RainGain

Investing in Opportunities

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INTERREG IVB

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Impact of small scale rainfall variability in urban areas : a case study with 2D/1D hydrological models in a multifractal framework

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The Multi-Hydro model

Overall description:

- Multi-hydro is a numerical platform developed at LEESU (v1, El Tabach et al, 2008, v2, A. Giangola-Murzyn et al., 2012) in the framework of SMARTesT. It is currently in a validation and demonstration (Heywood site, Manchester; Villecresnes site, Val-de-Marne) phase.

- It a is core that makes interact different modules, each representing a portion of the water cycle in urban hydrology.

Main goals:

- taking into account small scales → fully distributed model

- physically based model (no calibration)

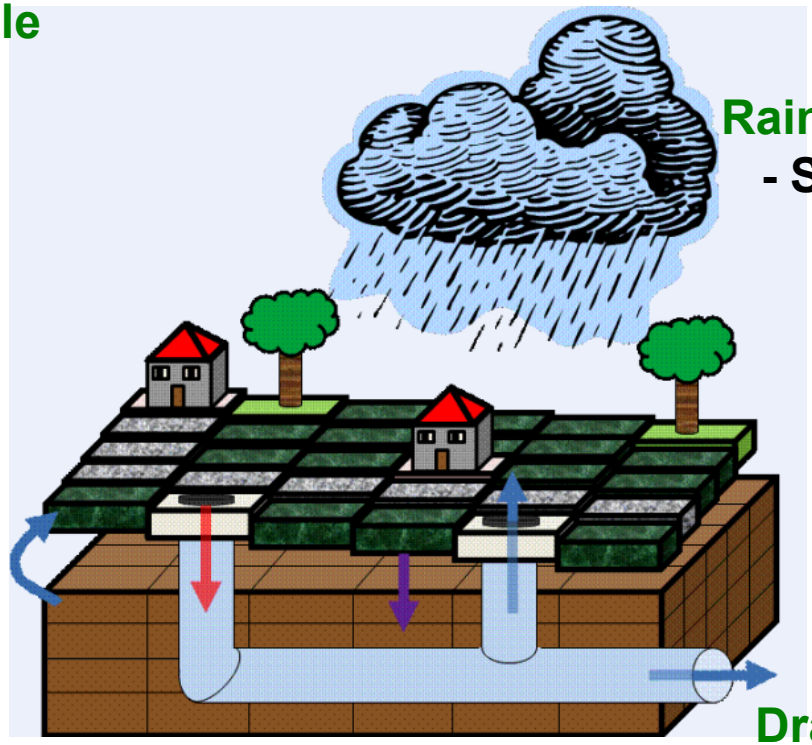
- easily transportable → a conversion module to generate inputs from available GIS data

- open access software packages to benefit from the feedback of a large community and frequent update.

