**Biogeosciences
Discussions**

Interactive comment on "Fractal metrology for biogeosystems analysis" *by* V. Torres-Argüelles et al.

Anonymous Referee #2

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I consider that the ideas, the tools and the results are worth publishing but that there is a lot of a work to do in order to clarify the objectives and to summarize the results. The manuscript is rather well written but would need to be better organized, better focused and shortened. Let us first give an example as regards the organization : The manuscript is divided in 7 sections, Section 4, entitled metrology, consists in a single paragraph, whereas Section 5 , entitled fractal metrology, covers 11 pages!!

The authors write at the end of the introduction: "The present study has three goals: (i) To validate the step-by-step protocol for measuring the scale invariance of roughness on the structural patterns of a complex system (soil in our case), paying special attention to the uncertainty of each used measurement technique; (ii) To test some new (designed by our group), as well as some common roughness measurement tech-

niques on three soils with contrasting structural patterns, but with the same reference-mineralogy; (iii) To compare qualitatively (by visualization) and (a) quantitatively (in terms of the Hurst exponent) the symmetry breaking of soil aggregates under a degradation process (sodium salinization). Âż

I cannot see clearly the distinction between these three goals in the present manuscript nor three relative conclusions in the general conclusion of the paper. I consider that goal (i), as regards the validation of the protocol is missing, and that it would be better to avoid mentioning it. The world "to validate" could at least be replaced by 'to argue"...

I consider that the manuscript has three parts 1) A general review on concepts (complexity, criticality, scale invariance, measure and measurand, uncertainty, etc.), and namely on Metrology focusing on the measure of roughness. 2) The presentation of a toolbox called Fractal Metrology and gathering some classical and some new techniques which could be used in several applications. 3) An application to soils in order 3.1. to test the toolbox on three soils with same mineralogy but contrasting structural patterns, paying special attention to the uncertainty of each used measurement technique; 3.2 to use these results to compare quantitatively the symmetry breaking of soil aggregates under a degradation process.

and I will present my following both general and specific comments follow accordingly:

1) The 4 first sections (Introduction, Complexity, Criticality and Roughness, Fractals and Scale Invariance, Metrology) mix very general considerations about Metrology from a literature review and original ideas plus a discussion on the soil data.

I would suggest either to merge everything in a large introduction section, or to write a short introduction to the whole paper, including data and goals) then a second section about the conceptual background (Metrology, Complexity, Criticality and Roughness, Fractals and Scale Invariance)

Fig.1 is clearly associated to this first part. I have several questions as regards this

figure. What is the importance of dimensional metrology respectively in scientific, industrial and legal metrology? Do all the nine types of metrology deal with measurement of length? Is yes, could you give an example for biometrology? There are references in all the nine boxes except for fractal metrology. Why? Where do you locate the present study (surface?, computational?, fractal?, statistical?, optical?)

Specific comments: - p.4750: metrological constants-> metrological variables - p.4752: Could you explain how the definition of complexity of Christensen and Moloney apply for the solid and pore patterns of the studied soil: which are the repeated rules in the applicative context? - p.4753: Could you explain to the reader how k-rough numbers with prime factors greater than k are linked to any intuitive idea of roughness or better drop these reference to internet Websites? - p.4754: The paragraph about the 4 types of spatial invariance in physics is out of the scope of the present paper - p. 4755. There is a 3.1 section and no 3.2! - In this 3.1 section, entitled "Optics of fractal objects" there are curiously two types of information which are not at all on the same level . On the one hand one has very general remarks about reflectance properties, which are almost beyond the scope of the present paper, since nothing is mentioned later on this issue, for example on the necessary condition of a skewed distribution of illuminant intensities... If it is linked to the acquisition of the soil images , please refer to it in the 6.1 experimental setup section, or drop it. - On the other hand one has a description of the practical method to build histograms or firmagrams from 2 dimensional images which should be moved to the toolbox section (section 5) in respective sections 5.2.1 about firmagrams and 5.2.3 about histograms (where, by the way, this information is given again in a redundant way). - p4756, l.1 With your notations, $pk=nk/(NrXNc)$

2) Section 5 is the main section which presents the FM toolbox

From the introduction of this section, one expect " a generic framework suitable for the measurement of complexity". Please avoid so ambitious claims and describe how the toolbox has been designed to measure spatial indicators on gray level images.

