Answers of authors of manuscript npg-2018-57, to the remarks of reviewer RC1.

First of all we would express sincere gratitude to Prof. Papadimitriou for careful reading of our manuscript and highly competent and valuable remarks. Below we present reviewer's remarks, with our answers to them.

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Interactive comment on "Mahalanobis distance based recognition of changes in the dynamics of seismic process" by Teimuraz Matcharashvili et al.

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The paper deals with the recognition of changes in the dynamics of the earthquake process, as it is clearly stated by the title per se, by estimating the Mahalanobis distance (MD) in Southern California, an earthquake prone area, and for this reason is important. The importance is connected with the identification of regularities in the seismicity behavior during periods of seismic excitations, whereas it turns to random – like during periods of decreased activity. There are, however, several points inside the paper that need additional work and corrections. Specific comments are reported, which I hope will contribute to the improvement of its revised version.

MAJOR COMMENTS

1. Considerable improvement of syntax and grammar is re-quired. In some places the reader needs to "infer" the meaning of the content.

After the discussion stage the improved manuscript will be checked and corrected by a language expert.

2.Lines 91 and 92: This point is crucial for the paper and even more for the reader. It is necessary, therefore, to be more specific and more explanation to be given, how this goal will be approached and what is expected from the analysis.

To make more understandable what was the goal and what we expected, Lines 91 -92 and further were rewritten as follows:
Such multivariate comparison of original catalogue with randomized catalogues may help to gain new knowledge about the character of changes which definitely occur in the extent of order/disorder of seismic process. Besides, we will have stronger arguments to speak where and how the dynamics of original seismic process in analyzed catalogue was close to disorder (irregularity) or to order (regularity). We also may find out how such changes may be related with the process of strong earthquakes preparation.

Obtained in our research results show that the extent of regularity in the analyzed seismic process is changing, being closer to randomness in periods prior to strong earthquakes. After strong earthquakes, the regularity of original seismic process assessed by used temporal spatial and energetic characteristics is clearly increased.

3. It is important to see the details of the plots commented and determined. For example, in Fig. 3, the MD variation and the connection with the strong earthquakes, shown in the upper part of the figure.

In the upper part of Fig.3 we present calculated for consecutive windows seismic energies and averaged MD values in the bottom. Time scale or the numeration of windows for upper and bottom plots is the same. So, in Fig.3 we wanted to make easily comparable the time (window) location of strong earthquakes and the location of time periods (windows) when seismic process according to our results was closer to regular or random behavior.
Dotted line in figures shows MD value which corresponds to critical Fc=3.99 (according to statistical tables for given degrees of freedom, Fc=3.99 corresponds to significant difference between groups at p=0.01). Thus if MD value for given window is larger than MD=0.68 (i.e. if F value for this window >3.99) then this window is significantly (at p=0.01) different from randomized windows. We underline here that by mistake in our manuscript p=0.05 was shown what is corrected in revised version.

4. Lines 301 – 302: ": : : we observed two separate processes prior and after main shocks : : :". Is this observed only in the case of the strong earthquakes' occurrence or not? And how it could be determined in the cases that the same pattern is met without a strong earthquake occurrence?

We are sorry for the unclear text. Here we have just meant the fact (known from literature) about differences between processes prior and after strong events, based on authors cited in followed text. In the revised version the text related to this remark is in our opinion more clear. In addition to the text in manuscript we add here that we do not state that windows with smaller earthquakes will always be random-like; what we would like to say is that portion of such windows after strong earthquakes is zero, while prior to strong earthquakes increase at least to 33% of all windows.

5. Lines 322 – 323: Why did you chose this period and not repeat the exercise for all M6.0 earthquakes shown in Figure 3?

As it is pointed in the manuscript, we show in Figs. 6, 7, 8, certain periods selected from the Fig. 3 just for better visibility of observed changes. Thus, we have chosen a part of the catalogue with the strongest observed earthquake and the preceding smaller ones. As for other M > 6.0 earthquakes we think that changes are well visible in Fig. 3, for the case of 50 data windows shifted by 50 data and we did not want to overburden the text with figures with similar results.

