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Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "A statistical feature of anomalous seismic activities prior to large shallow earthquakes in Japan revealed by the Pattern Informatics method" *by* M. Kawamura et al.

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To Reviewer #1 We deeply appreciate your instructive comments for improving the manuscript. Revision works resulted in the replacement of many original sentences and figures with new ones. We recalculated by a little bit changing grid sizes (60$\times$ 60 km $\rightarrow$ 80 $\times$ 80 km for Mc = 3.5 and 80 $\times$ 80 km $\rightarrow$ 100 $\times$ 100 km for Mc = 4.0 or Mc = 4.5), then revised most of the contents pointed out by you and the other reviewer. Before revision, a success was declared when a large (M $\geq$ 6.4) earthquake occurred on a PI hotspot cell and its surrounding eight cells. However, because this rule causes readers' confusion, we adopted another simpler but severer rule that a success

is declared when a large earthquake occurs on a PI hotspot cell without its surrounding grid cells included. Primary characteristics of spatiotemporal PI maps obtained after recalculation (new Figs. 3–5) were not so different from the original ones (old Figs. 3–5) although statistical performances for a large part of Molchan's error diagrams became insignificant. Please note that spatiotemporal alarm area maps (new Figs. 6–8) were newly added to the manuscript according to the other reviewer's suggestion and new Figs. 3–5 and 9–11 replaced old Figs. 3–8.

The followings are our responses to your questions or suggestions. 1) There are significant issues with the English grammar. Please revise, with special care for appropriate verb tense. $\rightarrow$ According to your suggestion, we revised the whole English sentenses.

2) The figures, particularly 3, 4, and 5, need to be enlarged (although the Molcan diagrams are also too small). They are not legible and it makes it difficult to validate the authors points in the text. $\rightarrow$ According to your suggestion, we enlarged the respective figures.

3) Some discussion as to the particulars of the anomalies, ie whether they are a function of quiescence or activation, and to what degree, would be illuminating. $\rightarrow$ It is originally impossible to discriminate between seismic quiescence and seismic activation because our method (PI method) incorporate both of them to calculate PI value. However, as you suggested, it is important to investigate which of seismic quiescence and activation is representative of anomalous seismicity change for each grid cell for each time period. To address this problem, we combined the PI method with the ETAS model and ZMAP method and applied the combined model to Taiwan earthquake catalog data prior to the Nantou M6.2 earthquake on March 27, 2013 (submitted). In the study, we indicated that region with large temporal change in seismicity obtained using the PI method corresponds to seismic quiescence region obtained using the ETAS model and ZMAP method. The focus of this study is a systematic application of the PI method to the earthquake catalog of Japan Meteorological Agency, and combination of the PI method with other statistical models is out of scope but is an issue to be tackled

in the near future.

To Reviewer #2 We deeply appreciate your instructive comments for improving the manuscript. Revision works resulted in the replacement of many original sentences and figures with new ones. We recalculated by a little bit changing grid sizes (60$\times$ 60 km $\rightarrow$ 80 $\times$ 80 km for Mc = 3.5 and 80 $\times$ 80 km $\rightarrow$ 100 $\times$ 100 km for Mc = 4.0 or Mc = 4.5), then revised most of the contents pointed out by you and the other reviewer. Before revision, a success was declared when a large (M $\geq$ 6.4) earthquake occurred on a PI hotspot cell and its surrounding eight cells. However, because this rule causes readers' confusion, we adopted another simpler but severer rule that a success is declared when a large earthquake occurs on a PI hotspot cell without its surrounding grid cells included. Primary characteristics of spatiotemporal PI maps obtained after recalculation (new Figs. 3–5) were not so different from the original ones (old Figs. 3–5) although statistical performances for a large part of Molchan's error diagrams became insignificant. Please note that spatiotemporal alarm area maps (new Figs. 6–8) were newly added to the manuscript and new Figs. 3–5 and 9–11 replaced old Figs. 3–8.

