EGU HS7.1/AS4.8/NH1.10/NP3.9

Quantifying the uncertainty on urban runoff associated with small-scale rainfall variability: a comparison of two case study

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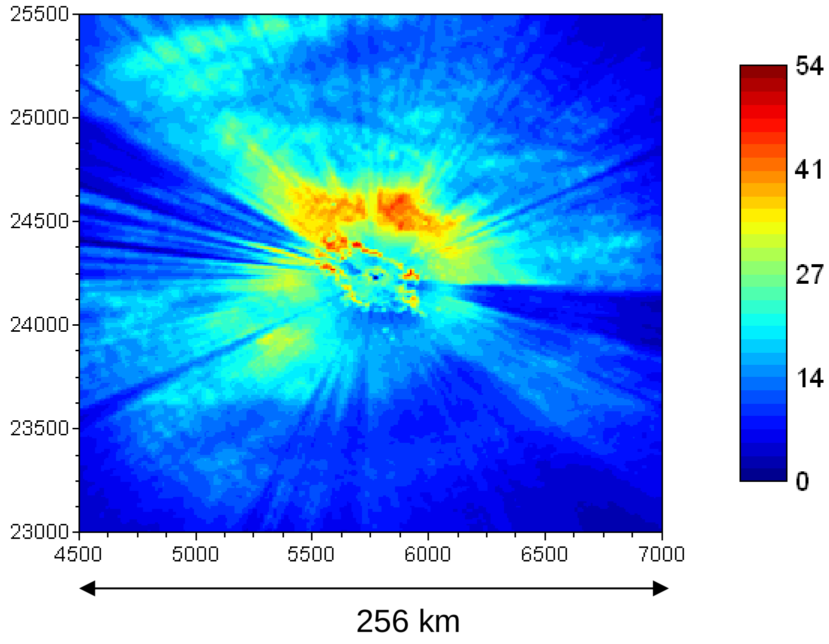
Introduction

- Rainfall is extremely variable over wide ranges of spatio-temporal scales

- Numerous studies suggest a significant impact of this variability on hydrology, and moreover in urban hydrology (greater coeff. of imp. and shorter response time)



→ Aim : quantifying on two cases study the impact of small scale unmeasured rainfall variability (i.e. at a scale < 1km*1km*5min) on urban discharge

Two study cases:

- Two urban catchments : one in Seine-Saint-Denis (Paris area), and one in Cranbrook (London)
- Rainfall event of February 9th, 2009

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**

Downscaling of rainfall data

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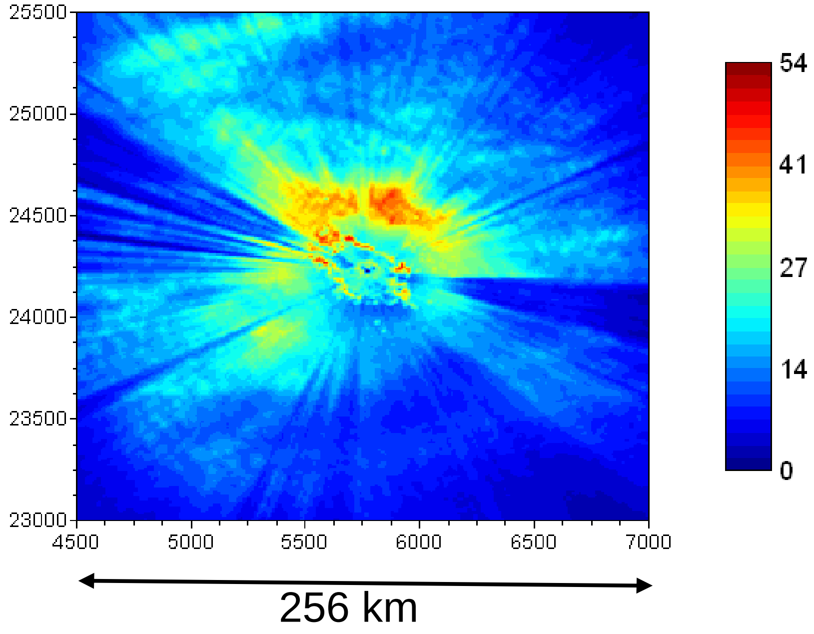
Rainfall event of February 9th 2009