6. In Figure 7, the increase around 12300 is also profound, as before the M6.1 event. How do you determine that?

What can be said for sure is that after strong EQs we observe a largely increase number of windows in which seismic process looks as regular. Number of the windows is larger for stronger EQs. This apparently is related with the correlated aftershock activity. For smaller EQs such period is smaller. The fact is that number of windows with random like behavior of seismic process essentially increases for periods of smaller EQ activity.

7. Line 340: earthquake of M5.23, a moderate magnitude event. Could you choose and suggest a threshold for the strong events, which for the pattern is seeking? Could you present then the catalog of all these events and for which the pattern is observed and is statistically significant?

After reviewer's remark we changed and expanded text after Fig.7 in following manner: There are two large events occurred in this period: the moderate M5.23 (06.03.1998) and the strong M7.1 (16.10.1999) earthquakes. Here we underline the obvious fact that there is no use to try to find a magnitude range which may occur in windows where seismicity behaves random-like. Indeed, as we see from our results (see Fig. 3, 6 and 7), earthquakes of any size may occur in any windows both in those where seismic process is closer to regular behavior or where it is more random-like. So, we cannot speak about the magnitude threshold or about the range of magnitudes in the sense of their immediate influence on changes in the extent of regularity of seismic process. On the other hand, our results show that in periods of mostly small earthquakes generation, prior to strong earthquake occurrence, seismic process in the considerable amount of windows is indistinguishable from randomness. Thus, as assessed by simultaneous variations of *ICT(i), ICD(i)* and *ICE(i)* characteristics the seismic process of relatively small earthquakes generation prior to strong earthquakes can be regarded as random-like.

8. Line 345: ": : : is strongly different from random process : : :" Could you clarify this statement in relation with details in Figs 7 & 8?

We base our statement on the results of our analysis showing that MD is larger than the threshold value what means that seismic process in these windows should be regarded as different from random process. Corrected text after reviewer's remark reads as following:
Exactly, strong and relatively strong (for selected short period) earthquakes are preceded by considerable amount of windows in which seismic process, in the original catalogue, is indistinguishable from what we observe for randomized catalogues. Contrary to this, in all (50 data) windows followed strong (or relatively strong) earthquakes, we observe statistically significant difference of original seismic process from processes taking place in randomized

catalogues. Indeed, the multivariate comparison of these windows, based on variation of ICT(i), ICD(i) and ICE(i) characteristics, convinces us that in these windows seismic process is strongly different from random process (see Figs. 7 and 8).

9. Fig. 8: How is the pattern before and after the M5.23 earthquake and how is it explained?

As we mentioned above we had not try to find magnitude range of events which may occur in windows where seismicity behaves random-like or regular. Apparently at present we cannot answer this question. Based on our results we see that, some strong EQs occur in random-like windows while others occur in regular windows. Also, small EQs occur both in more regular as well as in the more random-like windows. Apparently all this is related with presently unknown background physics of earthquake generation and related changes in the long range features of seismic process. In present work we aimed to provide additional arguments in favor of based on recent researches view that the degree of regularity (randomness) of seismic process undergoes essential changes which can be detected and even assessed quantitatively.

10. Fig. 8: What happened before and after the M7.1 earthquake, how is it determined and how is it compared with the corresponding behavior connected with the M7.3 of Fig. 7?

Most 50 data windows prior to M7.1 indicate a random-like behavior (MD<threshold value) but after, in a number of windows we observe the pattern significantly different from a random behavior. In this sense results in Fig.7 and 8 are in fact similar. It can be supposed that increase in MD values observed prior M7.1 and M7.3 may be related with foreshock activity. At the same time we point that in the present research we want just to present new results on a changing extent of regularity, what someway should be related with the foreshock activity during strong earthquakes preparation.