The followings are our responses to your questions or suggestions. 1) I find that the English grammar of the paper is rather poor. It needs a careful revision for improvement. I have a personal suggestion for the use of the words "seismic activity" rather than "seismic activities" in the title and throughout the text. $\rightarrow$ According to your suggestion, we revised the whole English sentences and replaced "seismic activity" by "seismic activity".

2) For my own curiosity: I wonder why this paper includes the analysis of earthquakes until the date of 28 February 2011 (11 days before the great Tohoku Earthquake of 11 march 2011) and considers a rectangular area that leaves the epicenter of this great earthquake just outside, although it includes wide offshore seismic zones. $\rightarrow$ In order to focus primarily on large (M $\geq$ 6.4) inland Japan earthquakes occurred from 2000 on, we set the rectangular region (Fig. 1) so as to include all the large inland earthquakes but to exclude as much interplate earthquakes as possible including the epicenter of the

2011 Tohoku earthquake. Because the shape of analysis region must be rectangular, one large shallow interplate earthquake (index (K) in Table 1) was obliged to be allowed for.

3) The paper introduces the term of "probability of earthquake occurrence in the prediction period" at line 14 of page 725 and makes use of it throughout the text. However the quantity defined in the paper is not a probability (its normalized value is negative). I would strongly recommend avoiding the use of the word "probability" in this context. $\rightarrow$ As you suggest, we avoided the use of "probability of earthquake occurrence in the prediction period" but used "the common logarithm of PI value" (as shown in Fig. 2).

4) The size of the total spatiotemporal area occupied by prediction periods depends on the length of the time interval t3-t2. t3 is mentioned only twice (lines 14 of page 725 and line 21 of page 726), but the paper never gives information on the size of t3-t2. This is a critical aspect of the forecast method and its evaluation. $\rightarrow$ According to your suggestion, we added information on the size of t3-t2 (t3-t2 = t2-t1) to Data and Methodology section.

5) Figures 3 to 5 are of difficult interpretation. It is difficult to appreciate the size of the target areas. I can't find the reason of many red stars appearing in completely blue areas, unless they are included among success even when a strong earthquake occurs many years after the occurrence of a hot spot. Again, the duration of the prediction periods is critical for evaluating the results of the method. The reader would like to see figures where the relation between alarm areas and strong earthquakes is clearly shown. $\rightarrow$ To assist interpretation of Figs. 3–5, we inserted the figures (new Figs. 6–8) showing the relationship between the alarm area (the total spatiotemporal area occupied by the prediction periods that follow the change intervals with large seismicity changes) and the locations of strong earthquakes.

6) Lines 13-17 of page 727 state that "Even if target events are included in grid cells with low earthquake occurrence probabilities in change intervals, as long as they are located

next to grid cells 15 with high earthquake occurrence probabilities in the same intervals, they are shown by using read color stars and are regarded as the events accompanied by anomalous seismic activity." This is a critical concept for evaluation of the test and should be very clearly explained. Does it mean that a success is declared when a strong earthquake occurs in any of the eight cells surrounding a hot spot cell? This would mean that the alarm area is nine times larger and it should be taken into account in the preparation of the Molchan's error diagrams both for the x-axis (fraction of the total alarm volume) and for the y-axis (number of missed events). Without a clarification on this issue I must consider the results meaningless. → As you mentioned, a success was declared when a strong earthquake occured in any of the eight cells surrounding a hot spot cell. However, because this rule causes readers' confusion, we adopted another simpler but severer rule that a success is declared when a strong earthquake occurs in a hot spot cell, not including its surrounding grid cells.

7) Figures 6 to 8 are poorly described both in the text and in the captions. What is the difference between open and solid circles and that of the unique larger solid circle in each plot? The captions should also describe the meaning of the curve lines. → According to your suggestions, we added explanation on the two kinds of circles in the captions. We also described the meaning of the curve lines in the captions.

Please also note the supplement to this comment:
http://www.nat-hazards-earth-syst-sci-discuss.net/1/C1281/2013/nhessd-1-C1281-2013-supplement.pdf

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Interactive comment on Nat. Hazards Earth Syst. Sci. Discuss., 1, 721, 2013.