Improving the water budget in the urban surface scheme TEB for a better evaluation of greening strategies for adaptation purposes

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CONTEXT

- Urbanisation growing
  - Microclimate impacts (UHI)
  - Hydrological impacts (floods, groundwater recharge)
- Global climate change
  - Potential urbanisation effects increasing ?
  - Adaptation strategies with vegetation => evapotranspiration process in both water and energy budgets
- Need for numerical tools coupling both detailed water and energy budgets

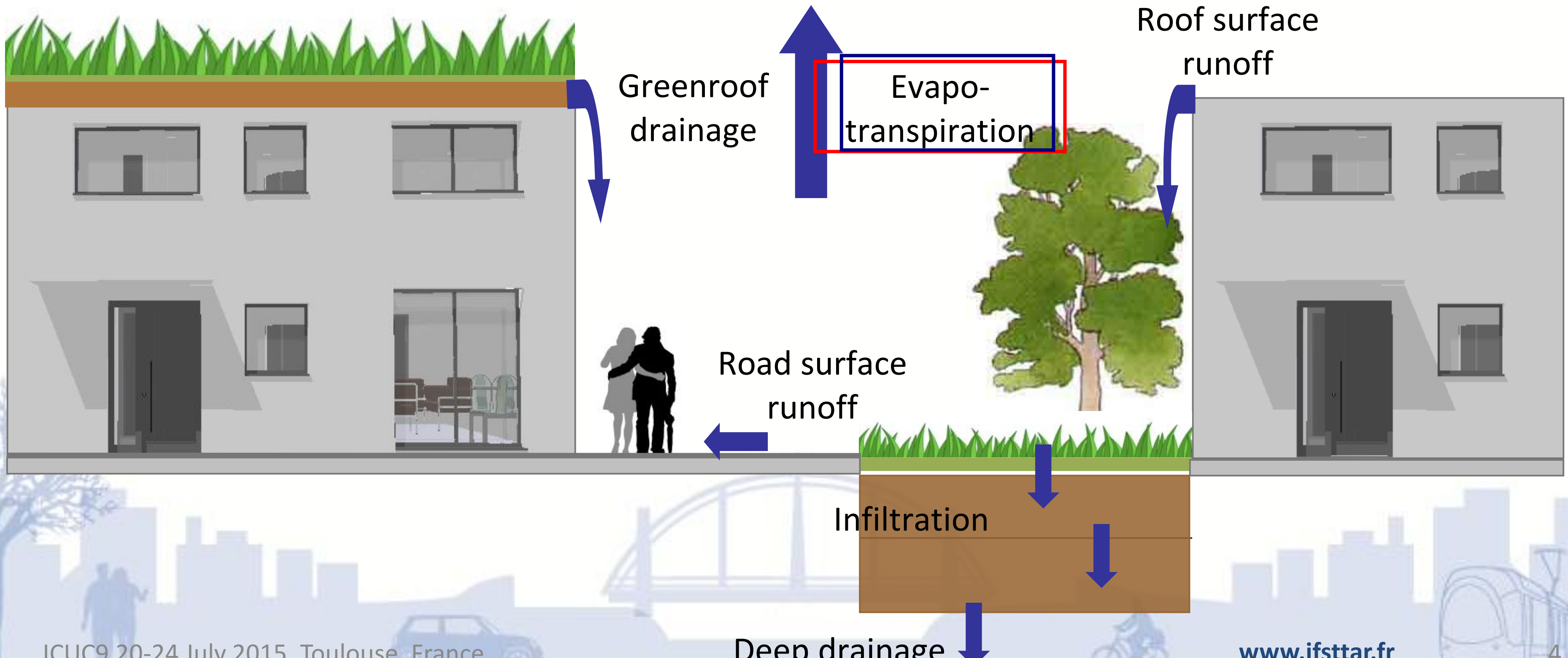
➢ VegDUD Project (funded French Research Agency)

OUTLINE

1. Urban surface scheme TEB and its evolutions
2. TEB-Hydro : a new water budget
3. Sensitivity study and evaluation : small urban catchment (Northwestern France)
4. Greening strategies evaluation : large domain in Nantes City (Northwestern France)

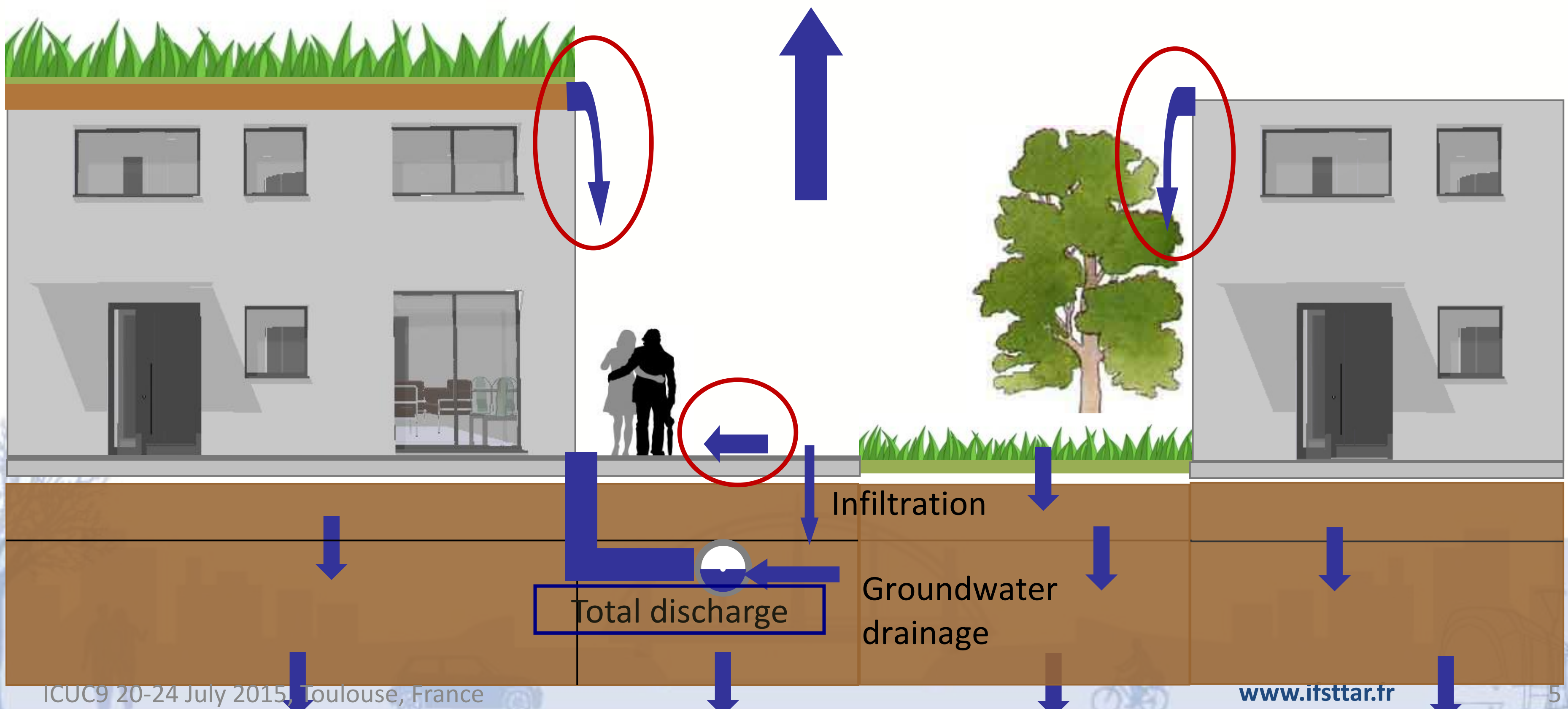
Urban surface scheme TEB

- TEB - mesh gridded model, urban canyon concept *(Masson, 2000)*
- Introduction of vegetation into the canyon, green roofs *(Lemonsu et al, 2012;De Munck et al, 2014)*



