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Nonlinear Processes in Geophysics Discussions

Interactive comment on "Site effect classification based on microtremor data analysis using concentration–area fractal model" *by* A. Adib et al.

A. Adib et al.

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Received and published: 9 November 2014

Dear Natascha So far, we have received 5 comments at dates: Aug. 20, Aug. 25, Sep. 25, Oct. 8 and Oct. 18 of 2014 and replied them during the next 12 days after the receptions. However, replying to your last e-mail about resending all the comments and replies in a new file, it will be send to you. In any case of duplicate or complementary comments and replies, it refers to the last reply. Meanwhile, figures 2, 3, 7, 8 and 9 are edited based on reviewers' ordering.

20 August 2014 1-1) comments from Referees: The novelty of this article is to propose to apply the well known Concentration area Multifractal classification model (Cheng et al., 1994) that was designed for extreme distribution detection on geochemical dataset, on the dataset on microtremor. The Concentration Area classification model (C-A) is

not fractal but multifractal (see Cheng et al., 1994). The text is often using fractal (supposed to be monofractal) and multifractal. Please clarify the text. My main concern is about the use of C-A classification for more than two classes. The basic idea of C-A is to simplify asymptotically, the multifractal statistics in two scale domains: close to alpha_min and close to alpha_max. In both cases, the area statistics follow a scaling power law with different slope. This was done originally in order to separate usual variability and extreme fluctuation. The C-A model in not adapted for more than two classes. Cheng et al., 1994 discuss another type of model: the bifractal, which consist to claim that the geophysical data follow two monofractal scaling laws separated by a threshold scale. Both asymptotic multifractal and bifractal can create apparent break in the power law slopes. 1-1) Author's response: Concentration-Area could be used for both monofractal and multimodal area. This method has been used for the booth and there are many references about it such as data characteristics have been determined even by multifractal method such as Afzal et al. (2010). Consequently, there is no need to change. (Afzal, P., Khakzad, A., Moarefvand, P., Rashidnejad Omran, N., Esfan-diari, B., Fadakar Alghalandis, Y., 2010. Geochemical anomaly separation by multifractal modeling in Kahang porphyry system, Central Iran. Journal of Geochemical Exploration 104, 34–46)

1-2) comments from Referees: Another comment is about the lack of justification of the classification on the frequency. Why the authors are choosing frequency (table 6) instead of amplification or k-g? Please justify this choice. 1-2) Author's response: As it is mentioned in the paper we perform the C-A method to improve the Nogoshi's classification results in the Meybod city. This Classification and many other standard classifications are based on frequency or period. Additionally, it is said that the actual site amplification cannot be estimated from the amplitudes of HVSR peaks (Bard, 1998; Gosar et al., 2008; Sesame, 2004). Consequently, classification based on frequency is more reliable than amplification or k-g (as related to amplification). 1-3) comments from Referees: Figure 2: "cultivated land" is not a geological unit but a vague pedological concept. 1-3) Author's response: Please replace the new figure 2 instead of the earlier.

manuscript change

1-4) comments from Referees: Figure 8 and figure 9: The comparison is hard between the two classification method. Please plot all the microtremor points for both figures. 1-4) Author's response: By adding microtremor points and names to the figure 8, the figure becomes very crowded and distinguishing the results may not be possible easily.

1-5) comments from Referees: Please represent a classification map for figure 9, instead of an interpolated map. 1-5) Author's response: The new figure 9 has been prepared and attached to the E-mail. Please replace it with the earlier. manuscript change

25 August 2014 2-1) Comments from Referees: Cheng and Agterberg (1996), Sim et al (1999), Goncalves et al (2001) are not using classification method for more than 3 classes but detection tool for extreme data (2 classes, as shown in all plots of those articles). The article from Afzal et al. (2010) proposes to extend the Concentration-Area method to more than two classes without theoretical justification. More than a theoretical work, this article should point out at least a discussion about the justification for the case of more than 2 classes, in the framework of fractal/multifractal. Also the authors should state clearly that their use of the C-A method is extended from the initial version from Cheng et al., 1994. 2-1) Author's response: Cheng et al (1994) did not use any limitation for the C-A method entitled a bi-fractal method. They introduced the model for bi-fractal and multifractal natures (see section 4.1 and Appendix of the paper). They wrote formulation for both of them in this Appendix. Cheng and Li (2002) used the model in multifractal nature data. Many researchers used the method for multifractal modelling (e.g., as follow):Cheng, Q., 1994, Multifractal modeling and spatial analysis with GIS: Gold potential estimation in the Mitchell-Sulphurets Area, Northwestern British Columbia: unpublished Ph. D. thesis, University of Ottawa, Ottawa, 268p. Cheng, Q., 1997, Fractal/multifractal modeling and spatial analysis, in Proceedings of the International Association for Mathematical Geology Conference, V. Pawlowsky-Glahn (ed.), Barcelona, Spain, September 22-27, 1, 57-72. Cheng,

