Statement on the Revision

We are grateful to the referees and the editor for their constructive comments. The suggestions for the revision are carefully considered in the revision process, and described one by one according to the order of the comments/suggestions.

Review #1

I found manuscript entitled "Spatiotemporal Heterogeneity of *b* Values Revealed by a Data-Driven Approach for June 17, 2019 M_S 6.0, Changning Sichuan, China earthquake Sequence" very interesting and worth to be published. The composition, reasoning and presentation of results are clear and understandable. However, I have some issues , which should be cleared before accepting the manuscript for further editorial steps. I list them below:

1. My main concern is the b-value analysis done by authors. Missing point in this analysis is how the b-value was fluctuating in the same area long before the main event. If the b-value is stable it should be more or less the same in shorter period long before the main shock, than taken into account in this analysis. Authors calculated b-values before and after the main event, but did not checked if during the time of almost 10 years before the main event, there were any changes in b-value in the analyzed area. Assuming that b-value distribution in time and space is stable according to other studies is in my opinion not enough. The b-value spatiotemporal distribution should be checked for annual changes or cumulatively 1 year before the main event, 2 years before the main event etc. It should clearly show if the main finding of the study of the low *b*-value location in the area of main shock is a long term feature of the process.

RE: We are very grateful to the reviewer for pointing out this problem and giving a detailed research scheme. In accordance with the scheme given by the reviewer, we have studied the temporal variation of *b* values on the scale of 10 years before the Changning earthquake and verified the spatiotemporal heterogeneity of *b* values of Figure 6b.

According to the temporal and spatial evolution characteristics of *b* values, we divide the region A'B'C'D' into three sections, Section 1 with lower *b* values uniformly and stably distributed in time and space and containing the nucleation point of mainshock, Section 2 with higher *b* values extending to the nucleation point, and section 3 with higher *b* values always distributed. We used a fixed window of 300 seismic events and a window of gradual cumulative increase with 300 seismic events. In both methods, the earthquakes are selected and calculated retrospectively from the failure time of the mainshock to the past, and the calculation is stopped when there are less than 300 events in the current window/step. The reason why we use 300 earthquake windows/steps subjectively is to ensure the statistical reliability when fitting the OK1993 model, and to obtain more results of temporal variations of *b* values at the same time.

The results (Figure S3) show that the temporal variations of the *b* values of segment 1 is very stable and maintains a lower value (about 0.75), the *b* values of segment 2 continuously increases from 0.8 to about 1.2, and the *b* values of segment 3 is always greater than 1.0 and it climbed rapidly about one year before the mainshock. The temporal variations of *b* values of three segments are highly consistent with the spatiotemporal migration pattern in Figure 6b, which further verifies the reliability of Figure 6b. it is also confirmed that the area where the nucleation point is located has stable lower *b* values on the long-term scale close to 10 years before the mainshock.

For a detailed explanation of the above content, please refer to Figure S3 and the text in the *Supplementary Materials*. We also briefly described the above supplementary content in the " Spatiotemporal Heterogeneity of *b* values" section of the revised manuscript. This added Figure S3 is also posted here.