A new water budget : TEB-Hydro

- Introduction of soil and vertical water transfers (SVAT ISBA Boone, 2000)
- Groundwater drainage $if\ w_g > w_{th}, I_{sew} = K_s I_p D_{sew} \frac{w_g}{w_{sat}}, else\ I_{sew} = 0$
- No explicit water transfer from each mesh to the outlet



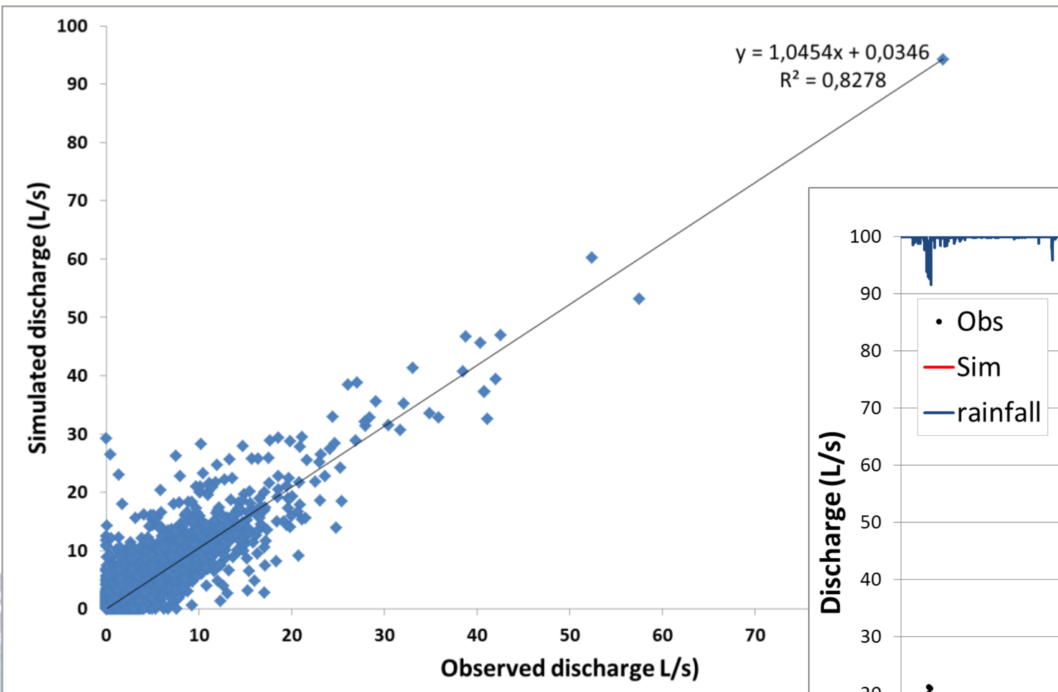
Sensitivity study and evaluation on a small French urban catchment (Rezé)

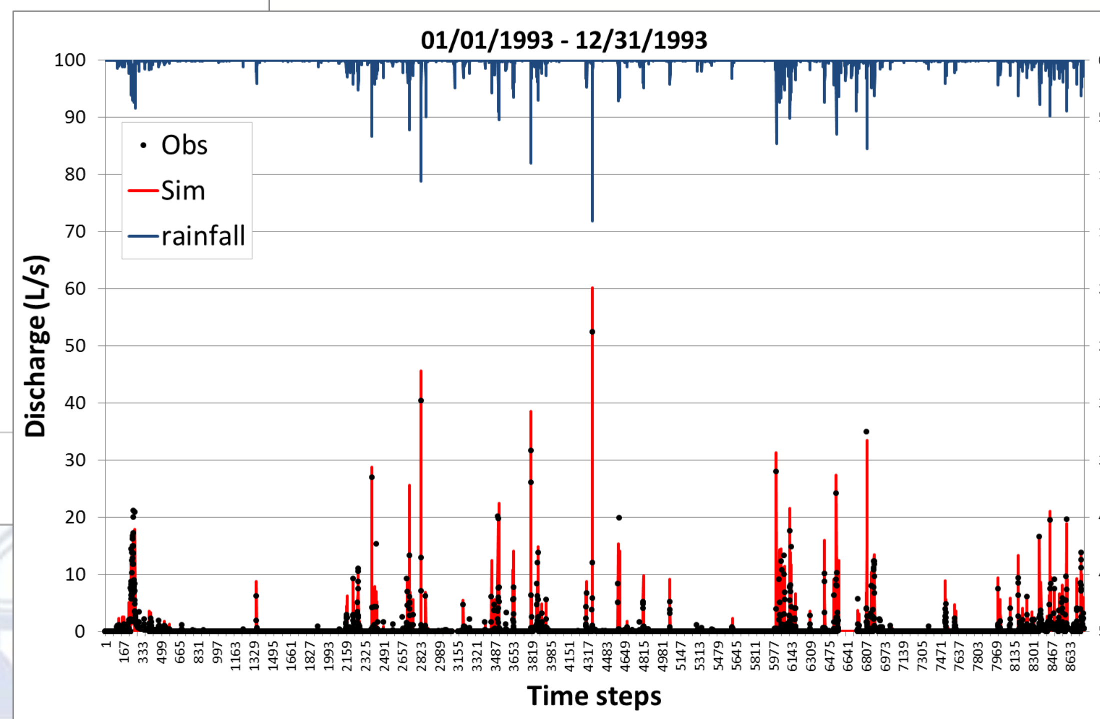
- Rezé catchment (4,7 ha)
- 1D simulations, off-line, 1993-1997
- Parameters:
  - Maximal road surface interception capacity S_{road}(mm)
  - Maximal roof surface interception capacity S_{roof} (mm)
  - Maximal road infiltration rate I_{road} (m/s)
  - Parameter for groundwater drainage I_p (-)
  - Effective impervious surface fraction F_{conn}

Parameters	Ref value	Min value	Max value
S_{road}	**1.0 mm**	0.5 mm	3.0 mm
S_{roof}	**1.5 mm**	0.5 mm	3.0 mm
I_{road}	10^{-5} mm.s^{-1}	**10^{-6} mm.s^{-1}**	10^{-4} mm.s^{-1}
I_p	10^{-2}	**10^{-3}**	5.10^{-2}
F_{conn}	0.8	**0.7**	0.9

Sensitivity study and evaluation on a small French urban catchment (Rezé)

