The Nature of Burst-type Repeating Earthquakes in Taiwan: Where and When?

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EARTH SCIENCES STUDENTS SUMMER PROGRAM 2022

Introduction

Repeating earthquake sequence (abbreviated as RES), is a group of events with identical waveforms and occur at same location. In other words, rupturing the same patch of fault repeatedly at different times.

From numerical and laboratory studies, stable creeping in the surrounding of a repeater is found to be necessary to allow an asperity to recur with the same size. That means RES can provide crucial information for creeping behavior at depth.

Area A (Chi-Chi source area)

When we looked into the Chi-Chi source area, we found that those RES occurred majorly on the main rupture fault of the September 21, 1999 Chi-Chi earthquake. The time - number of repeaters plot (Fig. 3) suggests that the activity of RES seems to follow the Omori's law.

(Fig. 4) If we compare the post-seismic distribution and the locations of the RES, it seems that those RES occurred to coincide with the higher post-seismic rate area, which suggests that those B-type RES might be triggered by the stress perturbation due to the 1999 M7.3 event.

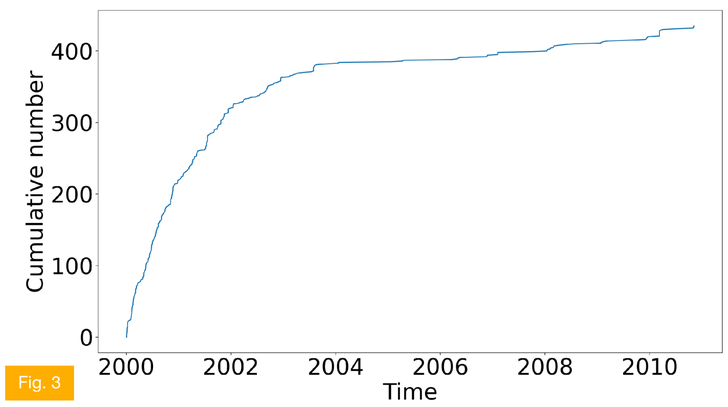


Fig. 3

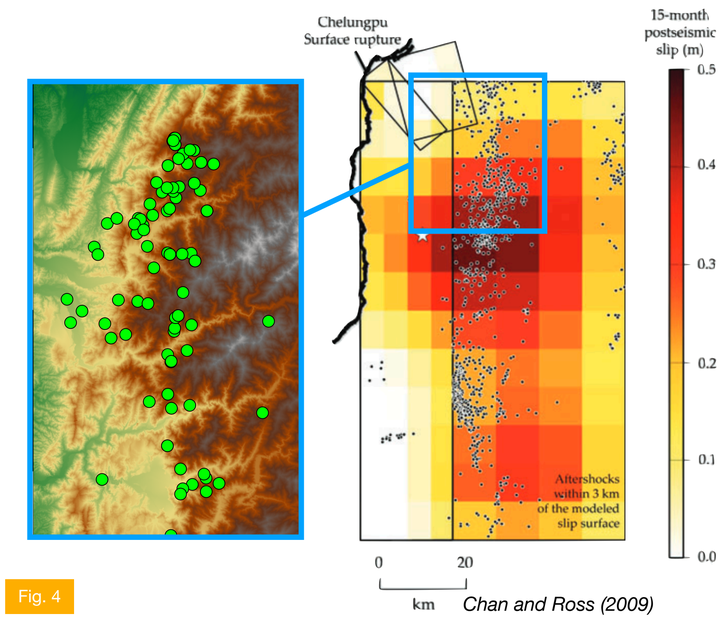


Fig. 4

(Left) Spatial distribution of B-type RES in Chi-Chi source area.
(Right) The post-seismic distribution of the 1999 M7.3 Chi-Chi event.

Area B (Southern Central Range)

In the southern Central Range area, you can visually identify several bumps from the time - numbers of repeaters plot (Fig. 5), we found that each bump in general represent one sequence, and the largest sequence occurred in 2001.