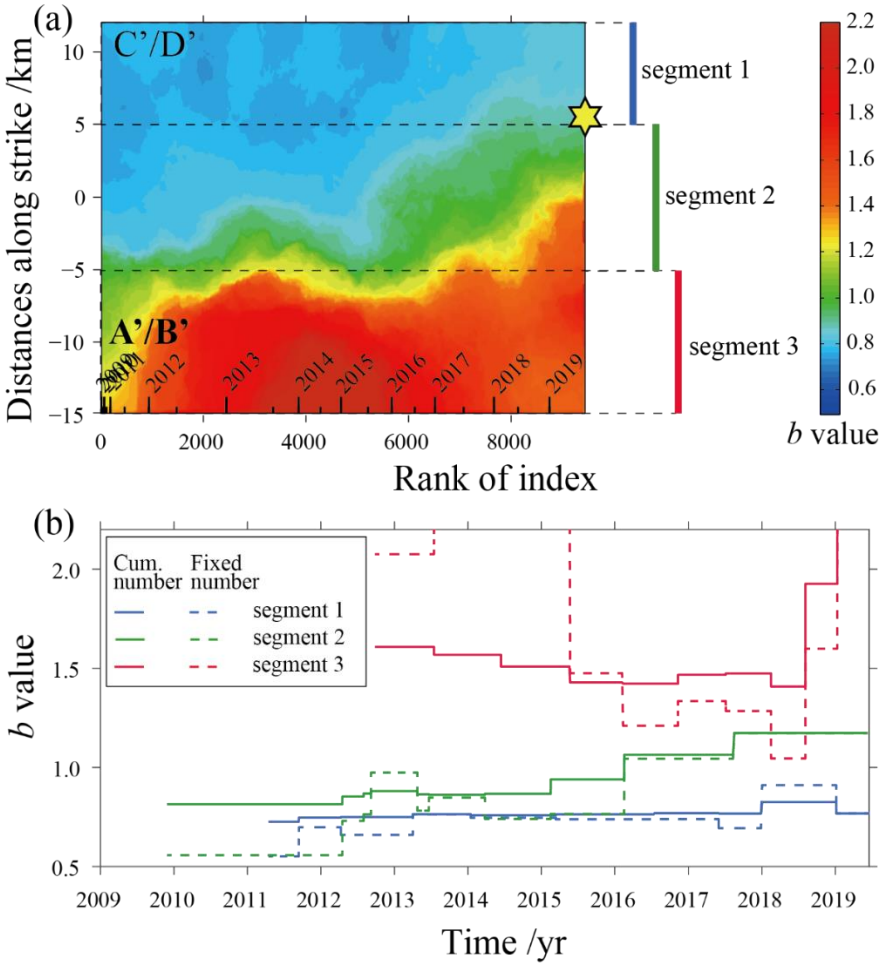


Fig. S3 The temporal variations of the *b* values before the Changning earthquake. (a) The temporal and spatial distribution of *b* values (Figure 6b) before the Changning earthquake and the division of spatial segments (Segment 1, 2 and 3) for the study of temporal variations of the *b* values. (b) The temporal variations of the *b* values in three segments before the Changning earthquake. The solid lines and the dashed lines respectively represent the *b* value results obtained by using a fixed window of 300 seismic events and a window of gradual cumulative increase with 300 seismic events, and different colors

indicate the results on different segments.

2. It is well known, that the b- value estimation methods may be sensitive to both magnitude range and completeness level. Did You check Your methods towards this issue?

RE: The question pointed out by the reviewer is very important. We have added some work in the *Supplementary Materials* to discuss whether the *b* values calculation results are sensitive to completeness level. we randomly deleted 13.5% of the 18371 events (the same as the number of events lost in the relocation) in space and recalculated the *b* values of Figure 4a and the uncertainty of Figure 5a. The Figure S5 in the *Supplementary Materials* show that the distribution of the *b* values and its uncertainty obtained after this loss of part of the events is still relatively close to Figure 4a and Figure 5a, which also implies that the completeness level will not significantly affect the results of this paper. For a detailed explanation of the above content, please refer to Figure S5 and the text in the *Supplementary Materials*. This added Figure S5 is also posted here.

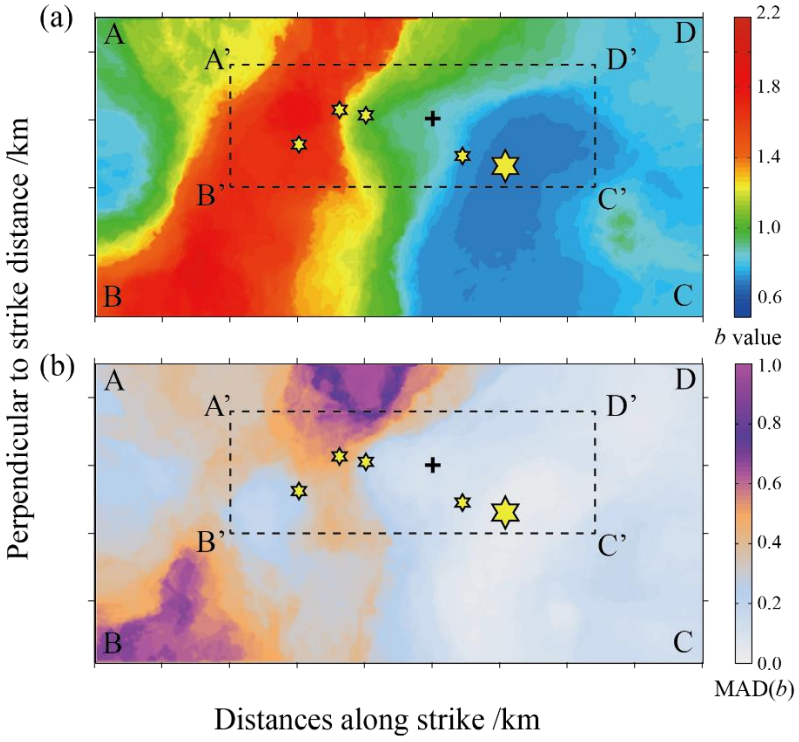


Fig. S5 Distribution of the ensemble *b* values (a) and MAD *b* values (b) of the best-100 solutions prior to the Changning M_S 6.0 earthquake, in which the events used were randomly deleted from 13.5% of the 18371 events.

3. I can't find the completeness level value in the manuscript. What was the completeness level of the data set? I think, it should be calculated and taken into account in the analysis. Otherwise, the *b*-value computations may be spoiled.

RE: The analysis of the minimum completeness magnitude M_c of the earthquake catalog is an important basis for the calculation of *b* value. we added Figure S4 of the M_c distribution in the

Supplementary Materials, and it is also posted here. Please refer to the section of "Minimum Completeness Magnitude and its Influence on the Calculation of *b* Values" in the *Supplementary Materials*.

