

Pilote Sites

The ENPC Green Wave

Filip STANIĆ (HMCo-ENPC)



Kick-Off Meeting – Lundi 16 Octobre 2017

PhD Thesis

High resolution monitoring and modeling of hydrological fluxes in a green roof, ubiquitous sensors network

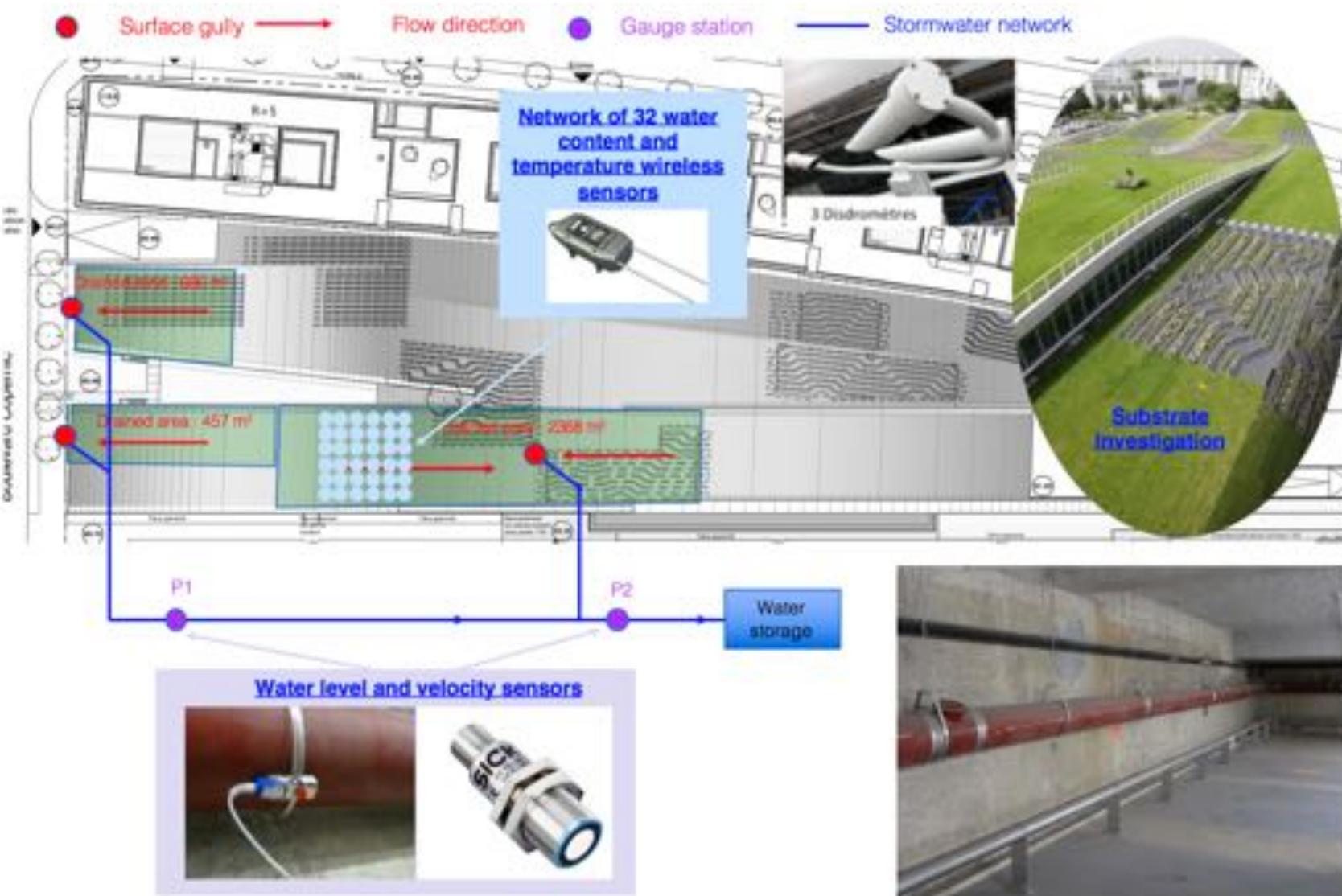
Main objective: Investigation of hydrological responses of green roofs, by taking into account slope of the roof, spatial and temporal variability of water content and temperature.

Methodology: Detailed Green Wave monitoring, modeling and laboratory investigation for better understanding the geotechnical processes inside the substrate.



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Green Wave



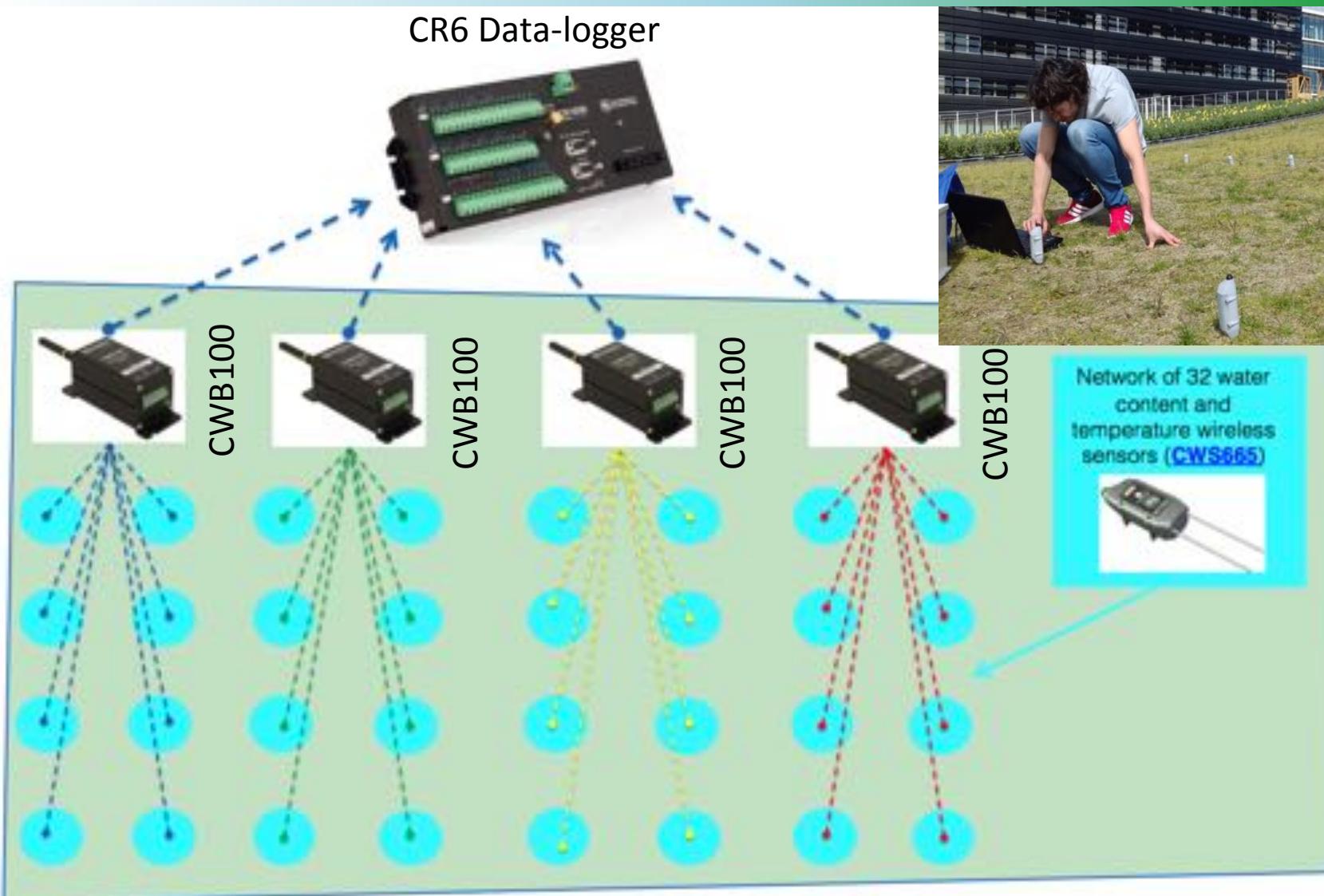
BGD



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Green Wave monitoring - WSN

CR6 Data-logger



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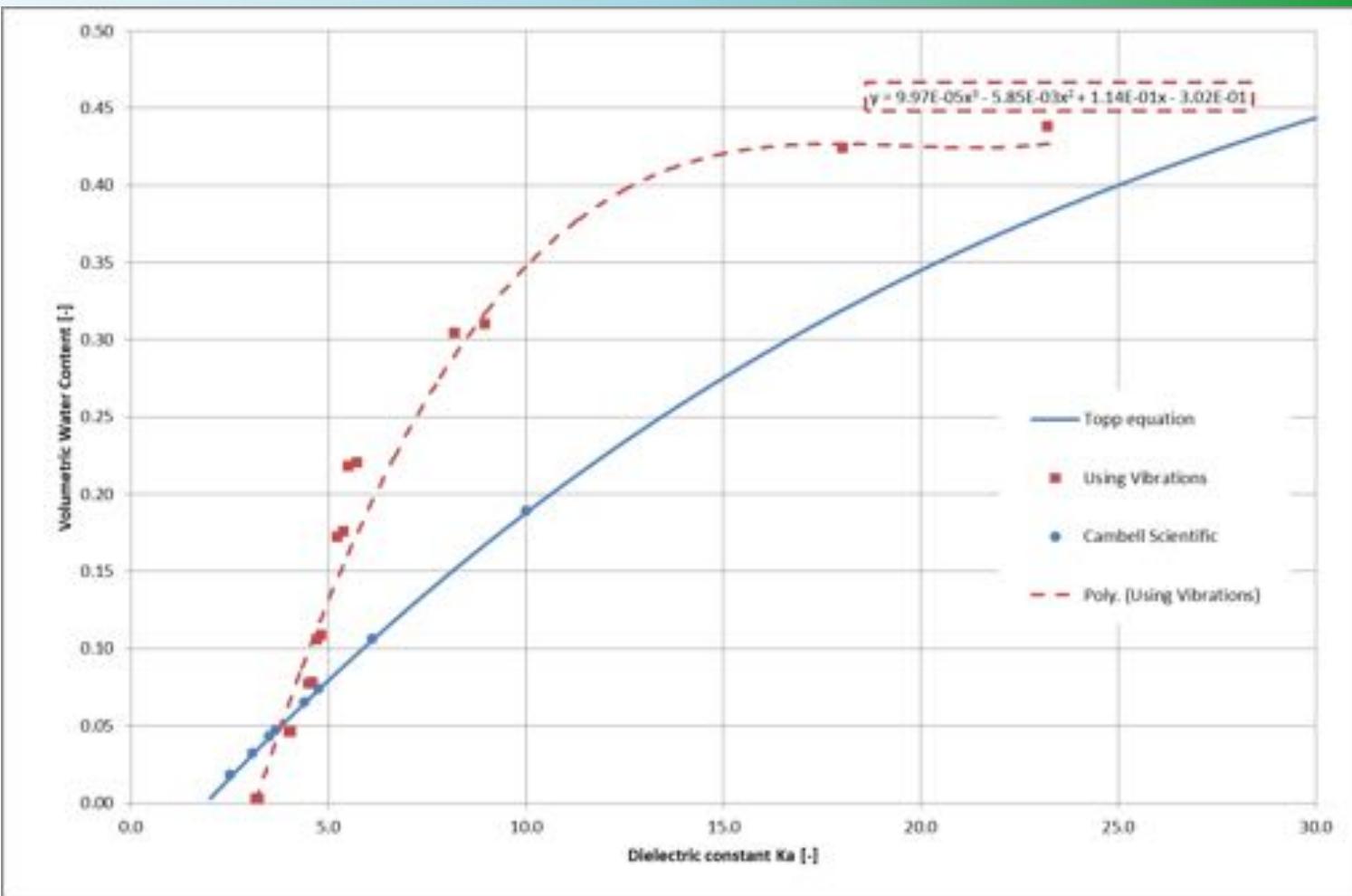
Green Wave monitoring - WSN