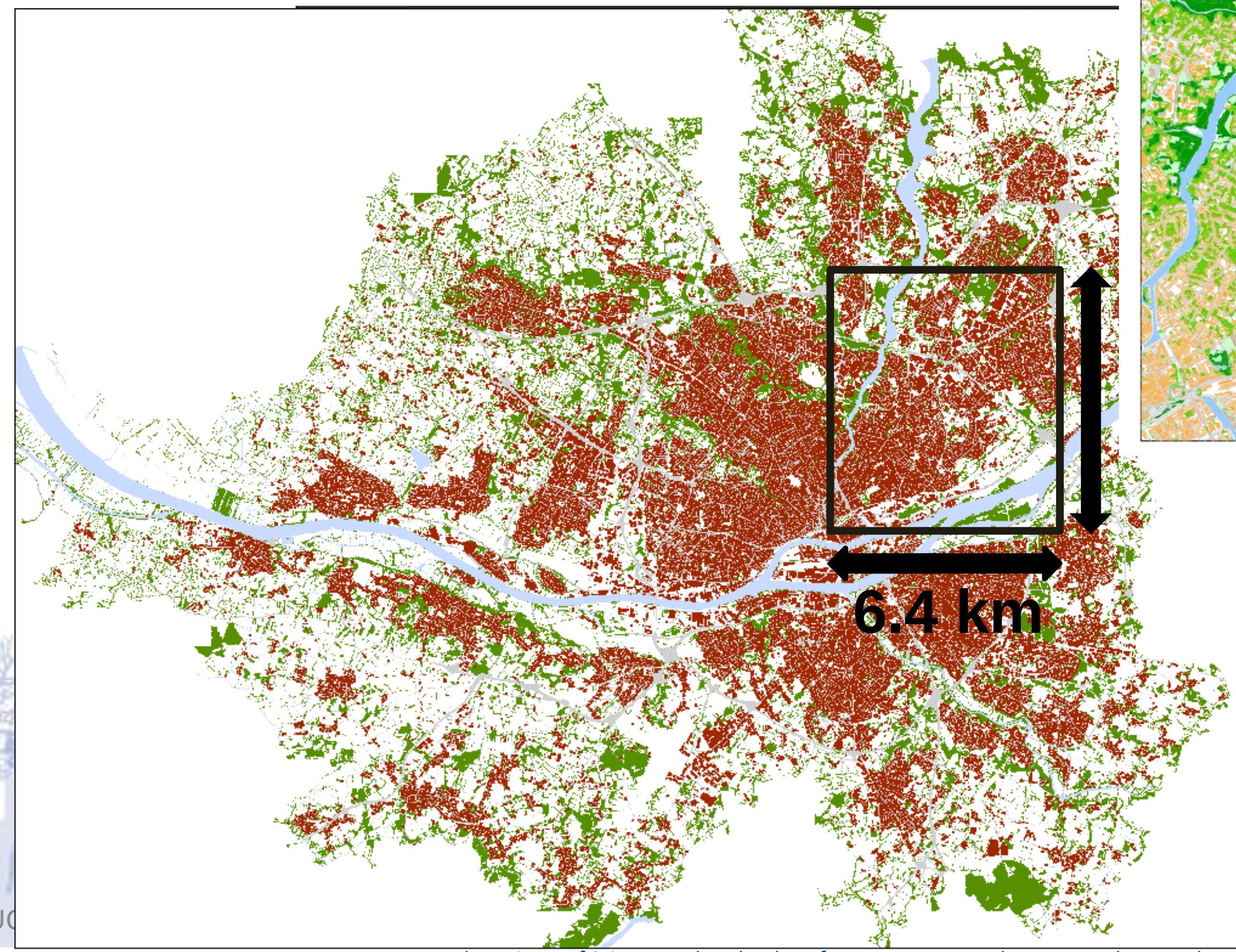
Year	1993	1994	1995	1996	1997	1993-1997
NSE	0.82	0.82	0.83	0.75	0.43	**0.77**
Bias	-2.3%	6.55%	14.8%	-14.3%	-25%	**-2.4%**

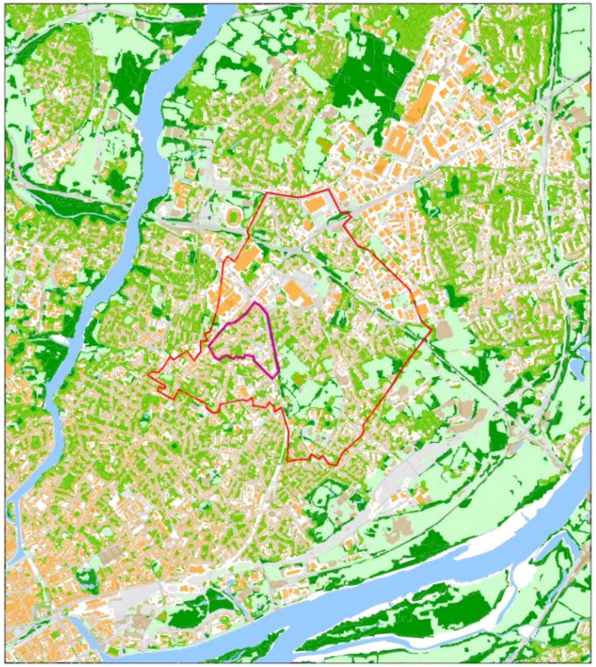




Evaluation of greening scenarios

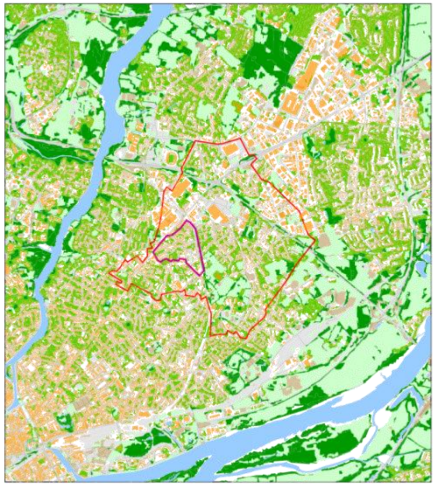
- Test case : 6.4km x 7.2km





Evaluation of greening scenarios

- Base case (REF) 05/01/2010 – 08/01/2012
  - Off-line
  - 1h forcing and output time step
  - 5' model time step
  - $\Delta x = 200$m
  - ➢ 08/01/2011 – 08/01/2012
  - ➢ Vegetation ratio : 44%

