Testing aftershock decaying model by using Taiwan earthquake catalog

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Summary

Based on Dieterich's aftershock decaying model, the initial aftershock production rate, $n(t_0)$ is proportion to the backbround seismicity rate $n(t^-)$ after the mainshock, and the seismicity rate $n(t)$ is proportional to the stressing rate ($\dot{S}$) (Dieterich, 1994). One important and potentially testable prediction of this model is that the relaxation time (t_r) of the aftershocks scales with the stressing rate, according to $t_r = \frac{a\sigma_n}{\dot{S}}$

Here, We use the Taiwan CWBSN (1991-2006) catalog to examine this aftershock decaying model. We use three aftershock sequences piror to the *Chi-Chi* earthquake, and two secondary aftershock sequences after the *Chi-Chi* earthquake in the western Taiwan. Our result suggests that relaxation time t_r are qualitativity proportional to $1/\dot{S}(0^-)$ before the *Chi-Chi* earthquake. Also, the initial seismcity rate in a secondary aftershocks sequence is proportional to the seismicity rate right before the secondary mainshock. Our observation also suggests that the ratio of the secondary aftershock seismicity rate follows the same decaying model as the primary aftershock seismicity rate decay, as expected form the models

Aftershock decaying model

To fit the aftershock seismicity rate, we use 3+1 parameters: $n(0^-)$, t_r, d and p in eq(1) and eq(2). In order to fit the seismicity rate of the secondary aftershocks, we first use eq(1) to model the primary aftershock seismicity rate $n(t_{abs})$ then use eq(2) to fit the secondary seismicity rate.

Eq(1)

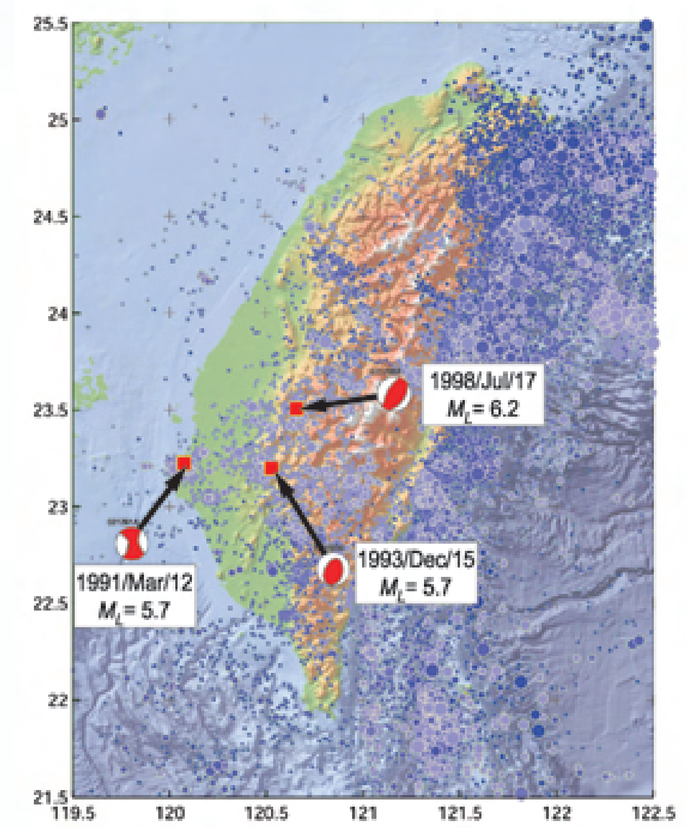
$$n(t) = \frac{n(0^-)}{\left[(\frac{1}{d^{\frac{1}{p}}} - 1)\exp(\frac{-t}{t_r}) + 1\right]^p}$$