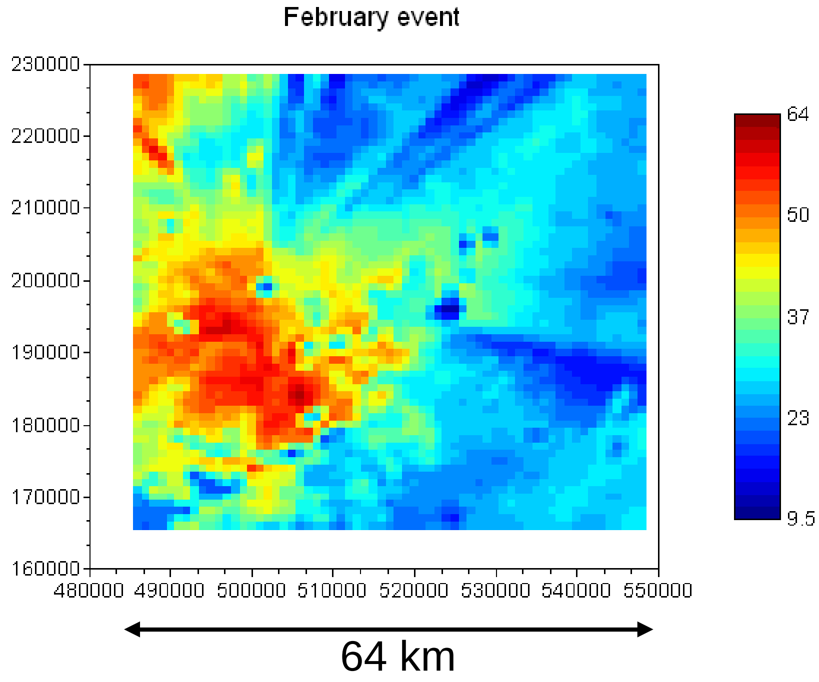
Paris area

London area

Resolution : 1 km * 1 km * 5 min



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



Nimrod Mosaics

Data was provided by Méteo-France

Data was provided by UK Met-Office

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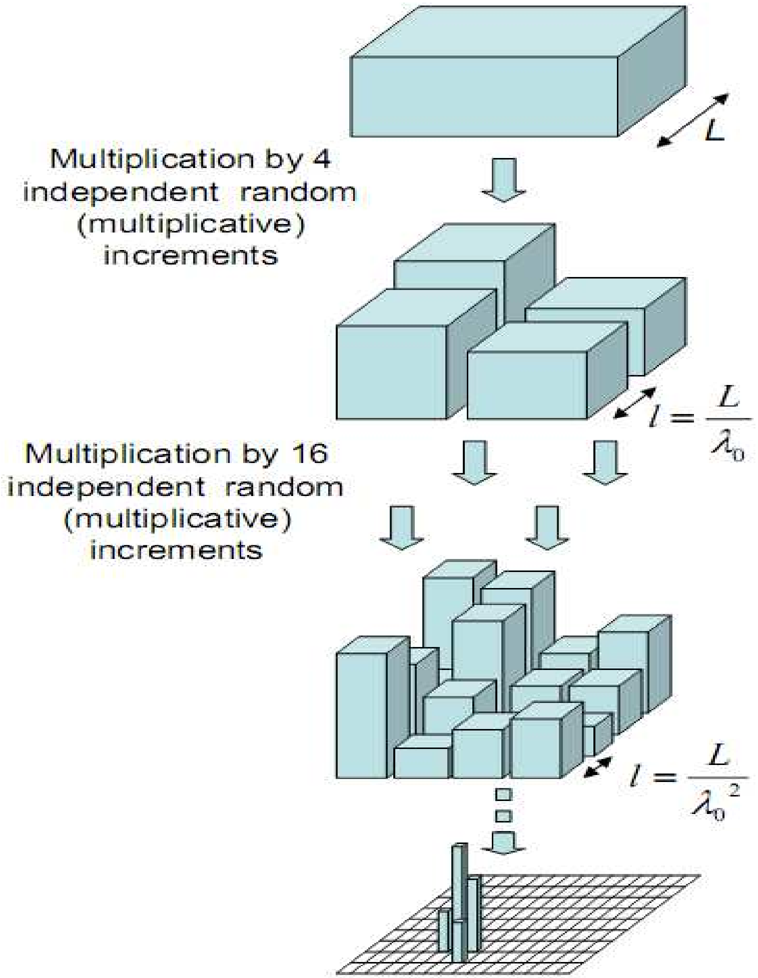
Downscaling of rainfall data — Multifractal framework

Based on the assumption that rain is generated through a cascade process → **Multifractal fields**



Resolution

$$\lambda = \frac{L}{l}$$

Singularity **Codimension function**

$$\Pr(R_\lambda \geq \lambda^\gamma) \approx \lambda^{-c(\gamma)}$$

$$\left\langle R_\lambda^{\,q} \right\rangle \approx \lambda^{K(q)}$$

Moment order **Scaling moment function**

K(q) ⟵ **Legendre transform** ⟶ c(γ)

For "universal multifractals", K and c only depends on 2 parameters :

- **C_1 : mean intermittency**
- **α the multifractality index**

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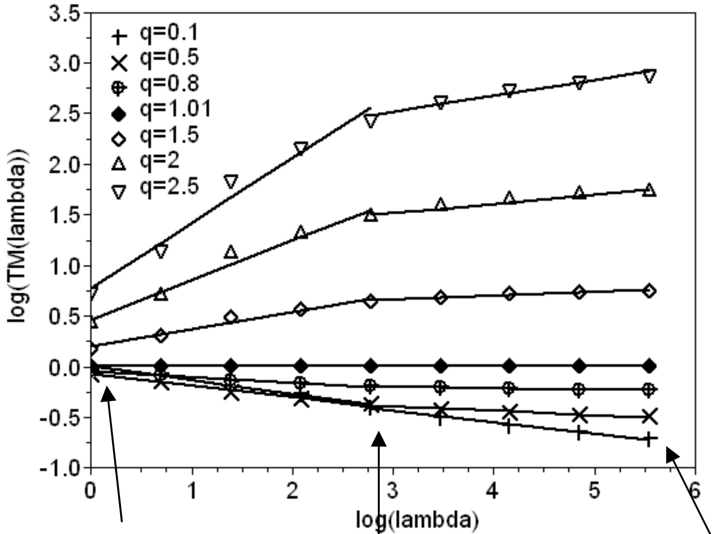
Downscaling of rainfall data

