Weak Off-fault Structure Alters Overall b-Value of Xiaojiang Fault Zone: Implications for Seismic Hazard Analysis

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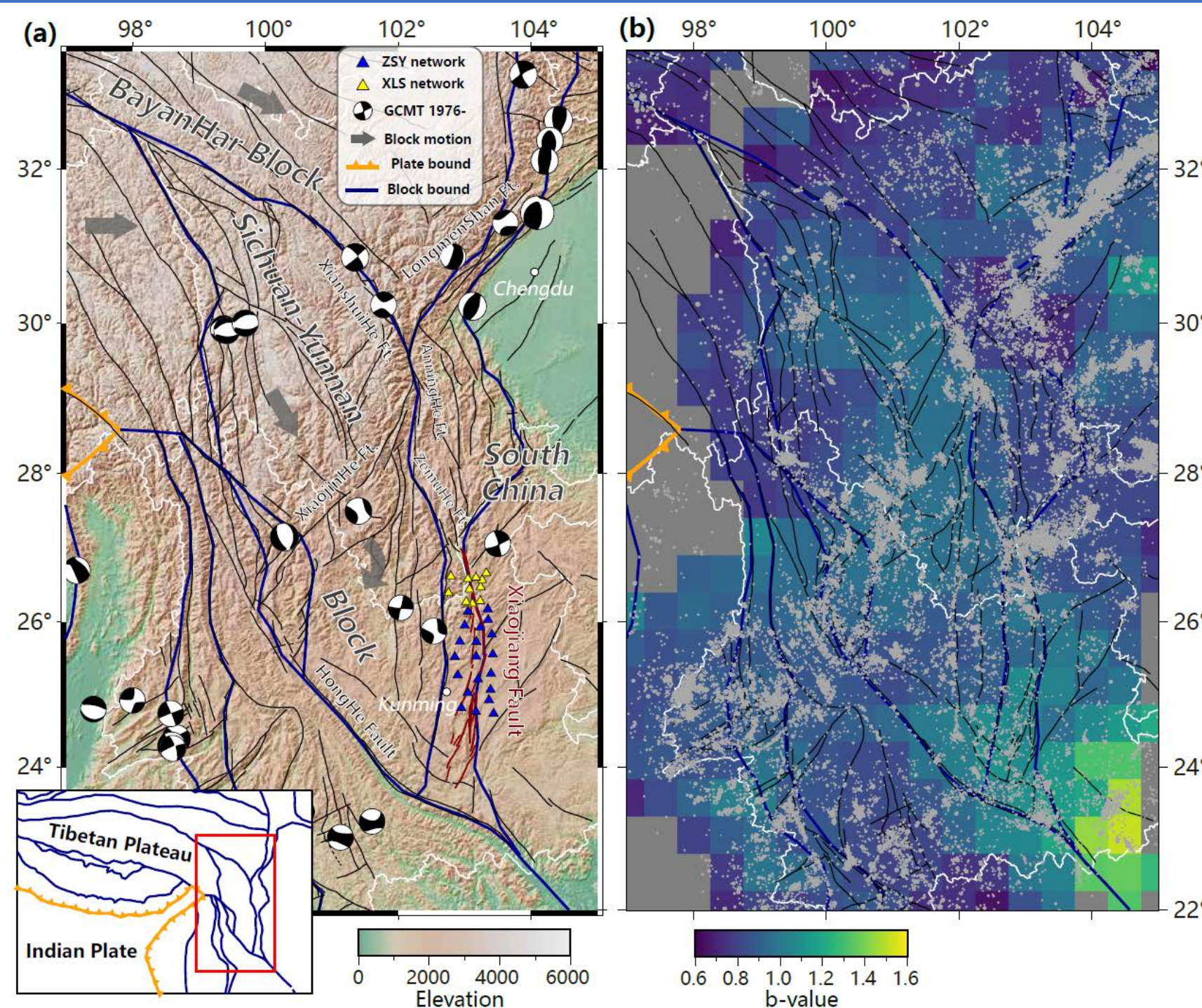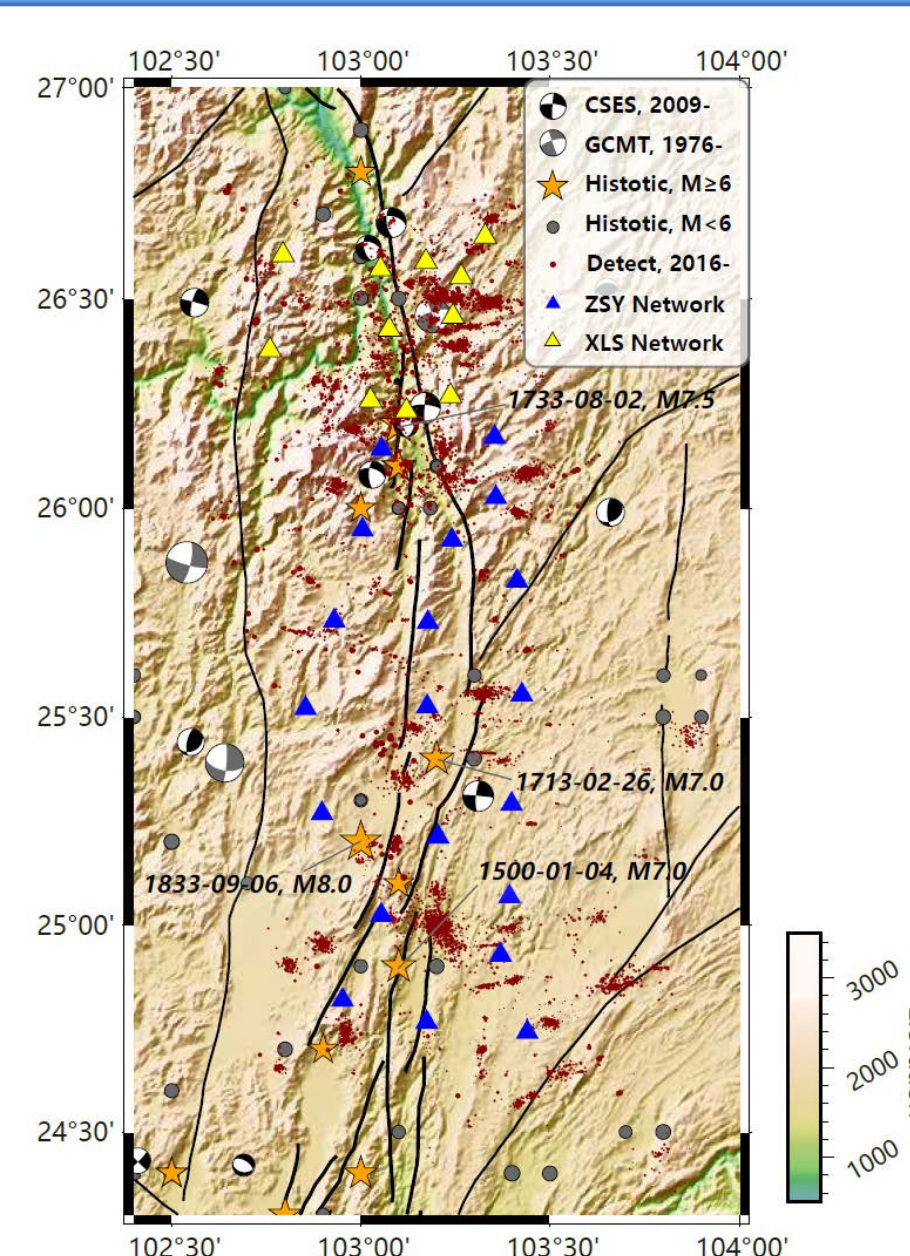Contact Information: *yijian_zhou@pku.edu.cn*

