

Simulating reference rainfall scenarios for hydrological applications using a multifractal approach

Arun Ramanathan¹, Pierre-Antoine Versini¹, Daniel Schertzer¹, Ioulia Tchiguirinskaia¹,
Remi Perrin² & Lionel Sindt²

¹ *École des Ponts Paristech (ENPC), Laboratory of Hydrology Meteorology & Complexity (HM&Co)*

² *SOPREMA*

Objective and Datasets used

- Simulate rainfall scenarios specified by the storm-water discharge regulations (Paris, Nantes, Aix-en-Provence)
- Scenarios able to take into account the temporal variability during the event

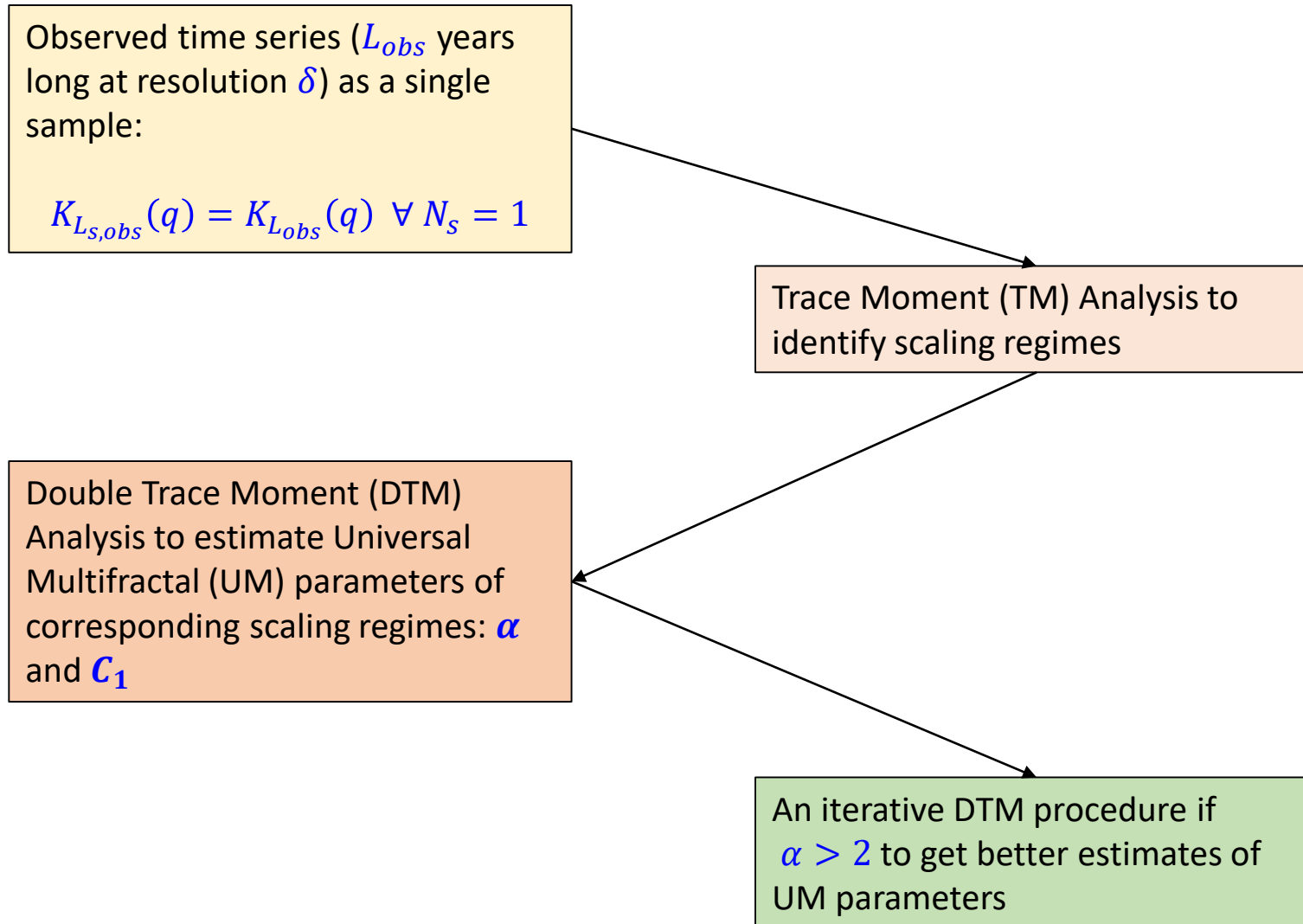
Ex: 10 scenarios (D=4 hours, P=16mm, T= 6 months) for Paris