Scaling moment function

$$\log\langle R_\lambda{}^q\rangle \propto K(q)\log\lambda$$

Resolution

Paris

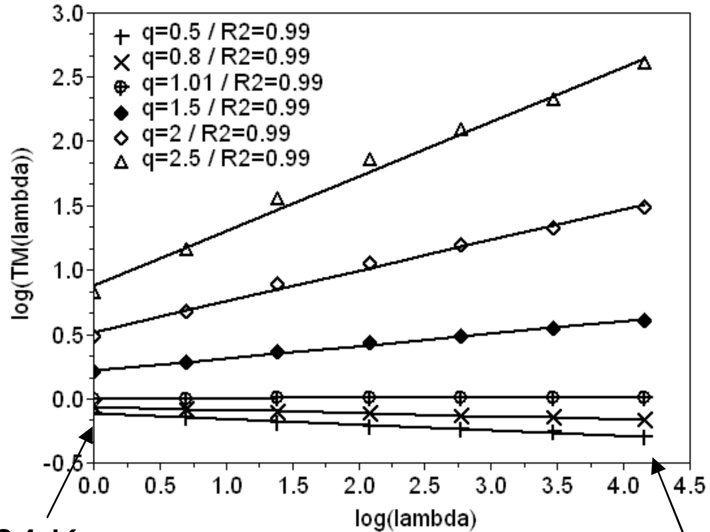


256 Km   16 Km   1 Km

→ A scaling break

	α	C_1
Small scale	**1.52**	**0.056**
Large scale	**1.08**	**0.28**

London



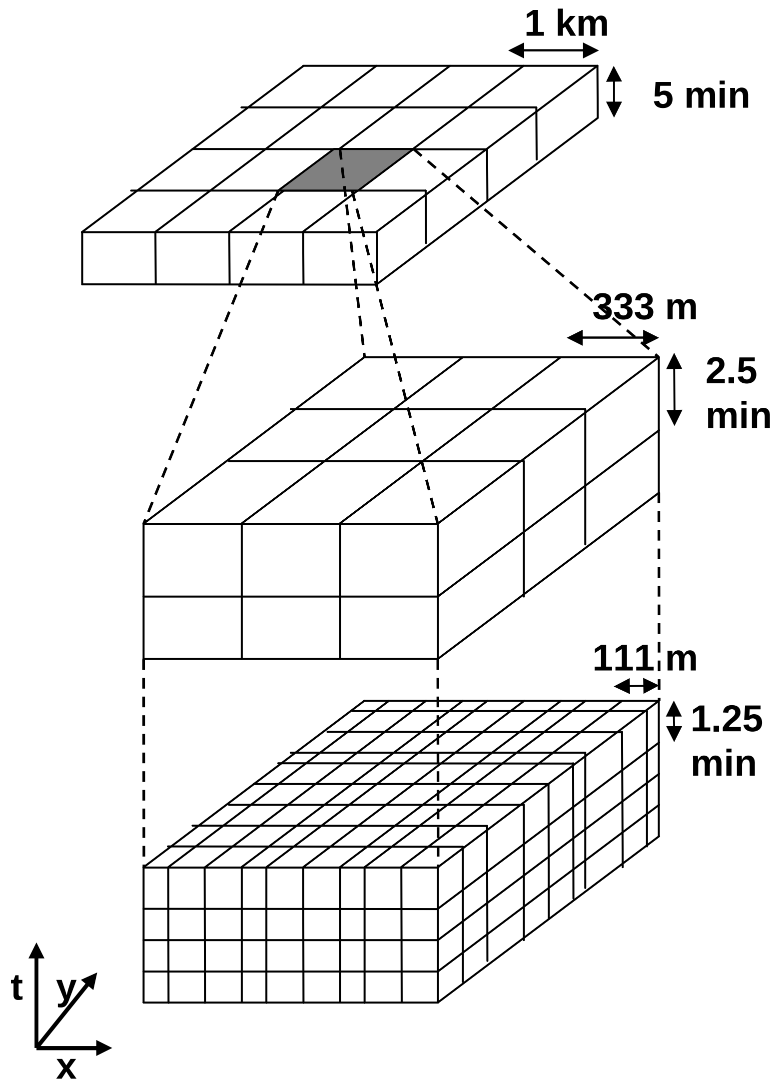
64 Km   1 Km

→No scaling break
(May be not observed)

α	C_1
1.62	**0.14**

Downscaling of rainfall data

Downscaling technique



Measured or deterministically nowcasted

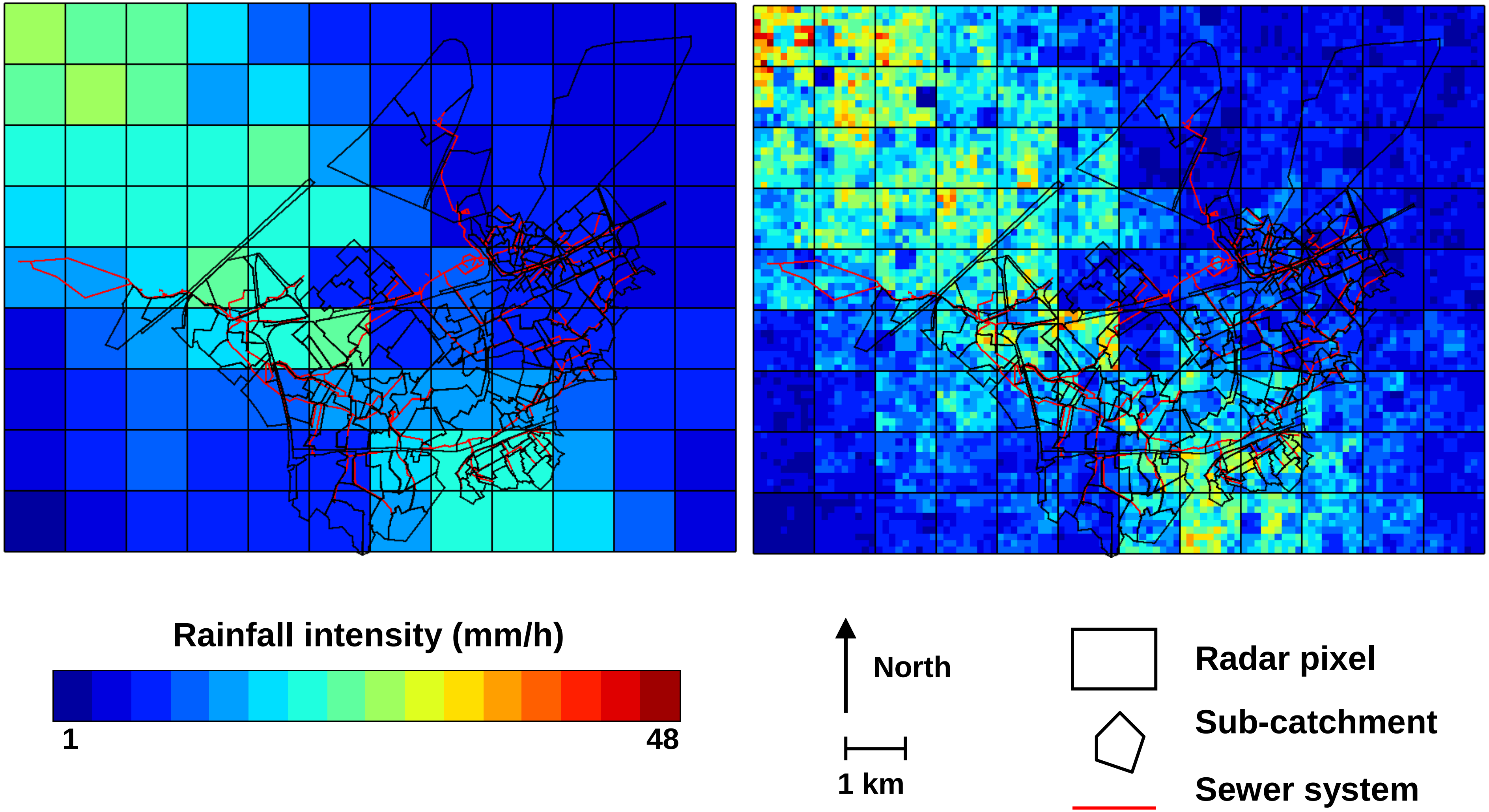
Multifractal analysis
→ α and C_1

Stochastic downscaling for each pixel

Performed with the help of discrete universal multifractal cascades of parameters α and C_1