Abstract

Xiaojiang Fault Zone (XJF) lies in the southeastern boundary of Sichuan-Yunnan block. GPS measurements show a high locking rate in XJF (*Zhao et al. 2015*), indicating high seismic hazard; while regional seismicity gives high b-value, pointing to low hazard. Thus, We deployed 31 broad-band seismic stations along XJF to image the detailed seismicity pattern, trying to solve this paradox. More than 13,000 micro-seismic events are detected and located with a newly developed architecture, incorporating STA/LTA and matched filter. The micro-seismicity reveals abundant near-orthogonal off-fault structure along XJF, while the main fault trace is strongly locked and has a low seismic rate. To unravel the difference in slip behavior between main trace and off-fault structure, we further calculated the distribution of b-value and detected repeating events. Results show that the off-fault structure is characterized by a high b-value, high stress heterogeneity and are able to generate repeaters. These characteristics indicate a creeping slip behavior that alters overall b-value. We conclude that overall b-value estimation cannot directly implicate seismic hazard.

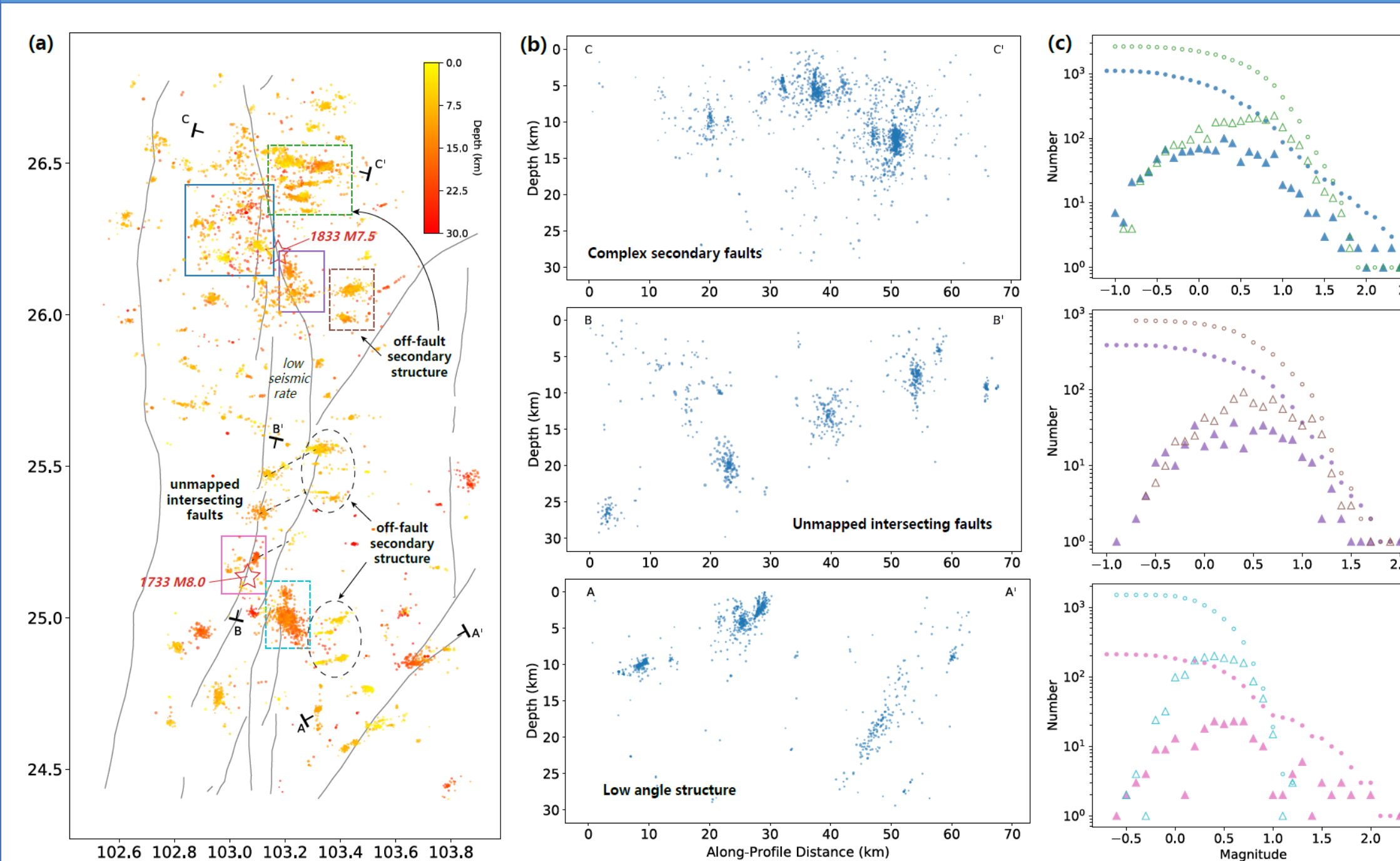## 1. Tectonic Setting & Seismicity

Figure 1. (a) Sichuan-Yunnan block and its movement. Plate boundary, block boundary and fault traces are marked with dark blue line, orange line with ticks, and black lines respectively. Block movement is denoted with dark gray arrows. The blue and yellow triangles denote broad-band seismic stations of ZSY and XLS network, respectively. (b) Regional seismicity and b-value. Seismic events are marked with gray dots. b-value is mapped to color.
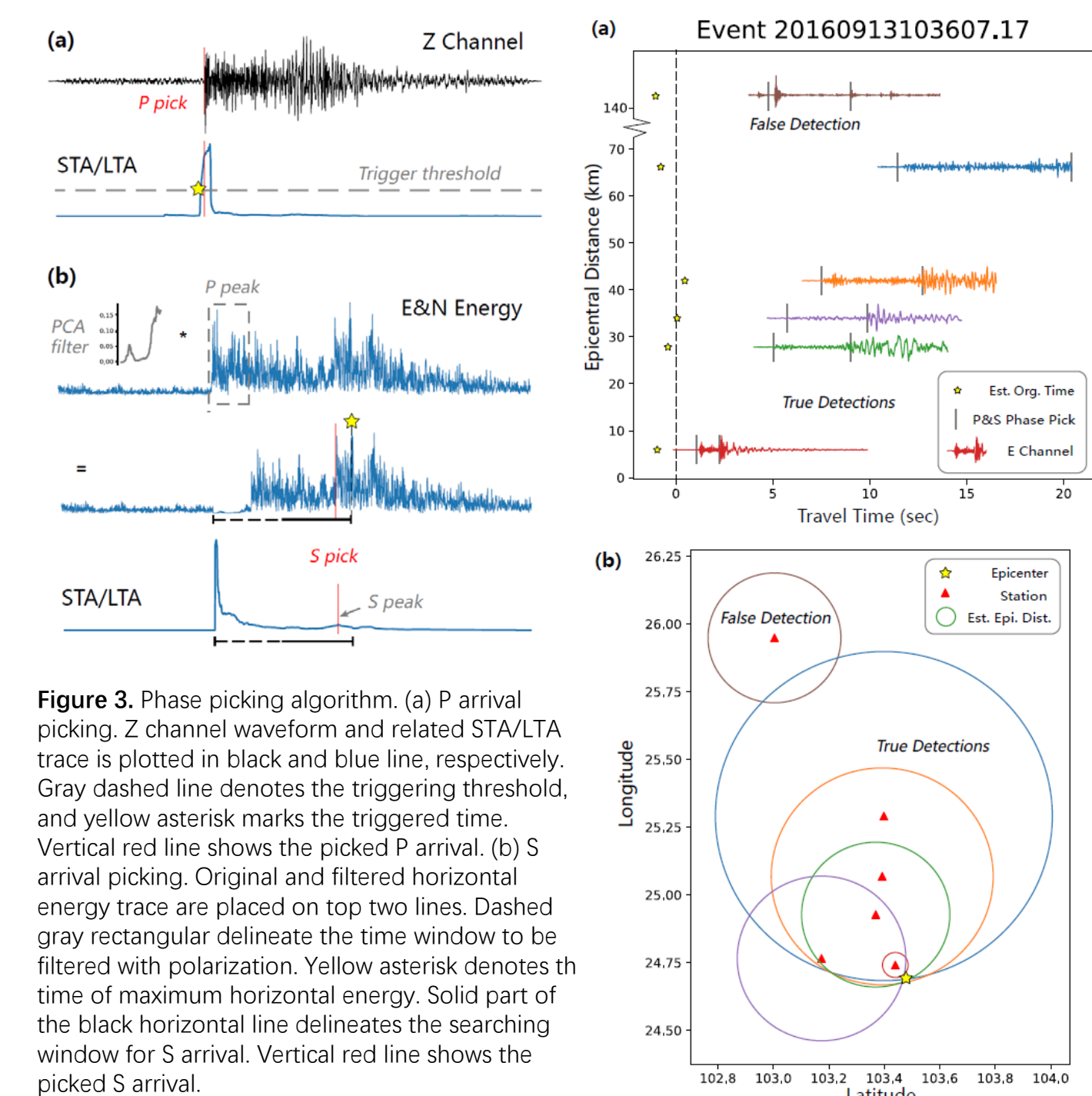
2. Seismic Data