The Multi-Hydro model

Urban area physical processes modeled in Multi-Hydro

Surface module
- Runoffs
- Infiltration

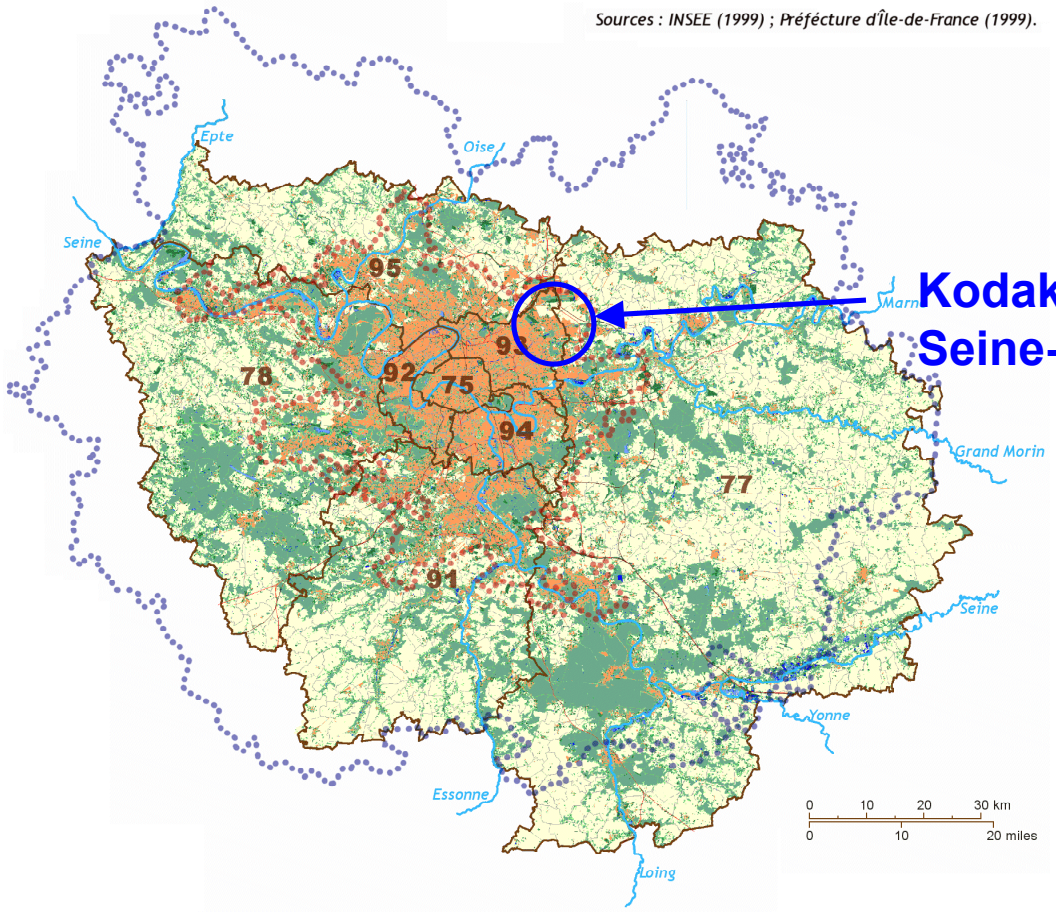


Rainfall module
- Spatio-temporal rainfall

Soil module
- Vertical flow in the non-saturated area
- Saturation during a rainfall event