--> Use of observed rainfall data (Météo France) and Universal MultiFractals (UM)



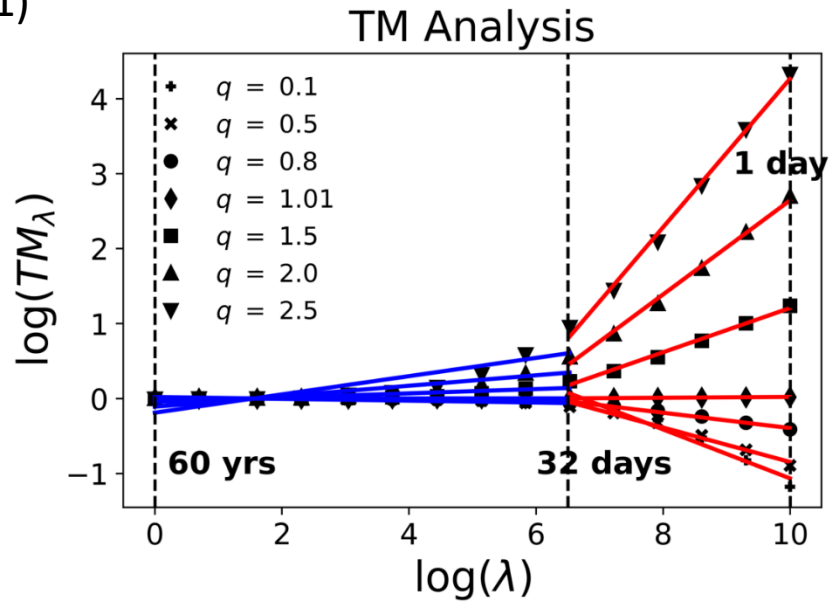
Region	Dataset (resolution)	Length L_{obs} (years)	Missing
Paris	PD1 (daily)	100 (1921 - 2020)	0 %
	PD2 (hourly)	28 (1993 - 2020)	0.3 %
	PD3 (6 minutes)	15 (2006 – 2020)	0.6 %
Nantes	ND1 (daily)	75 (1946 - 2020)	0 %
	ND2 (hourly)	28 (1986, 1994 - 2020)	0.7 %
	ND3 (6 minutes)	15 (2006 – 2020)	0.1 %
Aix	AD1 (daily)	60 (1961 - 2020)	0 %
	AD2 (hourly)	28 (1993 - 2020)	0.7 %
	AD3 (6 minutes)	15 (2006 – 2020)	0.17 %

Data analysis procedure:

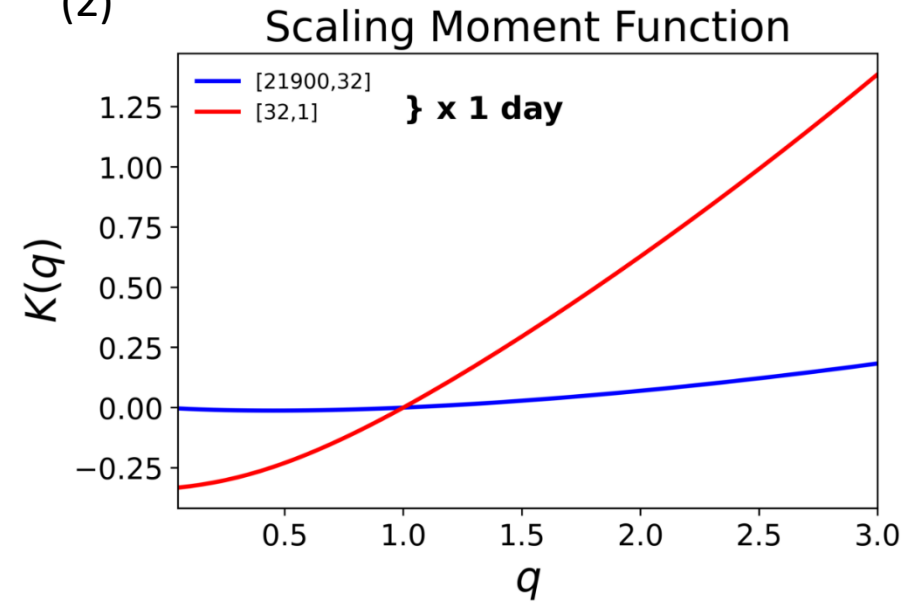


UMF Data Analysis: Aix – 60 years Daily Dataset – AD1

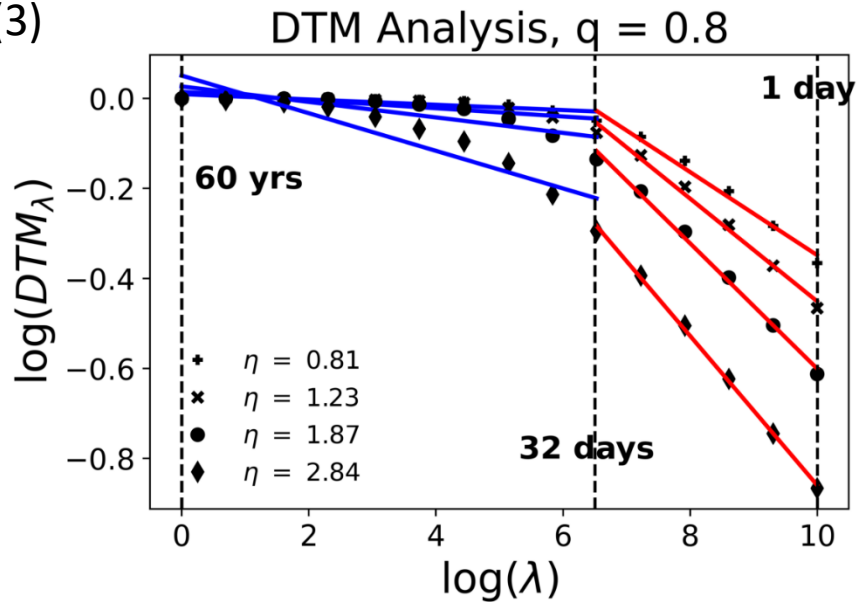
(1)



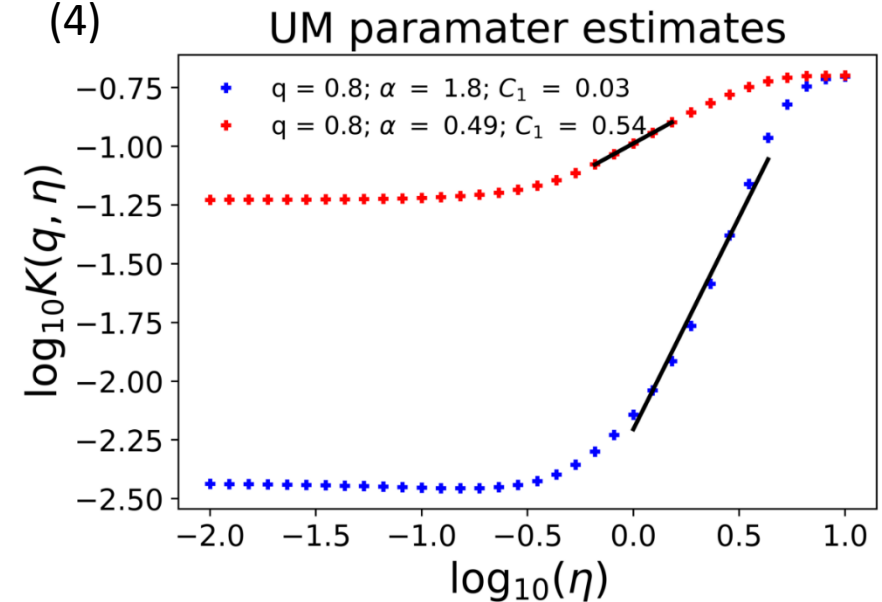
(2)