Figure 2. Seismic Stations in XJF. Blue and yellow triangles denote broad-band seismic stations from ZSY and XLS network, respectively. The detected micro-seismic events are shown in dark red dots. Large and small historical earthquakes are denoted by orange asterisks and gray dots. Recent events from GCMT and CSES are shown in gray and black beachballs, respectively.
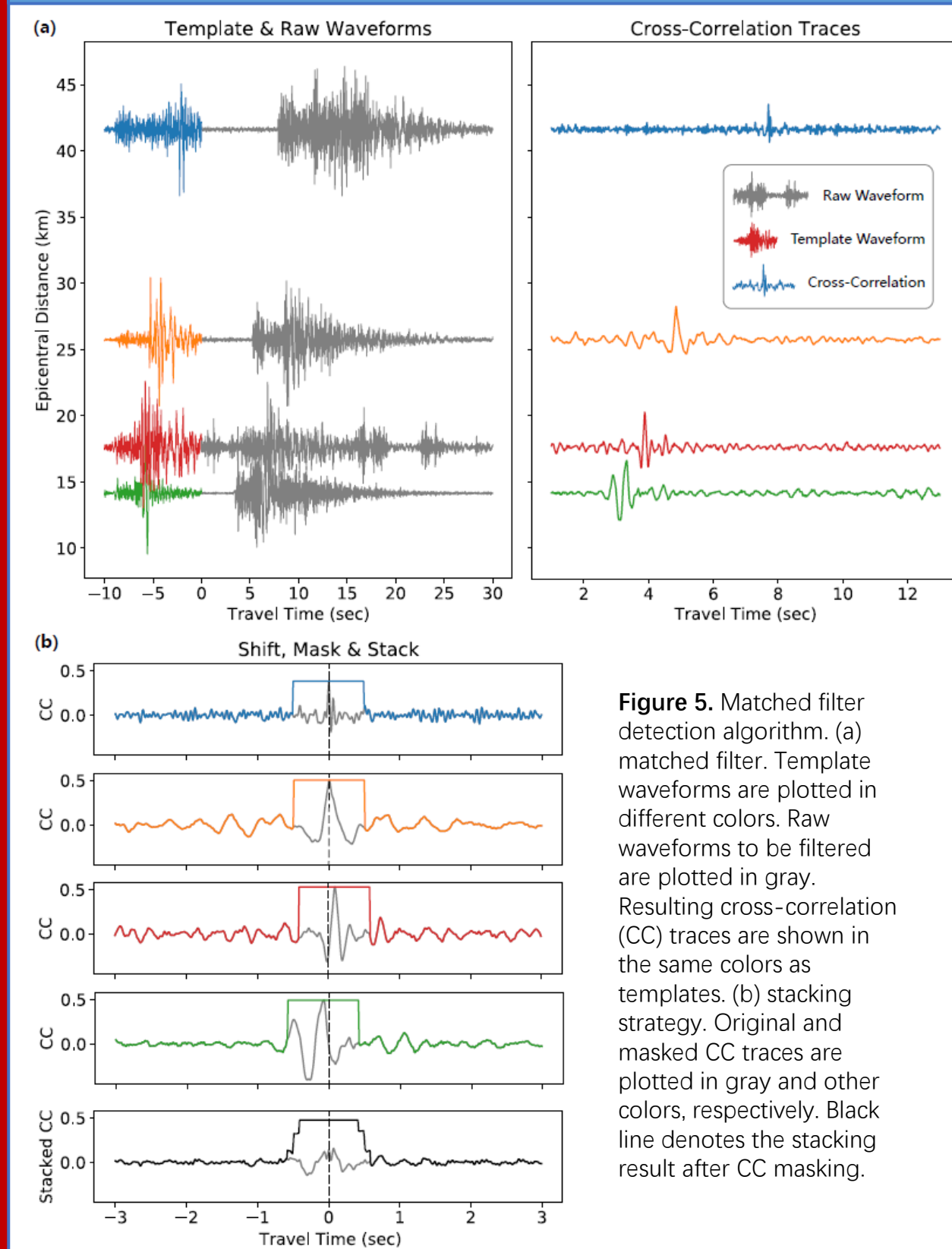
5. Evidence 1: Seismic Rate