Downscaling of rainfall data

Illustration for an arbitrary time step of the Paris event



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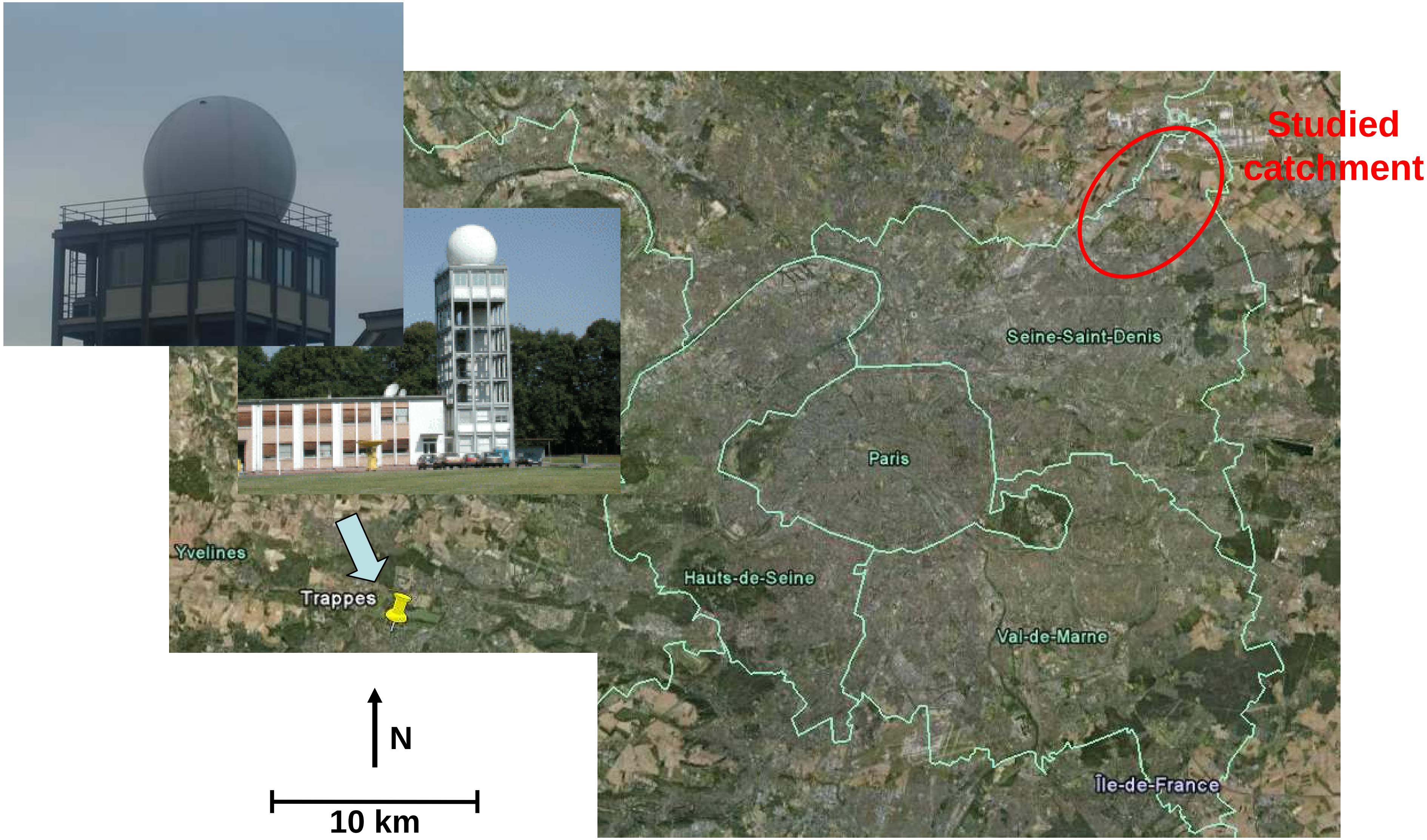
Case study

Paris area



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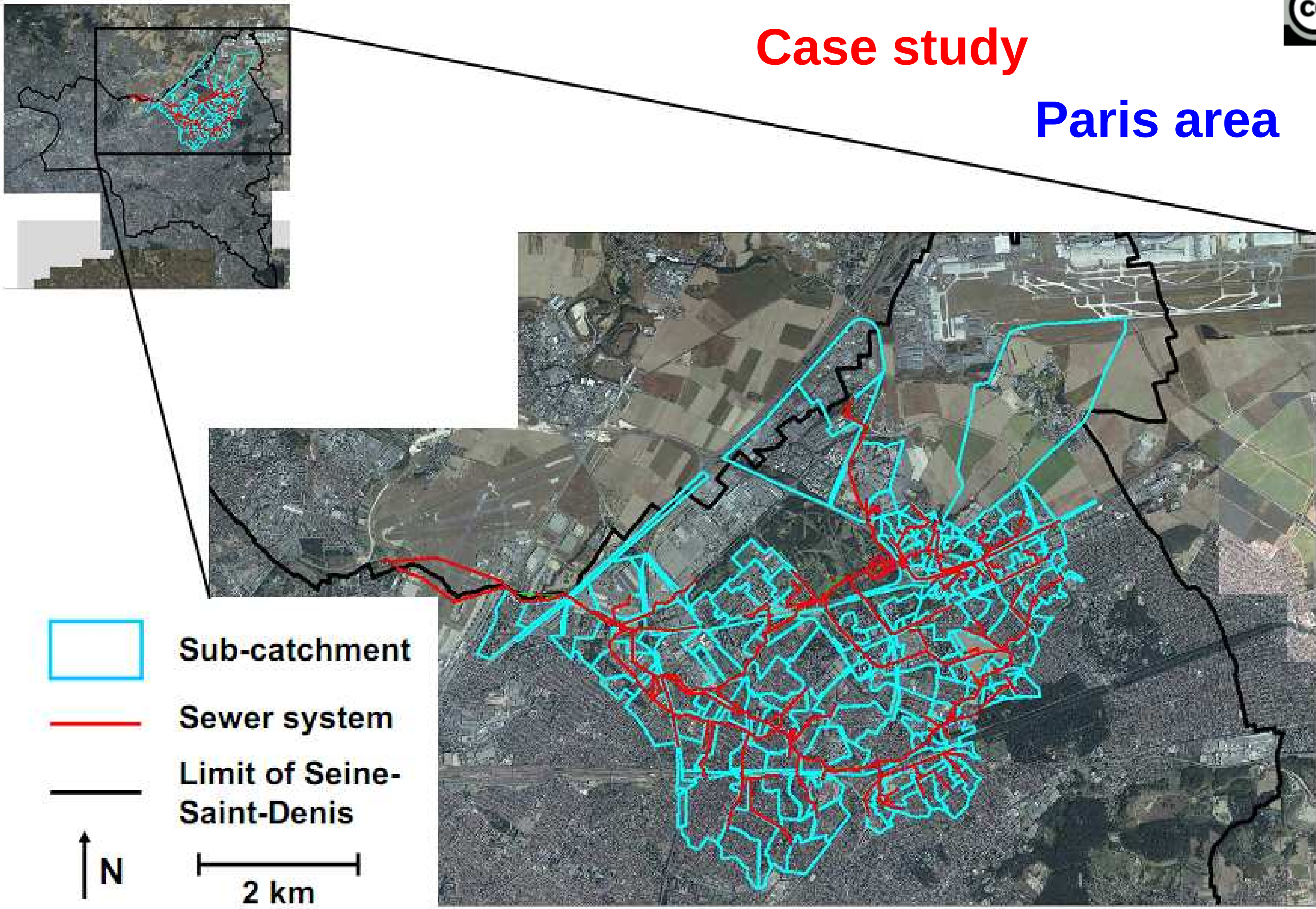
Case study