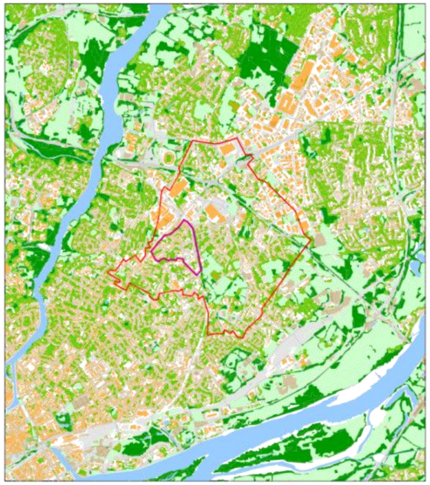


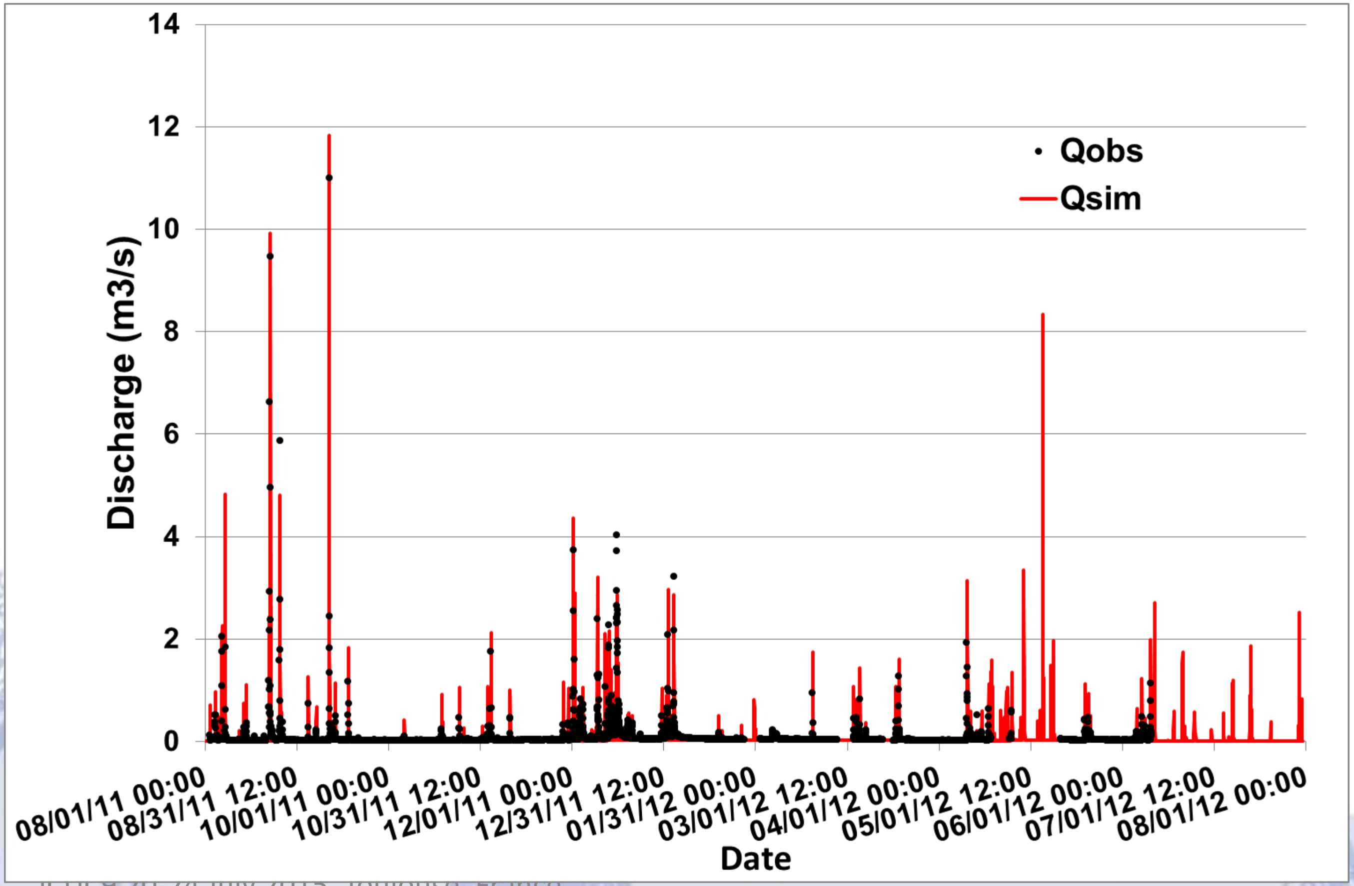
- Decreasing vegetation ratio (GARDEN20)
  - Vegetation ratio = 20% => impervious surfaces
- Introduction of green roofs (+7% veg ratio)
  - Public, industrial and apartments buildings

Evaluation of greening scenarios

- Evaluation of the base case

Discharge Gohards catchment (450 ha)