Figure 6. Seismicity pattern of XJF. (a) annotated seismicity map. Events are plotted in dots colored by depth. Fault traces are plotted in black lines. Reference points for cross section in fig 6b are marked with capital letter. Solid and dashed rectangles enclosed events for FMD comparison in fig 6c. (b) cross sections. Blue dots denote events. Horizontal and vertical axis are along-profile distance and depth, respectively. (c) example FMD comparisons. cumulated and non-cumulated distribution are denoted with dots and triangles. The color of markers is one-by-one correspond to fig 6a, with solid and hollow markers correspond to solid and dashed rectangular in fig 6a, respectively.

3. Phase Picking & Association
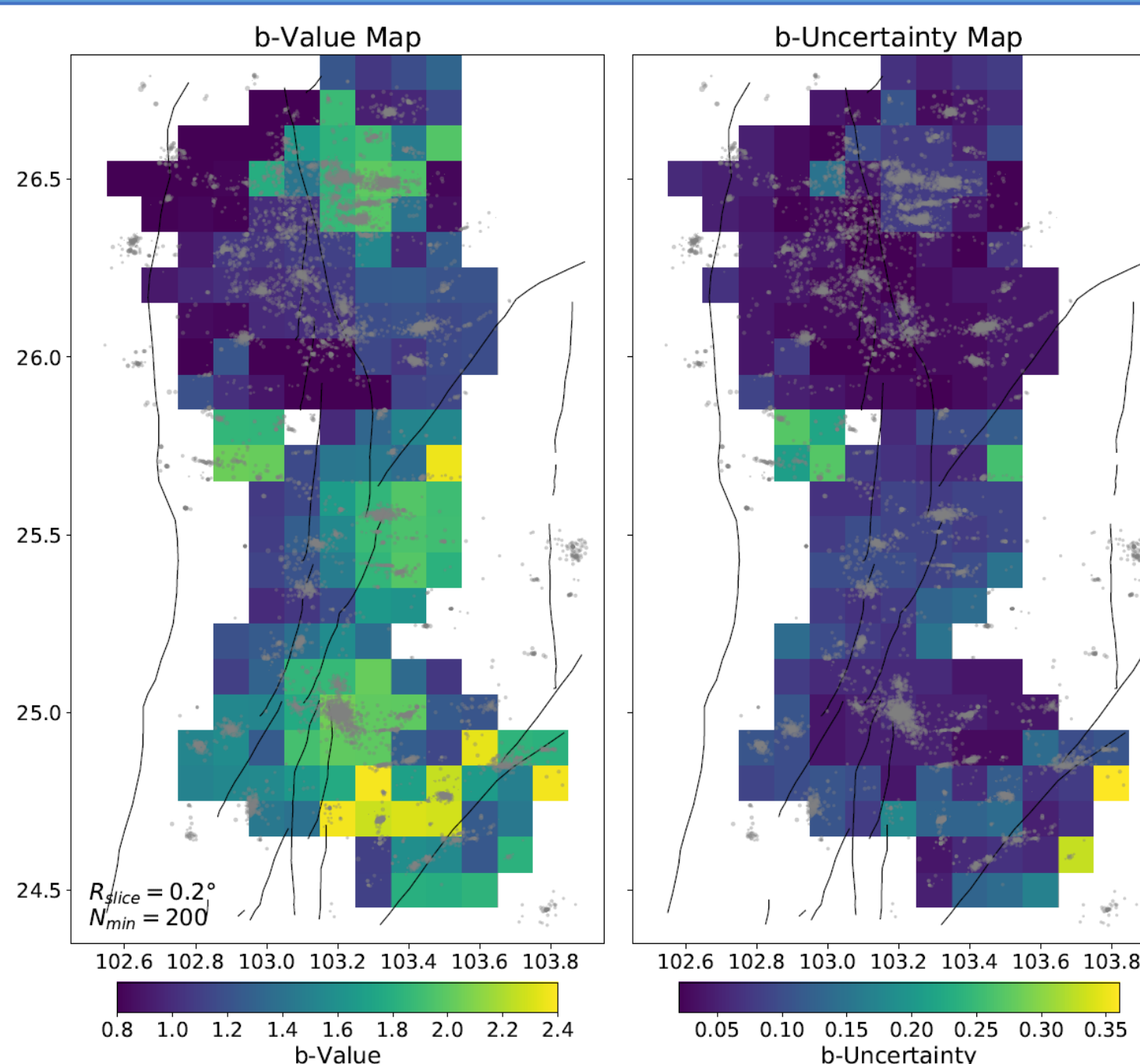
PAD: https://github.com/YijianZhou/PAD

Figure 3. Phase picking algorithm. (a) P arrival picking. Z channel waveform and related STA/LTA trace is plotted in black and blue line, respectively. Gray dashed line denotes the triggering threshold, and yellow asterisk marks the triggered time. Vertical red line shows the picked P arrival. (b) S arrival picking. Original and filtered horizontal energy trace are placed on top two lines. Dashed gray rectangular delineate the time window to be filtered with polarization. Yellow asterisk denotes th time of maximum horizontal energy. Solid part of the black horizontal line delineates the searching window for S arrival. Vertical red line shows the picked S arrival.

Figure 4. Phase association algorithm. (a) Temporal association. E channel waveforms are plotted in different colors. Vertical gray lines marks picked P&S arrivals. Yellow asterisks denote estimated origin time. (b) Spatial association. Red triangles show the location of seismic stations. Circles are plotted with a radius proportional to the epicentral distance. Yellow asterisk denotes the estimated epicenter.