Paris area

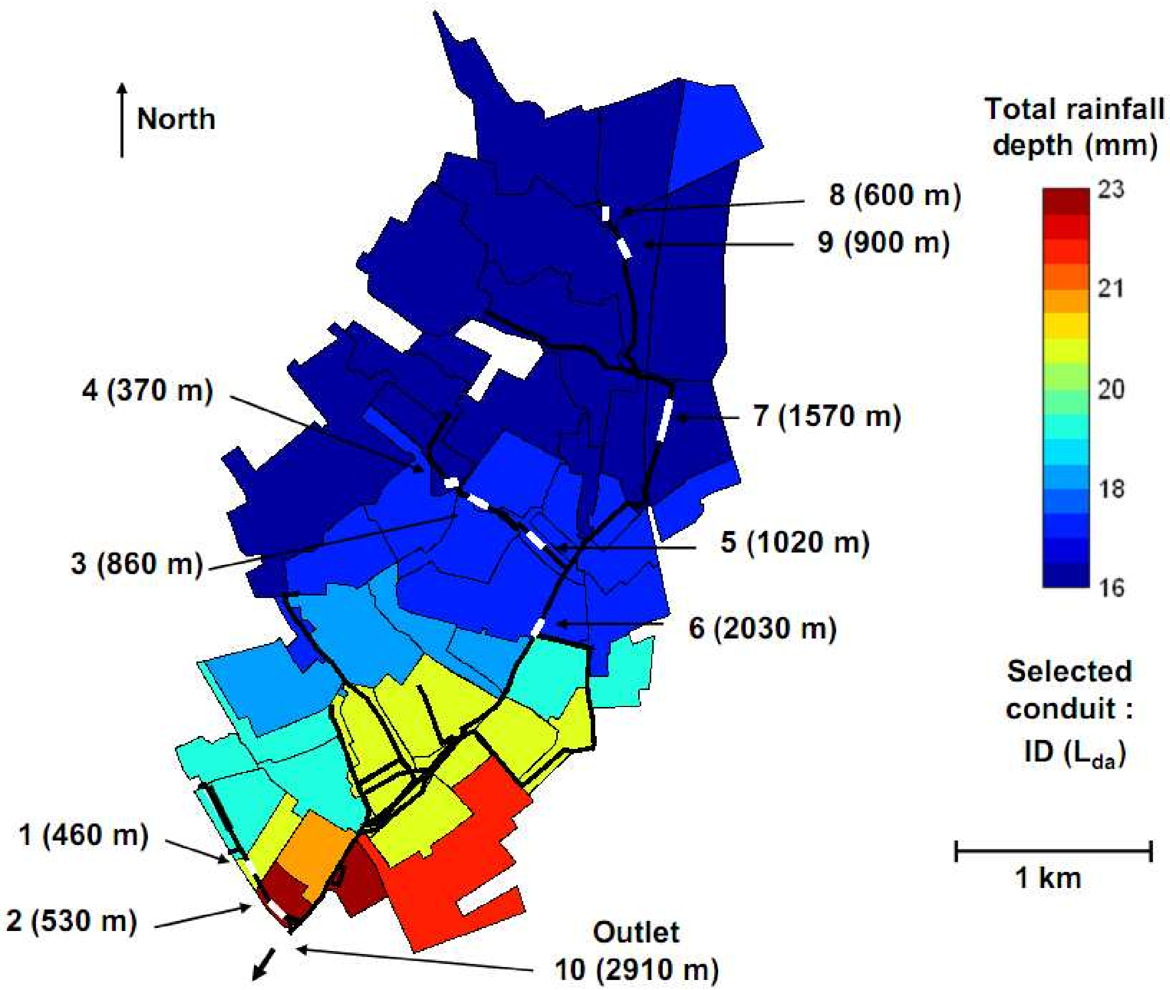


- Modelled with Canoe (lumped model for each sub-catchment and Saint-Venant equations in the links)

- 3400 ha with 198 sub-catchments (avg 17 ha)
- 69 Km of links (avg slope 0.009 m/m)
- Total rainfall: 19 mm (North-West) → 9mm

