École des Ponts ParisTech

Chair "Hydrology for Resilient Cities"
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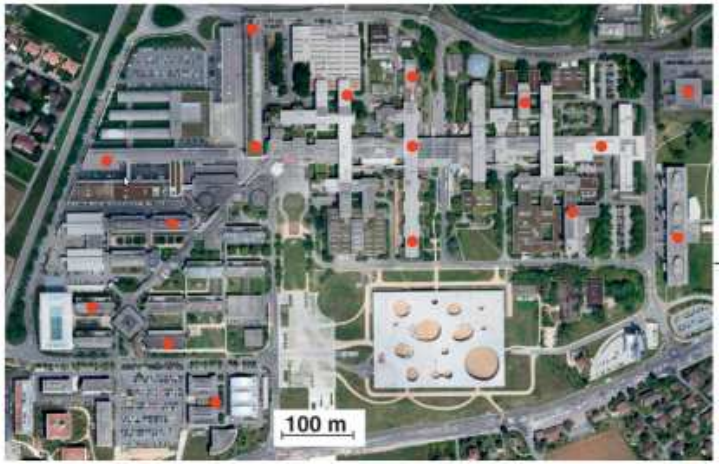
Rain Gain

leesu laboratoire eau environnement systemes urbains

Validation of a Universal Multifractal downscaling process with the help a dense network of disdrometers.

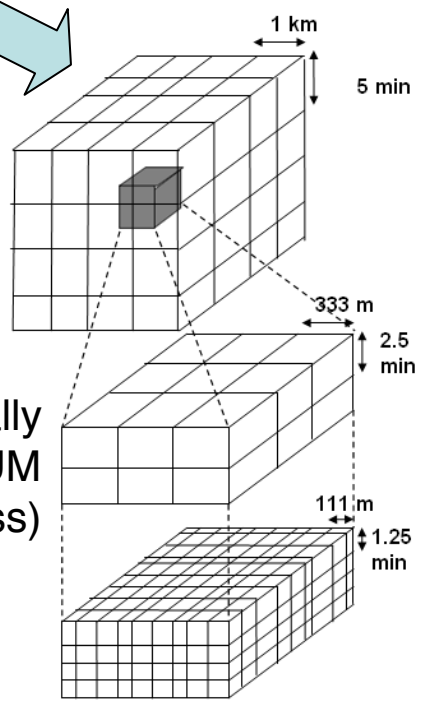
A. Gires, I. Tchiguirinskaia, D. Schertzer, A. Berne (EPFL) and S. Lovejoy (McGill Univ.)

16 PARSIVEL® Point measurement, 1 min



EPFL Campus (Switzerland)

Aggregation to 1km x 5 min

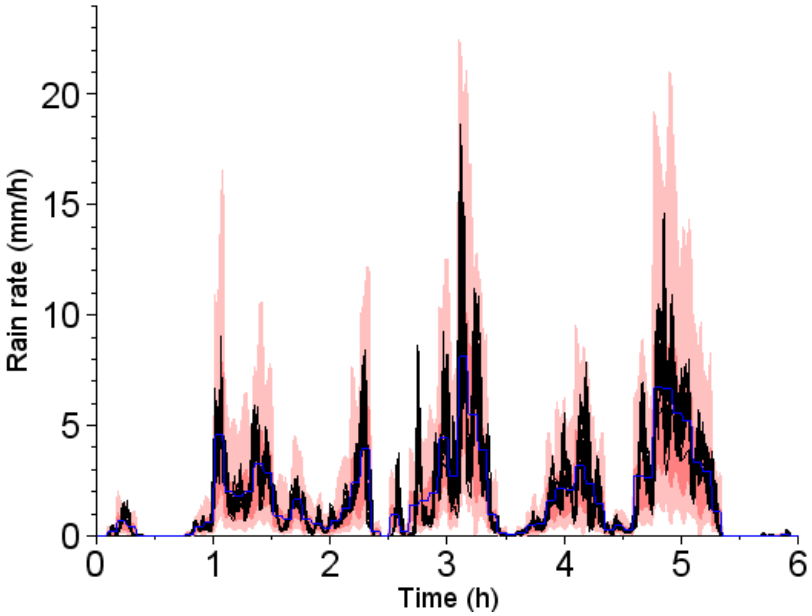


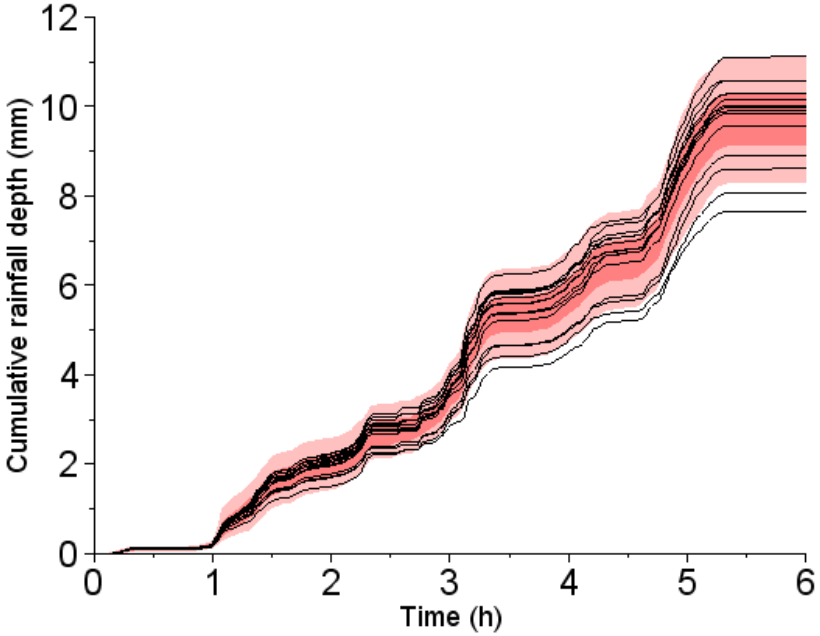
Downscaling (stochastically continuing the underlying UM cascade process)

Generation of the output of 2187 x 2187 virtual point measurements with observation scale of 46 cm x 1 min

Results for 6 June 2009

16 disdrometers measurements + uncertainty range (75% and 95% quantile)



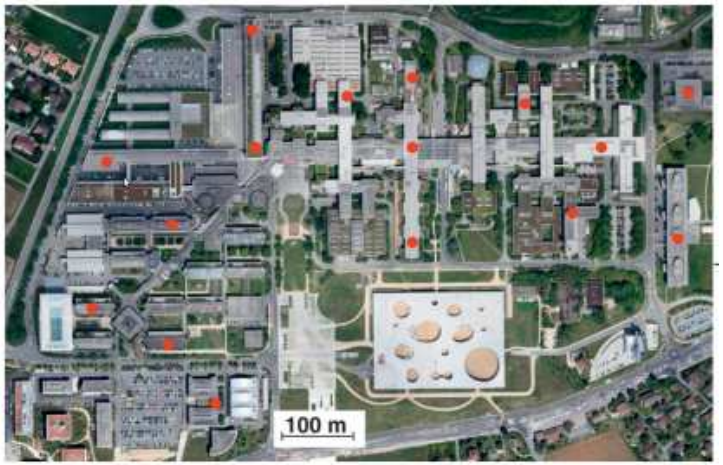


Example of application : revisiting the radar - rain gauge comparison

Contact : auguste.gires@leesu.enpc.fr

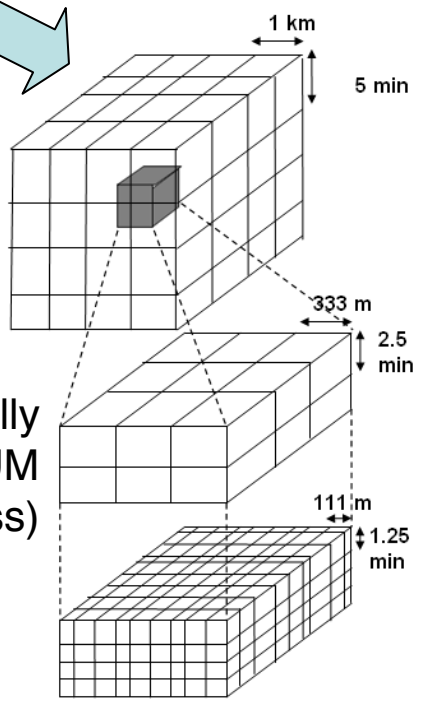
Validation of a Universal Multifractal downscaling process with the help a dense network of disdrometers.