(3)

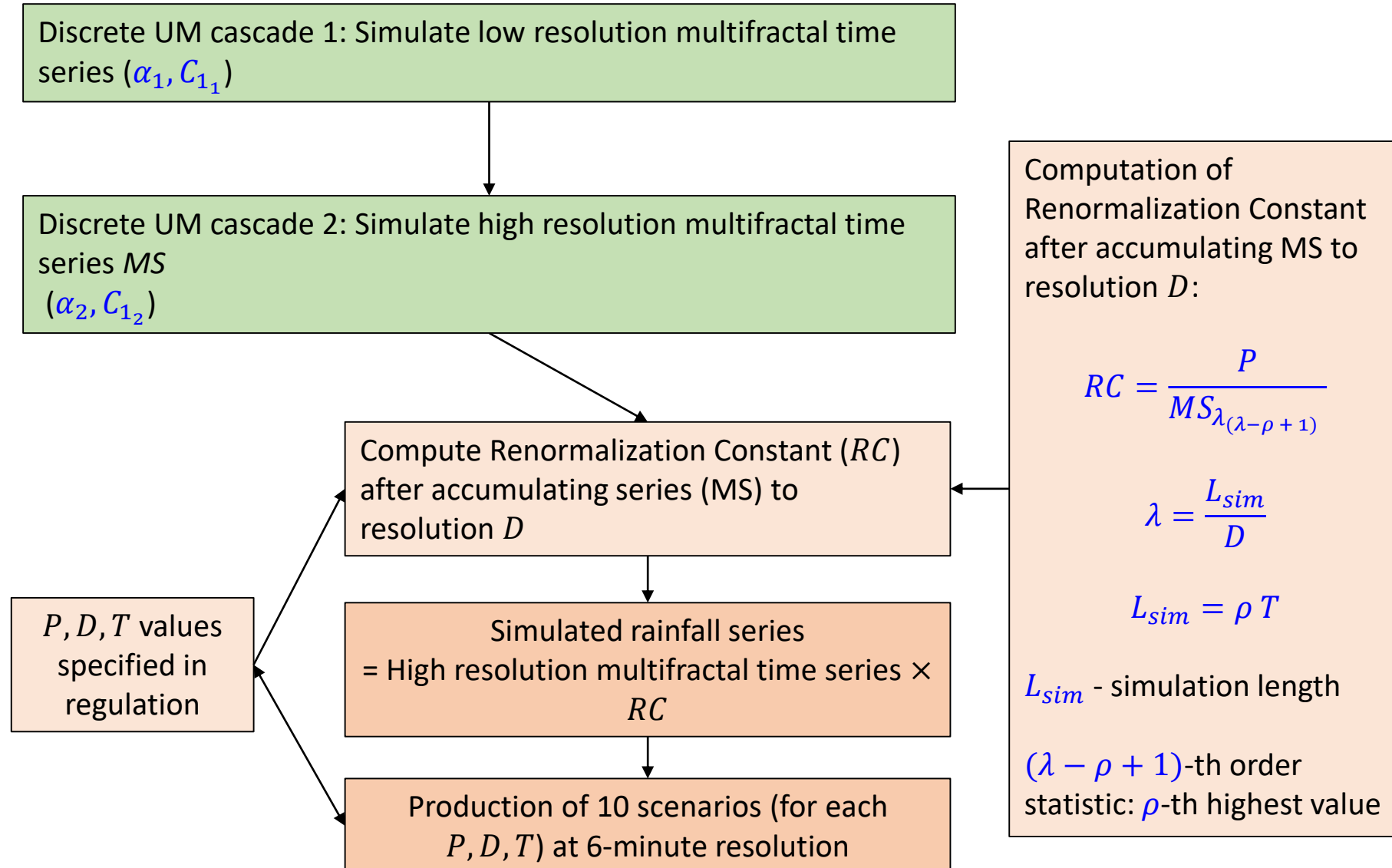


(4)