Q., 1999, Spatial and scaling modeling for geochemical anomaly separation. Journal Geochemical Exploration, 65 (3), 175-194. Goncalves, M. A., Vairinho, M., and Oliveira, V., 1998, Study of geochemical anomalies in Mombeja area using a multifractal methodology and geostatistics, In Proceedings of International Association for Mathematical Geology Meeting. A. Buccianti, G. Nardi, and R. Potenza (eds.), De Frede, Ischia Island,Italy, 2. 590-595. Goncalves, M.A., 2001. Characterization of geochemical distributions using multifractal models. Math. Geol 33 (1), 41-61. Goncalves, M.A., Mateus, A., Oliveira, V., 2001. Geochemical anomaly separation by multifractal modeling. Journal of Geochemical Exploration 72, 91-114. Cheng Q., Li Q., A fractal concentration-area method for assigning a color palette for image representation. Computers &Geosciences., 2002, 28, 567-575 Lima, A., De Vivo, B., Cicchella, D., Cortini, M., Albanese, S., 2003. Multifractal IDW interpolation and fractal filtering method in environmental studies: an application on regional stream sediments of (Italy), Campania region, Applied Geochemistry 18, 1853–1865.

2-2) Comments from Referees: Figure 3: the scale is still missing. 2-2) Author's response: Please replace the new figure 3, the new figure has been attached. manuscript change

2-3) Comments from Referees: Figure 8: The points without names will improve the visibility of the figure and the comparison with figure 9. 2-3) Author's response: The new figure has been attached. manuscript change 2-4) Comments from Referees: Figure 9: The figure would be more easy to interpret in color using the same color legend than figure 8. 2-4) Author's response: The new figure 9 has been prepared and attached to the E-mail. Please replace it with the earlier. manuscript change

25 September 2014 3-1) Comments from Referees: Please find here an excerpt of Section 4.1 from Cheng et al., 1994: "In Appendix A it is shown in detail that if the element concentration per unit area satisfies a fractal or multifractal model, then the area A(p) has indeed a power-law type relation with p. When the concentration per unit area follows a fractal model, this power-law relation has only one exponent. On

the other hand, when the concentration per unit area satisfies a multifractal model with a spectrum of fractal dimensions, then several separate power-law relations between area A(p) and p can be established. For a range of p close to its minimum value p the predicted multifractal power-law relations are: Equation (2a) where C1 and C are constants and al and be are exponents associated with the maximum singularity exponent. For a range of p close to its maximum value p, the predicted power law relation is: Equation (2b) where C1 is another constant and C is the exponent associated with the minimum singularity exponent (see Appendix A)." The two extreme asymptotical relationships are developed for p close to minimum and maximum. The appendix A contains the mathematical developments of those two asymptotical relationships, which is the heart of the article: separating geochemical "anomalies" from "background". All graphs presented in this article show one or two linear asymptotical domain in log/log space but never more than 2 linear domains. Again, several power laws can be established in the multifractal case, which apparently the case of your data but there is no rationale in the Concentration-Area model to identify them. A discussion of this point should appear in the article. Cheng and Agterberg (1996), Sim et al (1999), Goncalves et al (2001) are not using classification method for more than 3 classes but detection tool for extreme data (2 classes, as shown in all plots of those articles). The article from Afzal et al. (2010) proposes to extend the Concentration-Area method to more than two classes without theoretical justification. More than a theoretical work, this article should point out at least a discussion about the justification for the case of more than 2 classes, in the framework of fractal /multif ractal. Also the authors should state clearly that their use of the C-A method is extended from the initial version from Cheng et al., 1994. 3-1)Author's response: Cheng et al (1994) did not use any limitation for the C-A method entitled a bi-fractal method. They introduced the model for bi-fractal and multifractal natures (see section 4.1 and Appendix of the paper). They wrote formulation for both of them in this Appendix. Cheng and Li (2002) used the model in multifractal nature data.Many researchers used the method for multifractal modelling (e.g., as follow): Cheng, Q., 1994, Multifractal modeling and spatial analysis with GIS: Gold