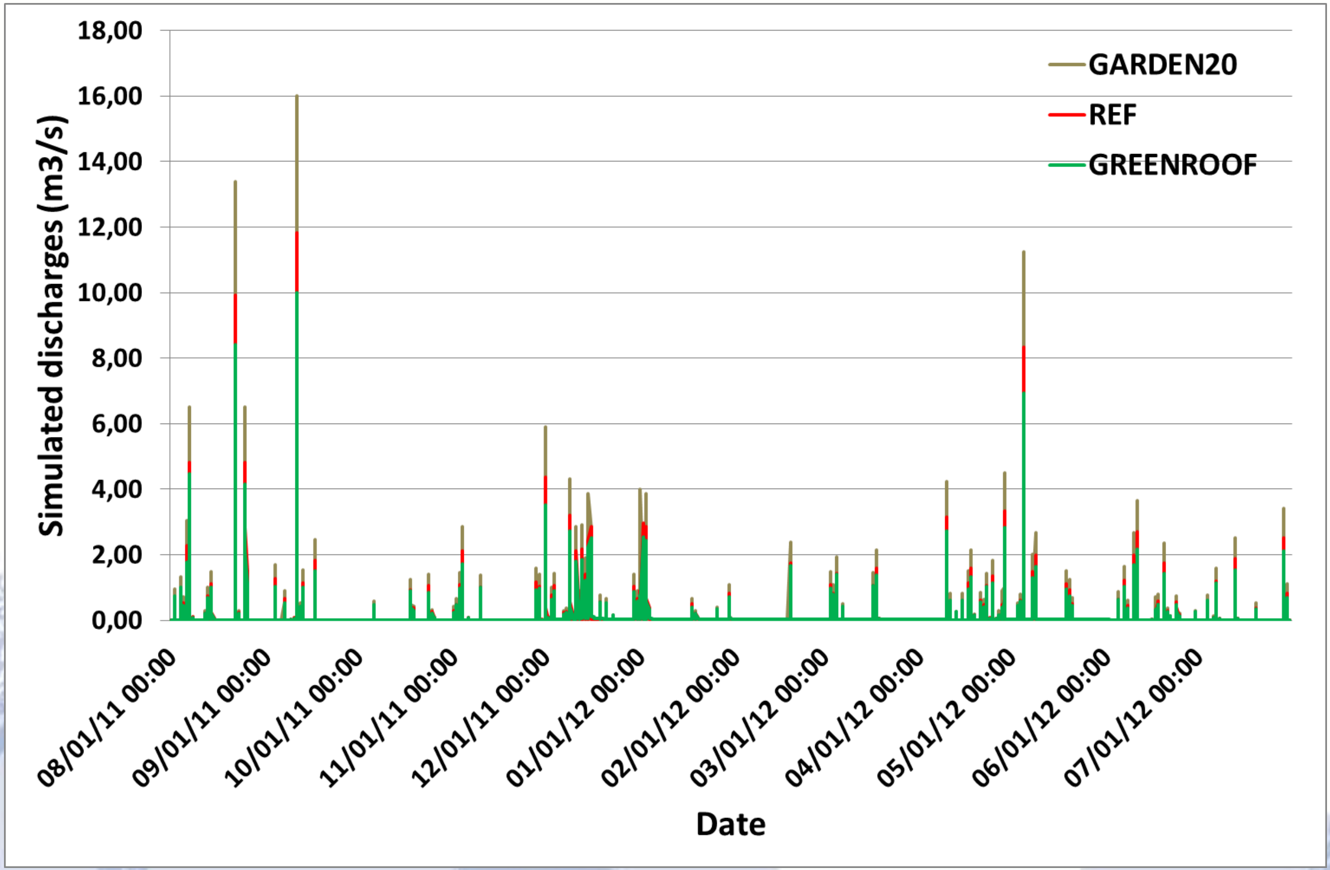


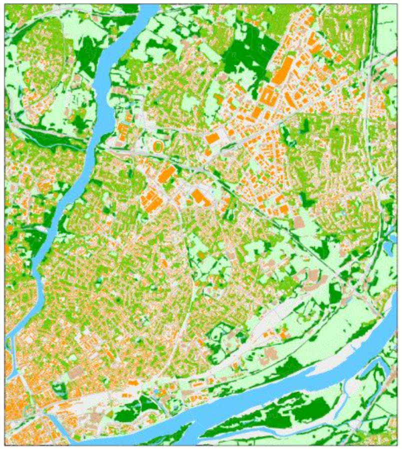
NSE=0.6
Bias=33%
➔ Bad simulation of groundwater drainage