Eq(2)

$$n(t) = \frac{n(t_{abs})}{(\frac{1}{d} - 1)\exp(\frac{-t}{t_r}) + 1}$$

d	the ratio of seismicity rate before and after the mainshock
$n(t)$	seismicity rate
$n(0^-)$	background seismicity rate before the mainshock
$n(t_{abs})$	ongoing seismicity rate if without the secondary mainshock
p	adjustable coefficient, usually ~1
t_r	relaxation time, time for seismicity to return to background state
t	time, time after the mainshock

Relaxation time in different tectonic region



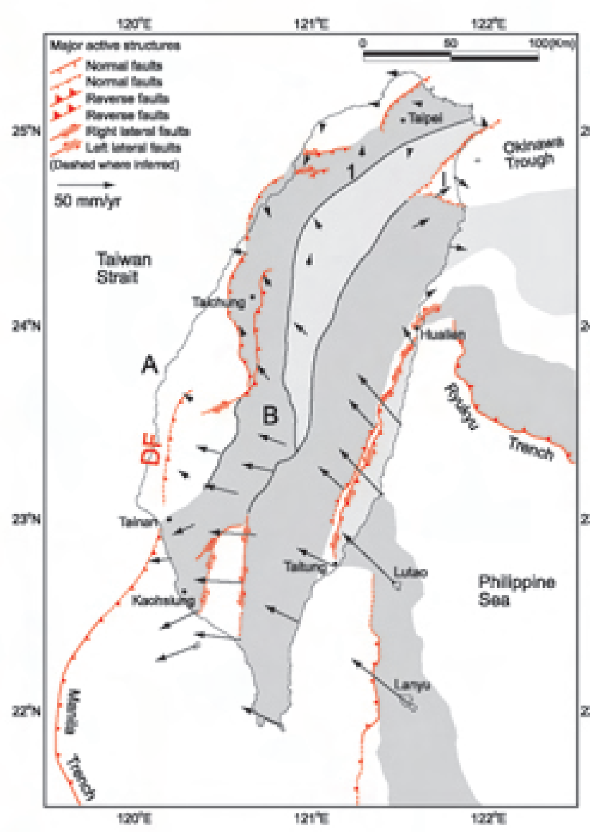
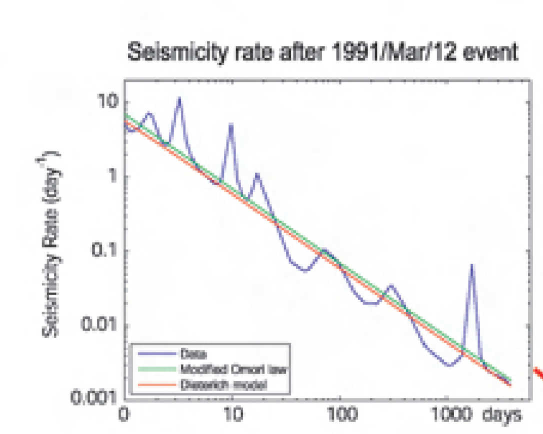
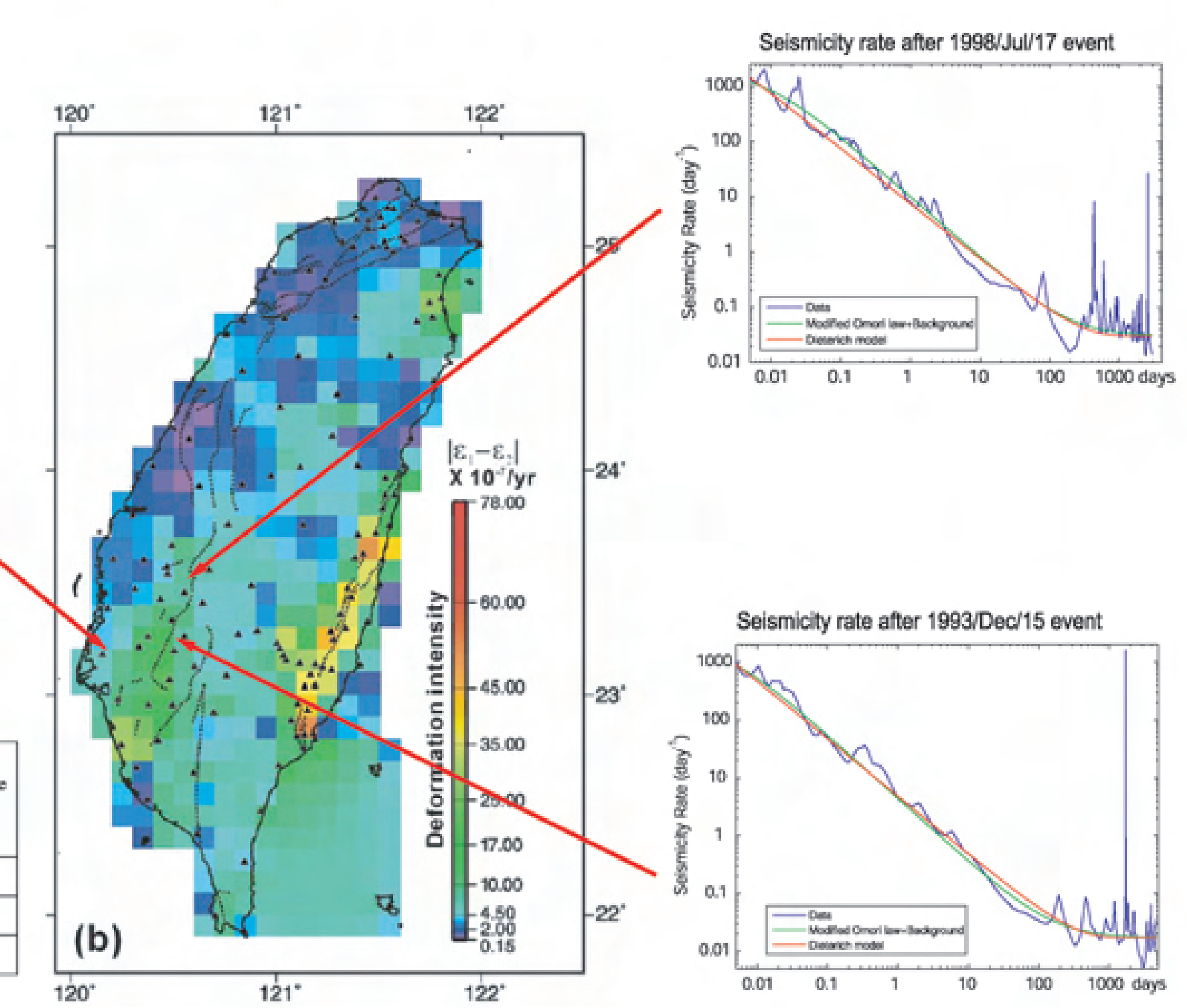


