Hydrol. Earth Syst. Sci. Discuss., 10, C8497–C8503, 2014
www.hydrol-earth-syst-sci-discuss.net/10/C8497/2014/

Hydrology and Earth System Sciences
Open Access
Discussions

HESSD
10, C8497–C8503, 2014

Interactive Comment

Interactive comment on "Imperfect scaling in distributions of radar-derived rainfall fields" *by* M. J. van den Berg et al.

M. J. van den Berg et al.

martinus.vandenberg@ugent.be

Received and published: 25 July 2014

[]article

We thank both referees for the helpful comments, and would like to apologise for the unfortunate delay due to health issues. Below we reply to all points raised by the referees. Prior to that, we would like to adress an issue which was left untouched in the previous version. The correlations found in the previous study are, in part, due to the presence of zeros in coarse graining. Indeed, we found that after compensating for this effect, the correlations were no longer negative and decreasing with scale, but rather the opposite, they were positive and increased with scale (up to a point). To analyze this, we changed a few key points

Full Screen / Esc
Printer-friendly Version
Interactive Discussion
Discussion Paper

in the analysis, namely:

- **We only average over active pixels, i.e. non-raining pixels are removed prior to averaging.**
- **We use partial correlations to remove the effects of zeros.**
- **Only pixels with less than 10% non-raining pixels at the osberved scale are used.**
- **Finally, because these analysis require much data, we used a sliding box coarse graining rather than the usual disjoint coarse graining.**

This updated analysis resulted in strongly changed results, with a different behavior of the correlation function and shape parameters. As a result, the paper and its conclusions have changed, although we attempted to stay as close to the previous version as possible while maintaining a clear and easy to read manuscript. The updated manuscript has been attached.

General Comment #1 In the Introduction, the authors provide a literature review on multifractal rainfall scaling. Except for the technical part associated with the construction of discrete multiplicative processes, it would be useful if the authors could point to the large number of studies showing that rainfall fields follow a more general scale invariance condition (than simple scaling) known as stochastic self similarity or multifractality; see e.g. Tessier et al. (1993), Perica and Foufoula-Georgiou (1996a,b), Harris et al. (1996), Olsson (1998), Deidda et al. (1999, 2004, 2006), GuÌĹtner et al. (2001), Ahrens (2003), Nykanen and Harris (2003), Gebremichael et al. (2004, 2006), Veneziano and Langousis (2005a), Veneziano et al. (2006a, 2007, 2009), Langousis and Veneziano (2007), Langousis et al. (2009, 2013), Veneziano and Lepore (2012), Langousis and Kaleris (2013), Veneziano and Yoon (2013), and the reviews in Veneziano et al. (2006b) and Veneziano and Langousis (2010).

HESSD
10, C8497–C8503, 2014

We updated this section to include more of the body of literature. Moreover, we removed some of the technical introduction and included a more thorough technical discussion of multifractals (section 2).

General Comment #2 In the Concluding section, the authors should discuss more their findings and relate them to observed deviations of rainfall from exact multifractal scaling, such as breaks in the power-law behavior of the spectral density (Fraedrich and Larnder, 1993; Olsson, 1995; Menabde et al., 1997), lack of scaling of the non-rainy intervals (Schmitt et al., 1998; Olsson, 1998; GuÌĹntner et al., 2001; Veneziano et al., 2006a; Langousis and Veneziano, 2007), differences in scaling during the intense and moderate phases of rainstorms (Venugopal et al. 2006), the power deficit at high-frequencies relative to multifractal models (Perica and Foufoula-Georgiou, 1996a,b; Menabde et al., 1997; Menabde and Sivapalan, 2000), and dependencies of the multiplicative weights on the scale of spatial averaging and the large scale rainfall intensity (e.g. Veneziano et al., 2006a; Rupp et al., 2009, and Serinaldi, 2010).

We improved the conclusions and attempt to link back to previous studies

General Comment #3 (technical soundness) One concern is the transformation in equation (5). Note that the resulting field (referred to as "conservative") is not scaling. The case is similar to the results obtained when using the gradient amplitude method, where the transformed field scales in a multifractal way independently from the scaling of the original field (see e.g. Veneziano and Iacobellis, 1999; Veneziano and Langousis, 2010; Neuman 2010a,b; 2012; Guadagnini and Neuman, 2011). It is my understanding that the authors use the transformation in equation (5) solely for illustration purposes, and perform their scaling analysis using the original rainfall fields. If this is the case, I suggest that the authors remove this part of the analysis and associated Figures. In case the scaling analysis has been conducted using the transformed (i.e. "conservative") fields, the authors are advised to change their approach and apply the scaling analysis to the original rainfall fields. Another concern is the issue of zero rainfall. It is not clear to me how equation (11) applies in the case when Rk+1 = 0. I *suggest that the authors provide a brief explanation.*

In the previous version we used the Laplacian of the fields rather than the direct version. This was done because of the natural assumption of independence for the increments. However, the concerns raised by the referee are valid and we repeated the analysis on the untransformed fields and modified the paper to reflect the new findings.