Case study

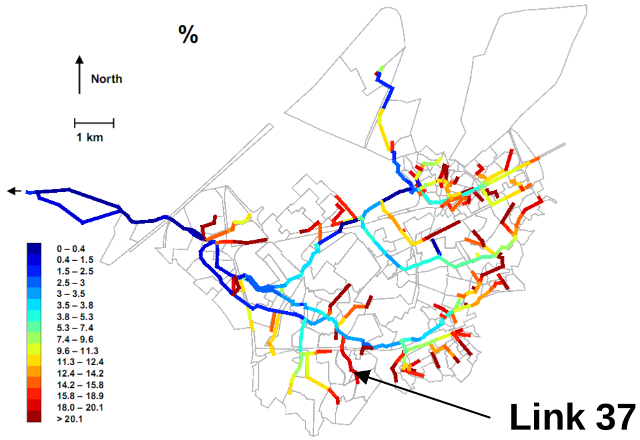
London area

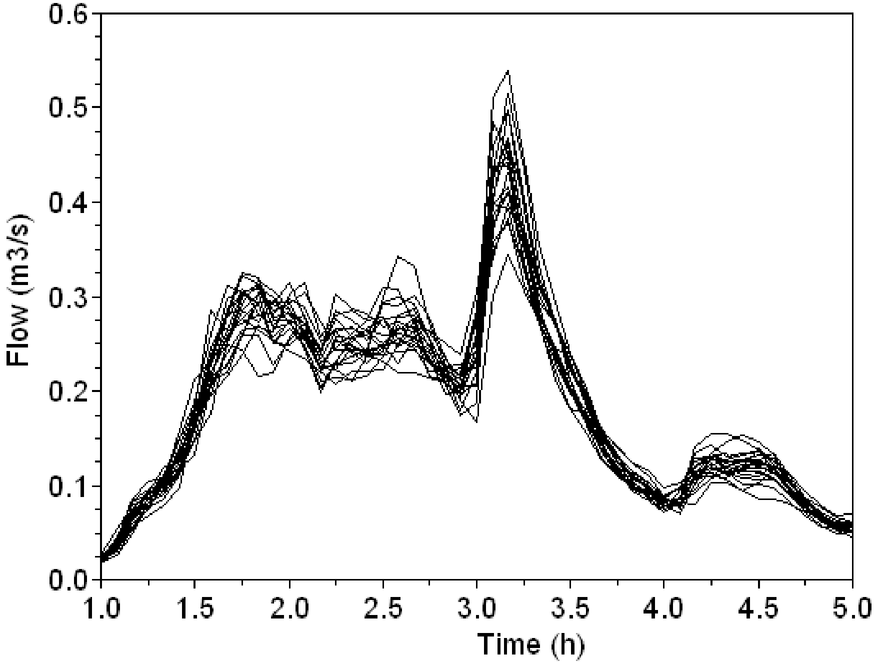


- **900 ha**
- **Modelled with Infoworks CS**
- **51 sub-catchments (avg 17ha)**
- **Flow analysed in 10 selected conduits**
- **The characteristic length L_{da} of a conduit is the square root of its drained area.**

