099**	28.543	27.541
MAE	**9.800**	9.923	10.953	31.205	**31.175**	32.745	**20.295**	21.940	21.836
BIAS	**8.981**	9.007	10.507	**9.952**	10.101	13.594	**-10.004**	-12.054	-14.102
R2	**0.988**	0.988	0.986	**0.919**	0.918	0.915	**0.785**	0.736	0.753

Conclusion

- Improved offline results obtained when applying UGIWS instead of PE or NE
- Impervious water storage characteristics: determined with a matching procedure using continuous measurements for long-wave radiation
- rooting depth is important for latent heat during Summer.
- Latent heat was underestimated → anthropogenic sources (e.g. household, combustion, irrigation)
- The annual-mean evaporation from the urban impervious surface is much lower than evaporation for the mediterranean environment with peaks of 250 W/m^2 max.
- 20% of the total precipitation evaporated from the urban impervious surface.

  → urbanization could considarably alter the surface water balance and precipitation patterns in the future
- Sky-view factor?!

Thank you for your attention!

- Questions, remarks suggestions?

vito
vision on technology

KATHOLIEKE UNIVERSITEIT
LEUVEN