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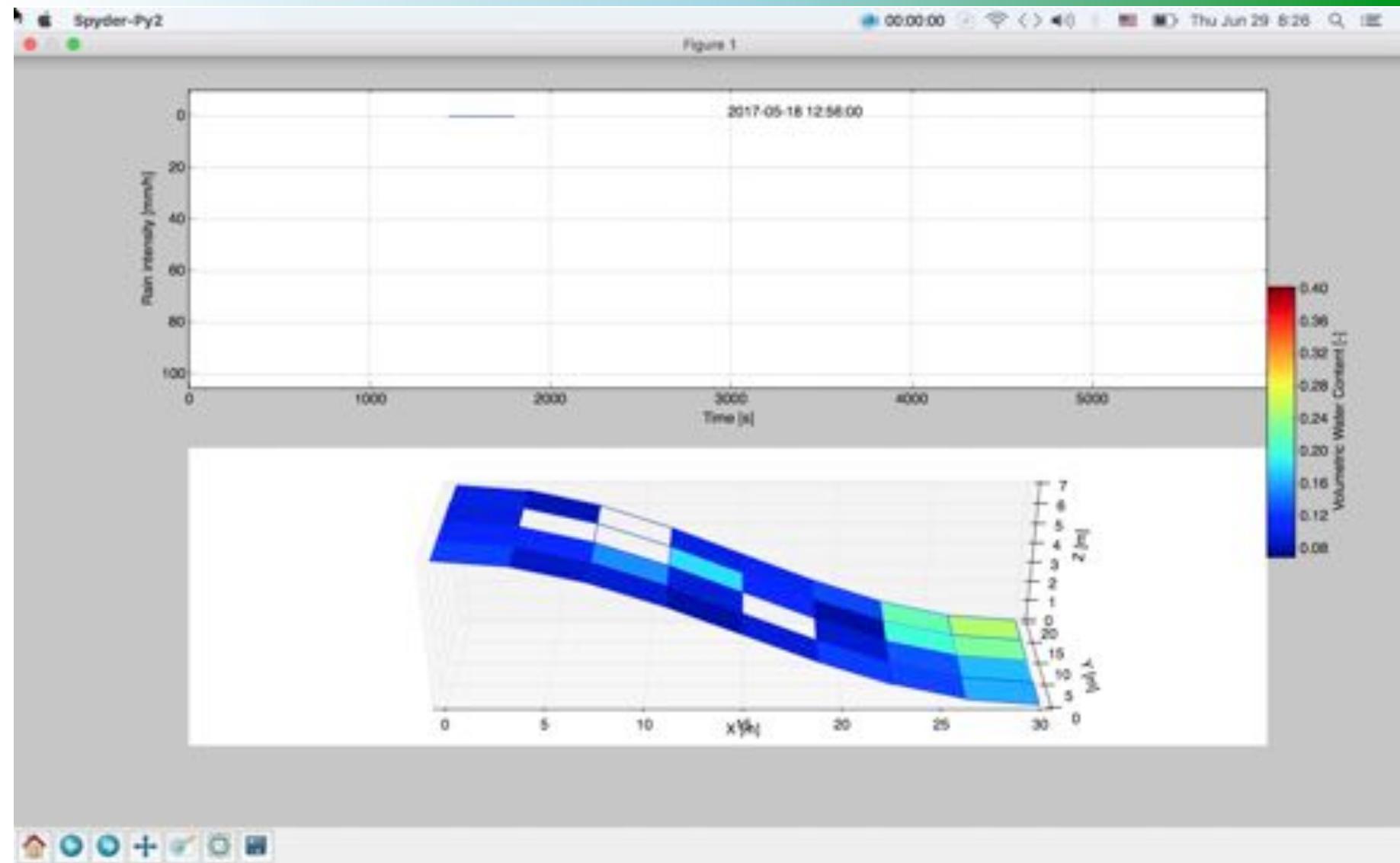
Green Wave monitoring

- Calibration of TDR sensors -



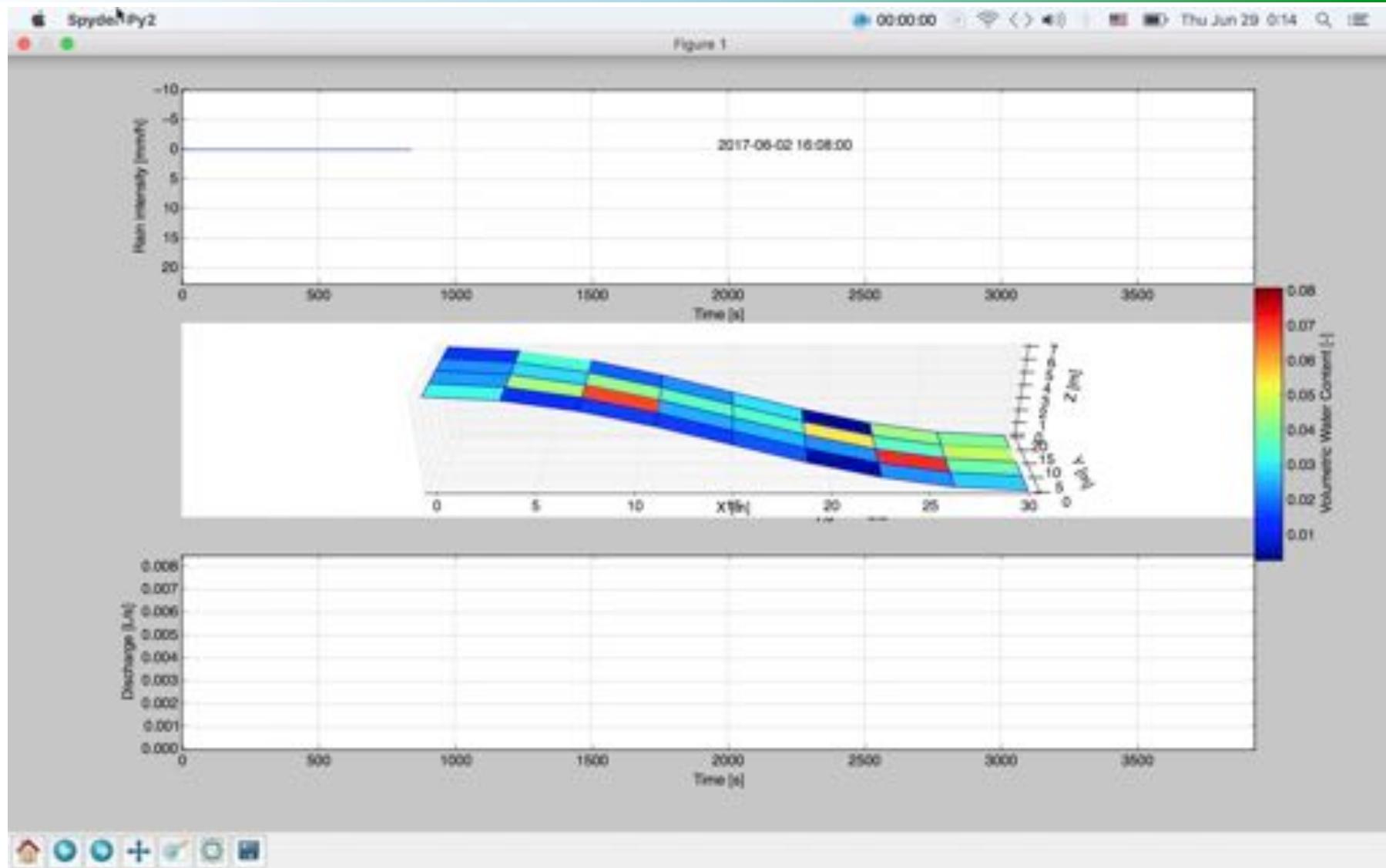
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Green Wave monitoring



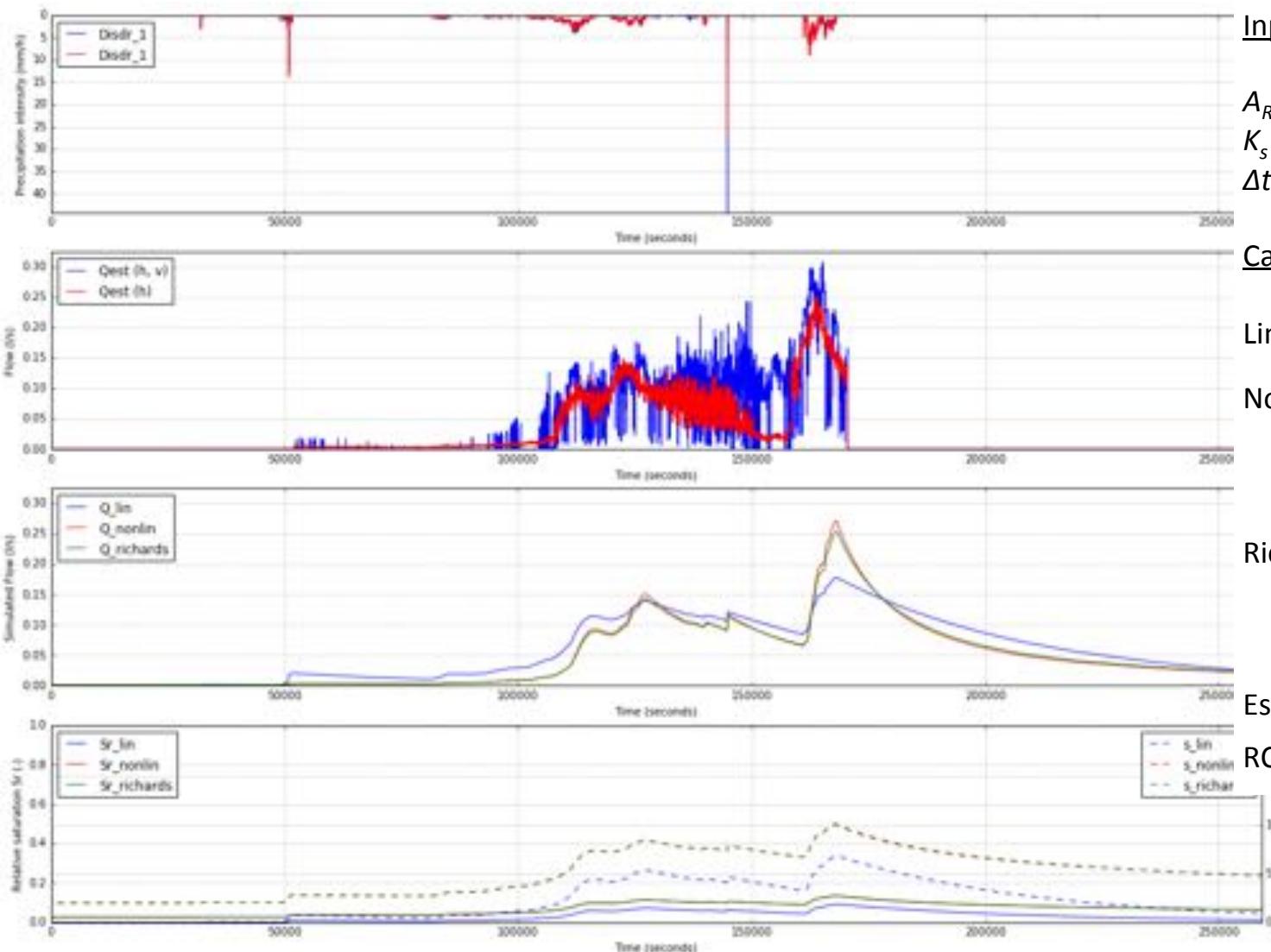
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Green Wave monitoring