Evaluation of greening scenarios

- Scenarios simulated discharges comparison

Discharge Gohards catchment

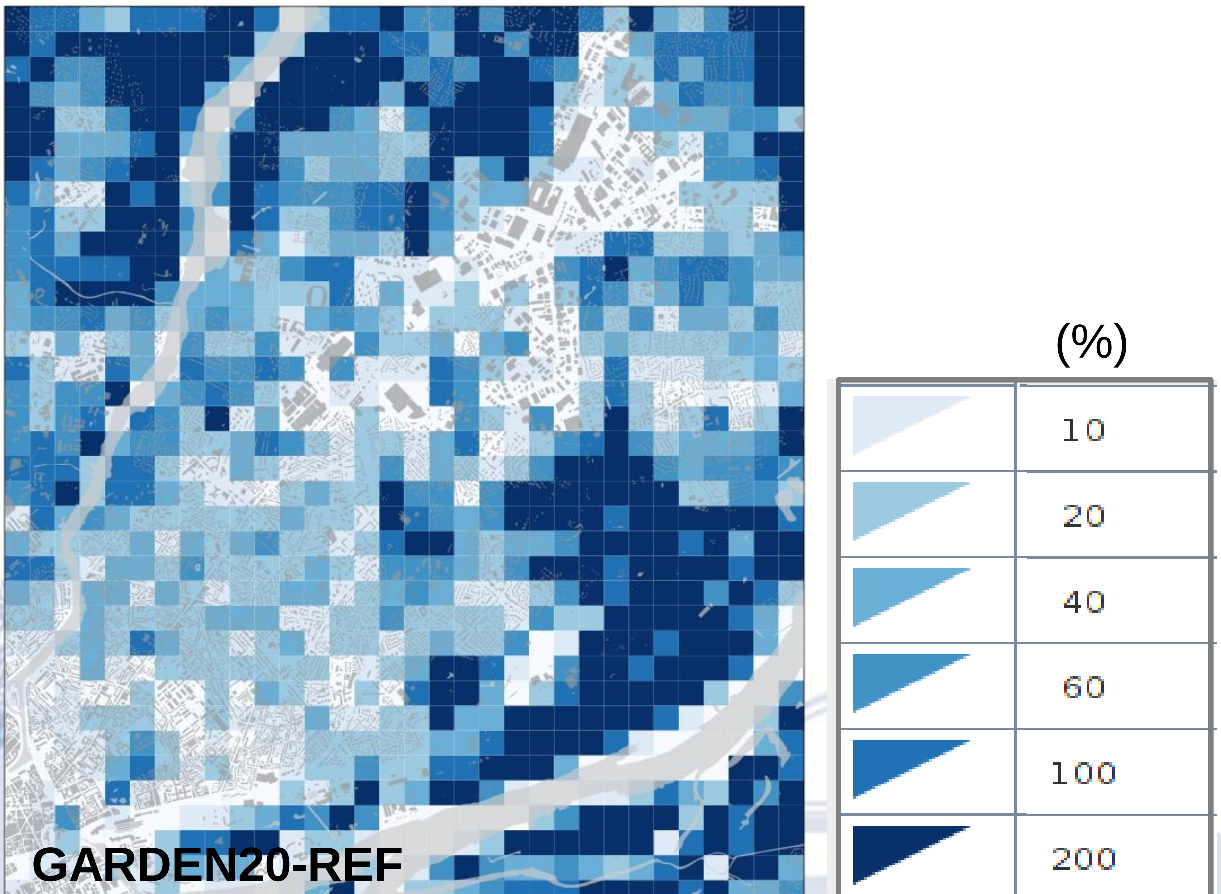




ΔVol (%)
GARDEN20=23%
GREENROOF=-6.5%

Evaluation of greening scenarios

- Spatial distribution of surface runoff variations



Evaluation of greening scenarios

- UTCI : outdoors, sunlight conditions

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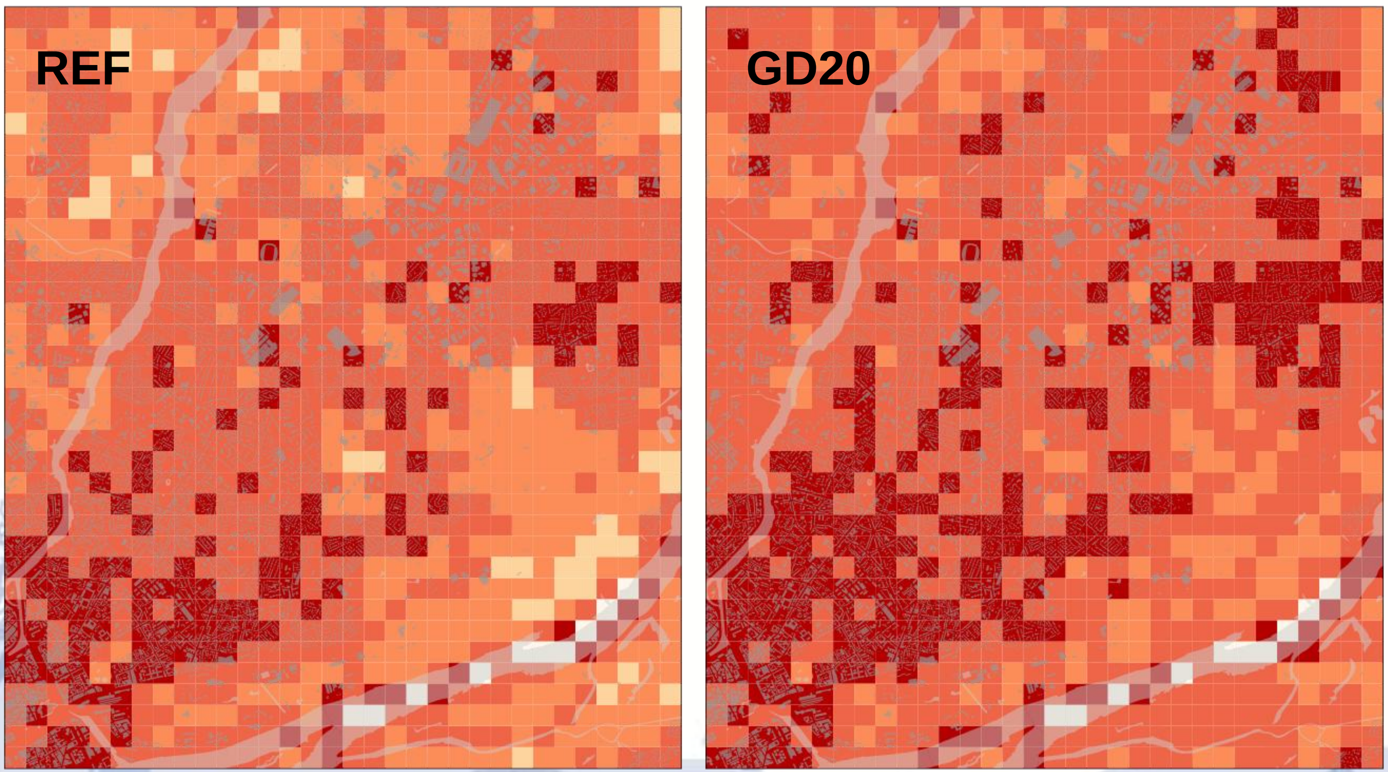
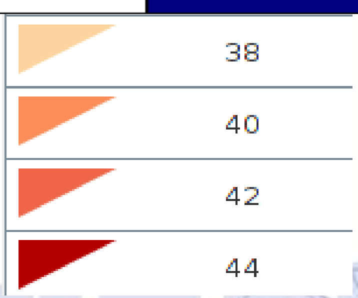
UTCI (°C) range	Stress Category
above +46	extreme heat stress
+38 to +46	very strong heat stress
+32 to +38	strong heat stress
+26 to +32	moderate heat stress
+9 to +26	no thermal stress
+9 to 0	slight cold stress
0 to -13	moderate cold stress
-13 to -27	strong cold stress
-27 to -40	very strong cold stress
below -40	extreme cold stress





CONCLUSIONS

- Water budget has been improved in the Town Energy Budget model (TEB => TEB-Hydro)
  - Introduction of soil
  - Groundwater drainage by sewer systems is taken into account

- TEB-Hydro has been evaluated over two catchments
  - Effective impervious surfaces rate is the major parameter
  - Comparison to observed data show satisfying results
  - Groundwater drainage underestimated

- Evaluation of greening scenarios for both water and energy budgets is now possible

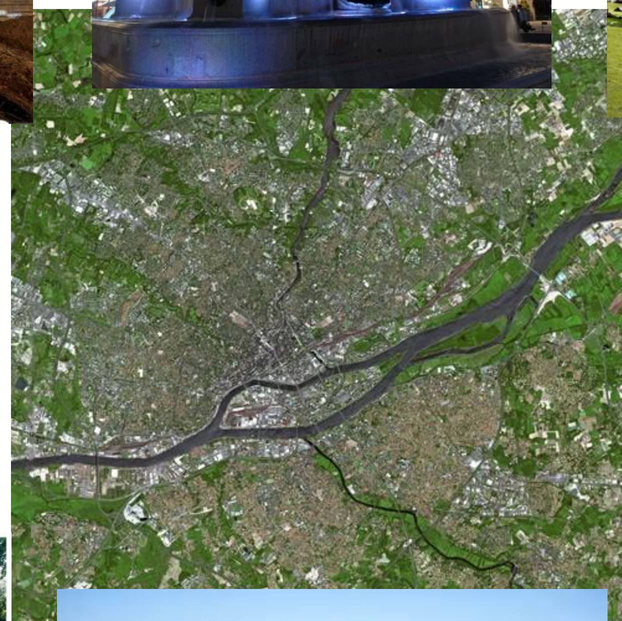
FUTURE WORK

- Improving the representation of saturated zone level to better simulate the groundwater drainage by the drainage system
- Water transfer between meshes to outlets has been developped (under evaluation) (A. Allard PhD)
- New adaptation strategies : street trees (Redon et al. ICUC9), swales
- Application to other cities (different climates, sewer systems)
- More realistic greening scenarios : urban water management (city and annual scales) ➔ Climate change

Thank you for your attention





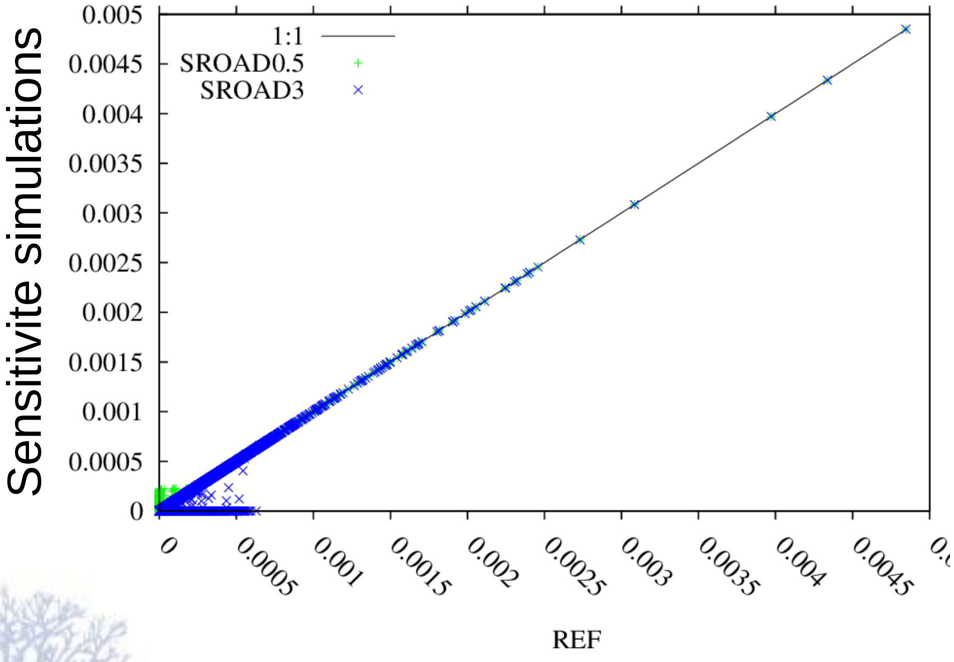




Sensitivity study on a small French urban catchment (Rezé)