16 PARSIVEL® Point measurement, 1 min



EPFL Campus (Switzerland)

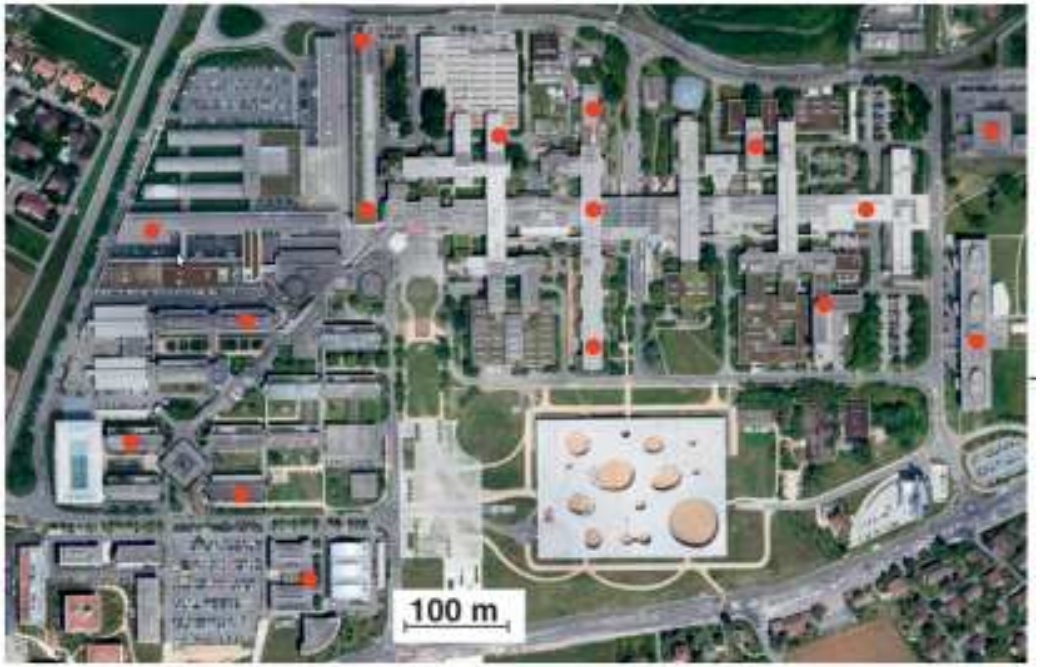
Aggregation to 1km x 5 min



Downscaling (stochastically continuing the underlying UM cascade process)

Generation of the output of 2187 x 2187 virtual point measurements with observation scale of 46 cm x 1 min

Rainfall data : a dense network of disdrometers



16 PARSIVEL®
Point measurement, 1 min

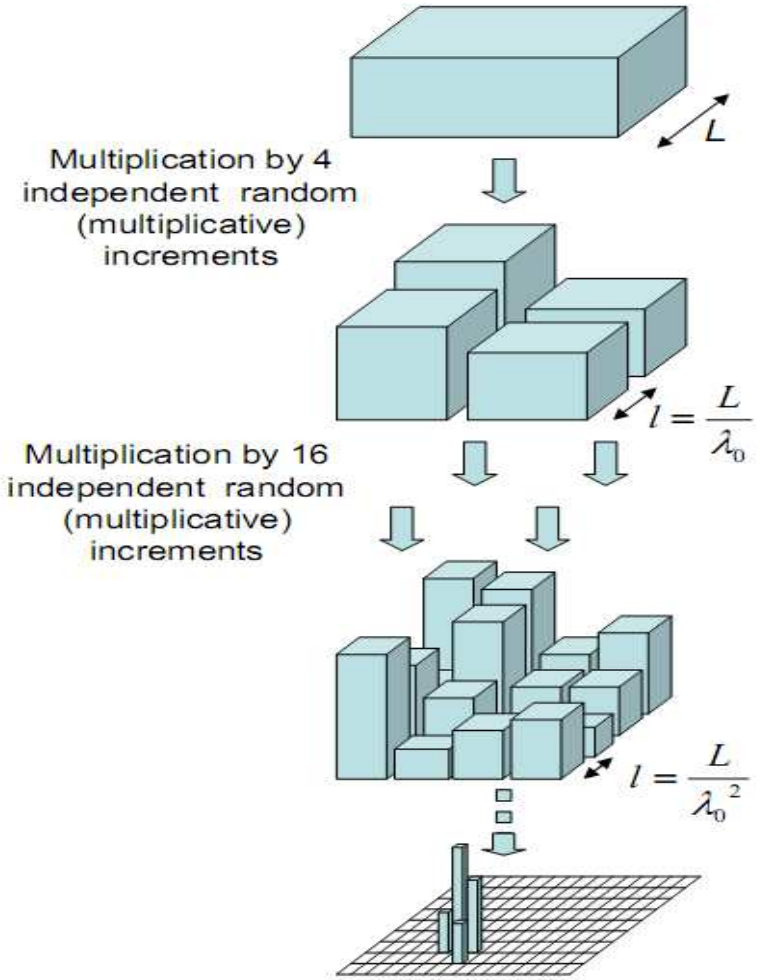
EPFL Campus (Switzerland)

	6 June 2009	17 July 2009	8 Oct. 2009	26 March 2010	3 April 2010	5 August 2010
~ event duration (h)	6	7.6	7.9	5.8	7.3	4.5
# Disdro	15	16	15	16	16	15
Cumul. depth (mm)	9.7 (11.1 – 7.6)	22.9 (26.5 – 18.0)	12.2 (13.4 – 10.8)	11.8 (13.8 – 10.2)	14.0 (16.2 – 12.1)	5.5 (6.6– 4.6)

Downscaling methodology

Theoretical framework of multifractals

Based on the assumption that rain is generated through a cascade process



Multifractal fields

Singularity **Codimension function**

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

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

Resolution

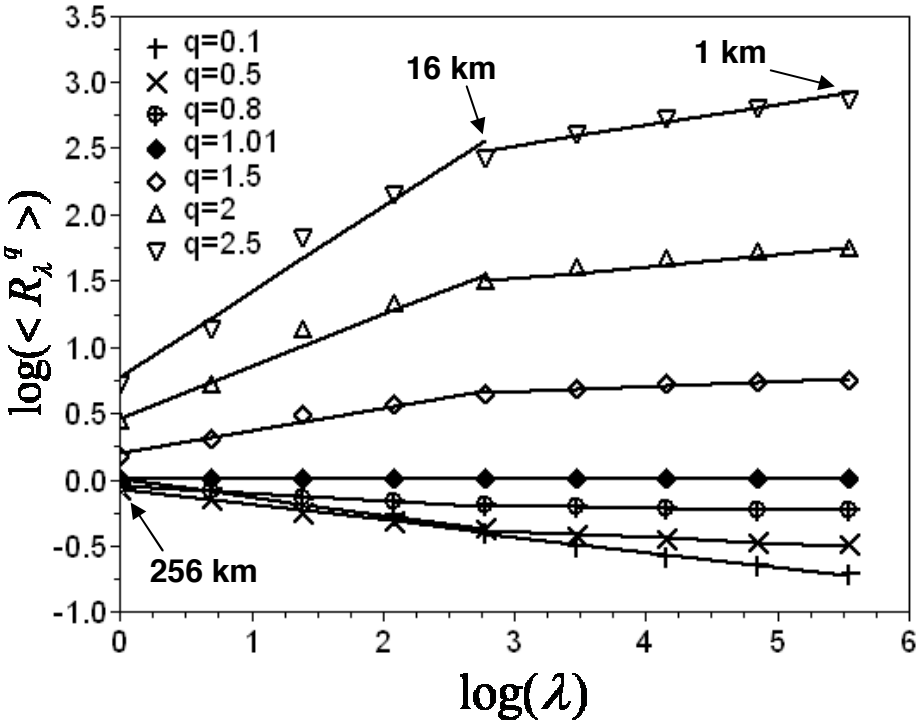
$$\lambda = \frac{L}{l}$$

Moment order **Scaling moment function**

K(q) **Legendre transform** c(γ)

