# Spatio temporal characteristics of the early-2014 tectonic tremors in Taiwan

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Different from earthquakes that usually take seconds to minutes to release the seismic energy, slow earthquakes are a class of earthquakes that release seismic energy over a longer period of time, from several minutes to hours. Their amplitudes are weak, therefore only seismometers can detect their activities. Over the past two decades, a new generation of dense and sensitive earthquake- monitoring networks has led to a series of discoveries that have clearly revealed an entire class of slow earthquakes ranging in size from  $M \sim 1$  to at least M 7.6 (Beroza and Ide, 2011).



(Courtesy of Kelin Wang)

Tectonic tremor has the following characteristics:

- (1) Weak amplitude and no obvious body wave phase.
- (2) Main frequency between 2 to 8 Hz

(3) Energy duration ranging from several minutes to several hours(4) Consistent arrival at stations tens of kilometers apart



Tectonic tremors that indicate slow slip at depth has been found to concentrate underneath southern Central Range of Taiwan, as indicates by circles in the mapview.

Different color represent different tremor catalogs published earlier. They appear to occur below the seismogenic zone in the orogeny and show anti-correlation with shallow seismicity.



#### 2018)

As indicated by the total duration of tremor per day (black vertical line in lower panel of Figure), the relatively high frequency of tremors occur in the middle of each year, revealing an annual variation. In early-2010,the frequent background seismicity may be associated with the 2010 M6.4 **Jiashian** event and several M > 5 aftershocks. In early-2008, an earthquake swarm composed of >800 earthquakes in 11 days, with a highest magnitude of 5.2, also seems to coincide with the active tremor rate. The possible correlation between tremor and seismicity was inferred

by the static stress from coseismic slip and earthquake swarms (Chuang et al., 2014).



Previous studies indicate that since the year of 2012, tremor activities seem to quite down.

So there are some questions.

- Is the smallest number of tremors in 2014?
- Does visual inspection by different person change the outcomes?
- Purpose of this project:
  - (1) Understanding how is tremor identified.
  - (2) Study the temporal and spatial behavior of tectonic tremors in Taiwan.



(吳郁柔,2020)

During this summer, I mainly worked on the data from January 1 to April 30, 2014. The main area of this study is southern Central Range of Taiwan. I will use the data from these stations to detect and locate tremor events.

The triangle on the picture is the station used to detect events, and the colored ones are for visual inspection.



There is my data processing. After removing instrument response ; Removing the linear trend and the mean ; band-pass filtering with 2-8 Hz ; envelope. I applied a program of Hypoecc, which uses the relative arrival between stations to locate possible events , and ask for similar enough energy burst taking place in more than 10 stations. If the data meet the threshold of hypoecc, we will get possible events. We next used the global and local earthquake catalogs to exclude earthquakes. Together with visual inspection, the final tremor catalog can be confirmed.

At the stage of visual inspection, the waveforms display from multiple stations is needed.

We ask for.

- (1) The arrival time difference of energy burst at each station is less than 20 seconds.
- (2)The duration of a single burst is greater than 50 seconds.
- (3)The inter-burst time is less than 80 seconds.
- (4)The duration of the entire event is longer than 150 seconds.

From January to April, There are 4950 possible events have been found by hypoecc. You will find that most of the detected events are concentrated in eastern Taiwan.



Through visual inspection, there are 33 tremor events have been found, and those events are concentrated in Central Range of Taiwan This indicates that **Careful and consistent treatment on visual inspection is important. The visual judgement by different person may be different.** 



When we look into the time-frequency plot which is spectrogram, we found that tremor has different frequency content at different stations. For example tremor in TPUB has frequency range from 0.5Hz to 8 Hz, and tremor in WTP has frequency range from 2Hz to 8 Hz.Whereas two other stations have narrower frequency.



And in this event on 4/24. You can also see the higher range of frequency from TPUB and WTP, and narrower two other station. Different events

produce very similar frequency pattern. We argue that different frequency behavior for different station is likely due to site effect.

Compared to previous study, the temporal distribution reveal very similar trend, as shown by the two figures. They tend to occur every 9-10 days, and during the time period of 80<sup>th</sup> to 90<sup>th</sup> day of 2014 there appears to show a small cluster of events.



Not only the judgement in visual inspection ,the selection of potential events also matter.

As shown by this table, the number of station used, definition of event duration could lead to very different number of tremor events.

目錄來源	戴心如(2016)	吳郁柔(2020)	顏元奕	本研
目錄時間	2007/01~2012/12	2013/01~2014/01	2014/01~2015/12	2014/01/01~2014/04/30
測站數目	南段;56站	中段;25站	南段;61站	南段;61
波形前處理	濾波 2 至 8Hz、振幅平方後低通濾波 0.2Hz			
Hypoecc 偵測參數	時間窗 300 秒、平移時間窗 150 秒、相似度門檻 0.6、10 個測站對為門檻			
二次偵測	波形自動辨識系統	無	無	無
持續時間定義	目視判斷持續時間 60 秒以上	目視判斷持續時間 60 秒以上	目視判斷持續時間 150 秒以上	目視判斷持續時間 150 秒以上
定位方法	Нуроесс	WECC (一維模型;波形 相關係數殘差)	無重新定位	Нуроес
目錄數量	1893 個	193 個	85 個	33
目錄持續時間	60~2300 秒	60~2550 秒	195~1775 秒	152~1937
主要震源區	中央山脈南段	中央山脈南段與 北段零星事件	中央山脈南段	中央山脈南段

(吳郁柔,2020)

There are two factors **affecting the number of tremor events** (1) **Differences in the distribution of station networks** 

 $\rightarrow$ Increasing in the number of stations will easier to reach the detection threshold of

"10 stations matching"

(2) Visual inspection and duration definition criteria are different

 $\rightarrow$  When the defined duration is longer, the fewer events can meet the threshold

## Conclusion

- Using January to April 2014 continuous data, 33 tectonic tremors are detected in this study. The detected tremors are located near southern Central Range.
- The number of tremor is about two times larger than previously identified.
- The frequency content of tremor varies from stations, which is likely associate with site effect.
- In time, tremors tend to occur quite regularly, with an inter-event time ranging from 9 to 10 days. There also exists a small cluster of events occurred during the time period of 80<sup>th</sup> to 90<sup>th</sup>. The similar pattern is also seen in the previous tremor catalog. This indicates that despite the different event number, different tremor catalogs have consistent trend in time.

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