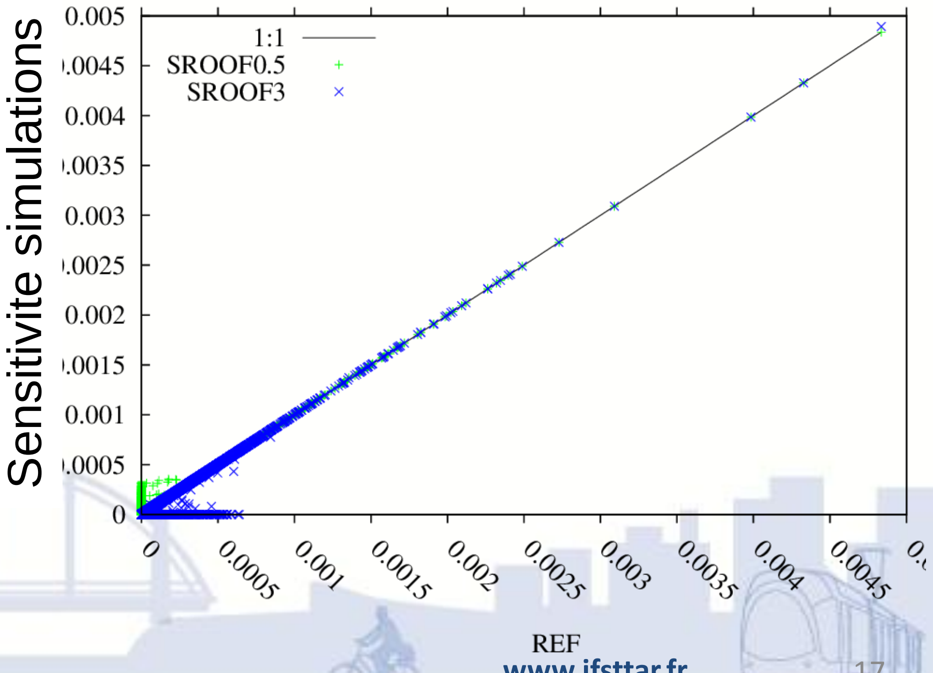
- Maximal interception capacity : Roads and roofs surfaces

➢ Initial losses



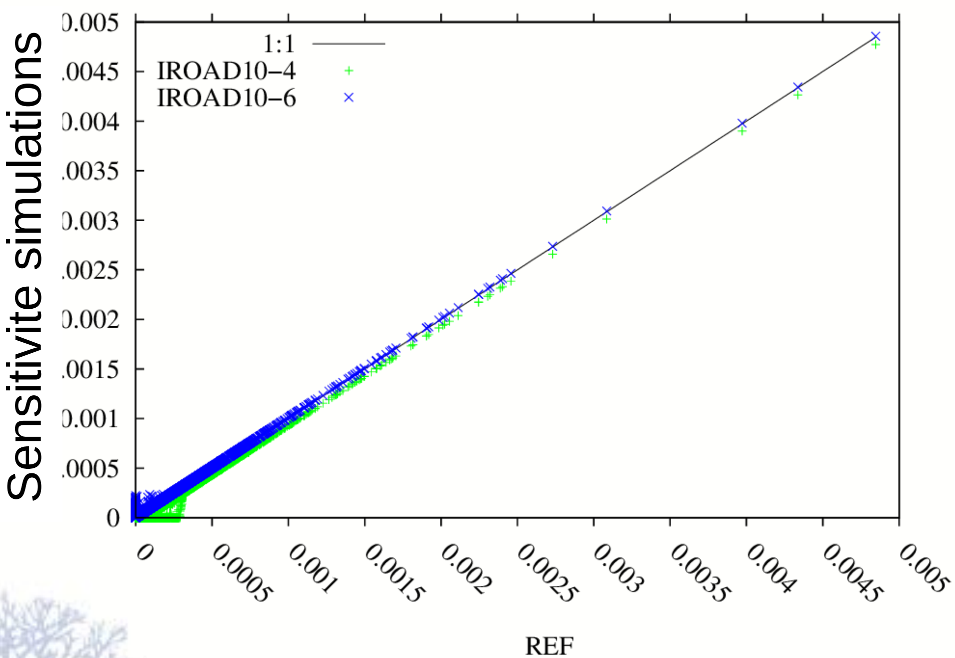
Road surface runoff (mm/s)

Roof surface runoff (mm/s)

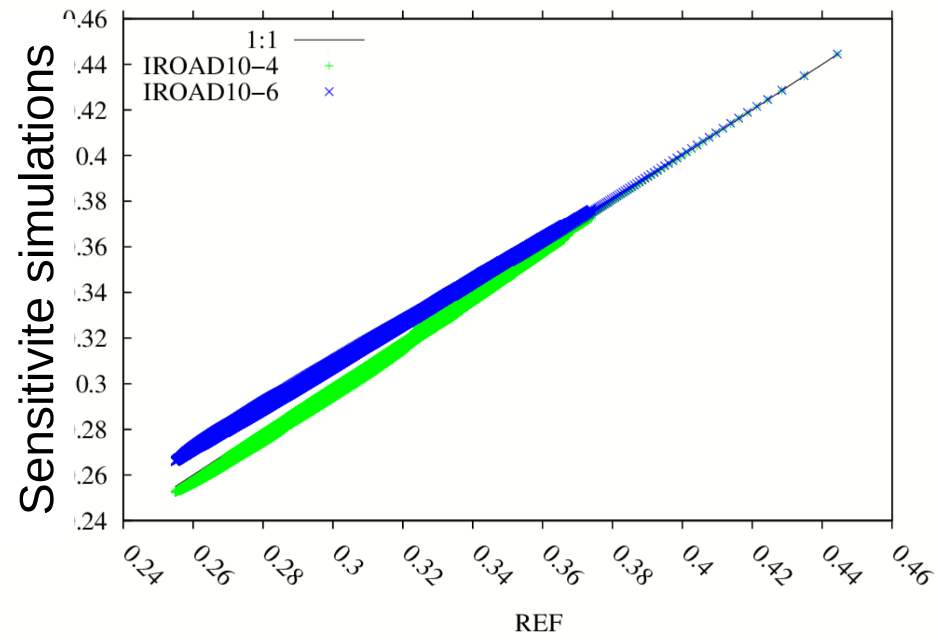


Sensitivity study on a small French urban catchment (Rezé)