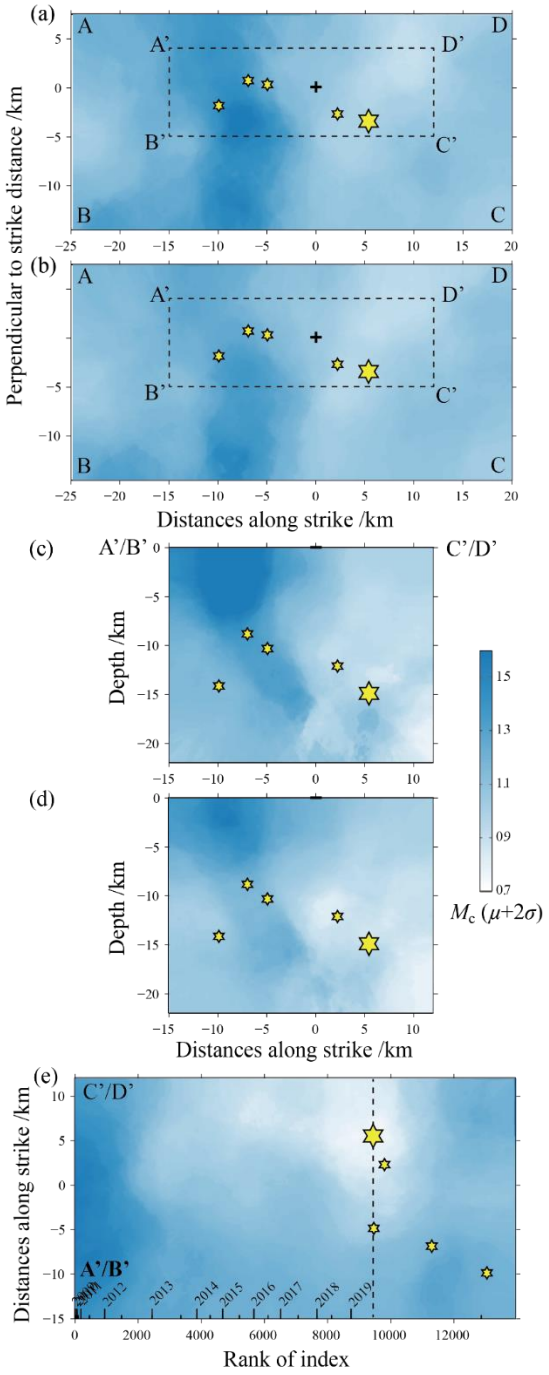


Fig. S4 Distribution of minimum magnitude of completeness $M_c(\mu+2\sigma)$. (a) Distribution of $M_c(\mu+2\sigma)$ on the horizontal plane after the rotation calculated by the events before the Changning M_S 6.0 earthquake; (b) Distribution of $M_c(\mu+2\sigma)$ on the horizontal plane after the rotation calculated by all the events including the aftershocks of the Changning M_S 6.0 earthquake; (c) Distribution of $M_c(\mu+2\sigma)$ in the rectangular frame A'B'C'D' on the depth profile calculated by the events before the Changning M_S 6.0 earthquake; (d) Distribution of $M_c(\mu+2\sigma)$ in the rectangular frame A'B'C'D' on the depth profile calculated by all events including aftershocks of the Changning M_S 6.0 earthquake. The hexagonal star

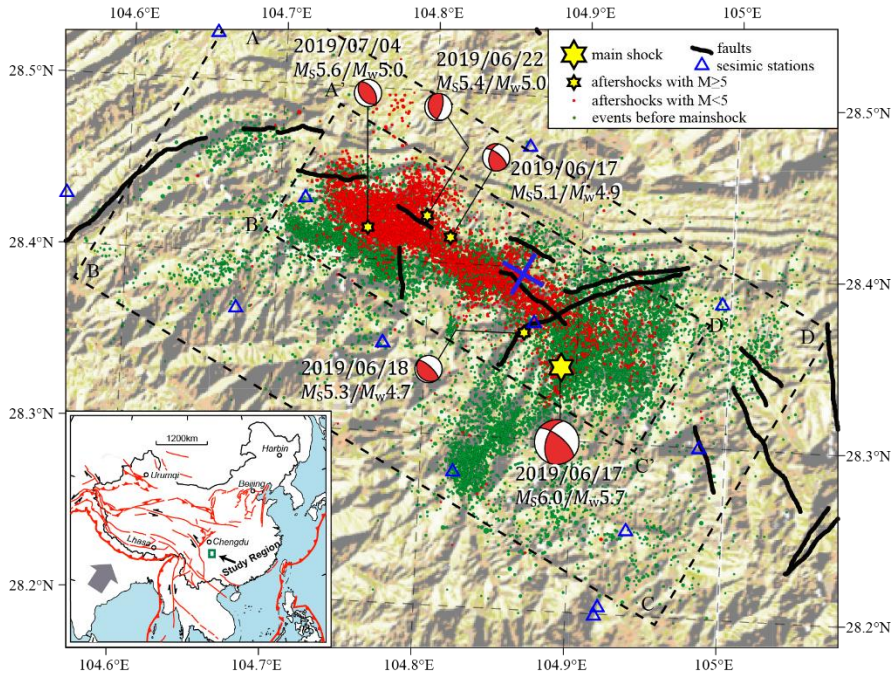
marks the locations of the mainshock and four aftershocks with magnitude no less than 5.0.

4. The last issue is related with the activity rate in the studied area. It was not included in the analysis. Activity rate of the events respectively to b-value may be very informative. It may be interesting to see, what was the activity on the considered area (eg. within Voronoi cells) and cross-sections.

RE: The activity rate proposed by the reviewer is very important information, but because the OK1993 model used in this article is a continuous function describing the magnitude-frequency relationship, so it is difficult to directly obtain the activity rate compared to the traditional G-R relationship. But anyway, the reviewer's suggestions are very enlightening, thank you again.

5. I would suggest to change the color of the fault lines to black in Fig. 1, because they are hardly visible when plotted together with the aftershocks.