Drainage module
- Sewer flow (free surface, and loaded)
- Overflow

Kodak catchment



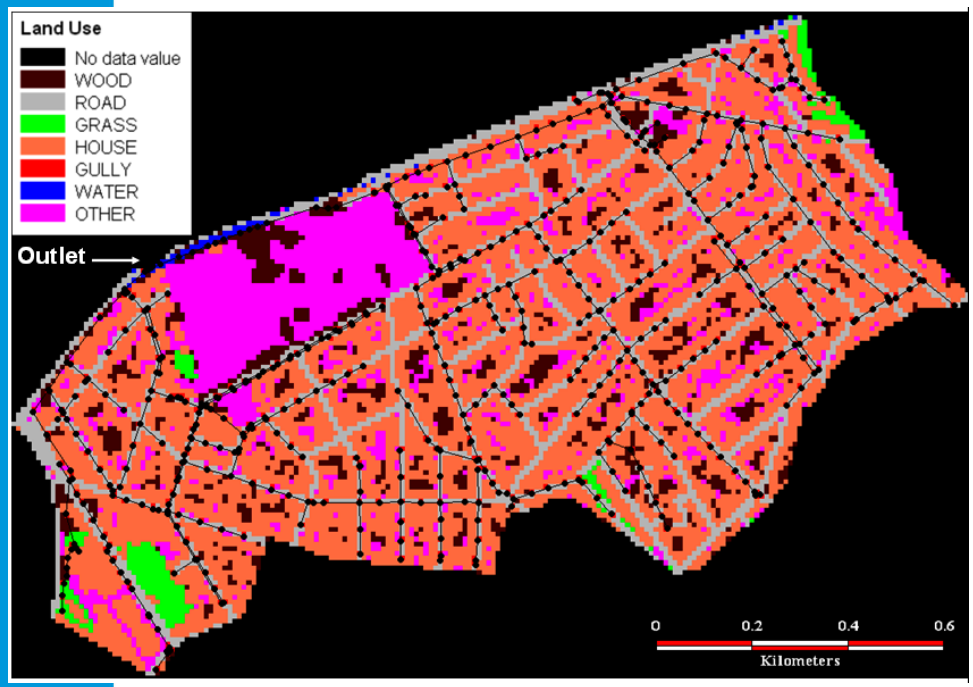
Kodak catchment, in Seine-Saint-Denis

Kodak catchment

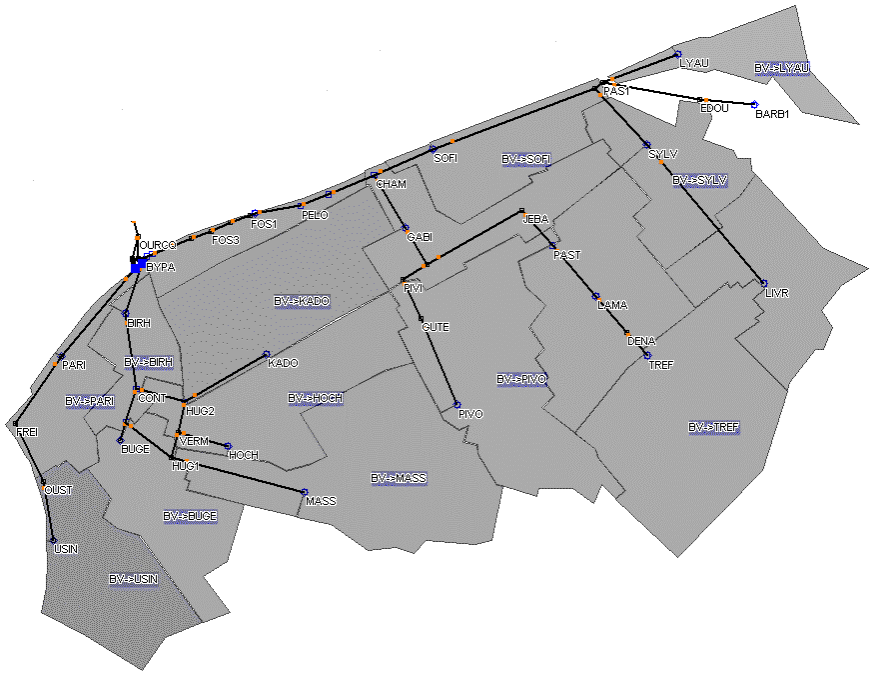
- 1.47 km²
- Known for regular overflow
- Project to build a storm water storage basin

Kodak catchment

Multi-Hydro : 10 m resolution



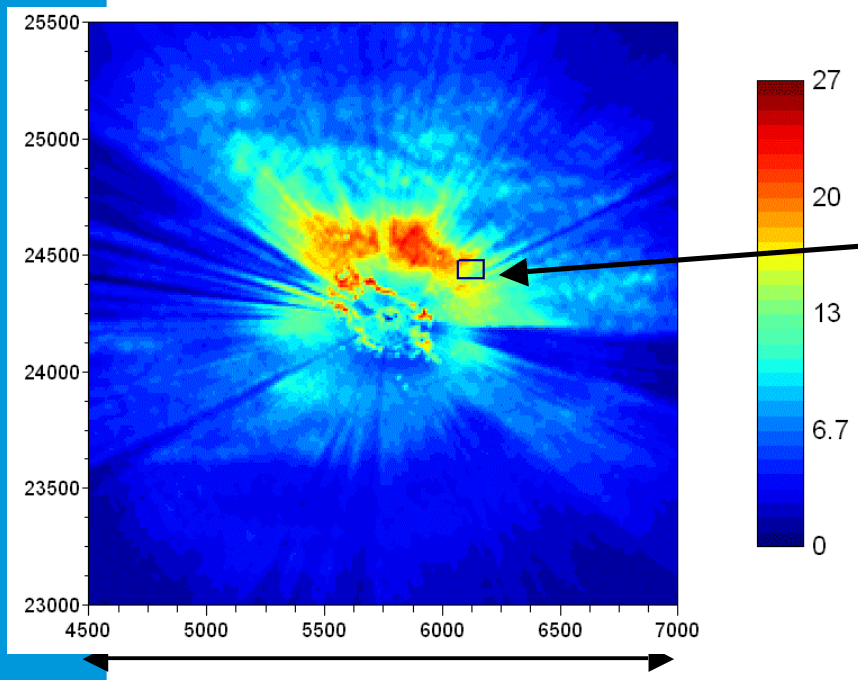
Semi-distributed 1D model



- Modelled with semi-distributed 1D model Canoe (lumped model for each sub-catchment and Saint-Venant equations in the links)
- 16 sub-catchments (considered homogeneous) with size ranging from 4 to 14.5 ha
- Calibrated by DEA 93