4. Matched Filter

MSMS: https://github.com/YijianZhou/MSMS

Figure 5. Matched filter detection algorithm. (a) matched filter. Template waveforms are plotted in different colors. Raw waveforms to be filtered are plotted in gray. Resulting cross-correlation (CC) traces are shown in the same colors as templates. (b) stacking strategy. Original and masked CC traces are plotted in gray and other colors, respectively. Black line denotes the stacking result after CC masking.
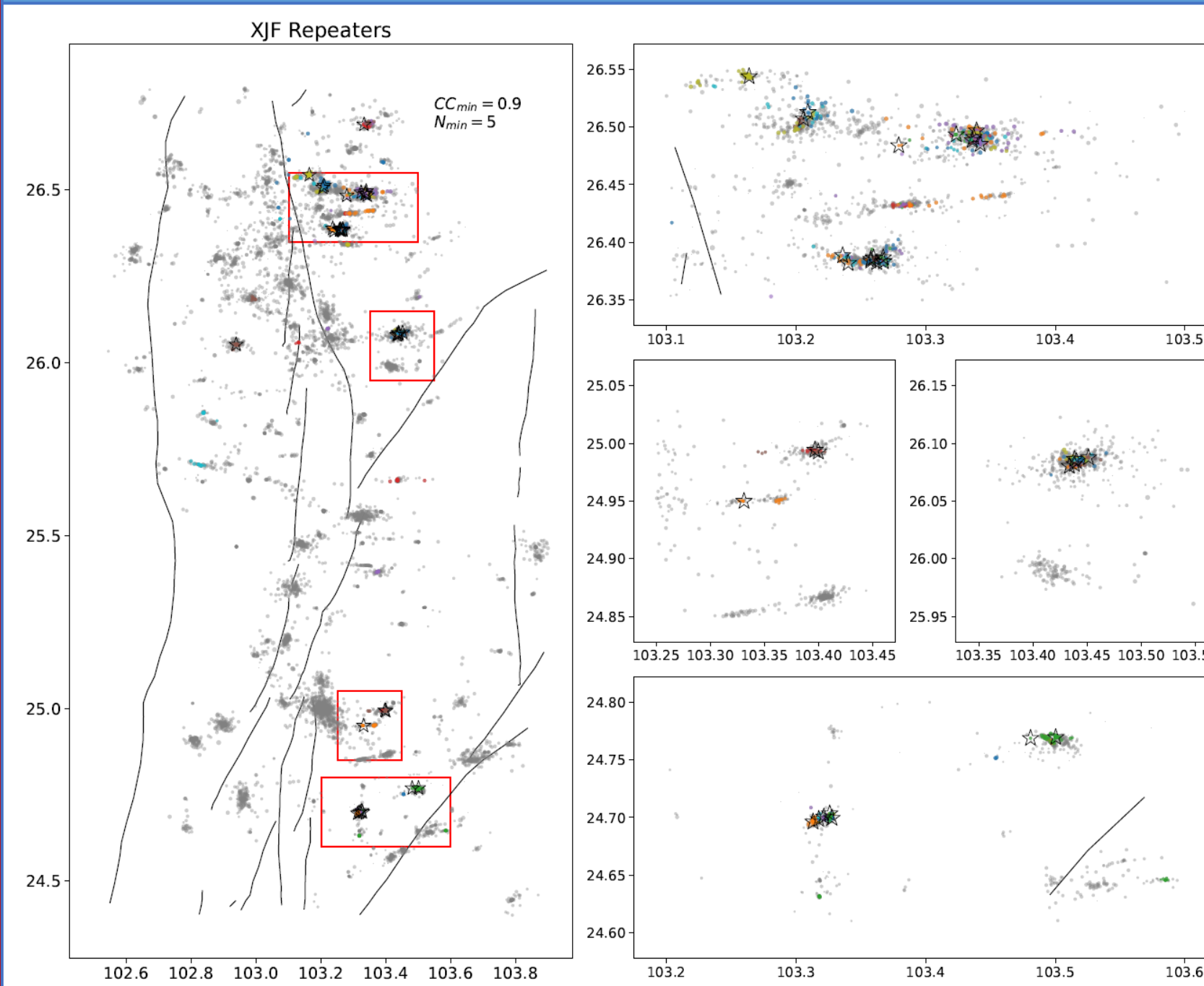
6. Evidence 2: b-Value

Figure 7. b-value map. b-value and its uncertainty are mapped by color, arranging from left to right. Events and fault traces are plotted in gray dots and black lines, respectively.

7. Evidence 3: Repeating Earthquake

Figure 8. Repeaters distribution. Left and right panel are whole and zoom-in view of repeater distribution, respectively. Events in clusters are plotted with different colors. Background seismicity and clusters with less than 20 events are plotted in gray and black dots, respectively. Red rectangles marks zoomed in regions. Repeater sequence of more than 10 events are denoted with hollow asterisks.

Reference

1. ZHAO Jing, JIANG Zai-Sen, NIU An-Fu et al. 2015. Study on dynamic characteristics of fault locking and fault slip deficit in the eastern boundary of the Sichuan-Yunnan rhombic block. Chinese Journal Of Geophysics,58(3): 872-885,doi: 10.6038/cjg20150316

2. Chinese Seismic Experimental Site 2019, Focal mechanism DOI:10.12093/01md.02.2019.07.v1; Relocated catalog DOI:10.12093/01md.02.2019.05.v1