RE: Thanks to the reviewer's suggestion, we have changed the color of fault lines in Fig. 1 to black, and the revised Figure 1 is posted here.



Review #2

I have reviewed the manuscript "Spatiotemporal 1 Heterogeneity of b Values Revealed by a Data-Driven Approach for June 17, 2019 Ms 6.0, Changning Sichuan, China earthquake Sequence" by Jiang et al. The paper focuses on investigating the spatiotemporal heterogeneity of b values for Changning Sichuan, China earthquake sequence, using a data-driven approach. Based on their analysis, the authors have shown strong spatiotemporal heterogeneity of b values on the horizontal surface distribution, depth profile distribution and distance-rank index map. The study of Jiang et al. provides detailed calculations of the spatiotemporal distribution of Changning earthquake sequence that are potentially important to improve the seismic hazard assessment. Moreover, this work may support the application of the data-driven methods to estimate better b values, which may be of interest to a broad audience. I suggest that the paper can be published with minor revisions. However, I have several concerns from the current version of this study, which are listed below.

RE: Thank the reviewer for your positive comments and encouragement.

1. The calculations of *b* values strongly rely on choice of cut-off magnitude (Harte, 2016). However, the authors did not show efficient information on this issue. I suggest the authors provide more information on choice of cut-off magnitude and completeness magnitude of the seismic catalog.

RE: We thank the reviewer for pointing this out. In order to show the results of the minimum completeness magnitude and discuss its impact on the calculation of the *b* values, we have added Figure S4 of the M_c distribution in the *Supplementary Materiasl*, and discussed whether the completeness of the earthquake catalogue affects the result of the *b* values. This added Figure S4 is also posted here.

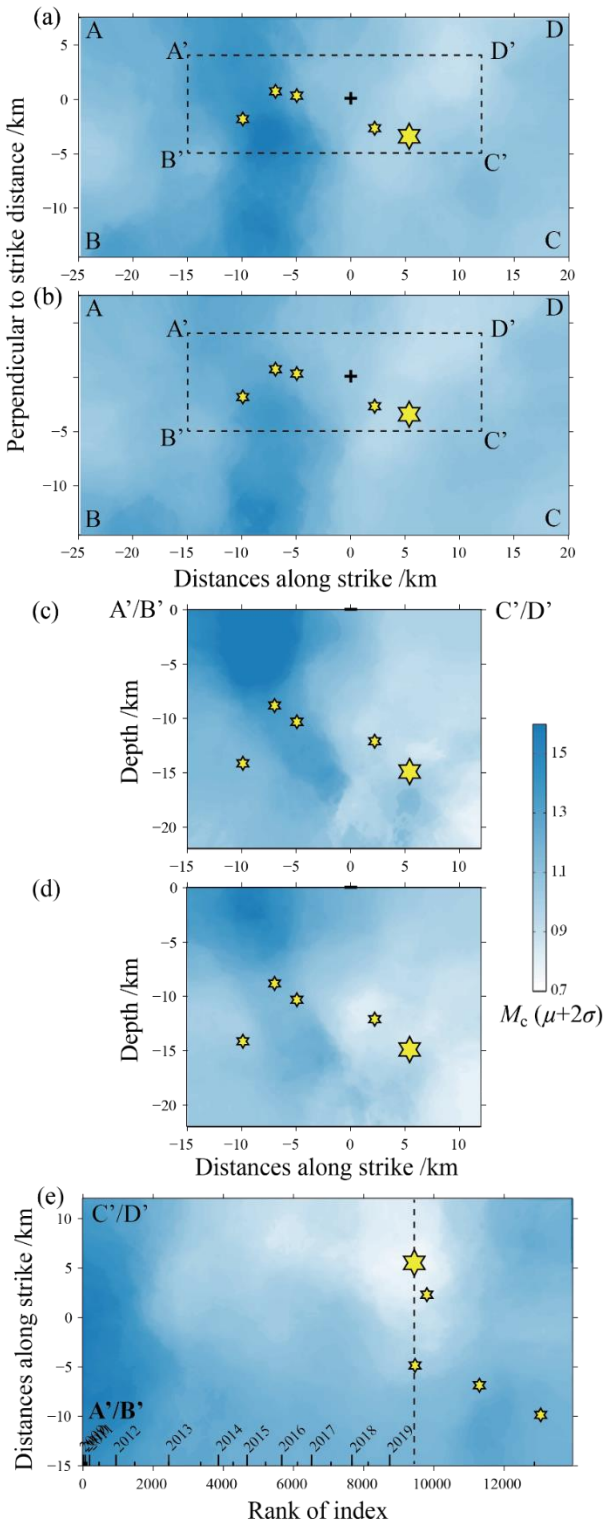


Fig. S4 Distribution of minimum magnitude of completeness $M_c(\mu+2\sigma)$. (a) Distribution of $M_c(\mu+2\sigma)$ on the horizontal plane after the rotation calculated by the events before the Changning M_S 6.0 earthquake; (b) Distribution of $M_c(\mu+2\sigma)$ on the horizontal plane after the rotation calculated by all the events including the aftershocks of the Changning M_S 6.0 earthquake; (c) Distribution of $M_c(\mu+2\sigma)$ in the rectangular frame A'B'C'D' on the depth profile calculated by the events before the Changning M_S 6.0 earthquake; (d) Distribution of $M_c(\mu+2\sigma)$ in the rectangular frame A'B'C'D' on the depth profile calculated by all events including aftershocks of the Changning M_S 6.0 earthquake. The hexagonal star

marks the locations of the mainshock and four aftershocks with magnitude no less than 5.0.