Fig. 1 Regional seismicity (1991-1999) and 3 selected mainshocks before the *Chi-Chi* earthquake. These 3 events are located in western foothills to coastal plain area in the southwestern Taiwan. Each of them are followed by a series of aftershocks in the surrounding area (6-10km in radius). The focal mechanisms from Havard CMT solution. Mainshocks' local magnitude from CWBSN catalog.

Fig. 2 Active tectonic setting and major tectonic elements around Taiwan (Shyu *et al.*, 2005). The major active structures are shown in red. The different color shows different tectonic elements. Black arrows show GPS vectors before the *Chi-Chi* earthquake relative to the stable Eurasian continental shelf (Yu et al.,1997). A: western coastal plain, B: foothills, DF: deformation front. Compare with the regional seismicity map, we can find the three selected events are in two different tectonic region. The western-most event is setting on the minor deformed foreland basin, and other two events are in the western foothills which is dominate by the active fold and thrust belt.





Major parameter of aftershocks

Event Time	Magnitude (M_l)	Affecting radius (KM)	Cutoff Magnitude (M_c)	Mean aftershock depth (-KM)	Relaxation time t_r(Days)
1991/Mar/12	5.7	11	3.5	-12.5	>4000
1993/Dec/15	5.7	6	2.5	-11.6	~280
1998/Jul/17	6.2	7	2.5	~-9	~250

Table. 1 This table list the major parameter we use in these 3 aftershock sequence. d is set to 10^6 In these 3 events. p is also fix to 1 to fit the original Dirterich's model. It seems that the mean depth of aftershocks is not vary too much, we believe *tr* can reflect the local stressing rate.

Fig. 3 The aftershock modeling result of 3 selected events. The map in the middle part from Change et *al.*(2003). It shows the 8 years average strain rate in Taiwan area. Although it do not have good constrain along the coast area, it still shows the qualitativity low strain rate west of the deformation front (see Fig.2). It is consisting with the prediction of our observation in the 3 selected aftershocks sequence that the western-most event should have the lower stressing rate than the other two area.

Secondary aftershocks after Chi-Chi earthquake

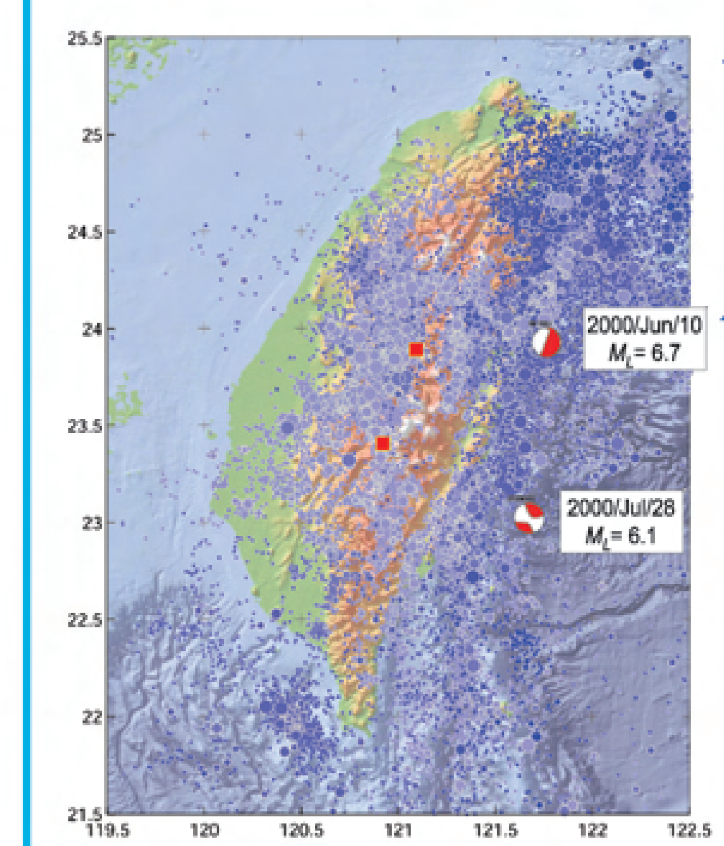
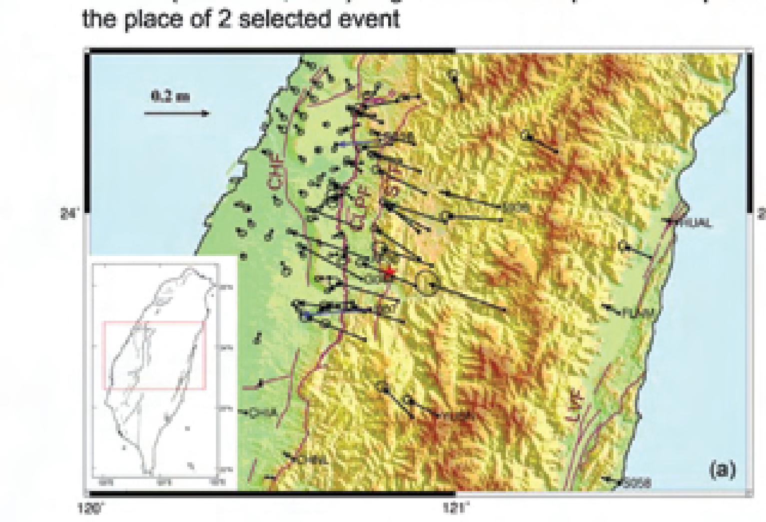