- Maximal infiltration rate through roads
- ➢ Initial losses



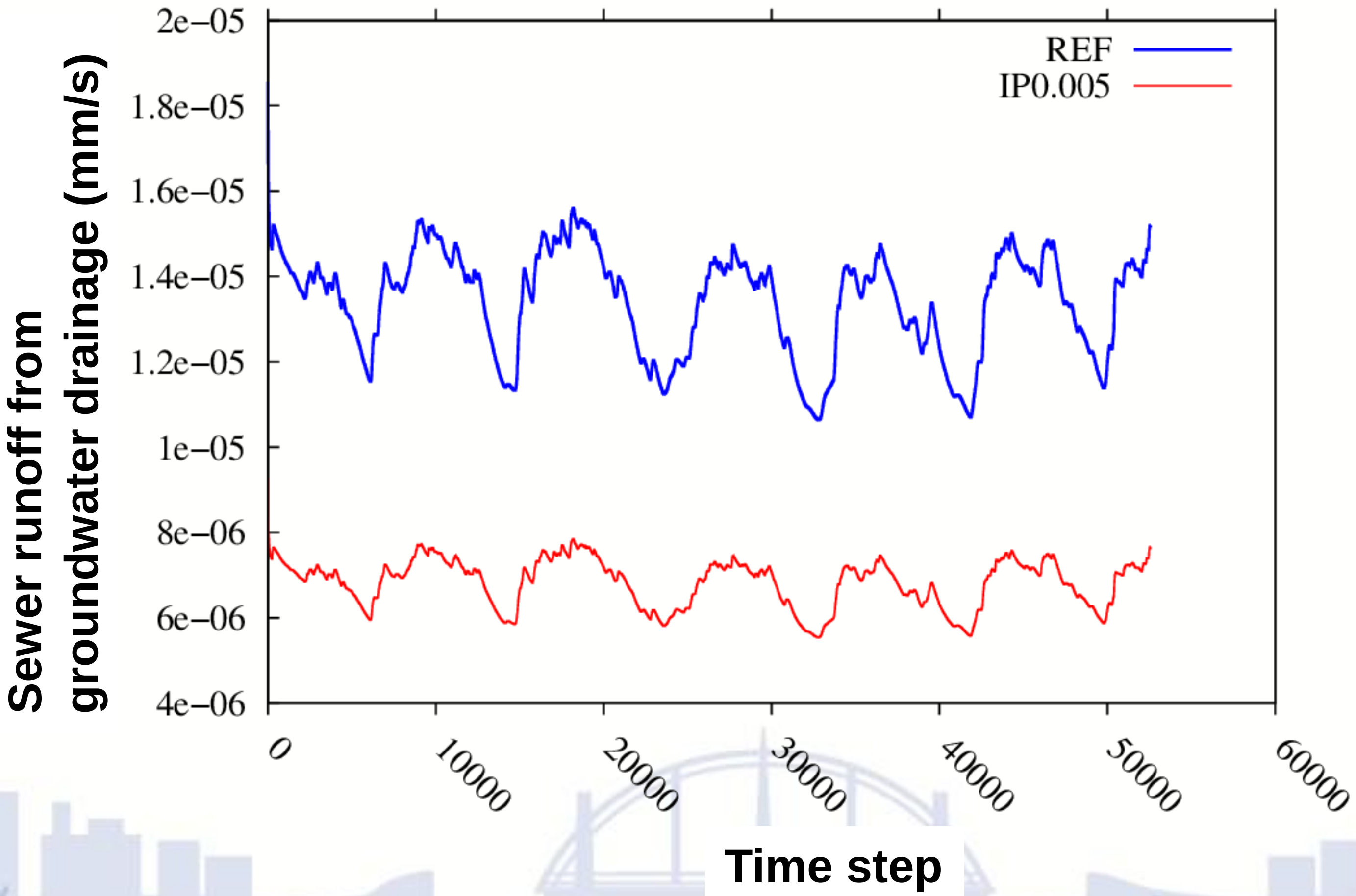
Sewer runoff (mm/s)



Groundwater under roads (m^3/m^3)

Sensitivity study on a small French urban catchment (Rezé)

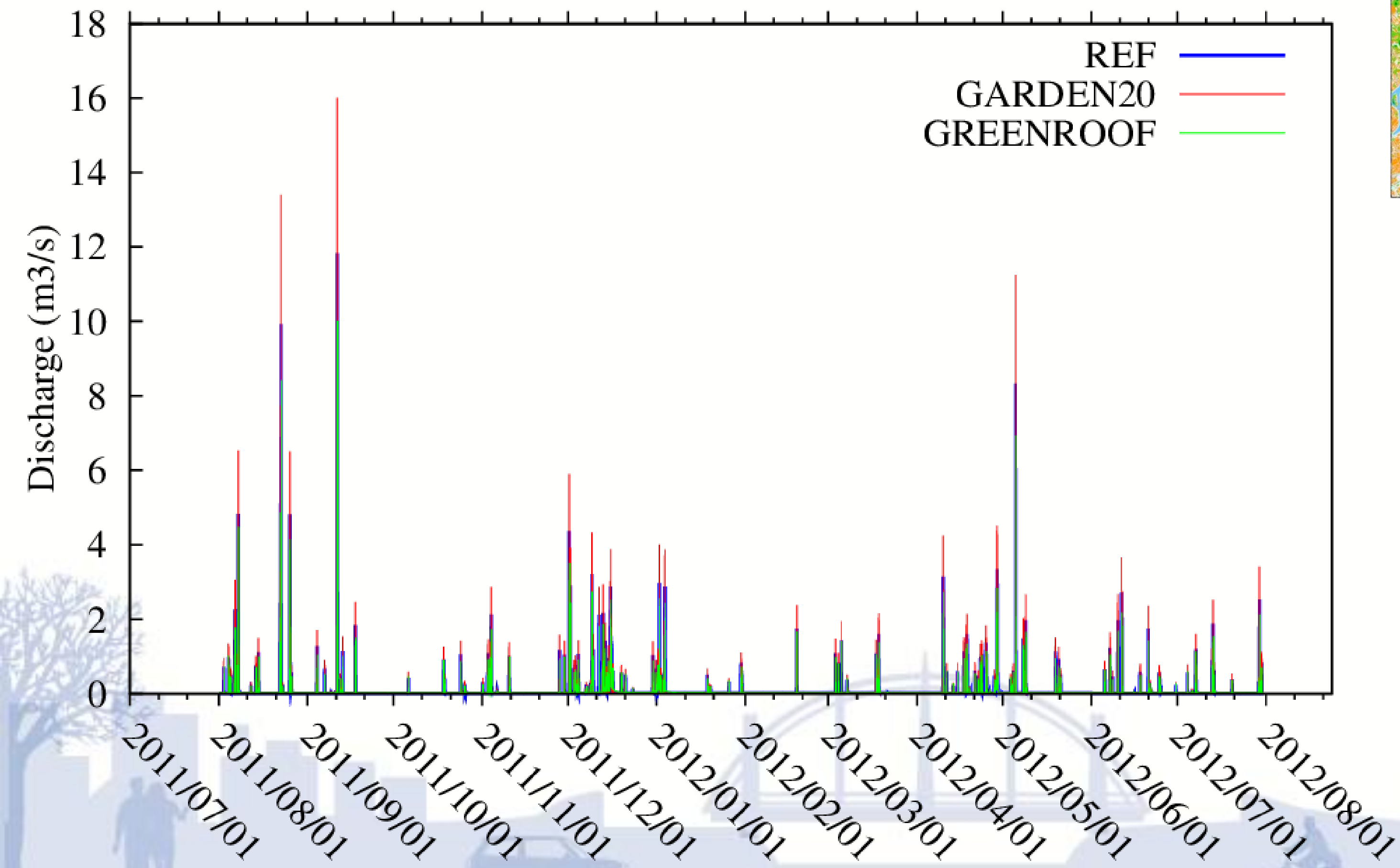
- Groundwater drainage parameter (Ip)

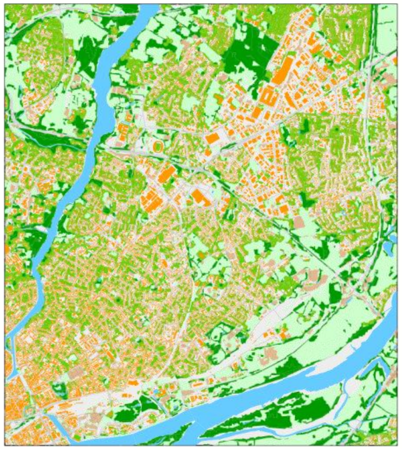


Evaluation of greening scenarios

- Scenarios simulated discharges comparison

Discharge Gohards catchment





Variation vol eau