Rainfall event of February 9th 2009

Total rainfall depth

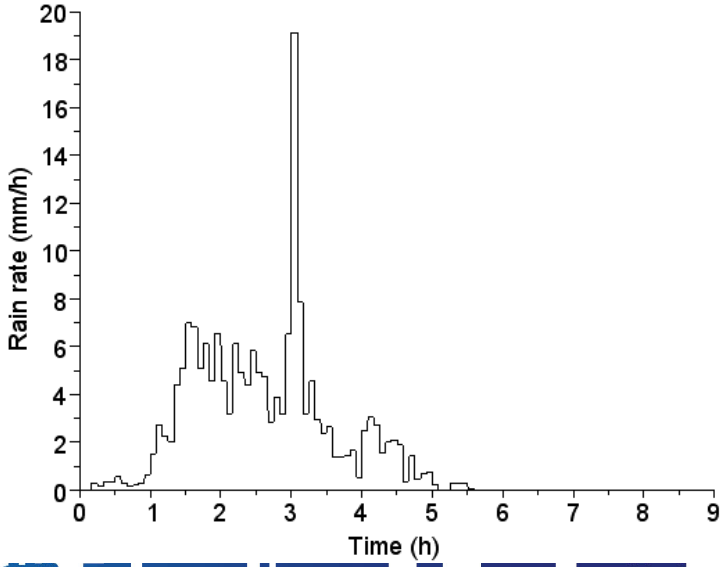


C band radar of Trappes (operated by Météo-France)

Studied catchment

Resolution :
1 km * 1 km * 5 min

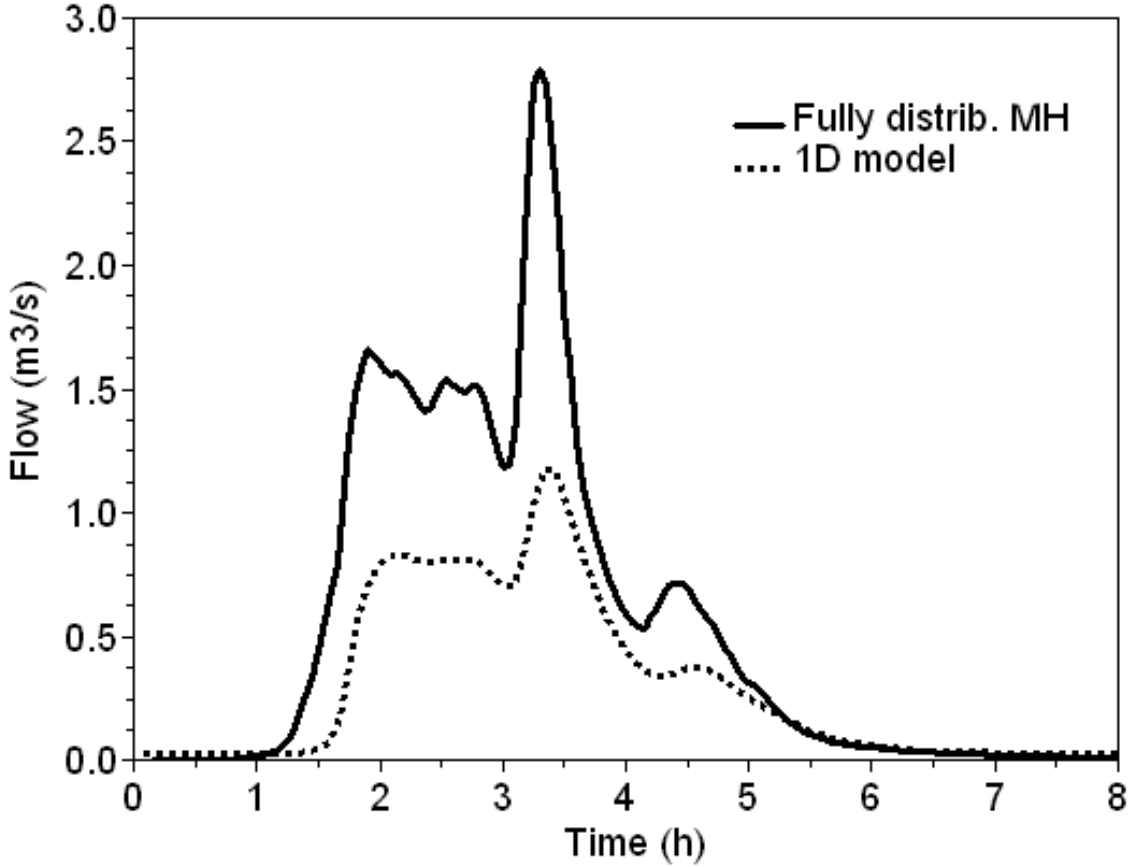
Time evolution of the rain rate for the studied catchment