If we look into the spatial distribution of this 2001 sequence. It shows a clear migration from north to south (Fig. 7), and the temporal evolution (Fig. 8) suggest that this RES shows a swarm like sequence.

This suggests that the B-type RES occurred at the central range might share similar mechanism as earthquake swarm.

(Fig. 9) This area is also characterized by low Vp/Vs ratio and the enhanced activity of tectonic tremor, which suggest that stress perturbation that caused the RES is mainly caused by the fluid flow.

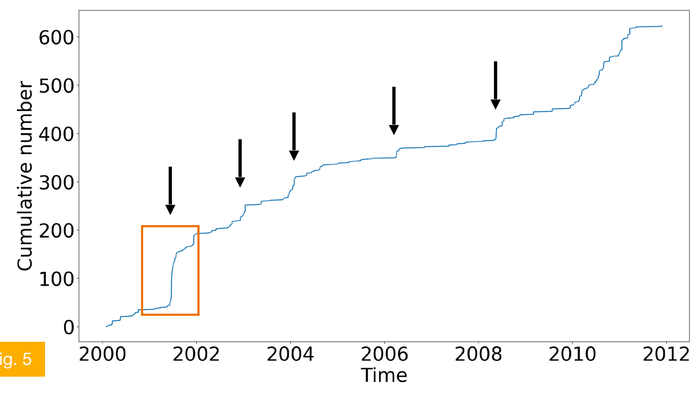


Fig. 5

Materials and methods

The RES are identified based on waveform similarity. For searching repeaters in Taiwan, Chen et al. (2020) used cross-correlation coefficients (CCC) of higher than 0.90 at more than 3 stations as the detection scheme.

But the workflow Chen et al. (2020) established may find several "false detections". Hence, in this summer, we've tried to improve the detection scheme by adding two reasonable constraints: (1) Instead of scanning the daily continuous waveform, only the earthquake catalog provided by Central Weather Bureau is considered now. (2) Applying distance threshold. Previous study has shown that for an event pair with magnitude smaller than 4, its hypocenter differences should be less than 150 meters to be qualified as a repeating pair. So, we only consider templates within 150 meters.

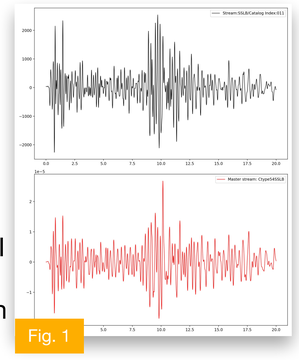


Fig. 1

Identical waveforms found after our improvements.