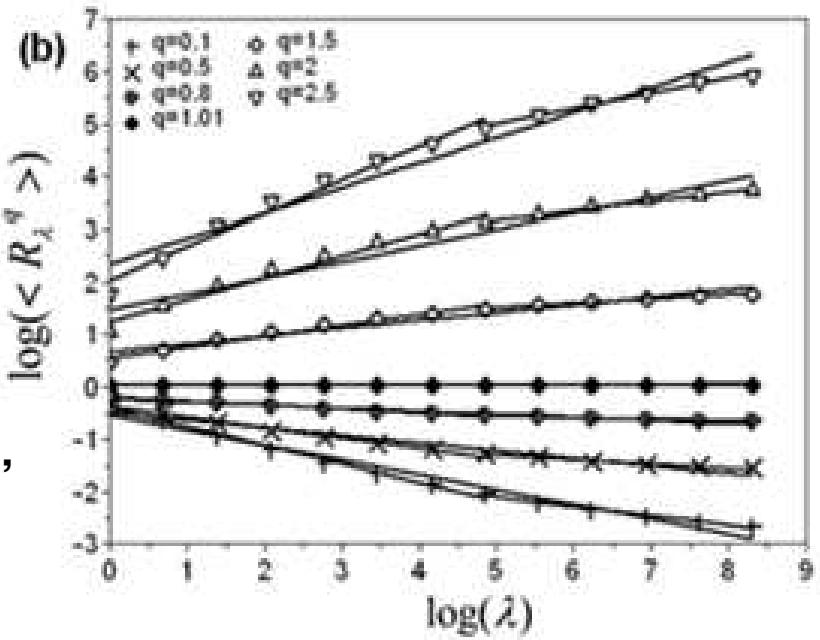
Downscaling methodology

Scaling behaviour for the February 2009 event



→Scaling break: likely to be due to a misrepresentation of the zeros in this framework

→ Dvp of a new "toy model"



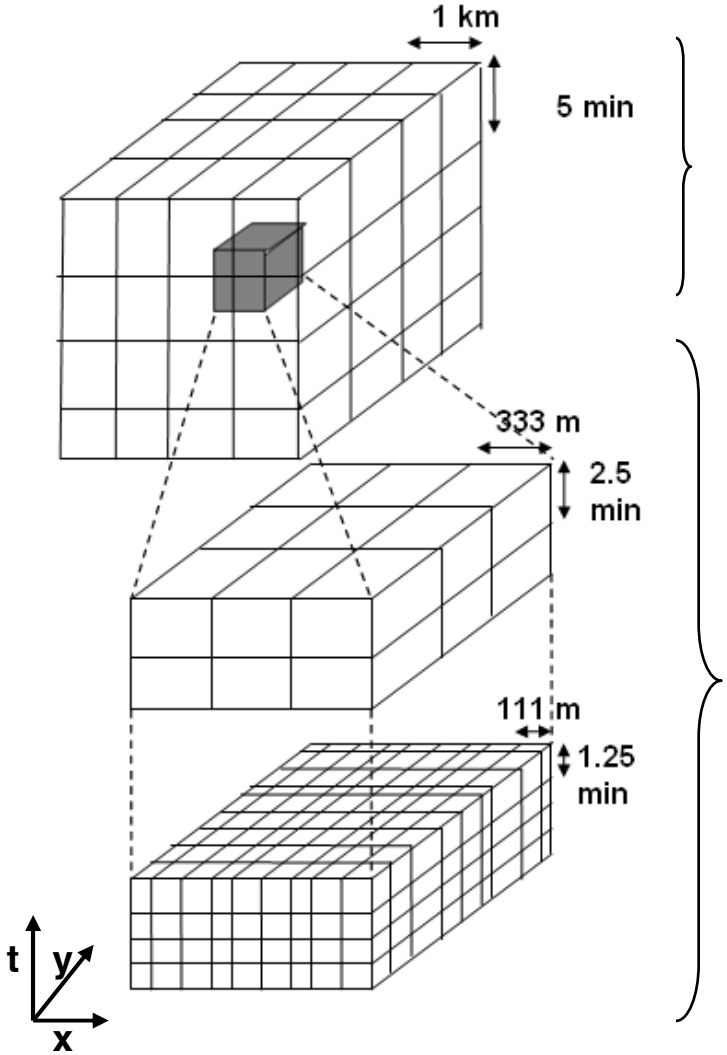
Gires et al., accepted in NPG

Downscaling methodology

H_t = scaling anisotropy coefficient

$\lambda_{xy} = 3$

$\lambda_t = \lambda_{xy}^{1-Ht} \sim 2$



Measured or deterministically nowcasted

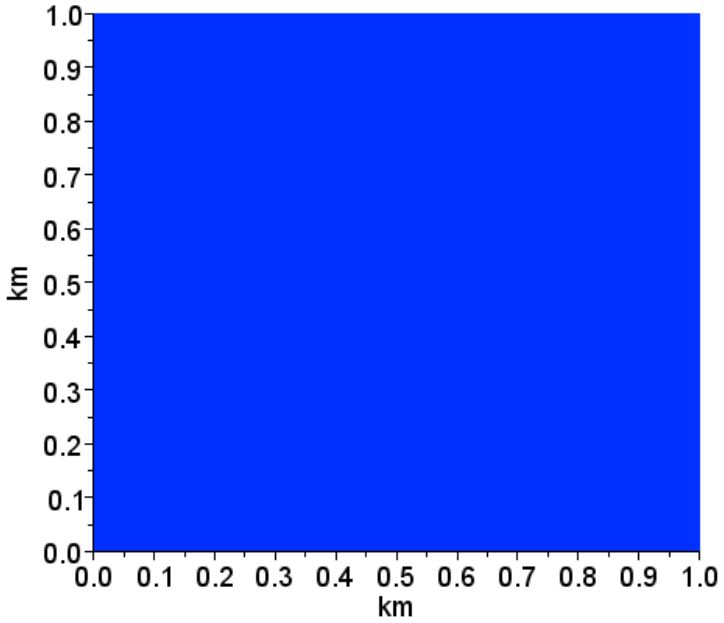
Multifractal analysis → α and C_1

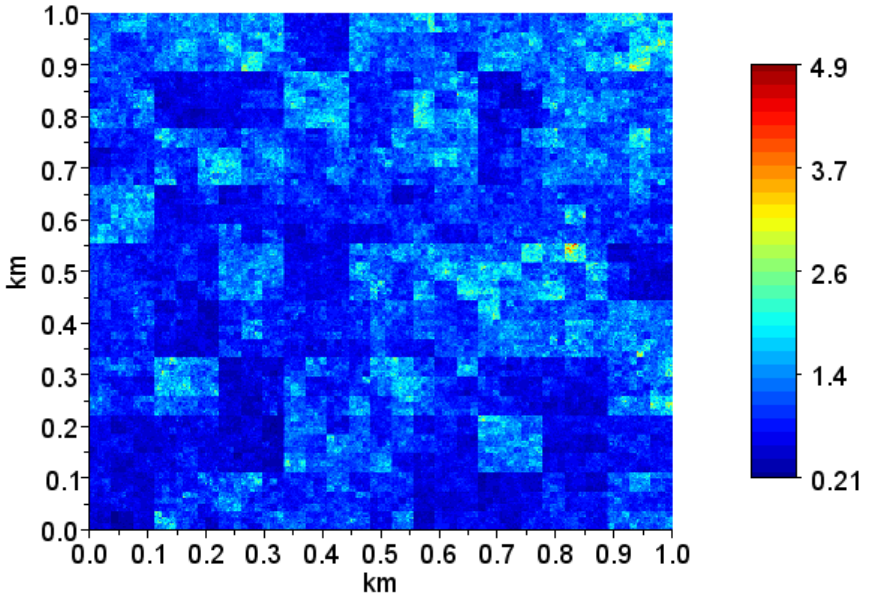
Stochastic spatio-temporal downscaling for each pixel