Data was provided by Météo-France

Comparison of the simulated flow with raw radar data

For the outlet



- **Similar patterns**

- **Significant differences in terms of values (a need to check with flow measurement)**

Quantifying the uncertainty associated with small scale rainfall variability

Methodology : stochastic ensemble approach

(i) Generation of an ensemble of realistic downscaled rainfall fields :

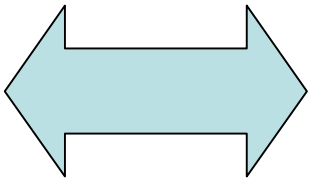
- Multifractal analysis of rainfall data
- Downscaling with the help of discrete universal multifractals cascades

(ii) Simulation of the corresponding ensembles of hydrographs :

- Use of operational hydrological/hydraulic urban models

(iii) Analysis of the ensembles :

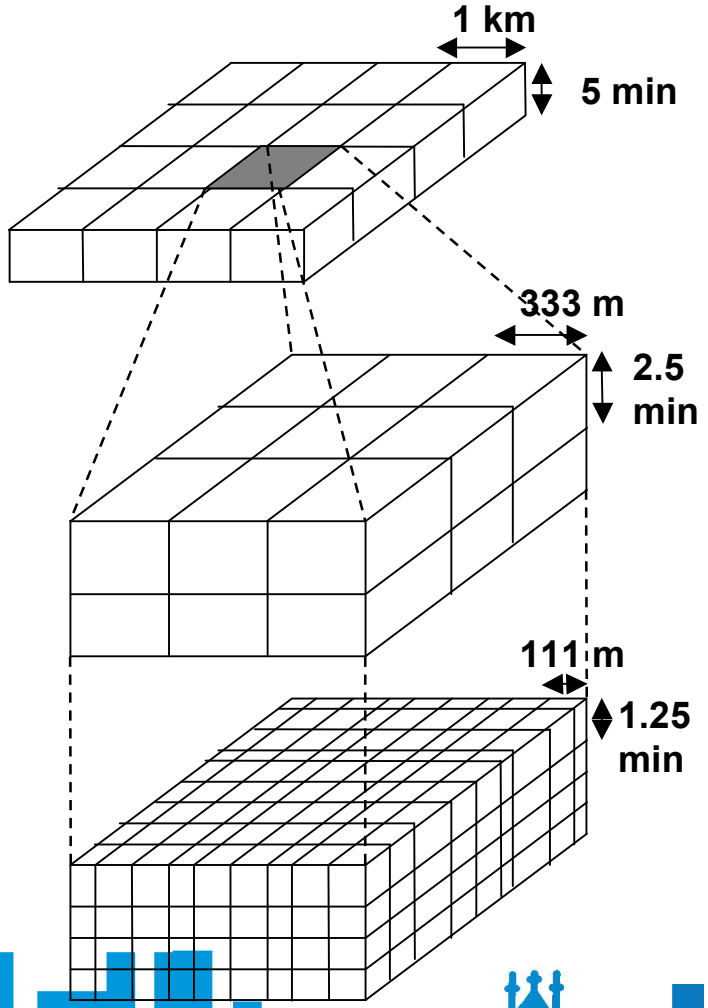
Variability among the 100 samples