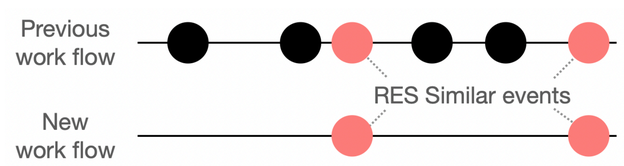
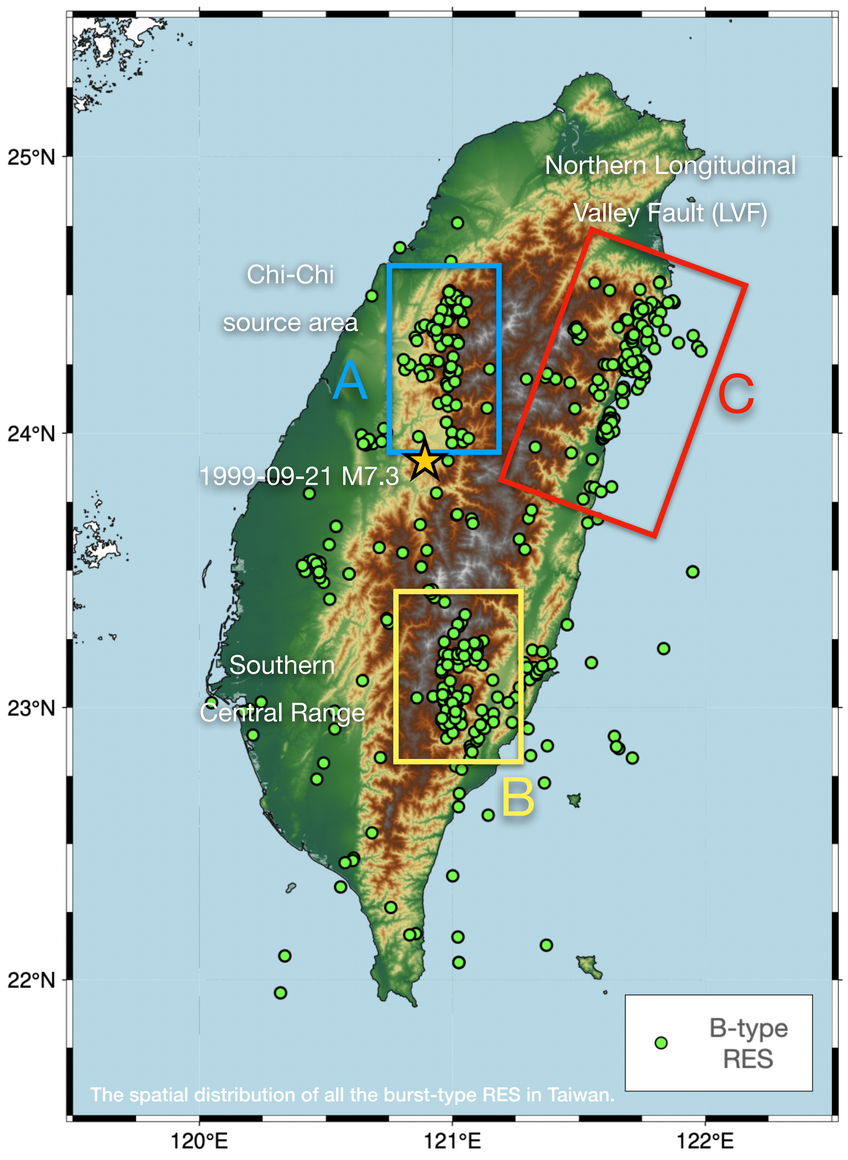


Fig. 2

For previous work flow, we found 6 events with CCC larger than 0.7, which has 4 false detections (black dots); through our new work flow, we can identify the similar events (pink dots) in a more efficient way.



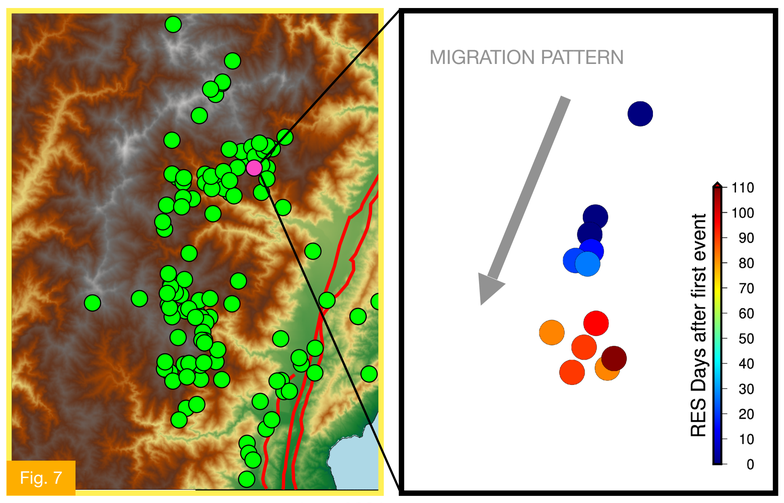


Fig. 7

The spatiotemporal distribution of the 2001 sequence shows a migration pattern.