2. The choice of region selection is also an important issue in calculation of b values (Gulia and Wiemer, 2019; Dascher-Cousineau et al., 2019). For the data-driven method, how does the selection of region effect the calculation of b values? I suggest the authors at least discuss the potential impacts their selection of regions ABCD and A'B'C'D'.

RE: The question pointed out by the reviewer is very important. The data-driven method relies on a large number of random Voronoi meshing and automatic selection of BIC values to achieve close-to-real *b* values and other parameters, and the continuous function of the OK1993 model can also make full use of incompletely recorded seismic events. Due to the above two characteristics, the calculation result of the *b* value has little relationship with the selection of the region in theory. Considering that there are very few earthquake events outside the region ABCD, and region A'B'C'D' is the natural range of aftershocks, we did not further test whether changing the two regions will affect the *b* value results. In our ongoing research on data-driven methods for the calculation of b-values in a larger study area, we will consider this enlightening suggestion.

3. The authors provide a spatiotemporal distribution of *b* values on depth profile. Their findings are interesting and provide additional understanding of seismic hazard at depth. However, the uncertainties of depth location are usually large (several kilometers). The authors claimed the vertical uncertainty of relocation is 0.654 km, which may need more information to support this. At least, the authors should consider the potential influence of uncertainty of depth in the calculation of *b* values.

RE: We thank the reviewer for pointing this out. In order to investigate the potential influence of uncertainty of depth in the calculation of *b* values, we conducted random disturbance tests on the locations of the earthquake sources in Figure 4c.

We performed a random disturbance of ±1km in the horizontal position of the earthquake, and used the uncertainty of ±2km, ±4km and the random distribution in the range of [-22km 0km] to disturb the original depth respectively. The above-mentioned disturbance amplitude at these depths should be much larger than the uncertainty caused by the earthquake location method. In order to prevent the occurrence of air-quake with depth ≥0 km during random disturbance, we force the random number generator to run repeatedly until the depth <0 km.

The random test results show that the difference between the *b* values distribution and Figure 4c is not significant when the depth disturbance scale is ±2km, and the *b* values distribution can be kept similar even when the disturbance reaches ±4km. But when the depth is a completely random number, the distribution characteristics of the *b* values on the depth profile disappear. The above three random test results imply that the uncertainty of depth is difficult to significantly affect the

distribution characteristics of the *b* values in Figure 4c.

For a detailed explanation of the above content, please refer to Figure S1 and the text in the *Supplementary Materials*. We also briefly described the above supplementary content in the "Spatial Distributions of *b* Values on Surface and Depth Profiles" section of the revised manuscript. This added Figure S1 is also posted here.

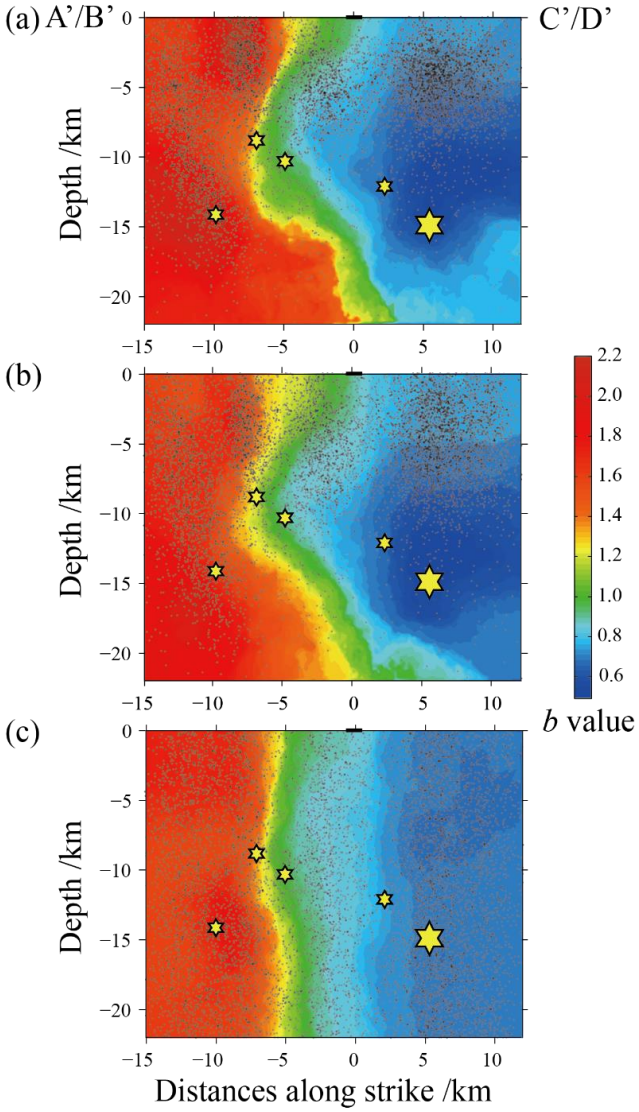


Fig. S1 The spatial distribution of the ensemble median *b* values on the depth profile obtained after random perturbation experiments on the focal depth in Figure 4c. (a) Distribution of ensemble median *b* values calculated from the earthquake catalog obtained by ±1km disturbance in horizontal position and ±2km disturbance in depth; (b) Distribution of ensemble median *b* values calculated from the earthquake catalog obtained by ±1km disturbance in horizontal position and ±4km disturbance in depth; (c) Distribution of ensemble median *b* values calculated from the earthquake catalog obtained by ±1km disturbance in horizontal position and random distribution in depth. The black dots mark the seismic events whose locations are randomly disturbed and used for *b* values calculation. The hexagonal star marks the locations of the mainshock and four aftershocks with magnitude no less than 5.0 that have undergone random disturbances.