Fig. 4 Regional seismicity after the *Chi-Chi* earthquake in 21-Sept-1999. 2 selected secondary mainshocks shows as the red cube in the map. Seismicity are significantly increasing around the CLP fault patch and on the deeper part of the detachment. Both of the selscted events are setting on the eastern edge of the seismicity increasing area. The focal mechanisms from Havard CMT solution. Secondary mainshocks' local magnitude from CWBSN catalog.

Fig. 5 Post-seismic deformation after the Chi-Chi earthquake in the Central Taiwan (Hsu et *al.*,2007). Signaifcant afterslip are taken place near the place of 2 selected event



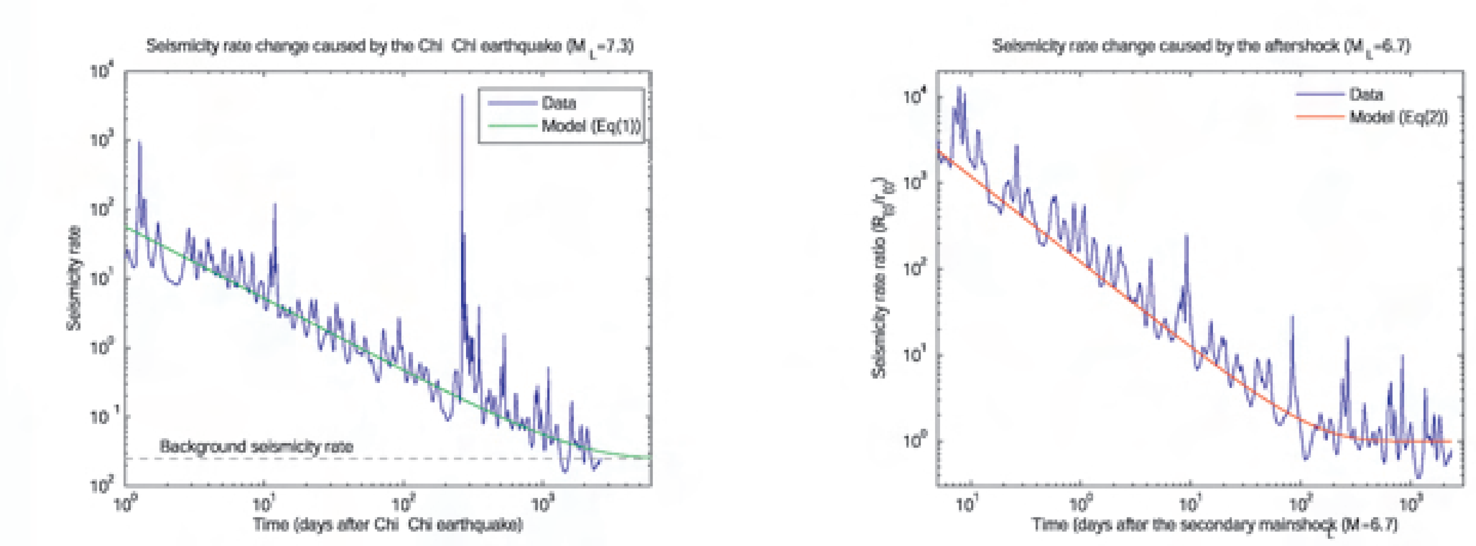


Fig. 6 Modeling result of the M=6.7 event sequence. Left part shows the fitting result for the seismicity rate that is affected by the *Chi-Chi* earthquake (Mw=7.6). Green line shows the fitting cruve. For the secondary aftershocks (the high peak in the middle) we use the ratio between the green cruve and the data to generate the decay ratio