General Comment #4 (page 11394, lines 1-20) While necessary, the log-log linear dependence of different moment orders on the scale of spatial averaging is not a sufficient condition for multifractal scale invariance; i.e. simple scaling is also associated with log-log linear plots. To study the type of rainfall scaling (i.e. simple or multifractal), the authors should specify the particular form of the moment scaling function K(q); see e.g. Veneziano and Langousis (2005a), Veneziano et al. (2006b), Langousis and Veneziano (2007), and the review in Veneziano and Langousis (2010). The authors are encouraged to further investigate the multifractal character of the rainfall signal, by extending their analysis to include calculation of the moment scaling function. Please note that for logstable cascade generators, the moment scaling function receives a specific form; see e.g. Veneziano and Furcolo (1999).

We expanded the investigation of the scaling behavior to include a direct fit of $K(q)$. This new analysis can be found in section 3.2.

Specific Comment #1 (page 11388, line 25) Detailed analyses on the statistical properties of the dressing factor for discrete multifractal cascades, have been conducted by Veneziano and Furcolo (2003), Veneziano and Langousis ï£ij (2005b), Langousis and Veneziano (2007) and Langousis et al. (2009). The first study developed a numerical procedure to obtain the exact distribution of the dressing factor for discrete multifractal measures, while the other studies devised approximations for hydrological applications; see the reviews in Veneziano et al. (2006b) and Veneziano and Langousis (2010).

Specific Comment #2 (page 11392, line 09) Several studies have tried to link the max-

imum scale up to which multifractal scale invariance holds, to the characteristics (i.e. spatial extent and lifetime) of rainstorms; see e.g. Veneziano and Langousis (2005a), Langousis and Veneziano (2007), and Langousis and Kaleris (2013).

Specific Comment #3 (equation 11) Please note the typo in the subscripts of equation (11). **This has been fixed.**

Specific Comment #3 (Figures 10-17) Figures 10-17 are not easy to understand. The authors should provide a more comprehensive discussion of their findings; see also General Comment #2.

More explanation has been added and the figures have been updated (see also our general comments)

The range of scales that are used in the multifractal analysis is quite small, 0.6 km to 9.6 km, and the analysis is based on a single image. I expected to see an analysis that was based on the entire data set, all 17 storms, and over a larger area under the radar. Multifractal analyses require large data sets so as to demonstrate that onaverage the fields have a multifractal behaviour. A 200 km domain under the radar is entirely reasonable in the summer months and an extra couple of points in the scaling analysis would add credibility to the analysis.

We extended the scale with a few more cascade levels and increased the range under the radar. We did find that the inner 60 km produces strange results and is often corrupted with large amounts of speckle, and therefore removed it.

I also missed seeing a power spectrum for the untransformed rainfall fields that is based on the entire data set. The scaling break that is observed in rainfall is typically around 20-30 km in my experience, eg Seed et al 2013, Water Resources Research, 49. The slope of the power spectrum is an important diagnostic in deciding the nature of the scaling and some comments on the implications of the value that is found would be useful. Rainfall is a physical process that has absolute zeroes in the field, there are *times when it simply is not raining irrespective of the sensitivity of the radar, and the rain-no rain process is the likely cause of the scaling break, not the sensitivity of the radar or thresholds.*

We added an analysis of the power spectra for all storms, and found that the scaling regime changes between summer and winter storms (the breaks and slopes change), see section 3.1 and associated figures. Furthermore, we added some discussion of the results in the same section. Furthermore, we linked this with the results of multiaffine analysis, i.e. the coefficient H to corroborate these findings.

The paper makes the reasonable assumption that the increments in the transformed cascade follow the Levy stable probability distribution, but no evidence is presented that this is actually the case. An analysis based on the entire data set for each of the cascade levels would add value to the paper.

This assumption was graphically investigated (see section 5 and figures 12 and 13) and it was shown that, up to some minor deviations, this approximation was solid.

I found that the notation that is used for the probability distributions is unnecessarily complex (Equations 7-10) and the paper would be easier to read if it was simplified. The captions for the figures are very informal and do not provide adequate information about the figure.

We improved both these equations and the captions.

The questions that are posed in Section 1 are not very clear and the conclusion does not reference them. The two questions in my mind are: 1 Are the increments in the cascade IID? The answer to this is that they are not IID and there are dependencies with the scales above and the distribution parameters change with scale. This is a big deal since the fields were transformed using the Laplacian so as to render them

HESSD
10, C8497–C8503, 2014

Interactive Comment

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

conservative, IID in other words, so a comment about the implications of this finding is required. The alternative is to use a multiaffine frame work and use the rainfall fieldsdirectly. 2. If not IID, what is the nature of the dependence? The paper provides a nice framework and analysis for this question.

We changed these questions and no longer use the Laplacian due to the comments of the other referree. Also, we improved a discussion on the nature of the scaling.

The subsequent analysis of the temporal behaviour of this scaling behaviour is a big topic and is not really done justice in this paper. I would be inclined to remove it and publish a more thoughtful analysis of the dependence of scaling parameters on the meteorology of the day as a separate paper.

We removed this section.

HESSD

10, C8497–C8503, 2014

Interactive Comment