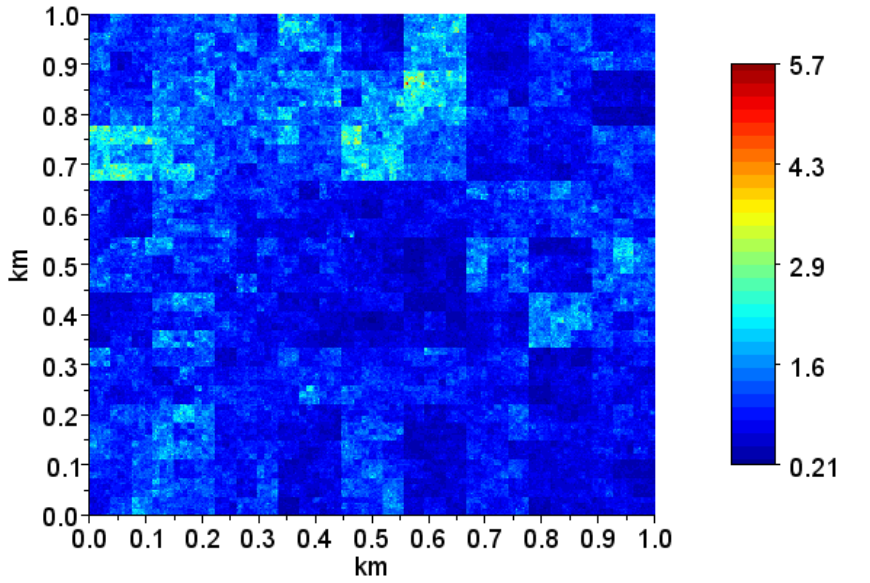
Performed with the help of discrete universal multifractal cascades of parameters α and C_1

… (7 steps + re-aggregation to 5 min in time) → 2187x2187 pixels of size 46 cm

Downscaling methodology
Illustration

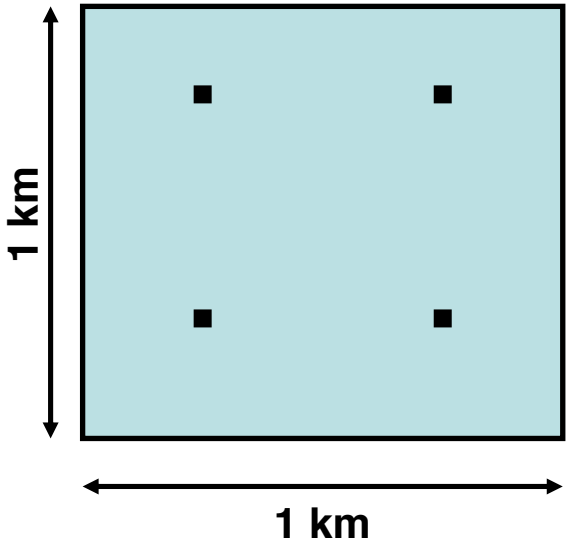






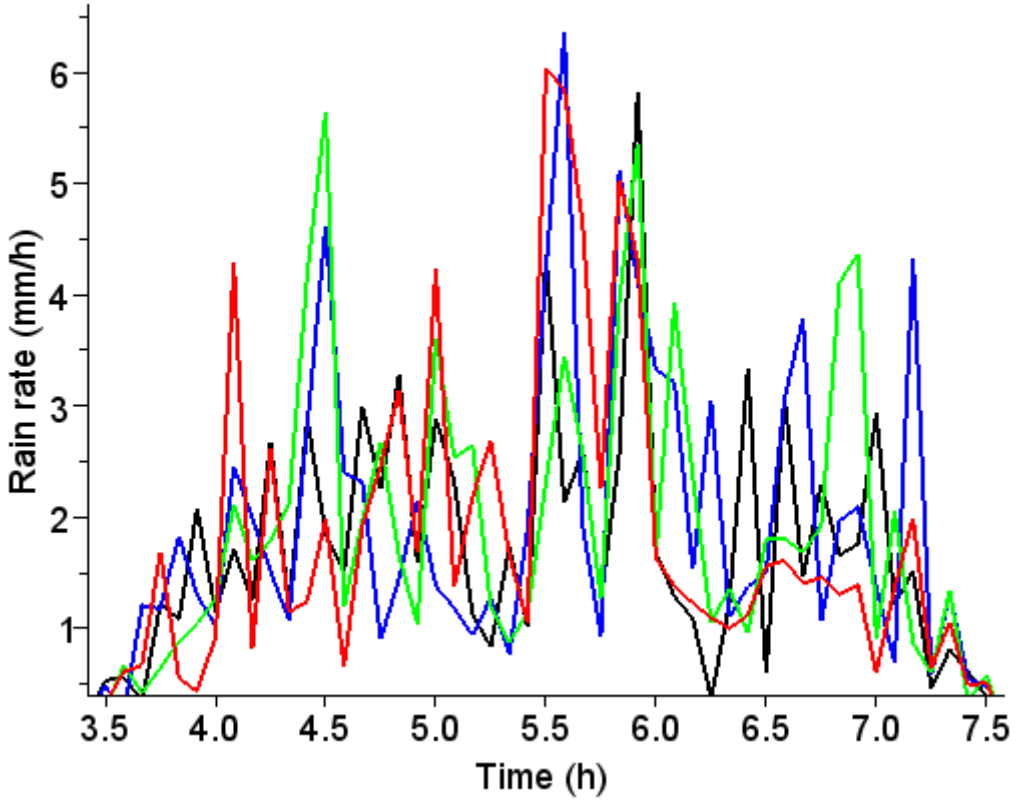
A single colour 80% of the max

Generation of 2187 * 2187 virtual “disdrometers”