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How is the Weierstrass-Mandelbrot function appearing at the top of the tree (Figure 2) is used in the present study? This function is mentioned in 5.1 then an analytical expression is given in 5.5. But it is never used in the application to soils! One cannot spend 1 page on a concept which is never used, and one should at least explain how such a function could be used.

Specific comments: p.4757,l.15: Could you explain how Kaneko's "hierarchical ordering, clustering, coding, switching and control in a network" apply in the FM tree? or drop the reference? p.4757,l.28 : Again the reference to networks (such as commented by Monroe) is not clear for me. Which network are we talking about? which are the nodes, the links and the interactions? p.4758, l.2: What is the main measurand: roughness? of the Hurst exponent? p.4759, l.11 Histo-Gene vs l.22 Hist-Gene, be consistent, I would prefer Hist_gene. Later on, I would prefer Freq-Hist than Frequ-Hist p.4759. l.27. No need to describe the content of each column of an excel file (by the way the 1st column would contain the value of gray tone and the 3rd one the gray value: What is the difference?) p.4760. The whole paragraph beginning with Berry(1996) and ending p.4761 is out of the scope of the present paper. The equations are not labelled, not used, and not useful for the reader. p.4763, l.4. Five techniques are mentioned, then 4 are listed (DB, DR/S, DPS, DW), then 3 are shown in Fig.3. Please be consistent.

3) Section 6 presents the results

I have a major concern as regards the conclusion of the study for the 3 studied soils (Chernozem, Solonetz, Chocolate Clay) : Does the fractal analysis or the Hurst exponent enable the quantification of the observed visual differences of the macrostructural patterns of these soils? One reads (p.4773, l.14) about the "statistically insignificant differences of the Hurst exponent values Âż of the Solonetz and Chocolate Clay, (p.4774, l.6) about the Âń statistically significant similarity between the roughness of Chernozem and Solonetz Âż, and p.4770. " neither the box fractal dimension nor the standard deviation were able to detect any differences in the roughness of digital images of the compared soils Âż How can we conclude about the "effectiveness of certain fractal de-

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scriptors for measuring the dynamics of complex systems "(p.4773, l.22)? Which fractal descriptors are "effective"? One goal of the paper was to "compare qualitatively (by visualization) and quantitatively (in terms of the Hurst exponent) the symmetry breaking of soil aggregates under a degradation process (sodium salinization)". What is the conclusion with respect to this goal? How far can any of the 11 Hurst exponents or quantify the symetry breaking?

The conclusion has to be very clear as regards the detection of structural patterns using the FM toolbox as well as the detection of the transition from the Chernozem state to the degraded Solonetz state. Which fractal descriptors or Hurst exponents can "measure" (as claimed) or at least detect soil dynamical changes? Maybe I am wrong, and the conclusion of the paper is that the fractal descriptors are useful only to detect the same microstructure and same mineralogy and they cannot detect the obvious differences in the macrostructure?

Specific comments: p.4772, transition from l.26 to l.27: The study about uncertainty (section 6.3) must show better that there are two types of uncertainty, one on the parameters estimations (ex : standard deviations of several Hurst exponents, Table 5), another one the central moments of the raw data (Tables 8 to 11). No further specific comments: I recommend the detailed statistics to be checked by a statistician.

TABLES

The paper is very long, Tables 8,9,10,11 are not commented. I would suggest to drop these tables to focus on the discussion of the results obtained using Fractal Metrology according to the title of the paper

REFERENCES: Where can the two JCGM documents be found (Geneva is not enough in a scientific paper)?

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