A two-dimensional stochastic rainfall simulator

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Context

- The Precipitations are due to complex meteorological phenomena
- Precipitations can be described as intermittent processes.
- The spatial and temporal variability of this phenomenon is significant and covers large scales

goal

- adapt a one-dimensional time series model previously developed by the authors [Akrour et al., 2015] to a two-dimensional rainfall generator.
- Simulate realistic radar rain maps.

Data

MeteoFranace meteorological RADAR:

location : Trappes near Paris
Spatial resolution : 1 km
Temporal resolution : 5 min
Area : 130 km x 130 km
Date : year 2012 (103 200 rain maps)

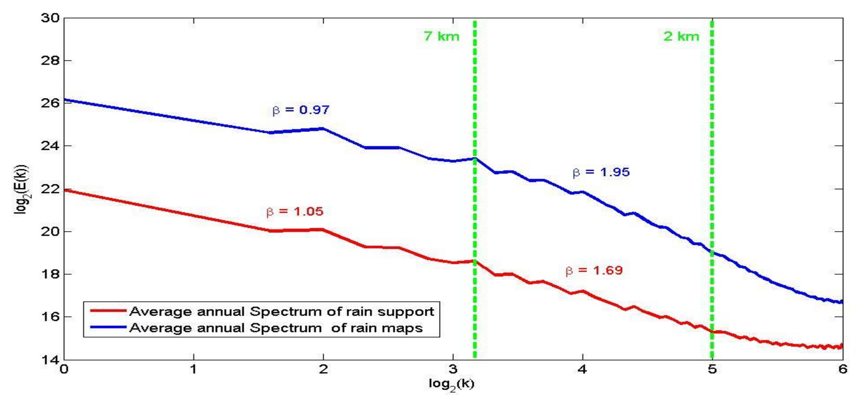


FIgure1: Average power spectrum of observed radar rain maps and the corresponding rain supports.

Methodology

- Based on sequentiel steps:

Step 1 → Simulation of rain support using SIS method

Step 2 → Simulation of rain events using FIF model

Step 3 → Rain intensity Re-normalisation

Step 4 → Transition processing

Model

1- Simulation of rain support using SIS method

Sequential Indicator simulation
Hypothesis :
- isotropic and stationary
- spherical model

Variogram parameters are estimated on observed rain maps (Figure 2) Obtained parameters.

Simulation parameters:
Range: a uniform [10, 100[
Still: c= 0.17
Nugget: $c_0 = 0$
occurrence probability :μ Uniform [0.15, 1]