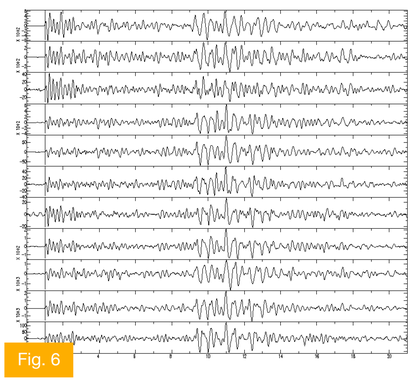


Fig. 6

Waveforms from the sequence in 2001, the waveform of events are identical.

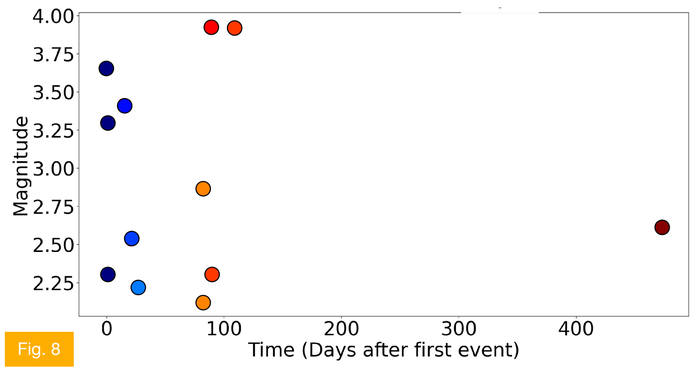


Fig. 8

The temporal distribution of the 2001 sequence shows a swarm-like sequence.

Area C (Northern LVF)

In the northern Longitudinal Valley Fault area, we see an increase of repeaters activity between year 2009 to 2010 (Fig 10). First we suspect this area shares the same cause of RES in Chi-Chi Source Area. So we've add grey dashed lines onto the plot representing events of Magnitude larger than 5.5 and there's no nearby events within this period with post-seismic response.

And if we take a closer look, we find a sequence which includes 8 repeaters with no migration pattern (Fig. 12). For this result, we exclude the possibility of influence of fluid. Thus, this could be further examine through future works.