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Green Wave monitoring + modeling



Input parameters:

$$A_{ROOF} = 1147 \text{ m}^2, \omega_{max} = 0.5, \\ K_s = 2.6 \times 10^{-4} \text{ m/s}, h_{sub} = 0.2 \text{ m}, \\ \Delta t = 30 \text{ s.}$$

Calibration parameters:

Linear reservoir: $k = 4 \times 10^{-4} \text{ m/s}$

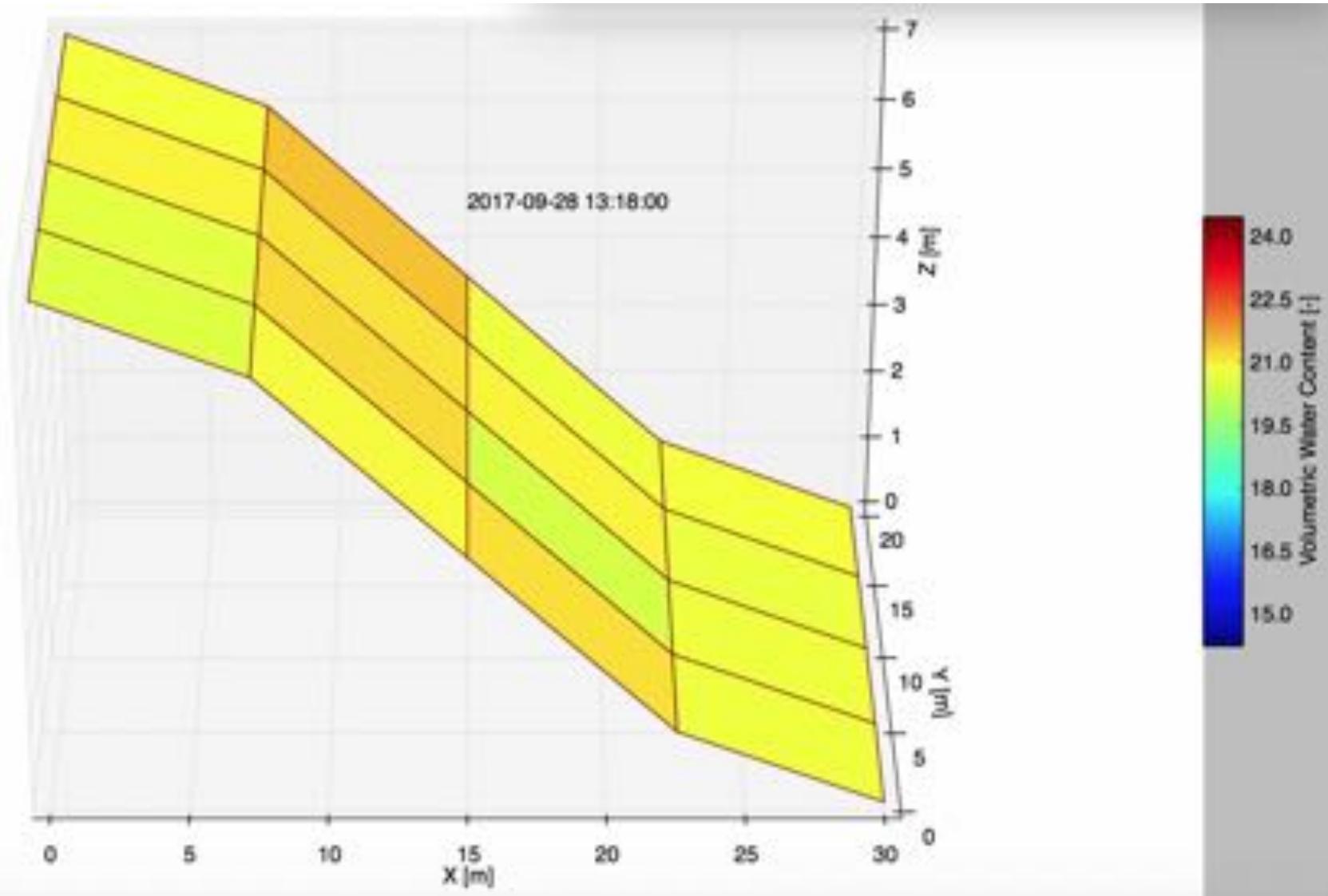
Nonlinear reservoir: $\omega_0 = 0.14$
 $\omega_r = 0.13$
 $c = 3.5$

Richards: $\omega_0 = 0.14, \omega_r = 0.13$
 $\alpha = 0.02 \text{ 1/cm}$
 $n = 3.7$

Estimated runoff coefficient:
RC = 0.8

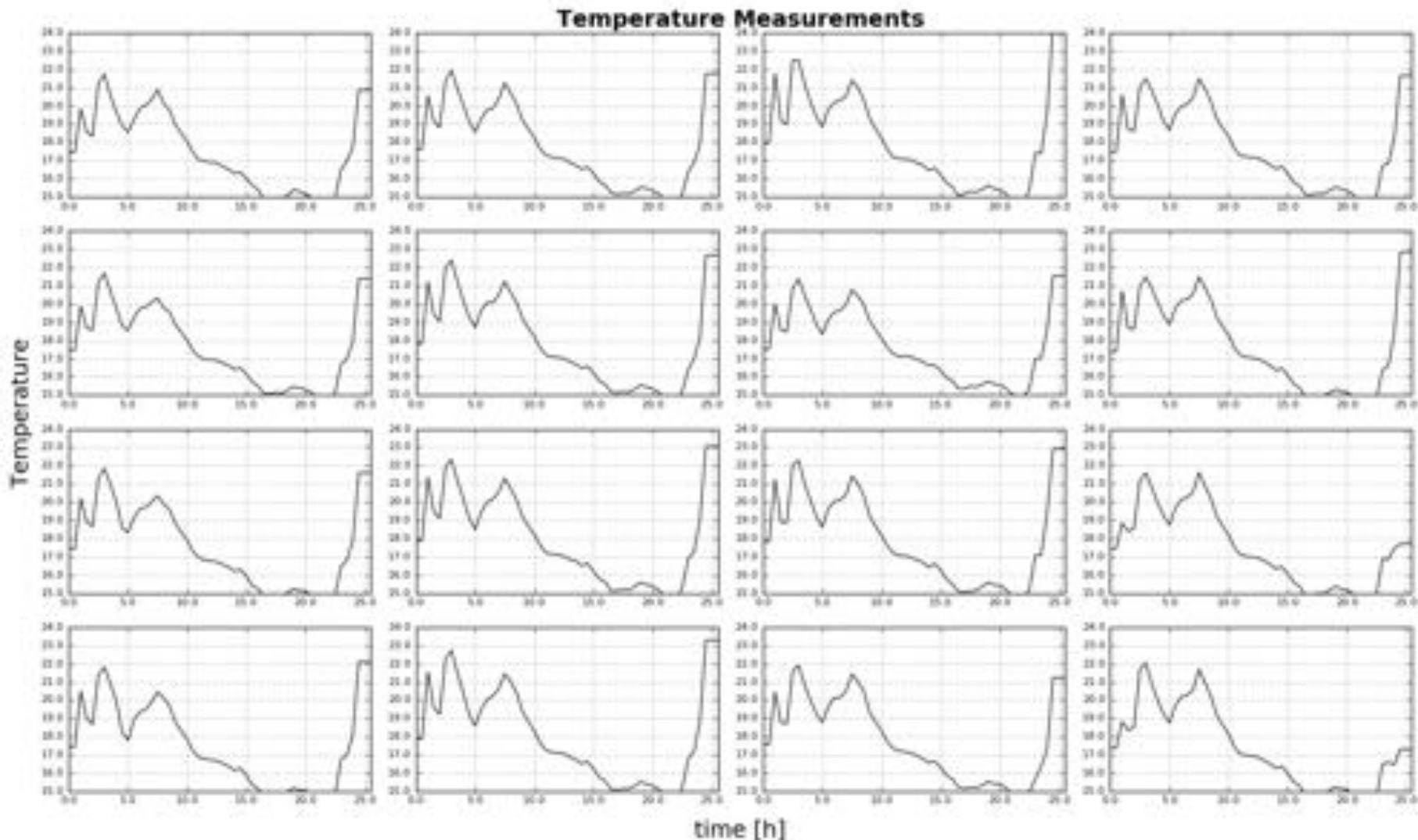


Green Wave monitoring



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Green Wave monitoring



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Multifractals

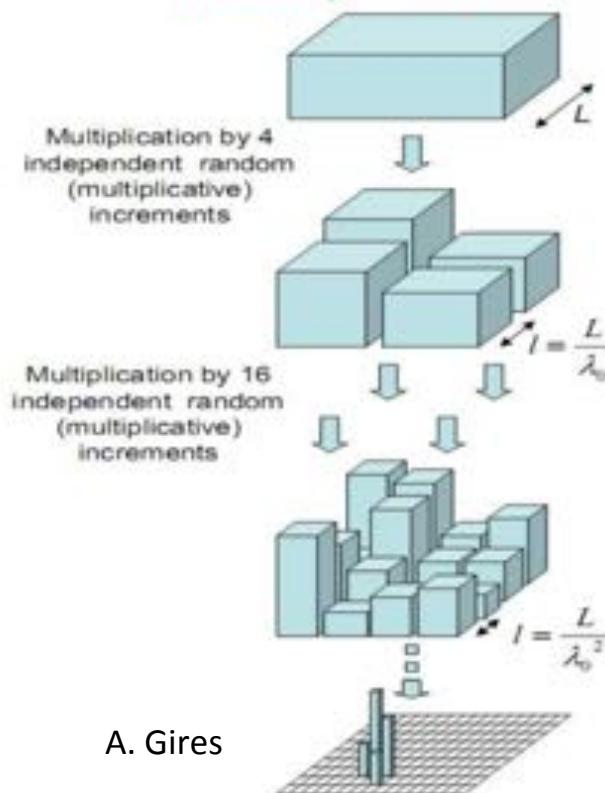
Universal Multifractals

Theoretical framework

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



Multifractal fields



Resolution

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

Singularity

Codimension function

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

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

Moment order

Scaling moment function

$$K(q) \quad \text{Legendre transform} \quad c(\gamma)$$



Multifractals

Universal Multifractals

Theoretical framework

Multiplicative cascade processes converge towards UM (broad generalization of the central limit theorem)

$$\begin{matrix} K(q) \\ c(\gamma) \end{matrix}$$

Two relevant parameters :
 C_1 and α

C_1 : mean intermittency

- It measures how concentrated is the average field and it is the codimension of the singularity of the average field for a conservative field

- $C_1=0$ for uniform field

α : multifractality index $0 \leq \alpha \leq 2$

- It measures how fast the intermittency evolves when considering singularities slightly different from the average field singularity. in the monofractal case