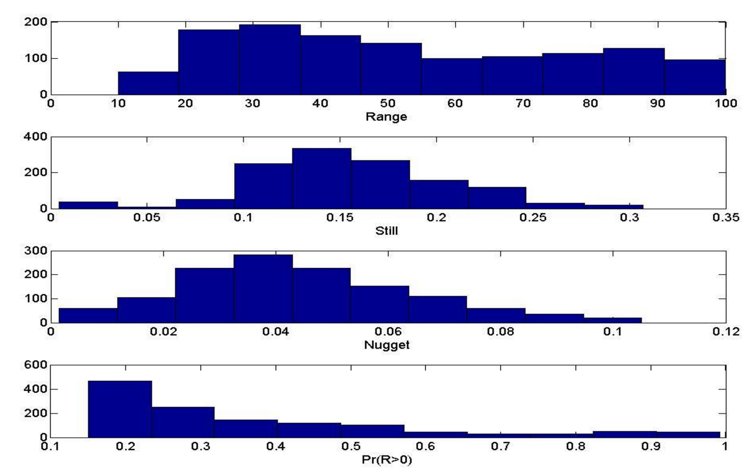


FIgure2: Histogram of parameters estimated on observed rain maps

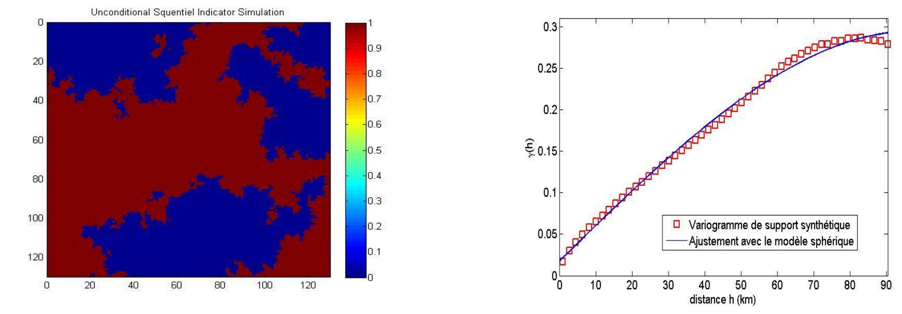
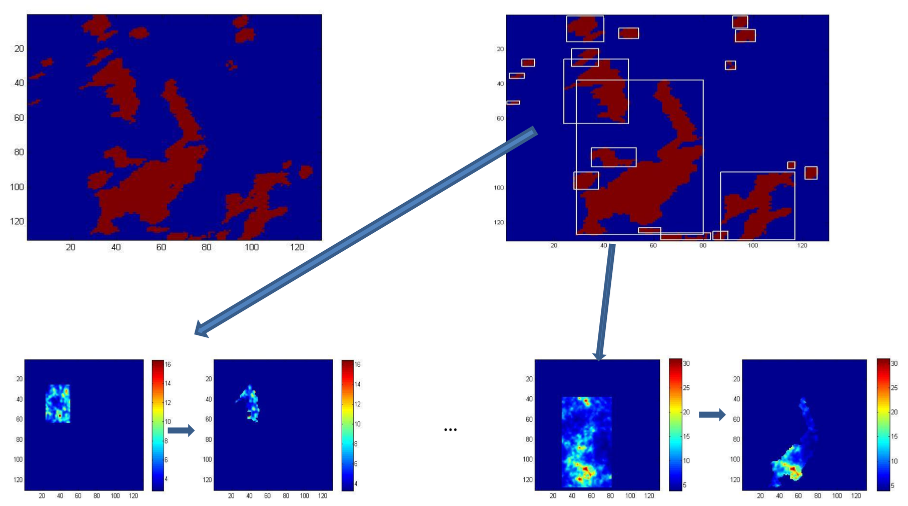


FIgure3: example of simulated rain support with parameters (μ=0.55, a=86.44, c=0.17 et c_0=0) and its variogramme

2- Simulation of rain events using multifractal model FIF

FIF (Schertzer and lovejoy, 1987)
parameters: α=1.60, C_1=0.10 et H=0.40



3- Renormalization

Following relationship is used:

$$RR = \frac{RR}{Mean(RRi)} RR_m$$

where RR_m are randomly drawn following alpha stable distribution

alpha stable distribution parameters are estimated on 330 346 observed rain events (Figure 3). Obtained parameters: α=1.18; β=1; γ=0.03 s
μ = 0,09 s +0,65
where s is the event surface