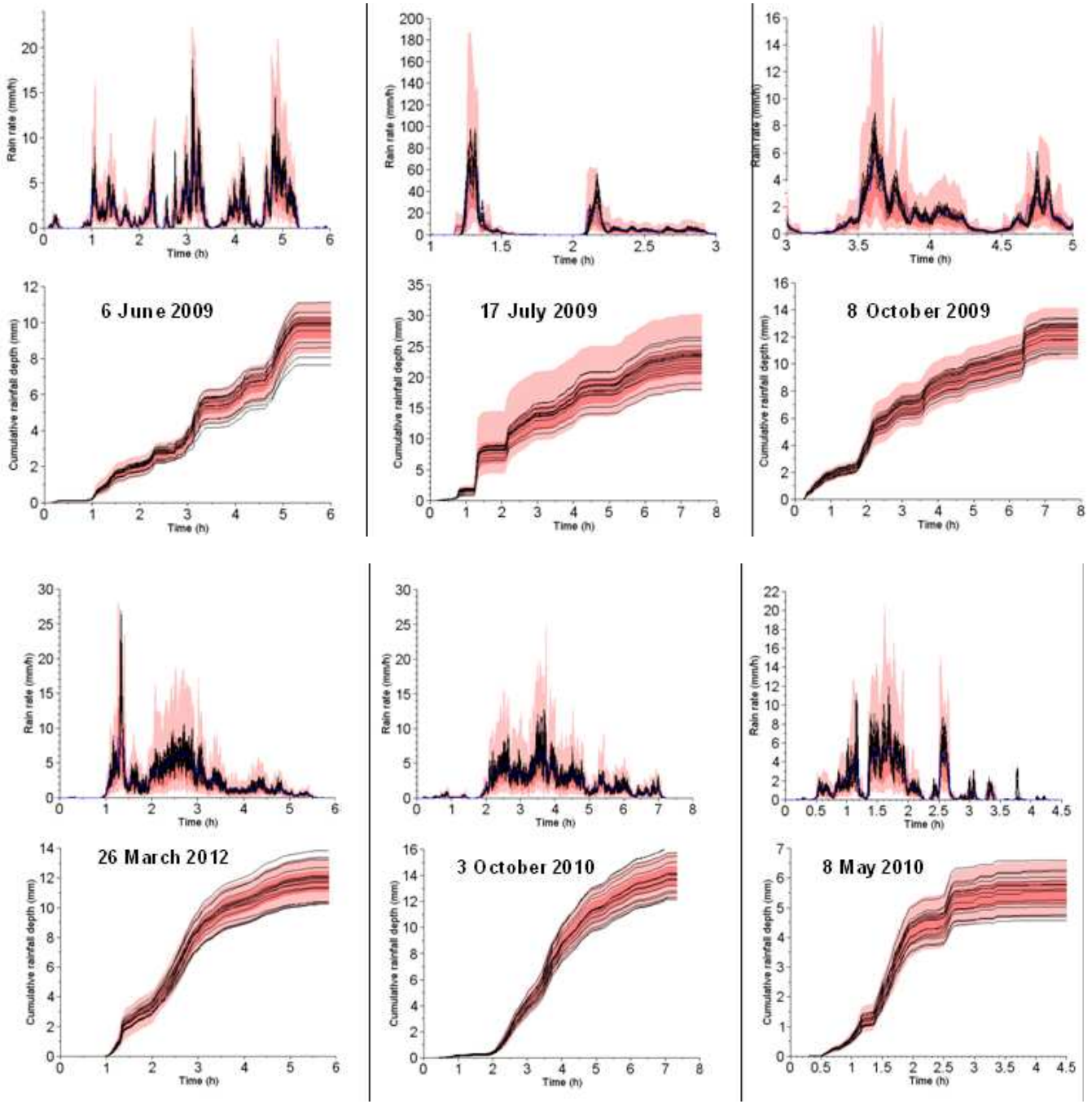
February 2009 event

4 virtual rain gauges



Results

→ Observations in overall agreement with theoretical expectations



Revisiting the comparison between radar and rain gauge data

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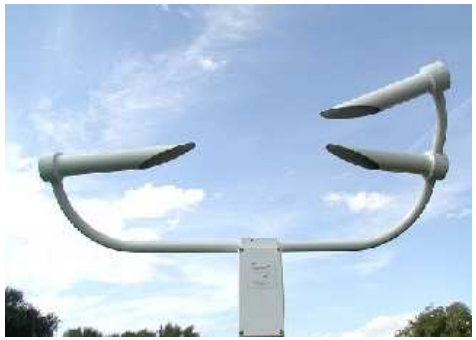
- Rainfall measurement at various scales

C band radars

C-band radar of Trappes (Météo-France)

~ 1 km

Disdrometers or raingauges



www.campbellsci.co.uk

www.precis-mecanique.com

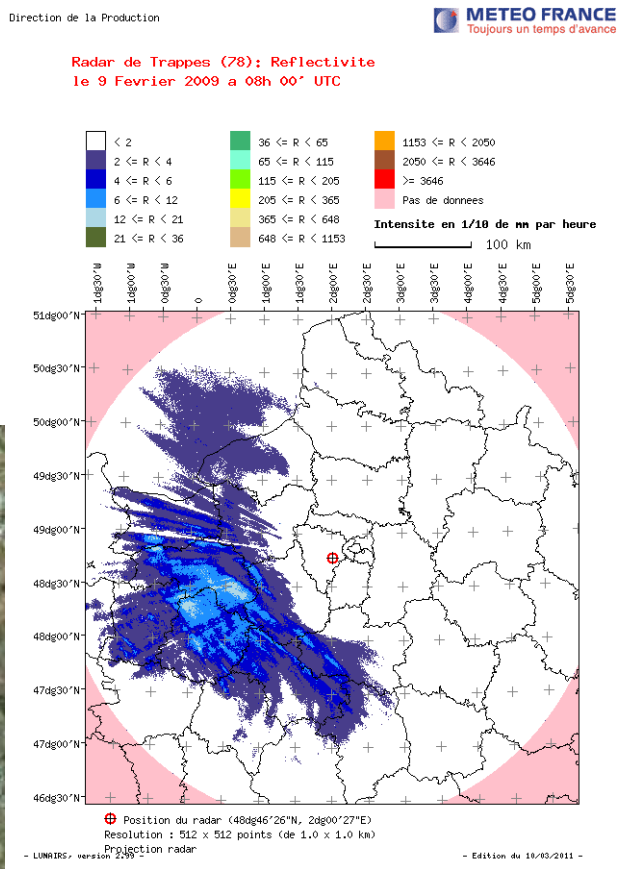
~ 20 cm

- Rainfall extremely variable over wide range of scales

How to compare the two rainfall estimates ?