4. Figure 4 clearly provide spatiotemporal heterogeneity of *b* values before the Changning earthquake and for the entire study period. I suggest the authors add results of *b* values for Changning mainshock and aftershock sequence to present comparisons between *b* values before and after Changning mainshock.

RE: Thanks for the reviewer's suggestion. We used the mainshock and aftershocks to calculate the *b* values and its uncertainty for comparison with Figures 4 and Figure 5. For the corresponding results, please see Figure S2 in the *Supplementary Materials*.

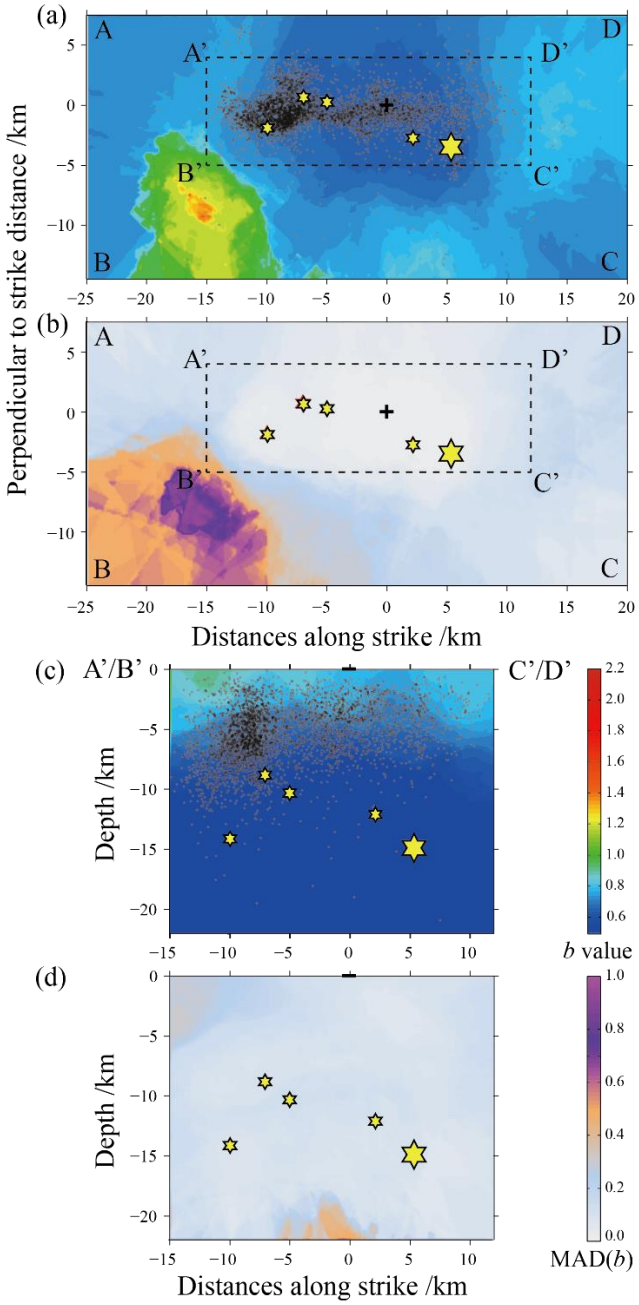


Fig. S2 The spatial distribution of the ensemble median *b* values and MAD *b* values of the best-100 solutions after the Changning M_S 6.0 earthquake. (a) The ensemble median *b* values is distributed on the horizontal plane after the rotation; (b) The ensemble MAD *b* values is distributed on the horizontal

plane after the rotation; (c) Distribution of the ensemble median *b* values in the rectangular frame A'B'C'D' on the depth profile; (d) Distribution of ensemble MAD *b* values in the rectangular frame A'B'C'D' on the depth profile. The black dots mark the seismic events used in the calculation.

5. Line 270-275. The authors show that the occurrence of the Changning mainshock has a great impact on the continuity of temporal b values. In addition, there were four M>=5.0 aftershocks, which might also contribute to the continuity of temporal *b* values. Their effects should be considered or discussed.

RE: The question pointed out by the reviewer is very important. Like the main shock, the four M>=5.0 aftershocks will also contribute to the continuity of temporal variation of *b* values. We have made a supplementary discussion on this issue in the "Discussion" section and clarified the possibility of this impact. See the revised manuscript for details.

Minor/general comments:

Line 3. “Earthquake”.

L70. Consider replace “found out” with “investigated”.

L159-160. Remove “There were”.

L166. Remove “As can be seen”, and use capital form of “from”.

L184. Remove “is shown”.

L185. “shows”.

L189. “Distributions”.

L210. Remove “where”.

L259. Remove “occurred”.

L266. Remove “occurred”.

L300. I suggest replace “Although the b values to drop” with “Although the decrease of b values”

L301. Remove the last “,”.