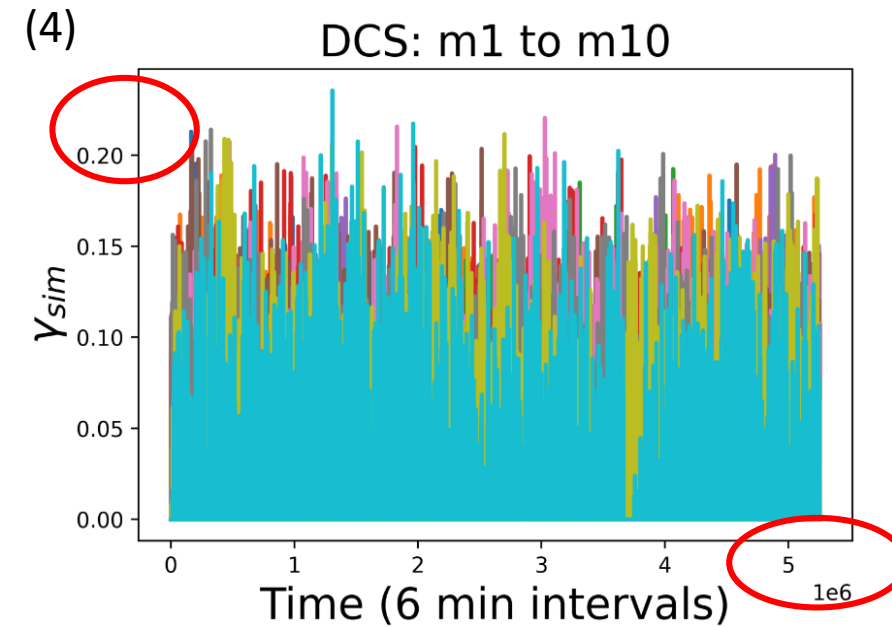
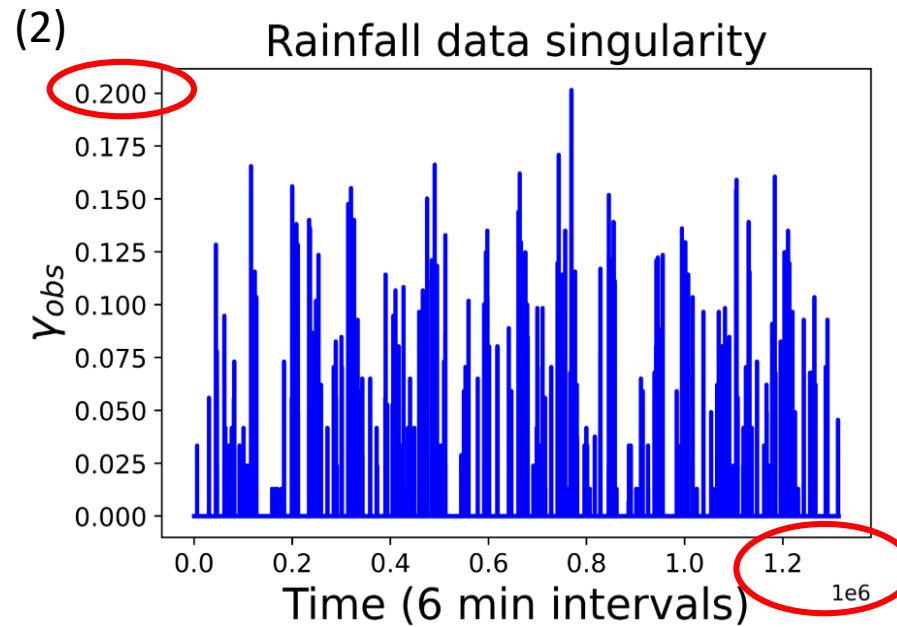