11. Lines 362 – 365: Please, clarify your statement and provide arguments to support it.

We are grateful for this remark. Here we have cited works of other colleagues. Statement in lines 362-365 is that: "….. aftershocks spatial, temporal and energetic features are causally related with the mainshock". This well known and accepted view is based on facts which often were described in related literature. In the manuscript we provide some, among many others, references, which agree with statement in our manuscript. In our opinion presented results agree with this vision.

12. Line 392: ": : : 2 – 5 days period : : :" How this period has been set? This need to be supported and clearly stated how is it associated with the aftershock activity evolution.

We have selected (mentioned in manuscript) 2-5 days period followed soon after strongest M7.3, M7.1, and M7.2 earthquakes. We based our selection on the fact that the larger is main shock magnitude the larger is the number of aftershocks. Also the selected period started soon (1 to 3 days) after three strongest catalogue earthquakes when aftershock activity could not be ended. Moreover, we calculated distances from these aftershocks to corresponding main shock and find that they are localized in close vicinity to main shocks. Exactly, 90% of earthquakes in this 2-5 days period occurred in 0.5-70km distance from epicenter of M7.3; 92% of earthquakes in this period occurred in 1.2-60km distance from epicenter of M7.1; . 99% of earthquakes in this period occurred in 0.7-60km distance from epicenter of M7.2. All this has convinced us that we mostly deal with small earthquakes related to the mainshocks aftershock activity. We could also show maps of these earthquakes location but finally we abandoned this idea in order to not overburden manuscript with not too informative figures.

SPECIFIC COMMENTS

1. Special caution should be paid to the citation, since a unique format is not followed. For example, in page 2 the same paper is written as: "Iliopoulos et al., 2012" and "Iliopoulos, et al. 2012". For this citation in particular, you need to correct in line 610: Instead of "Papadimitriou, P. P." the correct name is "Papadimitriou, E. E.". More: when the authors names are shown inside the text the commas should be avoided, like in lines 135 & 136: Kanamori [1977] (without a comma). Line 306: Bowman and Sammis (written properly some lines below), instead of Bowman et al. Lines 362 & 366: Please, be kind enough to correct the citation format.

We are grateful to reviewer for this remark and have tried to correct all inaccuracies with citations.

2. Page 3: The map should be limited to the boundaries of the catalog – it seems now that seismicity has ceased (there is no seismicity) northern than 38 degrees for example, or to the west of -122 degrees.

New map in revised version is better limited by boundaries of the catalog.

3. It could be of broad interest and concern of many readers to see why the authors did not prefer to use seismic moment, which is nowadays routinely estimated, instead of seismic energy.

It is pointed in the manuscript that we aim at assessment of dynamical changes in entire seismic process based on all its domains, temporal, spatial and energetic. Thus, it was logical to use seismic energy in our research. On the other hand, we had not special reasons to go in discussion regarding the using of seismic energy and seismic moment, characteristics which both are calculated from earthquakes magnitudes, in researches of other authors. Moreover in this work we preferred to use energy values calculated from magnitudes because we usually did so in our last researches and

it looked logical to use in this research the same characteristic. This of course do not mean that we question using of seismic moment by other authors and in future works we also will use seismic moments in cases when it will look appropriate for certain research goal.

4. Syntaxis in many
places needs substantial review, for the text to be conceivable.

Thanks for this comment, we have done our best to correct the text.

5. When you refer to
"strong" earthquake, please, pay attention to not name them "strongest" (it is met in many places in the manuscript).

Many thanks for useful remark. In revised version text is corrected.

6. Lines 402 – 404: Could you make it more clear?

Here we just mean that during the period of aftershock activity seismic process looks more regular and significantly different from random process comparing to the period prior earthquake; apparently this is happening not only in case strongest but also smaller and even moderate earthquakes too.
This part of manuscript after Fig. 9, is now considerably rewritten.

7. Line 476: ": : : 29 of such earthquakes occurred for considered period : : :": What do you mean by that?

Thanks for remark. Now the text reads: Further increase of threshold to M5.6 had no sense because only 29 of such earthquakes, i.e. with magnitudes larger than M5.6, occurred in south Californian catalogue for the period considered in this research.