L303. Replace “b values time variation” with “temporal variations of b values”.

L304. Replace “(Parsons, 2007), or some studies” with “(Parsons, 2007). Some studies”.

L312. Replace “calculated the pattern migration” with “investigated the migration pattern”. Replace “space” with “dimension”.

L316. “migration pattern”

L331. “we believe” to “we deduce”.

L333. “mainshock triggering” to “mainshock which triggered”

L334. “earthquakes” to “aftershocks”

L337. “the b values” are not specific, because there are a lot “b values” calculated in this manuscript.

L346. “people” to “studies”.

L347. The author should refer Gulia and Wiemer (2019) at the end of this sentence.

L351. Remove “a parameter calculation method for ”.

L364-365. The “fluid intrusion” and “increased pore pressure” is not opposite, therefore it could be confusing. Please, rephrase it. The same problem is in L367-368.

L367. “It may be that the mainshock triggered” to “The mainshock may triggered”.

L380. Lack of the second bracket.

L583. “fromall” to “from all”.

RE: Thanks to the reviewer for above detailed comments on the grammar and expression. We have revised them one by one.

L254-255. The sentence “study the entire period as a whole ….. were studied separately” should be rewritten.

RE: This sentence has been rewritten as “One is to study the seismicity before and after the mainshock as a whole, and the other is to study the seismicity before and after the mainshock as two independent periods”. Please refer to the revised version.

L315-318. The logic of this sentence is not clear. I can’t figure out how the migration pattern could lead to “increase the pore fluid pressure”. The author should rephrase this.

RE: The expression of sentence L315-318 is indeed logically problematic. We have revised it to "under the assumption that the fault - structural heterogeneity will not change in the short term, and based on previous understanding of the correlation between high b values and fluid induced seismicity, the migration pattern in this paper may be explained by the erosion of fluid in the high differential stress area where the nucleation point is located”. Please refer to the revised version.

Fig. 4. Is that possible to plot small earthquakes in the spatial distribution of the ensemble median b values? This could help compare spatial distributions of seismicity and b values.

RE: According to the reviewer’s suggestions, we plotted the distribution of earthquakes used in the calculation on Figure 4. Please see Figure 4 of the revised manuscript, which is also posted below:

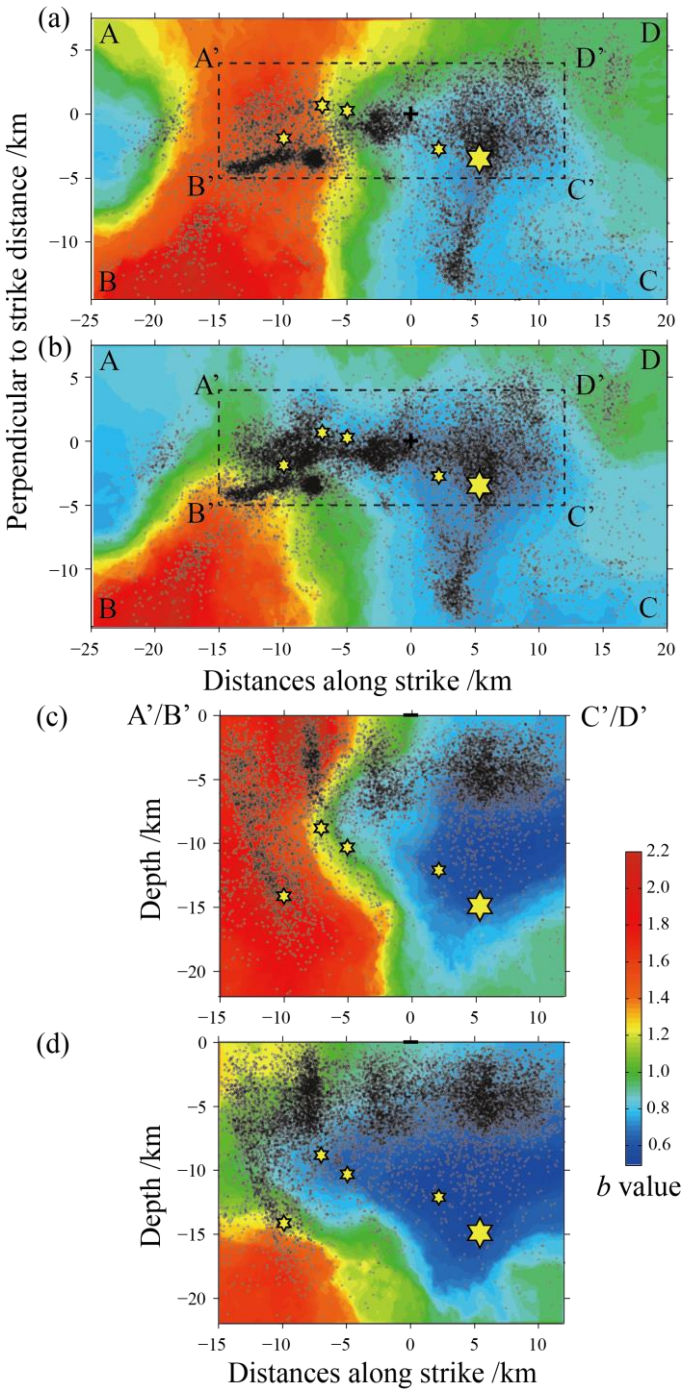


Fig. 4 The spatial distribution of the ensemble median *b* values of the best-100 solutions for N_v=2~40 in the Changning area. (a) The ensemble median *b* values before the Changning M_S 6.0 earthquake is distributed on the horizontal plane after the rotation; (b) The ensemble median *b* values obtained by calculation of all the earthquake including the aftershocks of the Changning M_S 6.0 earthquake is distributed on the horizontal plane after the rotation; (c) distribution of the ensemble median *b* values before the occurrence of the Changning M_S 6.0 earthquake in the rectangular frame A'B'C'D' on the depth profile; (d) distribution of ensemble median *b* values obtained by calculation of all earthquakes including aftershocks of the Changning M_S 6.0 earthquake in the rectangular frame A'B'C'D' on the depth profile. The black dots on each subgraphs mark the seismic events used in the calculation.

Fig. 6-7. I suggest plot the time at the upper x-axis to better show temporal evolution of b values.

RE: We added the time scale at the upper *x*-axis according to the reviewer's suggestions. Please see Figure 6 and 7 of the revised manuscript, they are also posted below:

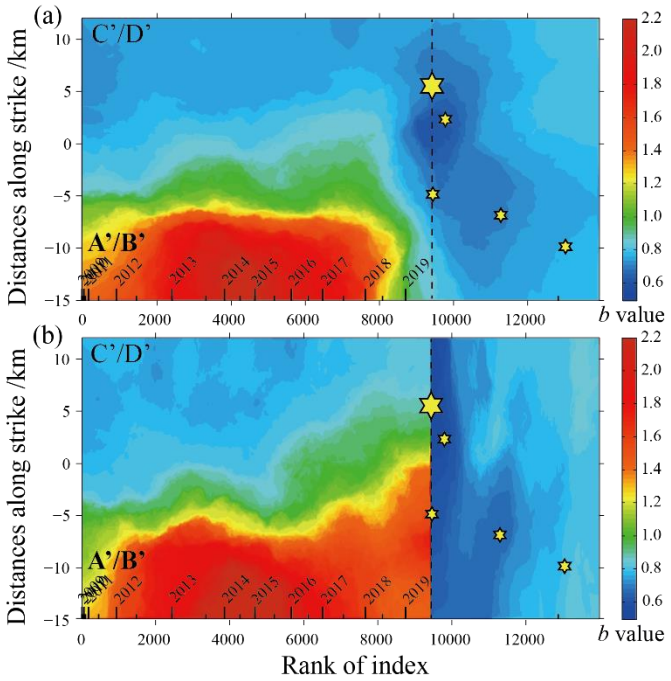


Fig. 6 Spatiotemporal distribution of the ensemble median *b* values of the best-100 solutions for N_v=2~40 on a 2-D space consisting of distance alone strike and rank of index. (a) The ensemble median *b* values obtained from all data before and after the Changning M_S 6.0 earthquake; (b) The ensemble median *b* values obtained from the data before and after the Changning M_S 6.0 earthquake, respectively. The vertical dotted line shows where the M_S 6.0 earthquake occurred. The time scale is marked at the upper *x*-axis, including the time of whole year marked by long tick and the half-year time marked by short tick.

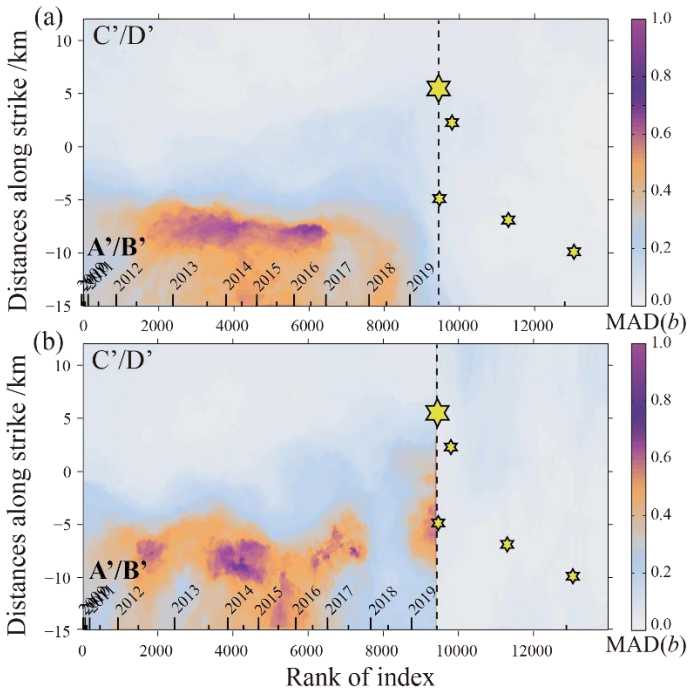


Fig. 7 Spatiotemporal distribution of the median absolute deviation (MAD) of the *b* values of the best-100 solutions for N_v=2~40 on a 2-D space consisting of distance alone strike and rank of index. (a) The ensemble MAD *b* values obtained from all data before and after the Changning M_S 6.0 earthquake; (b) The ensemble MAD *b* values obtained from the data before and after the Changning M_S 6.0 earthquake, respectively. The vertical dotted line shows where the M_S 6.0 earthquake occurred. The time scale is marked at the upper *x*-axis, including the time of whole year marked by long tick and the half-year time marked by short tick.