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# Improving Universal Multifractal parameter estimation for large data sets, a case study in the Greater Paris

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## Introduction

Precipitation is a highly complex and variable phenomenon. The purpose of this work is to analyse, and inter-compare 5 different products of X-band radar with pulsed emissions for simple and dual polarization, using the Universal Multifractal analysis.

## Methodology

### a. ENPC polarimetric X-band radar

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

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

$E(k) \approx k^{-\beta}$ , where  $\beta$ : spectral slope calculated  $k$ : 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 ( $C_i$ : 0 for homogeneous fields)
- $H$ : the degree of non-conservation, the scale dependency of the mean field ( $H=0$  considered in our case)

$C_1$  and  $\alpha$  estimated with the **Trace Moment (TM)**

$$K(q) = \begin{cases} \frac{C_1}{\alpha-1} (q^\alpha - q), & \alpha \neq 1 \\ C_1 q \log(q), & \alpha = 1 \end{cases}$$

$$C_1 = \frac{dK(q)}{dq} \Big|_{q=1} \quad C_1 \alpha = \frac{d^2 K(q)}{dq^2} \Big|_{q=1}$$

- and with the (uni/mono) fractal correction [5]

$$K^*(q) = K(q) + c(q-1) \quad C_1^* = \frac{dK^*(q)}{dq} \Big|_{q=1} = C_1 + c \quad C_1^* \alpha^* = \frac{d^2 K^*(q)}{dq^2} \Big|_{q=1} = C_1 \alpha$$

- and **Double Trace Moment (DTM)** technique [1]

$$\langle (R_\lambda^{(n)})^q \rangle \approx \lambda^{K(q,n)} \quad K(q,\eta) = \eta^\alpha K(q)$$

## Data

Table 1: The five radar products compared in this study (-SP: Simple Filter, -PS: Pseudo, TFL: Terrain Following Layer)

| Product     | Dual Polarization | Data used for products | Required parameters | Equation used | Filter | Data considered for TFL below/above lowest/highest elevation |
|-------------|-------------------|------------------------|---------------------|---------------|--------|--|
| DPSRI_150_s | ✓                 | dBZ, $K_{DP}$          | $a=150$ $b=1.3$     | $Z=aR^b$      | FIR    | no data  |
| DPSRI_200_s | ✓                 | dBZ, $K_{DP}$          | $a=200$ $b=1.6$     | $Z=aR^b$      | FIR    | no data  |
| DPSRI_SP    | ✓                 | dBZ, $K_{DP}$          | $a=150$ $b=1.3$     | $Z=aR^b$      | Median | no data  |
| DPSRI_PS    | ✓                 | dBZ, $K_{DP}$          | $a=150$ $b=1.3$     | $Z=aR^b$      | FIR    | Data of lowest/highest elevation used                        |
| SRI         | ✗                 | dBZ                    | $a=200$ $b=1.6$     | $Z=aR^b$      |        | no 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 2: Rainfall events and their characteristics

| Event | Date          | Start time (UTC) | End time (UTC) | Duration (in h) | Time steps |
|-------|---------------|------------------|----------------|-----------------|------------|
| E1    | 21-23/05/2016 | 12:25:00         | 23:50:00       | 59.42           | 1264       |
| E2    | 28-31/05/2016 | 08:25:00         | 00:00:00       | 87.58           | 1686       |
| E3    | 17/06/2016    | 00:00:00         | 21:15:00       | 21.25           | 422        |

## Analysis

The values of UM parameters of event 28-31/05/2016 for TM and TM corrected are presented:

Table 4: Values of UM parameters for TM and TM corrected

| Radar Products | $\alpha^*$ | $\alpha$ | $C_1^*$ | $C_1$ | $c$  |
|----------------|------------|----------|---------|-------|------|
| DPSRI_150_s    | 1.443      | 4.016    | 0.047   | 0.017 | 0.03 |
| DPSRI_150_l    | 0.861      | 2.146    | 0.278   | 0.112 | 0.17 |
| DPSRI_200_s    | 1.854      | 4.85     | 0.049   | 0.019 | 0.03 |
| DPSRI_200_l    | 1.137      | 2.735    | 0.278   | 0.116 | 0.16 |
| DPSRI_SF_s     | 1.743      | 4.20     | 0.051   | 0.021 | 0.03 |
| DPSRI_SF_l     | 1.743      | 2.244    | 0.288   | 0.121 | 0.17 |
| DPSRI_PS_s     | 1.545      | 4.20     | 0.047   | 0.017 | 0.03 |
| DPSRI_PS_l     | 0.952      | 2.053    | 0.277   | 0.129 | 0.15 |
| SRI_s          | 1.296      | 5.715    | 0.039   | 0.009 | 0.03 |
| SRI_l          | 0.812      | 2.178    | 0.226   | 0.084 | 0.14 |

For every simulation the following figures are obtained (in red: small and in blue: large scales):