- $\alpha = 0$ for the mono-fractal case

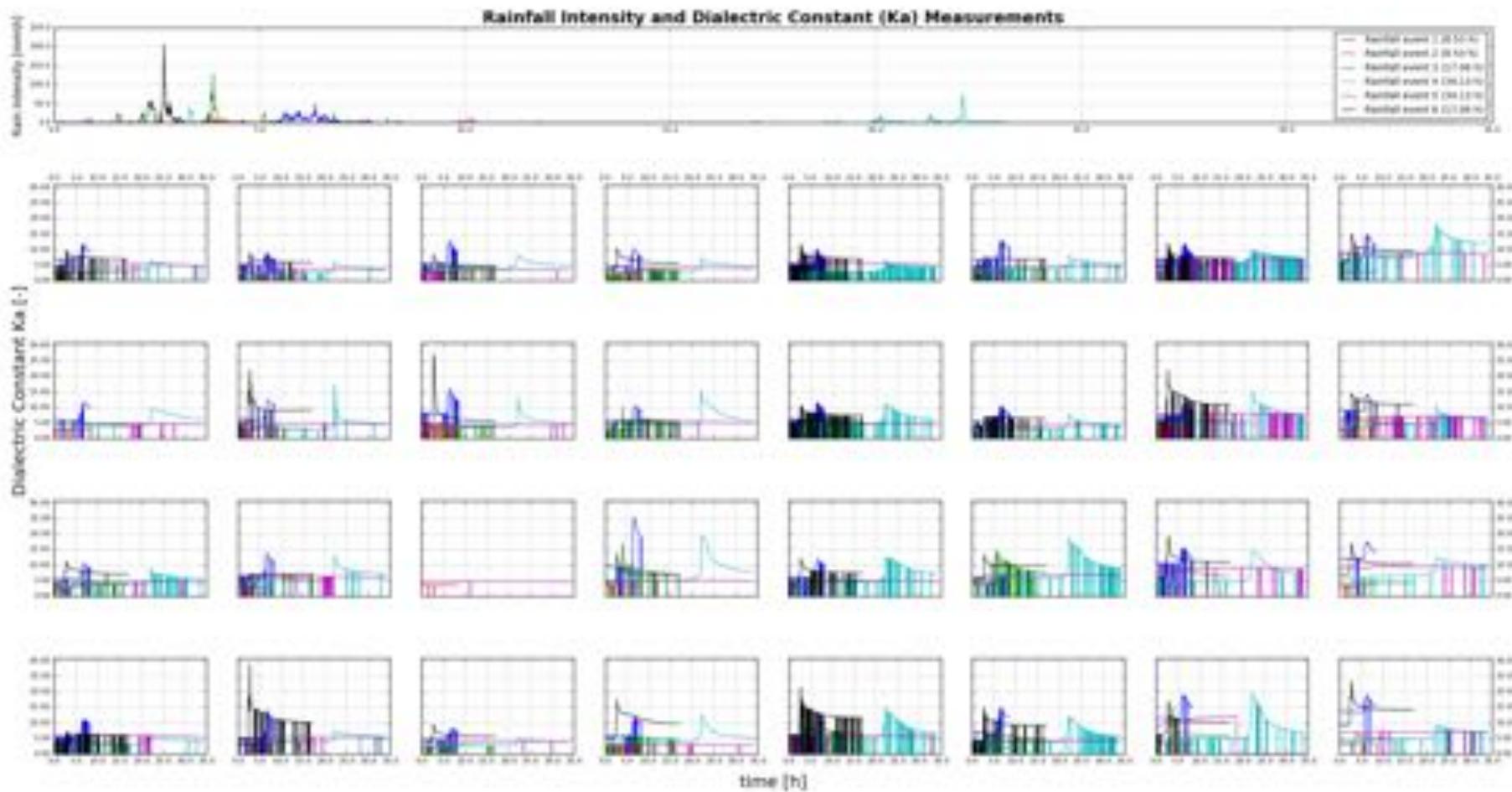
Straightforward consequence on the extremes:

- C_1 and α great \rightarrow strong extremes
- C_1 and α small \rightarrow weak extremes

A. Gires

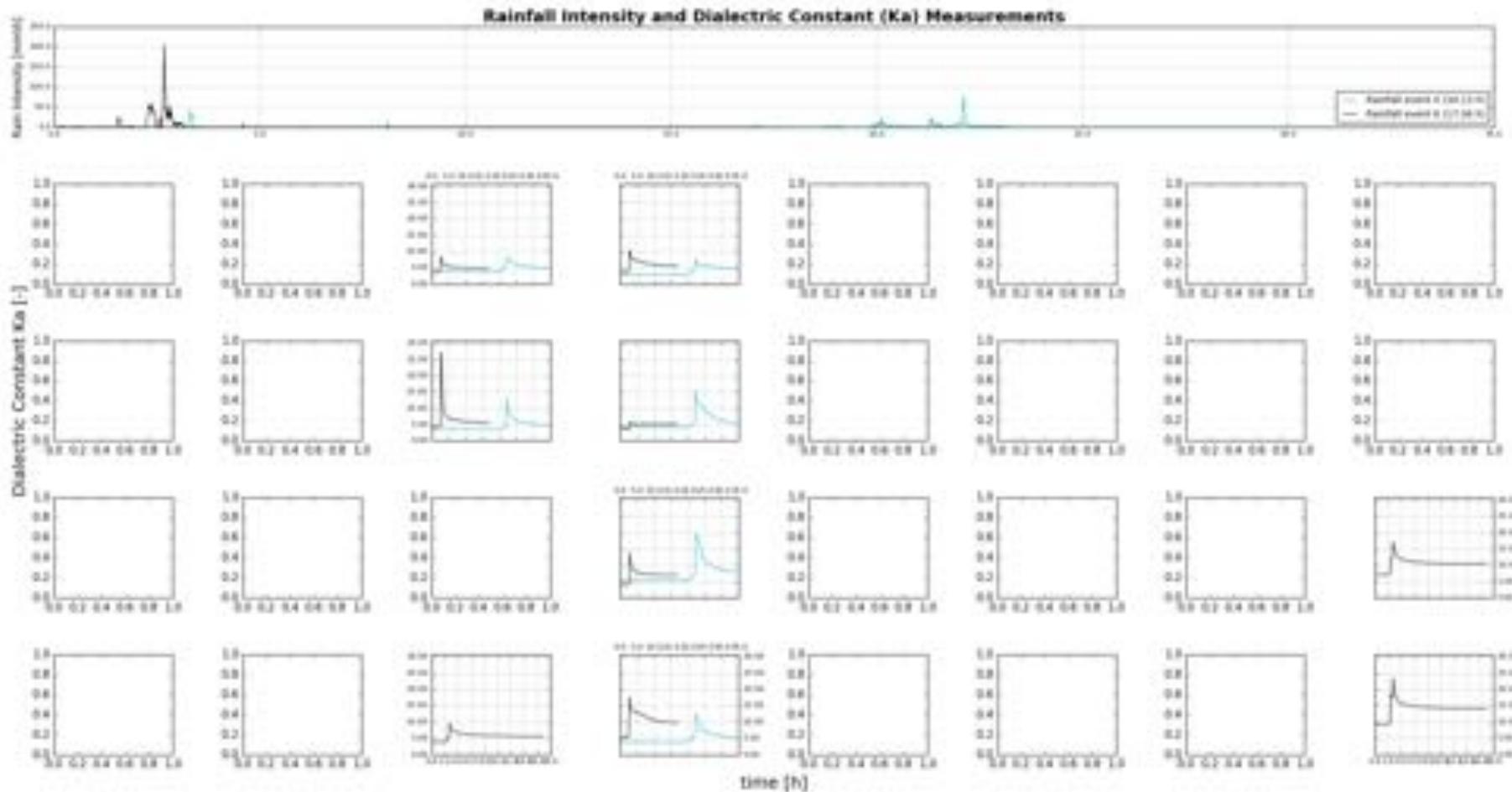


Multifractals - Results



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Multifractals - Results



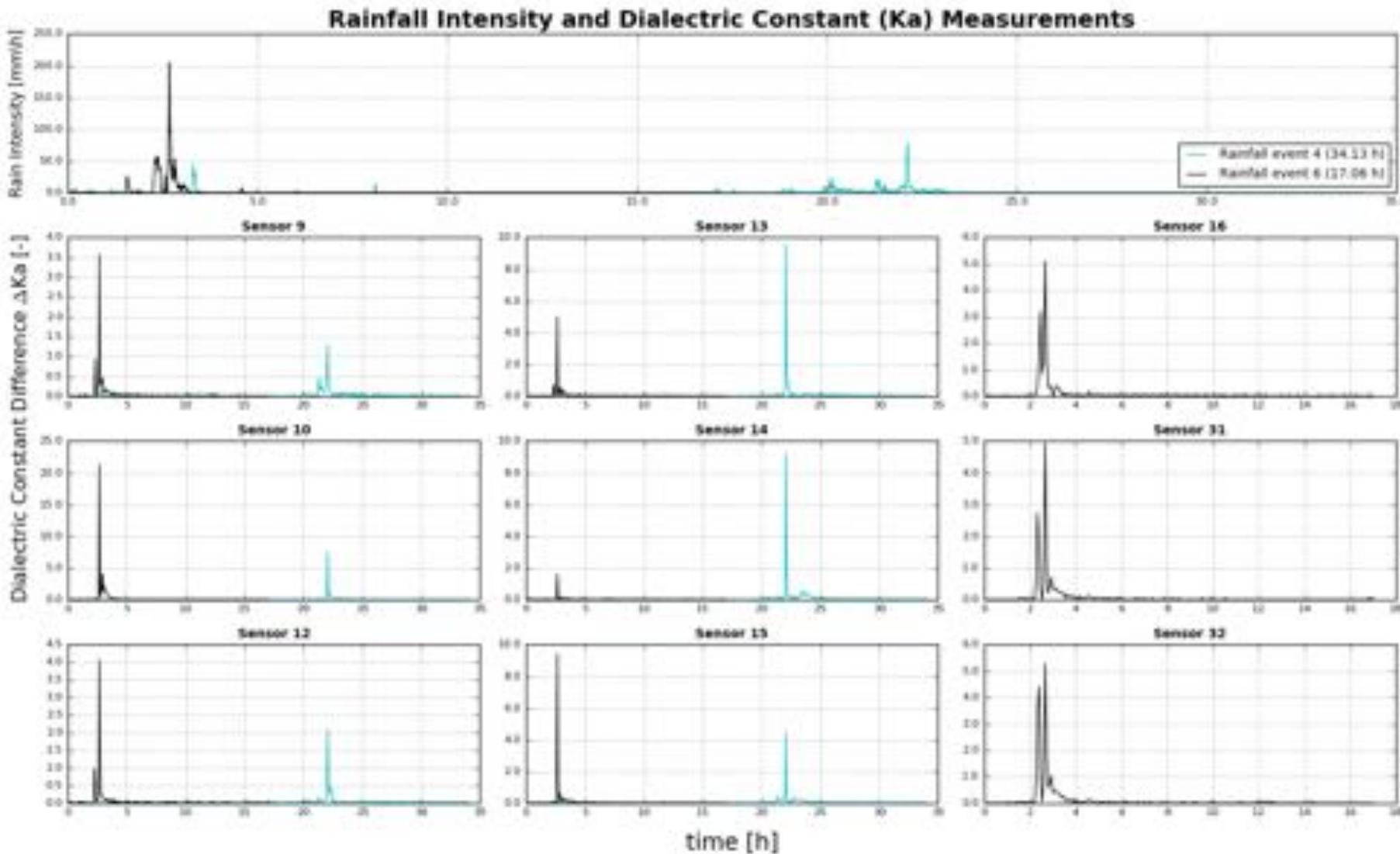
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Green Wave monitoring - WSN