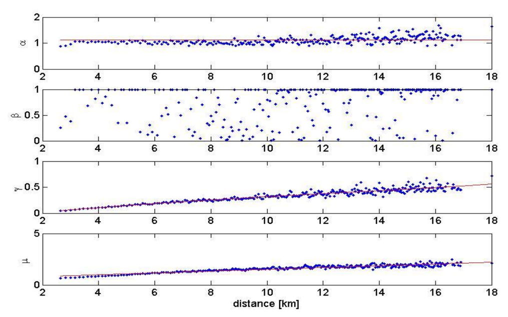


FIgure4:parameters estimated on mean rain rate knowing events surface

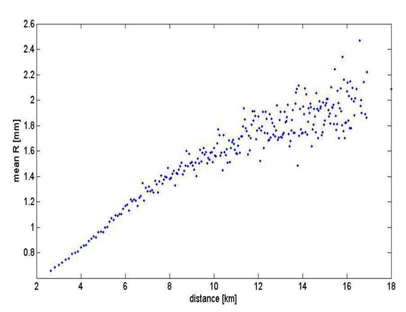
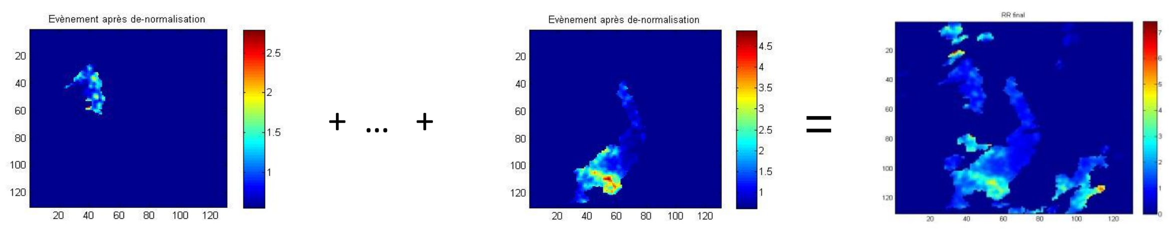
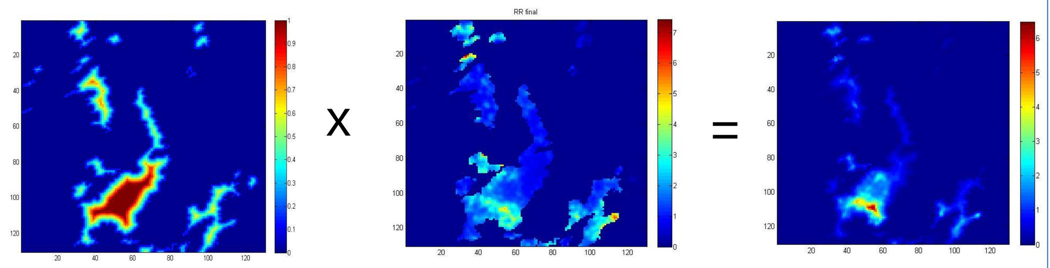


FIgure5: mean events rain rate as function of events surface



4- Transition processing

F(z)=min(||z-y||) normalized and ϵ [0,1]
z ϵ {x, I(x)=1} inspired (Shleiss et al. 2014)
y ϵ {x, I(x)=0} I(x) Rain support



Results

Comparison : one year observed rain maps / four years simulated rain maps

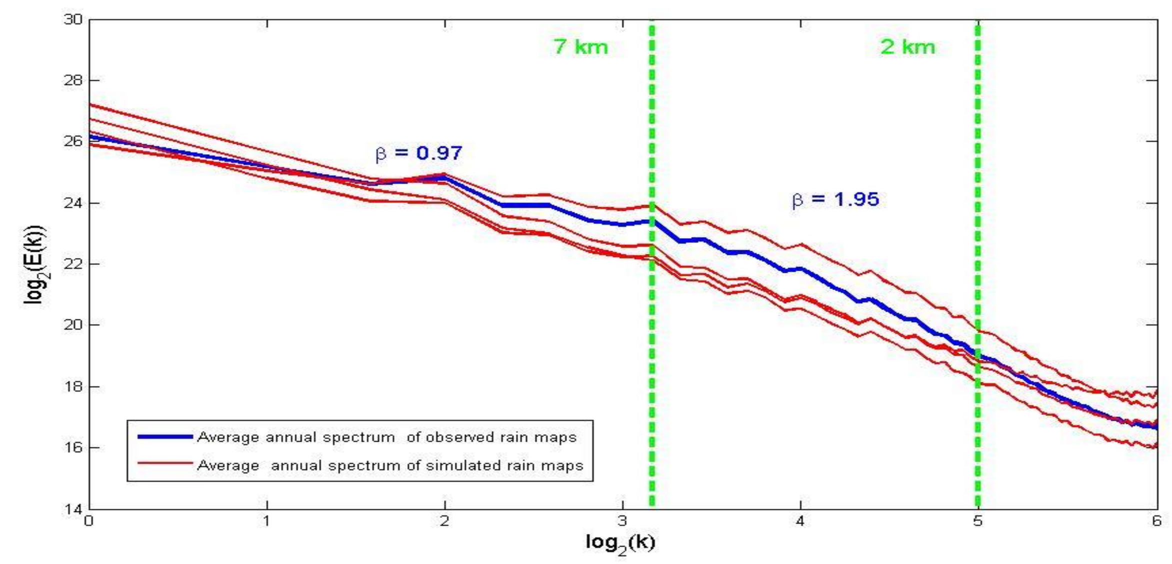


FIgure6: Average power spectrum of observed radar rain maps and 4 years simulated rain maps.