Rainfall data

Seine-Saint-Denis area



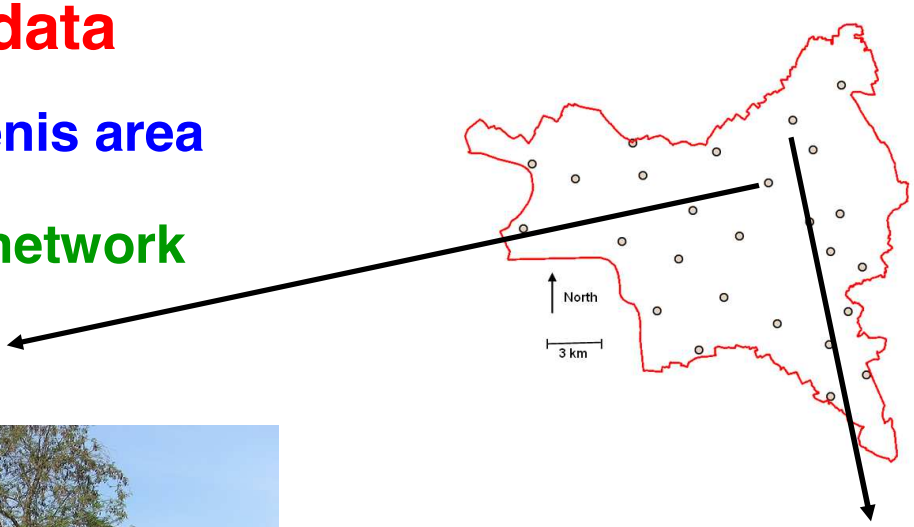
C band radar of Trappes

Resolution : 1 km x 1 km x 5 min

Rainfall data

Seine-Saint-Denis area

A raingauge network



Gérard Philippe

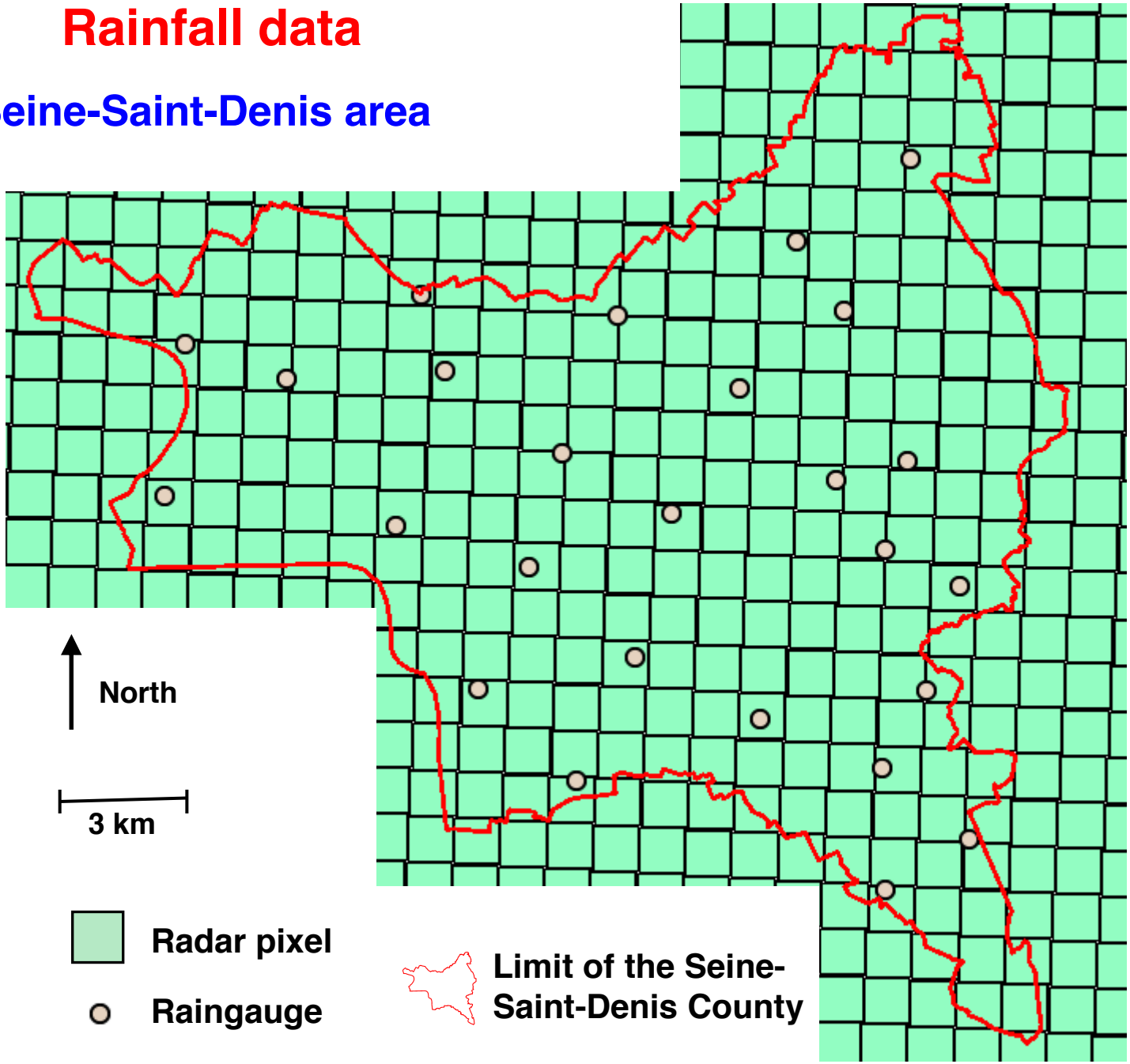
Petit Marais

→ Two rain gauges are collocated at each location to ensure a backup.

Operated by the Direction Eau et Assainissement of Seine-Saint-Denis

Rainfall data

Seine-Saint-Denis area



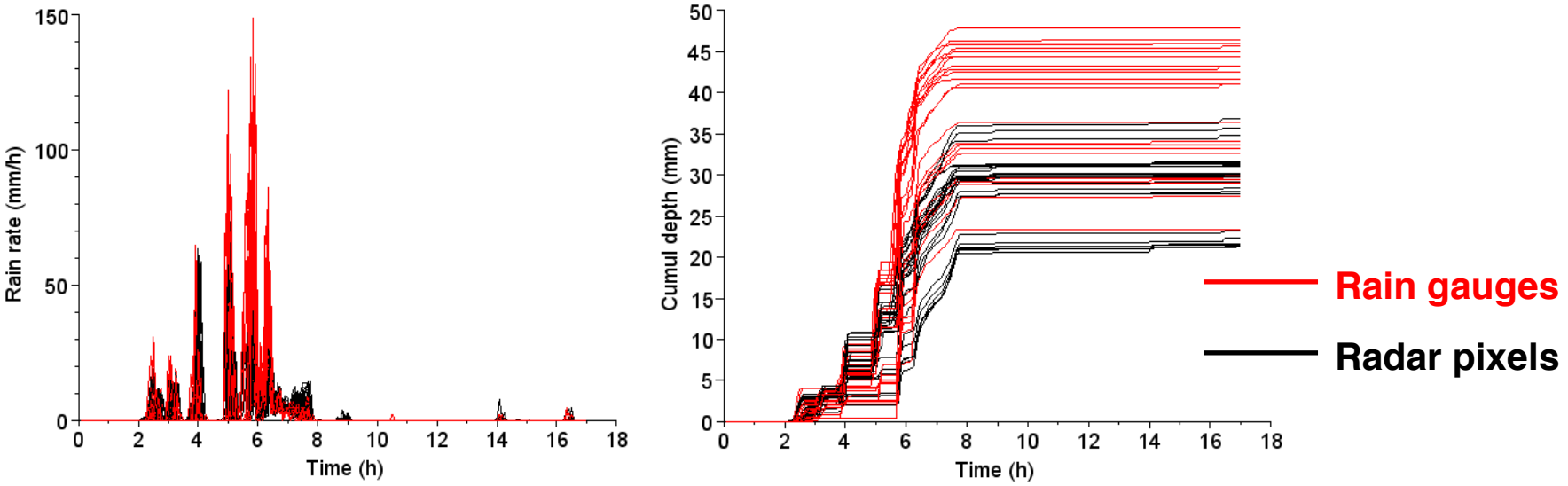
Rainfall data

Seine-Saint-Denis area

4 rainfall events

	9 Feb. 2009	14 Jul. 2010	15 Aug. 2010	15 Dec. 2011
Approx. Event duration (h)	9	6	30	30
Available gauges	24	24	24	26
Rain gauge cumul. Depth (mm)	11.4 (10 - 12.8)	37.9 (47.8 – 23.4)	50.1 (62.8 – 27.4)	22.4 (28.2 – 18.2)
Radar cumul. Depth (mm)	8.5 (9.3 – 7.5)	28.7 (35.8 – 21.2)	50.6 (59.2 – 36.0)	22.4 (28.2 – 19.8)

Illustration for February event



Standard comparison between radar and rain gauges

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- **Normalized Bias (*NB*) :**

$$NB = \frac{\langle R \rangle}{\langle G \rangle} - 1$$

- **Correlation (*corr*) :**

$$corr = \frac{\sum_{\forall i} \left(G_i - \langle G \rangle\right)\left(R_i - \langle R \rangle\right)}{\sqrt{\sum_{\forall i} \left(G_i - \langle G \rangle\right)^2} \sqrt{\sum_{\forall i} \left(R_i - \langle R \rangle\right)^2}}$$