in the right and fit the ratio by using Eq(2). Our result suggests the secondary aftershock seismicity rate decay is buliding on top of the original ongoing seismicity rate, which is similar with the single aftershocks dacay. Parameters in this model: Left part: n(0-)=0.025, d=10^5, p=1.05, *tr=1600 days;* Right part (seconday aftershocks) d=10^5, p=1, *tr*=120 days. M_{cutoff} = 2.5 for both model.

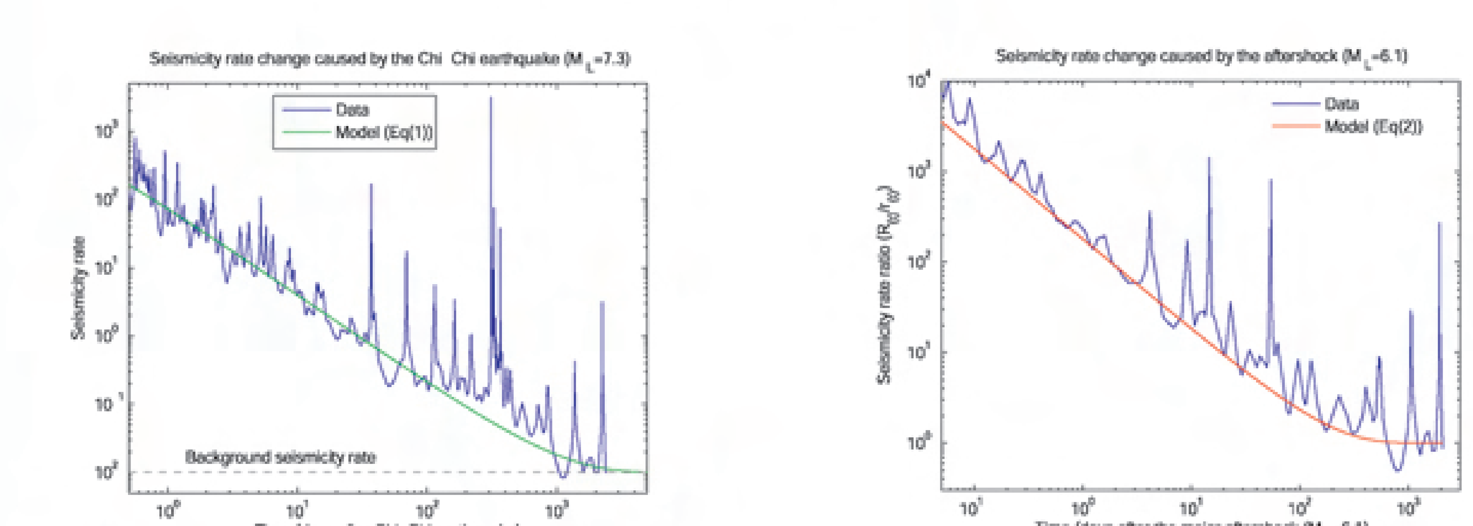


Fig. 7 Modeling result of the M=6.1 event sequence. Left part shows the fitting result for the seismicity rate that is affected by the *Chi-Chi* earthquake (Mw=7.6). Green line shows the fitting cruve. For the secondary aftershocks (the high peak in the middle) we use the ratio between the green cruve and the data to generate the decay ratio in the right and fit the ratio by using Eq(2). Parameters in this model: Left part: n(0-)=0.01, d=2.5*10^5, p=1.3, *tr=1000 days;* Right part (seconday aftershocks): d=20000, p=1, *tr*=180 days. M_{cutoff} = 2.5 for both model.