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8 October 2014 4-1) Comments from Referees: The improvement of the figure, in particular the explicit values of the fits and the R2 are significant. The rationale of the “linear-portion” are better demonstrated. Nevertheless, the text is still uncomplete. The “linear-portion” in a log-log plot is not a signature of multifractal but it could also be a fractal by scale! Again the reference Agterberg et al., 1996 is never arguing on such “linear- ortion”. In order to demonstrate the “multifractal” nature of their data, Agterberg et al., 1996 used different statistical moments. For each moment, a single power-law is demonstrated empirically (only one linear fit) but the exponent is different. The reference Spalla et al. 2010 is new but not complete. Please add the full reference. 4-1) Author's response: Based on the reviewer comment, We add descriptions about

multifractal natures of my parameters in the area. Fig. 7 is edited and power-law relationships with R2 are added to the log-log plots for showing of multifractal nature of the data. There are multifractal natures for frequency, amplification and K-g based on the more than two straight segments. The straight segments fitted lines were derived based on least-square regression (Agterberg et al., 1996; Spalla et al., 2010). All R-squared values are higher than 0.9 and most of them have R2 higher than 0.95 which is show a proper correlation (Fig. 7). The power-law relationships between the geophysical parameters and their occupied areas were indicated in the Fig. 7. According to the Eq. 2, there is different values for) which is exponent equal to fractal dimensions, as depicted in Fig. 7. The variation of fractal dimensions reveals a multifractal nature for frequency, amplification and K-g in the area. manuscript change

18 October 2014 5-1) Comments from Referees: Thank you for an interesting and valuable contribution that deserves publication. Even so, I have a serious concern, reservation: based on the histogram of amplification's and k-g's values in the figure 4, is there really a justification for grouping all these data into one data set? It seems rather obvious that there are likely to be multiple populations, presumably related to geology, e.g. lithology. Certainly from my point of view I would expect that anyone looking at this data would consider at least the relationship between lithology and multiple domains for different frequencies' populations? This should be discussed through the contents of the paper! With respect to the Fig.5 of histograms, more statistical analysis should be conducted . however; the lack of adequate information is feeling! According Fig.1, there are too many information on the Map of Iran which makes it overcrowded! The authors are highly recommended to replace this map with a readable one. 5-1) Author's response: Thank you very much for your valuable comments. The answer of your questions and corrections are follow: 1. Frequency, amplification and k-g are different variables which reveal various characteristics of soils in the urban areas. The frequency and k-g show velocity of the wave and power of destruction. Combination of the three parameters cannot be possible. For more description for classical statistics the following sentences are added in lines 167-169: The separated populations are

clear in their histograms and also, high amounts of the parameters are lower than their means. Moreover, their median could be assumed for their threshold values because their distributions are not normal. 2. The microtremor data used for classification of different grounds of an urban area (may relates to different compaction or density and etc.) not just for lithological separation. The study area is located on a silty and clayey plain (quaternary units), so we describe about soil types derived via the boreholes (Section 2). Based on the resulted frequencies, the most parts of the city contain soft soils. As it is mentioned in the Section 2, there is not any major variation in the composition of sediment in the area, except for some variation of clay and silt contents in the eastern part based on boreholes data. However, shear wave velocity data shows that there are differences in soil hardness values within the area. Consequently, one can concludes that the different category of frequency, amplification or k-g value may relate to variation of soil hardness in different places of the city. 3.Figure 1 was replaced but we recommend the earlier.

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Fig. 1.

Site effect classification based on microtremor data analysis using Concentration-area fractal model

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Abstract

The aim of this study is to classify the site effect using concentration-area (C-A) fractal model in Meybod city, Central Iran, based on microtremor data analysis. Log-log plots of the frequency, amplification and vulnerability index (k-g) indicate a multifractal nature for the parameters in the area. The results obtained from the C-A fractal modeling reveal that proper soil types are located around the central city. The results derived via the fractal modeling were utilized to improve the Nogoshi's classification results in the Meybod city. The resulted categories are: (1) hard soil and weak rock with frequency of 6.2 to 8 Hz, (2) stiff soil with frequency of about 4.9 to 6.2 Hz, (3) moderately soft soil with the frequency of 2.4 to 4.9 Hz, and (4) soft soil with the frequency lower than 2.4 Hz.

Keywords: Site effect classification, Concentration-area fractal model, Microtremor, Frequency, Meybod city, Iran

1 Introduction

Site effect caused by an earthquake may vary significantly in a short distance. , Seismic waves trapping phenomenon leads to amplify vibrations amplitudes that may increase hazards in sites with soft soil or topographic undulations. Theoretical analysis and observational data have illustrated that each site has a specific resonance frequency at which ground motion gets amplified (Bard, 2000; Mukhopadhyay and Bormann, 2004).

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Fig. 2.