- **Root mean square error (*RMS*E) :**

$$RMSE = \sqrt{\frac{\sum_{\forall i} \left(R_i - G_i\right)^2}{N}}$$

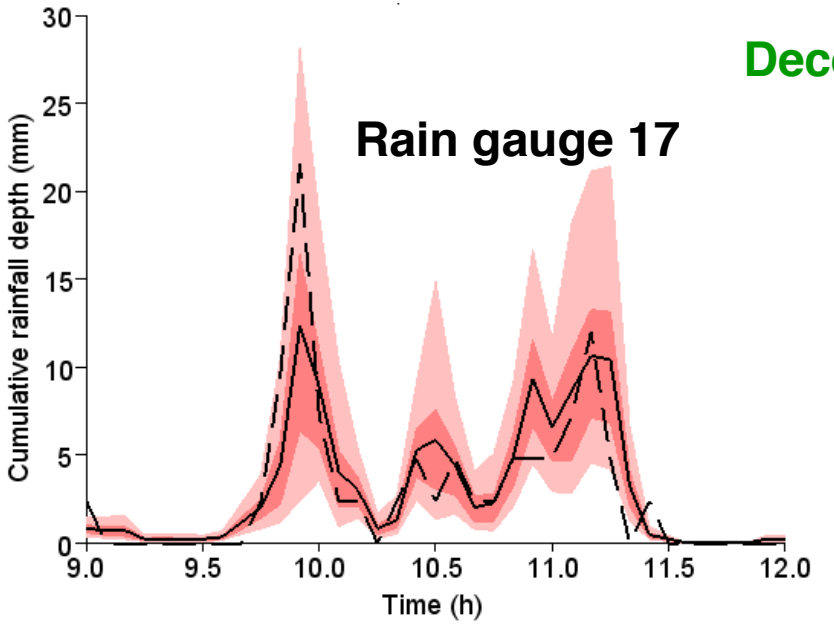
- **Percentage ($\%_{1.5}$) of radar time steps (R_i) contained in the interval** $\left[1.5G_i ; G_i / 1.5\right]$

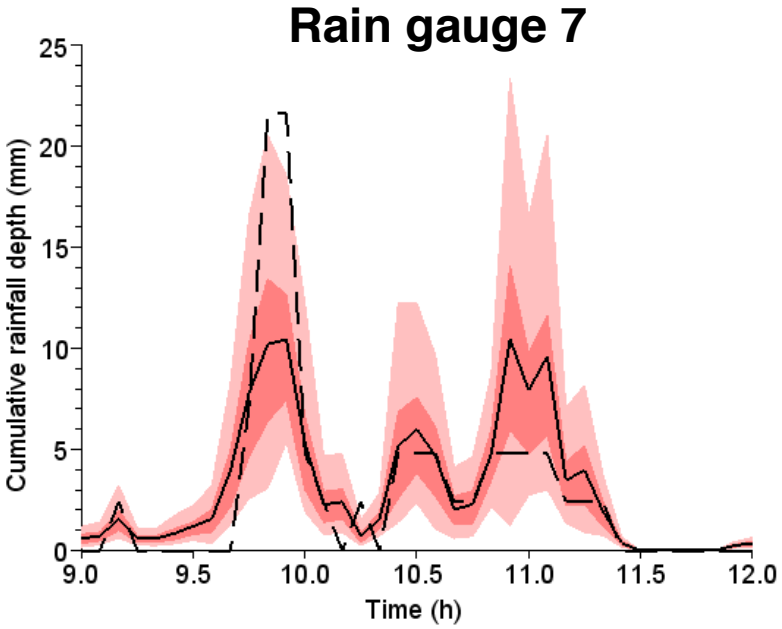
Time steps of 15 min are considered

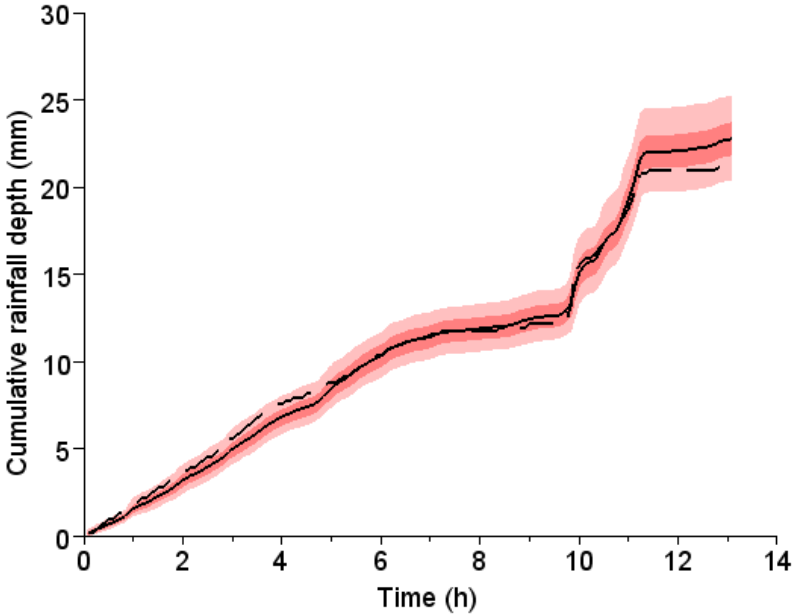
Bridging the scale gap through downscaling

Seine-Saint-Denis rainfall data

December 2011







Envelop curves with 5, 25, 75, 95 % quantiles for each time step

Impact of standard rainfall variability on standard scores

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Methodology

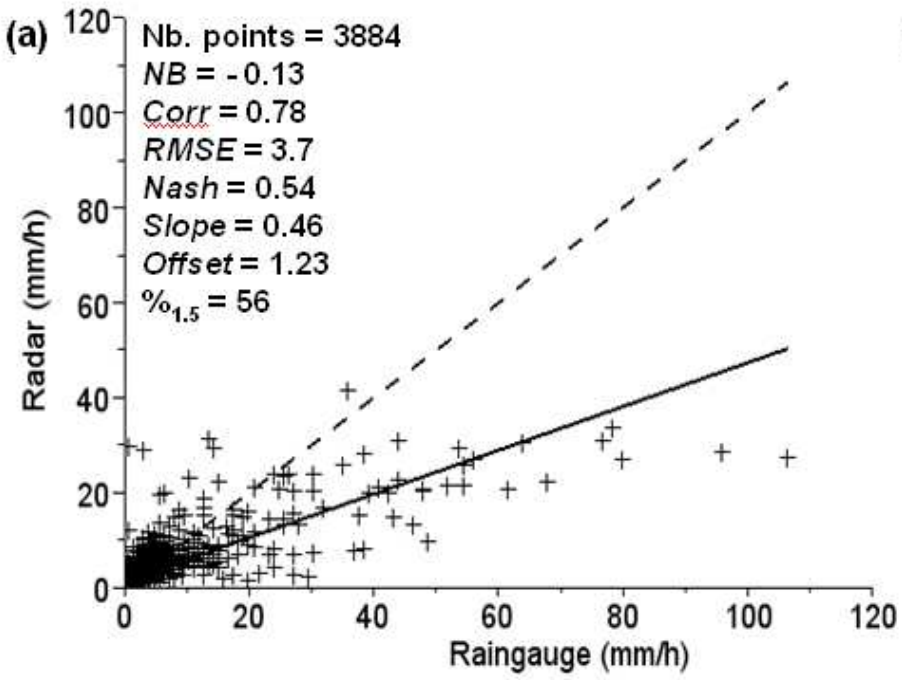
(i) Downscaling the radar data for each radar pixels to a resolution of 46 cm in space and 5 min in time → outputs of "virtual rain gauges" for each of the 26 radar pixels.