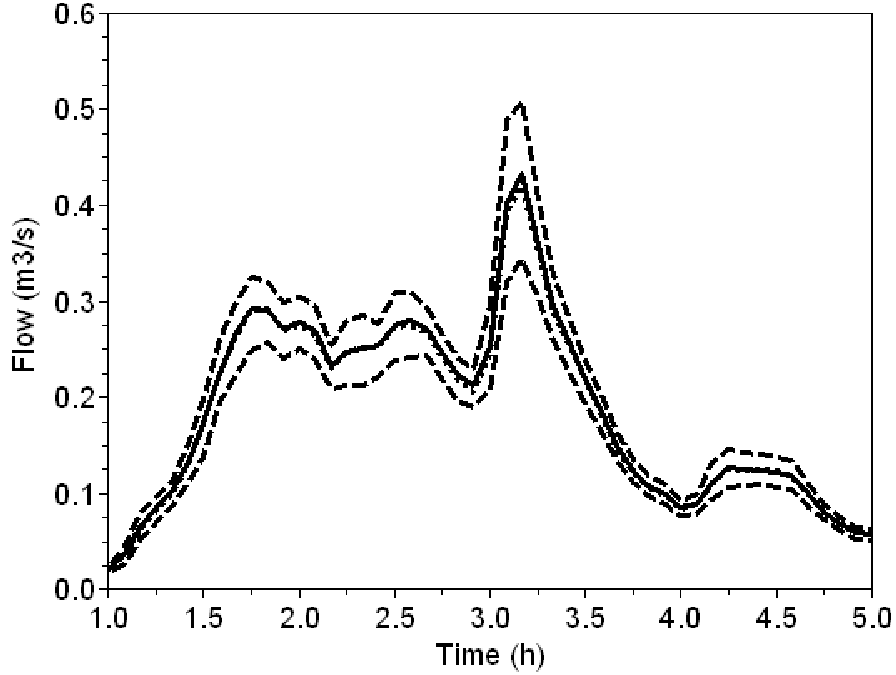
Results

Link 37





20 (arbitrarily chosen among the ensemble) hydrographs

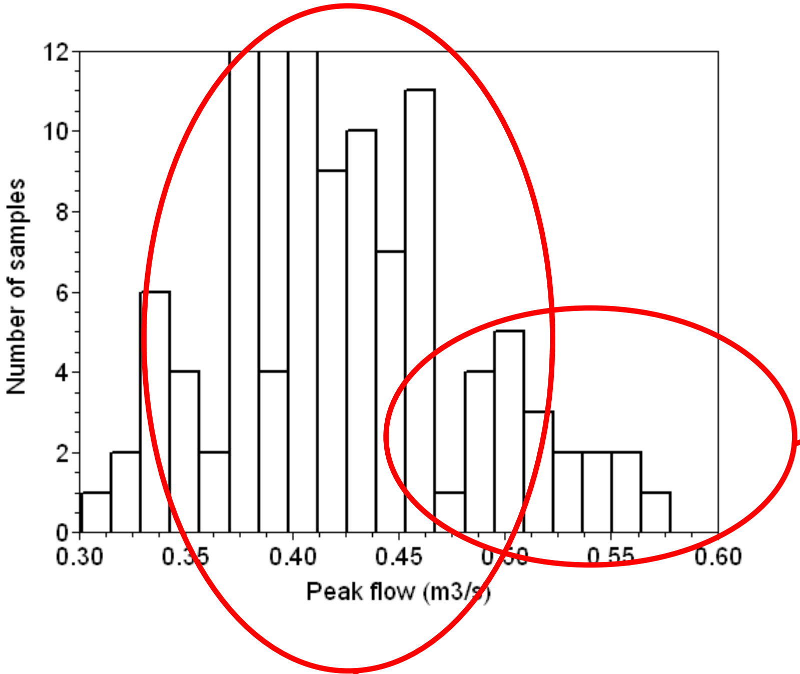


—— Q_{radar}

- - - $Q_{0.9}$ et $Q_{0.1}$

Results

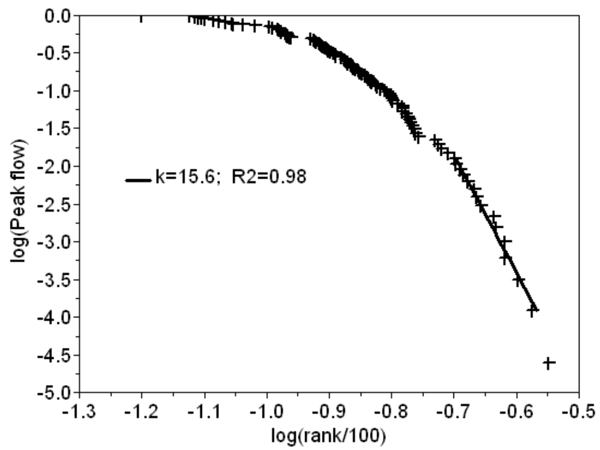
Peak flow for link 37



Histograms of the peak-flow

(no significant differences for time of occurrence)

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



$$CV' = \frac{DP_{0.9} - DP_{0.1}}{2 * DP_{radar}}$$

CV' = 19 %

Power-law behavior also observed on downscaled rainfall

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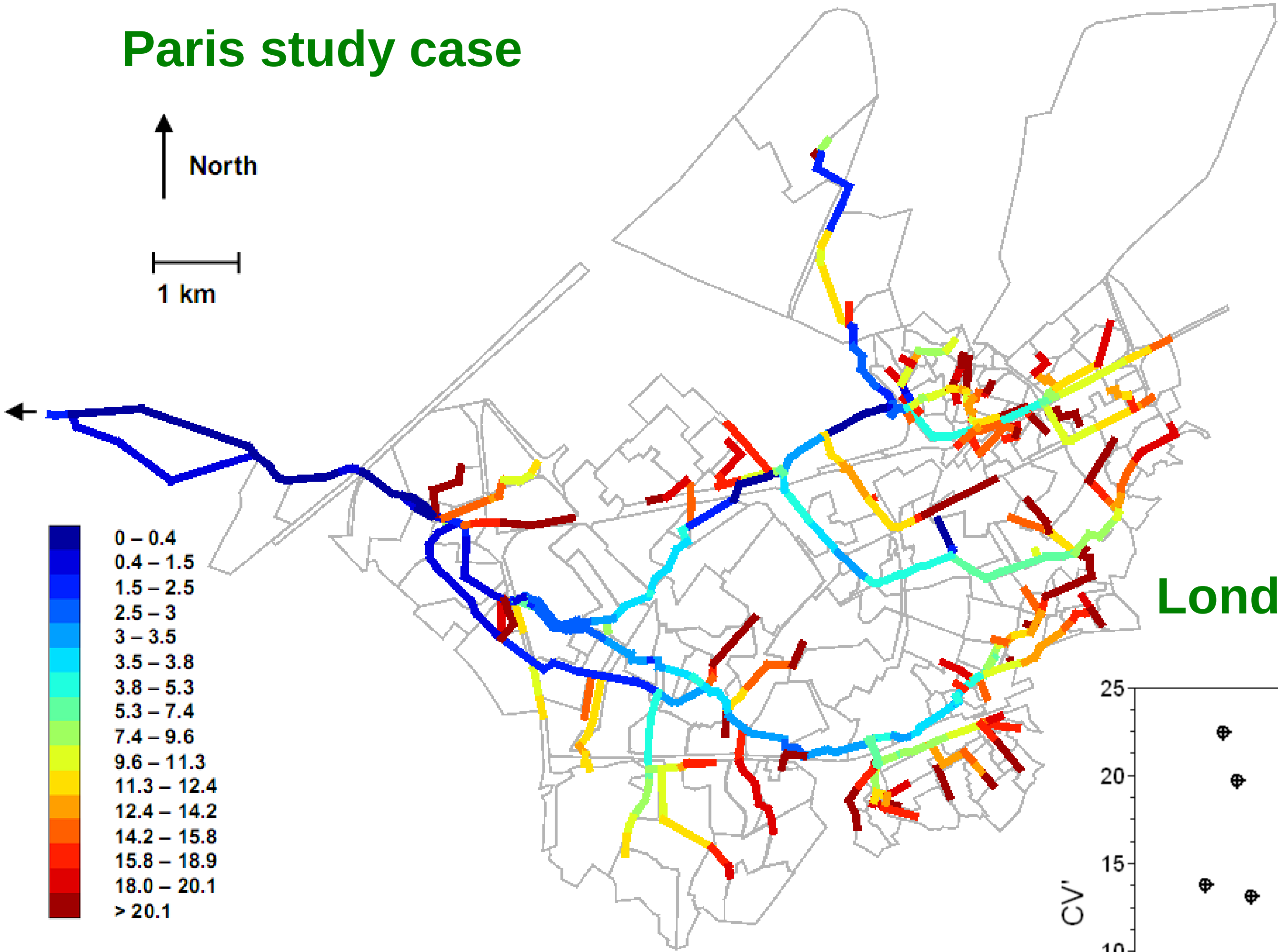
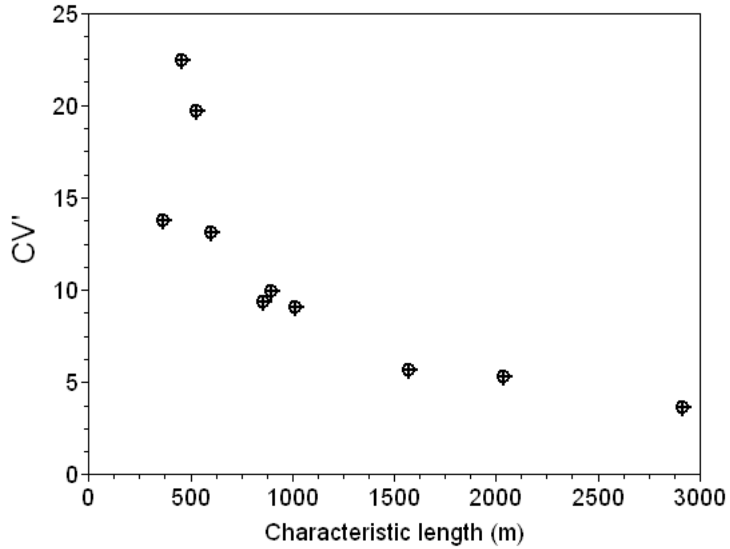
Results