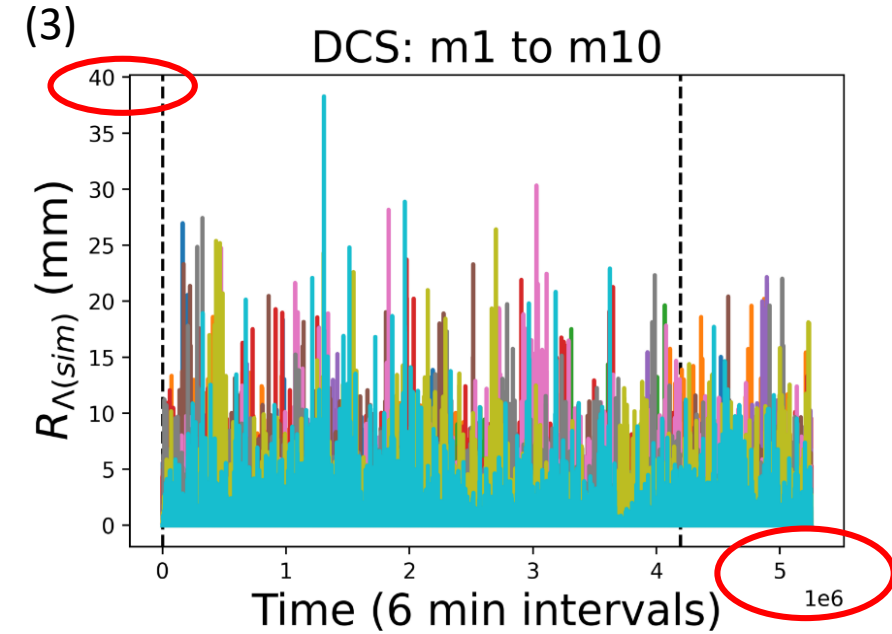
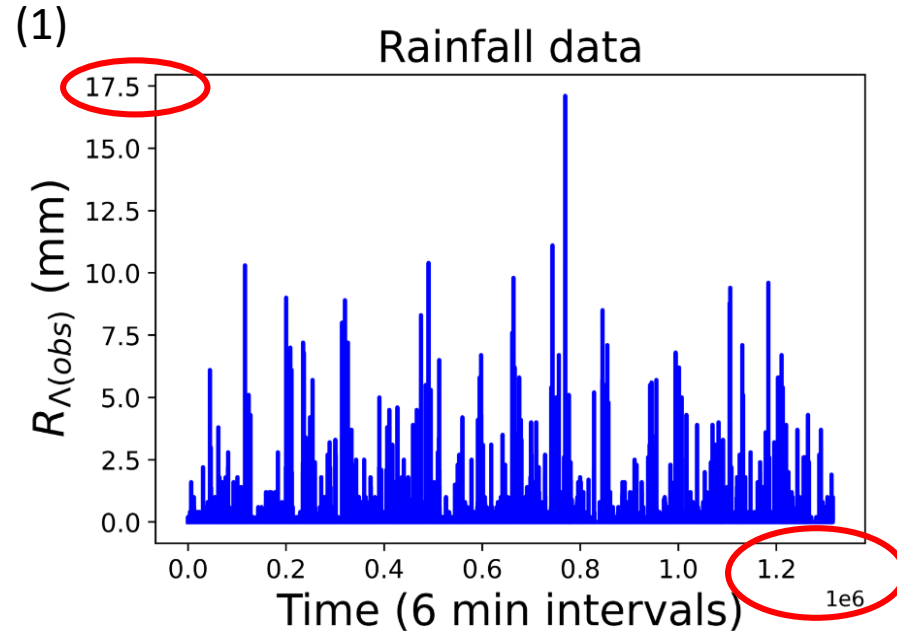