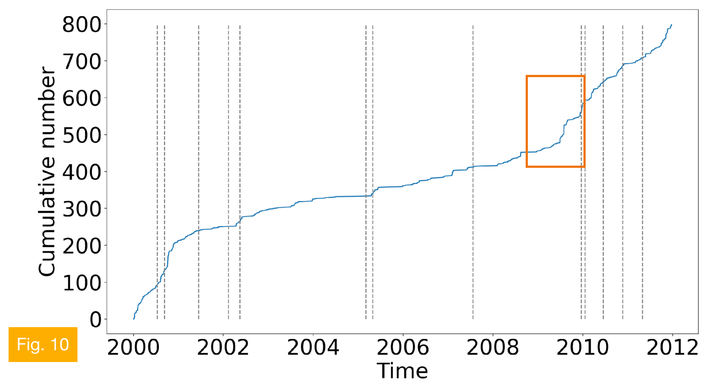


Fig. 10

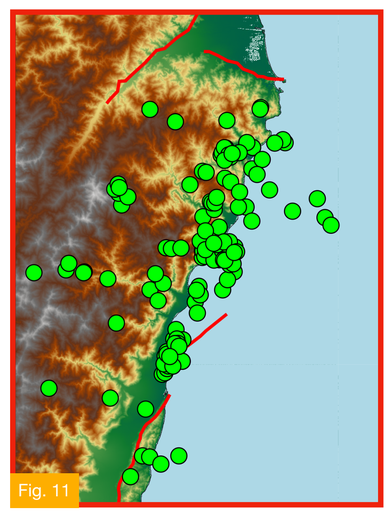


Fig. 11

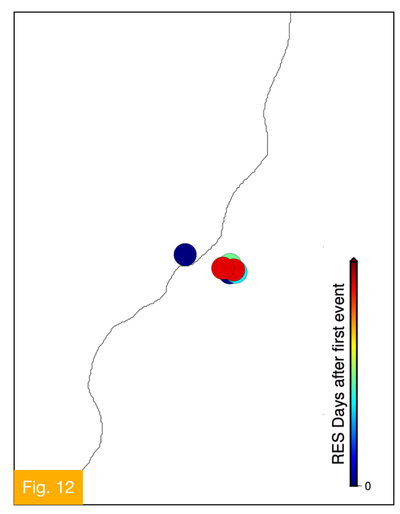


Fig. 12

The spatial distribution of B-type RES in northern LVF (Fig. 11) and the spatiotemporal distribution of the 8 repeaters sequence (Fig. 12) shows its triggering mechanism is neither nearby larger earthquake nor fluid activity.

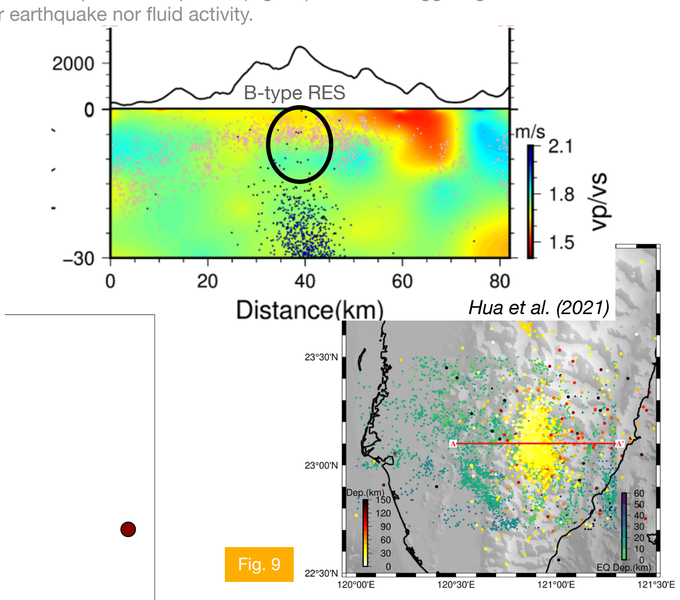


Fig. 9

Hua et al. (2021) suggests the southern Central Range area has low Vp/Vs ratio. By comparing their result and the distribution of the B-type RES (black circle), we suspect that the triggering mechanism in this area might be associated with fluid flow.

Summary

Using the catalog of repeating earthquake sequences (RES) conducted by Chen (2017), we studied the short-lasted sequence called "burst-type" (B-type) RES for **where**, **when**, and **how** they occurred in Taiwan.

The 485 B-type RES are mostly concentrated in (1) Chi-Chi source area (2) Southern Central Range with different physical mechanisms (3) Northern Longitudinal Valley Fault, a place with high creep-rate.

In the Chi-Chi source area, the location of RES are coincided with higher post-seismic slip of 1999 M7.3 Chi-Chi event. Their temporal distribution also reveals strong association with the Chi-Chi earthquake.

In the southern Central Range, the B-type RES are more associated with fluid activities.

In the northern LVF, the physical mechanism of B-type RES requires further examination through future works.

Acknowledgements

We thank for all the lectures and guidance from all the members of the Observatory Seismology Lab of ES, NTNU. For the lecture given by Prof. Kate every week in this summer, we've learned a lot about repeating earthquakes and many of the seismological knowledges. The program training section in the beginning did a significant enhancement to our abilities for programming. From the catalog and program established by Yaochieh Chen (2017) and much of the scientific supervision by Dr. Wei Peng and Prof. Kate.

Thank you for giving me this chance to join the lab for 2022 summer internship.

References