Uncertainty due to the unknown high resolution rainfall variability

Quantifying the uncertainty associated with small scale rainfall variability

Rainfall downscaling technique



Measured or deterministically nowcasted

Multifractal analysis → two relevant parameters of the cascade process

Stochastic spatio-temporal downscaling for each pixel

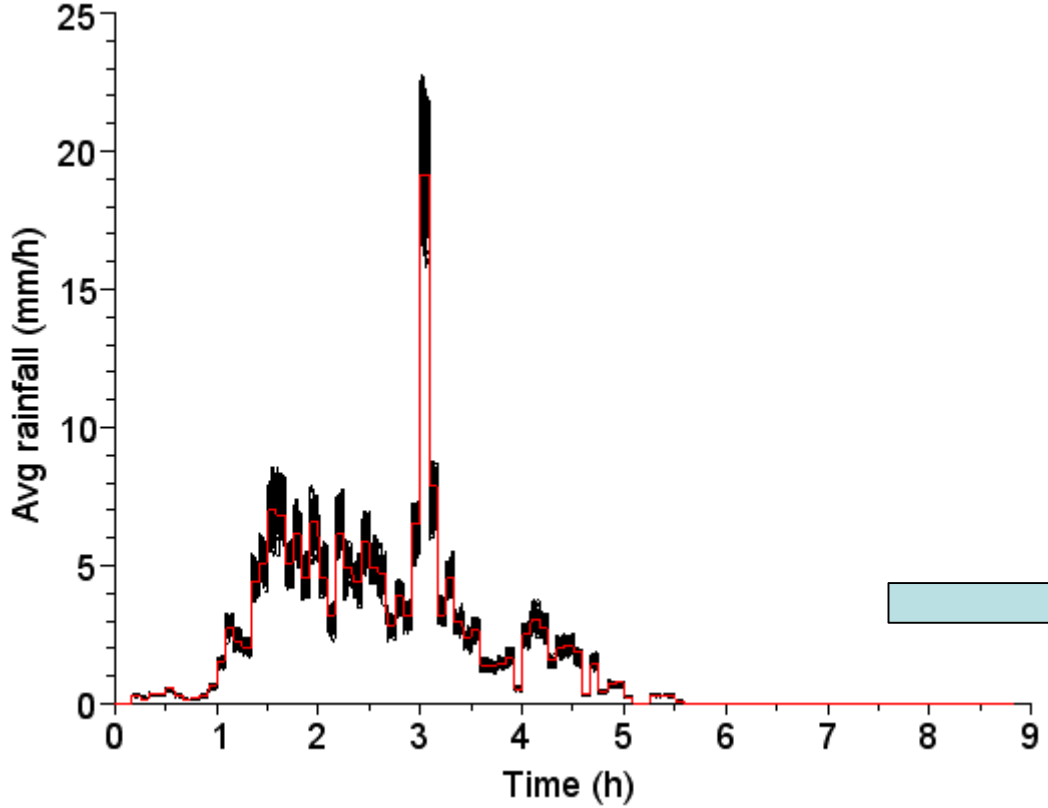
Performed with the help of discrete Universal Multifractal cascades

Two more cascade steps… → 11 m x 19 s

Quantifying the uncertainty associated with small scale rainfall variability

Rainfall downscaling technique

Temporal evolution of the avg rain rate over the studied area



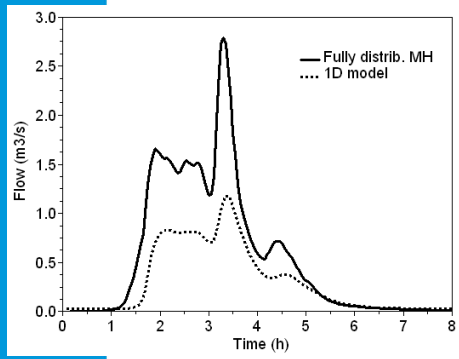
Total rainfall amount :

- Raw radar : 15.2 mm

- Simulated ensemble : 15.2 ± 0.12 mm (CV=0.8%)