	β in the regime of scaling 2km – 7 km					β in the regime of scaling 7km – 130 km				
	Mean	std	Q1	Q2	Q3	mean	Std	Q1	Q2	Q3
Observation (2012)	1.95	0.7	1.50	1.88	2.30	0.97	0.5	0.33	0.80	1.15
simulation 1 (1 year)	1.80	0.8	1.30	1.96	2.28	0.80	0.6	0.32	0.75	1.10
Simulation 2 (1 year)	1.85	0.78	1.28	1.97	2.34	0.86	0.52	0.32	0.77	1.12
Simulation 3 (1 year)	1.93	0.8	1.41	1.90	2.31	0.94	0.6	0.33	0.77	1.13
Simulation 4 (1 year)	1.87	0.72	1.35	1.91	2.32	0.95	0.55	0.32	0.80	1.14

Table 1 : Statistical characteristic of spectrum slopes

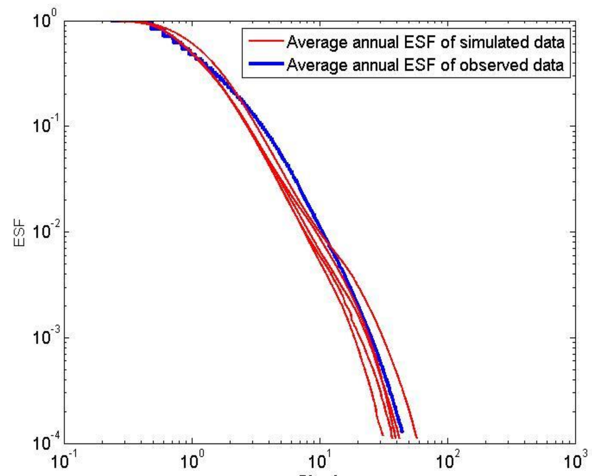


Figure7 : survival function of observed and simulated data.

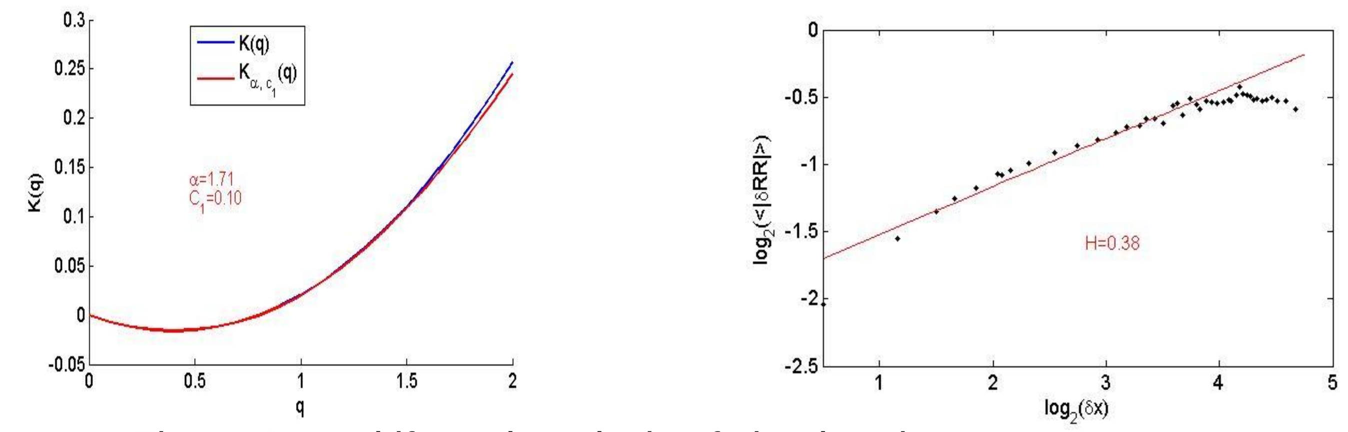


Figure 8 : multifractal analysis of simulated events.

conclusion

- generalization of the one-dimensional model (akrour and al. 2015) to a two-dimensional model.
- the simulated two-dimensional fields look realistic, they moreover have coherent statistical properties (cumulative rain rate distribution, power spectrum and structure function) with observed one.
- The proposed simulation processes is very general and can be adapted to any climatic area

references

Akrour, N., Aymeric; C., Verrier, S., Mallet, C., Barthes, L.: 2015: Simulation of yearly rainfall time series at micro-scale resolution with actual properties: intermittency, scale invariance, rainfall distribution, submitted to Water Resources Research (under revision)
Schertzer, D., S. Lovejoy, 1987: Physically based rain and cloud modeling by anisotropic, multiplicative turbulent cascades. J. Geophys. Res. 92, 9692-9714
Schleiss, M., S. Chamoun, and A. Berne (2014), Stochastic simulation of intermittent rainfall using the concept of dry drift, Water Resources Research, 50 (3), 2329–2349