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Multifractal analysis of different hydrological products of X-band radar

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Introduction

The project aimed to compare the data between X-band and C-band radar to study the impact of small-scale rainfall variability over the Bièvre catchment (in SW of Paris) which is 40km away from the radar (see I. Paz et al. X4.145 on Fri 28 Apr)^[5]. The purpose of this work is to analyse and inter-compare 5 (where was available) different products of X-band radar with pulsed emissions for simple and dual polarization.

Methodology

a. ENPC polarimetric X-band radar

- Oblate drops \rightarrow differential phase shift (Φ_{DP}) between the horizontal and vertical axis. The specific differential phase shift ($=\text{grad}\Phi_{DP}$) is used for rainfall rate computation.
- Rainfall estimations
 - Strong KDP ($> 1^\circ/\text{km}$) \rightarrow directly $R = c \left(\frac{KDP}{f}\right)^d$
 - Low KDP \rightarrow Marshall-Palmer relation $Z = aR^b$

b. Spectral analysis: the first indication of the scaling behaviour of the field

Spectral slope β calculated $E(k) \approx k^{-\beta}$, where k : wavelength

c. Universal Multifractals parameters fully define statistics across scales^[2,3,4]

- $\alpha \in [0,2]$ (multifractality index): the variability of intermittency with respect to intensity level
- C_1 (mean intermittency): mean inhomogeneity of the field at large and small scales ($C_i: 0$ for homogeneous fields)
- H : the degree of non-conservation, the scale dependency of the mean field ($H=0$ considered in our case) $\left(\left(R_\lambda^{(q)}\right)\right) \approx \lambda^{K(q,\eta)}$ $K(q,\eta) = \eta^\alpha K(q)$

C_1 and α estimated with the Double Trace Moment (DTM) technique^[1]

Values in italics correspond to a scale break at 4km, while beige background correspond to a scale break at 2km. The events E7 and E6 are long so in order to calculate the parameters we had to divide them into shorter equal events. The E7 is divided in three and the E6 in two. The first line of every product shows the values for small scales and the second for large scales.

Data

The signal of KDP is noisy so the use of a smoothed signal is used to compute KDP. Two different filters are used: the Finite Impulse Response (FIR) and the median one. The data were processed with standard Rainbow software.

Table 1: Different radar products (-SP: Simple Filter, -PS: Pseudo)

Product	Dual Polarization	Data used for products	Required parameters	Equation used	Filter
DPSRI	✓	dBZ, ZDR, KDP	a=150 b=1.3	$Z = aR^b$	FIR
DPSRI	✓	dBZ, ZDR, KDP	a=200 b=1.6	$Z = aR^b$	FIR
DPSRI-SP	✓	dBZ, ZDR, KDP	a=150 b=1.3	$Z = aR^b$	Median
DPSRI-PS	✓	dBZ, ZDR, KDP	a=150 b=1.3	$Z = aR^b$	FIR
SRI	x	dBZ	a=200 b=1.6	$Z = aR^b$	FIR

Analysis

The results of three different events are presented (E7, E6, E8) with different index of multifractality (strong, common, weak respectively)

Table 4: UM parameters for three selected events for all the radar products. In the left side there is the values of α and in the right of C_1 .

Event	Product	α			C_1		
		Small	Large	Small	Large	Small	Large
E7	DPSRI a=150 b=1.3	1.3	1.6	1.6	0.12	0.04	0.05
	DPSRI (simple) a=150 b=1.3	1.3	1.8	1.7	0.14	0.05	0.05
	PseudoDPSRI a=150 b=1.3	1.3	1.7	1.6	0.14	0.04	0.05
	DPSRI a=200 b=1.6	1.1	2.0	1.8	0.13	0.04	0.05
	SRI a=200 b=1.6	1.7	1.8	1.7	0.09	0.03	0.03
	DPSRI a=200 b=1.6	1.1	1.1	1.2	0.49	0.17	0.13
E6	DPSRI a=150 b=1.3	1.6	1.9	1.9	0.05	0.06	0.06
	DPSRI (simple) a=150 b=1.3	1.6	2.0	2.0	0.07	0.07	0.07
	PseudoDPSRI a=150 b=1.3	1.4	1.9	1.9	0.07	0.05	0.05
	DPSRI a=200 b=1.6	1.5	2.0	2.0	0.07	0.06	0.06
	SRI a=200 b=1.6	2.0	2.1	2.1	0.06	0.04	0.04
	DPSRI a=200 b=1.6	1.6	1.3	1.3	0.20	0.18	0.18
E8	DPSRI a=150 b=1.3	1.3	1.3	1.3	0.22	0.81	0.81
	DPSRI (simple) a=150 b=1.3	1.2	0.5	0.5	0.23	0.83	0.83
	PseudoDPSRI a=150 b=1.3	1.3	1.3	1.3	0.24	0.84	0.84
	DPSRI a=200 b=1.6	0.9	0.5	0.5	0.20	0.82	0.82
	SRI a=200 b=1.6	1.3	1.3	1.3	0.17	0.76	0.76
	DPSRI a=200 b=1.6	0.7	0.7	0.7	0.76	0.76	0.76