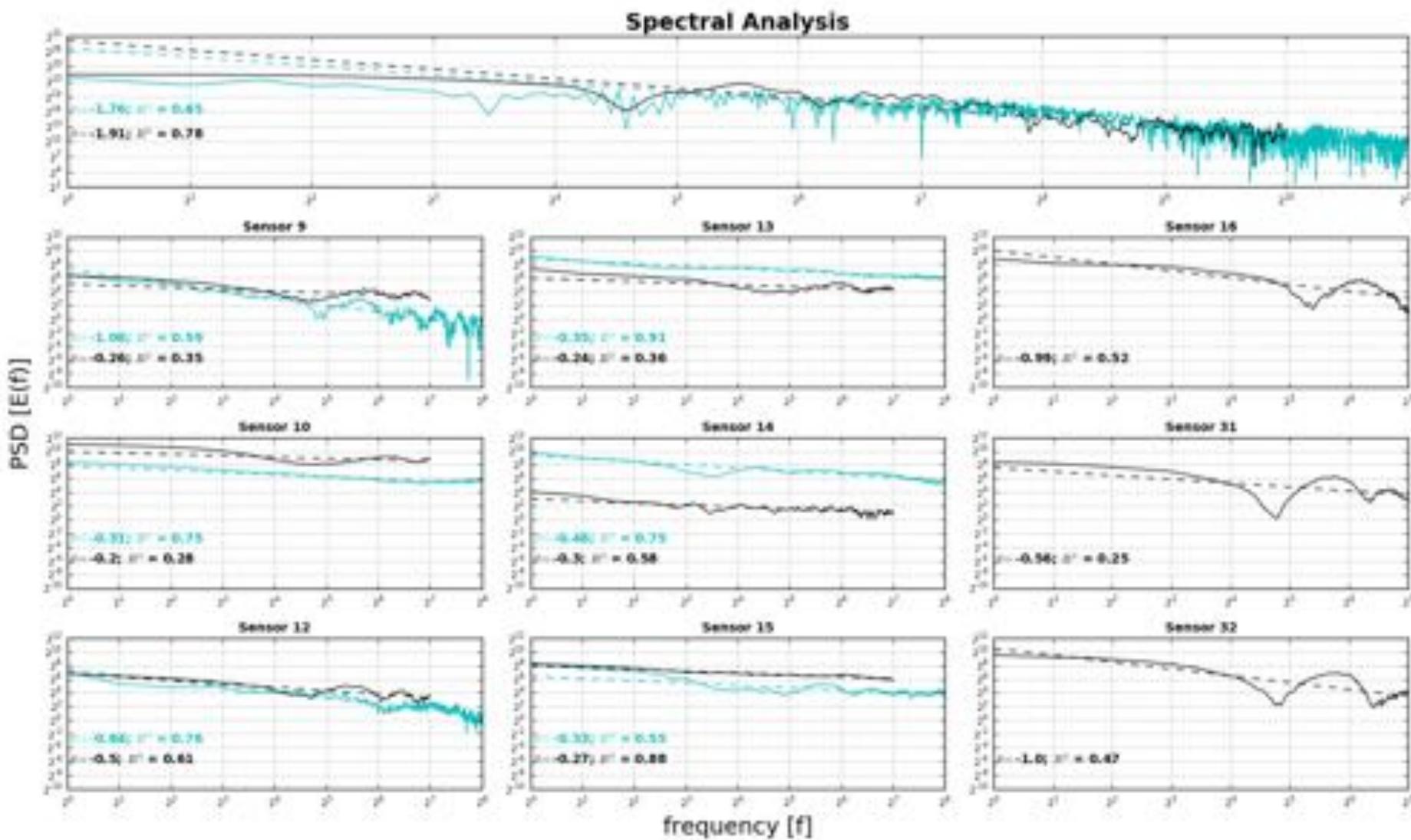
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Multifractals - Results



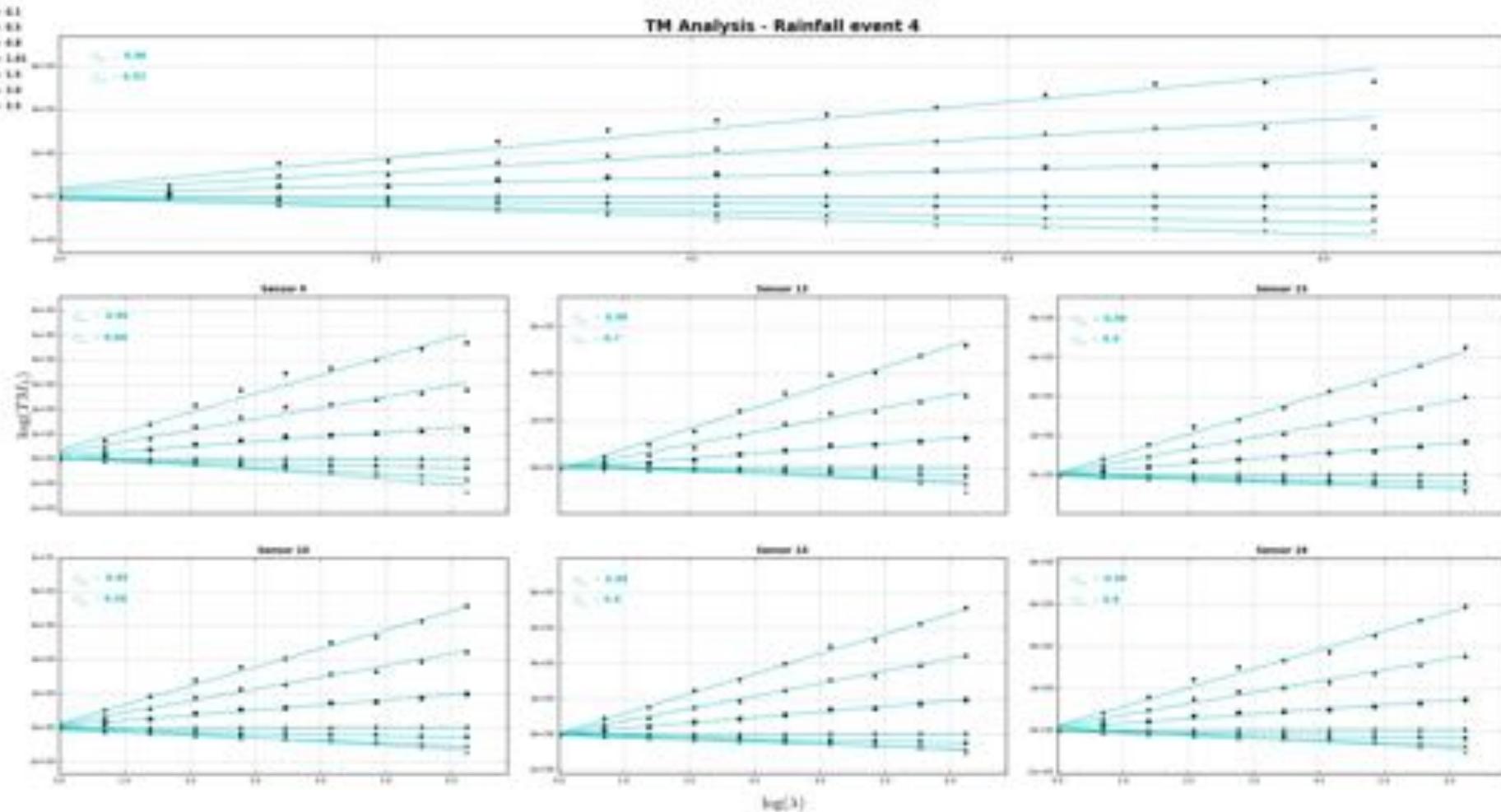
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Multifractals - Results



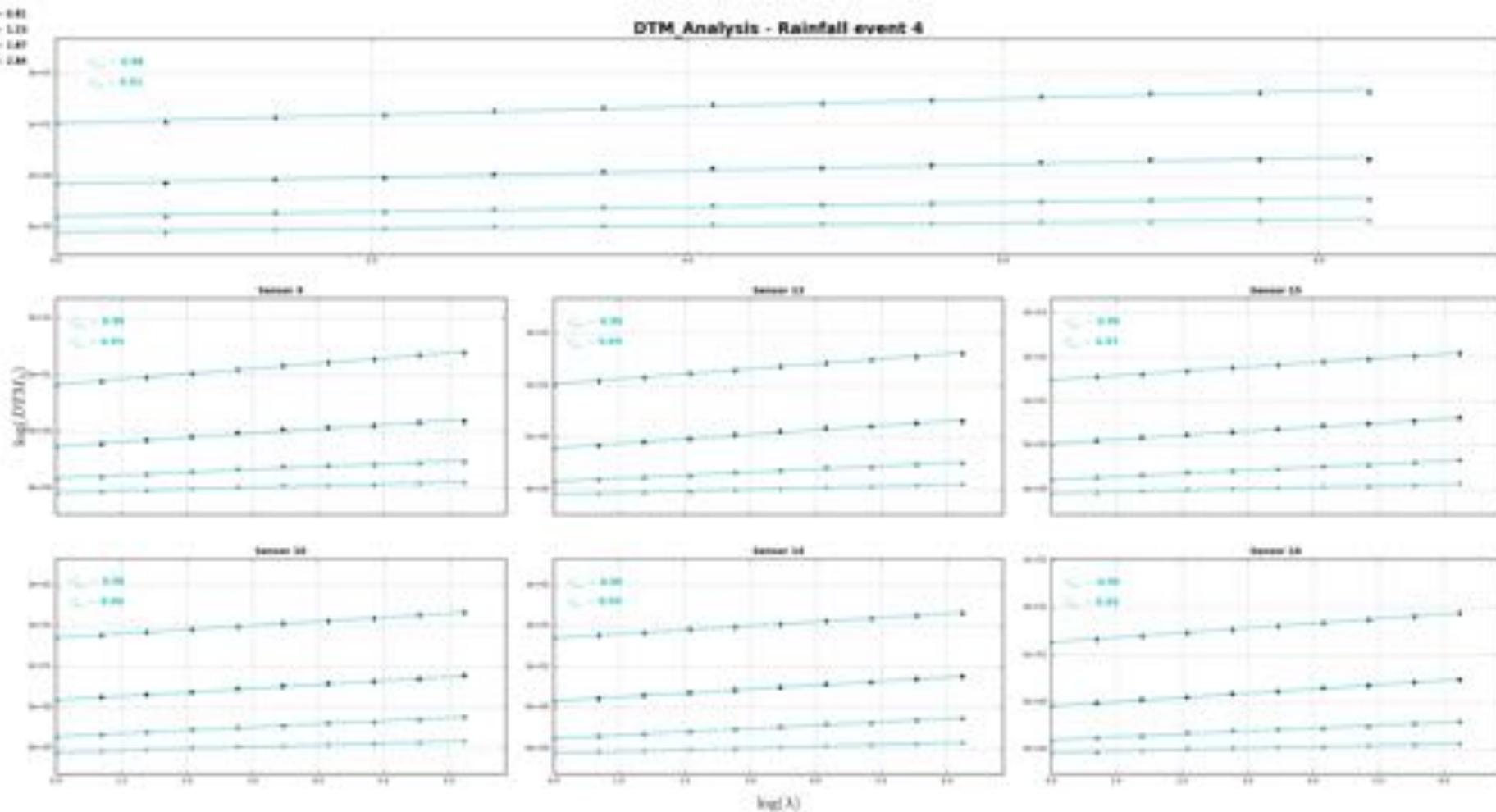
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Multifractals - Results