(i) Randomly selecting a "virtual rain gauge" for each radar pixel and computing the corresponding scores. In order to generate a distribution of possible values for each score, 1000 sets of 26 virtual rain gauges locations (one per radar pixel) are tested

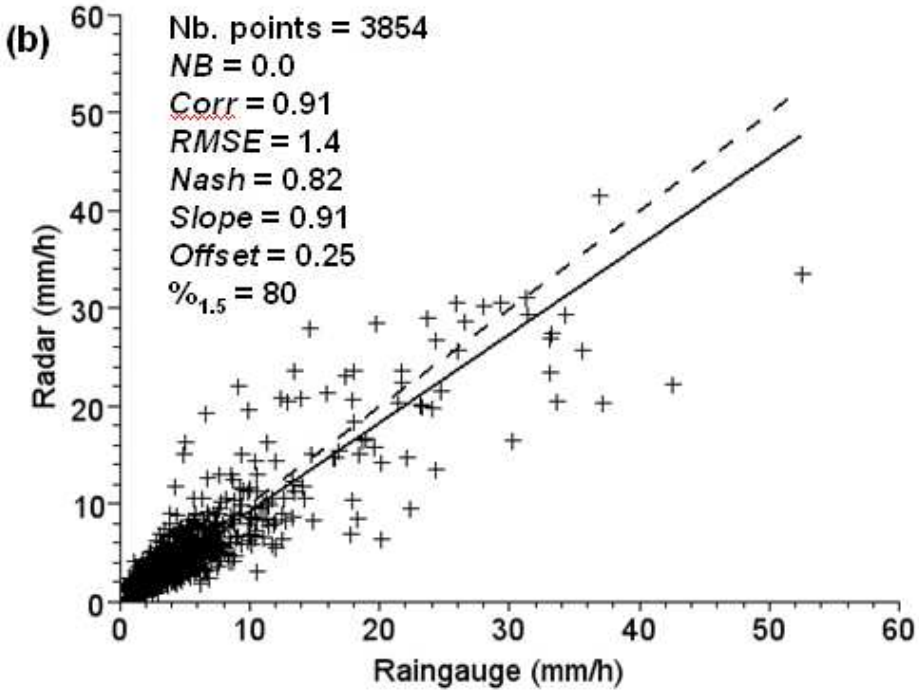
Impact of standard rainfall variability on standard indicators

Scatter plot for all the events with a 15 min time steps

Radar vs. rain gauges measurements

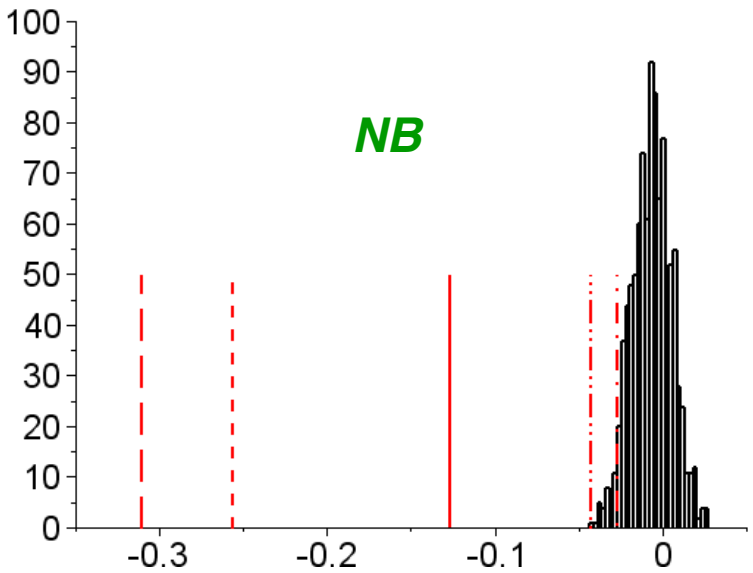


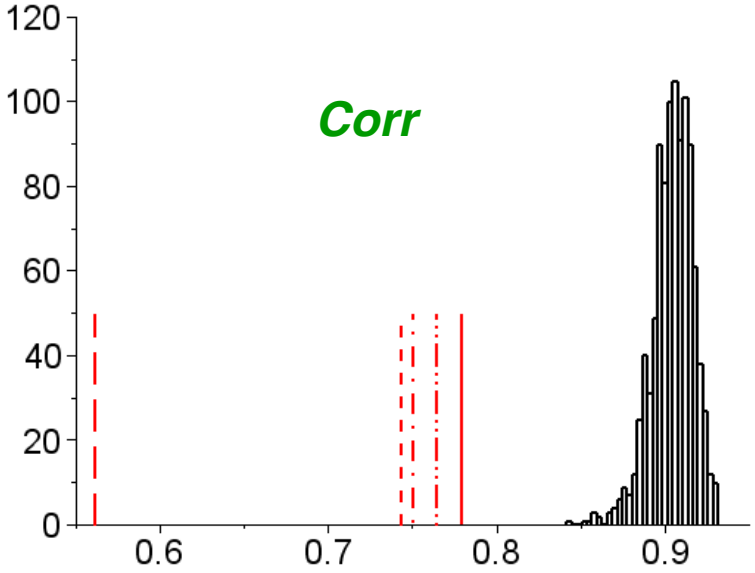
Radar vs. a set of virtual rain gauges (one per radar pixels)

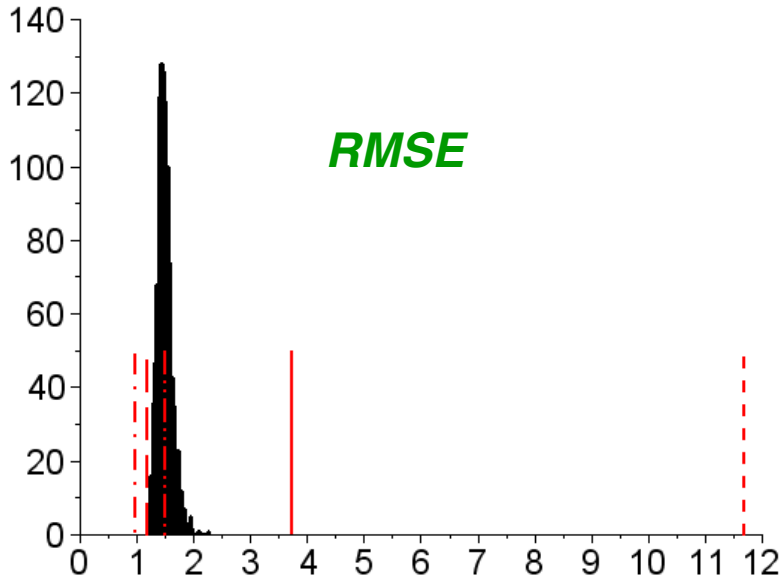


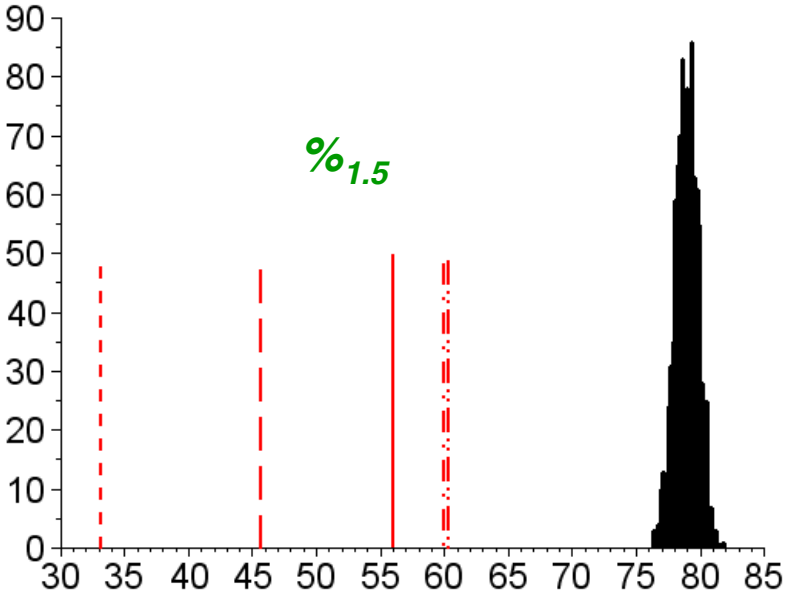
Impact of standard rainfall variability on standard scores

Distribution of the standard scores with the virtual rain gauges (Δt = 15 min)









Conclusion

Validation of a Universal Multifractals downscaling process

Revisiting the issue of representativeness of punctual measurements with regards to average ones

- Explicit modelling of small scale unmeasured (at scales smaller than 1km*5min) rainfall variability
- A significant impact on standard comparison indicators (change in the target values of scores, and quantification of the uncertainty associated with small scale rainfall variability)

Further investigations :

- Improvement of representation of small scale rainfall variability
  - Measurements → dvp of a multi-scale observatory (X-band radar, 1D Disdro network, 3D video disdro)
  - Theoretical development
- Improvement of merging techniques by explicitly taking into account small scale rainfall variability