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Nonlinear Processes in Geophysics
Discussions

Interactive comment on "Negentropy anomaly analysis of the borehole strain associated with the Ms 8.0 Wenchuan earthquake" *by* Kaiguang Zhu et al.

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Response to Reviewer 1:

We are very grateful to your comments for the manuscript. They have important guiding significance for our manuscript and our research work. We have revised the manuscript according to your comments. The response to each revision is listed as follows:

Comment 1

The method of detection of anomalies of the borehole strain, is not well-known to non-specialists, and – I would say – to the specialists neither. In my opinion, at least one additional explanatory paragraph entirely devoted to this subject is needed, in the "Introduction" Section.

Response:

This is a constructive suggestion! We did not mention the background of negentropy in the "Introduction" Section. An explanatory paragraph has been supplemented. The corresponding references are also added to the "References" Section.

Changes:

We have supplemented an explanatory paragraph after Line 49 in the "Introduction" Section:

"Hence, it is implied that possible precursor anomalies lead to an increase in disordered components of observation data during earthquake preparation processes. K. Eftaxias et al. (2008) proved that the pre-catastrophic stage could break the persistency and high organization of the electromagetic field through studying fractional-Brownian-motion-type model using laboratory and field experimental electromagetic data. In view of Lévy flight and Gaussian processes, Lévy flight mechanism prevents the organization of the critical state to be completed before earthquakes, since the long scales are cut-off due to the Gaussian mechanism (S.M. Potirakis et al., 2019).

Entropy can serve as a measure of the unknown external energy flow into the seismic system (Akopian, S. T., 2014). K. Karamanos et al. (2006, 2005) quantified and visualized temporal changes of the complexity by approximate entropy, they claimed significant complexity decrease and accession at the tail of the preseismic electromagetic emission could be diagnostic tools for the impending earthquake. Yukio Ohsawa (2018) detected earthquake activation precursors by studying the regional seismic information entropy on earthquake catalog. Angelo De Santis (2011) recalled the Gutenberg

- Richter law and considered the negative logarithm of b-value is the entropy of the magnitude frequency of earthquake occurrence associated with two earthquakes in Italy.

Negentropy definition is based on the entropy and it is also widely used to detect non-Gaussian features. Yue Li (2018) proposed an arrival-time picking method based on negentropy for microseismic data. In this study, the negentropy is applied to borehole strain at Guza station associated with the Wenchuan earthquake, approximated by skewness and kurtosis. Subsequently we study the extracted negentropy anomalies in different scales to investigate correlations with crustal deformation."

Comment 2

In my opinion, in Fig. 6, "$kurtosis = 0.28699 skewness^2 - 0.28696$" should boil down to "$kurtosis = 0.287(skewness^2 - 1)$", I mean that in equation (9), A=B which is a Remarkable result, if it holds true !!! At least one additional explanatory paragraph entirely devoted to this result is needed, in the "Discussion and Conclusions" Section !

Response:

We can change the parabolic relation into "$kurtosis = 0.287(skewness^2 - 1)$". Since in our case, A is always equal to -B because the kurtosis and skewness of the study period are normalized. There are

$$E(skewness) = E(kurtosis) = 0 \tag{1}$$

and

$$D(skewness) = E(skewness^2) = D(kurtosis) = E(kurtosis^2) = 1 \tag{2}$$

According to equation (9) in the manuscript and equation (1) and (2), there is

$$E(kurtosis) = E(A \cdot skewness^2 + B)$$

$$\begin{aligned} &= \frac{1}{n}\sum_{i=1}^{n} A \cdot skewness^2(i) + n \cdot B \\ &= A \cdot \frac{1}{n}\sum_{i=1}^{n} skewness^2(i) + B \\ &= A \cdot D(skewness) + B \\ &= A + B = 0 \end{aligned} \tag{3}$$

Thanks to your inspiration, we have derived a new relation based on this relation and supplemented it after equation (9) in the "Methodology" Section. Besides, the corresponding explanation has been supplemented in "Discussion and Conclusions" Section.

Changes:

We have supplemented an additional equation after equation (9) in Line 118-120 in the "Methodology" Section:

"Here we calculate the normalized skewness and kurtosis in the study period, so equation (9) can be derived into

$$kurtosis(X) = A \cdot (skewness^2(X) - 1) \tag{10}$$

indicating the test day is super-Gaussian when the skewness is outside the range (-1,1)."

We have also supplemented an explanatory paragraph after Line 239 in the "Discussion and Conclusions" Section:

"In the skewness-kurtosis domain, we observed the evolution of the negentropy distribution prior to the earthquake. Negentropy gradually transformed its distribution to a

parabolic relation since July 2007, indicating a relatively stable state was broken due to the non-Gaussian mechanism ."

Comment 3

In line 153, is stated that "k*=1.1130". What is the meaning of keeping so many significant digits ? Why not " k*=1.1 " or "k*=1.11" ? Please explain ! At least one additional explanatory paragraph is needed !

Response:

The meaning of k* value itself is a threshold for extracting negentropy anomalies. First, k* is calculated by Otsu's method by searching for k when the within-class variance of negentropy becomes the maximum, according to equations (10) to (13). Second, the format of the negentropy depends on the sample data. The YRY-4 borehole strainmeter has a measurement accuracy of 10^{-9}, so we usually cutoff four digits after the decimal point in practical calculations. Then, the calculated k* is consistent with the accuracy of the negentropy and the strain data, resulting in 5 significant digits.

In fact, when we take the threshold k* as 1.1 or 1.11, there are 367 or 363 anomaly days respectively in study period (912 days), which is almost no difference with "k*=1.1130" (363 anomaly days). However, we still keep this result for the above reason when the numbers of anomalies are counted and accumulated.

Changes:

We have supplemented an explanatory paragraph after Line 155:

"Otsu threshold k* here is consistent with the accuracy of the negentropy and the strain data, The YRY-4 borehole strainmeter has a measurement accuracy of 10^{-9}, however, we usually cutoff four digits after the decimal point in practical calculations."

Comment 4

In line 157, Fig.5, explain the Units !

Response:

X-axis and y-axis of the Fig. 5 are negentropy and its variance. The negentropy is defined as the weighted square of skewness and kurtosis in equation (6) in this manuscript. Because the skewness and kurtosis can be seen as ratios according to equation (7) and (8), there are no units.

Minor corrections:

Thanks for helping us with these typing errors.

- In line 17, "earthqake" → "earthquake" !

It has been modified.

- In lines 26 and 27, the citation has no uniform style !

(M.J.S. Johnston et al., 2006, Chi S. L. et al., 2014) has been modified as (Johnston M.J.S. et al., 2006, Chi S. L. et al., 2014).

- In lines 295 and 296, of the References list, there are quotation marks in the title of the Reference. This is the only place in the whole list where this happens !

It has been modified.

- In line 153, there are superscripts in the middle of the sentence, for no reason !

It has been modified.

- In line 157, the end dot (final punctuation mark) is missing !

It has been added.

- In line 159, it is mentioned "Fig 6(a)" instead of the correct "Fig. 6(a)" (the dot is missing) !

It has been added.

- In line 297, “Gutenber” → “Gutenberg” !

It has been modified.

- In line 325, the style is not uniform ! Dots are missing !

It has been modified.

References

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Please also note the supplement to this comment:
https://www.nonlin-processes-geophys-discuss.net/npg-2019-22/npg-2019-22-AC2-supplement.pdf

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