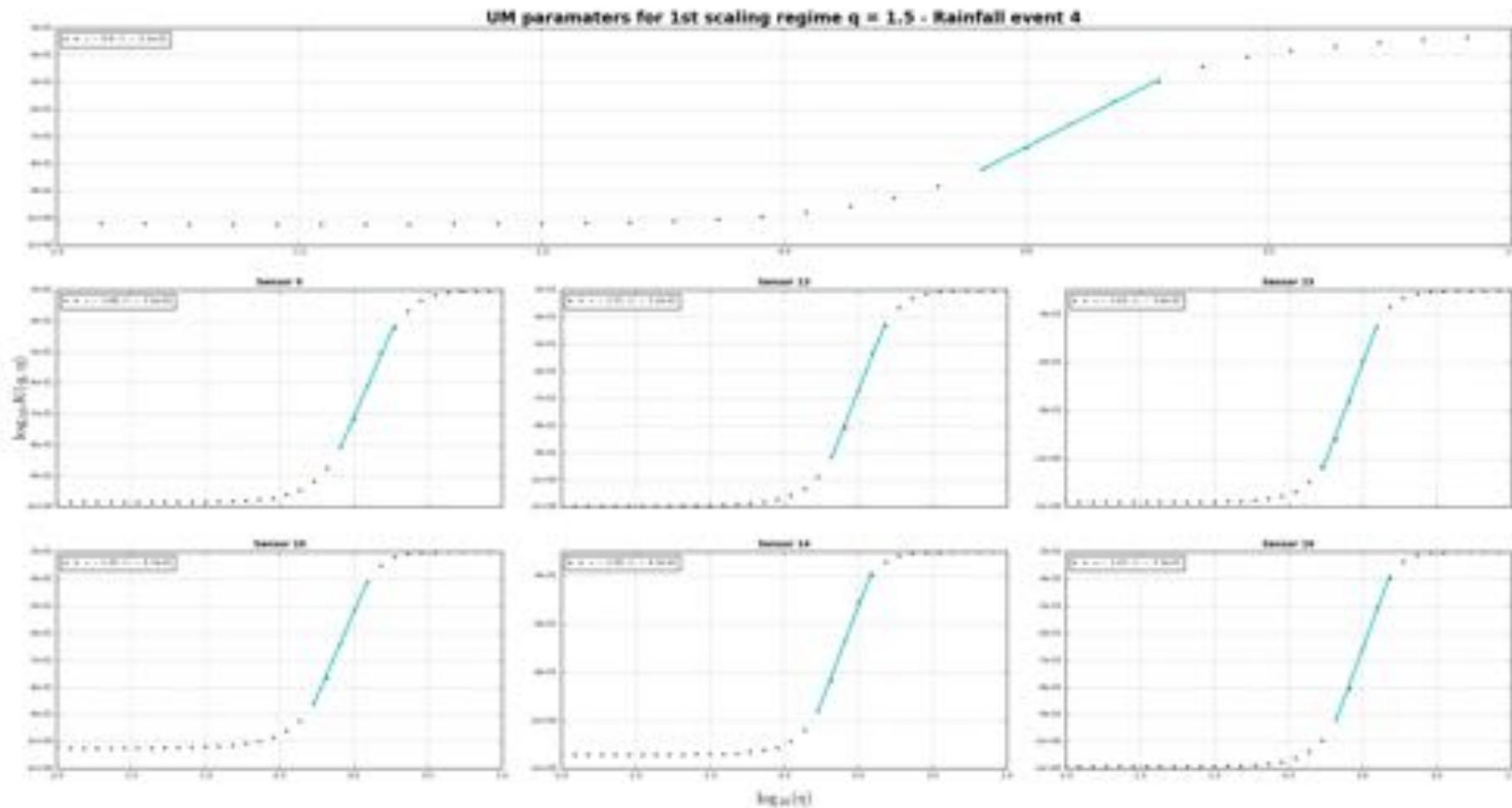
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Multifractals - Results



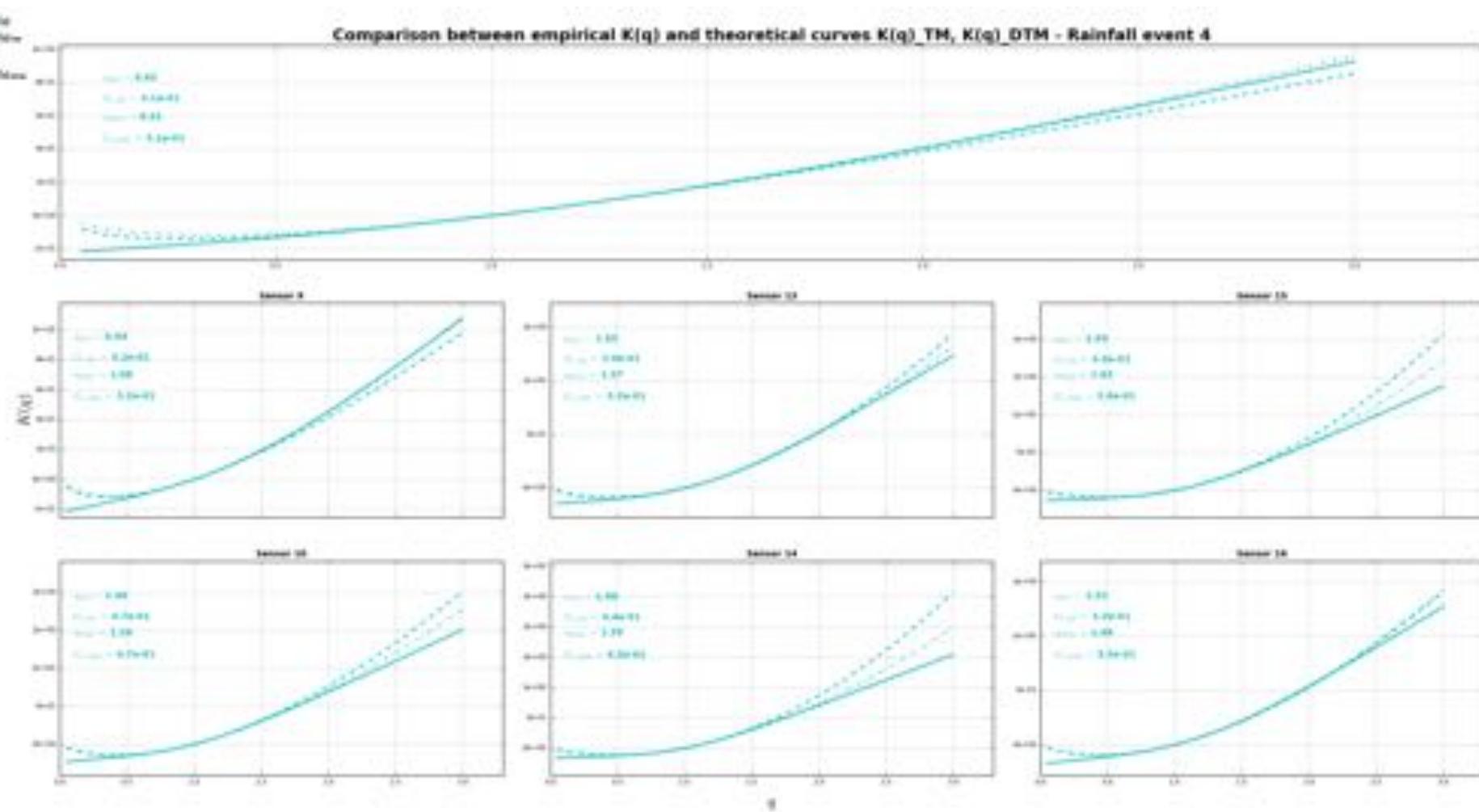
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Multifractals - Results



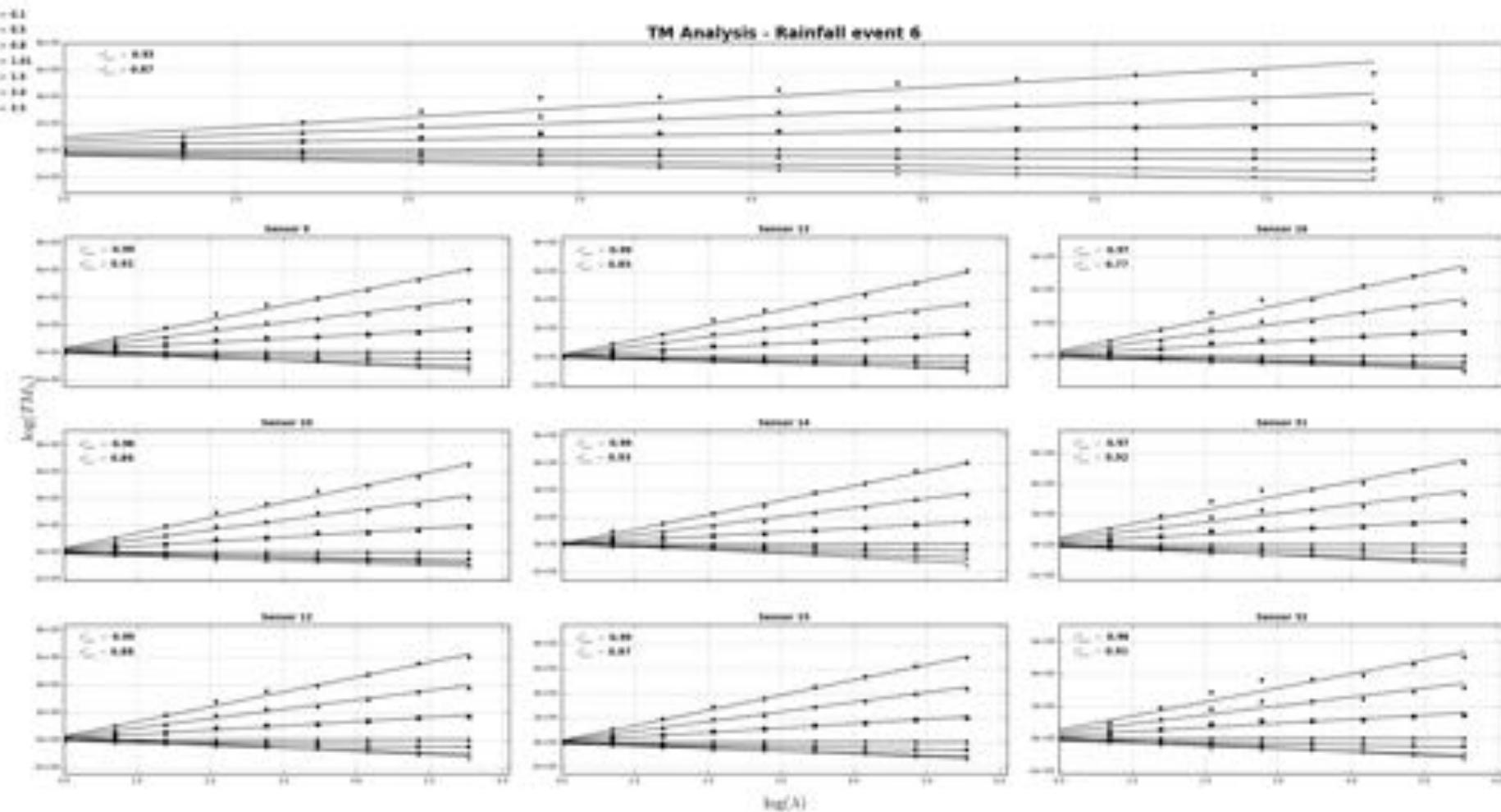
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Multifractals - Results