Region	Dataset	Scaling Regimes	α_1, α_2	C_{1_1}, C_{1_2}	Selected for simulations		
					Scaling Regimes	α_1, α_2	C_{1_1}, C_{1_2}
Paris	PD3	15 years - 17 days 17 days – 6 min	1.97 0.56	0.03 0.45	100 years – 21 days 21 days – 6 min	1.89 0.56	0.02 0.45
	PD2	28 years – 21 days 21 days – 1 hour	1.84 0.55	0.03 0.48			
	PD1	100 years – 32 days 32 days – 1 day	1.89 0.71	0.02 0.37			
Nantes	ND3	15 years - 17 days 17 days – 6 min	1.85 0.69	0.03 0.38	75 years – 21 days 21 days – 6 min	1.7 0.69	0.02 0.38
	ND2	28 years – 21 days 21 days – 1 hour	1.86 0.59	0.02 0.42			
	ND1	75 years – 32 days 32 days – 1 day	1.7 0.65	0.02 0.35			
Aix	AD3	15 years - 34 days 34 days – 6 min	1.79 0.51	0.04 0.48	60 years – 32 days 32 days – 6 min	1.8 0.51	0.03 0.48
	AD2	28 years – 21 days 21 days – 1 hour	1.76 0.48	0.06 0.55			
	AD1	60 years – 32 days 32 days – 1 day	1.8 0.49	0.03 0.54			

Procedure to generate possible O-E reference rainfall scenarios



Aix 0-E rainfall: 10 scenarios ($P = 100\text{ mm}$, $D = 2\text{ hrs}$, $T = 30\text{ yrs}$)



Metrics for comparing Simulations with Datasets

$$\text{MCM} = \frac{1}{6} \sum_{j=1}^3 \sum_{i=1}^2 \left| \gamma_{s,obs(j)}(i) - \frac{1}{10} \sum_{k=1}^{10} \gamma_{s,sim(k)}(i) \right|; \quad \gamma_s = \frac{C_1 \alpha}{\alpha - 1} \left(\left(\frac{1 + D_s}{C_1} \right)^{\frac{\alpha-1}{\alpha}} - \frac{1}{\alpha} \right)$$

$$\text{RCM} = \frac{1}{3} \sum_{j=1}^3 \frac{\left| \max [R_{\Lambda(obs(j))}] - \frac{1}{10} \sum_{k=1}^{10} \max [R_{\Lambda(sim(k),j)}] \right|}{\max [R_{\Lambda(obs(j))}]}; \quad \Lambda(obs(j)) = \frac{L_{obs(j)}}{\delta(j)};$$