Table 2: Rainfall events and their characteristics

Event	Date	Start time (UTC)	End time (UTC)	Duration (in h)
E1	12-13/09/2015	06:05:00	18:55:00	36.83
E2	12/09/2015	06:05:00	01:15:00	20.25
E3	13/09/2015	05:45:00	18:55:00	13.17
E4	16/09/2015	00:05:00	16:50:00	16.75
E5	05-06/10/2015	09:10:00	16:05:00	30.92
E6	21-23/05/2016	12:25:00	23:50:00	59.42
E7	28-31/05/2016	08:25:00	00:00:00	87.58
E8	17/06/2016	00:00:00	21:15:00	21.25

Table 3: Figures of cumulative rainfall of the selected events as it is presented in the report for Veolia^[6]

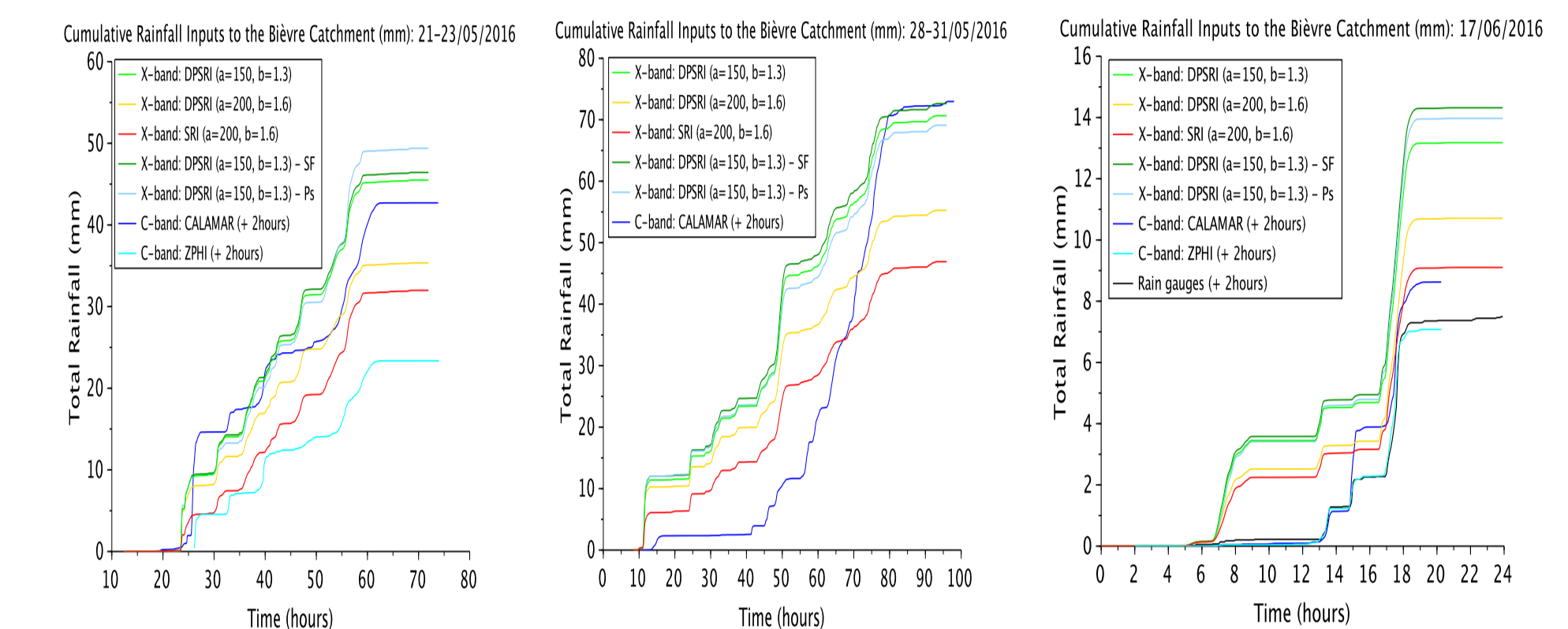
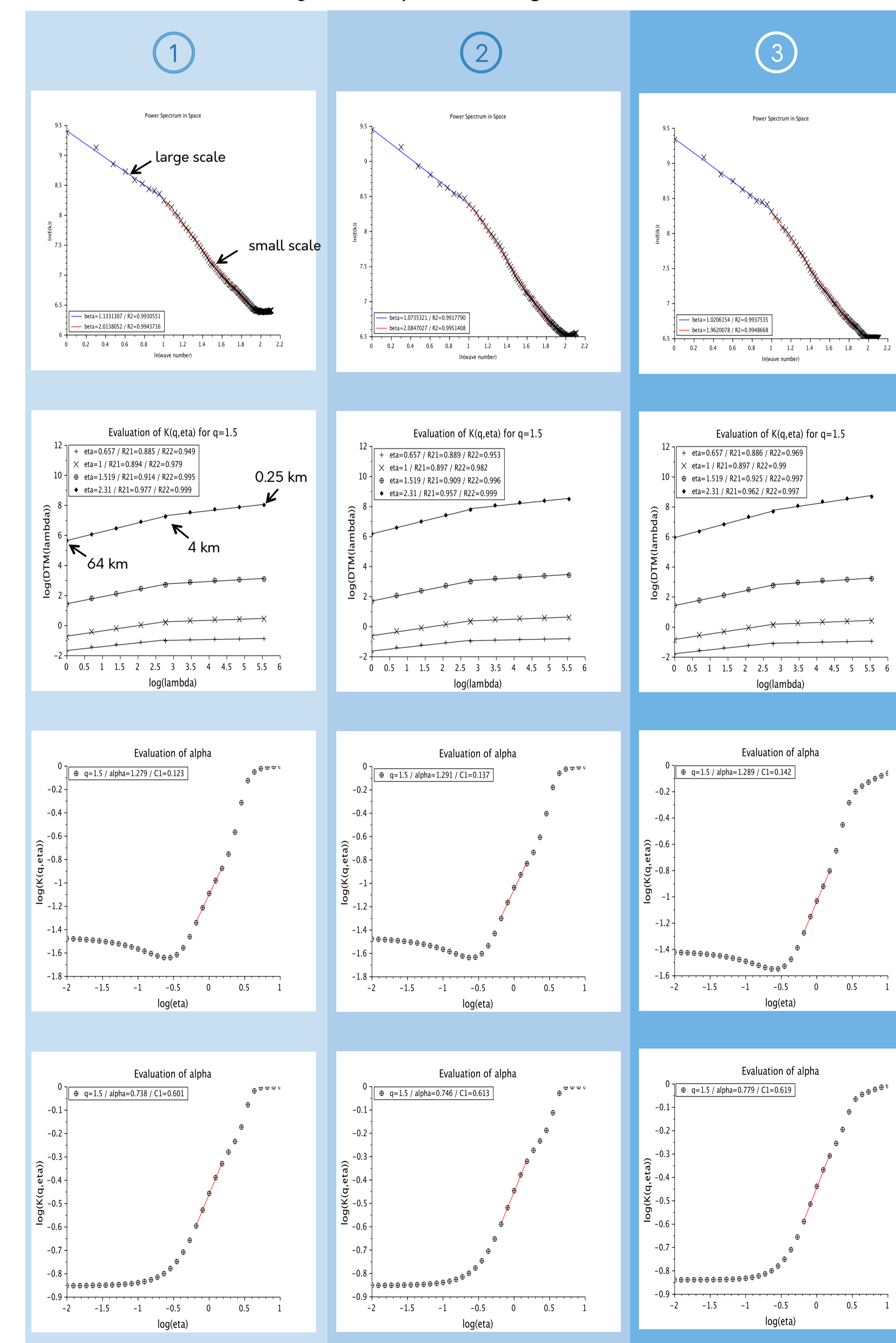


Table 5: Figures of spectral analysis and DTM method



- DPSRI a=150 b=1.3 28-31/05/2016 (1P)
- DPSRI a=150 b=1.3 simple filter 28-31/05/2016 (1P)
- PsDPSRI a=150 b=1.3 28-31/05/2016 (1P)

Conclusions

- With the X-band radar, a scale break can be seen in 2km. It means that small scale behaviour is not accessible with C-band radars
- The scale break is less pronounced for some events (i.e. 28-31/05/2016)
- SRI seems to produce data with higher homogeneity
- α stronger for SRI and DPSRI a=200 b=1.6

Future work

- Analysing more events of lower and higher intensity
- Comparing with other types of radar data and with rain gauge measurements
- Use them in urban hydrological models (Multi Hydro) to find out which filter is better to use

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