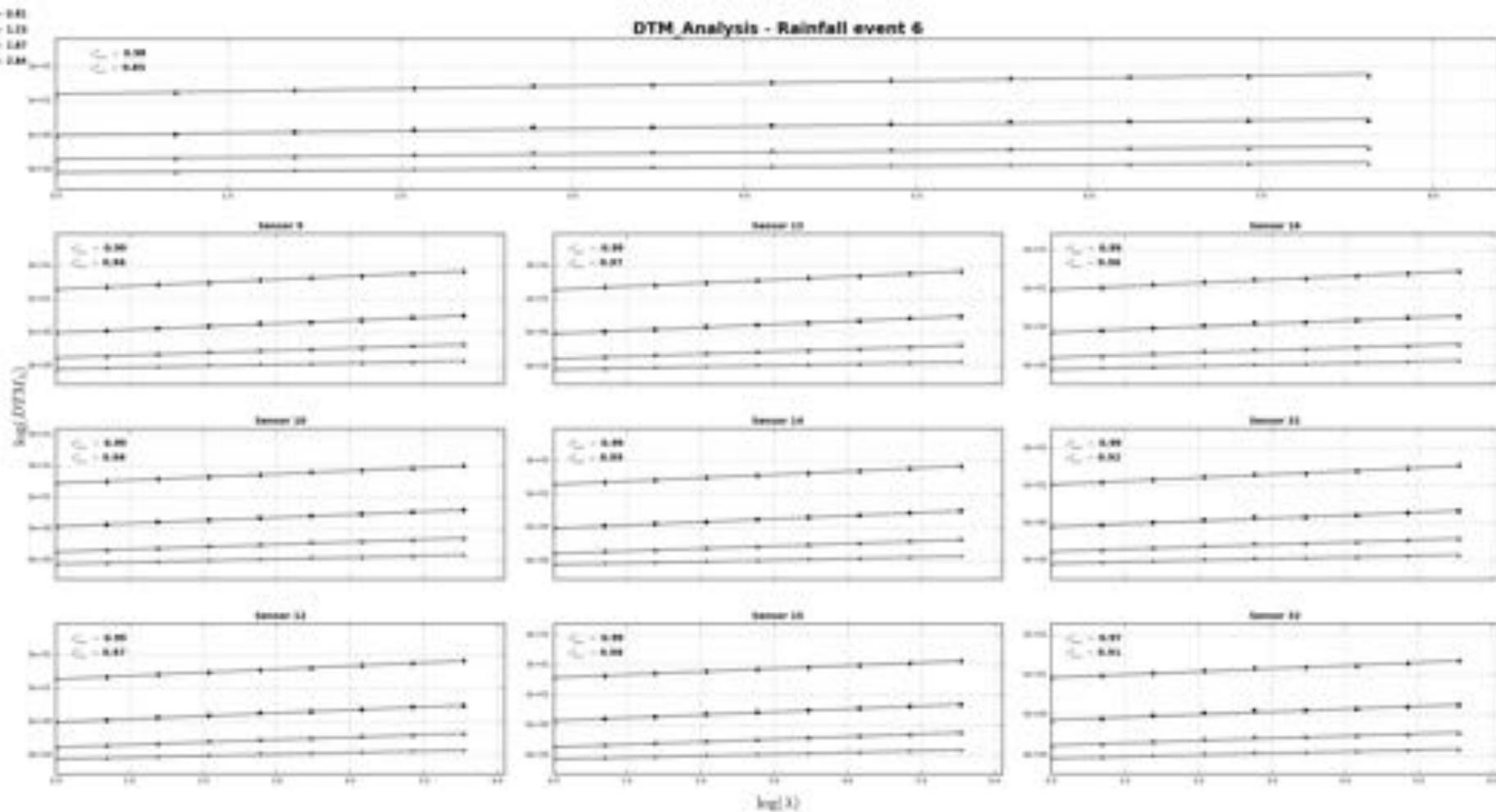
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Multifractals - Results



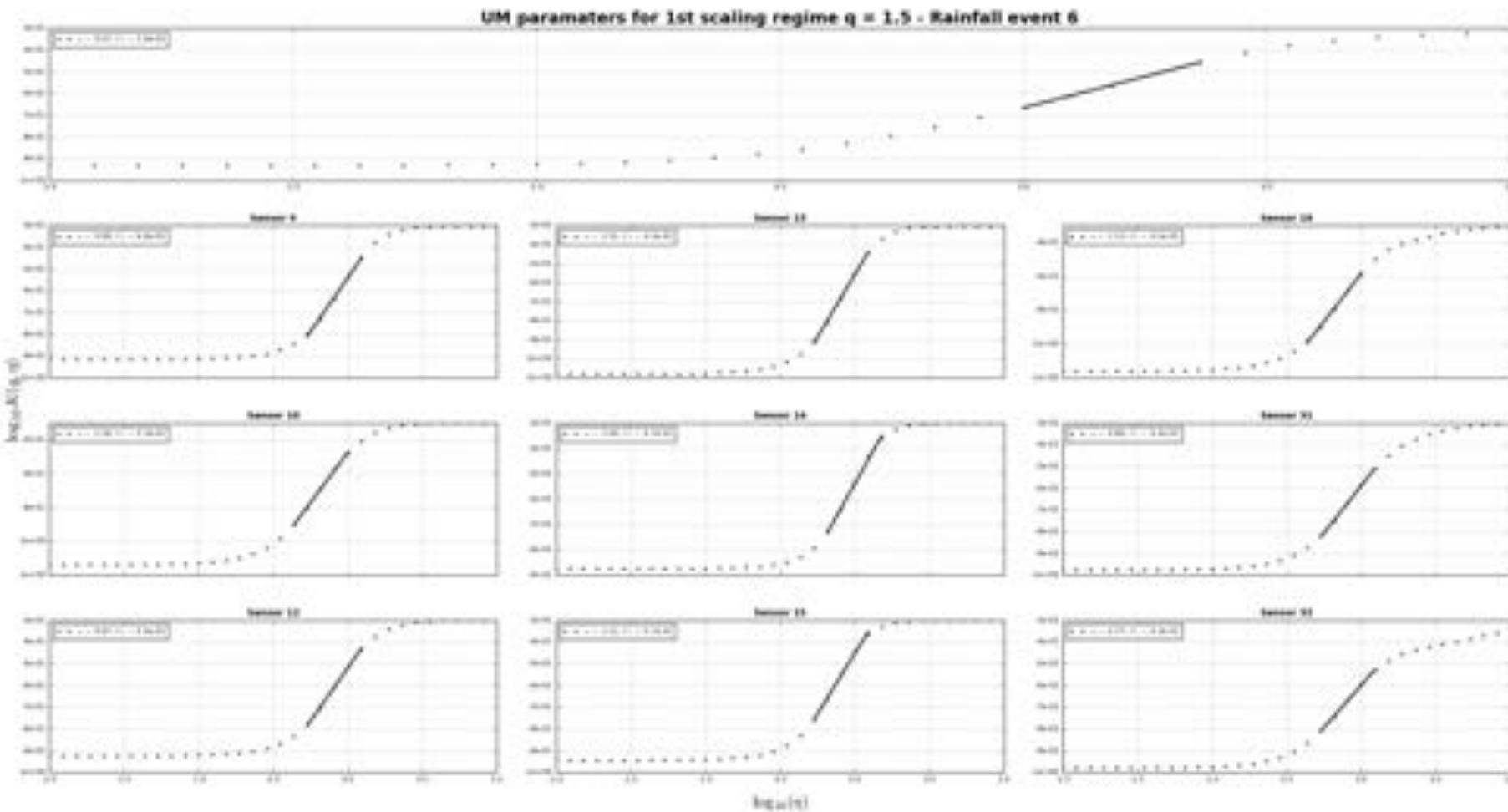
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Multifractals - Results



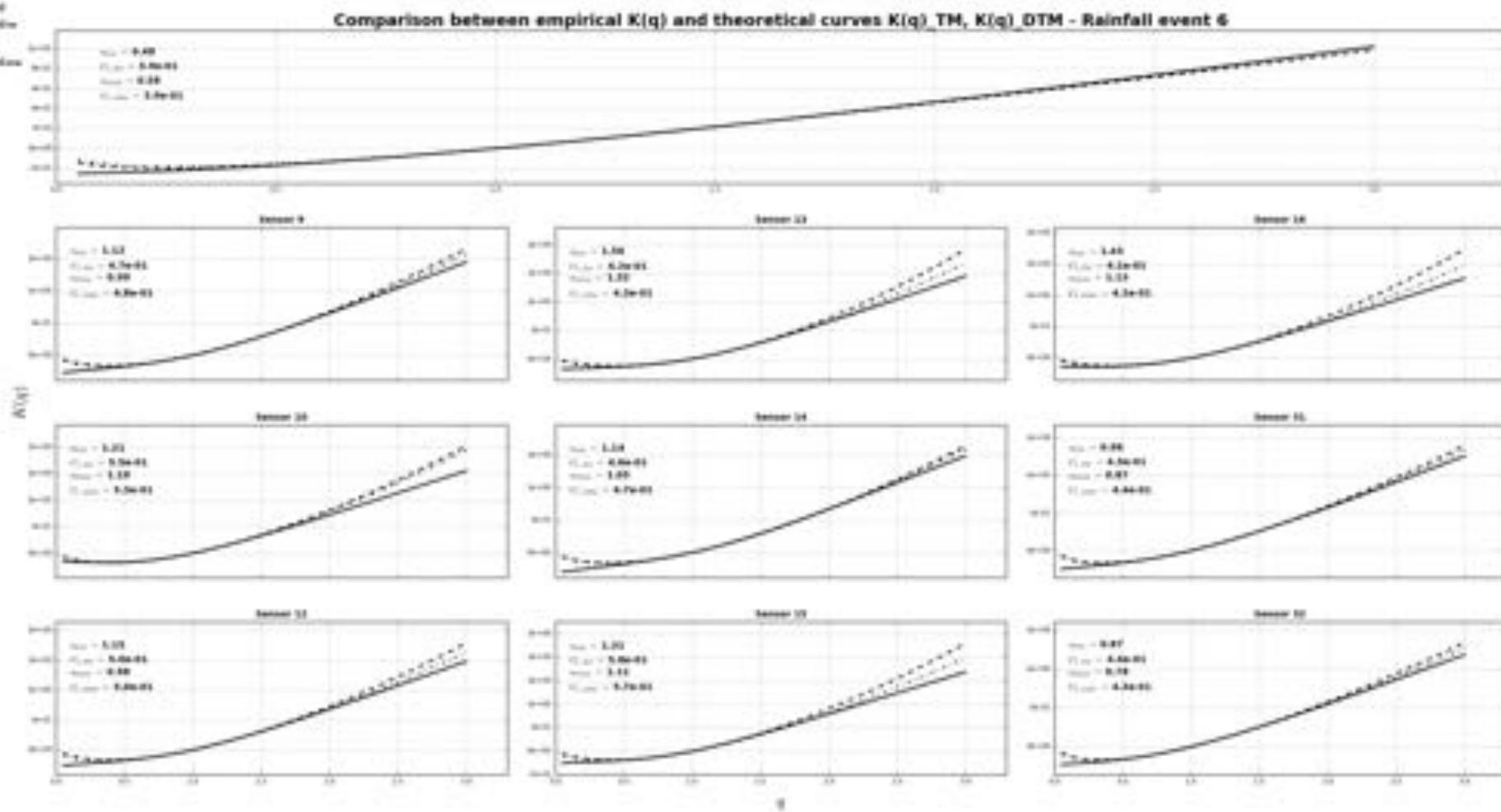
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Multifractals - Results



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Multifractals - Results



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Pilote Sites

Trappes Green roofs

David Ramier (Cerema IdF)



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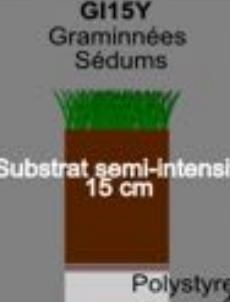
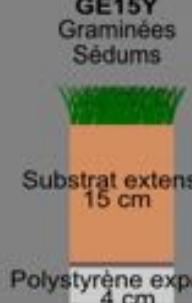
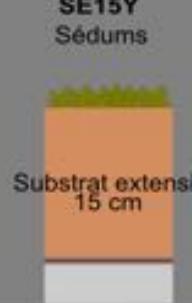
Experimental device

6 VGR

(35 m²)

2 references

(21 m²)