Table 6: TM analysis and  $K(q)$  for small (in red) and large (in blue) scales

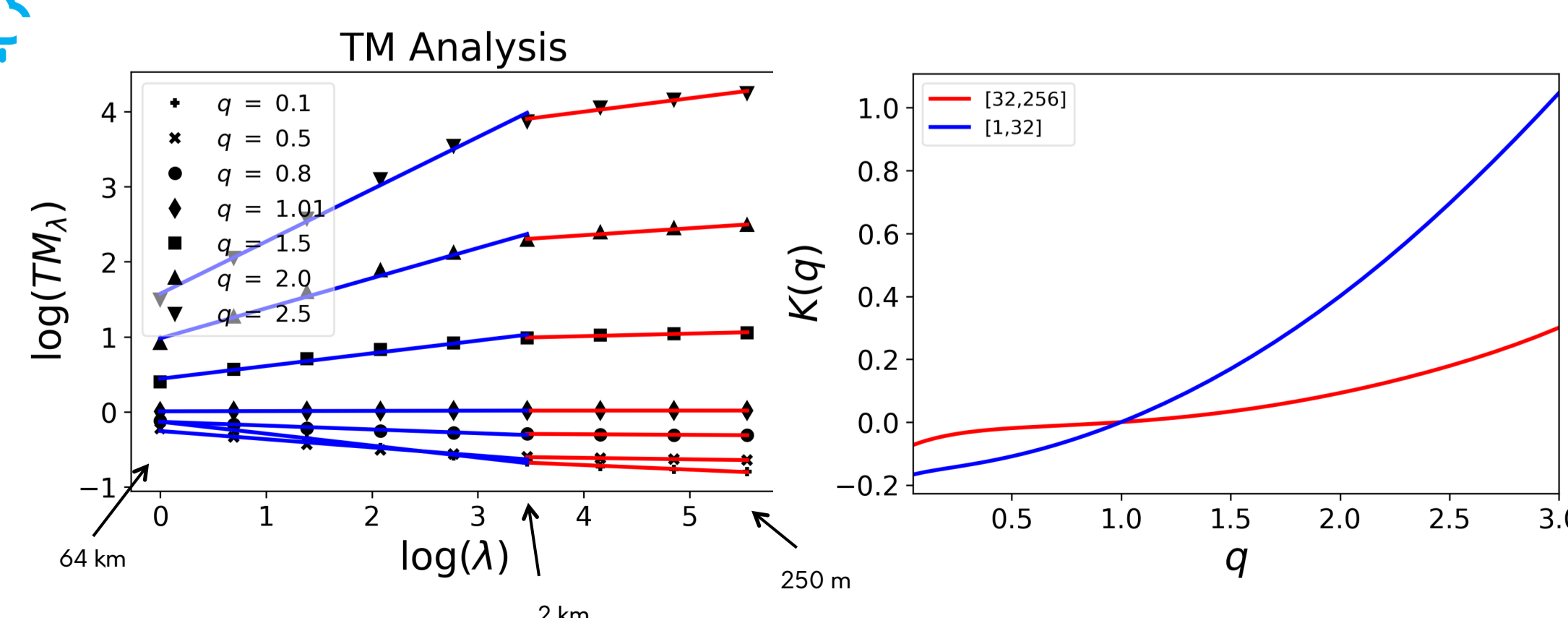
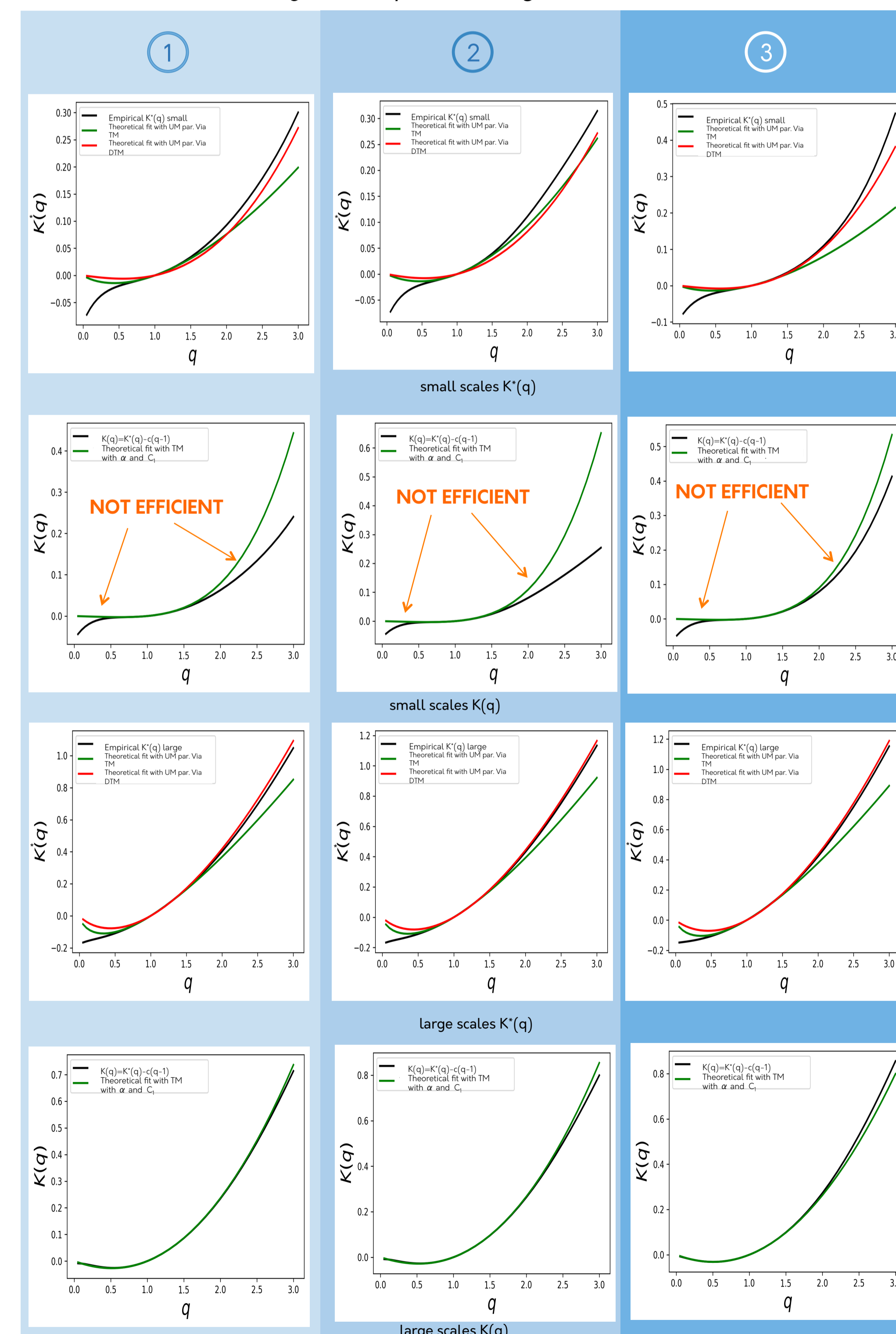
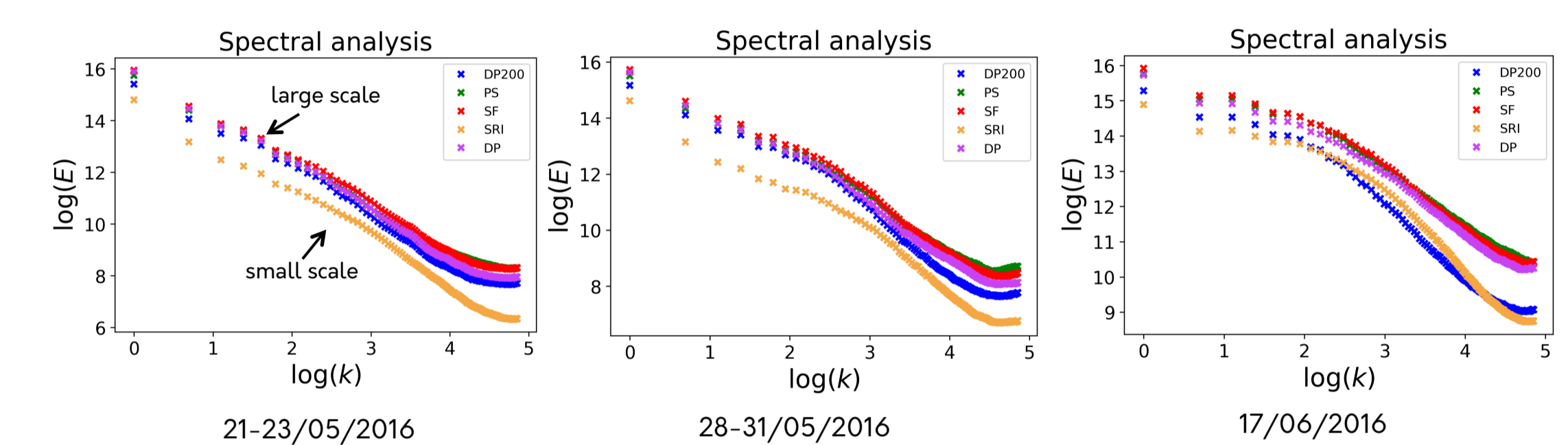


Table 5: Figures of spectral analysis and DTM method



- 1 DPSRI  $a=150$   $b=1.3$  28-31/05/2016
- 2 DPSRI  $a=150$   $b=1.3$  simple filter 28-31/05/2016
- 3 PsDPSRI  $a=150$   $b=1.3$  28-31/05/2016

Table 3: Figures of spectral analysis of the selected events



## Conclusions

- The correction does not work for small scales (difficulty in estimating  $c$ )
- Efficient for large scales (but strong values for  $\alpha$ )

## Future work

- Test it for events of 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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