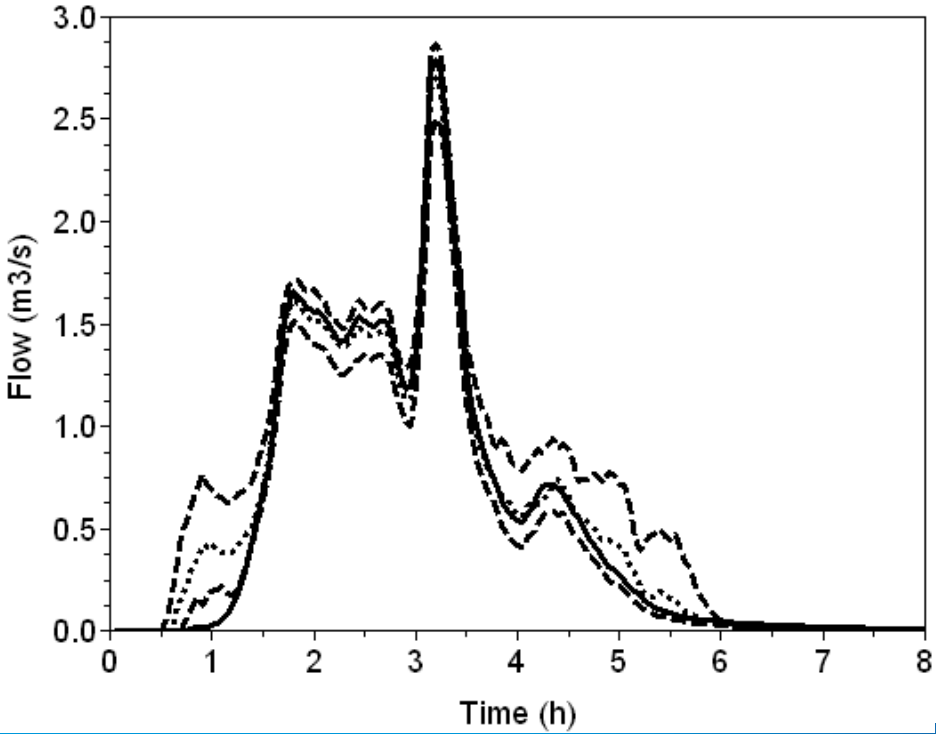
Potential hydrological effects are due to disparities of spatio-temporal distribution, not total amount.