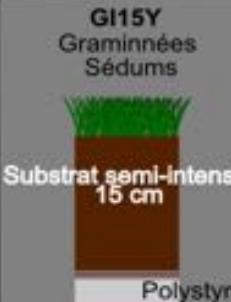
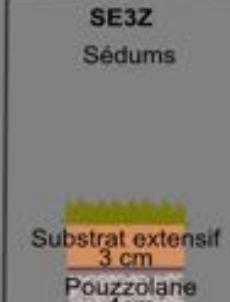
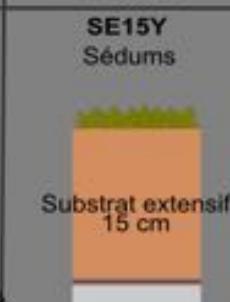
Nu	Gravier	GI15Y Graminées Sédums  Substrat semi-intensif 15 cm Polystyrene expansé 4 cm	SE3Y Sédums  Substrat extensif 3 cm	SE3Z Sédums  Substrat extensif 3 cm Pouzzolane 4cm
		NE3Y pas de végétation  Substrat extensif 3 cm	GE15Y Graminées Sédums  Substrat extensif 15 cm Polystyrène expansé 4 cm	SE15Y Sédums  Substrat extensif 15 cm



Experimental device

Measurements of :

- Rain
- Runoff
- Sol moisture content
- Temperature

Nu	Gravier	GI15Y Graminées Sédums 	SE3Y Sédums 	SE3Z Sédums 
		NE3Y pas de végétation 	GE15Y Graminées Sédums 	SE15Y Sédums 

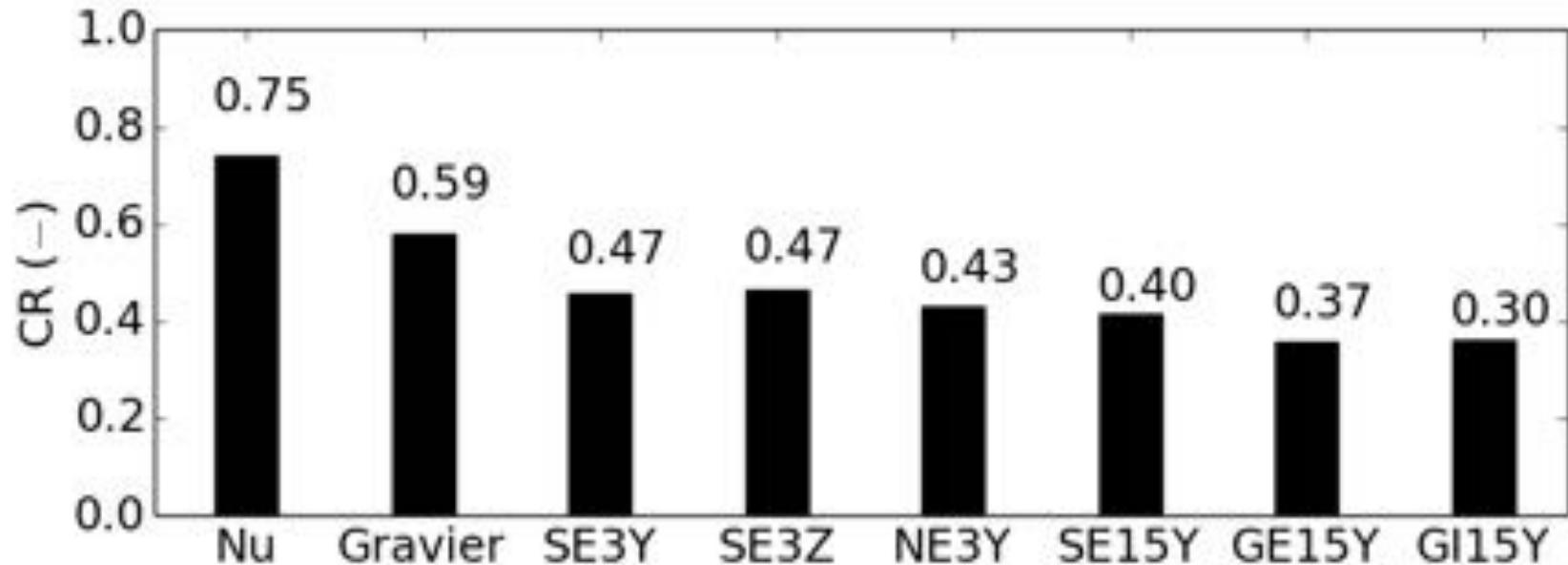


Experimental device



Results

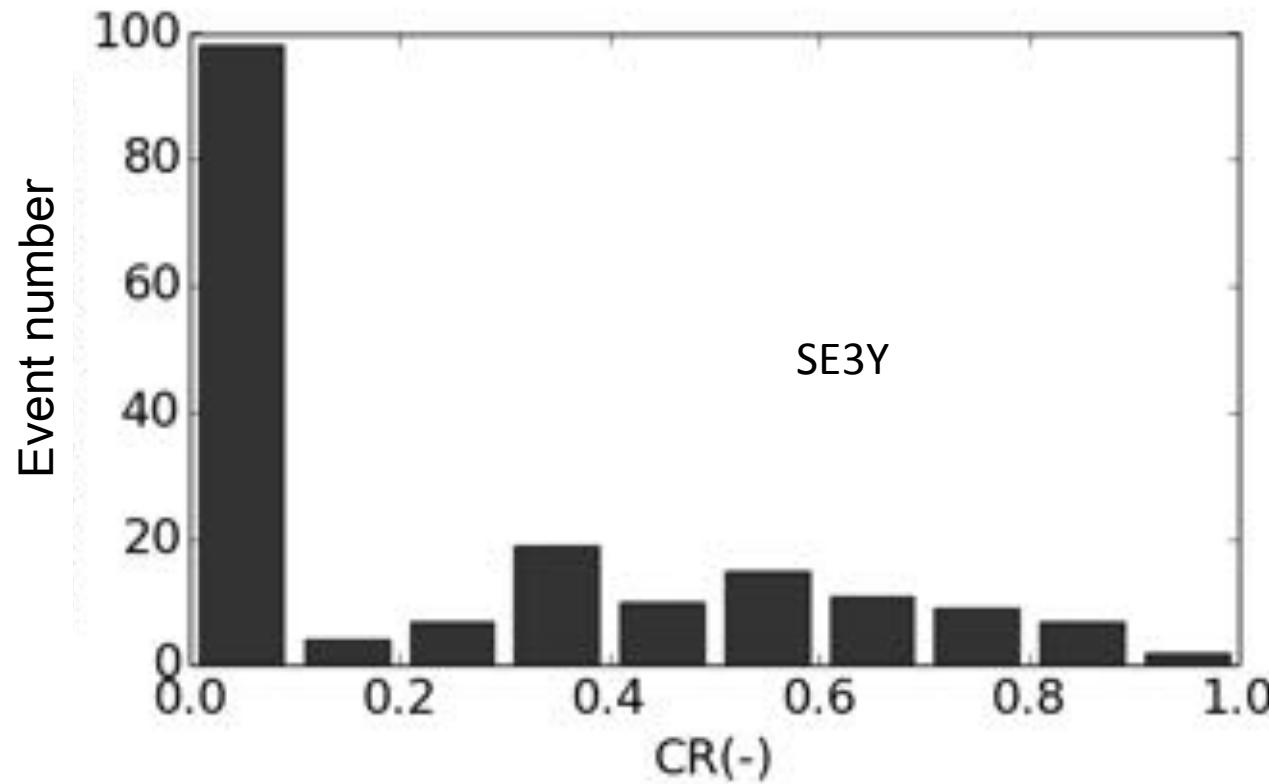
- Annual Runoff coefficient (CR) ; Rain events > à 1mm
 - 11/06/11 - 24/02/15 : Total rain amount = 2493 m, 263 events



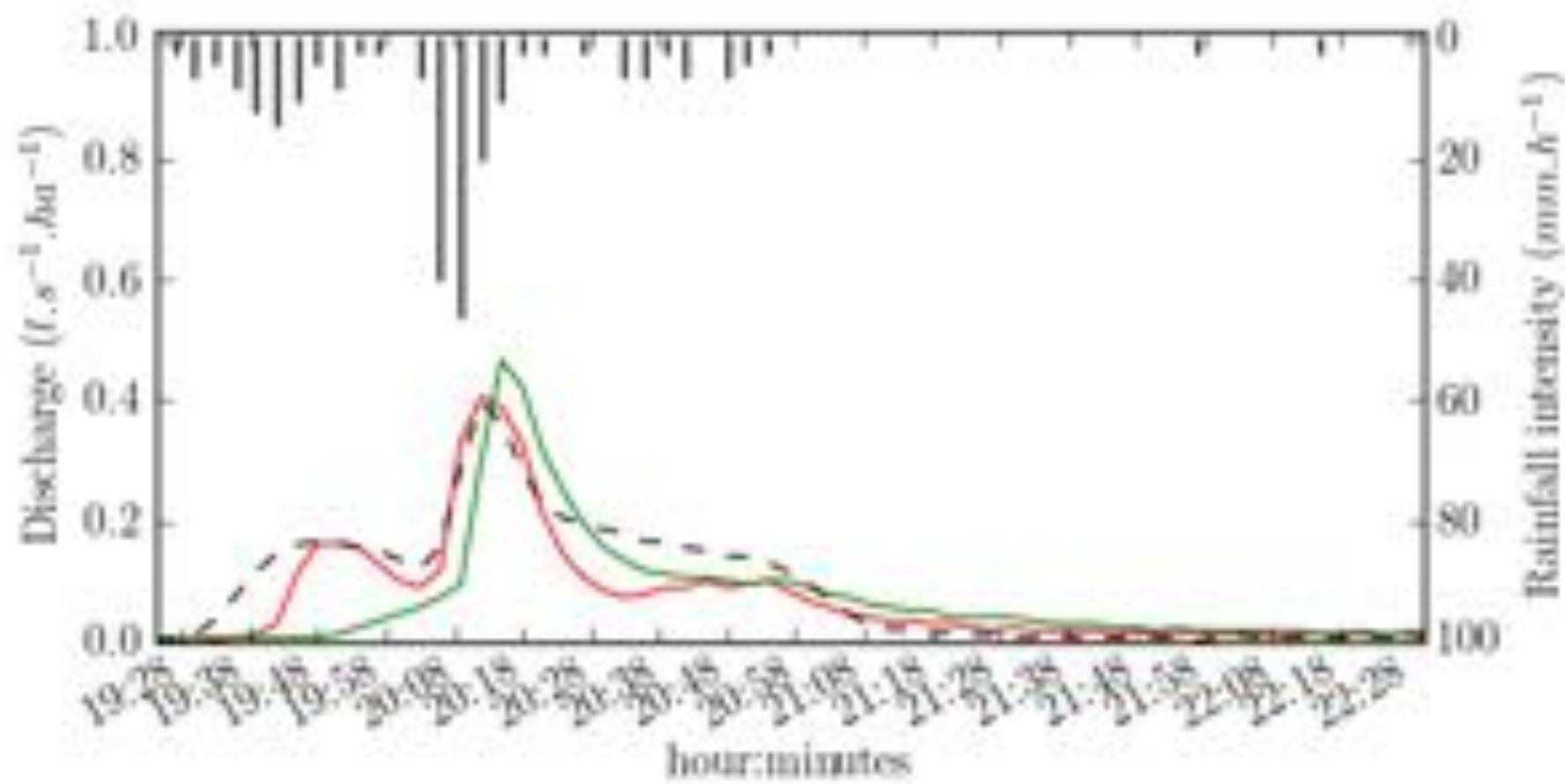
- No evolution since 2011
- Annual retention from 50 à 70 % but ...

Results

- ...strong inter-events variability



Results



To be continued...



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Potential additional sites



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