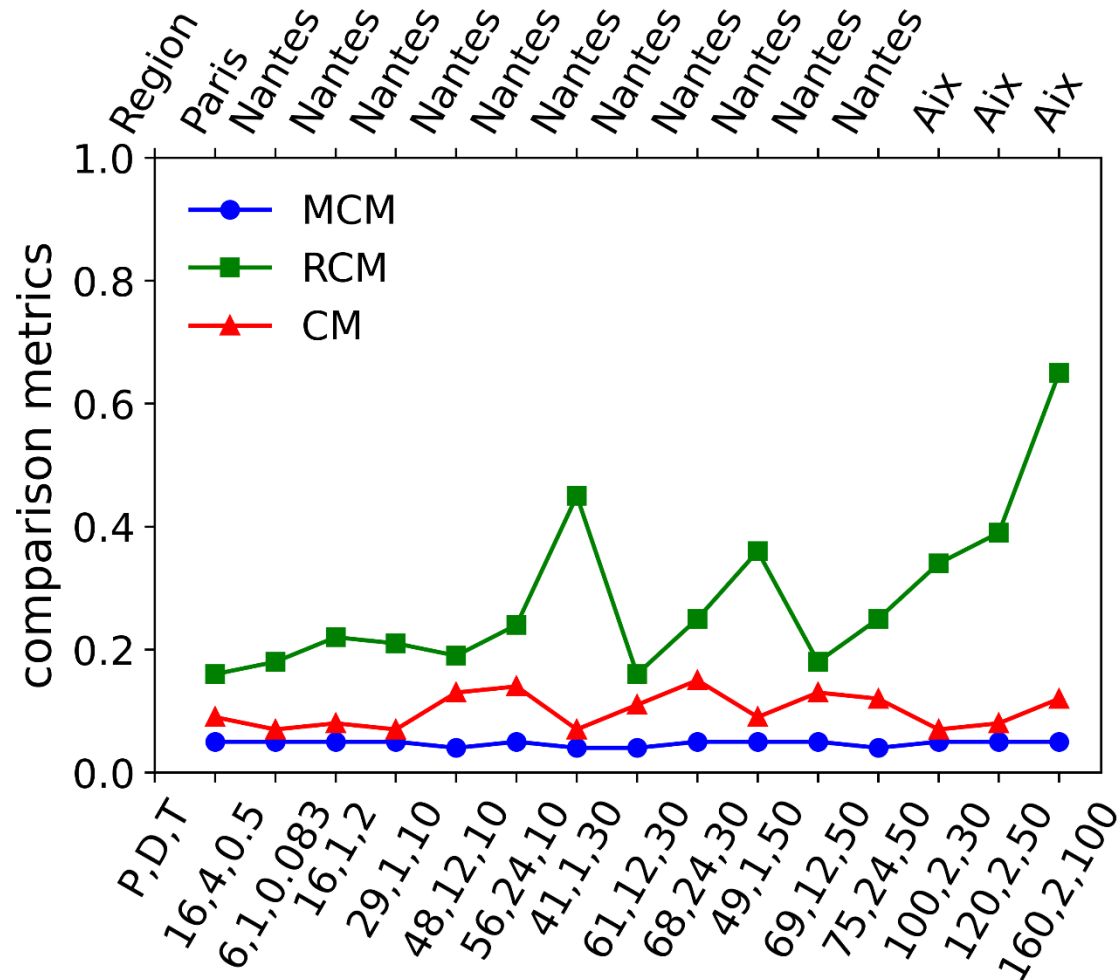
$$\Lambda(sim(k),j) = \frac{L_{sim(k)}}{\delta(j)}$$

$$\text{CM} = \frac{1}{3} \sum_{j=1}^3 \frac{\left| \max [\gamma_{\Lambda(obs(j))}] - \frac{1}{10} \sum_{k=1}^{10} \max [\gamma_{\Lambda(sim(k),j)}] \right|}{\max [\gamma_{\Lambda(obs(j))}]}; \quad \gamma_{obs(j)} = \frac{\log(R_{\Lambda(obs(j))})}{\log(\Lambda(obs(j)))};$$

$$\gamma_{\Lambda(sim(k),j)} = \frac{\log(R_{\Lambda(sim(k),j)})}{\log(\Lambda(sim(k),j))}$$

j – observational dataset, k – ensemble member, i – scaling regime

Comparison of simulations with datasets



Multifractal Comparison Metric (MCM):

- *Scale-Independent* & independent of P, D, T

Rainfall Comparison Metric (RCM):

- *Scale-dependent* (highly sensitive to scale) & dependent on P, D, T

Comparison Metric (CM):

- Dependent on P, D, T & *less sensitive to scale (although scale-dependent)*

Conclusions

- The extreme variability of P, D, T values: direct result of the extreme space-time variability of precipitation and underlying atmospheric processes --> use of UM framework.
- 2 (MCM and CM) out of the 3 comparison metrics: simulations & observations are close
- RCM behaviour: artefact of comparing different sized datasets
- Longer observational datasets could help to overcome this issue
- Future scope: generalizing approach to higher (spatial) dimensions