Quantifying the uncertainty associated with small scale rainfall variability

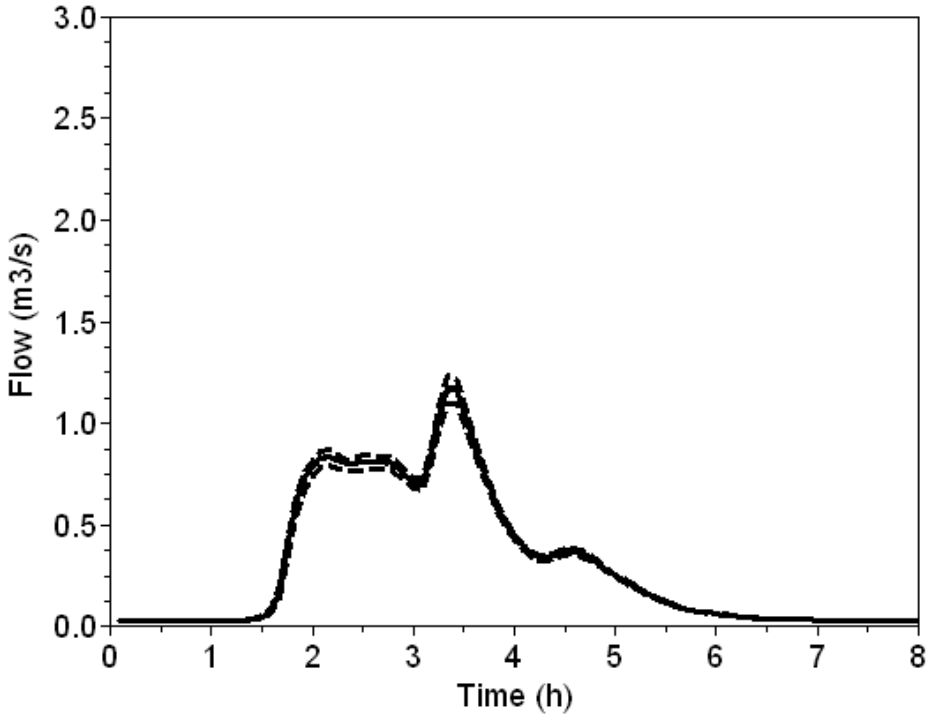


Uncertainty on the simulated flow for the outlet

Multi-Hydro 10m

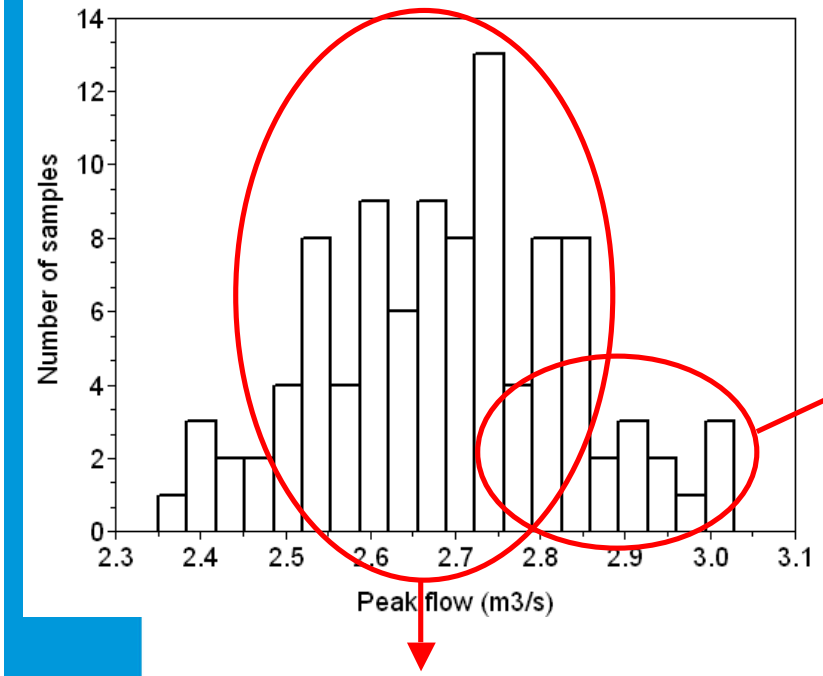


Semi-distributed 1D model



Quantifying the uncertainty associated with small scale rainfall variability

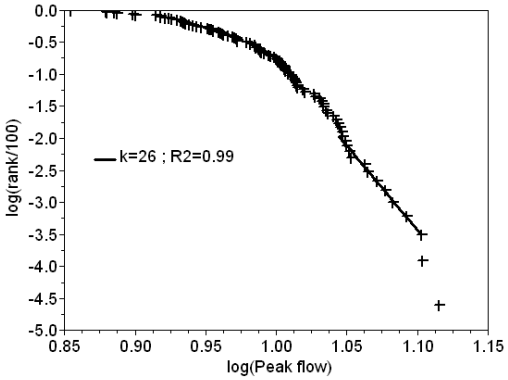
Focus on the peak flow



Histograms of the peak-flow

(no significant differences for time of occurrence)

A power-law behavior $\Pr(Q_{\max} > x) \alpha\ x^{-k}$



$$CV' = \frac{PF_{0.9} - PF_{0.1}}{2 * PF_{0.5}}$$

***CV'* = 7 % for MH and 6% for 1D model**

***k* = 26 for MH and 34 for Canoe**

Power-law behavior also observed on downscaled rainfall

Conclusion

Quantifying the uncertainty associated with unmeasured small scale rainfall variability :

- It cannot be neglected (*CV*' reaches 30% for up-stream links and 7.5% for the outlet, and power law fall-off for probability distribution for both discharge and rainfall).
- A need to implement X band-radars (which provide an hectometric resolution) in urban area

Comparison of fully a distributed model (10 m resolution) with semi-distributed one (300 m resolution)

- Much more uncertainty is unveiled with the fully distributed / Even moderate rainfalls are affected

→ Small scale phenomenon must be taken into account in urban hydrology

Limits / further investigations :

- Perform similar study with other inputs
- More heaviest rainfall, actually generating floods should be tested