CV' in %

Paris study case



London study case



Results

Power-law exponent *k*

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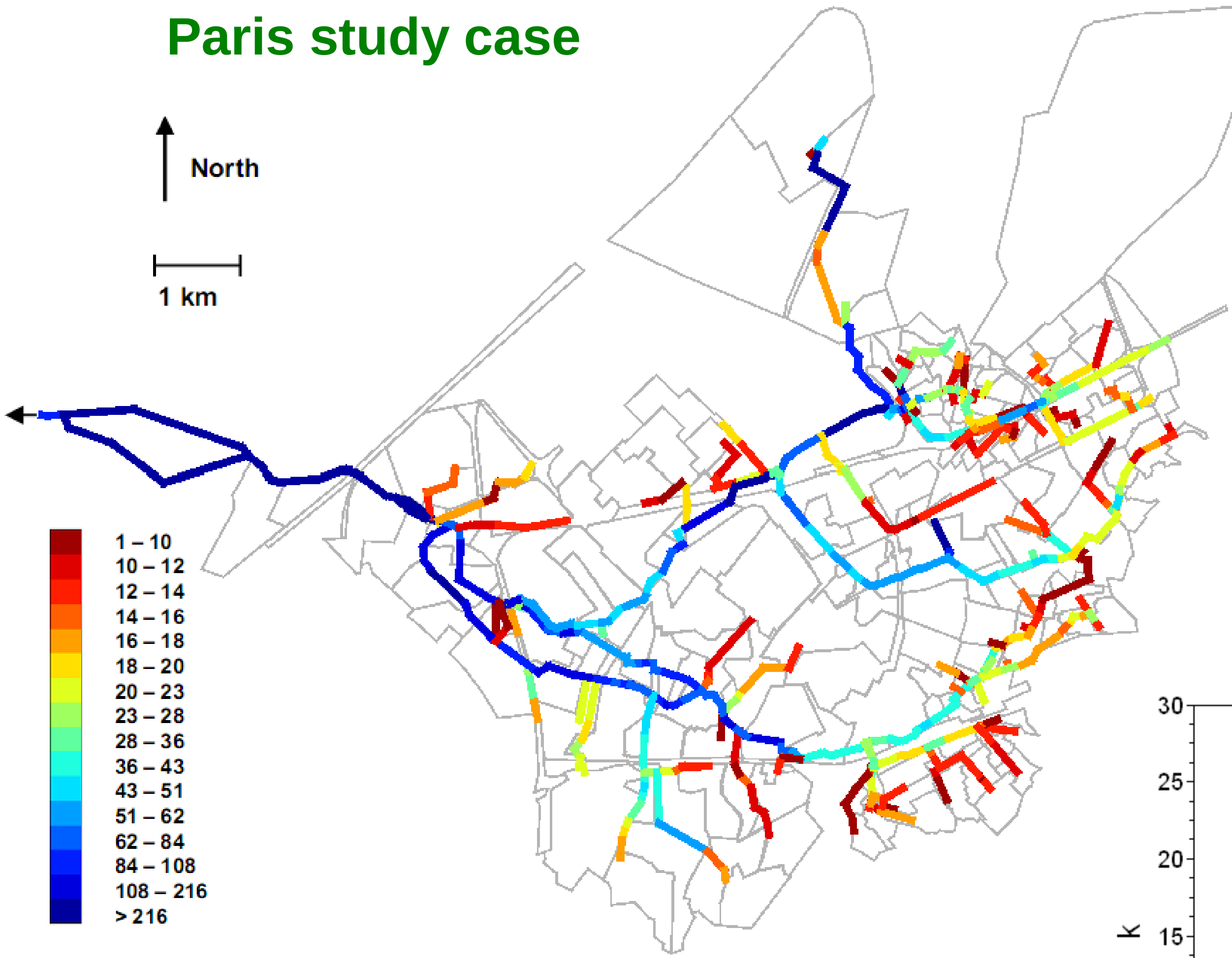
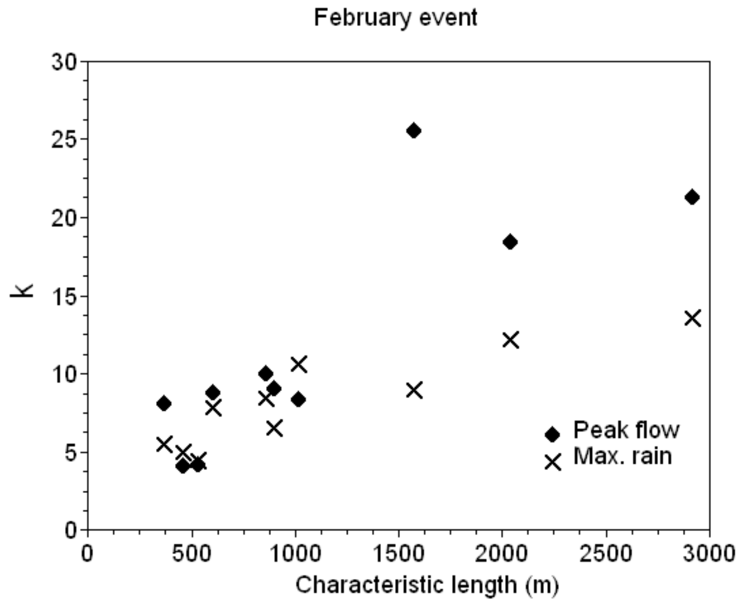
Paris study case



London study case



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Conclusion

- Multifractal techniques are implemented in urban hydrology to quantify the uncertainty associated with small-scale unmeasured rainfall variability

- The uncertainty on urban discharge associated with small scale unmeasured rainfall variability can not be neglected :

  - CV' reaches 25% for both the Paris and London study case.
  - Power law fall-off of the probability distribution (for both rainfall and discharge).
  - A decrease of the uncertainty for downstream links

- Limits

Nothing is done on the hydrological model. A need to :

  - increase the model resolution
  - take into account surface flow

- Perspectives

  - Improve rainfall resolution (X band radar in urban areas)
  - Improve real time management of sewer systems

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